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Social media browsing while driving: Effects on driver performance and attention allocation

Mahmoud Hashash [a], Maya Abou Zeid [b], Nadine Marie Moacdieh [a,*]

[a] Department of Industrial Engineering and Management, American University of Beirut, Lebanon
[b] Department of Civil and Environmental Engineering, American University of Beirut, Lebanon

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ABSTRACT

Texting while driving is known to lead to performance decrements; however, it is still unclear to what extent browsing social media while driving also negatively affects driver performance and attention. There is a need to determine what guidelines and warnings should be in place. The aim of this research study is to analyze the effects of browsing social media on young driver performance and attention allocation (using eye tracking). To this end, a driving simulator experiment was carried out. Participants were asked to drive and either browse a Facebook page or send text messages on a given cell phone. Results showed that both texting and browsing social media lead to performance decrements, but texting while driving is more detrimental to performance. However, in terms of attention allocation, texting and browsing social media seem to be very similar, confirming the need for more awareness about the visual distraction caused by browsing social media.

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1. Introduction

Motor vehicle crashes remain the leading cause of death and injury for people aged 5–34, accounting annually for over 30,000 deaths and 100 times as many injuries in the US (LaVoie, Lee, & Parker, 2016). While many factors can play a role in such accidents, the main cause of these fatalities and injuries has been found to be distracted driving (Caird, Johnston, Willness, Asbridge, & Steel, 2014), which has been repeatedly highlighted as a significant threat to the safety of drivers (Ascone, Lindsey, & Varghese, 2009; Ferdinand, & Menachemi, 2014; Klauer et al., 2014; Lee, Roberts, Hoffman, & Angell, 2012; Metz, Landau, & Just, 2014; Strayer et al., 2013). This study focuses on distracted driving caused by social media browsing, which has received little focus in the literature to date. In particular, this study analyzes how social media browsing affects driving performance and attention allocation. The application is to a sample of young drivers in Lebanon, a country where an estimated 4675 motor vehicle accidents (with 649 fatalities) took place in 2013, for a population of around 4 million people (Kunhadi, 2018).

1.1. Distracted driving

Distracted driving can be defined as the presence of any secondary activity that causes decrements in driver performance or diverts the driver's attention from the main driving task (Hancock, Mouloua, & Senders, 2009). This results in what is

* Corresponding author at: Department of Industrial Engineering and Management, American University of Beirut, Bliss Street, Beirut, Lebanon.
E-mail addresses: mah102@aub.edu.lb (M. Hashash), ma202@aub.edu.lb (M. Abou Zeid), nm102@aub.edu.lb (N.M. Moacdieh).

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known as divided attention, where attention is split across tasks, resulting in poorer performance on both (e.g., Kahneman, 1973; Liu & Wickens, 1992). Driver distraction can take on many different forms, including both external distractions and within-vehicle distractions. Distractions from outside the vehicle stem mainly from road advertisements and billboards (Wallace, 2003). As for within-vehicle distractions, these could be due to interactions with phones and portable music players (Salvucci, Markley, Zuber, & Brumby, 2007), infotainment systems (Lee, 2007), or conversations with other passengers (Heck & Carlos, 2008; Laberge, Scialfa, White, & Caird, 2004). In Lebanon, driver distraction contributed for around 20% of motor vehicle accidents in 2013 (Kunhadi, 2014). Driver distraction can also be classified as visual (a driver's eyes are off the road), cognitive (a driver's mind is not on the driving task), or manual (a driver's hands are not on the wheel; NHTSA, 2016).

Despite the varied forms of distraction, the main focus when it comes to distracted driving has consistently been on cell phone use while driving, which over 90% of drivers have reported doing (LaVoie et al., 2016). The concern about the use of a cell phone while driving is that it has been shown to cause visual, cognitive, and physical distraction (Fitch, Grove, Hanowski, & Perez, 2014; Hancock, Lesch, & Simmons, 2003; Klauer et al., 2014; Lesch & Hancock, 2004; McKnight & McKnight, 1993; Papadakaki, Tzamalouka, Gnardellis, Lajunen, & Chliaoutakis, 2016; Simmons, Hicks, & Caird, 2016; Strayer & Drews, 2004). The risks of cell phone-based distraction are especially high for novice or inexperienced drivers (Cook & Jones, 2011; Klauer et al., 2014; Lee et al., 2008). Drivers under the age of 20 form the largest percentage of distracted drivers and those in their 20 s constitute nearly 40% of deaths due to cell phone use while driving (NHTSA, 2016).

In particular, the emphasis in the literature has been on two types of phone use that can cause distraction: texting and talking while driving (Bayer & Campbell, 2012; Caird, Willness, Steel, & Scialfa, 2008; Kahn, Cisneros, Lotfipour, Imani, & Chakravarthy, 2015; Moreno, 2014; Olsen, Shults, & Eaton, 2013). When it comes to talking on the phone while driving, studies have shown that this can lead to an increase in drivers' reaction time and a decrease in their overall recognition of road hazards (Ishigami & Klein, 2009; Strayer, Drews, & Crouch, 2006). Talking on the phone also reduces self-awareness of performance (Sanbonmatsu, Strayer, Biondi, Behrends, & Moore, 2015); in other words, distracted drivers tend to mistakenly believe that their performance is not degraded by the use of cell phones or other communication devices. The theoretical underpinning for the distraction caused by talking on the phone can be explained by the cognitive interference hypothesis, which posits that the central executive part of working memory can only function in a serial fashion (Kunar, Carter, Cohen, & Horowitz, 2008). In other words, any secondary task the driver has to do in the car which uses up cognitive resources will interfere with the driver's ability to steer and detect events in the environment. So even though talking on the phone involves very little physical distraction, the cognitive resources needed to carry out a conversation can negatively affect driving performance. This is evident by the fact that even in studies where talking on the phone was hands-free, there were significant performance decrements observed (Ishigami & Klein, 2009; Sanbonmatsu et al., 2015).

Texting while driving, however, is largely considered more dangerous than talking (Gershowitz, 2012; Olson, Hanowski, Hickman, & Bocanegra, 2009). In addition to cognitive interference, texting uses up manual resources (typing on the keypad) and visual resources (moving the eyes to the phone) that are needed for driving, causing structural interference. Structural interference is defined as decrements in performance that occur when two concurrent tasks share the same mental or physical resources (Wickens, 2002). Tasks that share fewer resources of the same nature, such as an auditory task and a visual task, would not suffer from as much structural interference. One research study has shown that texting while driving increases driver reaction time by 35%, compared to 12% and 21% for alcohol consumption and cannabis consumption, respectively (Reed & Robbins, 2008). In addition, texting can lead to increased stopping distance at sudden events (Austin, 2009) and can increase the risk of crashing by more than 20 times (Olson et al., 2009). In comparison, Olsen et al. (2009) found only a marginal increase in the crash rate when talking on a cell phone.

