Penerbit Akademia Baru

Journal of Advanced Research Design

Journal homepage: www.akademiabaru.com/ard.html
ISSN: 2289-7984

Distracted driving while doing mobile phone conversation: A driving simulator study

Open Access

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ARTICLE INFO

Article history:
Received 11 June 2019
Received in revised form 11 August 2019
Accepted 6 October 2019
Available online 14 October 2019

Keywords:
Driver distraction; driving simulator; response time; road safety

ABSTRACT

Mobile phone is a very useful instrument to mankind whereby it can do lots more than make and receive telephone calls. Unfortunately, it has the potential to distract drivers in many ways. The aim of the study is to measure the distraction in term of participants' response time for different conversation task and driving scenarios using a driving simulator. In this study, 54 participants completed a secondary task (i.e. mobile phone conversation task) while concurrently performing the Detection Response Task (DRT) in a driving simulated environment. For driving scenarios comparison, three scenarios were used; free flow (40 km/h) with medium traffic volume, free flow (40 km/h) without traffic and traffic jam. For different conversation task, the contents of conversation were in emotional and factual conditions with hands-free and hand-held mobile phone. Overall, the results of this research showed that participants responded to lesser stimuli when dealing with more difficult conversation task. On another note, we also found that drivers were more distracted when dealing with more demanding tasks of using mobile phone (i.e. conversation tasks) as compared to baseline. In addition, participants attended the worst in term of stimuli and higher response time in traffic jam scenario as compared to other scenarios. Besides, the study discovered that novice drivers' group was identified to respond significantly faster rate than the experience drivers' group.

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1. Introduction

6,284 fatalities were recorded due to road crashes in year 2018 [1]. This alarming figure generate an average of 17 people killed every day. In worldwide, road traffic injury is the eighth leading cause of death and more than one million are killed every year because of road crashes [2]. Human errors are the main contributing factor whereby about 90% of the road traffic accident [3]. One of the severe and growing threat to road safety is driver distraction. Driver distraction can be defined as doing any task other than main task (i.e. driving) in which can divert driver's attention [4]. Driver distraction can impair the driver performance when drivers unable to allot adequate attention to the main task

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during dangerous situation since they are involved in additional task that can cause to the impairment in the ability to drive safely [5]. Many literatures mentioned that driver distraction is well known as a causal factor in at least a quarter of vehicle accident [6,7,8]. This numbers could increase in the future due to the high usage of mobile phone while driving that has a high possibility to distract drivers.

Extensive studies from around the world have shown that driving distraction including mobile phone usage while driving increases the risk of crash involvement [9,10,11]. Other researches have shown that as little as 1 hour per month of cell phone use while driving increases a driver's crash risk 400–900% [12,13,14]. Cell phone use while driving has been reported to be more disruptive than ethanol intoxication [15]. Some studies revealed that there were negative effects on driver performance when talking on mobile phone while driving. These studies also summarised that hands-free and hand-held mobile phones usage yield similar impairment in performance as compared to normal driving (i.e. without mobile phone usage) [16,17].

Studies carried out concerning driver distraction specifically on mobile phone usage in Malaysia is still insufficient. One very limited experimental study using a driving simulator conducted by MIROS to measure the response time of several secondary tasks including texting usage while driving without specifying the character numbers concluded that 97% difference of texting response time as compared to baseline task [18]. Furthermore, a self-reported survey pertaining mobile phone usage while driving in Klang Valley has shown that 43.4% of drivers in Klang Valley used their mobile phone while driving, 61.9% while stopping at red lights and 53.6% used their mobile phone during traffic jams [19]. There were no specific accident data reported in term of type of fault related to driver distraction in Malaysia. Nearly related but arguable are careless driving, dangerous driving, dangerous turning, dangerous overtaking, driving too close, careless at entrance or exit and negligent signalling that have total percentage of 74.81% [20]. Approximately 176.5 million mobile cellular phones subscribed in Malaysia with ratio of 5.8 mobile cellular phones for each Malaysian in 2015. In addition, approximately 25,856 million Short Message Services (SMS) were sent in the same year [21]. With the advancement of smartphones and aforementioned figures, it is expected that will affect the usage of mobile phones while driving in Malaysian context. Seeing the critical issues of mobile phone usage as a source of distraction, MIROS conducted the study and published the paper that explains the methodology, data analysis and research findings. The study was aimed to measure the distraction in term of participants' response time for different mobile phone conversation task and driving scenarios.

