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"Mate! I'm running 10 min late": An investigation into the self-regulation of mobile phone tasks while driving

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ABSTRACT

The adaptive behaviour of mobile phone distracted drivers has been a topic of much discussion in the recent literature, but the mechanisms of behavioural adaptation are still unclear. This study investigated the influence of driving demands, secondary task characteristics, and personal characteristics on behavioural adaptation of mobile phone distracted drivers. In particular, distracted drivers' self-regulation at strategic, tactical, and operational levels was investigated through a driving simulator experiment. In a high-fidelity driving simulator, participants driving through various driving conditions (e.g. interactions with pedestrian crossings, signalized intersections, merging ramps, roundabouts, etc.) needed to decide where and how to perform the following four mobile phone tasks: (a) ring a doctor and cancel an appointment, (b) text a friend and tell him/her that the participant will be arriving 10 min late, (c) share the doctor's phone number with a friend, and (d) take a 'selfie'. At a strategic level, the decision to pull over was modelled as a function of self-reported personal/attitudinal characteristics with a logistic regression model. Similarly, tactical self-regulation (decision to engage in a task while driving in a specific situation) and operational self-regulation (decision to temporarily stop the mobile phone task) were modelled as a function of driving demands and personal/attitudinal characteristics using a random-effects logistic regression model, which accounts for correlations resulting from multiple observations of a driver. Results suggest that tactical self-regulation is more common among distracted drivers followed by operational and strategic self-regulation. Personal beliefs regarding how safe it is to use the mobile phone for texting/browsing while driving were predictors of self-regulation for all levels. Drivers were observed to use the mobile phone more when the driving demands are low, e.g. while stopped at an intersection. This research suggests that distracted drivers engage in various levels of self-regulation, and future research could be focused on further theoretical refinement and development of technology-based interventions.

1. Introduction

The use of mobile phones while driving is a common risky behaviour and represents a major concern for road safety. An observational study conducted in the United States found that 31% of 3265 drivers observed at intersections talked on the phone and 16.6% texted or dialled (Huisingh et al., 2015). Another observational study reported that 6% of 5379 drivers observed in free-flowing traffic on a straight roadway held a mobile phone (Kidd et al., 2016). Other studies have estimated that this behaviour occurs among 5% (n = 5813) of drivers at intersections in Australia (Young et al., 2010), 3% (n = 7168) of drivers in random locations in the United Kingdom (Sullman et al., 2014), 14% (n = 6578) of drivers in random locations in Spain (Prat et al., 2015), and among 14% (n = 1700) of drivers at intersections and along highways in Saudi Arabia (Alghnam et al., 2018). These values are observations of drivers using the phone while driving, which confirm a substantial proportion of drivers using the phone at any time in the road network. Mobile phone distracted driving is likely to increase in future, given the pervasiveness of this ubiquitous technology (Brace et al., 2007).

The relationship between mobile phone use while driving and safety has been subject to much debate. Research has suggested that drivers could be using behavioural changes in vehicle control to self-regulate mobile phone demands, e.g. driving with a reduced speed (Metz et al.,

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2015; Oviedo-Trespalacios et al., 2017c; Choudhary and Velaga, 2017; Oviedo-Trespalacios, 2018), decreased or increased lateral vehicle control variability (Svenson and Patten, 2005), increased headway (Saifuzzaman et al., 2015), and hard braking (Rossi et al., 2012; Haque and Washington, 2015). Another possibility is that these changes in driving behaviour are a by-product of multi-tasking that just happens to look like a positive behaviour. For example, hard braking could indicate that drivers failed to detect a hazard because they were distracted, rather than deliberately reducing speed to mitigate risk because they were answering a phone call. In addition, there have not been studies which have investigated the mechanisms of these behavioural changes or compared differences in terms of system safety. As empirical studies around this topic are scarce, there is a limited knowledge about the motivations and mechanisms of such behavioural adaptations. An understanding of what moderates behavioural adaptation among distracted drivers is critical for the effective design of countermeasures and to understand differences in driving populations (Young and Regan, 2009).

1.1. Self-regulation of mobile phone use while driving

Self-regulation of secondary tasks while driving is a topic of growing interest in the mobile phone distracted driving literature. The main premise is that drivers may intentionally or unintentionally regulate their behaviour to mitigate risk associated with distraction (Young and Regan, 2013), which can often be experienced as elevated driving demands (Oviedo-Trespalacios et al., 2018b; Kinnear and Helman, 2011). One of the first attempts at a more generalized characterization of self-regulation of mobile phone tasks while driving was made by Young and Regan (2013), which included three distinct levels of self-regulatory behavioural adaptation: strategic, tactical, and operational self-regulation. Strategic self-regulation refers to the decisions about mobile phone use that are stable during the entire drive. A good example of strategic self-regulation is the decision to not use the phone at all while driving a vehicle (Zhou et al., 2012; Young and Lenné, 2010; Oviedo-Trespalacios et al., 2017c). Another form of strategic self-regulation could involve the decision to not engage in visual-manual mobile phone tasks and use only voice-based commands.

Tactical self-regulation includes driver decisions to engage (or not engage) in a mobile phone task at a certain time or place. Research has largely reported that drivers prefer to use their mobile phone in low complexity situations, e.g., Huth et al. (2015) reported that drivers can make tactical decisions such as restricting mobile phone usage to when the vehicle is not moving at signalised intersections during a red traffic light. An increased driving workload is likely to reduce the likelihood of a driver engaging in mobile phone tasks (Oviedo-Trespalacios et al., 2018b; Hancox et al., 2013; Kidd et al., 2016). It is important to note that tactical self-regulation is only possible if a driver makes a strategic decision to use the mobile phone during a drive.