1.2. Social media browsing in a driving context

The advent of the smartphone, however, has led to a wealth of new driving-related problems. The architecture of the smartphone itself, with a touchscreen as opposed to buttons, has been shown to be problematic, with a lack of tactile feedback leading to more physical distraction than older phones (Kujala, 2013). The more significant problem, though, is the wide variety of new applications to potentially occupy drivers, including opening email, browsing the internet, and browsing social media (e.g., Basacik, Reed, & Robbins, 2012; George, Brown, Scholz, Scott-Parker, & Rickwood, 2018) that can lead to both cognitive and structural interference. However, it is still unclear to what extent browsing social media applications, such as Facebook, Instagram, and Twitter, contributes to driver distraction. This is particularly important for young drivers who are at a higher risk for accidents (Moreno, 2014). They tend to be heavy users of social media (Smith & Anderson, 2018) and are more likely to use their phones while driving for various applications, including browsing social media (George et al., 2018). At the same time, young drivers are also inexperienced and more likely to overestimate their driving skills (White, Cunningham, & Titchener, 2011), which makes it possible that they will think browsing social media while driving is fine.

While browsing social media has been considered to be under the broad umbrella of "texting" in some cases (e.g., Llerena et al., 2015), here we will define *browsing* as the process of scrolling through a social media feed and clicking on a "like" button for certain posts. In other words, we have isolated browsing from "texting", which we have defined here as the act of reading, typing, and sending electronic messages into a phone (Ferdinand et al., 2014). There are several key differences between the two applications that warrant treating each as a separate problem. First, texting requires more physical interaction with the phone than does browsing social media. Texting is normally done with two hands, whereas browsing only

needs one. Second, the cognitive processes involved in reading a conversation, thinking about a reply, and responding are different from what would be required for looking at a combination of images and text and responding with one click. Third, texting as part of a conversation is often triggered by a response from the recipient, meaning that it is a data-driven (i.e., externally-driven; Theeuwes, 2010) process that contains a temporal demand element (McNabb & Gray, 2016). Browsing, on the other hand, is more self-driven; drivers can browse when they want and as fast or slow as they wish. Fourth and finally, texting typically involves exchanging words, whereas scrolling social media fields often involves looking at colored images, which tend to be salient or capture visual attention well (although there are several factors that play a role; see Wolfe (1994)). These differences provide motivation for the need to study the two applications separately.

Additional motivation is provided by the widespread use of social media. More than 80% of Americans under the age of 30 are reported to have a Facebook account (Duggan, 2015). In addition, in a survey conducted in 2016, 43% of drivers between the ages of 18 and 29 admitted to browsing social networks while driving, up from 21% in 2009 (State Farm, 2017). Interestingly, the number of people talking while driving decreased over that period. A 2015 survey showed that 40% of drivers use social media while driving, with Facebook the most used social media application (AT&T, 2015). In another recent survey of young adults, browsing social media was selected as the phone application they found the most distracting (Braitman & Braitman, 2017). As such, there is a need to better understand how browsing social media affects a person's driving behavior and attention allocation. Given that social media is so prevalent among young adults, it is only natural that its use in the car will increase and that this will impact driver safety. While some of the key differences between texting and browsing – such as the increased physical distraction when texting – point to browsing being less detrimental to performance than texting, it may be that the two applications are similar in terms of visual distraction.

Four studies to date have examined the effects of social media applications on driving. In Basacik et al. (2012), the use of the Facebook chat messenger application led to more lane departures and more time with drivers' eyes off the road. The Facebook text messenger application, however, was used in the same way as the texting functions available on one's phone, making the task equivalent to a texting task.

McNabb and Gray (2016) were the first to focus specifically on social media browsing, rather than texting. The researchers asked participants to follow a lead car in a driving simulator and participants were given specific tasks to do using either Facebook, Snapchat, or Instagram. They also had one drive that included texting and one baseline drive. For the Facebook task, participants had to read text updates from a created Facebook account; for the Instagram task, participants had to do the same for image updates (no text at all), and in the Snapchat task, they had to send pictures from their phone that matched the pictures sent to them by the experimenter. Brake reaction time and time headway (the time between the driver's car and the leading car they were instructed to follow) variability were measured, and participants were asked to do a recognition task at the end of each drive to determine whether given sentences/images had been presented to them before. The texting task consisted of responding to specific questions from the experimenter, and the baseline task did not have any phone tasks. The researchers divided the four phone conditions into those triggered by the experimenter (texting and Snapchat) and those that were participant- or self-driven (Facebook and Instagram). The tasks were also classified based on whether they involved using and/or searching for words (texting and Facebook) or images (Instagram and Snapchat).

Results showed that the word-based tasks resulted in significantly worse brake reaction time and variability of time headway. However, this was not the case for the image-based tasks, suggesting image-based interfaces are a safer option in cars. The image-only Instagram account used, though, is not entirely realistic. There was no significant difference between self-paced and experimenter-paced tasks, although this was attributed to the fact that there were no intersections in the driving task that participants could use to defer their task to. Moreover, the emphasis in that study was on recalling information following the drive, which may not necessarily be the primary concern of drivers using social media. They may simply want to scroll through and search for images or texts that are of interest. The use of the like button is also something that could happen frequently while driving, but this was not accounted for in this study.

A follow-up study by Gunnarsson (2017) addressed some of the limitations in McNabb and Gray (2016). There was no leading vehicle and there were more varied social media tasks with Facebook and Snapchat, such as searching for a user and a particular update. In this study, drivers had significantly worse performance in each of the social media conditions as compared to the baseline (no phone). However, the fact that all of the tasks in this study included writing/typing suggests once again that performance decrements only exist when there is some element of texting.

Finally, a study by Dumitru, Girbacia, Boboc, Postelnicu, and Mogan (2018) also recorded the performance effects of using social media (Facebook). There were significantly more lane departures when using social media, but the main focus in this study was on examining the benefits of an advanced driver assistance system (ADAS), so the results were primarily a comparison between the ADAS and no-ADAS scenarios. The social media tasks once again contained some texting element. This study did, however, improve on previous studies by using eye tracking to analyze the attention allocation effects, and not just performance effects, of using social media. Given the discrepancies in the literature, it is important to analyze the effects of social media browsing more comprehensively, necessitating the need for eye tracking as a window to attention allocation.

