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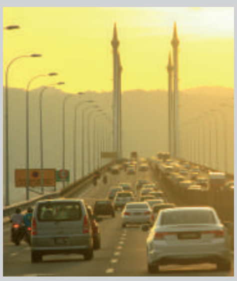

Research Report

Measurement of Driver Distraction While Using Navigation Device via Driving Simulator

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Ahmad Azad Ab. Rashid
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Abstract

The navigation device is a very helpful tool to assist and guide drivers that travelling from point A to point B. Unfortunately, it has the potential to distract drivers through several means. The main objective of the study is to measure the driver distraction of navigation device usage in a simulated traffic environment using Detection Response Task (DRT) method. In this study, 46 participants completed a number of secondary tasks while concurrently performing the DRT in a simulated driving environment. For driving scenarios comparison, three (3) scenarios were used; low speed (40 km/h), high speed (110 km/h) and traffic jam. Apart from the 0 character number, other secondary tasks such as 1, 2, 3, 4, 5, 7, 9, 14, 20 number of characters were also assessed. Overall, the results of this research showed that participants responded to lesser stimuli as the number of character increases. On another note, we also found that drivers were more distracted with more demanding task to handle the navigation device as compared to baseline. Besides, the study discovered that novice drivers group was identified to respond significantly faster rate than the experience drivers group.

1. Introduction

The number of fatalities due to road accidents in Malaysia has been consistently above 6,000 over the past few years. According to Transport Minister, in year 2016, 7,152 fatalities were recorded due to road crashes as compared to 6,706 deaths in the year before (Babulal, 2017). This alarming figure generates an average of 19 people killed every day in last year. In worldwide, road traffic injury is the eleventh leading cause of death and more than one million are killed every year because of road crashes (Peden, 2004). Human errors are the major contributing factor, which is about 90% of the road traffic accident (Chan, 2007).

One of the severe and rising menace to road safety is driver distraction. Driver distraction can be defined as doing any task other than main task (driving) in which can divert driver's attention (Ranney, 1994). According to Young and Salmon (2012), driver distraction can impair the driver performance when drivers unable to allow adequate attention to the main task during dangerous situation since they are involved in additional task that can cause to the impairment in the ability to drive safely. Many literatures mentioned that driver distraction is well known as a causal factor in at least a quarter of vehicle accident (McEvoy, Stevenson & Woodward, 2007; Stutts, Reinfurt, Staplin & Rodgman, 2001; Wang, Knipling & Goodman, 1996). This numbers could increase in the future due to the amplified usage of in-vehicle technologies such as navigation device.

Seeing the critical issues of navigation device as a source of distraction, MIROS conducted the study and published this report that explains the methodology, data analysis and research findings. The study was generally aimed to measure the driver distraction of navigation device usage in simulated traffic environment using Detection Response Task (DRT) method.

1.1 Objectives of the Study

The specific objectives of this study were:

i. To measure the distraction in term of participants' Adjusted Response Time (ART) for different character numbers of navigation task and driving scenarios using a driving simulator.
ii. To compare between participants' Adjusted Response Time (ART) with respect to within-subject variables and between-subject variables.

1.2 Limitations of the Study

A limitation of this study is that a driving simulator was used instead of driving in an actual car, in which not resemble real road driving condition and the likelihood that participants suffer from simulator sickness. The sickness occurred when participants were exposed to a virtual environment where effects of visual simulation constraints, participants gender and age.

2. Literature Review

2.1 Navigation Device as Source of Distraction

The navigation device is designed to guide and assist drivers to a specific destination. While such a device may be helpful but it has the potential to distract drivers in several ways. Burnett, Summerskill and Porter (2004) in their study revealed that the use of the navigation device in a vehicle might bear up increasingly frequent and inessential use of the device, including browsing through attractions list. Ranney (2008) analysed that navigation device usage while driving can distract drivers in several ways, which are a physical, visual, auditory and cognitive distraction. Physical distraction exists when the driver has to use hand to operate the device to do manual destination entry. In term of visual distraction is due to the amount of time looking at the display while entering a destination or observing the directions. Auditory distraction can happen when the driver is listening to auditory turn-by-turn commands. In addition, cognitive distraction involves delays in attention and judgment. It occurs when two mental tasks are performed at the same time when drivers think about the information presented by the navigation device.

As eloquently stated by Young, Regan and Hammer (2003), destination entry when using navigation device can be considered as the most distracting activity while driving and it required a time-consuming process. Tijerina, Parmer and Goodman (1998) also examined the effects of destination entry using four (4) route guidance systems on closed-road driving performance. They discovered that destination entry using the manual systems had a greater possibility for distraction as compared to the voice triggered system since it involved longer frequent glances at the device and a greater number of lane deviations.

Unfortunately, a comprehensive study carried out concerning driver distraction specifically on navigation device usage in Malaysia is still unavailable. In addition, there were no specific accident data reported in term of the type of fault related to driver distraction in Malaysia. Nearly related but arguably 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% (PDRM, 2015). The usage of navigation device can be found generally from a mobile application that installed in the smart phone. According to MCMC (2015), approximately 176.5 million mobile cellular phones subscribed in Malaysia with ratio of 5.8 mobile cellular phones for each Malaysian in 2015. (MCMC, 2015). With the advancement of smartphones and figures as mentioned above, it is expected that will affect the usage of navigation device using a mobile phone while driving in the Malaysian context.