Operational self-regulation refers to the strategies adopted by drivers to integrate the mobile phone task into driving after the mobile phone task is initiated. In a recent systematic review conducted by Oviedo-Trespalacios et al. (2016), it was concluded that most of the research on mobile phone use while driving has studied changes in vehicle control including driving speed and headway distance. In particular, operational self-regulation has been reported to influence driving behaviour through reduced speed and increased headways (Choudhary and Velaga, 2017; Oviedo-Trespalacios et al., 2017b,a). Emerging evidence in the mobile phone distracted driving literature has shown that drivers might be able to self-regulate the secondary tasks in addition to vehicle control. For example, drivers using a mobile phone prioritise the driving task and therefore experience less conversation quality while talking and driving (Becic et al., 2010) or an increased number of errors while texting and driving (Alosco et al., 2012). A recent experiment conducted by Oviedo-Trespalacios et al. (2018a) showed that in complex situations such as driving along reverse curves, drivers reduce their involvements in both cognitive and visual-manual mobile phone tasks. It is assumed in this study that a driver—who self-paces a mobile phone task to match driving demands but does not fully stop the mobile phone task—is self-regulating at an operational level.

1.2. Factors associated with self-regulation of mobile phone use while driving

The study of self-regulation in mobile phone distracted driving has been conducted with limited theoretical guidance. The Behavioural Adaptation Theory (BAT) framework to understand the potential mechanisms/processes involved in self-regulation of mobile phone use while driving was proposed by Young and Regan (2013) and later advanced by Oviedo-Trespalacios et al. (2017b). The BAT postulates that self-regulation by mobile phone distracted drivers at operational, tactical, or strategic levels is the product of changes in secondary task demands, driver characteristics, and driving task demands. The driver is addressed in terms of driver characteristics and perception, secondary task demands depend on the mobile phone task characteristics, and the driving task demands include aspects of the road traffic environment. Although the components and relationships comprising BAT are still in an early stage of maturity, there is growing empirical evidence supporting the suitability of BAT for explaining self-regulation in mobile phone distracted driving.

BAT assumes that personal characteristics have an influence on self-regulation (Young and Regan, 2009, 2013; Oviedo-Trespalacios et al., 2017b). Two main elements related to driver characteristics will be considered in the current research: demographic characteristics (e.g., age, gender, driving experience) and perception (e.g. attitudes and beliefs). Typically, research has confirmed that young and less experienced drivers tend to modify their driving behaviours in the direction of greater safety when they perform mobile phone tasks. In particular, drivers aged up to 25 years and less experienced drivers select a lower speed while having mobile phone conversations (Oviedo-Trespalacios et al., 2017b,a). In addition, driver perception of task demands appears to play an important role in self-regulation. As suggested by previous research, perceived crash risk and task difficulty are correlated and influence vehicle control (Lewis-Evans and Rothengatter, 2009).

Secondary task demands have been found to influence self-regulation at various levels. Secondary task demands are typically influenced by the task nature (e.g. talking, texting, answering a ringing phone, etc.) and interfaces (e.g. handheld, hands-free, etc.) (Young and Regan, 2013). Regarding mobile phone tasks, drivers are less likely to use the phone for visual-manual tasks compared to conversation tasks (Hancox et al., 2013). In addition, greater driving demands, usually expressed in terms of road traffic conditions, are associated with less mobile phone use while driving (Kidd et al., 2016; Oviedo-Trespalacios et al., 2018b). Indeed, research has suggested that drivers prefer to use the phone when the driving demands are reduced to a minimum (Huth and Brusque, 2013; Huth et al., 2015).

1.3. Research aim

The current research addresses an important gap in the literature concerning the incidence and mechanisms of behavioural changes during self-regulation in mobile phone distracted driving. Three levels of self-regulation (strategic, tactical, and operational) as identified in the BAT were investigated. In particular, the influence that driving demands, secondary task characteristics, and personal characteristics have on self-regulation (see Oviedo-Trespalacios et al. (2017b) for additional information on BAT). In this study, the exploration of self-regulation will focus on *drivers' interactions with mobile phone tasks*. This is exploratory research with the main objective being to determine the dimensions that comprise self-regulation in mobile phone distracted driving.

2. Methods

The current research was approved by the Queensland University of Technology Human Research Ethics Committee and was conducted in accordance with the Declaration of Helsinki, with explicit consent obtained from each subject.

2.1. Participants

A total of 35 drivers (63% male) were recruited through email, newsgroups and social networks. Participants were required to hold a valid driver's license in Australia and drive on a regular basis. The age of participants ranged between 18–29 years with an average age of 22.9 years (SD 4.0). The average driving experience of participants was 3.48 years. Participants reported driving an average of 1.35 (SD 1.04) hours per day and most (80%) drove a small/medium sized car. Thirty seven percent of participants reported being involved in a crash and 31 percent reported being fined for a traffic infringement in the last three years. The majority of participants had an iOS phone (72%), and others had an Android (17%) or Windows (11%) phone.