1.3. The present study

The overall goal of this research study is to analyze the effects of social media browsing on performance and attention allocation in the context of a driving simulator, as compared to texting and baseline (no-phone) driving. The focus here is on young drivers as they are the most likely to be browsing social media while driving. The social media application that

was investigated is Facebook, given that it is the most popular social media application in use today (Duggan, 2015). The main gaps observed in the available literature – recall of information rather than search, use of unrealistic social media pages that contain either text or images, inclusion of texting as part of browsing, and lack of focus on attention allocation – were addressed in this study. Eye tracking has been extensively used in research on driver distraction in order to trace attention allocation (Domeyer, Diptiman, Hamada, Toyoda, & Maynard, 2015; Dukici, Ahlstrom, Patteni, Kettwich, & Kircheri, 2013; Kaber et al., 2012; Kountouriotisa & Merat, 2016). While an eye tracker cannot fully capture all aspects of attention – peripheral vision (Rosenholtz, 2016) and the useful field of view (UFOV; Wolfe, Dobres, Rosenholtz, & Reimer, 2017) are notable examples of what is missing in eye tracking data – the information gleaned from eye tracking metrics can nonetheless act as a very useful window into attention allocation (Duchowski, 2007).

The unique aspect of this study is its focus on social media browsing in isolation – scrolling for posts that match a topic of interest and liking these posts, without any form of texting. This will make it possible to compare browsing and texting in terms of both driving performance and attention allocation. If browsing affects driving as negatively as texting, this will provide evidence for the need to develop guidelines that warn against browsing social media while driving, similar to the campaigns against texting (Frietze & Cohn, 2018). While banning texting and driving has become commonplace in various jurisdictions (National Highway Traffic Safety Administration, 2010), drivers may have the mistaken impression that browsing is not dangerous. For example, in Lebanon, a leading driving safety organization, Kunhadi, has spearheaded several campaigns against texting and driving, but never any specific guidelines aimed at browsing social media while driving (Kunhadi, 2018). In addition, by determining which eye tracking metrics reflect changes in attention allocation between browsing and texting, this can pave the way for eye tracking-based in-vehicle intelligent systems that can detect what the user is doing with their phone based, in large part, on eye movements.

Based on the previous literature, it was expected that social media browsing while driving would not be as detrimental to performance as texting (Hypothesis (H)1), as the additional physical interference when texting would lead to more structural interference. However, it was expected that browsing would lead to similar visual distraction as texting (H2), given the need to mentally process the social media feeds. Browsing would then lead to similar cognitive interference as texting. We also expected that drivers would believe that texting while driving is more detrimental to their driving performance than browsing social media (H3), given the more publicized dangers of texting.

2. Methods

2.1. Participants

Twenty-six students (16 men and 10 women; average = 20.95 (standard deviation (*SD*) = 2.36; years of driving experience: 3.95 (*SD* = 2.36)) from the American University of Beirut (AUB) volunteered in this experiment. Students were eligible to participate if they were between 18 and 26 years old, had a valid driver's license, had normal or corrected to normal vision, and had an active Facebook account. Participants were also required to be free of certain medical conditions that might put them at risk in the simulator, such as heart problems, ear problems, or epilepsy. The age range was chosen as this is a typical range used to classify young drivers (e.g., Braitman & McCartt, 2010; Hosking, Young, & Regan, 2009). Students were recruited using emails sent to a random sample of 100 students, as well as flyers posted around the university campus. This study was approved by the AUB Social and Behavioral Sciences Institutional Review Board (IRB).

2.2. Experiment setup

The experiment was conducted using a DriveSafety DS-600c Research Simulator, a mid-level simulator with relative validity (see Fig. 1a). This simulator consisted of a full-width Ford Focus automobile with standard driver controls, instrumentation, and motion cues. A 180° screen displayed the outside road. Performance measures were provided by the simulator at a frequency of 60 Hz. Distance was calculated in "simulator units", which corresponds to meters/second.

The simulator was equipped with an infrared-based Fovio eye tracker located above the dashboard (see Fig. 1b). This eye tracker was not in contact with the participant and had a sampling rate of 60 Hz, with an accuracy of 0.78 (*SD* = 0.59) degrees visual angle. The eye tracker range subtended around 178 degrees visual angle horizontally on the outside screen. The eye tracker did not capture eye movements on the phone or within the car. The front screen (see Fig. 1c) was where all eye gaze points were collected. Any gaze points on the simulator screen that were outside this screen area were discarded and not considered in the analysis. Participants sat at a distance of around 50 cm from the eye tracker and around 165 cm from the front center screen.

2.3. Experiment design

The independent variable for this experiment was the phone application (none/control, Facebook, texting) and it was varied within-subjects. Participants were asked to do three drives along a given path (total length: 6.8 km), with each drive corresponding to each of the three independent variable conditions. Participants were told which direction to turn at intersections using voice commands embedded into the simulator. Each drive, or scenario, contained three events set at

(a)

(b)

(c)

Fig. 1. Driving simulator used in this study: (a) overview of the simulator, (b) location and position of the eye tracker, and (c) the outside view on which eye tracking fixations were collected.

specific locations: a green light turning yellow then red as the participant approaches the traffic signal, a pedestrian crossing in front of the car, and a car braking suddenly in front of them (see Fig. 2). The event type was treated as a blocking variable in the study, not as another independent variable, since we were not interested in comparing across very different events. Rather, we wanted to investigate how the type of phone application affected performance and attention allocation at each of the different events. There were three set locations along the drive for each of the three events; in other words, during the control scenario, all participants encountered the three events at the same three locations. Similarly, the texting scenario contained the three events at fixed locations; however, the locations were different from those in the control scenario. It was the same approach for the Facebook scenario, with three different locations for the events. The road itself did not change across the scenarios. To avoid any learning bias, the presentation order of the scenarios was fully counterbalanced across participants. In other words, participants were randomly assigned to one of six possible sequences of the three experiment scenarios.

The conditions of the simulator were set such that participants drove single-lane (per direction), two-way urban roads, with traffic in both directions and the mean traffic density and speed set to "light" in all scenarios. There was no set speed

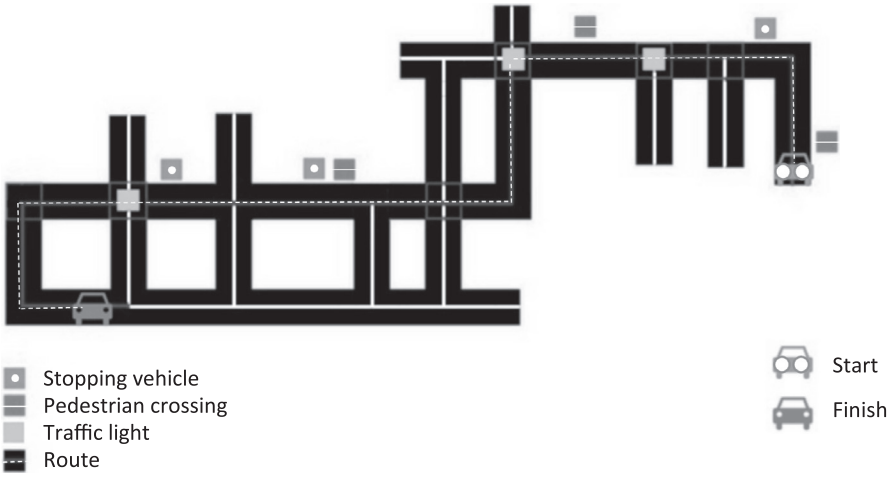

Fig. 2. The path that participants had to drive, with the three possible locations of each event designated. Note that participants only encountered one instance of each type of event during every scenario.

limit as we did not want participants to check their speedometer continuously throughout the drive, as that might unnaturally affect the eye tracking metrics. In summary, all three experiment scenarios were exactly the same except for the locations of the events. With all conditions being equal, we were confident in attributing any changes in performance or attention allocation to the phone application used, despite the fact that the eye tracker did not capture on-phone fixations.

