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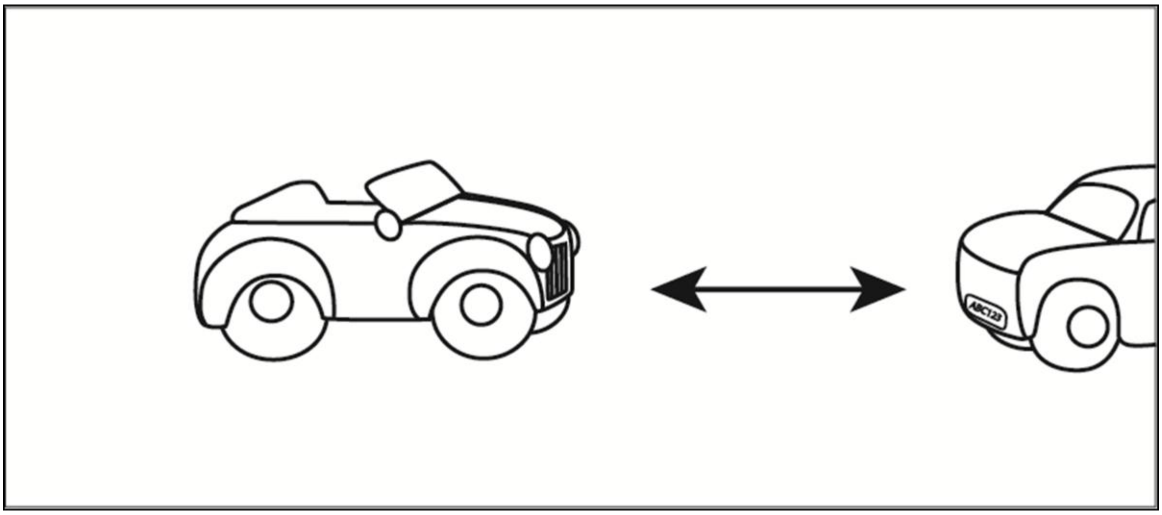

Factors influencing headway selection while negotiating secondary tasks in real-traffic

Master's Thesis in the Automotive Engineering

LI XI

Department of Applied Mechanics
Division of Vehicle Safety
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sverige 2010

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ABSTRACT

Recently, naturalistic studies have been able to relate a large amount of rear-end crashes to driver's inattention while following another vehicle. Several simulator-based researches have claimed that drivers get a longer mean-reaction-time while doing a secondary task. However, very few studies on drivers' headway selection while performing a secondary task during car-following in real-traffic have been done. Therefore, this study aims to discover whether drivers increase time headway to a forward vehicle while negotiating a secondary task by using a naturalistic and field operational test database.

This study was conducted using the Volvo Car data from SeMiFOT database. SeMiFOT is a Naturalistic and Field Operational Test study which was carried out by 12 different partners in Sweden from January 2008 to December 2009[1].

The methodology followed in this investigation comprised of four steps. In the **first** step, all the known secondary tasks from the literature were classified into nine categories based on their different characteristics. Then the nine secondary tasks were assigned to three different levels: complex task, moderate task, and simple task; according to the number of required button-press and/or eye-glance; in the **second** step, videos were manually reviewed to mark all the following action periods containing secondary task events; in the **third** step, data incorporating vehicle following and secondary tasks was imported into Matlab for further analyses, more specifically, four variables were selected from the VCC database: time index, headway distance, vehicle speed, and adapted cruise control lamp status, moreover, time headway was selected as the standard measure in this study; finally, in the **fourth** step, mean values of time headway for all selected events were compared in order to derive different headway selection for different secondary task related periods.

The results concluded in this study can be used as an indicator which points out which factors may have influence on drivers' headway selection while negotiating secondary tasks during car-following in real-traffic.

Key words: naturalistic driving, driver headway selection, secondary task

[1] http://www.chalmers.se/safer/EN/news/events/semifot-final-seminar

Contents

Preface

In this study, the data from SeMiFOT database which selected by Volvo Car Corporation has been utilized as the main data-source to investigate the factors which affects driver headway selection while negotiating a secondary task during car-following. The analyses have been carried out from June 2010 to September 2010. This research is a part of a Volvo Car Corporation project ASIS which aims to predict driver behaviour. The work was carried out at SAFER (Vehicle and Traffic Safety Centre) at Lindholmen Science Park, Göteborg, Sweden. Volvo Car Corporation is the main financier for this project.

This work has been carried out by Li Xi as researcher, Henrik Lind as supervisor, and also Marco Dozza as examiner. Most of the analysis works have been done at SAFER. Furthermore, I would like to thank Marco Dozza, Matias Viström, Selpi Selpi, and Helena Gellerman from Chalmers and Jorge Alejandro León Cano from Volvo Car Corporation for their support.

Finally, it should be noted that without my supervisor Henrik Lind's as well as my examiner Marco Dozza' s great guide and advice. I would not have been able to properly address the complexity of this thesis project.

Göteborg November 2010

Li Xi

1 Introduction

Car following situation is a common on road scenario. It is also a potential hazardous situation if the driver is inattentive and the forward vehicle performs an unpredicted braking action [Mary F. Lesch and Peter A. (2003)]. Hence, for the last half century, several car-following models had been invented, developed, and then improved. Early studies on car-following were focus on physical and mathematical development and can be referred as Static Model [Chandler R.E. et al. (1958), Louis A. Pipes (1967), Sten Bexelius (1968), M.P. Heyes and R. Ashworth (1972), J.E. Tolle (1974), and P.G. Gipps (1981)]. However, as the research went deeper and deeper, they have successively discovered that in order to develop an appropriate and realistic car-following model, not only the physical and mathematical features had to be taken into account, but also the psychological level of driver had to be concerned [P.A. Hancock (1999), Mark Brackstone and Mike McDonald (1999), and Erwin R. Boer (1999)]. Since then, researchers realized that the driver plays a crucial role in car-following. It is the driver who makes the decision after all. Some researchers even concluded that a certain type of personality of driver, called Type A personality, could be used as a significant predictor of risky driving style, such as close-following, and speeding [Thomas E. Boyce and E. Scott Geller (2002)]. Of course, driver's behavior differs due to gender, age, mental-workload, etc. One study showed that there was a strong tendency to believe that one is safer and more skillful than their fellow drivers [Ola Svenson (1981)]. In response to these studies, several countries made restriction on the minimum following distance to keep the driving environment safer. Even though, a research conducted on UK's motorway indicated that current headway distances were far lower than believed [Mark Brackstone et al. (2002)]. Thus, researchers realized that it was important to understand why some drivers intended to maintain short headway distances even it increases the risk. In other words, the question is: "What factors influence driver's decision on their headway distance to the forward vehicle?" A recent study conducted by several researchers examined four potential influencing factors in drivers' following behavior [Mark Brackstone et al. (2009)]. And they have concluded that the type of lead vehicle is a contributing factor to driver's following behavior, also they presented that drivers are inconsistent in their choice of headway distance. Other two potential factors, level of traffic flow and road characteristics were found not to be significant in.

Distraction is another important factor when comes to traffic safety field [Katja Kircher (2007)]. Driver distraction is the voluntary diversion of attention from the primary driving tasks not related to impairment (from alcohol, drugs, or a medical condition) where the diversion occurs because the driver is performing an additional task (or tasks) and temporarily focusing on an object, event, or person not related to the primary driving tasks. The diversion reduces a driver's situational awareness, decision making, and/or performance resulting, in some instances, in a collision or near-miss or corrective action by the driver and/or other road user [Australian Road Safety Board (2006)]. It is obvious that driver distraction is associated with secondary tasks while driving [Thomas A. Ranney (2008)]. At the very beginning of driving history, the secondary tasks that driver could to perform were limited. Nowadays, an increasing number of modern systems and wireless devices are mounted on-board. Thus, driver can nowadays participate in more enjoyable- yet complex- secondary tasks while driving. For instance, using cellular cell phone browse websites or even updating their facebook, using navigation system to guide direction, using in-vehicle entertaining device, etc. It is widely accepted that intelligent transport systems are not only assisting driver, but also distracting the driver too [Danielle Lottridge and Mark Chignell (2007)]. An interesting current research manifested that drivers did not tend to strategically postpone the initiation of the secondary task even though they were fully aware of the relative demands of the road [William J. Horrey and Mary F. Lesch (2009)]. In other word, drivers intended to initiate the secondary tasks regardless of the current driving conditions. As consequence, the combination of doing secondary tasks and following another vehicle is inevitable. Another research claimed that some drivers even pay attention to displays in neighboring vehicles while driving which leads to impairment of driving performance [Julie Hatfield and Timothy Chamberlain (2008)]. Because of varied forms of secondary tasks, some researchers have suggested a new secondary task classification criterion based on the required number of button-presses and/or eye-glance, in order to make the driver behavior more reasonable and understandable [Klauer (2006)]. Those tasks mentioned above are obviously demanding more than two button-presses and/or eye-glance. Based on this criterion, one could assume that driver's vehicle following behavior differs due to on-going task's difficulty level. Many studies have been conducted to investigate different degradations of distraction for various secondary tasks by using diverse methods. Specifically, three common methods have been used, there are, simulator study, on-road track (including on-road test-track and on-road real-track), and survey study [Jeffery Dressel and Paul Atchley (2008)].

Because of the importance of car-following and driver distraction (secondary tasks), many researchers are devoted to investigate in-depths the combination of those two parameters. Due to rapidly increase of cellular cell phone use and its negative impact on driver's performance [Mark J.M. Sullman, Peter H. Baas (2004), M. Eugenia Gras, et al. (2006), David W. Eyb, et al. (2006), and Erik Nelson, et al. (2009)], the most comprehensive target is to study cellular cell phone use while driving, which mainly focusing on driver's following and braking behaviors [Michael E. Rakauskas, et al. (2004), Paul J. Treffner and Rod Barrent (2004), David Shinar, et al. (2005), William J. Horrey and Christopher D. Wickens (2006), Joel M. Cooper and David L. Strayer (2008), Joel M. Cooper, et al. (2009), and David B. Bellinger, et al. (2009)]. However, there were only few studies that concentrated on the effects of diverse secondary tasks in car following situation, [Sonia Amado and Pinar Ulupiner (2005), and David L. Strayer, et al. (2006)]. Thus, it is essential to investigate driver's headway selection under various secondary tasks.

Hence, this thesis was aimed to re-examine some of the potential influencing factors of drivers' headway selection discussed in former studies, and to validate some other hypothetical, but likely factors, which associated with secondary tasks. This thesis's results will provide some indications on whether drivers will increase their time headway distance to the forward vehicle as a compensation of engaging to secondary tasks.

It should be emphasized that, due to the quantity of selected samples and limited number of drivers, the quality of measurements, and other uncontrollable factors, the analysis performed in this thesis has some limitations, which are presented in the discussion section.

2 Methodology

2.1 Materials

The main source of data for this study is the data from SeMiFOT database collected by Volvo Car Corporation.

SeMiFOT is a SAFER project that ran from January 2008 to December 2009, which gathered 13 organisations from the automotive industry, the Swedish Road Administration, and academia, around the development of the Naturalistic FOT method, which combines from both Naturalistic Driving Studies and Field Operational Tests. SeMiFOT addressed challenges related to technology and implementation and to analytical approaches [2].

In the Volvo Car Corporation data, 29 Volvo drivers made 7892 trips for a total 1142 hours [VCC database]. Two types of Volvo cars were utilized, V70 and XC70, both have 5 engine cylinders with automatic transmission and standard chassis powered by diesel.

2.2 Participants

Overall, nine drivers were involved in this study. Four of them were male, and five of them were female. Participants' mean age was 49 with standard deviation and range of 6.0 and 17, respectively. According to drivers' background check, all nine drivers had a valid driver's license with mean driving experience of 31 years with standard deviation and range of 6.3 and 19. It should be mentioned that two drivers' age and driving experience were missing in the VCC database, one male and one female.

2.3 Method

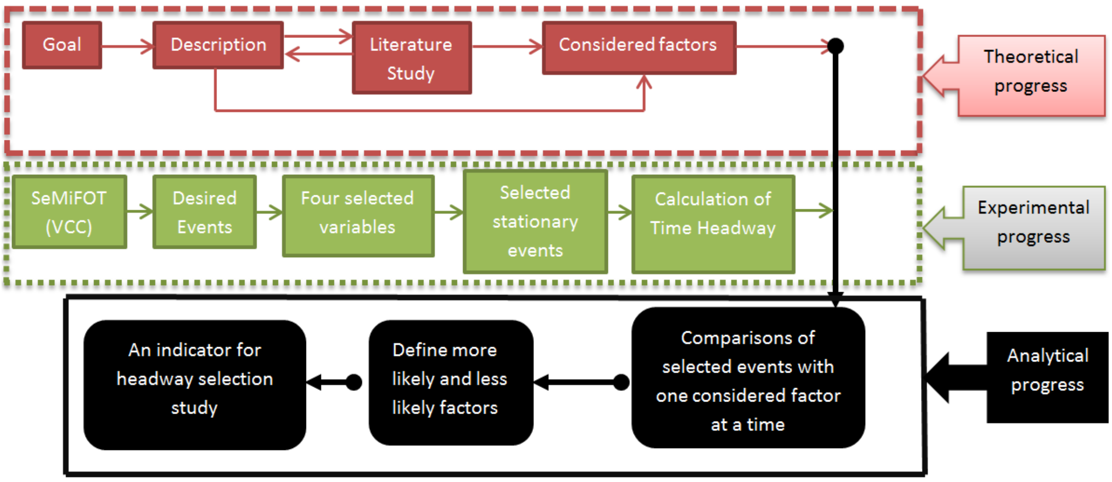

Figure 2.1 Overall methodology layout

Figure 2.1 illustrates the overall methodology applied in this study. It comprises three sub-progresses, they are, theoretical progress, experimental progress, and analytical progress shown as in the above figure. Details will be depicted in following sections.

[2] http://www.chalmers.se/safer/EN/news/events/semifot-final-seminar

2.3.1 Theoretical progress

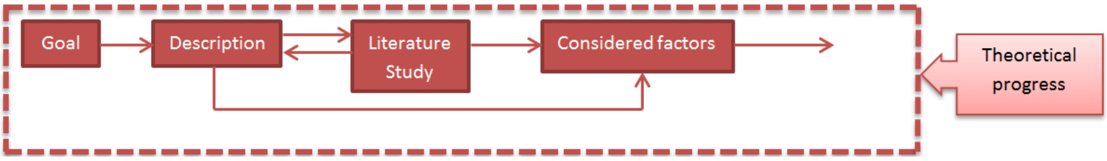

Figure 2.2 Theoretical progress layout

During theoretical progress as it illustrates in figure 2.2, after defined the goal of this thesis, a description was made, which detailed the planning and procedures of the further experiment, based on literature studies. Moreover, during the description phase, three variables and one variable for checking purpose in the database have been decided as the considered variables in this study, which will be discussed in section 2.3.1.2. In additional, in order to examine the factors that influence driver's headway selection as much as possible, one has searched academic papers which mainly were simulator-based studies with the key words of secondary task, headway selection, and car-following situation to obtain some potential influencing factors. For instance, a recent study [Kathy L.M. Broughton, et al. (2007)] investigate whether different visibility condition and speed range would affect drivers' car-following decision has claimed that the higher mean vehicle speed often associated with longer mean time headway. Therefore, vehicle speed range could be an influencing factor on drivers' headway selection.

2.3.1.1 Considered factors

2.3.1.1.1 Literature findings

Based on researches conducted previously [Mark Brackstone (2009), Kathy L.M. Broughton et al. (2007), and Sirpa Rajalin et al. (1997)], four likely influencing factors on drivers' headway selection were purposed. Detailed as following:

- Drivers' headway selection differs with road characteristic, i.e., highway, urban road, and rural road.
- Drivers' headway selection is affected by the type of lead vehicle, i.e., passenger car, motorcycle, van, and SUV.
- Drivers' headway selection is impacted by participants' vehicle speed range.
- Drivers' headway selection differs with gender.

It should be mentioned that during literature study, there were many researches have been found which focused on one or two specific types of secondary task, such as phone-related task. Most of those researches were simulator-based studies, targeted on investigating drivers' braking performance, which are less contributing to investigate drivers' headway selection, still these researches may some useful insight for further follow-up study of this thesis. Therefore, these literatures are attached in appendix A.