2. Materials and Method

Mixed method experiment and convenience stratified sampling was used in this study. Fifty-four participants, with twenty-seven males and twenty-seven female participants, took part in the study. All participants are right-handed drivers and have no specific knowledge or expertise about the study. Participants' ages range between 18 and 57 years old, with a mean of 31.47 years old. Participants took part in the study voluntarily, having read and signed a consent form that informed the purpose and procedures of the study. All participants are licensed drivers with an average driving distance of 20,478.27 km a year and an average driving experience of 10.42 years. Participants were selected among the staff at MIROS and the general public. Participants must be able to drive using automatic transmission. Two groups of participants were involved in the study which are novice and experience drivers. Novice drivers are drivers who have the experience of driving less than 4 years and age between 18-24 years. While, experience drivers considered as more than 10 years driving experience and age between 30-59 years [22].

The MIROS Fixed-base Driving Simulator Cabin (CabinDS) was used in this study that utilised a platform from a second generation of Perodua Myvi 1.3L. The main components of the simulator are simulation software, steering wheel, pedals, transmission, full car cabin, LCD projector and screen, computer, video camera and sound system. Figure 1 illustrates the CabinDS system.

Fig. 1. Integrated CabinDS system

Three different driving scenarios were designed in this study, which were free flow (40 km/h) with medium traffic volume, free flow (40 km/h) without traffic and traffic jam. Figure 2 presents an illustration of the designated driving scenarios.

(a) Traffic jam

(b) Free flow (40 km/h) with medium traffic volume

(c) Free flow (40 km/h) without traffic

Fig. 2. Illustration of the simulation scenarios

Driving was performed in a simulated traffic condition and the Detection Response Task (DRT) was used in a dynamic setting. DRT is one of the methods for measuring driver distraction

[23].Participants performed the driving task and the secondary tasks concurrently according to road conditions. Stimulus presentations for the DRT were controlled by the DRT software. Tactile DRT was used in the study. The stimulus on the DRT was presented at temporal intervals randomly, uniformly distributed between three and five seconds. Participants responded by pressing a microswitch attached to the right index finger on the steering wheel. The microswitch provided mechanical feedback indicating that a response has been made.

Mobile phone usage with conversation task was applied in the study as secondary task. For different conversation task, the contents of conversation were in emotional and non-emotional (i.e. factual) conditions with hands-free and hand-held mobile phone. There was an emotion induction procedure to induce emotional moods while converse using mobile phone. Participants were asked to read a short passage and watch short videos designed to make them angry, and then write for 12 minutes about a past experience that make them angry [24, 25]. Then, the conversation revolved around the past experience to preserve their anger. For the factual condition, questions and answers methods were involved in the conversation that related to the histories and facts. Every conversation took about 2 minutes to be completed. Figure 3 shows the conversation task that using hand-held mobile phone.

Fig. 3. Conversation task using hand-held mobile phone as a secondary task

Each participant required approximately one and a half hours to perform the procedures of the data collection. Participants were given some instructions before executing the procedures. Participants were also asked to fill out the informed consent and personal detail forms. Safety briefing was given to participants before the data collection was conducted. Then, participants were subjected to simulator sickness screening prior to the experiment. The purpose of the screening was to ensure participants were well, fit and capable to drive the driving simulator. Next, they were asked to perform training and familiarization session for secondary task, driving simulator and the DRT device. Participants were not given time limit during this training session but the session was stopped when participants felt comfortable performing the tasks. During the actual data collection session, participants needed to complete all tasks and allowed to stop the experiment without coercion. After that, participants were also subjected to post simulator sickness screening after they have completed the actual data collection. After completion of all tasks, participants were interviewed about their driving experience. Then, participants were thanked and rewarded for their participation.

3. Results and Discussion

Figure 4 shows the percentage of stimuli participants responded to when doing the secondary tasks for three respective driving scenarios. Participants responded most to the stimuli presented in the baseline condition – 96.9% in the 40 km/h situation with relative medium traffic volume, marginally 0.5% lower in the 40km/h situation without traffic, and slightly lower in the traffic jam scenario. The percentage of stimuli responded were lower than the baseline in the other four conversation related conditions. Inspection of Figure 6 suggests that, within each traffic situation, participants responded to the least stimuli during the emotional conversation without holding the phone, followed by emotional conversation while holding the phone. Participants responded relatively equal frequent to the other conditions involving factual conversations.