For the two scenarios that consisted of using a phone, the experimenter gave participants the same phone to use, a Samsung Galaxy S3. The phone had the Facebook application installed and had an account set up specifically for this experiment. Before starting the Facebook scenario, participants were told verbally by the experimenter that they have to look for any posts related to sports and "like" those posts by pressing the "like" button. The posts contained a combination of images and text, and sports was selected as a generic, easy to identify theme. The Facebook application on the given phone was opened by the experimenter and given to the participant before starting the scenario. Participants were told that they could browse and "like" at any point during the drive, but that locating less than 80% of posts related to the specified theme rendered the drive null. This was done to motivate participants to browse Facebook as much as possible throughout the drive, simulating the situation where a driver has a strong desire to browse social media. At the same time, participants were told to drive as they normally would and pay attention to pedestrians and driving signs.

For the texting task, the Facebook messenger application was opened for participants. Participants were instructed that during the drive, they would receive arithmetic questions (addition or subtraction only) involving numbers between 1 and 10 (participants would hear an auditory notification upon receipt of a text). Their text message response had to be the result of that arithmetic operation written in text (not numbers). In this way, the texting task was data-driven (i.e., externally triggered), as opposed to the browsing task, where it was up to the driver to determine when to browse. There was a 20-second interval between each two texts. This interval duration was established during pilot testing to make sure that it did not overwhelm participants, but nonetheless kept them steadily texting throughout the scenario. Participants had to answer within this 20-second interval; otherwise, it would count as a missed text and they would then have to move to the next one they received. Similar to the Facebook scenario, the participants were informed that a response rate less than 80% would render the drive and results null. For the scenario with neither social media browsing nor texting, participants were just instructed to drive normally. For all scenarios, more than two crashes rendered the drive and results null.

2.4. Dependent variables

The dependent variables were a set of driving performance, eye tracking, and subjective measures. The performance measures included both continuous data (i.e., data collected across the whole scenario) and event data (at one of the three events). Table 1 describes all the performance measures used in this experiment.

The eye tracking measures used are shown in Table 2. Fixations were calculated by the Eyeworks software package (associated with the Fovio eye tracker) using a 75-ms default minimum fixation duration. One area of interest (AOI) was identified and that was the simulator central outside screen, which included the road, sidewalks, traffic lights, and pedestrian crossings. All gaze points collected on the outside screen were considered to be gazes "on the road".

At the completion of each scenario, participants were also asked to fill out a modified NASA-Task Load Index form (TLX; Hart & Staveland, 1988) to assess the experienced workload. They rated three of the factors of the full NASA-TLX scale that we thought were most relevant to this study: their perceptions of mental demand, temporal demand, and effort on a scale from 1 (least demand or effort) to 20 (most demand or effort). Mental demand refers to how much mental workload the par-

Table 1
Performance measures used in this study.

Metric (unit)	Type	Notes
Average speed (simulator units/sec)	Continuous	Average driver speed throughout the whole drive of a given phone application condition
Average lane position deviation (simulator position)	Continuous	Average of the absolute value of the difference between the car position and the center of the lane; a position of 0 corresponds to the center of the lane, 1.375 corresponds to the right edge of the lane (where cars are parked), and −4.125 corresponds to the left edge of the lane (note, however, that the simulator did not prevent drivers from going beyond those limits)
Average brake reaction time (sec)	Event	Average time from the start of an event (car stopping, pedestrian crossing, traffic light change to yellow, then red) to the participant initiating deceleration

Table 2
Eye tracking metrics.

Metric (unit)	Notes
Number of fixations on the road (fixations/minute)	More fixations on the road suggests less phone distraction
Mean fixation duration on the road (seconds)	A higher mean fixation duration can suggest more visual processing of information (Just & Carpenter, 1976)
Fraction of time looking at the road	The total fixation time on the road divided by the total driving time
Mean X and Y gaze position on the road	The bottom left values of the outside view are (X = 0, Y = 0) and the top right values are (X = 1833, Y = 980)
Spatial density	This measure consists of dividing an area (in this case, the outside view seen by the car) into grid cells. The spatial density is then the number of grid cells containing fixations divided by the total number of cells (Goldberg & Kotval, 1999). A higher spatial density on the outside screen is associated with more spread of attention and could indicate more awareness of the outside environment

ticipants experienced, temporal demand is linked to how much they felt under time pressure, and effort is related to how taxing they felt the drive was. Following that, at the end of the experiment, participants were also asked to fill out a post-experiment questionnaire in which they assessed their own performance in each of the scenarios. In addition, they were asked to respond to the questions shown in Table 3, all of which are related to their opinions and experiences with phone use while driving.

2.5. Experiment procedure

The experiment consisted of four phases. In the first phase, participants were asked to read and sign the consent form and were briefly informed about the overall purpose of the experiment (investigating distracted driving). The experimenter then conducted a short (5-minute) interview with participants to make sure that they have all the necessary qualifications and meet all the experiment inclusion criteria. Participants who did not meet the criteria were not allowed to continue with the experiment. In the second phase, participants were shown the road that they will be driving and taught how to use the simulator for the experiment. Participants were then allowed to practice driving the experiment road (the same one that was used in the experiment scenarios) until they were comfortable with all the controls and instructions. During the training phase, participants experienced all of the same conditions as the experiment scenarios, including all of the events, except a car suddenly braking. We wanted to keep this event as a purely unexpected one in order to better gauge driver attentiveness. This training phase took around 10 min. The eye tracker was then set up and calibrated using a 9-point grid (participants had to look at 9 points on the outside screen in sequence), which took around 5 min. The third phase consisted of the actual experiment, in which participants were asked to drive the three scenarios in the (counterbalanced) sequence assigned by the experimenter, with the necessary explanation before each one. There was a 5-minute rest break between scenarios before the next set of instructions. Participants were asked to hold the phone comfortably at arm's length in front of them.