2.3.1.1.2 Other influencing factors

This study comprised of diverse secondary tasks. The secondary task classification was given by Matias Viström from project SeMiFOT.

In a second step the secondary tasks, was categorized into three levels based on their complexity, the catalogue scheme will be discussed in experimental progress section in details.

A possible external factor may be gender. Drives were recorded under different weather conditions. Thus it is may be possible to suggest if the weather condition influences the headway selection.

Hence, three potential influencing factors have been assumed by the researcher herself as following:

- Drivers' headway selection may be influenced by the complexity levels of secondary tasks, i.e., complex secondary task, moderate secondary task, and simple secondary task.
- Drivers' headway selection may impact by different types of secondary task, i.e., phone-related task, passenger-related task, and in-vehicle distraction, etc.
- Drivers' headway selection may vary with different weather conditions, i.e., sunny, cloudy, and foggy.

In summary, seven potential factors have been decided during theory study phase. On the basis of their characteristics, these seven factors were further categorized as shown in table 2.1.

Table 2.1 Table of seven factors

Individual factors	**Situational factors**
Gender	Weather condition
	Complexity level of secondary task
	Type of secondary task
	Participant's vehicle speed range
	Type of lead vehicle
	Road characteristics

2.3.2 Experimental progress

Figure 2.3 Experimental progress layout

As it indicates in figure 2.3, during experimental progress, one have to take a security tutorial first and signed the confidential document before using the database, since the SeMiFOT database belongs to several companies and institutions.

After having got access of the VCC database, the preparation of secondary task classification has been done before starting to review the videos. And then, selected all the trips from VCC database, and manually reviewed videos based on driver's ID number. It should be noted that the number of reviewed trips belonging to each driver are not equal on quantity. Hence, in order to make the final results reasonable, the researcher has tried to review each driver's video equally, more specifically, after reviewed 30 trips of driver A, then as for driver B, also tried to reviewed approximately 30 trips. During the reviewing phase, firstly, checked whether the trip contains headway distance data and whether the adaptive cruise control system was off, if not, skipped that particular trip. Otherwise, reviewed the videos and marked all the secondary task events, which are detailed as possible as the researcher could. The table detailing all the found secondary task events is attached in appendix B.

The next step is to further classify the nine types of secondary task have been found into three complexity levels, which are, complex secondary tasks, moderate secondary tasks, and simple secondary tasks. The reason to do the classification again is because the criterion used before was focusing on the characteristics of different secondary tasks, for instance, if there was a cell phone involved, then this event would be classified as phone-related task. However, based on many phone-related studies [Simon G. Hosking, et al. (2009), Katherine M. White, et al. (2009)], conversing on a cell phone may be not as distracted as dialling a phone call or texting message since dialling and texting demands more attentions which means more than two button presses and/or eye-glances which is also known as complex secondary task. Therefore, classifying the secondary tasks according to their requirement of numbers of button press and/or eye-glance, in other word, their difficulty levels, makes more sense since there were various secondary tasks involved in this study. Take phone-related task for example, total 15 phone-related tasks were involved in this study, and its complexity level is showing as following. It should be noted that the abbreviation 'ST' in table 2.2 refers to secondary task. The table regarding the complexity level for all 9 types secondary task is attached in appendix C.

Table 2.2 Complexity level for phone-related secondary task

Type of ST	Complex ST	Moderate ST	Simple ST
Phone-related tasks	10	3	2

The criterion was defined as following: if the secondary task required more than two button presses and/or eye-glances, this secondary task would be labelled as complex secondary task; if the secondary task required two button presses and/or eye-glances, this particular secondary task would be categorized as moderate secondary task; if the secondary task required less than two button presses and/or eye-glances, then this secondary task was simple secondary task.

Then, all which contained both headway distance data and secondary task events were marked. In order to select the wanted data, SQL query was used. In this study, two software have been utilized as data selection tool: Simpleviewer and Matlab. The Simpleviewer functions as SQL developer which mainly used to view videos. All the desired data were selected by Matlab. And all the applied Matlab scripts are attached in the appendix D. With the purpose of investigating drivers' headway selection, headway distance, vehicle speed, time index, and time headway were selected and/or calculated as mentioned in the following section.

2.3.2.1 Variables considered

2.3.2.1.1 Directly selected variables

- Time index, which is the time historical line of each trip, and units in millisecond. All the desired videos are selected based on time index sequence.
- Vehicle speed, units in kilo meter per hour. Vehicle speed measures participant's vehicle relative ground speed.
- Headway distance, measures the distance from the front of participant's vehicle to the rear-end of the lead vehicle. Units in meter. It is notably, when the headway distance exceeding 120 m, there will be no headway data due to limitation of the measurement. Another limitation of this measurement is that, there is no headway distance while driving into a roundabout.
- Adapted cruise control lamp, no unit. ACC lamp acts as a checking criterion in this study. In order to investigate the following behaviour of driver, one has to ensure that the ACC is off, meaning that is the driver who generate reaction on car-following situation without help.

2.3.2.1.2 Derived variable

It has been shown that the driver get a longer mean reaction when performing secondary tasks [Håkan Alm and Lena Nilsson (1995)]. Thus, it can be assumed that the driver compensates for part of the reaction time extension by prolonging the time headway to the forward vehicle leaving additional time to react in a safe manner on forward traffic flow changes. The time headway was therefore selected as the standard measure.

- Time headway distance, units in second, is generally used in research of following behaviour. In this study, time headway obtained by calculation, the expression shown as following:

$$Time\ headway\ [s] = \frac{Headway\ distance\ [m]}{Vehicle\ speed\ [m/s]} \qquad (2.1)$$

Due to the influence of data noise, after selected all wanted events, one has checked their time headway plots as function of time index to differentiate stationary- and un-stationary-events. By stationary, meaning the time headway plots were not noisy. To minimize the influence of data noise, only events with stationary headway data would be used to produce final results.

After all the wanted data was selected, the mean values of time headway and vehicle speed was calculated for each event for further comparison.

2.3.3 Analytical progress

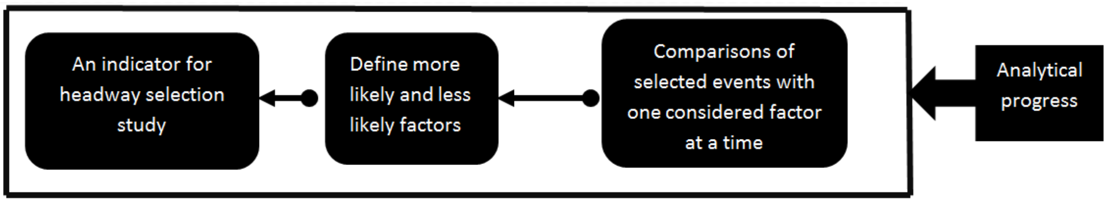

Figure 2.4 Analytical progress layout

During analysis progress, the first step is make the comparison of mean time headway values for all selected events with one considered factor at a time, in order to examine the seven potential factors defined before. For one particular secondary task event, the method applied is showing in figure 2.5.

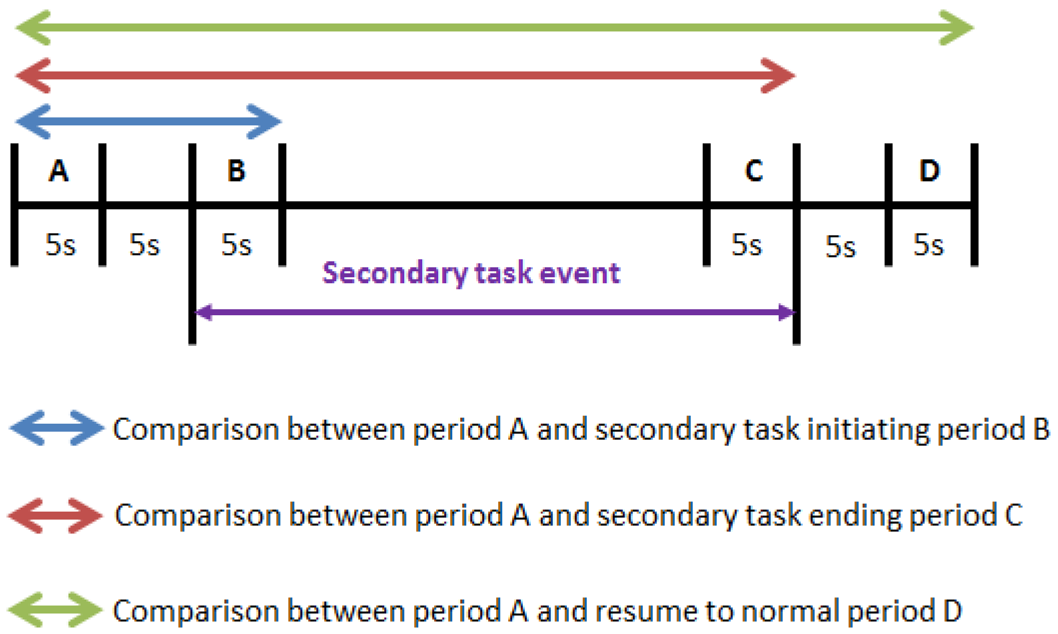

Figure 2.5 Headway selection comparison for each secondary task event

As Figure 2.5 illustrates, for one particular event, headway distance, vehicle speed, and time index were selected for four individual periods. Assuming the total event duration was 20 seconds. Period A refers 10 seconds before the initiating of secondary task event. It should be mentioned that in this study, Period A acts as the baseline since it represents the normal headway selection without secondary tasks involvement in that particular event. Period B represents 5 seconds after the initiating of secondary task event. And period C indicates 5 seconds before the ending of secondary task event. Finally, period D stands for 10 seconds after finishing the secondary task event. It should be noted that the duration of four individual periods is 5 seconds in this example. By comparing the mean values of time headway, different following behaviours during different periods were derived. More specifically, comparison of time headway between period B and A can indicate that negotiation had been taken during the initiation of secondary task; comparison between period C and A explains the headway distance changing during the end of secondary task; finally a comparison between period D and A describes changes in headways after resumed to normal driving. Hence, by comparing time headway of all selected events with one potential influencing factor (seven hypothetical factors) at a time could result in different following behaviours during different periods.

As it illustrates in figure 2.4, by comparing the mean values of time headway for all selected secondary task events, seven possible headway selection influencing factors could be validated, which would further result in an indicator for further study.

3 Results

3.1 Overall database observation

During this study, total 1411 trips were reviewed. Among these 1411 trips, 70 (5%) trips with total duration of 2022 minutes contained headway distance data. In addition, 185 secondary task events (total time duration is 237 minutes) were found within those 70 trips. Moreover, 24 (30%) out of 70 trips had stationary time headway plots with total trip duration of 760 minutes. Total 48 secondary task events were found within these 24 trips, with total duration of 22 minutes.

Within founded 185 secondary task events, 87 events were phone-related task, 48 events were passenger related task, 29 events were labelled as in-vehicle distraction, 10 events represented dining and eating task, other 10 events indicated vehicle-related task, 8 events were categorized to personal hygiene task, 4 out of 185 events were other task, 1 event referred as external-related task, and 1 event belonged to talking and singing task. The detailed table of overall database observation is attached in appendix E.

Of 48 secondary task events, 8 (17%) events were double secondary tasks which refer as containing more than one type of secondary task during a single event. The frequency and common combinations of double secondary task is shown in figure 3.1.

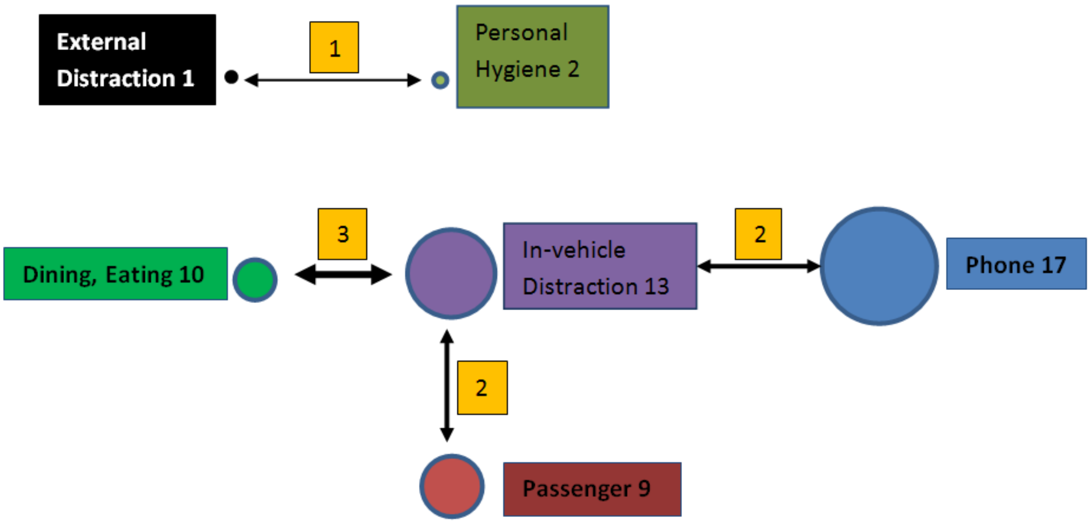

Figure 3.1 Frequency and pattern of double secondary task

Figure 3.1 demonstrates that most frequent secondary task event is in-vehicle distraction which in turn was part of 7 (88%) double secondary task events. It should be emphasized that the sizes for each secondary task cell (circle) depend on their number of occurrence in total 48 selected events. And the yellow blocks with numbers indicate the number of interaction happened between two secondary tasks.

Other findings regarding to different type of secondary task are attached in appendix E. Though these findings are less contributing to drivers' headway selection they still may provide some insight to further traffic safety studies.

3.2 Comparison of secondary task initiating period

In the following figures, 'TH' stands for Time Headway, 'ST' refers to Secondary Task, 'In.' and 'De.' represent Increase-behaviour respective Decrease-behaviour. 'VS' indicates participant's Vehicle Speed. Additional, in the following tables, all mean time headway changed values unit by second; 'S.D.' indicates the Standard Deviation of the mean time headway changed value; 'Mean.Increase.TH' refers to the mean increased time headway value, and 'Mean.Decrease.TH' depicts the mean decreased time headway value.

3.2.1 Gender

As mentioned in methodology section, there are four male drivers and five female drivers participating in this study. In total 48 secondary task events, 22 (46%) events were contributed by male drivers, and other 26 (54%) events were done by female drivers.

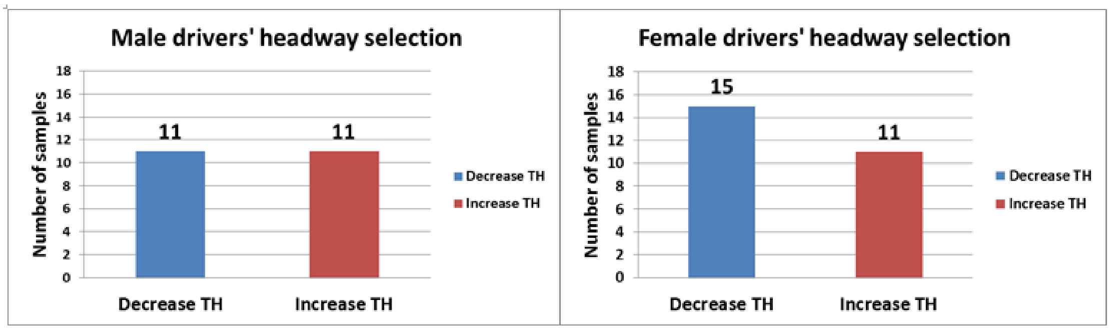

Figure 3.2 Comparison of gender difference during the initiation of secondary task

It should be mentioned that in this study, 48 secondary task events were found done by 9 Volvo drivers. Due to each driver's secondary task events were not evenly selected which will be discussed in discussion section. Hence the following results may affect by one particular driver the most.

5-10 seconds after the initiation of secondary task, as it depicts in figure 3.2, while negotiating a secondary task, the number of increased and decreased behaviour of male drivers are identical and equal to 11. In addition, there is a small difference on female drivers' number of increased and decreased behaviour during the secondary task initiating period. Moreover, the mean time headway changed during this period for both male and female drivers is shown as following table:

Table 3.1 Mean time headway changed values for male and female drivers during secondary task initiating period

	Mean. Increase. TH	S.D.	Range	Mean. Decrease. TH	S.D.	Range
Male	0.11	0.10	0.27	0.06	0.04	0.13
Female	0.08	0.08	0.23	0.06	0.08	0.26

As describes in table 3.1, during secondary task initiating period, the mean time headway changed values for male and female drivers are relative small and resembled.