2.2 Measuring Driver Distraction via Driving Simulator and Using Detection Response Task (DRT) Method

One of the prominent empirical approaches to study human-related issues specifically for driver distraction performance is a driving simulator. Driving simulator is an instrument, which able to simulate a virtual driving environment and resemble real driving condition (Kang & Abdul Jalil, 2004). There are some advantages of using driving simulator as compared to other method such as on road driving research, which are the controlled and repeatable environment, safety purposes and cost reduction (Nilsson, 1993).

Driving simulator enables researchers to isolate experimental variables from other factor that might influence driving performance, therefore improving the accuracy of the recorded measures. Furthermore, simulator can study the hazardous driving situation that could not be replicated by on road study without exposing subject to unacceptable risks. Simulator study could reduce the research operation cost since the simulation environment and other factors can be controlled. Hence, there are no costs for fuel, toll fare, on road vehicle maintenance (Eskandarian, Delaigue, Sayed & Mortazavi, 2008). Driving simulator experiment is also an alternative to traditional methods such as self-reports which was widely argued to have limitations in studying driving behaviours. Among the limitations were the quality, type and the infrequency of occurrence of the pre-crash data (Boyce & Geller, 2001; Dingus, 2006) and the integrity and reliability of self-reports (Boyce & Geller, 2001).

Detection Response Task (DRT) is one of the methods for measuring driver distraction (Young et al., 2003). As stated by Engström, Larsson and Larsson (2013), DRT is employed for measuring the consequence of driving as the main task and doing secondary tasks on driver attention. The DRT method is a task in which participants respond to repeated stimuli presented within a specific duration. Detection performance measured in terms of response time represents the degree to which selective attention is affected by the tasks under evaluation. Tactile Detection Response Task (TDRT) will be utilised in this study. It requires drivers to respond to the vibration they feel, by pressing a small switch attached to their finger. It involves tactile stimuli that are presented by means of small vibrators attached to the skin (ISO, 2016). According to Engstrom, Aberg, Johansson and Hammarback (2005), the original study attached the vibrators on both participants' wrists, and stimulus presentation was varied randomly between them. Merat, Johansson, Engstrom, Chin, Nathan and Victor (2006) and Merat and Jamson (2008) amended the method by attaching a vibrator to participants' necks. This amended method of TDRT minimises the use of wires or cables that can interfere with the driving activity. TDRTs are more reliable and sensitive in the field (Engstrom et al., 2005) and do not affect drivers' visual behaviour (Mattes, Fohl & Schindhelm, 2007), compared to classical DRT.

The aforementioned studies provide an important motivation to carry out this study, and perhaps it can give some benefits for road safety betterment in Malaysia. The potential benefits of this study are to provide better awareness among Malaysian road users on dangerous of doing distracted activities specifically navigation device while driving. Besides, it can provide supporting information and evidence for the Malaysian Government in developing and strengthening the road safety interventions related to driver distraction.

3. Methodology

This study used the DRT method to measure driver distraction in which participants respond to repeated stimuli presented within a specific duration. Participants were set up in a simulated traffic environment using a driving simulator. This section explains the research design, sampling used and the overall implementation of this study.

3.1 Research Design and Sample

The study was designed using a mixed method experiment in which we manipulated within-subject variables (various character numbers and driving scenarios) and between-subject variables (gender and age group). Convenience stratified sampling method was used to recruit the participants for this study. 46 participants, with 24 males and 22 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 31.43 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 have licensed drivers with an average driving distance of 19,673 km a year and an average driving experience of 11 years. Participants were selected among the staff at MIROS and Perbadanan Aset Keretapi (PAK), students from Universiti Kuala Lumpur (UniKL) and the general public. Participants must be able to drive using automatic transmission and were given RM40 for their participation. Two groups of participants were involved in the study which are novice and experienced drivers. Novice drivers are drivers who have the experience of driving less than 4 years and age between 18–24 years (SWOV, 2009). While, experience drivers considered as more than 10 years driving experience and age between 30–59 years (SWOV, 2009).

3.2 Instrument

The MIROS Driving Simulator Cabin (CabinDS) was used in this study. The platform for the simulator is a second generation Perodua Myvi 1.3L, which was sponsored by Perusahaan Otomobil Kedua Sdn. Bhd. (Perodua). Table 1 presents the specifications of the car.

Table 1 Full car cabin specification according to car manufacturer

No.	Description	Technical specification
1	Car brand/Model	Perodua Myvi 1.3 SX
2	Engine capacity	1298 c.c.
3	Transmission	Automatic
4	Tyres	175/65 R14
7	Kerb weight (kg)	950
8	Overall length/width/height (mm)	3690/1665/1545
9	Interior length/width/height (mm)	1850/1380/1265
10	Wheelbase (mm)	2440
11	Colour	White
12	Body type	5-door hatchback
13	Driver position	Right Hand Drive (RHD)
14	Chassis no.	PM2M602S002000015
15	Engine no.	T00A26A

The main components of the integrated system of CabinDS are steering wheel, pedals, transmission, full car cabin, LCD projector and screen, computer, simulation software, video camera and sound system. Figure 1 illustrates the integrated system of CabinDS.

Figure 1 Integrated CabinDS system

SILAB Version 5.0 was used as the simulation software in the development of the driving scenarios. It is a comprehensive driving simulation software package that consists of several programs that interact with each other such as simulation preparation, test configuration, simulation realisation and evaluation. Three different driving scenarios were designed in this study, which was low speed (40 km/h), high speed (110 km/h) and traffic jam. SILAB workflow and application programs are shown in Figure 2. While Figure 3 presents an illustration of the designated driving scenarios.