Table 3
Post-experiment questionnaire questions and scales for each one. Note that where numbers are used here, each of those was a separate question.

Questions	Answer format
How was your performance while (1) browsing social media, (2) texting, (3) not using a phone?	4-point scale (poor, fair, good, excellent)
How often do you (1) browse social media while driving, (2) text while driving?	4-point scale (never, sometimes, often, always)
Do you believe that (1) browsing social media, (2) texting has a significant effect on your driving?	4-point scale (not significant, a little significant, significant, very significant)
Do you believe browsing social media while driving is as dangerous as texting while driving?	3-point scale (not as dangerous, just as dangerous, more dangerous)

They were also instructed to drive safely as they normally would, respecting all traffic rules, but at the same time to make sure to complete their secondary tasks as instructed, otherwise the drive would not count.

Each scenario took around 6–10 min. After completing each scenario, participants were given the NASA-TLX ratings sheet to complete, which took around 2 min each time. Finally, after completing all scenarios, participants were asked to complete a post-experiment questionnaire, which took around 5 min. The full experiment took around an hour.

3. Results

Unless otherwise specified, a one-way repeated measures analysis of variance (ANOVA) was used to analyze the results. The results for two participants were discarded, which resulted in a final total of 24 participants for the data analysis. One participant failed to achieve the 80% response rate for the texting task, while the other participant had three accidents during one of the drives. No other participant had any accident, and no participants experienced any discomfort that forced them to discontinue the experiment. In general, participants did not have any trouble with either the texting or the browsing tasks, with an average of 87.2% (SD = 6.1) of the Facebook posts successfully located and 91.6% (SD = 5.6) of the arithmetic texting questions answered correctly within the time limit. There was no significant correlation between texting or social media browsing performance and any of the driving performance measures.

The normality of the data was confirmed using normal Q-Q plots. Bonferroni adjustments were used for all multiple comparisons and partial eta squared (η_p^2) was used as a measure of effect size. The error bars on all graphs represent the standard error of the mean (SEM) and asterisks on the graphs indicate significant differences between conditions.

3.1. Performance results

3.1.1. Average speed

There was no significant effect of the scenario on the average speed ($F(1, 23) = 5.417$, $p = 0.120$, $\eta_p^2 = 0.102$). The average speed throughout the whole drive was 12.81 (SD = 2.01), 11.26 (SD = 1.73), and 12.17 (SD = 2.06) simulator units/sec for the control, Facebook, and texting scenarios, respectively.

3.1.2. Average lane position variation

There was no significant effect of the scenario on average lane position variation ($F(1, 23) = 1.171$, $p = 0.316$, $\eta_p^2 = 0.033$), with averages of 0.38 (SD = 0.12), 0.39 (SD = 0.06), and 0.49 (SD = 0.10) units for the control, Facebook, and texting scenarios, respectively.

3.1.3. Brake reaction time

Only one participant stopped for pedestrians across all scenarios, so this event was not analyzed. The other two events – stopping at a light that turns red and stopping when the car in front brakes suddenly – were successfully done by all participants for all scenarios. In other words, there were no missed traffic light or car stopping events.

There was a significant effect of the scenario on the average reaction time to respond to a car stopping event ($F(1, 23) = 32.723$, $p < 0.001$, $\eta_p^2 = 0.767$; see Fig. 3). Fisher's LSD post-hoc tests showed a significant pairwise difference between the control and the Facebook condition ($p < 0.001$), between Facebook and texting ($p = 0.001$) and between control and texting ($p < 0.001$).

There was a significant effect of the scenario on the average reaction time to respond to a traffic light event; i.e., to come to a full stop at a traffic light turning red ($F(1, 23) = 33.195$, $p < 0.001$, $\eta_p^2 = 0.786$; see Fig. 4). Fisher's LSD post-hoc tests showed a significant pairwise difference between the control condition and the Facebook condition ($p < 0.001$), between the Facebook and texting ($p = 0.001$) and between the control and texting conditions ($p < 0.001$).

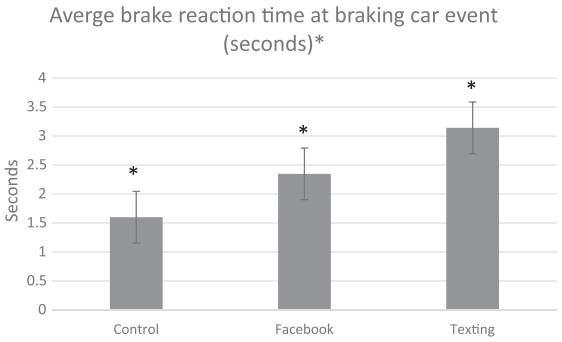

Fig. 3. Average brake reaction time (in seconds) at the braking car event. Asterisks represent significant differences between conditions.

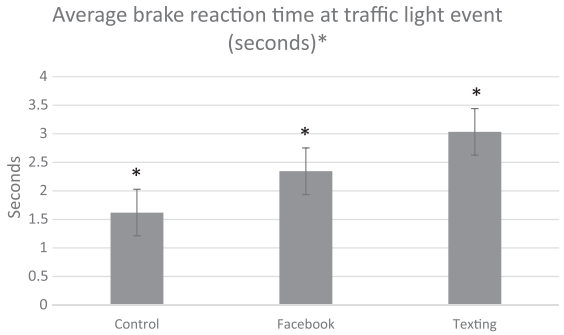

Fig. 4. Average brake reaction time (in seconds) at the traffic light event. Asterisks represent significant differences between conditions.

3.2. Eye tracking results

3.2.1. Number of fixations on the road

There was a significant effect of the scenario on the number of fixations on the road per minute ($F(1, 23) = 35.623$, $p < 0.001$, $\eta_p^2 = 0.36$; see Fig. 5). Fisher's LSD post-hoc tests showed a significant pairwise difference between the control condition and the Facebook condition ($p < 0.001$), between the Facebook and texting ($p < 0.001$) and between the control and texting conditions ($p < 0.001$).

3.2.2. Mean fixation duration on the road

There was a significant effect of the scenario on the mean fixation duration on the road ($F(1, 23) = 10.889$, $p = 0.01$, $\eta_p^2 = 0.325$; see Fig. 6). Fisher's LSD post-hoc tests showed a significant pairwise difference between the control condition and the Facebook condition ($p < 0.001$), and between the control and texting conditions ($p = 0.01$).

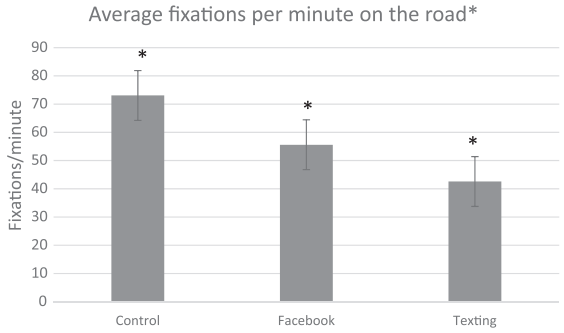

Fig. 5. Number of fixations per minute on the road. Asterisks represent significant differences between conditions.