3.2.2 Vehicle speed range

Within this study, the maximum and minimum vehicle speed occurred is 102.73km/h and 4.26km/h, respectively. There are three vehicle speed ranges involved in this study, there are, high-speed range within a scope between 81-110km/h; medium-speed range on a range of 31-80km/h; and low-speed range in a range between 0-30km/h. It should be noted that these speed ranges were defined by the researcher based on common sense on real traffic. In addition, as mentioned in methodology section, vehicle speed represents the relative ground speed of participant's vehicle.

During the initiation of secondary task period, 1 event was at low-speed range, 34 events were at medium-speed range, and 13 events kept their vehicle speed in high-speed range. Due to lack of low-speed samples, the further comparison will concentrate on medium-speed range and high-speed range.

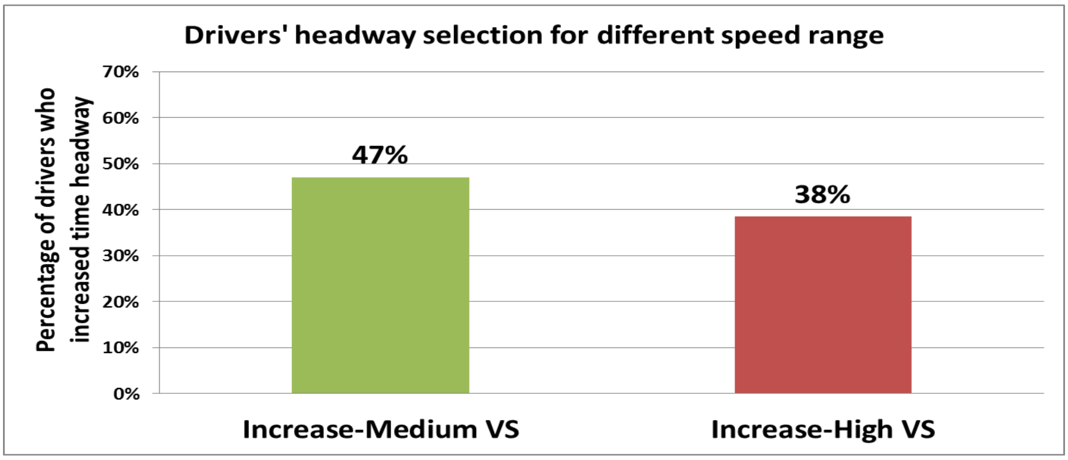

Figure 3.3 Percentage of drivers who increased headway distance under two vehicle speed ranges during secondary task initiating period

As profiled in figure 3.3, during the initiating of secondary task period, at both medium- and high-speed range, the percentages of drivers who increased their headway distance to the forward vehicle are similar for two vehicle speed ranges.

Table 3.2 Mean time headway changed values for two vehicle speed ranges during secondary task initiating period

	Mean.Increase.TH	S.D	Range	Mean.Decrease.TH	S.D.	Range
Medium-speed range	0.10	0.09	0.28	0.07	0.06	0.25
High-speed range	0.09	0.10	0.24	0.04	0.53	0.16

Shown by table 3.2, the mean time headway changed values for two speed ranges are resembled. Notably, the mean decreased time headway value at high-speed range indicates a relative large difference to its standard deviation. This may be caused by the amount of high-speed range sample is small.

3.2.3 Weather condition

There were five type of weather conditions appeared in this study, sunny, cloudy, raining, snowing, and foggy. It should be emphasized that there was no night situation in this study. The overall number of occurrence for five weather conditions is shown in table 3.3.

Table 3.3 Number of occurrence for five weather conditions during secondary task initiating period

Sunny	Cloudy	Raining	Snowing	Foggy
26	13	2	1	6

Due to lack of samples for raining and snowing condition, further comparison will not consider these two weather conditions.

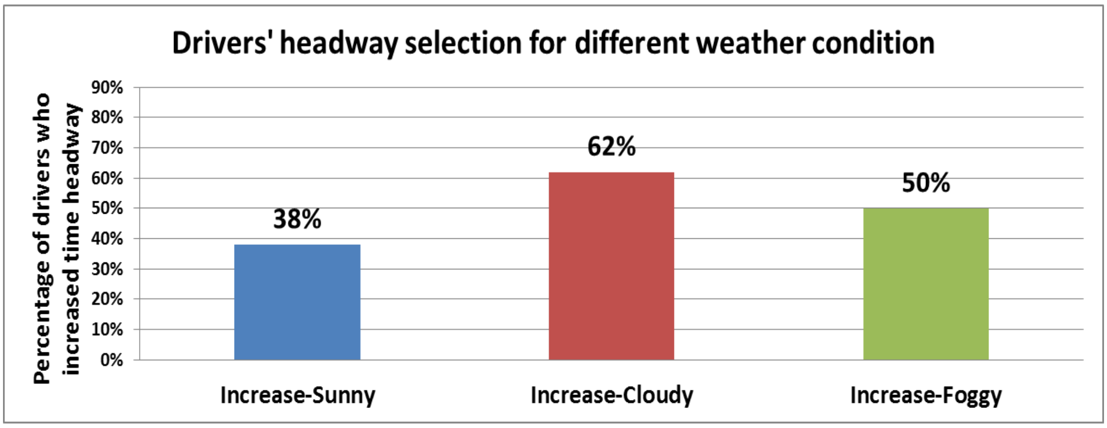

Figure 3.4 Percentage of drivers who increased headway distance for three weather conditions during secondary task initiating period

As illustrates in figure 3.4, under foggy weather, drivers who drove on a cloudy day intended to increase their headway distance. In contrast, only 38% drivers who drove on a sunny day chose to increase their headway distance. In addition, 50% drivers who drove on foggy day increased their headway distance to the forward vehicle during the initiation of secondary task.

Table 3.4 Mean time headway changed values for three weather conditions during secondary task initiating period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Sunny	0.12	0.11	0.27	0.07	0.05	0.15
Cloudy	0.08	0.07	0.22	0.07	0.10	0.25
Foggy	0.03	0.01	0.02	0.04	0.05	0.10

As table 3.4 displays, the mean values of increased time headway degrade by the following sequence, sunny, cloudy, and foggy. In contrast, the mean decreased time headway values for three weather conditions are similar during this period.

3.2.4 Road characteristics

Three types of road were involved in this study, highway, rural road, and urban road. Among 48 events, 21 events happened on highway, 25 events occurred on rural road, and 2 events recorded on urban road. As consequence, urban road condition will be excluded in the following comparison.

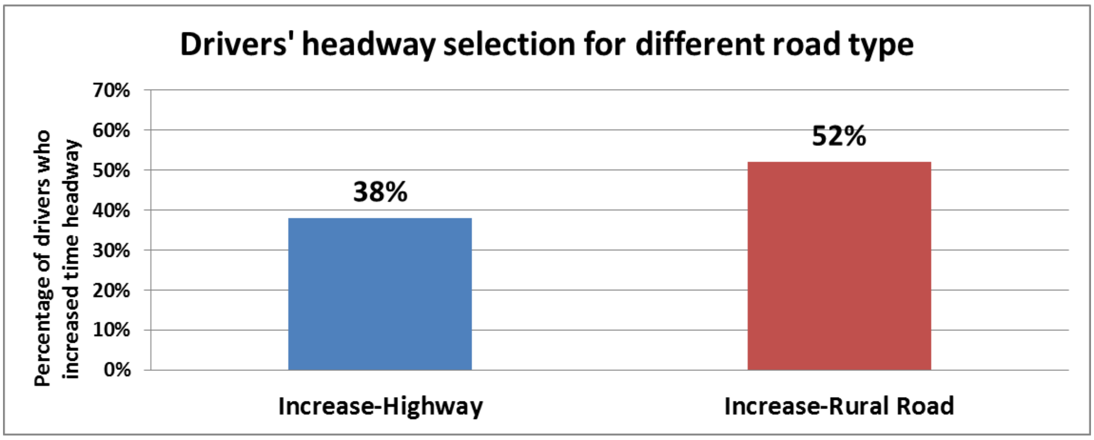

Figure 3.5 Percentage of drivers who increased headway distance for two road types during secondary task initiating period

As demonstrates in figure 3.5, during the first 5-10 seconds of secondary task, drivers who drove on rural road were more likely to increase their headway distance compared to drivers who drove on highway.

Table 3.5 Mean time headway changed values for two road characteristics during secondary task initiating period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Highway	0.13	0.09	0.23	0.07	0.07	0.05
Rural Road	0.06	0.07	0.22	0.05	0.25	0.16

As indicated in previous sections, the mean decreased time headway is generally smaller than its associated mean increased time headway. Additionally, the mean increased time headway on highway is approximately twice as it on rural road.

3.2.5 Complexity level of secondary task

In summary, three difficulty levels of secondary tasks were defined in this study, complex secondary task, moderate secondary task, and simple secondary task. 33 out of 48 events were classified as complex secondary task, 9 out of 48 events labelled as moderate secondary task, and 6 events were simple secondary task.

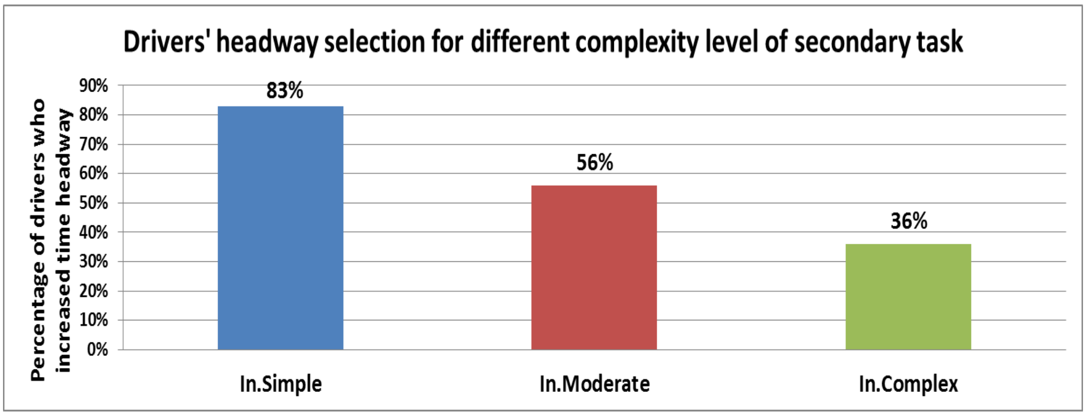

Figure 3.6 Percentage of drivers who increased headway distance of three levels of secondary task during secondary task initiating period

Figure 3.6 reveals that while engaging in different levels of secondary task, the less demanding the secondary task requires the greater tendency on increasing headway distance.

Table 3.6 Mean time headway changed values for three secondary task complexity levels during secondary task initiating period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Simple secondary task	0.12	0.12	0.28	0.03		
Moderate secondary task	0.08	0.07	0.16	0.07	0.04	0.07
Complex secondary task	0.09	0.09	0.26	0.07	0.07	0.25

As shown in table 3.6, it should be mentioned that there is no standard deviation and range for mean decreased time headway when performing simple secondary task. It is due to there was only one event for simple secondary task which driver decreased headway distance. In addition, the mean time headway changed values for three secondary task complexity levels during secondary task initiating period are similar and relative small.

3.2.6 Types of secondary task

Within 48 events, 9 types of secondary task were found, there are, phone-related task, passenger-related task, in-vehicle distraction task, vehicle-related task, dining and eating, personal hygiene, talking and singing, others, and external distraction task. The amount of each secondary task and percentage of each secondary task's duration in total secondary task duration are shown in following figures:

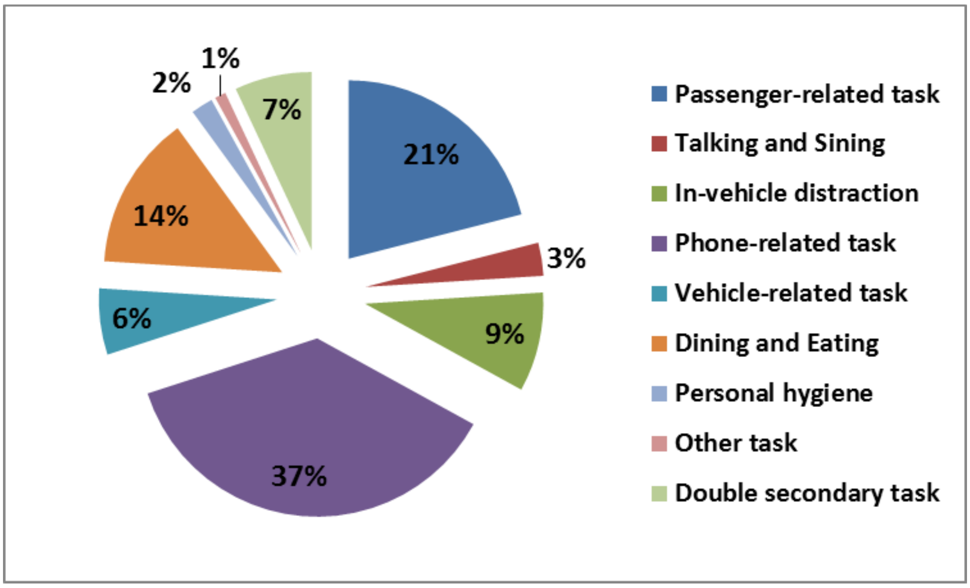

Figure 3.7Percentage of different secondary task duration in total secondary task duration

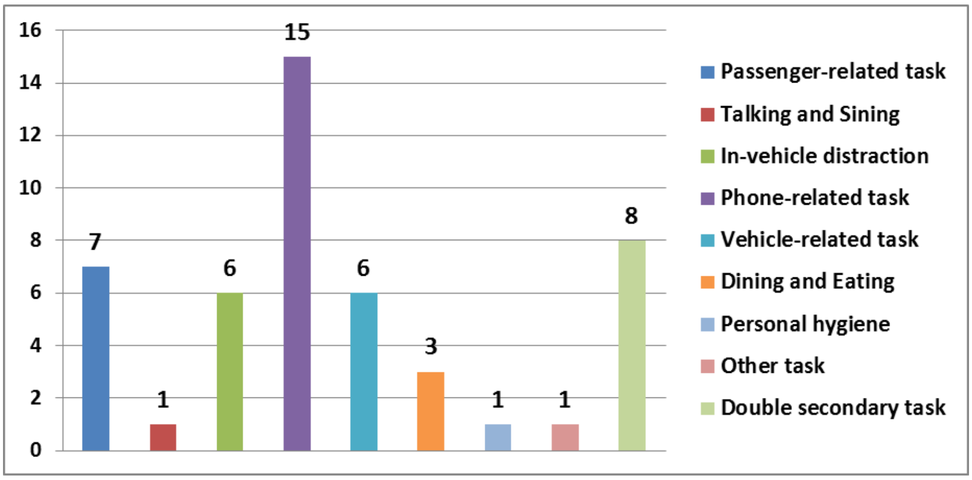

Figure 3.8 Amount of occurrence of nine type secondary task

It should be mentioned that there is no information of external distraction task in both figure 3.7 and figure 3.8 due to the only one external distraction task has been reviewed and it was labelled as double secondary task. In addition, double secondary task refers to the secondary task event contained two types of secondary task at a time. As presented in figure 3.8, the amount of talking and singing, dining and eating, personal hygiene, and others is small, therefore, further comparison will focus on passenger-related, in-vehicle distraction, phone-related task, vehicle-related task, and double secondary task.