2.2. Apparatus

The current research used a high-fidelity driving simulator located at the Centre for Accident Research and Road Safety-Queensland (CARRS-Q) at the Queensland University of Technology (QUT). The simulator is composed of a complete Holden Commodore with automatic transmission. The car has working controls and instruments on a 6°-of-freedom motion platform surrounded by three front-view projectors providing 180-degree high resolution field view to drivers. Wing mirrors and the rear-view mirror were substituted by LCD monitors to simulate rear-view mirror images. Road images and interactive traffic were generated at life size onto front-view projectors, wing mirrors and the rear-view mirror at 60 Hz to provide a photorealistic virtual environment. The simulator is also capable of producing realistic forces through the steering wheel to provide the realism of driving, particularly during negotiating the horizontal curves.

2.3. Experimental protocol

All participants were informed about the potential risks of participation (e.g., motion sickness or potential distress due to past road trauma), and provided informed consent. They also completed a questionnaire about demographics, beliefs and driving characteristics. Participants were then briefed on the protocol of the experiment, with detailed instructions on how to operate the simulator vehicle. Participants were instructed to drive as they normally would and to obey the posted speed limits/road rules.

Participants undertook a practice drive and were monitored for motion sickness before commencing the experimental drives. The practice drive included interactions with vehicle and pedestrian traffic that the participant might encounter during the experimental drives. The participants were asked to drive for a minimum of 10 min in order to become comfortable with the simulator. Participants also practised phone tasks with a research officer.

The experimental drive included driving while performing different mobile phone tasks (see Section 2.5 for detail). Each participant was reimbursed with AUD $50 for their time upon completion.

2.4. Simulated scenario

The experimental condition included a driving route with realistic traffic interactions similar to road traffic conditions in urbanized areas of Brisbane, Australia. Participants were instructed to follow directional signs to the airport. The simulated route included various interactions with traffic and roadway facilities, including interactions with signalized intersections, pedestrian crossings, roundabouts, merging ramps and motorways. Table 1 provides the details of road traffic scenarios from the start of the simulator drive to the end.

Table 1
Simulated scenario characteristics.

Road traffic condition	Speed limit	Length
Start - Straight segment	40 kph	400 m
Intersection with stop sign (Cross traffic from the right)	40 kph	–
Straight segment	40 kph	300 m
Pedestrian crossing (with pedestrian)	40 kph	–
Straight segment	40 kph	200 m
Signalised intersection during red light (no vehicle queue)	40 kph	–
Turn left	40 kph	–
Straight segment	40 kph	300 m
Signalised intersection during red light (no vehicle queue)	40 kph	–
Turn right	40 kph	–
Straight segment	40 kph	300 m
Pedestrian crossing (no pedestrian)	40 kph	–
Straight segment	40 kph	200 m
Intersection with stop sign (Cross traffic from the right)	40 kph	–
Turn right	40 kph	–
Straight segment	40 kph	300 m
Signalised intersection during red light (with vehicle queue)	40 kph	–
Straight segment	40 kph	200 m
Straight segment with traffic ahead of the driver	40 kph	500 m
Signalised intersection during red light (with vehicle queue)	40 kph	–
Straight segment with traffic ahead of the driver	40 kph	200 m
Intersection with stop sign (no traffic)	40 kph	–
Turn right	40 kph	–
Straight segment	40 kph	300 m
Pedestrian crossing (with pedestrian)	40 kph	–
Straight segment	40 kph	200 m
Intersection with stop sign (no traffic)	40 kph	–
Turn right	40 kph	–
Straight segment	40 kph	300 m
Signalised intersection during red light (no vehicle queue)	40 kph	–
Turn left	40 kph	–
Straight segment with traffic ahead of the driver	40 kph	500 m
Roundabout	40 kph	–
Merging ramp	110 kph	400 m
Motorway - End	110 kph	1000 m

2.5. Mobile phone tasks

Participants performed four mobile phone tasks: (a) ring the doctor's office and cancel an appointment, (b) text a friend to tell that they will be arriving 10 min late, (c) share the doctor's phone number with a friend, and (d) take a 'selfie'. Task (a) aimed to represent auditory tasks while tasks (b)–(d) represent different visual-manual tasks such as texting, browsing, and a short duration visual-manual interaction respectively. Participants were instructed to perform each of the four tasks, in any order and at any time, throughout the drive. Participants were also instructed during the experiment to repeat the four tasks in any order and at any time until the end of driving route. Please note that the instruction on task repetition was only given after they completed the first set of the above four tasks.

Participants used their own mobile phones and were asked to use their mobile phones while driving as they would do in their regular driving. Participants were asked to drive "as if it is a real driving experience". Although the driving task was the priority, participants were allowed to pullover to complete any mobile phone tasks. The research officer assisted participants to create doctor and friend contacts in their phones prior to the drive. For the doctor ringing task, participants were advised that if the doctor does not answer, they should not try to call again. Fig. 1 provides two snapshots of participants conducting the

Fig. 1. Participants in the simulator.

experimental drive.

2.6. Questionnaires

Two batteries of questionnaires were designed and administered in this study (before and after the simulator drive). Before the experimental drive, participants answered items regarding their beliefs and experience with mobile phone distracted driving as follows:

2.6.1. Risk perception towards mobile phone distracted driving

Risk perception was measured in terms of perceived likelihood of crash risk. Questions were designed to measure risky driver mobile phone interactions. These measurements were inclusive of visual-manual and auditory tasks reported in the literature on mobile phone distracted driving (see Oviedo-Trespalacios et al. (2017c)). A total of four questions were included as follows: How likely are you to have a crash if you are using a mobile phone for …? (*i*) a voice call, (*ii*) texting/browsing, (*iii*) looking at the phone continuously for more than 2 s, and (*iv*) answering a ringing phone. Responses were obtained using a Likert scale ranging from 1 ("very unlikely") to 5 ("very likely").