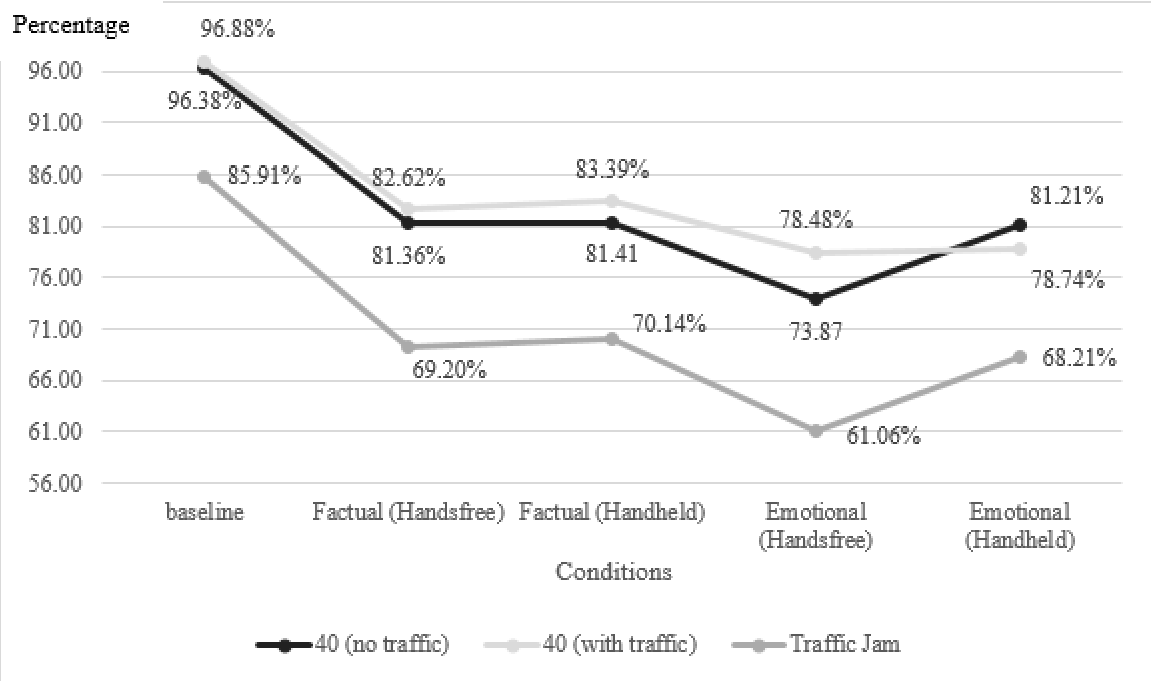

Fig. 4. Percentage of stimuli responded for each conversation related condition based on driving scenarios

To proceed with the analysis, the result of response times were subjected to mixed factorial repeated-measures ANOVA procedure to study for mean differences of response times with respect to various conversations, driving scenarios, and any potential interaction. As Mauchly's test indicated a violation to the assumption of sphericity for the main effect of conversation conditions, $X^2(9) = 24.84$, $p = .001$; the associated degree of freedom in the ANOVA was corrected using Greenhouse-Geisser estimates of sphericity. The results of the test revealed a significant main effect of conditions on response times, $F(3.21, 170.08) = 41.80$, $p < .001$. Further, simple contrasts revealed that response timesfor all conversation conditions are significantly higher than the baseline, $F_{baseline\ vs.\ factual\ (handsfree)}(1, 53) = 115.31$; $F_{baseline\ vs.\ factual\ (handheld)}(1, 53) = 93.27$; $F_{baseline\ vs.\ emotional\ (handsfree)}(1, 53) = 89.13$; $F_{baseline\ vs.\ emotional\ (handheld)}(1, 53) = 82.89$; all pairs had $p < .001$.

Main effect of driving scenarios on response times was also significant, $F(1.70, 90.28) = 89.86$, $p < .001$; with significant contrasts between traffic jam and both 40 km/h scenarios, $F(1, 53) = 120.51$, $p < .001$; and $F(1, 53) = 102.04$, $p < .001$; respectively. There was also a significant interaction effect between conversation conditions and driving scenarios, $F(5.79, 306.64) = 2.60$, $p = .02$ (Greehouse-

Geisser corrected). Figure 5 depicts these results. Response times for traffic jam scenario were longer than both 40 km/h driving scenarios across all conversation conditions.