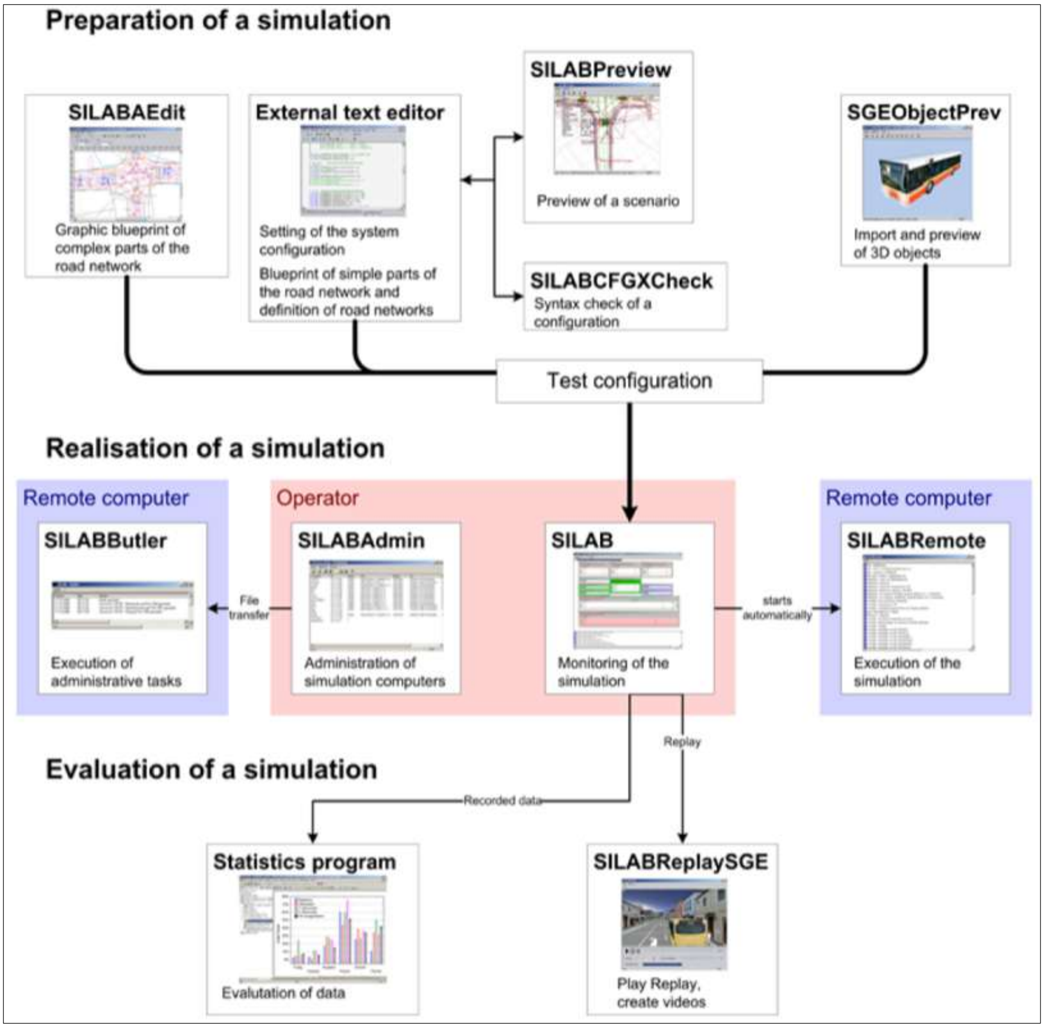
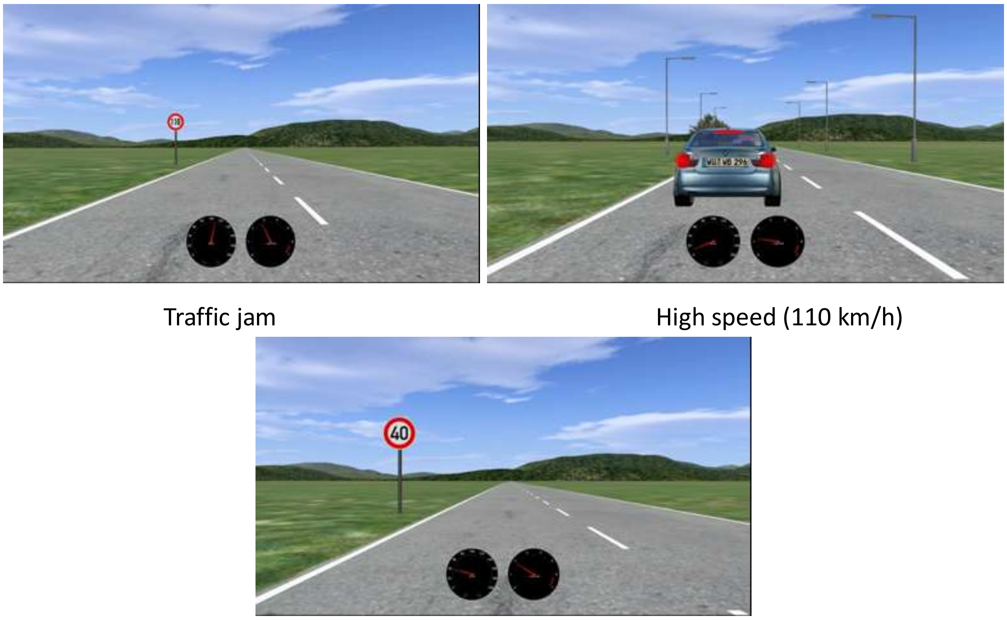