2.6.2. Experience using a mobile phone while driving

Participants were asked to report their experience with the four interactions utilised to study perception of crash risk. The items included: "while driving, how often do you use your mobile phone for …?" (*i*) having mobile phone conversations, (*ii*) manual interactions such as texting/browsing, (*iii*) answering phone calls, and (*iv*) reading or looking at the phone continuously for more than two seconds. Responses were obtained using a Likert scale ranging from 1 ("Never") to 5 ("Always").

2.6.3. Attitudes and beliefs towards mobile phone distracted driving

The attitudes and beliefs towards two mobile phone related behaviours were examined: mobile phone conversations and texting/browsing. No distinction was made between interfaces such as in-vehicle cell-phone, hands-free, handheld, or speaker. This was done for two reasons. First, we wanted participants' actual driving experience to reflect the definition of their beliefs. Second, the literature indicates that there is no major variation in crash risk between interfaces (Fitch et al., 2013; Oviedo-Trespalacios et al., 2016). The attitudes and beliefs questionnaire was adapted from White et al. (2004) and included five items for both talking or texting/browsing: (i) it is easy for someone to tell if their driving has been affected, (ii) I would need a lot of convincing to believe it is dangerous, (iii) the effects on driving ability are likely to be only very minor, (iv) the only people at risk are those who use a mobile while driving, (v) any distraction effects will last even after the task is finished. These questions assessed perceived detectability, danger threshold, severity, equitability, and immediacy of the mobile phone task, respectively. In addition, three items were designed to study perceived self-efficacy towards self-regulation as defined by Oviedo-Trespalacios et al. (2017c): (vi) demanding driving conditions will prevent me from talking on a mobile phone, (vii) presence of law enforcement and risk of a fine will prevent me from talking on a mobile phone, and (viii) it is completely safe because I am generally extra careful. Responses were obtained on a Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree").

After the experiment, participants answered questions regarding their experience and perception regarding each one of the four mobile phone related tasks:

2.6.4. Perceived characteristics of the secondary task

In order to study the relationship between driver decision making and characteristics of the secondary task, a number of questions were designed to assess participants' perceptions about each of the four mobile phone tasks. A total of seven items were developed based on the seven characteristics identified by Young and Regan (2013) (interruptibility, compatibility, complexity, ignorability, predictability, adjustability, and duration). The following items were also included: (i) how easy was it to interrupt the mobile phone task? (ii) how compatible was the mobile phone task with driving? (iii) how complex was the mobile phone task? (iv) how easy was it to ignore the mobile phone task? (v) how predictable was the mobile phone task? (vi) how adjustable was the mobile phone task? and, (vii) How long was the mobile phone task? The responses for questions (i–vi) were obtained on a scale ranging from 0 ("very low") to 100 ("very high") and question (vii) from 0 ("very short") to 100 ("very long")

2.6.5. Experience with the secondary tasks included in the experiment

Participants were also asked if they have performed this (or a similar) task while driving (yes or no). If they answered yes to the question, they were asked "how many times do you engage in this behaviour in a 60-min drive?"

2.7. Dataset and analysis techniques

The current research investigates the incidence and mechanisms of behavioural changes made by distracted drivers. Each level of self-regulation is analysed separately. Observations were conducted in a two-step process. Each behaviour was labelled independently by the first author of the paper and a research officer. Any disagreement was discussed in order to achieve consensus.

2.7.1. Strategic self-regulation

Strategic self-regulation was observed through driver decisions to pull over to perform a secondary task or not perform the mobile phone task while the vehicle was running. The outcome variable is a binary variable indicating whether or not they pulled over (no = 0; yes = 1). A logistic regression analysis was conducted. Specifically, associations between decisions to pull over and personal/attitudinal characteristics were determined. Personal characteristics included: gender (male/

Table 2
Demographic characteristics of drivers (n = 35).

Variables	M (SD)	Min, Max
Risk Perception		
Likelihood to have a crash if having a voice call	2.57 (1.07)	1,5
Likelihood to have a crash if texting/browsing	3.69 (0.99)	1,5
Likelihood to have a crash if looking at the phone continuously more than 2 s	3.57 (1.04)	1,5
Likelihood to have a crash if answering a ringing phone	2.94 (1.00)	1,5
Experience using a mobile phone while driving		
Frequency using phone for conversations	1.77 (0.69)	1,5
Frequency using phone for manual interactions	1.74 (0.85)	1,5
Frequency using phone for answering phone calls	1.97 (0.86)	1,5
Frequency looking at phone for more than 2 s	2.06 (0.84)	1,5
Mobile phone usage beliefs and attitudes (Talking)		
Easy to tell if someone's driving has been affected	3.34 (1)	1,5
Need a lot of convincing to believe it is dangerous	2.2 (1.11)	1,5
The effects on driving ability are minor	2.69 (1.05)	1,5
The only people at risk are those who use it	1.71 (1.13)	1,5
Effects will last after the task is finished	3.17 (0.92)	1,5
Demanding traffic conditions will prevent me from doing it	4.09 (0.95)	1,5
Presence of law enforcement will prevent me from doing it	4.31 (0.87)	1,5
It is safe because I am careful	2.34 (1.14)	1,5
Mobile phone usage beliefs and attitudes (Texting/browsing)		
Easy to tell if their driving has been affected	4.09 (0.98)	1,5
Need a lot of convincing to believe it is dangerous	1.63 (1.14)	1,5
The effects on driving ability are minor	1.89 (1.13)	1,5
The only people at risk are those who use it	1.51 (0.95)	1,5
Effects will last after the task is finished	3.49 (0.85)	1,5
Demanding traffic conditions will prevent me from doing it	4.43 (1.04)	1,5
Presence of law enforcement will prevent me from doing it	4.63 (0.55)	1,5
It is safe because I am careful	2.06 (1.24)	1,5

female), age, time with valid licence (years), hours driving (hours/day), having at least one crash in the last three years (yes/no), having at least one traffic offence in the last three years (yes/no), type of vehicle they usually drive (SUV-utility car/small-medium car), items related to risk perception, experience of using mobile phones while driving, and beliefs towards using mobile phones while driving. The descriptive statistics of these variables are presented in Table 2. The parsimonious model was obtained after removing all insignificant variables one by one by a backward elimination technique.