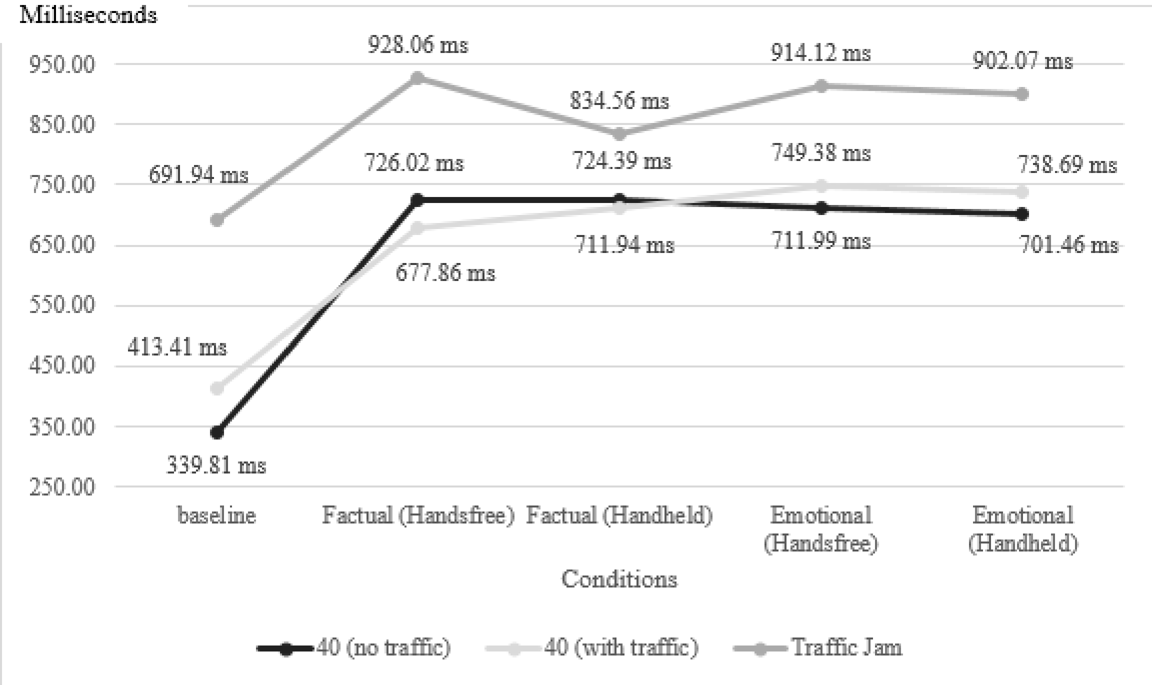

Fig. 5. Responded time for each conversation related condition based on driving scenarios

The analysis continued with investigation involving between-subject variables – gender and age group. The age group was defined as novice (less than 4 years driving experience and age between 18-24 years) and experience (more than 10 years driving experience and age between 30-59 years). The main effects of gender and age group on response times during conversation conditions were both non-significant: $F(1, 52) = 2.20$, $p = .14$ for gender; and $F(1, 52) = 3.87$, $p = .06$ for age group. The only interaction effect involving response times during conversation was only between age group and conversation conditions $F(3.11, 161.90) = 3.51$, $p = .02$. The remaining pairs had no significant interactions: between gender and traffic situations $F(1.71, 89.12) = 2.38$, $p = .11$; between gender and conversation condition $F(3.20, 166.24) = .36$, $p = .80$; and between age group and traffic situations $F(1.71, 88.74) = .34$, $p = .68$. Mean and standard deviations for each condition pair are in Table 1.

As mentioned in the literature review, drivers can get distracted by using mobile phone in several ways while driving. This study used DRT to measure the effects of driving demand and engagement in secondary tasks on driver attention. The secondary task involved conversation task in which emotional and factual conditions were induced during the dialog session between researcher and participants. This task was using hands- free and hand-held mobile phone. The current experimental setup was found to have successfully captured the response time and measured the driving distraction among the participants. A vital finding is that all conversation conditions (i.e. emotion and factual conversation using hands-free and hand-held) are significantly higher than the baseline (i.e. without doing secondary tasks). However, there were no significant difference between hands- free and hand-held mobile phone, also between emotion and factual conversation. This result is aligned with the existing studies, in which indicate that the use of hands-free and hand-held phones yield similar impairment in driving performance as compared to normal driving [26, 27]. In addition, the finding from the study seem to support the results from other study that revealed mobile phone conversation diverts drivers' attention away from components of the driving task that require explicit attentional processing, resulting in longer response times [28]. Strayer and Johnston (2001) also support our finding, in which any mobile phone conversation regardless of emotional conditions negatively affects driving performance [29].