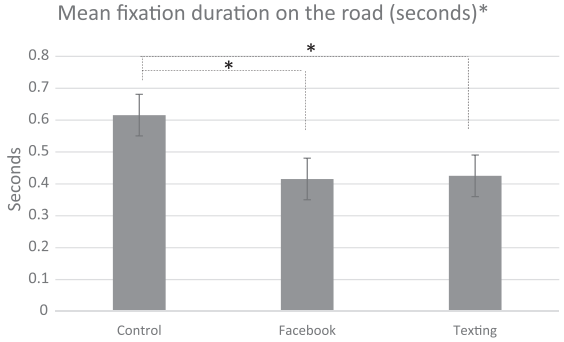

Fig. 6. Mean fixation duration on the road. Asterisks represent significant differences between conditions.

3.2.3. Fraction of time looking at the road

There was a significant effect of the scenario on the percentage of total driving time where drivers are fixating on the road ($F(1, 23) = 61.465$, $p < 0.001$, $\eta_p^2 = 0.64$; see Fig. 7). Fisher's LSD post-hoc tests showed a significant pairwise difference between the control vs. Facebook task ($p < 0.001$) and control vs. texting task ($p < 0.001$). There was no significant difference between Facebook and texting.

3.2.4. Mean X and Y position on the road

There was a significant effect of the scenario on the average X coordinate for the drivers' gaze ($F(1, 23) = 174.892$, $p = 0.01$, $\eta_p^2 = 0.683$; see Fig. 8). Fisher's LSD post-hoc tests showed a significant pairwise difference between the control condition and the Facebook condition ($p < 0.001$), and between the control and texting conditions ($p = 0.01$).

There was a significant effect of the scenario ($F(1, 23) = 39.798$, $p = 0.01$, $\eta_p^2 = 0.5$) on the Y coordinate for the driver's gaze; see Fig. 9). Fisher's LSD post-hoc tests showed a significant pairwise difference between the control condition and the Facebook condition ($p < 0.001$), and between the control and texting conditions ($p = 0.01$). Fig. 10 shows the average location of participants' gaze on the outside view.

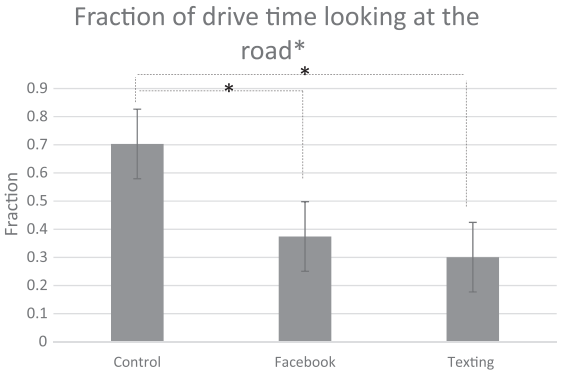

Fig. 7. Fraction of drive time looking at the road. Asterisks represent significant differences between conditions.

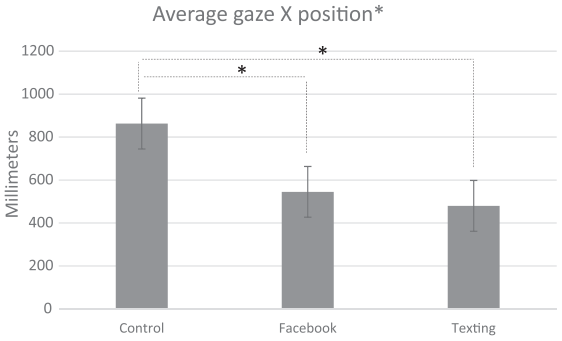

Fig. 8. Average X position of the drivers' gaze. Asterisks represent significant differences between conditions.

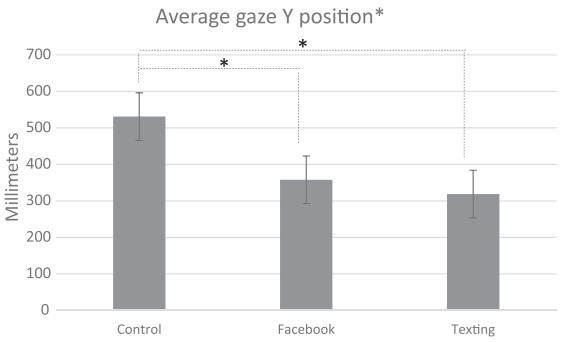

Fig. 9. Average Y position of the drivers' gaze. Asterisks represent significant differences between conditions.

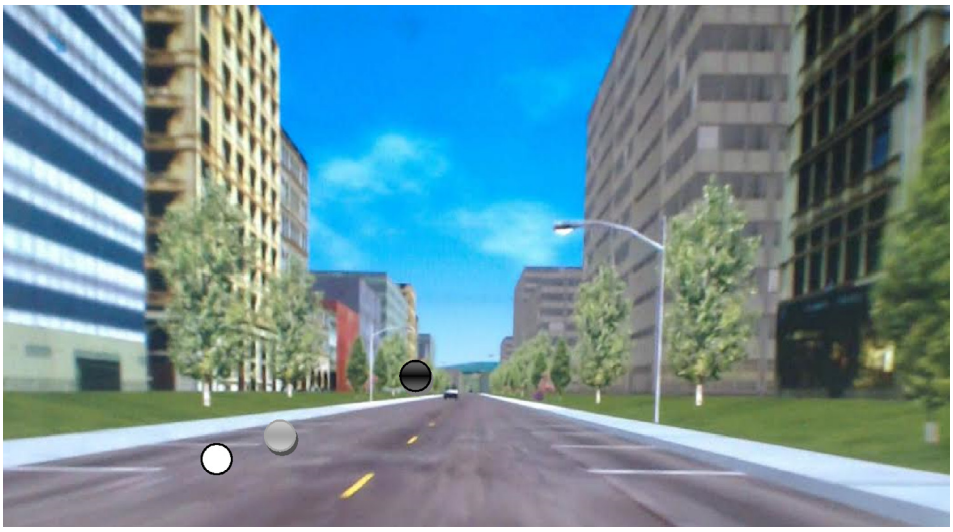

Fig. 10. Average locations of the drivers' gaze position on the road; black circle: control scenario, silver: Facebook scenario, white: texting scenario.