Figure 2 SILAB version 5.0 workflow and application programs



Traffic jam

High speed (110 km/h)

Low speed (40 km/h)

Figure 3 Illustration of the simulation scenarios

Driving was performed in a simulated traffic condition, and the DRT was used in a dynamic setting. 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 Detection Response Task (TDRT) was used in the study. The stimulus was presented at temporal intervals randomly, uniformly distributed between three and five seconds. The stimulus stayed on for a maximum time of one second. If the participant responded while a stimulus was on, that stimulus would be extinguished at the moment of response. TDRT consists of a 3.68 cm^2 vibrotactile pad (tactor) that provided the stimulus. Detailed specifications of the tactor are given in Table 2.

Table 2 Tactor specifications

Items	Value
Voltage (V])	3
Diameter of frame (mm)	10
Length of frame (mm)	3.4
Frame weight (g)	1.2
Voltage (V)	2.5~3.8
Speed (rpm)	12000
Current (mA)	75
Resistance (Ohm)	75
Vibration amplitude (G)	0.8

Participants responded by pressing a microswitch attached to the right index finger. Participants responded by pressing the switch to the steering wheel. The microswitch provided mechanical feedback indicating that a response has been made. Detailed specifications of the microswitch are given in Table 3.

Table 3 Microswitch specifications

Items	Value
Switching capacity	5 to 24 VDC, 1 to 30 mA (resistive load)
Insulation voltage	30 VDC
Contact figuration	SPST-NO
Contact resistance	100 mΩ max. (initial value) (Rated 5 VDC, 1 mA)
Insulation resistance	100 MΩ min. (at 250 VDC)
Dielectric strength	500 VAC, 50/60 Hz for 1 min
Bounce time	5 ms max.
Vibration resistance	Malfunction: 10 to 55 Hz, 1.5 mm double amplitude
Shock resistance	Destruction: 1,000 m/s^2 min (approx. 100 G min) Malfunction: 100 m/s2 min (approx. 10G min)
Weight	Approx. 0.30 g
Operating force (OF max.)	1.57 N (160 gf) max.
Reset force (RF min.)	0.2 N (20 gf) min.
Pretravel (PT)	0.25(+0.2/-0.1) mm

Navigation task using destination entry with different character number as used in the study as a secondary task. A mobile phone was secured in the driving simulator windscreen using a suction holder. Notes Application was installed on the mobile phone so that participants required to key-in the specific address repeatedly as much as possible within two minutes duration according to the specified character numbers. The addresses were provided on a sheet of paper secured to the dashboard. The details of addresses that associated with character numbers are shown in Table 4. The task setup is illustrated in Figure 5.

Table 4 List of character numbers and addresses

Number of characters	Addresses
0	Without address (baseline)
1	1
2	kg
3	lrg
4	sate
5	taman
7	pelangi
9	teknologi
14	jalan semenyih
20	lorong kajang raya 2

Figure 4 Navigation task as a secondary task

3.3 Procedures

Figure 5 illustrates the procedure of this study. Each participant required approximately three (3) hours to perform the procedures. Participants were given some guidelines and instructions before training and executing the procedures of the experiment. Prior to the detailed briefing, participants were given an overview of the experiment, its expected duration and the procedures. Researchers emphasised that the intention of the experiment was not to test participants' skills and explained the secondary task, also the general principles behind the study.

Participants were instructed to focus on the primary task (driving) and do their best to perform the DRT and the secondary task under evaluation. Participants were reminded that continuously pressing the button regardless of stimulus presentation would not yield better performance results. Participants were also asked to fill out the informed consent and personal detail forms.

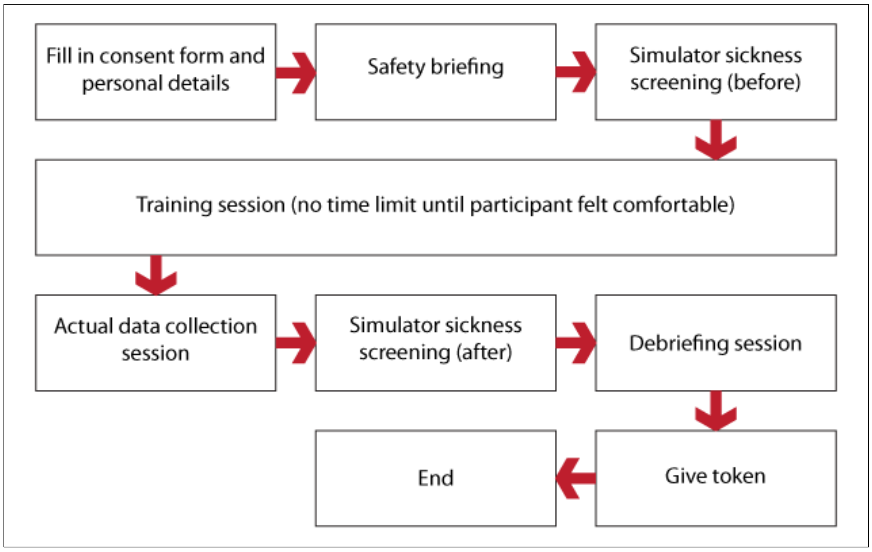


Figure 5 Procedure of the study

The safety briefing was given to participants before the data collection was conducted. The important safety elements include the importance of driving safely and adhering to the speed limit. The prohibition of using mobile phones while driving, emergency response measures and provision of accident compensation was emphasised to the participants. In addition, participants also completed the informed consent and personal details form.