Table 1
Summary of response time means based on gender and age group for conversation related conditions

Scenario	**Character Number**	**Adjusted Response Time, *M* (*SD*) milliseconds**			
		Male (*N* = 27)	**Female (*N* = 27)**	**Novice (*N* = 28)**	**Experience (*N* = 26)**
40 km/h (no traffic)	Baseline	320.86 (141.62)	362.90 (138.99)	334.31 (154.52)	350.03 (126.43)
	Factual (HF)	707.97 (387.94)	755.15 (289.49)	611.35 (304.53)	861.01 (333.32)
	Factual (HH)	667.49 (290.75)	787.72 (228.65)	644.35 (255.28)	817.27 (252.17)
	Emotional (HF)	632.58 (281.92)	787.59 (370.45)	684.30 (364.35)	737.85 (305.68)
	Emotional (HH)	668.33 (306.9)	727.05 (347.12)	649.50 (278.63)	749.59 (368.61)
40 km/h (with traffic)	Baseline	412.21 (202.78)	416.83 (187.57)	388.57 (193.22)	442.46 (193.59)
	Factual (HF)	672.15 (283.11)	688.61 (211.69)	617.31 (250.46)	748.30 (230.46)
	Factual (HH)	668.74 (307.87)	758.40 (314.05)	598.59 (268.96)	837.40 (310.82)
	Emotional (HF)	725.75 (447.16)	766.80 (336.84)	669.49 (321.81)	828.97 (448.66)
	Emotional (HH)	683.88 (294.92)	784.21 (303.98)	706.60 (278.11)	763.60 (326.65)
Traffic Jam	Baseline	628.37 (286.57)	755.80 (338.06)	691.91 (312.26)	692.27 (328.21)
	Factual (HF)	834.22 (389.94)	1029.33 (400.22)	899.45 (425.03)	966.60 (384.37)
	Factual (HH)	775.65 (293.07)	926.73 (371.32)	729.37 (295.84)	982.38 (340.59)
	Emotional (HF)	866.85 (255.96)	981.35 (351.06)	871.41 (298.58)	980.84 (317.25)
	Emotional (HH)	876.56 (332.02)	932.38 (303.51)	874.23 (355.29)	937.04 (271.44)

Note: HF and HH refer to hands-free and hand-held, respectively

Another important finding was that drivers' engagement in both secondary tasks while driving in a challenging driving scenarios increased their reaction time to stimuli, which indicate higher level of distraction. Drivers were found to be distracted the most when driving in a traffic jam, compared to a free-flowing traffic scenarios. In other words, the level of distraction due to mobile phone usage is worsen by a demanding driving scenarios. Although a previous study reported no relationship between the frequency of distracted driver behaviours and amount of traffic [30], our result could indicate potentially higher risk of distracted driving in certain traffic conditions. This risk can be even higher when the secondary tasks are more complex in nature as indicated by the significant interaction effects on participants' response times.

In this study, comparing the response times between experience and novice drivers revealed an interesting finding. The novice group was found to respond to the stimuli at significantly quicker rate than the more experience group. This finding was unexpected mainly because being more experienced was established by previous research as a factor that is associated with a greater degree of adaptation to increasingly complex driving environments [31]. A possible explanation for this might be that the effect of experience is not necessarily the same on driving performances, as compared to the level of distraction. In other words, being quicker in responding to stimuli might not guarantee a better driving performance among the novice group, vice versa. Interestingly, previous study conclude that experience is not a factor that can solve the safety issues related to distracted driving caused by dual tasking, mainly due to the complexity of the primary task at hand (e.g., driving a moving vehicle) [32].

4. Conclusion

In a nutshell, the objectives of the study were fulfilled whereby to measure the distraction in term of participants' response time for different conversation task and driving scenarios using a driving simulator. The findings of this research indicate that drivers were more distracted with the more demanding tasks of using mobile phone (i.e. conversation task) as compared to baseline. Among three driving scenarios, participants attended the worst in term of stimuli and higher response times in traffic jam scenario. Besides, novice group was identified to respond significantly faster rate than the experience group. This study shows that using mobile phone conversation whilst driving is considered as distracted activity that possibly raises the risk of crash.

Acknowledgement
The authors would like to express their sincere gratitude to Allianz Malaysia Berhad who become the main sponsor of this research project. Besides, to MIROS management, Director of Road User Behavioral Change Research Center (RUBC) and members of Human Reaction Simulation Unit (HURAS) for their valuable commitment and support.

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