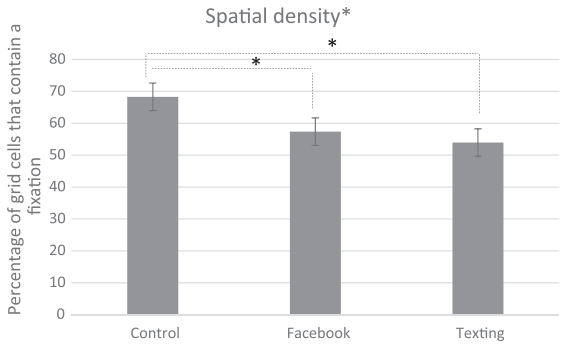

Fig. 11. Spatial density. Asterisks represent significant differences between conditions.

3.2.5. Spatial density

There was a significant effect of the scenario on spatial density ($F(1, 23) = 30.885$, $p < 0.001$, $\eta_p^2 = 0.998$; see Fig. 11). Fisher's LSD post-hoc tests showed a significant pairwise difference between the control condition and the Facebook condition ($p < 0.001$), and between the control and texting conditions ($p < 0.001$).

3.3. Subjective results

3.3.1. Participants' phone habits while driving

Fig. 12 shows the number of participants that use social media or text while driving. The same percentage (75%) of participants said they sometimes browse social media or text while driving.

3.3.2. Participants' evaluation of their performance

Fig. 13 shows participants' evaluation of their own performance during the scenarios. On average, participants believed that their best performance was during the control scenario, followed by the Facebook scenario. Participants believed their performance was the worst when texting and driving.

In addition, Fig. 14 shows the average NASA-TLX scores for all the participants. Friedman non-parametric tests were conducted to check for significant differences for the mental demand, temporal demand, and effort required in the three scenarios. There was a significant effect of the scenario on mental demand ($F(1, 23) = 928.664$, $p < 0.001$, $\eta_p^2 = 0.964$), temporal demand ($F(1, 23) = 2340.26$, $p < 0.001$, $\eta_p^2 = 0.985$), and effort ($F(1, 23) = 2035.39$, $p < 0.001$, $\eta_p^2 = 0.963$). Post-hoc tests showed significant pairwise difference between the control and Facebook conditions ($p < 0.001$), the control and texting conditions ($p < 0.001$), and between the Facebook and texting conditions ($p < 0.001$) for all three categories.

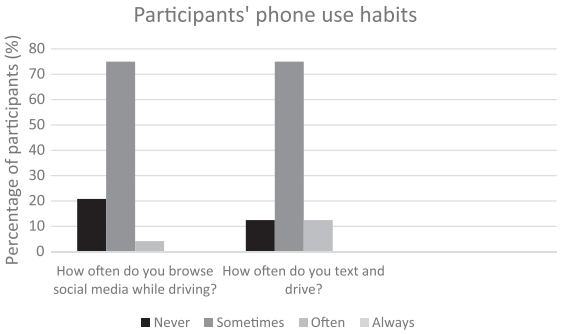

Fig. 12. Participants' phone use habits.

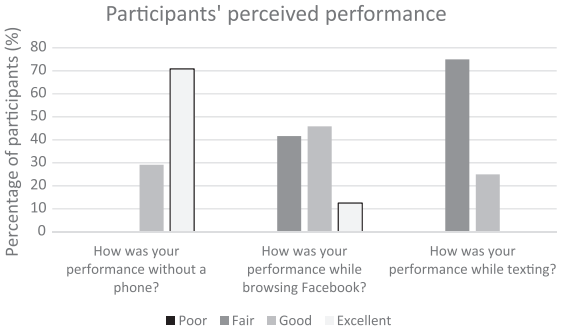

Fig. 13. Participants' perception of their own performance during the scenarios.

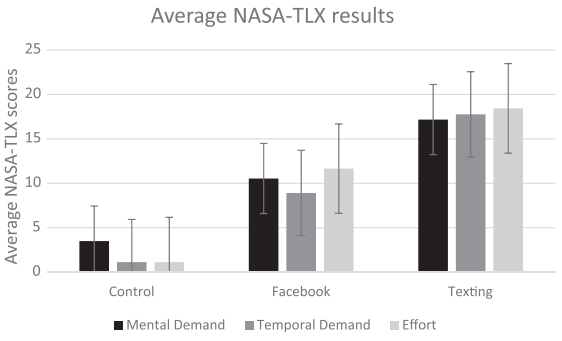

Fig. 14. Average NASA-TLX scores.

3.3.3. Participants' attitudes towards social media browsing while driving

Fig. 15 shows participants' perceived effect of browsing social media and texting while driving on their performance and attention. Only 38% of the participants believed that browsing social media while driving has a significant or very significant effect on their performance and attention compared to 92% who believed that texting while driving significantly or very significantly affects their performance and attention.

Finally, 79% of participants believed that browsing social media is not as dangerous as texting while driving, whereas 17% thought it was just as dangerous. The rest (4%; one person) thought that social media browsing while driving is more dangerous than texting.

4. Discussion and conclusion

The goal of this research study was to determine the effect of using social media while driving on drivers' performance and attention allocation. We expected that social media browsing would not be as detrimental to performance as texting

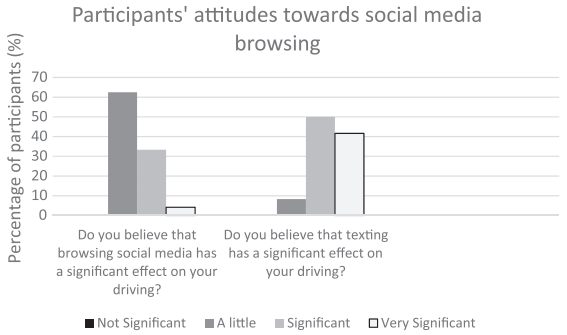

Fig. 15. Participants' attitudes towards social media browsing.

(H1), but would lead to similar decrements in attention allocation (H2). We also expected that drivers would believe that texting while driving is more detrimental to their driving performance than browsing social media (H3).

4.1. H1: Performance effects of social media browsing

From a performance standpoint, the drive seemed to be too easy for any decrements in average speed or lane position deviation to be evident for either texting or Facebook. It also appeared that the pedestrian crossing event was not visible enough in the driving simulator or not explained clearly enough during training, something that will be addressed in future studies. However, results suggest that browsing social media while driving did have a negative effect on event performance, but this effect was not as severe as texting while driving. This finding is consistent with H1; we expected that texting would lead to more structural interference given that it uses up more of the same physical resources needed to drive. This structural interference was evident by the average reaction times to the sudden car braking and light switching events, which were longest (i.e., worst) when texting, even though the times were significantly longer for the Facebook conditions as compared to control.