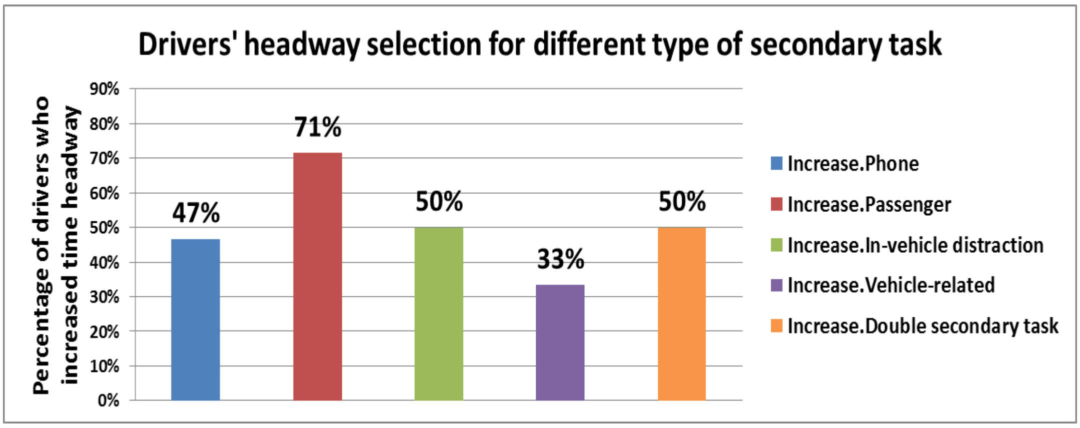

Figure 3.9 Percentage of drivers who increased headway distance of five types of secondary task during secondary task initiating period

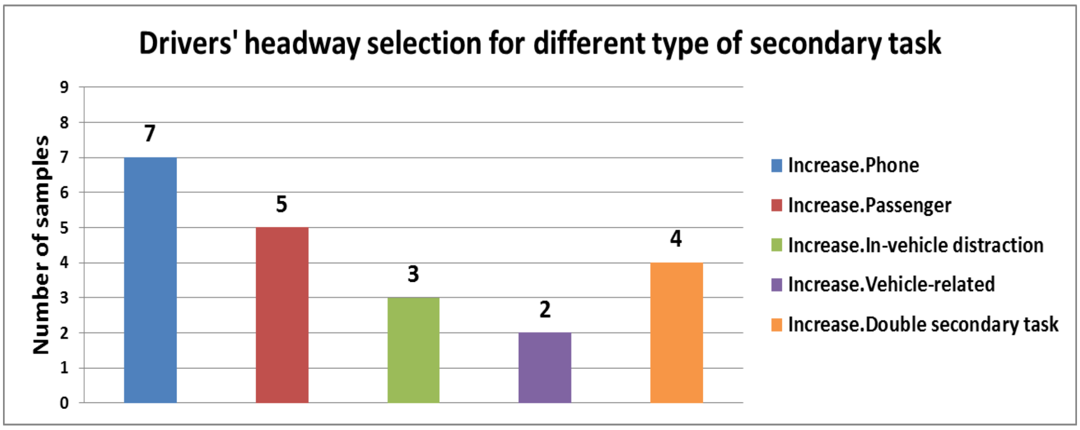

Figure 3.10 Number of increase-behaviour for five types of secondary task during secondary task initiating period

As it indicates in figure 3.9 and 3.10, 5-10 seconds after the initiation of secondary task, drivers who were engaging to either an in-vehicle distraction task or a double secondary task showed no difference in their increase-behaviour (50%). Moreover, there is a slight following difference while doing a phone-related secondary task compared to two types of secondary mentioned before. However, when performing a passenger-related task, the majority of drivers (71%) chose to increase their headway distance. In contrast, only 33% drivers who were involving in a vehicle-related secondary task intended to increase their headway distance.

Table 3.7 Mean time headway changed values for five types of secondary task during secondary task initiating period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Phone-related task	0.09	0.07	0.20	0.08	0.09	0.25
Passenger-related task	0.12	0.11	0.26	0.07	0.05	0.07
In-vehicle distraction	0.13	0.13	0.23	0.06	0.04	0.07
Vehicle-related task	0.09	0.10	0.15	0.02	0.02	0.05
Double secondary task	0.04	0.01	0.03	0.09	0.06	0.15

Table 3.7 indicates that the maximum mean increased time headway occurred while doing passenger-related task, yet, the minimum value associated with in-vehicle task. Additionally, the maximum mean decreased time headway value related to double secondary task during secondary task initiating period.

3.3 Comparison of secondary task ending period

In the following figures, 'TH' stands for Time Headway; 'ST' refers to Secondary Task, 'In.' and 'De.' represent Increase-behaviour respective Decrease-behaviour. 'VS' indicates participant's Vehicle Speed. Additional, in the following tables, all mean time headway changed values unit by second; 'S.D.' indicates the Standard Deviation of the mean time headway changed value; 'Mean.Increase.TH' refers to the mean increased time headway value, and 'Mean.Decrease.TH' depicts the mean decreased time headway value.

3.3.1 Gender

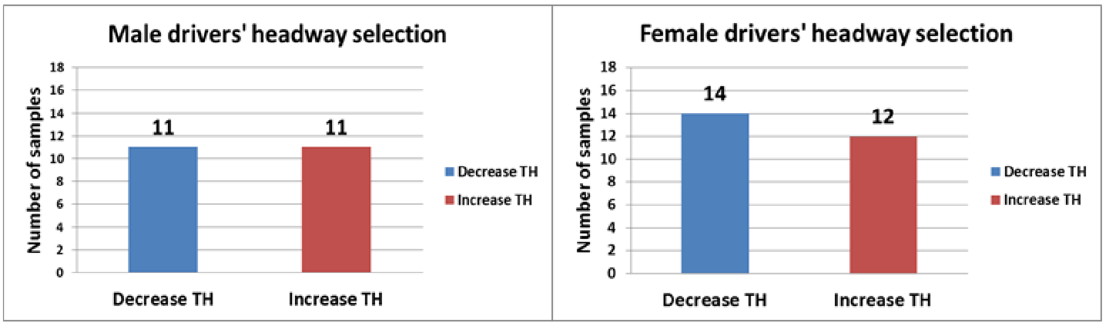

Figure 3.11 Comparison of gender difference during secondary task ending period

During 5-10 seconds before the end of secondary task, as illustrated in figure 3.11, 11 (50%) of male drivers and 14 (54%) of female drivers increased their headway distance which exhibits a resemble trend compared to the secondary task initiating period.

Table 3.8 Mean time headway changed values for male and female drivers during secondary task ending period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Male	0.18	0.16	0.40	0.11	0.10	0.35
Female	0.12	0.11	0.32	0.11	0.08	0.24

As indicated in table 3.8, for female drivers, similar to the findings for secondary task initiating period, the mean time headway changed values for male and female drivers are resembled and relative small during secondary task ending period.

3.3.2 Vehicle speed range

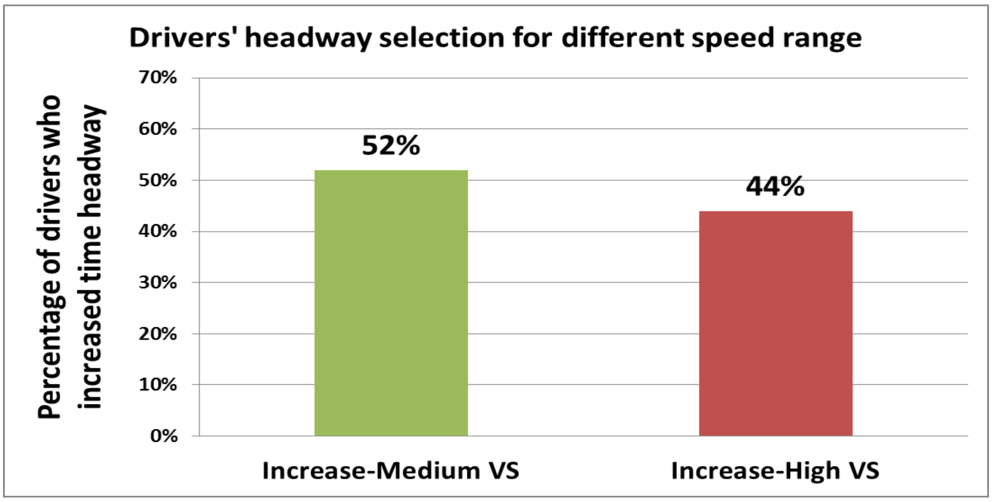

Figure 3.12 Percentage of drivers who increased headway distance for two vehicle speed ranges during secondary task ending period

Similar to secondary task initiating period, during secondary task ending period 52% drivers drove at medium-speed range increased their headway distance, 44% drivers drove at high-speed range increased their headway distance as well.

Table 3.9 Mean time headway changed values for two speed ranges during secondary task ending period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Medium-speed range	0.13	0.13	0.38	0.12	0.10	0.35
High-speed range	0.16	0.15	0.39	0.10	0.08	0.24

Table 3.9 indicates that the mean time headway changed values for two speed ranges are resembled and relative small which similar to secondary initiating period.

3.3.3 Weather condition

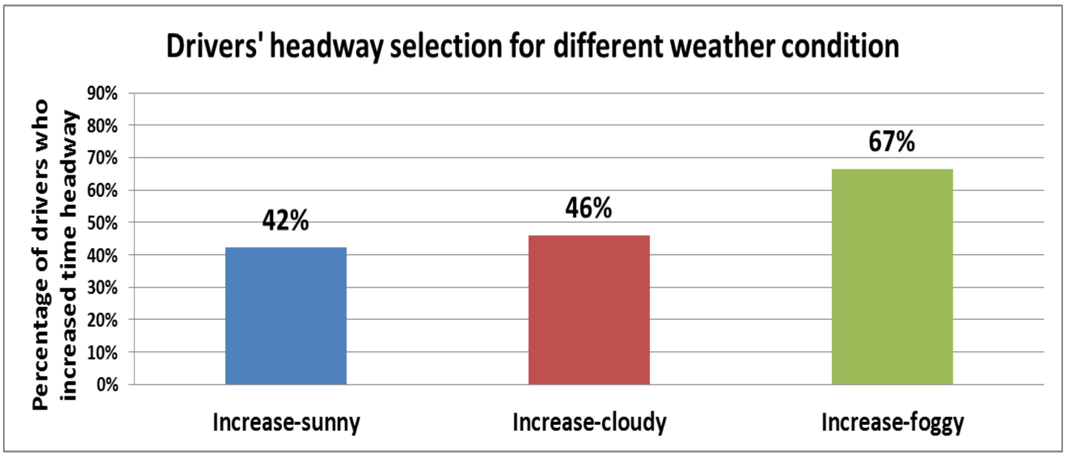

Figure 3.13 Percentage of drivers who increased headway distance for three weather conditions during secondary task ending period

As presented in figure 3.13, during secondary task ending period, there is a tendency demonstrating that drivers who drove on foggy day were more likely increased their headway distance to the forward vehicle compared to other two weather conditions. This finding differs to the finding for secondary task initiating period.

Table 3.10 Mean time headway changed values for three weather conditions during secondary task ending period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Sunny	0.19	0.16	0.39	0.13	0.07	0.24
Cloudy	0.16	0.09	0.25	0.09	0.13	0.35
Foggy	0.04	0.06	0.13	0.12	0.08	0.11

As exhibited in table 3.10, the argument, which claimed that the mean time headway changed values are relative small and similar to each other is verified. Note worthily, the mean increased time headway under sunny condition is thrice as the mean increased value under foggy condition which probably due to fewer samples of foggy weather.

3.3.4 Road characteristics

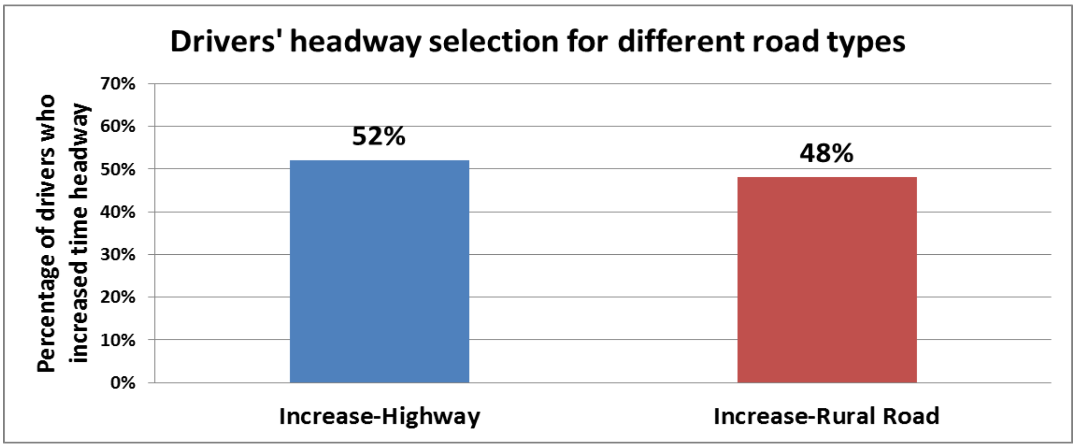

Figure 3.14 Percentage of drivers who increased headway distance for two road characteristics during secondary task ending period

As illustrated in figure 3.14, during the ending period of secondary task, the percentages of drivers who increased their headway distance to the forward vehicle for two road types are resembled. Notably, drivers who drove on highway were more likely to increase their headway distance during secondary task ending period compared to secondary initiating period.

Table 3.11 Mean time headway changed values for two road types during secondary task ending period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Highway	0.17	0.13	0.37	0.10	0.07	0.18
Rural Road	0.13	0.14	0.40	0.10	0.08	0.24

During secondary task ending period, not much difference was found on mean time headway changed values for two road types.

3.3.5 Complexity level of secondary task

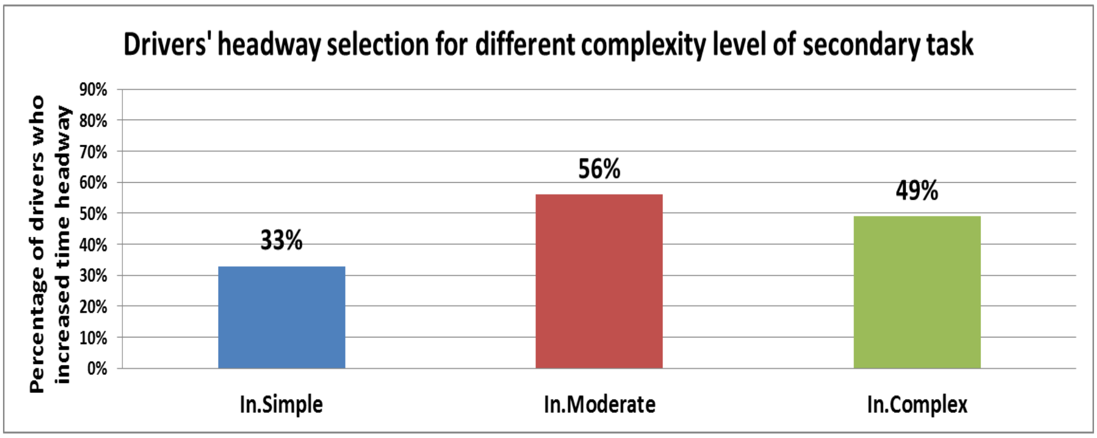

Figure 3.15 Percentage of drivers who increased headway distance of three levels of secondary task during secondary task ending period

As indicated in figure 3.15, differs to secondary task initiating period, during secondary ending period, only 33% drivers who were engaging to a simple secondary task chose to increase their headway distance. In contrast, the percentages of drivers increased their headway distance for other two complexity levels of secondary task exhibit resembled trend compared to secondary task initiating period.

Table 3.12 Mean time headway changed values for three levels of secondary task during secondary task ending period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Simple secondary task	0.24	0.19	0.26	0.07	0.06	0.15
Moderate secondary task	0.10	0.11	0.25	0.10	0.09	0.16
Complex secondary task	0.15	0.14	0.39	0.12	0.09	0.35

Similar as it showed in table 3.12, the mean increased time headway while engaging to a simple secondary task in higher than other two levels during secondary task ending period.