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 of driving the driving simulator. Participants were asked some questions related to their wellness such as conditions of general discomfort, fatigue, headache, eyestrain, focus difficulty, salivation increase, vertigo, sweating, nausea, concentration difficulty, head fullness, blurry vision, and dizziness when repeatedly opening and shutting their eyes.

As depicted in Figure 5, after participants were tested for simulator sickness screening, they were subjected to a training session. During this session, participants performed the secondary task (i.e. navigation task) without driving, get them accustomed to the simulator and the DRT device. Participants were not given a time limit during this training session, but the session was stopped when participants felt comfortable performing the tasks. Participants can stop the training session without coercion.

During the actual data collection session, participants needed to complete all tasks and allowed to stop the experiment without coercion. Participants were given time to rest about three to five minutes between each tasking. The sequence of the tasks used the counterbalancing condition that adapts a balanced Latin square, thus different in each run as shown in Table 5.

Table 5 List of tasks for each participant

Participant no.	Navigation task (Character numbers)									
1	7	9	2	3	14	20	1	5	0	4
2	2	0	1	7	9	4	5	20	14	3
3	1	2	3	4	20	14	9	7	5	0
4	20	4	5	2	1	0	3	14	9	7
5	14	1	4	20	2	5	0	3	7	9
6	9	3	20	0	4	7	14	1	2	5
7	5	20	14	9	7	2	4	0	3	1
8	3	5	9	14	0	1	7	4	20	2
9	4	7	0	5	3	9	20	2	1	14
10	0	14	7	1	5	3	2	9	4	20
11	5	2	9	7	0	14	20	1	3	4
12	14	1	3	5	20	7	4	9	0	2
13	7	4	1	3	14	2	9	20	5	0
14	20	0	7	2	1	4	14	3	9	5
15	9	14	4	20	3	5	2	0	7	1
16	3	9	14	0	4	1	5	2	20	7
17	1	5	2	14	9	3	0	7	4	20
18	0	20	5	1	7	9	3	4	2	14
19	2	3	20	4	5	0	7	14	1	9
20	4	7	0	9	2	20	1	5	14	3
21	0	2	9	20	3	7	4	5	14	1

22	3	14	0	2	1	9	7	4	5	20
23	9	20	1	4	2	14	3	7	0	5
24	1	7	20	9	4	2	5	0	3	14
25	5	1	3	0	9	4	14	20	7	2
26	20	5	2	1	7	3	0	14	9	4
27	2	3	14	7	5	20	9	1	4	0
28	4	9	7	5	14	0	20	2	1	3
29	14	4	5	3	0	1	2	9	20	7
30	7	0	4	14	20	5	1	3	2	9
31	14	0	5	20	2	7	4	9	1	3
32	7	9	20	4	5	0	3	1	2	14
33	9	3	0	14	7	1	5	4	20	2
34	4	14	7	2	0	20	9	3	5	1
35	20	5	14	3	4	9	1	2	7	0
36	3	7	2	9	1	5	14	0	4	20
37	1	2	4	0	20	3	7	5	14	9
38	5	4	3	1	9	2	20	14	0	7
39	0	1	9	7	14	4	2	20	3	5
40	2	20	1	5	3	14	0	7	9	4
41	5	7	0	4	14	2	1	20	3	9
42	14	5	3	20	7	4	9	2	0	1
43	1	2	14	3	0	20	5	9	4	7
44	0	14	2	7	20	5	3	1	9	4
45	20	3	7	1	2	9	0	4	5	14
46	9	4	5	3	7	14	1	0	2	20

Participants were also subjected to post simulator sickness screening after they have completed the actual data collection. Participants were asked some questions related to their wellness. The purpose of the post simulator sickness screening was to ensure that participants were feeling well after the experiment and the same procedures applied for the pre-sickness screening. Upon completion of all experiment tasks, participants were interviewed about their driving experience. Participants were thanked and rewarded for their participation.

4. Results and Discussions

4.1 Results

In general, every participant received an equal amount of stimuli for each condition on their shoulders – around 31 to 32 stimuli for each condition. The number of stimuli they attended to, however, varied. Some participants responded more; some attended to lesser stimuli. Figure 6 summarises the percentage of stimuli participants responded for each character condition. In general, as the number of character increases, participants attended to lesser stimuli. Relative to three (3) driving scenarios, participants attended poorly the most in traffic jam scenario. In contrast, the percentages of responded stimuli for both free-flowing scenarios (i.e. in 40 km/h and 110 km/h driving speed) are very similar.