These findings are in contrast to some previous experiments on browsing social media while driving. For instance, Basacik et al. (2012) reported reduced lane keeping performance while drivers browsed social media. However, our findings are consistent with those of McNabb and Gray (2016), who found longer reaction times for texting than browsing social media. However, the critical difference between our study and the previous ones is the more realistic browsing task adopted here that does not involve any texting and is completely participant-driven. It can be argued that, in previous studies, the presence of texting as part of the "social media" trial contributed to making the performance effects worse. It would seem that, in keeping with H1, social media browsing does not appear to be as detrimental to performance as texting.

4.2. H2: Attention allocation effects of social media browsing

The eye tracking metrics provide further insight into the effects of social media browsing on attention allocation and help explain how the performance effects came about. Drivers looked less at the road when browsing social media, and even less when texting, based on the number of fixations on the road. This was consistent with the performance results in that social media browsing was not as detrimental to drivers as texting while driving. It would seem that, contrary to H2, browsing social media results in less visual distraction than texting, allowing drivers to devote more visual attention to the road (although still significantly less than they would without a phone at all).

The other eye tracking metrics, however, provide results that are more consistent with H2. There was no significant difference between browsing and texting in terms of mean fixation duration. A lower mean fixation duration during both texting and browsing as compared to control suggests drivers were not cognitively processing the environment and what is happening in it as deeply or thoroughly during both conditions (Irwin, 2004). The fraction of time that participants were looking at the road was also the same whether texting or browsing social media. In both cases, the fraction of time was significantly lower than that during the control condition. Similarly, the average gaze position suggests that, whether texting or browsing social media, drivers were no longer looking at the center of the road as they were in the control condition. Instead, they were looking right in front of the vehicle and neglecting a good part of the environment. Spatial density confirms that drivers' coverage of the environment was not as comprehensive when texting or browsing as opposed to when driving without a phone. In other words, participants were sampling a narrower portion of the outside view when using a phone, with items or events in the periphery potentially missed.

In summary, these findings suggest that drivers' processing and coverage of the environment is equally poor in both texting and browsing social media, as is the total time spent looking at the road. The lower number of fixations on the road when texting could be attributed to participants going back and forth between the phone and the road more when texting, which would help explain the worse performance decrements in this scenario. Future studies will look to track fixations on

the phone in order to further explore this theory. Nevertheless, analyzing all the metrics together, and not just the number of fixations on the road, would suggest that the visual distraction caused by social media browsing is very similar, if not equivalent, to that caused by texting. It seems that, in keeping with H2, browsing social media did lead to similar cognitive interference as texting while driving, despite the greater structural interference when texting. It would seem that, similar to the case of hands-free talking while driving (e.g., Sanbonmatsu et al., 2015), the mental resources used up by having to process the images and text in a social media feed are enough to lead to significant visual distraction. While the physical distraction contributed more to the performance decrements, the visual distraction could translate into performance decrements in a different, more realistic, or more challenging context. More difficult tasks, such as those involving multiple pedestrians, billboards, bad drivers on the road, and more unexpected events, might see browsers exhibit equally bad performance when browsing as when texting.

4.3. H3: Subjective perceptions

The subjective results emphasize the need for more awareness about social media browsing. In general, results appear to support H3, which was that participants would believe that texting is worse for performance than browsing social media while driving. Participants felt that they did not drive as well when texting, they thought texting was more dangerous than social media browsing, and they reported that texting led to higher mental workload. Overall, an equal percentage of participants reported that they sometimes texted or browsed social media while driving.

While participants were correct in their assessment of their performance, and their ranking of the effects of texting vs. social media browsing, the fact that people tend to feel "safer" when browsing social media and driving is worrisome. There were still significant negative performance effects for social media browsing and, more importantly, degraded attention allocation when browsing that were equivalent to those when texting. It could be that the lesser physical distraction when browsing – the need for only one thumb to browse – is what makes drivers feel it is less dangerous. On the other hand, the cognitive interference caused by browsing may not be as apparent to drivers. This suggests that more awareness is needed – and for young drivers in particular, given their driving inexperience and tendency to use social media – so that they realize that browsing social media is not necessarily a safe pastime in the car. While texting and driving receives a much larger share in the literature and most of the negative attention, there needs to be more research about the effects of browsing social media, or browsing any website. Care must be taken not to mistake social media browsing for a safer option than texting, although the fact that participants were not asked to rate the dangers of social media explicitly (they were only asked about the dangers in comparison to texting) is one limitation that can be addressed in future work. Moreover, this study focused on young drivers, who are supposedly more comfortable with the technology. Some older drivers may have an equal desire to browse social media but may experience more negative performance or attention allocation effects. Follow-up research could investigate how browsing social media affects older drivers.

Moreover, one major advantage of using eye tracking is the fact that eye tracking data can be obtained in real time. This means that eye tracking measures such as the ones used here can be used to detect distraction as soon as it occurs while driving, and thus form the basis of in-vehicle warning systems (e.g., Ahlstrom, Kircher, & Kircher, 2013; Liang & Lee, 2014). Such a system could potentially differentiate between the different types of distraction and give targeted feedback to the driver. If these can be done using eye tracking only, which is non-invasive (nothing touches the driver) it would provide a significant advantage over other more invasive systems, such as EEG or ECG, that require something to be connected to the driver.

Other extensions to this study could also tackle the shortcomings of the eye tracker used here, which could only track fixations on the outside view. It would be helpful to also be able to track the number of fixations on the phone, rearview mirror, etc. as a measure of drivers' attention allocation as part of a more taxing scenario. In this study, we only compared the relative differences between the three scenarios, but being able to track fixations on the phone would make it possible to obtain absolute numbers regarding driver distraction. Further research could also extend the study to different sample populations, such as young people who are not university students, or older adults. It would also be interesting to test different types of tasks used within social media, as well as different themes if a similar search task is to be used. The texting task could also be varied to something closer to real-life conversations and to situations where the individual initiates texting as opposed to just reacting to received texts. Finally, isolating the key differences between texting and browsing would also allow for a more fine-grained analysis of the cognitive processes and attention allocation strategies involved with texting versus browsing. This would make it possible to determine exactly what caused visual distraction in each case.

In conclusion, browsing social media while driving can negatively affect drivers' performance and attention allocation in ways comparable to, but not always as dangerous as, texting while driving. At the level of performance, texting appears to be clearly worse, but at the level of attention allocation, browsing social media is arguably as detrimental when it comes to processing data from the environment and the coverage of the surroundings. This suggests that browsing social media is dangerous, contrary to people's impressions. It would seem that the dangers are more worrisome than other phone applications such as playing music, which have a clear endpoint (when the music is set, the phone is put away). Browsing could go on indefinitely. As a result, it is necessary to conduct more studies in this area to make sure to provide drivers with the proper recommendations regarding social media browsing, to an extent comparable to the campaign against texting and driving. Campaigns aimed at reducing accidents related to distracted driving should then provide clearer warnings about the dangers of browsing social media, as opposed to repeating warnings about only texting and driving.

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