3.3.6 Types of secondary task

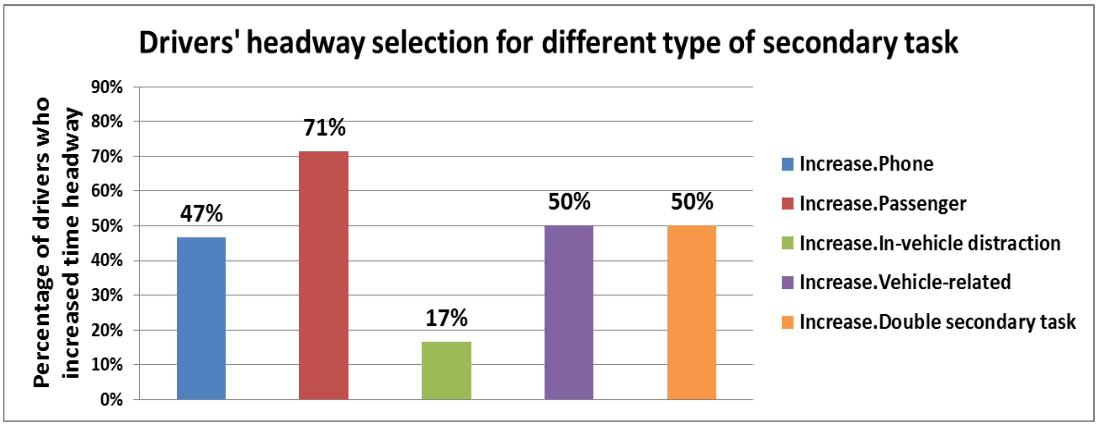

Figure 3.16 Percentage of drivers who increased headway distance of five types of secondary task during secondary task ending period

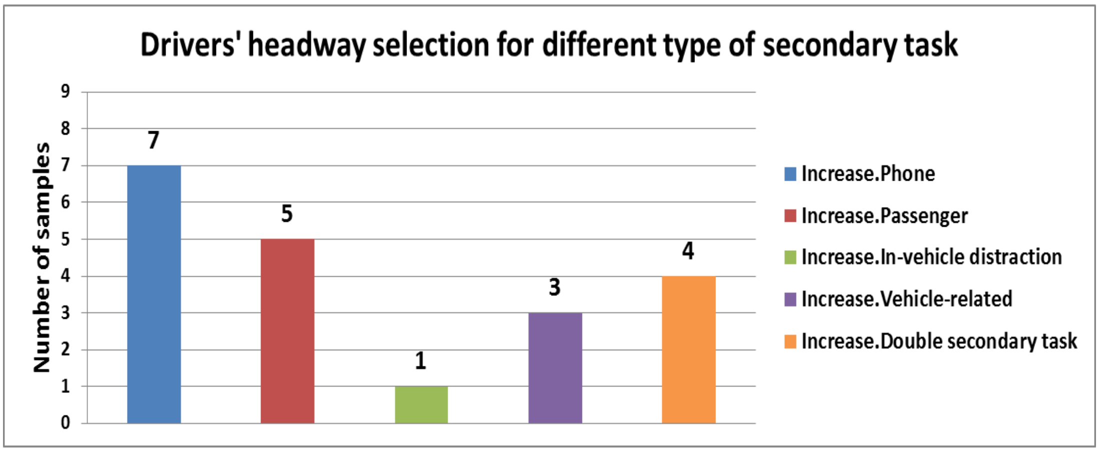

Figure 3.17 Number of increase-behaviour for five types of secondary task during secondary task initiating period

Demonstrated by figure 3.16 and figure 3.17, 5-10 seconds before the end of secondary task, drivers who were performing phone-related task, passenger-related task, as well as double secondary task showed the same trends comparing with secondary task initiating period. Yet, drivers' increased behaviour is different during this period while performing in-vehicle task and vehicle-related task.

Table 3.13 Mean time headway changed values for five secondary tasks during secondary task ending period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Phone-related task	0.14	0.10	0.26	0.09	0.08	0.19
Passenger-related task	0.17	0.15	0.38	0.10	0.10	0.15
In-vehicle distraction	0.32			0.10	0.06	0.13
Vehicle-related task	0.08	0.12	0.21	0.17	0.17	0.30
Double secondary task	0.14	0.18	0.39	0.15	0.11	0.24

Compared with secondary task initiating period, the maximum mean decreased time headway related to vehicle-related task. Still, the maximum mean increased time headway occurred during in-vehicle distraction task. It should be mentioned that there is no standard deviation and range for mean increased time headway for in-vehicle distraction, since only one event was increased headway distance.

3.4 Comparison of resuming to normal period

In the following figures, 'TH' stands for Time Headway; 'ST' refers to Secondary Task, 'In.' and 'De.' represent Increase-behaviour respective Decrease-behaviour. 'VS' indicates participant's Vehicle Speed. Additional, in the following tables, all mean time headway changed values unit by second; 'S.D.' indicates the Standard Deviation of the mean time headway changed value; 'Mean.Increase.TH' refers to the mean increased time headway value, and 'Mean.Decrease.TH' depicts the mean decreased time headway value.

3.4.1 Gender

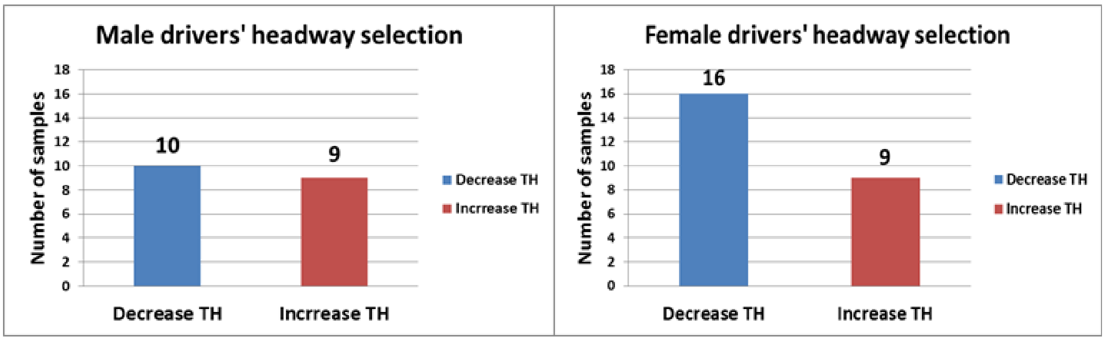

Figure 3.18 Comparison of gender differences during resume to normal period

It should be mentioned that there were total 4 events missing headway data during this period. Despite the missing events, the numbers of increased and decreased behaviour for male drivers are still similar. However, for female drivers, 16 out of 25 events increased their headway distance during this period.

Table 3.14 Mean time headway changed values for male and female drivers during resume to normal period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Male	0.14	0.14	0.46	0.10	0.11	0.34
Female	0.20	0.14	0.40	0.15	0.13	0.46

As it demonstrated previously, the mean time headway changed values for male and female drivers are related small and resembled.

3.4.2 Vehicle speed range

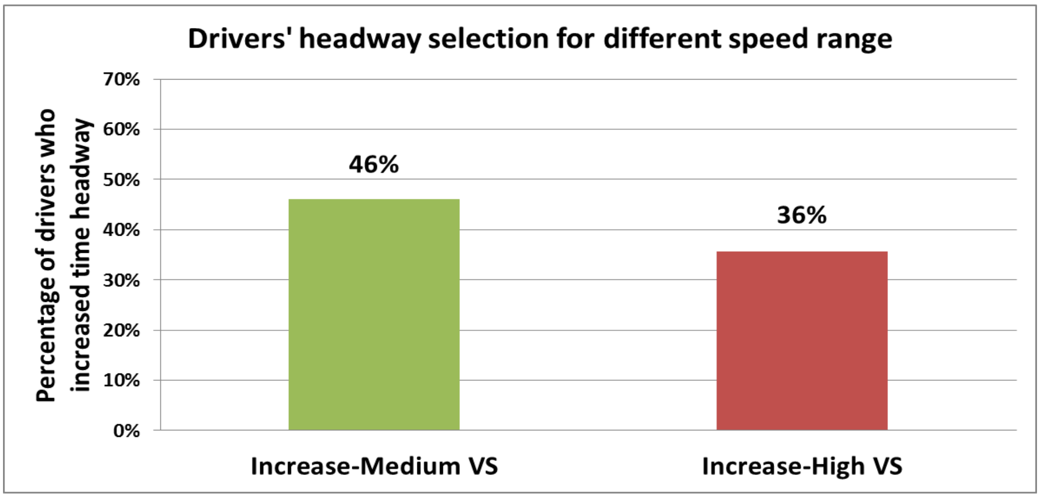

Figure 3.19 Percentage of drivers who increased headway distance for two vehicle speed ranges during resume to normal period

As shown in figure 3.19, the percentages of drivers who increased their headway distance for two speed range are still similar to each other during resume to normal period.

Table 3.15 Mean time headway changed values for two speed ranges during resume to normal period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Medium-speed range	0.16	0.15	0.46	0.11	0.12	0.35
High-speed range	0.19	0.14	0.31	0.16	0.16	0.44

Similar to other two periods, the mean time headway changed values for two speed ranges during resume to normal period are resembled and relative small.

3.4.3 Weather condition

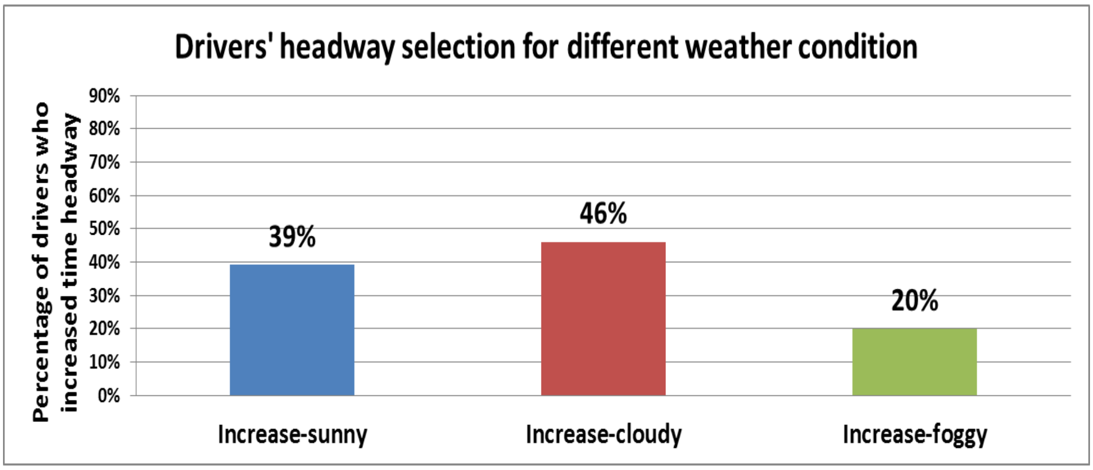

Figure 3.20 Percentage of drivers who increased headway distance for three weather conditions during resume to normal period

Compared to secondary task initiating period, drivers' headway selection is similar on sunny day. Moreover, drivers' headway selection on cloudy day is similar with secondary task ending period. However, drivers' headway selection is quite different under foggy condition compared with both secondary task initiating period and secondary task ending period, which instead of 62% during secondary task initiating period and 67% during secondary task ending period, 20% drivers who drove at foggy day increased their headways.

Table 3.16 Mean time headway changed values for three weather conditions during resume to normal period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Sunny	0.15	0.17	0.46	0.13	0.11	0.37
Cloudy	0.21	0.14	0.40	0.18	0.17	0.45
Foggy	0.16			0.06	0.09	0.19

As it demonstrated in table 3.16, similar to the findings previously, the mean time headway changed values are relative small. Additionally, compared with secondary task initiating period and ending period, the mean increased value is rose proportionally under foggy condition. It should be mentioned that there is no standard deviation and range for mean increased time headway under foggy condition, since only one event was increased headway distance.

3.4.4 Road characteristics

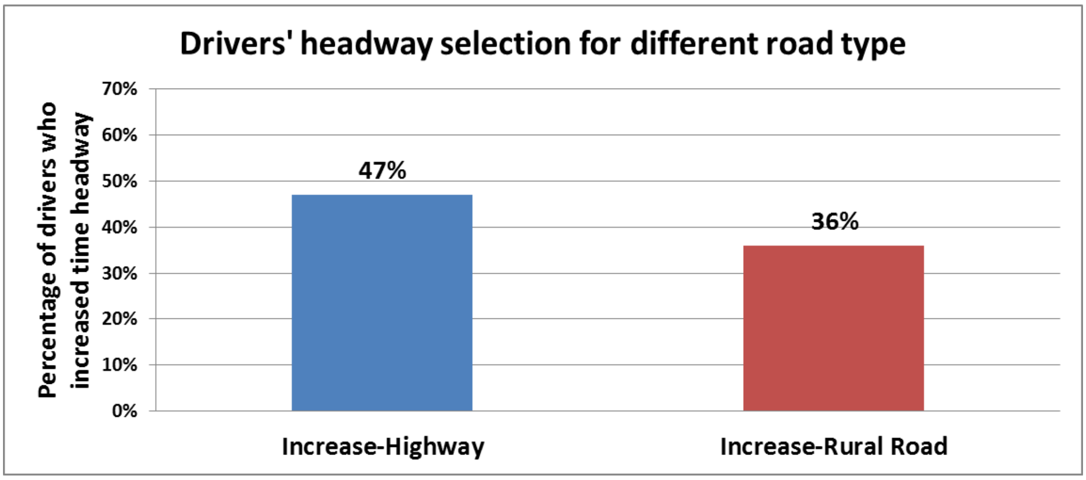

Figure 3.21 Percentage of drivers who increased headway distance for two road characteristics during resume to normal period

Differentiates from secondary task initiating period and secondary task ending period, after resume to normal driving, 47% drivers drove on highway and 36% drivers drove on rural road increased their headways.

Table 3.17 Mean time headway changed values for two road types during resume to normal period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Highway	0.21	0.14	0.40	0.11	0.09	0.29
Rural Road	0.12	0.15	0.46	0.14	0.14	0.46

As depicted in table 3.17, after resume to normal driving, drivers tended to adjust greater on their choice of headways compared with secondary task initiating period and secondary task ending period since the mean values of increased- and decreased time headway are higher than their associated values during other two periods.

3.4.5 Complexity level of secondary task

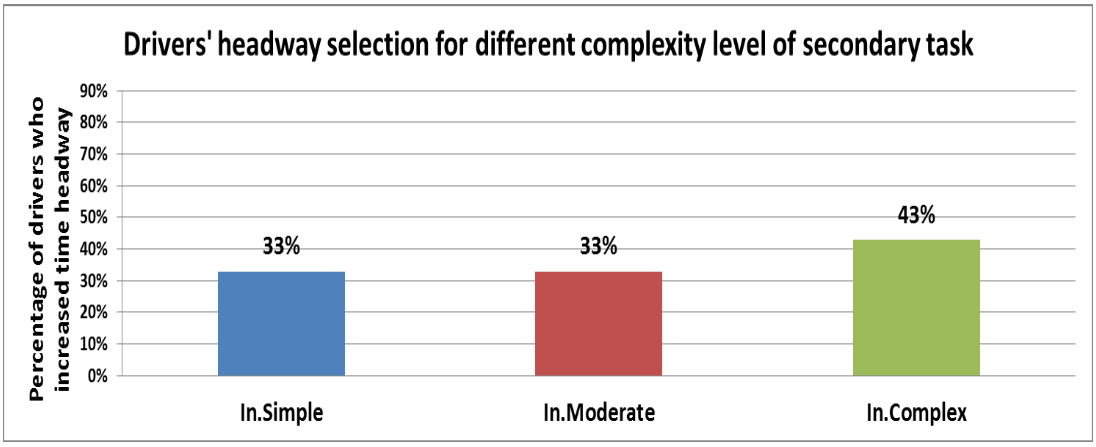

Figure 3.22 Percentage of drivers who increased headway distance of three levels of secondary task during resume to normal period

After resume to normal driving, as it demonstrated in figure 3.22, 33% drivers who were engaged a simple secondary task increased their headways which is similar to secondary task ending period. In addition, differs to other two periods, the increase-behaviour for the drivers who were engaged in a moderate secondary task reduces from 56% to 33%. And 43% drivers who were involved in a complex secondary task increased their headway distance to the forward vehicle.

Table 3.18 Mean time headway changed values for three levels of secondary task during resume to normal period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Simple secondary task	0.32	0.21	0.30	0.06	0.02	0.04
Moderate secondary task	0.19	0.10	0.20	0.10	0.10	0.21
Complex secondary task	0.14	0.14	0.43	0.16	0.14	0.45

As it shows in table 3.18, compared to secondary task ending period, the same increased value trend for three complexity levels also found during resume to normal period. However, there is an opposite tendency in mean decreased values for three complexity levels compared to increased values during resume to normal period.