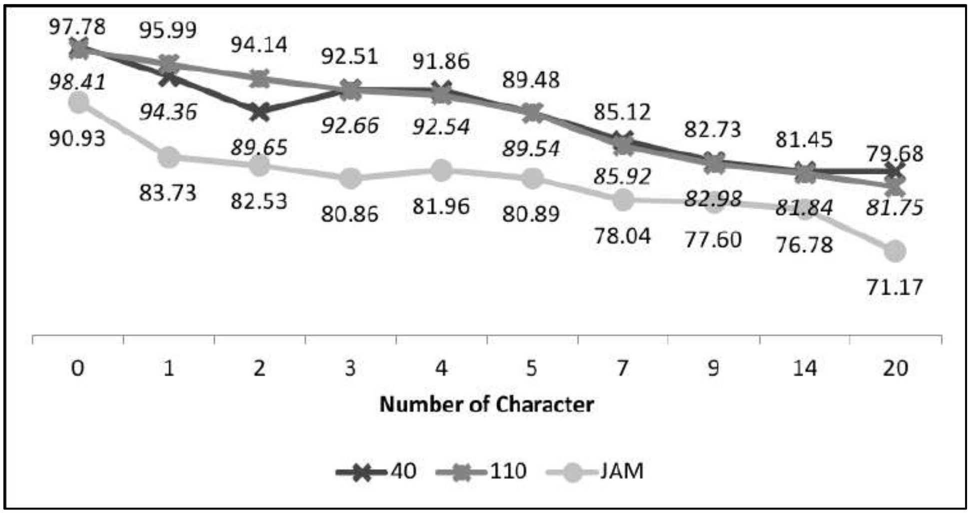


Figure 6 Percentage of stimuli responded for each number of character based on driving scenarios

From the responded stimuli, the computer measured their average Responses Time (RT). These RT reflect the mental workload: The higher the values (i.e. the slower the response), the higher the load. As the RT is only taken from stimuli that were attended, there is a bias if these values were to be directly considered as the indication of distraction level. This is because participants who attended to a smaller amount of stimuli were more likely to have a lesser load, and thus when responded to any stimuli, they could do it faster. Comparing, for example, between participant X who attended to only 15 stimuli but scored RT = 300 milliseconds; with participants Y who attended to 25 stimuli but scored RT = 400 milliseconds. In this case, considering only the RT would suggest that participant X is less distracted than participant Y. Whereas actually, participants Y did a lot more mental processing than X that might affect his or her distraction level.

Therefore, to address this issue, we also took the number of stimuli responded into account when making the decision. Consequently, the average response time was adjusted (ART) to normalise the influence of number of stimuli responded, using the following equation:

$$ART = RT \times \left(\frac{total\ stimuli}{responded\ stimuli}\right)$$

Using the previous example, ART_X for participants X, if the total number of stimuli he or she received was 31, is 620 milliseconds (i.e. $300 \times \frac{31}{15}$); whereas ART_Y, if the total number of stimuli he or she received was 32, is 512 milliseconds (i.e. $400 \times \frac{32}{25}$); resulting to an inverse conclusion as compared to when using only RT. Therefore, throughout this report, the subsequent analyses adopted this principle.

The analysis continued with averaging the RT across all responded stimuli, before proceeding with adjusting with the number of attended stimuli, as per description in the previous section. The resultant ARTs were subjected to mixed factorial repeated-measures ANOVA procedure to study for mean differences of ART with respect to within-subject variables (i.e. various character numbers, and driving scenarios), and between-subject variables (i.e. gender and age group).

As Mauchly's test indicated a violation to the assumption of sphericity for the main effect of character numbers, $X^2(44) = 114.21$, $p < .001$; the associated degree of freedom in the ANOVA was corrected using Greenhouse-Geisser estimates of sphericity. Mixed factorial repeated-measures ANOVA revealed a significant main effect of character numbers on ART, $F(6.10, 256.12) = 25.29$, $p < .001$. Further, simple contrasts revealed that ARTs for all other characters are significantly higher than the baseline (i.e. character 0), $F_{baseline\ vs.\ 1}(1, 42) = 96.12$; $F_{baseline\ vs.\ 2}(1, 42) = 76.53$; $F_{baseline\ vs.\ 3}(1, 42) = 51.71$; $F_{baseline\ vs.\ 4}(1, 42) = 85.39$; $F_{baseline\ vs.\ 5}(1, 42) = 77.42$; $F_{baseline\ vs.\ 7}(1, 42) = 78.76$; $F_{baseline\ vs.\ 9}(1, 42) = 126.24$; $F_{baseline\ vs.\ 14}(1, 42) = 95.63$; $F_{baseline\ vs.\ 20}(1, 42) = 94.89$; all pairs had $p < .001$.

Main effect of driving scenarios on ART was also significant, $F(2, 84) = 31.54$, $p < .001$; with significant contrasts between traffic jam and 40 km/h scenario, $F(1, 42) = 44.37$, $p < .001$; as well as between also traffic jam and 110 km/h scenario, $F(1, 42) = 41.90$, $p < .001$.

There was also a significant interaction effect between character numbers and driving scenarios, $F(9.51, 399.31) = 2.48$, $p = .001$ (Greehouse-Geisser corrected). Figure 9 depicts the ARTs for each character number based on driving scenarios. ARTs for traffic jam scenario, in general, were higher than both 40 km/h and 110 km/h driving scenarios in all conditions of character number.