2.7.2. Tactical self-regulation

Tactical self-regulation was observed using drivers' decisions to initiate a mobile phone task at a certain road section. The outcome variable was binary indicating whether or not they used the phone (no = 0; yes = 1) at any of the following sections: intersection with stop sign (cross traffic from the right), intersection with stop sign (no traffic), signalised intersection during red light (with queue), signalised intersection during red light (no queue), pedestrian crossing (with pedestrian), pedestrian crossing (no pedestrian), turning left at an intersection, turning right at an intersection, straight segment (no traffic), straight segment (with traffic ahead of the driver), roundabout, merging ramp, and motorway. It is anticipated that, for the *i*th individual, observations at different scenarios should exhibit certain within-person correlations. Therefore, given the repeated measures design of this analysis, a random-effect logistic regression model was used to model tactical self-regulation of drivers. These models contain both individual random effects components and within-individual errors that follow an (autoregressive) AR(l) time series process (Wang and Abdel-Aty, 2006). Using the variables described in the strategic self-regulation analysis, associations between the decision to engage in mobile phone multitasking while driving and personal/attitudinal characteristics were tested. The overall significance of the model was evaluated using a Wald chi-squared test (Allison, 1999).

2.7.3. Operational self-regulation

Operational self-regulation was observed using decisions to self-pace (or temporarily stop) the use of mobile phones at a certain section. It is assumed in this study that a driver who self-paces a mobile phone task to match driving demands but does not fully stop the mobile phone task, is self-regulating at an operational level. The outcome was a binary variable indicating whether or not they self-paced the task (no = 0; yes = 1). The frequency of participants engaging in self-pacing behaviour and other task performance features such as presence of traffic and speed limits were calculated for each task. For every individual, self-pacing observations at four different tasks should exhibit certain within-person correlations. Therefore, a random effect logistic regression model was utilised to model self-pacing decisions. Using the variables described in the strategic/tactical self-regulation analysis, associations between the decision to self-pace a mobile phone task while driving and personal/attitudinal characteristics were tested by the regression model. Furthermore, experience and perceived characteristics of the secondary tasks included in the experiment were included as potential explanatory variables in the logistic regression model for operational self-regulation

3. Results

3.1. Strategic self-regulation

A total of 8 (22.9%) drivers were observed to pull over to perform a secondary task. None of the drivers pulled over more than once. This is attributed to the fact that once the participants completed the four tasks, they were instructed to repeat the four tasks in any order and at any time. All of the drivers who pulled over did so in straight segments, with no traffic, and completed the four tasks at that point. Drivers who pulled over had an average of 4.50 years of driving experience (SD = 3.89) and half were male (50%). The parsimonious logistic regression of drivers' strategic self-regulation is presented in Table 3. The decision to pull over had only one significant predictor: the driver could easily tell if their driving was being affected for texting/browsing. For every additional unit in this attitude, drivers have 5.5 times the odds (95% CI = 1.7–17.9) of pulling over to perform the tasks.

Table 3
Logistic regression analysis: predicting decision to pull over.

Parameter	Odds Ratio	95 % CI	*β*	SE	*Wald Chi-Square*	Sig.
Intercept			−5.2	2.3	5.3	0.021
Easy for someone to tell if their driving has been affected for texting/ browsing	5.5	[1.68, 17.94]	1.7	0.6	7.9	0.005

Table 4
Usage of mobile phone per location (n = 35).

Road infrastructure and traffic interaction	Yes n (%)
Intersection with stop sign (Cross traffic from the right)	18 (51%)
Intersection with stop sign (no traffic)	9 (25%)
Signalised intersection during red light (with vehicle queue)	27 (77%)
Signalised intersection during red light (no vehicle queue)	32 (92%)
Pedestrian crossing (with pedestrian)	26 (75%)
Pedestrian crossing (no pedestrian)	14 (40%)
Turning left at an intersection	9 (25%)
Turning right at an intersection	11 (32%)
Straight segment (no traffic)	29 (83%)
Straight segment (with traffic ahead of the driver)	28 (80%)
Roundabout	7 (20%)
Merging ramp	20 (57%)
Motorway	25 (71%)

3.2. Tactical self-regulation

Tactical self-regulation was observed by identifying the locations where drivers decided to engage in any mobile phone task. Table 4 reports the mobile phone engagement frequencies of drivers across various locations. It appears that drivers engaged more often in multi-tasking while waiting at signalised intersections during red lights (with or without vehicle queue) or driving along straight segments with no traffic. Conversely, drivers engaged less often in multi-tasking when driving through a roundabout.