3.4.6 Types of secondary task

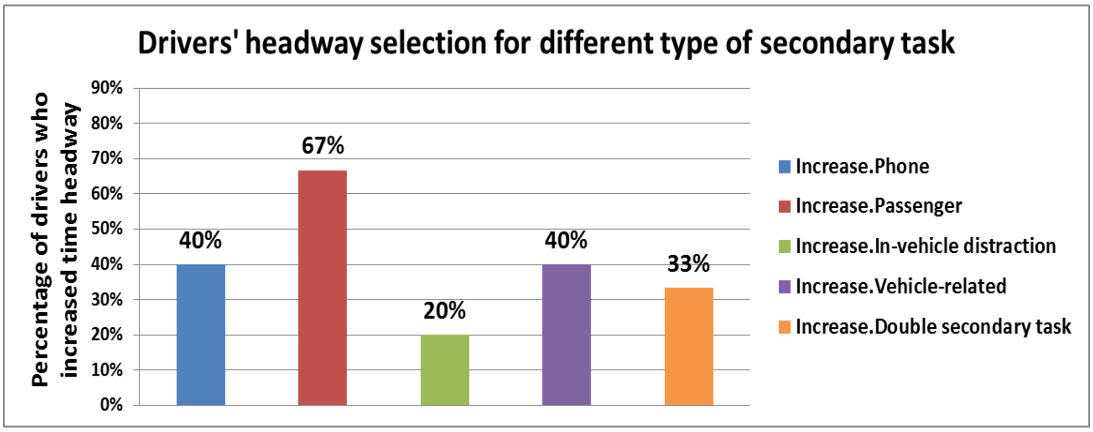

Figure 3.23 Percentage of drivers who increased headway distance of five types of secondary task during resume to normal period

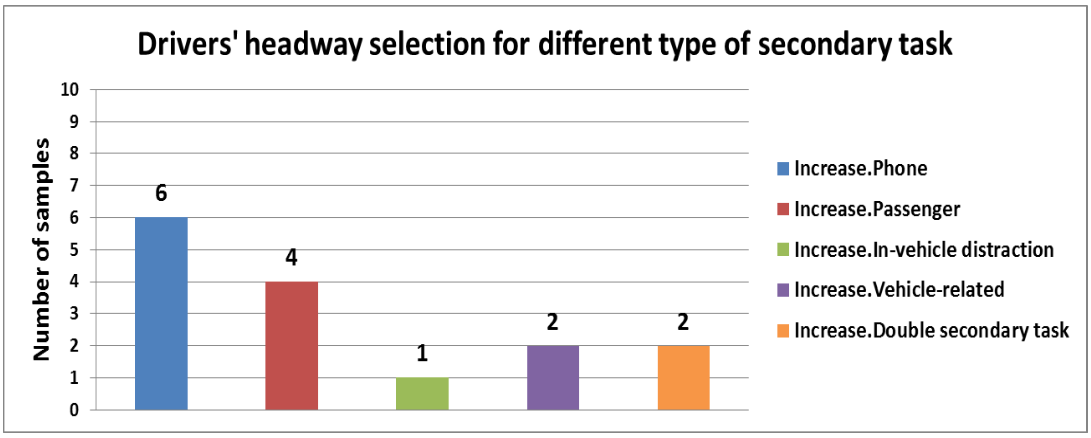

Figure 3.24 Number of increase-behaviour for five types of secondary task during resume to normal period

Compared to other two periods, after resume to normal driving, drivers who once involved in a phone-related task or a passenger-related task indicate similar headway selection. Drivers' headway selection after performed an in-vehicle task resembled to secondary task ending period. And after did a vehicle-related secondary task, there was a slightly difference in drivers' headway selection compared to other two periods. However, 33% drivers who performed a double secondary task intended to increase their headway distance after resume to normal which is different compared with other two periods.

Table 3.19 Mean time headway changed values for five types of secondary task during resume to normal period

	Mean.Increase.TH	S.D.	Range	Mean.Decrease.TH	S.D.	Range
Phone-related task	0.21	0.14	0.37	0.16	0.15	0.46
Passenger-related task	0.08	0.08	0.18	0.10	0.14	0.19
In-vehicle distraction	0.38			0.09	0.07	0.18
Vehicle-related task	0.13	0.12	0.16	0.17	0.16	0.32
Double secondary task	0.14	0.03	0.05	0.15	0.17	0.36

As indicated in table 3.19, the maximum mean increased time headway value during resume to normal period related to in-vehicle distraction task, and the maximum mean decreased time headway value occurred during vehicle related task. This trend is similar to the findings during secondary task ending period. It should be mentioned that there is no standard deviation and range for mean increased time headway for in-vehicle distraction, since only one event was increased headway distance.

4 Discussion

During this study six hypothetical situational factors and one individual influencing factor were examined. As one expected, some of the factors have been validated as the more likely influencing factors to drivers' headway selection. However, among those more likely influencing factors, some of them have been found impacted drivers' headway selection while negotiating to secondary tasks in an unexpected way.

4.1 Considered factors discussion

4.1.1 Drivers' headway selection may be affected by driver's gender

Rejected: Little evidence supporting this argument was found in this study.

During this study, there was no gender difference found among three compared periods. Results showed that when following a lead vehicle, despite other situational factors, the percentages of increase- and decrease-behaviour during three periods are approximately 50%. In contrast, the previous research [Sirpa Rajalin, et al, (1997)] has claimed that there is a gender difference in close-following situation with 73% males and 27% females were labelled as close-following drivers. Moreover, there is no literature was found verified gender difference in car-following situation in real-traffic. Obviously, combine with the finding in this study, while following a lead vehicle, there is no clear difference between the choice made by male driver and female driver. On the other hand, another potential individual factor influencing drivers' headway selection was examined by a recent study [Rui Ni, et al. (2010)] which claimed that the greatest decline occurred at moderate speeds under the highest fog density condition with older drivers keeping a headway distance that was 21% closer than younger drivers. Due to the age of 7 drivers whose age have been record in the VCC database are similar, no age-related comparison could be made during the study. Therefore, for further investigation in drivers' headway selection, one may validate age difference as an alternative individual factor instead of gender.

4.1.2 Drivers' headway selection may be affected by different ranges of vehicle speed

Rejected: Fewer findings are supporting this argument.

Combining the results for three individual periods, the range of vehicle speed seems have no impact on drivers' headway selection during car-following in real-traffic. Though all three secondary task related periods, the percentages of drivers who increased their headway distance to the forward vehicle are similar and approximate to 50%. In addition, the mean time headway changed values for two compared vehicle speed ranges during three periods are relative small and resembled within the same period. However, there actually were three speed ranges have been set up during this study, due to the less amount of low-speed range samples, the influence of low-speed range on drivers' headway selection was unknown and should be continued to investigate in further research.

4.1.3 Drivers' headway selection might vary with different weather condition

Confirmed: some evidences were found sustaining this argument.

Results validated that weather condition might be an influencing factor on drivers' headway selection during car-following while negotiating to secondary tasks in real-traffic. A study conducted previously [Kathy L.M. Broughton, et al. (2007)] has demonstrated that drivers intended to increase their headway distance while the visibility (three visibility conditions, clear, fog1, and fog2) of the weather reduced. This conclusion has been confirmed during both secondary task initiating period and secondary task ending period which indicates that the percentage of increase-behaviour elevated as the following sequence: sunny, cloudy, and foggy. However, during resume to normal period, the majority (80%) at foggy day decreased their headway distance which may be caused by fewer samples of foggy condition. In addition, other two general weather conditions (rain and snow) occurred in this study were not compared because of fewer associated samples.

4.1.4 Drivers' headway selection might differ with road characteristics

Confirmed: some findings are sustaining this argument

As concluded in result section, during secondary task initiating period, when driving on highway, fewer drivers intended to increase their headways. However, there was no evidence supporting different headway selection during secondary task ending period for two road characteristics. At last, during resume to normal period, 36% drivers on rural road increased their headways. A previous research [Bor-Shong Liu and Yung-Hui Lee (2006)] has demonstrated that the mean response time of drivers was markedly increased (11.9%) on urban road compared to motorway which implies that drivers' headway selection may be different on urban road compared to highways. Although there were events recorded on urban road, the amount of samples was small, so that no comparisons were produced in this study. Follow-up study should contain urban road situation.

4.1.5 Drivers' headway selection might be influenced by the complexity levels of secondary task

Confirmed: some evidences were found to support this argument

It has been proved that there was a relative large difference in drivers' headway selection during three individual periods while doing a simple secondary task compared to moderate and complex secondary task. More specifically, during secondary task initiating period, while engaging in a simple secondary task, drivers were most likely to increase their headway distance compared to moderate and complex secondary task situation. Whereas, during secondary task ending period and resume to normal period, drivers who were engaged in a simple secondary task intended to decrease their headways compared to secondary task initiating period.

4.1.6 Drivers' headway selection might be affected by types of secondary task

Confirmed: some findings are supporting this argument

Findings indicated that the types of secondary task might have influence on drivers' headway selection during different secondary task related periods. During secondary task initiating and ending period, most of the drivers (71%) who were engaging in a passenger-related task would increase their headway distance, whereas, 47% drivers who were performing a phone-related task would increase their headways during these two periods. This result in some way indicates that passenger-related task may be more distracted than phone-related task which also has been demonstrated by a previous study [William Consiglio, et al, (2003)].

4.1.7 Drivers' headway selection might be impacted by the types of lead vehicle

Unknown: one has failed to verify this hypothesis

It was the researcher's intention to examine whether types of lead vehicle is a likely influencing factor on drivers' headway selection. Yet, during this study, most of the events were following passenger cars (see table 4.1) which make it impossible to conclude representative result. As a result, one has failed to validate this factor.

Table 4.1 Amount of different types of lead vehicle

Passenger cars	Motorcycle	Van	SUV
43	2	1	2

However, other study [Mark Brackstone, et al, (2009)] has examined this factor before which concluded that in general drivers intended to follow closer to trucks/vans than cars. However, it should be mentioned that the study conducted by Mark Brackstone was not targeted on the compensation taken by drivers who were engaging to secondary tasks. Hence, the types of lead vehicle may have different influence on drivers' headway selection while performing a secondary task compared to normal driving. Despite this difference, further investigation on drivers' headway selection should still consider types of lead vehicle as a potential influencing factor.

4.2 Methodological issues

As mentioned in methodology section, several limitations were made in this study.

Firstly, the amount of samples is small (48 events). So that the results concluded before did not have statistical significance. Furthermore, some effect might be amplified due to fewer samples. For example, when comparing different weather condition, the amount of foggy samples was much smaller than sunny and cloudy conditions. As a result, the following behaviour under fog condition might be amplified.

The reason for such small amount of samples is caused by two issues: firstly, since the source of this study is a naturalistic and field operational test database, the scenario within the study cannot be controlled as in a simulator-based study. In other word, during this study, instead of producing (managing) an appropriate scenario, one has to find the better scenario in the database which suits the combination of following situation and a secondary task. Consequently, the sample quantity for each condition was not evenly selected; one potential factor which is type of lead vehicle even could not be validated due to this issue; secondly, the method utilized in this study for determining the desired events was depended on several parameters: first, the video should have a secondary task event containing headway distance data; second, the adaptive cruise control was off; finally, the headway data selected during all three periods should be stationary, which means the plots of time headway as function to time index were not noisy. By doing so, there was only few events (48 out of 185) left and could further be compared.

Another limitation is that the videos in VCC database did not contain audio data, which may result in some errors during classifying different type of secondary task. For instance, driver appeared talking while wearing a head set, it was difficult to judge either the driver was talking through a phone or talking to a passenger or just simply talking to himself/herself. Additionally, there was no eye-tracker data involved in VCC database, and the resolution ratio of the video was relative low. Yet, the classification of complexity levels of secondary task was depending on these two parameters. Hence, there might be some errors occurred during the video reviewing phase.

In addition, no video was found under night condition, which might lead to another influencing factor for drivers' headway selection.

In summary, the results have been concluded in this study only can be used as an indicator which points out which factors were more likely affecting drivers' headway choice for follow-up study in drivers' headway selection area.

5 Conclusion

This study used the SeMiFOT naturalistic and field operational test database, to examine seven potential factors that may have influence on drivers' headway selection while engaging in a secondary task during a car-following situation. A total of 9 Volvo drivers contributed 48 secondary-task events for 22 minutes. Overall, seven potential influencing factors were examined in this study. The conclusion obtained from this study are not statistically significant but can be used as an indicator for the follow-up research to determine a possible predictor for driver car-following behaviour to be used for active safety systems development.

In summary, the main conclusions from this study are shown in table 5.1:

Table 5.1 More likely and less likely influence factors on drivers' headway selection

More likely influencing factors	Less likely influencing factors
Weather condition	Gender
Road characteristics	Participant's vehicle speed range
Complexity level of secondary task	
Type of secondary task	

- In real-traffic, drivers did not necessarily increase their headway distance to forward vehicle as a compensation for engaging to secondary tasks. In addition, the compensated time headway values are smaller than we anticipated.

Further studies should, on the basis of this study's conclusion examine the missing factors in this study and re-examine the confirmed factors with a larger data set to produce more representative and statistical significant result. Despite the samll amount of data, these results still suggest that a change of time headway cannot be used as an indicator of secondary tasks engagement leading to distraction. Our results agree with a previous study [Thomas A. Ranney (1999)] which demonstrates that a driver following behaviour predictor, not only requires knowledge on traffic engineering, but also demands drivers' psychological factor as an supplement. In conclusion, this study highlights how difficult it is to develop an accurate predictor for secondary task engagement during car-following. Specifically, this study shows how the development of such predictor would, not only require very large amount of real-traffic data, but also good data quality.

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7 Appendix

A: Secondary task literature study table

Author/Year	Title	Analytic Approach	Results
Chandler R.E., Herman R. and Montroll E.W (1958)	Traffic dynamics: studies in car-following.	A mathematic study	Developed a car-following model
Louis A.Pipes (1967)	Car following models and the fundamental diagram of road traffic	A mathematic study devote to validate two developed car following models.	1). Based on the first model, discovered the driver accelerates his vehicle in proportion to the magnitude of the rate of change of the visual angle; 2). Greenberg's model distinguished the differences between tunnel traffic flow and highway traffic flow.
Sten Bexelius (1968)	An extended model for car-following	A mathematic method to improve the former car-following model's	Proved that drivers normally try to observe cars ahead which the earlier models cannot explain.
M.P. Heyes and R. Ashworth (1972)	Further research on car-following models	A literature review of former car-following models	Focus on mathmatical and vehicle dynamics
J.E. Tolle (1974)	Composite car following models	A theoretical study of four former car following models	Stated composite models were developed representing both congested and noncongested situations.
Ola Svenson (1981)	Are we all less risky and more skillful than our fellow drivers?	A survy study	There was a strong tendency to believe oneself as safer and more skillful than the average driver. In addition, there seemed to be a stronger tendency to believe oneself as safer than and more less risky than the average person.
P.G.Gipps (1981)	A behavioural car-following model for computer simulation	A mathematical study	A more accurate mathematic model. The corporate behaviour of the traffic is principally controlled by three factors: 1). The distribution of desired speed; 2). The reaction time of drivers; 3). The ratio of mean braking rate to driver's estimates of the mean braking rate.

Håkan Alm and Lena Nilsson (1995)	The effects of a mobile telephone task on driver behaviour in a car following situation	A simulator-based study.	It was predicted that the subjects should not compensate for their increased reaction time by increasing their headway.It was predicted that the subjects' ability to follow the road in an optimal way should be negatively affected by the mobile telephone task. The fact that someone is equal to,or more than 60 years old, does not necessarily mean that she or he reacts slowly.
Michael G. Lenne, Thomas J. Triggs and Jennifer R. Redman (1997)	Time of day variations in driving performace	A simulator-based study	Demonstrated that driver's performance including following behavior varies day to day.
Sirpa Rajalin, Sven-Olof Hassel and Heikki Summala (1997)	Close-following drivers on two-lane highways	A survey study	Results showed 73% males and 27% females were labeled as close-following drivers. And there were relatively more younger people (18-34years) and relatively less elderly people (>54years) among the close-following drivers.
Mark Brackstone and Mike McDonald (1999)	Car-following: a historical review	A theoretical study	Psychological aspect has become more and more important during the development of a car following model.
P.A. Hancock (1999)	Is car following the real question- are equations the answer?	A literature study	Car-following equals vehicle dynamics plus driver's psychological statement.
Dave Lamble, Tatu Kauranen, Matti Laakso, and Heikki Summala (1999)	Cognitive load and detection thresholds in car following situations: safety implications for using mobile (cellular) telephones while drving	A field operational test	Author concluded that neither a hand-free phone option nor a voice-controlled interface removes the problem of driver performance impairment when using a mobile phone in the car.
Thomas A. Ranney (1999)	Psychological factors that influence car-following and car-following model development	A literatures study	Conclude that a common car-following model should be invented by the corporation between traffic engineers and psychologists.