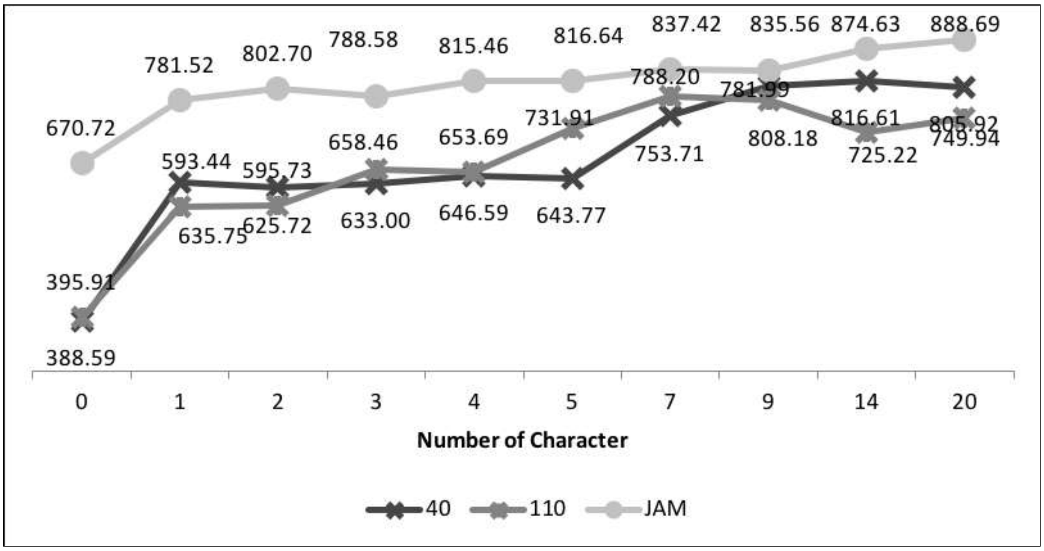


Figure 7 Adjusted response time for each number of character based on driving scenarios

The analysis continued to reveal no significant main effect of gender on ARTs, $F(1, 42) = 2.24$ $p = .14$; even though eyeballing the means of ART indicate that male participants were always faster (see Table 1). Further, there is no significant interaction involving gender with within-subject variables: neither with character numbers, $F(6.10, 256.12) = .31$, $p = .93$; nor driving scenarios, $F(2, 84) = 1.13$, $p = .33$.

The same analysis of the second between-subject variable, however, revealed a significant main effect of age group on ART, $F(1, 42) = 11.58$, $p = .001$. Inspection of Table 6 revealed that the ART of novice group was always lower, i.e. faster when responding than their experience counterpart. Further analysis revealed neither significant interaction between age group and character numbers, $F(6.10, 256.12) = 1.80$, $p = .10$.; nor between age group and driving scenarios, $F(2, 84) = 3.00$, $p = .06$.

Table 6 Summary of ART means based on gender and age group for all conditions

Driving scenarios	Character number	Adjusted Response Time, *M* (*SD*)			
		Male	Female	Novice	Experience
40 km/h	Baseline	340.81 (150.05)	440.70 (254.57)	346.38 (122.20)	427.27 (264.13)
	1	572.13 (225.40)	705.16 (295.94)	581.50 (213.30)	685.48 (304.41)
	2	581.31 (251.37)	674.17 (289.40)	505.36 (235.72)	736.06 (258.20)
	3	588.86 (241.05)	681.15 (288.38)	532.34 (173.61)	725.26 (303.63)
	4	604.01 (261.55)	693.05 (245.18)	527.41 (178.14)	755.85 (268.77)
	5	588.91 (248.41)	703.61 (185.72)	574.14 (186.71)	707.59 (243.00)
	7	696.50 (301.94)	816.12 (290.85)	631.13 (249.16)	866.08 (302.18)
	9	799.76 (398.37)	817.36 (344.68)	671.03 (289.60)	933.90 (395.31)
	14	757.64 (278.33)	880.94 (408.89)	785.21 (432.09)	845.39 (255.80)
	20	800.41 (368.83)	811.92 (250.50)	734.23 (321.69)	871.63 (299.14)
110 km/h	Baseline	347.50 (132.66)	448.73 (259.12)	352.26 (106.28)	435.93 (264.97)
	1	597.04 (259.24)	589.51 (221.90)	508.64 (177.43)	671.17 (265.07)
	2	591.47 (268.42)	600.38 (231.84)	471.01 (165.73)	710.06 (259.94)
	3	654.08 (406.91)	663.25 (242.66)	564.94 (268.65)	744.19 (370.74)
	4	643.48 (285.12)	664.82 (255.74)	525.21 (154.37)	771.46 (298.70)
	5	715.88 (423.17)	749.39 (284.53)	585.31 (256.46)	866.29 (392.56)
	7	710.00 (355.69)	873.50 (627.77)	592.98 (216.70)	967.14 (622.05)
	9	754.45 (342.53)	812.03 (329.82)	673.41 (361.58)	881.51 (278.07)
	14	689.80 (262.11)	763.87 (276.39)	606.43 (238.96)	834.12 (251.35)
	20	710.58 (263.74)	792.87 (324.91)	667.49 (238.79)	825.51 (323.74)
Traffic jam	Baseline	598.83 (298.10)	749.15 (314.23)	599.89 (266.66)	735.65 (340.85)
	1	692.45 (330.64)	878.69 (304.45)	670.64 (268.72)	883.16 (350.41)
	2	730.05 (364.17)	881.96 (490.52)	621.00 (299.66)	969.27 (470.42)
	3	751.66 (437.77)	828.86 (245.80)	618.17 (205.99)	944.80 (397.24)
	4	777.36 (478.59)	857.03 (375.43)	674.00 (466.13)	945.14 (354.73)
	5	753.01 (334.77)	886.07 (269.91)	669.26 (215.57)	951.74 (324.29)
	7	806.02 (343.83)	871.68 (228.84)	733.89 (291.78)	932.33 (266.08)
	9	770.66 (274.42)	906.36 (358.27)	708.96 (230.41)	951.62 (351.91)
	14	835.13 (476.01)	917.73 (428.27)	723.51 (409.81)	1013.17 (449.72)
	20	850.80 (450.62)	930.02 (308.59)	715.17 (215.77)	1047.74 (442.07)