Tactical self-regulation of drivers was modelled by a random effect logistic regression model, and the results are presented in Table 5. Results suggest that a combination of road traffic infrastructure and personal characteristics influence tactical self-regulation among distracted drivers. Among the 13 variables related to road infrastructure and traffic interactions as reported in Table 4, signalised intersection during a red light with no vehicle queue was initially used as the reference category. As there was no significant difference between *signalised intersection during red light with no vehicle queue* and other road traffic variables such as *signalised intersection during red light with queue*, *pedestrian crossing with pedestrian*, *straight segment with no traffic*, *straight segment with traffic ahead of the driver* and *motorway*, these variables in combination served as the reference category. Compared to the reference category, the odds of using a mobile phone while driving at an intersection with stop sign and cross traffic from the right were about 78% lower. The corresponding odds for a stop-sign intersection with no traffic were about 94% lower. The odds of using a mobile phone while driving during left and right turning manoeuvre at intersections were respectively 94% and 92% lower. The odds of using mobile phones were 88% lower at a pedestrian crossing, 96% lower at a roundabout and 71% lower along a merging ramp.

Among the personal characteristics of drivers, it is found that the odds of using a mobile phone while driving are 2.7 times higher among drivers who have had at least one traffic offence in last three years. Similarly, drivers who mentioned ‘needing a lot of convincing to believe texting/browsing is dangerous’ have about 37% higher odds to engage in mobile phone multi-tasking at any moment for every additional unit in the scale. Finally, drivers who reported that the presence of law enforcement will prevent me from talking in a mobile phone have 49% lower odds of engaging in mobile phone distraction for every additional unit in the scale.

3.3. Operational self-regulation

Operational self-regulation was identified by observing whether a driver self-paced the mobile phone task or not. Table 6 reports the perceived task characteristics, self-reported experience with the secondary tasks, and observed task performance. A larger proportion of drivers reported engaging in a ringing task and texting than sharing contacts or taking ‘selfies’. Furthermore, the most complex task appeared to be sharing the doctor’s phone number with a friend.

The logistic model estimates of drivers’ operational self-regulation are presented in Table 7.

The parsimonious model showed four significant variables that influence the operational self-regulation of distracted drivers. Compared to mobile phone tasks like ‘sharing a contact with a friend’ and ‘text a friend that you are running 10 min late’, each of the tasks ‘ring to cancel an appointment’ and ‘take a selfie’ is found to decrease the odds of self-pacing by 80%. The odds of self-pacing are 4.74 times higher among drivers who initiated the phone task while the vehicle is stopped than drivers who used mobile phones while the vehicle is moving. Finally, drivers who reported ‘needing a lot of convincing to believe texting/ browsing is dangerous’ have 85% higher odds of self-pacing in mobile phone tasks.

Table 5
Random-effects logit model for engagement in mobile phone tasks per location.

Parameter	Odds Ratio	95 % CI	*β*	SE	*z*	Sig.
Intercept			3.65	0.88	4.13	$p < 0.001$
Road infrastructure and Traffic Interactions (Signalise intersection (no vehicle queue) OR Signalise intersection (with vehicle queue) OR Pedestrian crossing (with pedestrian) OR Straight segment (no traffic) OR Straight segment (with traffic ahead of the driver) OR Motorway = 0)						
Intersection with stop sign (Cross traffic from the right)	0.22	[0.09–0.49]	−1.52	0.42	−3.64	$p < 0.001$
Intersection with stop sign (no traffic)	0.06	[0.02–0.14]	−2.86	0.48	−6.01	$p < 0.001$
Pedestrian crossing (no pedestrian)	0.12	[0.05–0.29]	−2.08	0.43	−4.83	$p < 0.001$
Turning left at an intersection	0.06	[0.02–0.14]	−2.86	0.48	−6.01	$p < 0.001$
Turning right at an intersection	0.08	[0.03–0.19]	−2.53	0.45	−5.59	$p < 0.001$
Roundabout	0.04	[0.01–0.1]	−3.25	0.51	−6.33	$p < 0.001$
Merging ramp	0.29	[0.12–0.65]	−1.24	0.42	−2.97	0.003
Presence of law enforcement will prevent me from talking in a mobile phone	0.51	[0.35–0.72]	−0.67	0.18	−3.71	$p < 0.001$
At least one traffic offence in the last three years (yes = 1)	2.68	[1.44–4.98]	0.99	0.32	3.13	0.002
Need a lot of convincing to believe texting/browsing is dangerous	1.37	[1.06–1.76]	0.31	0.13	2.45	0.014

Note: $\rho = 0.06$; $\sigma_u = 0.476$.

Table 6
Self-reported experience and characteristics of the secondary tasks included in the experiment.