Erwin R.Boer(1999)	Car following from the drivers perspective	A literature review	All car following models should obey these assumptions: 1). Drivers are generally engaged in multiple tasks which requires task scheduling and attention management; 2). Drivers use perceptual variables rather than Newtonian variables; 3). drivers adopt a satiscing performance evaluation strategy rather than an optimal one in trying to satisfy their needs.
D.E.Haigney, R.G.Taylor, and S.J.Westerman (2000)	Concurrent mobile (cellular) phone use and driving performance: task demand characteristics and compensatory processes	A simulator-based study	While using a mobile phone, participants drove more slowly in order to make a compensatory action. Participants drove more slowly in the during call period than they did either prior to or after the call.
Mark Brackstone, Beshr Sultan, and Mike McDonald (2002)	Motorway driver behaviour: studies on car following	A Field operational test	Examined and calibrated a so called Action Point car-following model. One interesting finding was, current headways are far lower than believed.
Thomas E. Boyce and E. Scott Geller (2002)	An instrumented vehicle assessment of problem behavior and driving style: Do younger males really take more risks?	A field operational test	Examined relationships among several driving behaviors. 1). Type A personality was a significant perdictor, 2). No significant gender difference occurred, 3). Speeding, close-following, and time spent emitting behaviors were unrelated to driving correlate significantly with one another.
Roland Matthews, Stephen Legg, and Samuel Charlton (2003)	The effect of cell phone type on drivers subjective workload during concurrent driving and conversing	A field operational test	The major finding in this study was that there were highly statistically significant differences in total subjective workload between HH (handheld), HFS (handfree speaker) and PHF (personal handfree) cell phones. The PHF phone was associated with the lowest total subjective workload, followed by the HH phone, while the HFS phone was associated with the highest total subjective workload.

William Consiglio, Peter Driscoll, Matthew Witte and William P. Berg (2003)	Effect of cellular telephone conversations and other potential interference on reaction time in a braking response	A simulator-based study	The phone use would cause poorer RT performance in the braking task. The RT would be significantly worse under condition C (conversation with passenger) than under the control condition . Hands-free phone would not provide an advantage over the handheld model. Finally, listening to music played on a radio would generate minimal interference, and thus not effect braking performance.
Mary F. Lesch and Peter A. Hancock (2003)	Driving performance during concurrent cell-phone use: are drivers aware of their performance decrements?	A field operational test	For male drivers, expressed confidence was more reflective of actual performance. As confidence level increased,the effect of the cell-phone task on brake response time and stopping distance decreased. Additionally, while male drivers' confidence generally decreased with age, it was also the case that those older males that did express high confidence also performed well in the face of distraction.
Paul J.Treffner and Rod Barrett (2004)	Hands-free mobile phone speech while driving degrades coordination and control	A field operational test	The first founding stated that conversing on a mobile phone, regardless of conversation type, will detract from a driver's ability to control a vehile compared to when driving in silence.The second result stated that conversation level will differentially degrade a driver's ability to control a vehicle but did not find a clear dependence of performance on the three conversation levels chosen in this experiment. The third result stated that the most difficult categorisation task was found to be significantly different from no conversation in cornering and controlled braking.

Mark J.M.Sullman and Peter H.Baas (2004)	Mobile phone use amongst New Zealand drivers	A survey study	The research found that more than half (57.3%) of the participants used a mobile phone at least occasionally while driving. Those who reported using a mobile phone more often whilst driving tended to; be male, reside in a main urban area, report a higher annual mileage, drive a later model car with a larger engine, prefer a higher driving speed, have less driving experience (in years) and to be younger. In line with previous research, there was also a significant relationship between crash involvement and use of a mobile phone whilst driving.
Michael E.Rakauskas, Leo J.Gugerty, and Nicholas J.Ward (2004)	Effects of naturalistic cell phone conversations on driving performance	A simulator-based study	Participants' workload ratings showed that the engagement of a conversation increased the reported effort to cope with the simultaneous task demands of driving. The driving performance degradations observed suggest that participants changed the optimal target state by reducing performance goals so that primary task demands were lowered.
Sonia Amado and Pinar Ulupiner (2005)	The effects of conversation on attention and peripheral detection: Is talking with a passenger and talking on the cell phone different?	A simulator-based study	Revealed that conversation has a negtive effect on attention and peripheral detection which are important components of driving and conversation type (remote(phone) or in-vehicle (passenger)) did not make a significant difference.

David Shinar, Noam Tractinsky and Richard Compton (2005)	Effects of practice, age, and task demands, on interference from a phone task while driving	A simulator-based study	1). Performance, in general, is poorest for the older drivers.The performance of the other two groups was similar, with a slight advantage to the middle age group over the young group; 2). Performance on the driving task is significantly affected by the required speed, being generally poorer when required to drive at the more demanding 65 mph than when required to drive at 50 mph or follow another vehicle (also at speeds less than 65 mph); 3). Of the two phone distracting tasks used, the math operations – that has been extensively used in previous research to demonstrate the harmful effects of cell phoneuse in driving – is a much more difficult task, as reflected in the poorer performance on the driving measures.
Jan E.B. Törnros, Anne K. Bolling (2005)	Mobile phone use—Effects of handheld and handsfree phones on driving performance	A simulator-based study	The handsfree and the handheld mode were rather equivalent in terms of increased workload caused by phone use according to the PDT results.The drivers reduced their speed when dialling.The speed reduction was, however, greater for the handsfree mode, which should be interpreted in terms of different degrees of compensation.
Willian J. Horrey and Christopher D. Wickens (2006)	Examining the impact of cell phone conversations on driving using meta-analytic techniques	A literatures study	There were clear costs to driving performance when driver were engaged in cell phone conversation. Hands-free and handheld phones revealed similar patterns of results for both measures of performance. There was a similar pattern of results for passenger and remote (phone) conversation.
M.Eugenia Gras, Monica Cunill, Mark J.M.Sullman, Montserrat Planes, Maria Aymerich, and Silvia Font-Mayolas (2006)	Mobile phone use while driving in a sample of Spanish university workers	A survey study	Overall, only 39.9% of the participants reported never using a mobile phone while driving. The majority of the sample (60.1%) reported using a mobile phone while driving to make or answer a call and/or to use SMS. Therefore, more people use the mobile phone for talking while driving, than for SMS. The only significant difference was that males use a mobile phone more often to make calls on the highway.
Klauer (2006)	Paper not found, mentioned in Thomas A. Ranney's paper.	Unknown	Some achieved results were presented in Thomas A. Ranney's study in 2008.

David W.Eyb, Jonathon M.Vivoda, and Renée M.St.Louis (2006)	Driver hand-held cellular phone use: A four-year analysis	A survey study	The cellular phone use has increased from 2.7% to 5.8% in four years which lead to a greater than twofold increase in the number of drivers conversing on hand-held cellular phones during daylight hours. Inasmuch as the use of cellular phones by drivers elevates the risk of a crash by a factor of four.
Bor-Shong Liu and Yung-Hui Lee (2006)	In-vehicle workload assessment: effects of traffic situations and cellular telephone use	A field operational test	Analysis of task performance revealed that mean response time was markedly increased (11.9%) for driving on urban roads compared to motorways. The mean driving speed only decreased 5.8% in the presense of phone tasks in comparison to normal driving without distractions.
David L.Strayer,Frank A.Drews,and Dennis J.Crouch (2006)	A comparison of the cell phone driver and the drunk driver	A simulator-based study	There is no significant difference between using a handheld phone or a handfree phone.Drivers using a cell phone exhibited a delay in their response to events in the driving scenario and were more likely to be involved in a rear-collision accident.By contrast, drivers in the alcohol condition exhibited a more aggressive driving style,following closer to the pace vehicle and with greater force. Thus, using cell phone while driving is dangerous and impariments associated with using a cell phone while driving can be as profound as those associated with driving while drunk.
Kathy L.M. Broughton, Fred Switzer,and Don Scott (2007)	Car following decisions under three visibility conditions and two speeds tested with a driving simulator	A simulator-based study	Validate the former researches that drivers tend to decrease the headway distance under poor visibility at higher vehicle speed, and higher mean vehicle speed associated with longer mean time headway.
Katja Kircher (2007)	Driver distaction: A review of the literature	A theoretical study on driver's distraction	
D.Alfred Owens, Joanne M. Wood, and Justin M. Owens (2007)	Effects of age and illumination on night driving: a road test	A field operational test	Average speed and recognition of road signs decreased significantly as functions of increased age and illumination.

Danielle Lottridge and Mark Chignell (2007)	Driving under the influence of phones: The importance of cognitive ability and cognitive style on interruption-related performance	A simulator-based study	The most important implication of the research reported in this paper is that information technologies that provide distractions to the driving task may be dangerous for field dependent drivers with low working memories.
Thomas A. Ranney (2008)	Driver distraction: A review of current state-of-knowledge	A literature review	
Julie Hatfield and Timothy Chamberlain (2008)	The impact of in-car displays on drivers in neighbouring car: survey and driving simulator	A survey and simulator study	Suggested that drivers pay attention to displays in neighbouring vehicles and this may impair driving.
Jeffrey Dressel and Paul Atchley (2008)	Cellular phone use while driving: A methodological checklist for investigating dual-task costs	A methodological research which investigates the advantages and disadvantages of three common way to study the effects of using cellular phone while driving.	Simulator studies provide the causal relationship that correlational studies lack at the possible expense of some ecological validity. Studies of specific congitive mechanisms used in driving probide more specific explanations for driving performance decrement than simulator studies can provide,yet may sacrifice still more ecological validity. Together, these studies converge to report reliable,valid findings that cellular phone use while driving increases accident risk.
Joel M. Cooper and David L. Strayer (2008)	Effects of simulator practice and real-world experience on cell-phone-related driver distraction	A simulator-based study	Results from the first day of practice indicated that drivers conversing on the cell phone responded more slowly to lead vehicle braking. By Day 4,driving performance differences were also observed on following distance and speed control.The study indicates that the concurrent performance of two unpredictable, attention-demanding tasks will exhibit persistent impairment. Practice also resulted in a relative increase in following distance and brake reaction time in both the single- and dual-task conditions.

Joel M.Cooper, Ivana Vladisavljevic, Nathan Medeiros-Ward, Peter T.Martin, and David L.Strayer (2009)	An investigation of driver distraction near the tipping point of traffic flow stability	A simulator-based study	The expected of this research is that drivers on cell phones would exhibit the following: a reduction in lane changes, an inverse U-shaped distribution of lane change frequency across the three flow conditions, pooper lane changes, an increase in forward following distance,and a reduction in mean driving speed. Two points are unexpected: 1).the following ratio in the low-flow condition did not appear to be affected by concurrent cell phone conversation;2).drivers on cell phones did not maintain greater forward folloing distances. The overall impact of cell phone use on traffic flow could be substantial.
David B.Bellinger, Bradley M.Budde, Moe Machida, Grey B.Richardson, and William P.Berg (2009)	The effect of cellular telephone conversation and music listening on response time in braking	A simulator-based study	As expected, the cellular telephone conversation resulted in a slower mean braking response time compared to when the cellular telephone was not in use. Voice communication has been shown to delay braking RT, and impair driver decision making. Music listening did not result in a significant improvement in response time. This finding does not suggest that there is a facilitative performance effect for moderate volume music that might be relevant to improved braking performance. The combination of music listening and cellular telephone conversation could impair response time beyond that already attributable to the cellular telephone conversation alone.
Erik Nelson, Paul Atchley, and Todd D.Little (2009)	The effects of perception of risk and importance of answering and initiating a cellular phone call while driving	A survey study	The first finding of note was the high rate of cellular phone ownership in the sample. What was completely unexpected was the fact that 72% of participants reported text-messaging while driving at least some of the time.

Simon G.Hosking, Kristie L.Young and Michael A. Eegan (2009)	The effects of text messaging on young drivers	A simulator-based study	The amount of time that drivers spent not looking at the road when text messaging was up to ~400% greater than that recorded in baseline (no-text-messaging) conditions. Furthermore, drivers' variability in lane position increased up to ~50%, and missed lane changes increased 140%. There was also an increase of up to ~150% in drivers' variability in following distances to lead vehicles.
Mark Brackstone, Ben Waterson, and Mike McDonald (2009)	Determinants of following in congested traffic	A field operational test	Four hypotheses had been verified. 1). The level of traffic flow affects driver behavior-Rejected; 2). Driver following behavior varies with road charateristics-Rejected; 3). Driver following behavior is affected by the type of lead vehicle-Comfirmed; 4). Driver are inconsistent in their choice of headway-Comfirmed.
William J. Horrey and Mary F. Lesch (2009)	Driver-initiated distractions: Examining strategic adaptation for in-vehicle task initiation	A field operational test	Althogh drivers were fully aware of the relative demands of the road, they did not tend to strategically postpone secondary tasks-a finding that was consistent across the different tasks. Rather, they tended to initiate tasks regardless of the current driving conditions.
Rui Ni, Julie J. Kang, George J. Andersen (2010)	Age-related declines in car following performance under simulated fog conditions	A simulator-based study	The greatest decline occurred at moderate speeds under the highest fog density condition, with older drivers maintaining a headway distance that was 21% closer than younger drivers.

B: Detailed secondary task table

Event No.	Secondary task classification	Secondary task difficulty levels	Total trip duration	Driver No.	Gender and Age	Enviromental condition	Time from start (s)	Description of secondary tasks	Remarks	Type of lead vehicle	Road characteristics	Adapted cruise control status
1	Extermal distraction/PH	Complex	22min 58sec	M-3	46	Sunny	478,473-487,098	Watched object left outside, scratched nose.		Passenger car	Highway	Off
2	Phone	Complex	22min 58sec	M-3	46	Sunny	937,745-949,088	Reached cell phone and looked,maybe checked SMS.	Handheld non-tactile phone	Passenger car	Highway	Off
3	Vehicle-related	Complex	25min 49sec	M-3	46	Cloudy	199,921-236,536	Changed CD. Took CD out, changed another one with CD box. And then adjucted CD player.	Almost dropped CD box during the changing action.	Passenger car	Urban road	Off
4	Talking&Sining	Complex	35min 45sec	M-3	46	Sunny	1629,423-1675,222	Sang		Passenger car	Rural Road	Off
5	Personal Hygiene	Complex	25min 21sec	M-3	46	Sunny	802,636-826,245	Checked his fingernail and watch.		Passenger car	Highway	Off
6	Phone	Complex	21min 34sec	F-1	48	Raining	223,050-248,769	Checked incoming SMS		Passenger car	Highway	Off
7	Phone	Complex	21min 34sec	F-1	48	Raining	1100,423-1108,673	Checked incoming SMS.		Passenger car	Highway	Off
8	Passenger	Complex	16min 18sec	M-1	48	Sunny	303,092-337,122	Talked to the passenger who sitted on the front left.		Passenger car	Rural road	Off
9	Passenger	Moderate	16min 18sec	M-1	48	Sunny	425,499-456,748	Talked to the passenger who sitted on the front left.		Passenger car	Rural road	Off

10	Passenger	Complex	1h 1min 42sec	M-1	48	Sunny	306,191-420,905	Talked with front-right passenger.	Null values of headway during this period was due to drive through a roundabout. The driver made a lots body language while talking to the passenger, sometimes no hands on the steering wheel.	Passenger car	Rural road	Off
11	Dining/Eating	Complex	1h 1min 42sec	M-1	48	Sunny	420,905-438,397	Held the water and drank which passed by the passenger while talking.	Double secondary task	Passenger car	Rural road	Off
12	InD/Dining,Eating	Complex	1h 1min 42sec	M-1	48	Sunny	649,629-669,284	Picked the water bottle and drank.		Passenger car	Highway	Off
13	Vehicle-related	Complex	16min 53sec	M-1	48	Sunny	37,013-48,873	Adjusted central control panel.		Passenger car	Rural road	Off
14	Dining/Eating	Simple	13min 32sec	M-1	48	Sunny	37,525-170,726	Chewed gum		Passenger car	Rural road	Off
15	InD	Simple	13min 32sec	M-1	48	Sunny	209,281-214,656	Put on sunglass.		Passenger car	Highway	Off
16	Passenger	Complex	30min 52sec	M-1	48	Sunny	764,467-815,732	Talked to the front-right passenger.		Passenger car	Highway	Off
17	P/InD	Complex	26min 07sec	M-1	48	Cloudy	48,666-56,041	Talked with the front-right passenger and read newspaper which the passenger was reading.		Passenger car	Rural road	Off
18	Vehicle-related	Complex	31min 17sec	M-1	48	Snowing	589,326-608,217	Adjusted central control panel.		Passenger car	Rural road	Off
19	InD	Complex	42min 03sec	F-1	48	Sunny	1404,823-1465,370	Took headset from pocket and organized it in order to put it on.		Passenger car	Highway	Off