Note: During baseline session, character number was zero

Referring to Table 7, the baseline ARTs was higher in traffic jam scenario, compared to 40 km/h and 110 km/h scenarios. In general, the average response time increased with an additional number of characters for each traffic scenarios, compared to the baseline. However, the magnitude of change was different across the three traffic scenarios. For example, the highest change from the baseline was 32.5% when driving in a traffic jam, as compared to 99.09% in 110 km/h scenario and 110.15% in 40 km/h scenario. In traffic jam scenario, the increase in response time was consistent with the increase in number of characters. However, a random pattern of change was observed for 40 km/h scenario and 110 km/h scenario. For instance, the biggest percentage increase in response time was recorded when the number of character was 7 in 110 km/h scenario and 14 in 40 km/h scenario.

Table 7 Percentage of ART change as compared to baseline for different number of characters and driving scenarios

Number of character	Traffic jam		110 km/h driving		40 km/h driving	
	ART (s)	Change from baseline (%)	ART (s)	Change from baseline (%)	ART (s)	Change from baseline (%)
0 (Baseline)	670.72	Reference	395.91	Reference	388.59	Reference
1	781.52	16.5	593.44	49.89	635.75	63.60
2	802.70	19.7	595.73	50.47	625.72	61.02
3	788.58	17.6	658.46	66.32	633.00	62.90
4	815.46	21.6	653.69	65.11	646.59	66.39
5	816.64	21.8	731.91	84.87	643.77	65.67
7	837.42	24.9	788.20	99.09	753.71	93.96
9	835.56	24.6	781.99	97.52	808.18	107.98
14	874.63	30.4	725.22	83.18	816.61	110.15
20	888.69	32.5	749.94	89.42	805.92	107.40

4.2 Discussions

As mentioned in the literature review, drivers can get distracted by using a navigation device in several ways while driving. This study used DRT to measure the effects of driving demand and engagement in a secondary task on driver attention. The secondary task involved inputting up to 20 characters as a destination entry for a navigation device. The current experimental setup was found to have successfully captured the ART and measured the driving distraction among the participants. One interesting finding is that the number of characters needed to be keyed-in affects the level of distraction measured among the participants. Drivers are more distracted by the increase in efforts to handle the navigation device as compared to baseline (i.e. without using navigation device). This finding confirms the association between the task demand and the level of distraction found by Knapper, Hagenzieker and Brookhuis (2015). In addition, Morris, Reed, Welsh, Brown and Birrell (2015) found that the demand required to handle a navigation device could affect driving performances and led to drivers glancing more frequently off the road.

Another important finding was that drivers' engagement in a secondary task while driving in a challenging driving scenario increased their reaction time to stimuli, which indicate a higher level of distraction. Regardless of driving speeds, drivers were found to be distracted the most when driving in a traffic jam, compared to a free-flowing traffic scenario. In other words, the level of distraction due to the handling of the navigation device is worsened by a demanding driving scenario. Although a previous study by Foss and Goodwin (2014) reported no relationship between the frequency of distracted driver behaviours and amount of traffic, our result could indicate a potentially higher risk of distracted driving in certain traffic conditions. This risk can be even higher when the secondary task is complex such as way finding using a navigation device, as indicated by the significant interaction effects of both factors on participants' ART.

This study has been unable to demonstrate the effect of gender on the level of distraction among drivers, across all variables. Although male drivers were generally faster at responding to the stimuli than their female counterparts, no significant differences were observed in their ART. This outcome is contrary to that of Irwin, Chekaluk and Geaghan (2011) who found the effect of gender on the level of distraction, measured by driving performances and errors. They found that female drivers were more distracted when conversing on a mobile phone compared to male drivers. Female drivers were also found to make more lateral or lane position errors when distracted. This rather contradictory result may be due to a different measure of distraction used in this study.

In the current study, comparing the ART between experienced and novice drivers revealed an interesting finding. The novice group was found to respond to the stimuli at a significantly quicker rate than the more experienced 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 (Rudin-Brown, Edquist, & Lenné, 2014). 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, Knapper et al. (2015) 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).

It is recommended that high-end driving simulator with advanced motion platform and realistic simulation scenarios could be utilised for future study to avoid and reduce the existence of simulator sickness among participants and capable of simulating a variety of actual navigation usages. Besides, a large-scale study that involves a higher number of participants with various types of road conditions is recommended for future research despite requires greater cost and much more time-consuming. For improving the safety of driving, a guideline of navigation device usage for drivers should be developed by relevant authorities. Undeniable that the device may be helpful but as prudent drivers, their safety should not be compromised, and they need to use the device with proper methods.

5. Conclusion

In a nutshell, the objectives of the study were fulfilled whereby to measure the distraction in term of participants' ART for different character numbers of navigation task and driving scenarios using a driving simulator. Besides, this study aimed to compare participants' ART with respect to within-subject and between-subject variables. The findings of this research indicate that participants responded to lesser stimuli as the number of character increases. In addition, drivers are more distracted by the more demanding task to handle the navigation device as compared to baseline. Among three driving scenarios, participants attended the worst in term of stimuli and higher ART in traffic jam scenario. Besides, novice group was identified to respond significantly faster rate than the experience group. This study shows that doing navigation task while driving is considered a distracting activity that possibly raises the risk of a crash.

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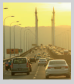

Research Report

Measurement of Driver Distraction While Using Navigation Device via Driving Simulator

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