Variables	Ring doctor to cancel Appointment *M (SD)* ‡*n (%)*	Text friend that you are going 10 min late *M (SD)* ‡*n (%)*	Take a selfie *M (SD)* ‡*n (%)*	Share Doctor phone number with friend *M (SD)* ‡*n (%)*
Perceived task characteristics				
Task interruptibility	52.42 (24.74)	52.35 (26.94)	58.14 (28.31)	47.2 (31.31)
Task compatibility	48.92 (25.15)	31.91 (20.3)	45.85 (31.35)	25.73 (22.8)
Task complexity	43.14 (23.64)	58.08 (25.04)	32.57 (29.13)	63.45 (26.91)
Task ignorability	48.14 (25.72)	52.94 (21.64)	47.57 (27.23)	46.02 (23.98)
Task predictability	61.78 (21.8)	48.67 (25.74)	59.28 (27.44)	40 (24.95)
Task adjustability	54 (21.85)	45.14 (21.47)	55.28 (29.6)	35.14 (18.76)
Task duration	37 (22.79)	43.82 (22.39)	26.21 (24.36)	52.64 (26.14)
Self-reported experience with the secondary task				
Previous experience with a similar task while driving	20 (57.1%)‡	20 (57.1%)‡	3 (8.5%)‡	3 (8.5%)‡
If yes, number of tasks per hour driving	2 (5.7)	3 (8.5)	2 (5.7)	1 (2.8)
Observed task performance				
Observed duration of the task (sec.)	58.82 (25.18)	65.88 (65.45)	76.02 (108.16)	12.45 (10.37)
Frequency of drivers self-pacing the task in the experiment	5 (14.2%)‡	17 (48.5%)‡	5 (14.2%)‡	10 (28.5%)‡
Mobile phone use when car is not moving	27 (77.1%)‡	27 (77.1%)‡	29 (82.8%)‡	26 (74.2%)‡
Mobile phone use with ongoing traffic	5 (14.2%)‡	4 (11.4%)‡	12 (34.2%)‡	4 (11.4%)‡
Mobile phone use when there is no traffic	21 (60%)‡	9 (25.7%)‡	23 (65.7%)‡	17 (48.5%)‡
Mobile phone use features in high speed zones (> 100 kph)	2 (5.7%)‡	1 (2.8%)‡	2 (5.7%)‡	4 (11.4%)‡

‡Signifies frequency and percentage.

Table 7
Random-effects logit model for self-pacing in mobile phone usage per task.

Parameter	Odds Ratio	95 % CI	β	SE	z	Sig.
Intercept			−4.38	1.53	−2.87	*0.004*
Mobile phone task (Text friend that you are going 10 min late OR share contact = 0)						
Ring to cancel appointment	0.20	[0.06, 0.68]	−1.59	0.62	−2.57	*0.005*
Take a selfie	0.20	[0.06, 0.7]	−1.58	0.62	−2.53	*0.01*
Initiated mobile phone use when vehicle is stopped (yes = 1)	4.74	[1.16, 19.42]	1.56	0.72	2.17	*0.03*
Need a lot of convincing to believe texting/browsing while driving is dangerous	1.85	[1.04, 3.29]	0.62	0.29	2.10	0.04

Note: $\rho = 0.16$; $\sigma_u = 0.811$.

4. Discussion

A large body of research has examined driving performance of distracted drivers such as gap acceptance, car following, speed selection, lateral control, and response to traffic lights. However, while it has been mentioned in recent studies (Oviedo-Trespalacios et al., 2016; Fitch et al., 2017; Haque et al., 2016), self-regulation has received less attention. Previous studies in the area of distraction have suggested the existence of operational adaptations such as speed selection among mobile phone distracted drivers (Oviedo-Trespalacios et al., 2015, 2017b; Wandtner et al., 2016; Oviedo-Trespalacios et al., 2017a) but studies of tactical and strategic self-regulation are underrepresented in the literature. Furthermore, previous research is even more limited with regard to the mobile phone task characteristics. To fill this research gap, the current investigation utilised a high-fidelity driving simulator to examine strategic, tactical, and operational self-regulation in the same setting considering different mobile phone tasks.

With regard to strategic self-regulation, only a small portion of the drivers were observed to pull over (23%). A previous study in Australia found that 67.8% of drivers self-reported pulling over to engage in a mobile phone task as a form of self-regulation (Young and Lenné, 2010). The difference between these figures suggests that pulling over may be employed by some drivers as a strategic form of self-regulation (i.e. they will always pull over) and by others as a form of tactical self-regulation if the traffic situation is demanding. This needs to be better understood, since pulling over is an ideal compensatory strategy. It was also interesting to find that safety beliefs about texting play a role in the decision to pull over. In this research, drivers who perceived that driving performance has been affected by texting/browsing were more likely to pull over. This is perhaps a consequence of previous experiences while using the mobile phone, given that this item is related to the detectability of the safety risks (White et al., 2004). Personal attitudes are generally considered strong predictors of risky behaviour (e.g. speeding (Scott-Parker et al., 2013) and distracted driving (Gauld et al., 2017)).

The current research also confirmed that drivers make tactical decisions when engaging in mobile phone use. Low complexity driving scenarios (e.g. straight segment with no traffic) and being stopped (e.g. stop at the red light) increase the likelihood of drivers engaging with their mobile phones. On the other hand, complex driving environments, such as roundabouts, tend to decrease the corresponding presence of distraction. The similar effects of road traffic complexity on distracted drivers have been suggested in previous naturalistic (Kidd et al., 2016; Xiong et al., 2014), self-reported (Hancox et al., 2013; Steinberger et al., 2017) and observational studies (Huth et al., 2015; Esbjörnsson et al., 2007). Although it can be argued that this could be positive in terms of risk, there is no guarantee that drivers make a rational judgement of the complexity of the road traffic condition. In addition, drivers in road traffic conditions with low demands may have longer response times when unexpected traffic events occur (Metz et al., 2011).

Beliefs were found to play a vital role in the tactical decision making of drivers. Specifically, beliefs about the likely presence of law enforcement reduce the likelihood of using a mobile phone while driving. In Queensland, Australia, mobile phone conversations with hand-held devices are illegal whilst hands-free devices are permitted (except for provisional licence holders under 25 years). Participants did not use hands-free devices during this experiment. Therefore, it is likely that drivers concerned about police enforcement were less likely to engage in mobile phone tasks in general. In contrast, drivers who were not convinced of the risk of texting/browsing were more likely to engage in mobile phone distracted driving. Associations between mobile phone distraction and perceived risk have been consistently reported in the literature (Truelove et al., 2018; White et al., 2010). In addition, having at least one traffic offence in the last three years was a predictor of mobile phone usage in any scenario. Márquez et al. (2015) reported a similar finding using questionnaire data. Recidivism might play a role in defining high-risk groups, and educational interventions based on attitudes could support development of target countermeasures.