20	InD	Complex	42min 03sec	F-1	48	Sunny	1465,370-1489,016	Put headset on.		Passenger car	Highway	Off
21	Passenger	Moderate	56min	M-1	48	Sunny	2551,837-2575,022	Talked the the passenger.	At 2473,408s, driver had been changed. The driver before sat on front-right as a passenger.	Passenger car	Highway	Off
22	InD	Simple	10min 45sec	F-3	56	Cloudy	68,376-72,813	Put on gloves (winter)		Passenger car	Rural road	Off
23	Phone	Simple	10min 58sec	F-3	56	Cloudy	37,110-78,277	Talked on the handheld cell phone without headset.	The vedio image initiated at 37,110s, driver was already on the phone, couldn't tell whether driver was answered an in-comming call or dialed.	Passenger car	Rural road	Off
24	Phone	Complex		F-3	56	Cloudy	78,277-100,136	Held the phone and put it on the next seat.		Passenger car	Rural road	Off
25	Phone	Complex	32min 52sec	F-3	56	Sunny	803,795-832,717	Checked the cell phone, maybe SMS or voice mail.		Passenger car	Highway	Off
26	Phone	Complex	32min 52sec	F-3	56	Sunny	832,717-858,076	Conversed on the handheld cell phone without headset.		Passenger car	Highway	Off
27	InD	Simple	16min 34sec	F-3	56	Sunny	130,124-152,687	Reached lip protector		Passenger car	Urban road	Off
28	Dining/Eating	Moderate	2h 3min 57sec	M-4	58	Sunny	41,516-71,126	Ate by one hand	Eat from the beginning of this trip.	Passenger car	Rural road	Off
29	InD/Dining,Eating	Complex	2h 3min 57sec	M-4	58	Sunny	160,361-174,127	Took the cola from the front-right passenger and drank.	Headway data only available for the first 3min 9sec, and then kept constant.	Passenger car	Rural road	Off

30	InD	Moderate	33min 40sec	F-4	46	Sunny	314,588-318,729	Turned and saw rear seat and oranged some objects.		SUV	Rural road	Off
31	Other	Complex	33min 40sec	F-4	46	Sunny	381,605-392,824	Looked down, and looked at her right hand, and then looked at front-right seat.		Passenger car	Rural road	Off
32	InD/Dining,Eating	Complex	28min 20sec	F-4	46	Sunny	646,682-659,838	Reached candy in the box and ate.		Passenger car	Rural road	Off
33	InD/Phone	Complex	28min 20sec	F-4	46	Sunny	1308,723-1314,848	Picked up something and then put it back.	Still on the phone.	Mini van	Rural road	Off
34	InD/Phone	Complex	28min 20sec	F-4	46	Sunny	1344,396-1351,614	Picked up the same object picked before and looked, and then put it back.	Still on the phone.	SUV	Rural road	Off
35	Phone	Complex	12min 34sec	F-5	41	Cloudy	22,646-53,693	Held cell phone using one hand and listened.		Passenger car	Highway	Off
36	Phone	Complex	12min 34sec	F-5	41	Cloudy	53,693-83,794	Talked on the handheld cell phone without headset.		Passenger car	Highway	Off
37	Phone	Moderate	12min 34sec	F-5	41	Cloudy	83,794-89,466	Dialed on the handheld phone		Passenger car	Highway	Off
38	Vehicle-related	Complex	12min 34sec	F-5	41	Cloudy	205,388-208,825	Adjusted seat.		Passenger car	Highway	Off
39	Phone	Moderate	19min 22sec	F-5	41	Cloudy	441,048-509,205	Answered in-comming phone call without headset.	The phone call initiated at 419,141s.	Passenger car	Highway	Off

40	Phone	Complex	19min 22sec	F-5	41	Cloudy	526,658-586,071	Still on the phone.		Passenger car	Highway	Off
41	Phone	Complex	19min 22sec	F-5	41	Cloudy	597,196-687,179	Still on the phone.	The phone call overed at 687,179s.	Passenger car	Highway	Off
42	Phone	Simple	19min 22sec	F-5	41	Cloudy	687,179-700,414	Dialed another phone call and listened.		Passenger car	Highway	Off
43	P/InD	Complex	44min 48sec	M-2	No age recored	Foggy	144,706-155,331	Talked to the front-right passenger and looked at the central panel six times.		Passenger car	Rural road	Off
44	Passenger	Moderate	44min 48sec	M-2	No age recored	Foggy	170,519-186,566	Talked to the front-right passenger.		Passenger car	Rural road	Off
45	Passenger	Moderate	44min 48sec	M-2	No age recored	Foggy	276,950-283,653	Talked to the front-right passenger.		Passenger car	Rural road	Off
46	Vehicle-related	Complex	44min 48sec	M-2	No age recored	Foggy	283,653-286,653	Adjust audio.		Passenger car	Rural road	Off
47	Vehicle-related	Complex	44min 48sec	F-2	No age recored	Foggy	1619,862-1628,768	Adjust seat and setbelt.	Changed driver.	Motorcycle	Rural road	Off
48	Phone	Moderate	44min 48sec	F-2	No age recored	Foggy	1632,346-1659,517	Operated on handheld cell phone, probably dialed a number.		Motorcycle	Rural road	Off

C: Table of complexity level for 9 types of secondary tasks

Note: abbreviation 'ST' indicates secondary task

Type of ST	Complex ST	Moderate ST	Simple ST
Phone-related	10	3	2
Passenger-related	3	4	
Others	1		
Personal Hygiene	1		
In-vehicle distraction	2	1	3
Vehicle-related	6		
Dining, Eating	1	1	1
Talking, Singing	1		
Double ST	8		

D: Matlab scripts

```
function dbData = load_dbdata_SQL_cont(query, pretime,posttime)
% LOAD_DBDATA_SQL
%   dbData = LOAD_DBDATA_SQL(query,dbConnection,adodb_connection)
%   Loads the data in the dbdata format structure from the result of the
%   sql query.
%   Only the first argument is needed
%   Edited By Christian Blåberg, Chalmers March 2009
%   Henrik Lind- Changed so that time index is continous per segment,
%   090918
%   CB Changed adding pretime (ms) and posttime (ms) in function

[dbConnection adodb_connection]=Connect_To_SeMiFOT;

% Some checks
tmp1=strfind(lower(query),'order by');
tmp2=strfind(lower(query),'timeindex');

if isempty(tmp1) || (~isempty(tmp2) && tmp1(1) > tmp2(end))
    warning('MATLAB:whatever','Consider ordering the result by "timeindex", and possibly by "trip_id"');
end

smaller_query=['select timeindex,trip_id ' query(strfind(query,'from'):end)];

rowCount = dbConnection.invoke('GetData_SQL', smaller_query);

% Get data.
dataMatrix = dbConnection.invoke('GetDataMatrix');

dataNames = dbConnection.invoke('GetColumnNames');

[m n]=size(dataMatrix);


columns_with_strings=find(mean(dataMatrix==-2)>0.9);

dataMatrix=mat2cell(dataMatrix,m,ones(1,n));

for i=1:length(columns_with_strings)
    new_query=replace_column_from_query(query,dataNames{columns_with_strings(i)});
    try
        new_column_data=adodbquery(adodb_connection,new_query);
    catch
        last_error=lasterror;
        disp(last_error.message);
        fprintf('Unable to fix this column %s\n',dataNames{columns_with_strings(i)});
        continue
    end
    if ~isempty(new_column_data)
        dataMatrix{columns_with_strings(i)}=new_column_data;
    end
end
% Create a structure containing all data except time
dbData = struct();
dbData.SQL.Query = query;
dbData.SQL.ExecTime = datestr(now,'yyyy-mm-dd HH:MM:SS');
% dbData.SQL.UserName = username;
dbData.SQL.UserName = getenv('username');
% dbData.SQL.Server = server;
dbData.SQL.Server = 'vessel.ita.chalmers.se';
% dbData.SQL.DbName = dbname;
dbData.SQL.DbName = 'nanna.ita.chalmers.se';
```

```
% Divide data into sections of continuous time
% Frequency of data is currently 10 Hz. CHANGED TO 1000, and added abs()
% NEED TO ADD CHECK FOR TRIP_IDs!!
iTimeIndex=find(strcmpi(dataNames, 'TIMEINDEX'), 1);
iTrip_ID=find(strcmpi(dataNames,'TRIP_ID'),1);
if isempty(iTimeIndex);
   error('Column TIMEINDEX not found, need it to create the dbdata structure');
end

t = dataMatrix{iTimeIndex};



s_start = find([true ; abs(diff(t))>100 ]);
s_end = find([abs(diff(t))>100; true]);
sections = length(s_start);

% This is what we do if the result is empty
if m==0
     dbData.SignalData=struct([]);
     dbData.TripData=struct([]);
   if display_text
       disp('0 rows loaded, found no data')
   end
  return
end

for s = 1:sections
   new_query=[query(1:strfind(query,'where')+4) sprintf(' timeindex >= %i and timeindex <= %i and trip_id = %i order
by timeindex ',t(s_start(s))-pretime,t(s_end(s))+posttime,dataMatrix{iTrip_ID}(s_start(s)))];
   temp_dbdata=load_dbdata_SQL(new_query);
   dbData.SignalData(s)=temp_dbdata.SignalData;
   dbData.TripData(s)=temp_dbdata.TripData;
   disp((max(dbData.SignalData(s).TimeIndex)- min(dbData.SignalData(s).TimeIndex))/1000) %seconds
end
dbData.SQL.Query=[mfilename ' was used with the query: ' query ', and added ' num2str(pretime) ' ms and '
num2str(posttime) ' ms'];
disp([num2str(rowCount+(pretime+posttime)/10) ' approximate number of rows loaded, representing ' num2str(sections)
' separate events.'])
```

```
%GetdbData_following_patterns

%Select TimeIndex,HeadwayDistance,VehicleSpeed,AccelerationPedalPosition BEFORE engaging to a ST;
dbdata=load_dbdata_SQL_cont('select trip_id, timeindex, FORVHLSPEED_VCC,
fcrdistmainvhlahead_vcc,FORACCPEDALPOS_VCC from trip_xc70_main_10hz where trip_id=XX and
TIMEINDEX>=XX and TIMEINDEX<=XX order by timeindex',0,0)
A=dbdata.SignalData.TimeIndex;%A refers to TimeIndex;
B=dbdata.SignalData.FORVHLSPEED_VCC;%B refers to tested vehicle speed unit by km/h;
C=dbdata.SignalData.FCRDISTMAINVHLAHEAD_VCC;%C refers to front headway distance in meter;
D=dbdata.SignalData.FORACCPEDALPOS_VCC;%D refers to the acceleration pedal position,no unit;
E=B.*inv(3.6); %normalized unit between headway distance and vehicle speed;
TH=C.\E; %SD indicates the Time headway distance of this specified trip;
Mean_VehicleSpeed=mean(E);
Mean_TimeHeadway=mean(TH);
save XX_A.mat;

%%Select TimeIndex,HeadwayDistance,VehicleSpeed,AccelerationPedalPosition at the BEGINNING of the ST event ;
dbdata=load_dbdata_SQL_cont('select trip_id, timeindex, FORVHLSPEED_VCC,
fcrdistmainvhlahead_vcc,FORACCPEDALPOS_VCC from trip_xc70_main_10hz where trip_id=XX and
TIMEINDEX>=XX and TIMEINDEX<=XX order by timeindex',0,0)
A=dbdata.SignalData.TimeIndex;%A refers to TimeIndex;
B=dbdata.SignalData.FORVHLSPEED_VCC;%B refers to tested vehicle speed unit by km/h;
C=dbdata.SignalData.FCRDISTMAINVHLAHEAD_VCC;%C refres to front headway distance in meter;
D=dbdata.SignalData.FORACCPEDALPOS_VCC;%D refers to the acceleration pedal position,no unit;
E=B.*inv(3.6); %normalized unit between headway distance and vehicle speed;
TH=C.\E; %SD indicates the standard Time headway distance of this specified trip;
Mean_VehicleSpeed=mean(E);
Mean_TimeHeadway=mean(TH);
save XX_B.mat;

%%Select TimeIndex,HeadwayDistance,VehicleSpeed,AccelerationPedalPosition BEFORE the END of ST event;
dbdata=load_dbdata_SQL_cont('select trip_id, timeindex, FORVHLSPEED_VCC,
fcrdistmainvhlahead_vcc,FORACCPEDALPOS_VCC from trip_xc70_main_10hz where trip_id=XX and
TIMEINDEX>=XX and TIMEINDEX<=XX order by timeindex',0,0)
A=dbdata.SignalData.TimeIndex;%A refers to TimeIndex;
B=dbdata.SignalData.FORVHLSPEED_VCC;%B refers to tested vehicle speed unit by km/h;
C=dbdata.SignalData.FCRDISTMAINVHLAHEAD_VCC;%C refres to front headway distance in meter;
D=dbdata.SignalData.FORACCPEDALPOS_VCC;%D refers to the acceleration pedal position,no unit;
E=B.*inv(3.6); %normalized unit between headway distance and vehicle speed;
TH=C.\E; %SD indicates the standard Time headway distance of this specified trip;
Mean_VehicleSpeed=mean(E);
Mean_TimeHeadway=mean(TH);
save XX_C.mat;

% %%Select TimeIndex,HeadwayDistance,VehicleSpeed,AccelerationPedalPosition AFTER the event while doing
normal driving;
dbdata=load_dbdata_SQL_cont('select trip_id, timeindex, FORVHLSPEED_VCC,
fcrdistmainvhlahead_vcc,FORACCPEDALPOS_VCC from trip_xc70_main_10hz where trip_id=XX and
TIMEINDEX>=XX and TIMEINDEX<=XX order by timeindex',0,0)
A=dbdata.SignalData.TimeIndex;%A refers to TimeIndex;
B=dbdata.SignalData.FORVHLSPEED_VCC;%B refers to tested vehicle speed unit by km/h;
C=dbdata.SignalData.FCRDISTMAINVHLAHEAD_VCC;%C refres to front headway distance in meter;
D=dbdata.SignalData.FORACCPEDALPOS_VCC;%D refers to the acceleration pedal position,no unit;
E=B.*inv(3.6); %normalized unit between headway distance and vehicle speed;
TH=C.\E; %SD indicates the standard Time headway distance of this specified trip;
Mean_VehicleSpeed=mean(E);
Mean_TimeHeadway=mean(TH);
save XX_D.mat;
```

E: Secondary task tables

Total time of trips (70 trips contain 185 events)	2022 minutes	33.7 hours
Total secondary task duration (185 events)	237 minutes	3.95 hours

Secondary task type	**Number of events**	**Total time**	**No of events with stable headway**
Phone-related	87	1.86 hours	17
Passenger-related	48	1.71 hours	9
Personal Hygiene	8	0.04 hours	2
Others	4	0.15 hours	1
In-vehicle distraction	29	0.22 hours	13
Talking and Singing	1	0.01 hours	1
Dining and Eating	10	0.21 hours	6
Vehicle-related	10	0.07 hours	6
External-related	1	9 seconds	1

NOTE: 13 out of 185 events are double ST

Total time of events with stable headway 22 minutes

Number of events												
Secondary task type per driver	M-1	F-1	M-2	F-2	M-3	F-3	F-4	F-5	M-4	M-5	F-6	M-6
Phone-related	3	36	10	5		3		21	1	2	2	
Passenger-related	8	10	13	4		3	2		1	2		1
Personal Hygiene	4			2							1	
Others	1					1						
In-vehicle distraction	8	2	2	4		1					2	
Talking and Singing	1											
Dining and Eating			3		1			1				
Vehicle-related	4		2	1				1		1	1	
External-related	1											
Double secondary task	2		4	1		4		1		1		

Secondary task difficulty level			
Difficulty Levels	**Simple**	**Moderate**	**Complex**
Phone-related	24	15	43
Passenger-related	27	9	9
Personal Hygiene	3		3
Others	1		1
In-vehicle distraction	3	4	13
Talking and Singing			1
Dining and Eating	3	1	1
Vehicle-related			10
External-related			
Double secondary task			14