Finally, operational self-regulation of the secondary task was investigated using a self-pacing secondary task. The proportion of drivers who self-paced the secondary task was generally low. Texting a friend was the task with the largest proportion (48.5%) of drivers interrupting the task. The less self-paced tasks were taking a selfie and ringing the doctor to cancel an appointment. This was not unexpected, given that taking a 'selfie' is a short duration task (average of 12.45 s in this study) and ringing the doctor lacks interruptibility (drivers cannot easily stop or they will need to start over). Some of these findings have been previously documented in the scientific literature, for example Huth and Brusque (2013) reported that a lack of interruptibility is an obstacle for self-regulation. In addition, these results confirm elements of the Behavioural Adaptation Theory (Young and Regan, 2013), e.g. the characteristics of the secondary task (e.g. interruptibility and duration) are argued to moderate self-regulation.

5. Limitations

The current research is subject to several limitations. First, there are ecological limitations associated with driving simulation. Even the most sophisticated driving simulators do not provide the complete visual, vestibular, and proprioceptive changes experienced in real driving. Simulation does, however, provide a useful method for investigating high risk driver behaviour in a relatively safe environment.

It is also important to note that the age of the sample was limited to drivers aged 25–30 years and included a higher proportion of males than females. This limits the generalisability of the findings to the wider population. The small number of significant predictors in the statistical models might be a consequence of limited variation in the sample, clearly indicating the need for extending the present study. Furthermore, given the voluntary nature of participation, selection bias my also have influenced experimental results.

The use of artificial tasks may also limit generalization of the observed adaptation behaviour. This was necessary however, to ensure a consistent level of task complexity. Nevertheless, without a systematic definition of complexity, it is difficult to confirm if the allocation of attentional resources while driving using a mobile phone while is more sensitive to the driving demands than the mobile phone task itself. In particular, drivers in this experiment were asked to complete the mobile phone tasks as soon as possible in a safe fashion. This pressure could have altered the judgement of participants regarding risk. There is a need for more naturalistic observation of mobile phone use while driving.

It is also important to note that the majority of measures utilised in this study were developed by the authors. Nonetheless, this is an original study that investigates a neglected topic in the area of mobile phone distracted driving. With regard to operational self-regulation, other variables such as shorthand/abbreviations when typing text, reduction in the speed of typing, or level of acceptance of typos may have been more suitable. However, due to ethical restrictions on accessing participants' mobile phones such measures were not feasible.

Finally, the mobile phone tasks utilised in this study were voluntary in that they were initiated by the driver. However, research on the epidemiology of mobile phone distracted driving shows that involuntary distractions such as ringing phones or unexpected notifications occur frequently while driving. From a sample of 484 drivers in a cross-sectional study in Australia, nearly 45% of participants reported that they had located and answered a ringing phone on a typical day (1.51 times per hour of driving) (Oviedo-Trespalacios et al., 2017c). Involuntary distractions (or device-initiated distractions) interrupt the driving task and may not allow anticipatory processes for self-regulation.

6. Conclusions and future research

Most drivers showed indications of tactical self-regulation while driving followed by lower proportions of operational and strategic self-regulation. It seems that drivers can identify low-demands and make decisions on where and how to engage in the secondary task. The influence of personal characteristics might cause drivers to make unsafe decisions, so the results do not support the deregulation of mobile phone use while driving. However, an open question here is: can these three levels of self-regulation support mobile phone use while driving while maintaining an acceptable level of safety? Answering this question could be the key to improving road safety since today's interventions have been shown to be insufficient in reducing the prevalence of mobile phone distracted driving (Ehsani et al., 2016). There is potential for future technology-supported interventions to use self-regulation strategies that maintain safety while enabling a degree of mobile phone usage while driving. Technology concepts such as context-aware systems could be utilised to inform drivers about the safe locations to use their mobile phones based on road and traffic conditions. In addition, this study confirms that mobile phone tasks have different degrees of compatibility with driving. Future research examining the impact on the relationship between task characteristics such as interruptibility and complexity and safety might help to support the development of workload management systems (see Teh et al. (2018)) to allow safe mobile phone use while driving.

This study further supports the claims that crash risk in mobile phone distracted driving has been frequently misrepresented in naturalistic studies (see Tivesten and Dozza (2014)). For instance, if drivers decide to engage in a mobile phone task while driving in specific locations or situations, then the estimation of crash risk should take these locations/situations into account. A fair comparison would involve matching mobile phone usage sequences with normal driving sequences on a scenario basis. A similar point applies to the preference of some drivers to engage in mobile phone tasks while stationary, which reduces their level of risk. Another implication is that simulator studies that do not consider self-regulation within the experimental protocol may lack ecological validity. Future simulator studies of system outcomes such as safety or mobility of mobile phone distracted drivers should allow and measure self-regulation to ensure realism.

Inattention and distraction are widespread problems in various safety-critical scenarios (e.g. crossing the road while distracted). The available literature suggests that distracted pedestrians might exhibit self-regulation behaviour in managing their walking and the use of mobile phones while walking (Hatfield and Murphy, 2007; Lennon et al., 2017). Future research should be conducted to examine the identified self-regulation patterns of this research in the context of distracted pedestrians.

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