MOBILE PHONE USE BY YOUNG DRIVERS: EFFECTS ON TRAFFIC SPEED AND HEADWAYS

George Yannis[1], Eleonora Papadimitriou, Xenia Karekla, Efrosyni Kontodima

National Technical University of Athens
School of Civil Engineering
Department of Transportation Planning and Engineering
5, Iroon Polytechniou str., GR-15773 Athens, Greece

Abstract

This research aims to investigate the effects of mobile phone use while driving on traffic speed and headways, with particular focus on young drivers. For this purpose, a field survey was carried out in real road traffic conditions, in which drivers' speeds and headways were measured while using or not a mobile phone. The survey took place within a selected University Campus area, allowing to distinguish between settings approximating either free flow or interrupted flow conditions. Linear and loglinear regression methods were used to investigate the effects of mobile phone use and several other young driver characteristics, such as gender, driving experience and annual distance travelled, on vehicle speeds and headways. Separate models were developed for average free flow, interrupted flow, as well as for total average speed. Results show that mobile phone use leads to statistically significant reduction of traffic speeds of young drivers in all types of traffic conditions. Furthermore, male and female drivers reduce their speed similarly when using a mobile phone while driving. However, male drivers using their mobile phone drive at lower speeds than female drivers not using their mobile phones. Variables sensitivity analysis revealed that, among all explanatory variables, the effect of mobile phone use on speed was most important. Accordingly, vehicle headways appear to increase for drivers using their mobile phone. However, this effect could not be statistically validated, due to the strong correlation between speeds and headways.

Keywords: mobile phone use; traffic speed; vehicle headways; free flow; interrupted flow.

---

[1] Corresponding Author: Dr. George Yannis, Assistant Professor
tel.: +30 210 7721326, fax: +30 210 7721454
e-mail: geyannis@central.ntua.gr

1. Background and objectives

The increased use of mobile phones while driving, in an international context where the number of road accidents and related casualties is still considered too high in most countries, has raised strong concerns about the impact of drivers' mobile phone communications on road safety and has initiated important ongoing research on that topic. On the basis of the well established concept of humans' inherently limited focus capabilities (Kahneman 1973), early research results have demonstrated that mobile phone communication is a quite demanding cognitive and operational task, which may compromise decision making while driving (McKnight and McKnight 1993). Nowadays, the use of a mobile phone while driving is prohibited by road traffic regulations in most European countries.

In several recent research results the use of mobile phones is blamed for increased risk of provoking or failing to avoid a road accident, mainly within simulated experiments. The effect is identified in (Laberge-Nadeau *et al.* 2003), where it is attributed to the distraction of driver's attention. Furthermore, the effect of mobile phone use on road accident risk is quantified in (Redelmeier and Tibshirani 1997), who suggest that road accident risk is quadrupled when using mobile phone while driving, not only during the actual mobile phone communication, but also during the short period following the end of the call. It was also reported (Lam 2002) that the risk of road accident injury of 25-29-year-old drivers who used a mobile phone was estimated to be almost 2.5 times higher than those not being distracted. In an extensive simulator survey (Wilcox 2004) it was found that drivers who used their mobile phone while driving experienced an increased risk of provoking a road accident compared to drivers who did not use their mobile phone while driving; interestingly, this effect was non significant for male drivers.

Several researchers address the effect of mobile phone use while driving on accident risk through the examination of the respective effect on traffic speeds and vehicle headways. It is argued that drivers may attempt to compensate for the increased mental effort resulting from the use of mobile phone while driving by adapting their speed accordingly (Haigney *et al.* 2007). In particular, it has been found that drivers reduce their speed while using their mobile phone, and this reduction ranges around 18% (Strayer and Drews 2001). The adjustment of driving speed while using a mobile phone appears to be largely affected by the road environment; in particular, speed reduction is expected to be higher in the more complex urban settings (Törnos and Bolling 2005).

Related effects may also rise from individual driver characteristics, such as age and gender. For instance, young drivers do not appear to significantly reduce their travel speed when using their mobile phone, whereas older drivers reduce their speed in accordance to the complexity of the trip. Moreover, higher speed reductions while using a mobile phone were observed among older female drivers, in relation to male drivers of the same age groups (Nowakowski *et al.* 2008).

Other researchers examine vehicle headways as an alternative measure of driving behaviour when using a mobile phone; however the related findings are rather contradictory. For example, a research (Rosenbloom 2006) reports a statistically significant reduction of vehicle headways in drivers using their mobile phones, whereas in (Strayer and Drews 2001), headways of drivers using their mobile phones were found by 12% higher than those of drivers who did not use their mobile phone while driving.

Although important research effort is recently devoted on the effect of using mobile phones while driving, most of the available results are compromised by features of the experimental design, as regards both the data collection and analysis methods. More specifically, most of these researches use driving simulator (Alm and Nilsson 1995, Ranney *et al.* 2005) or stated preference data (Chen 2007, Gras *et al.* 2007), i.e. the effects are seldom explored in real traffic conditions, therefore different types of bias may be involved in each case. Moreover, in very few researches has it been possible to quantify or validate the magnitude of the effect of using a mobile phone while driving on road safety. Finally, most researchers examine either traffic speed or vehicle headways alone as a measure of driving behaviour, while if their interdependence was taken into consideration, some of the results might appear counter-intuitive (Karekla and Kontodima, 2008).

Within this framework, the objective of the present research is to extend existing research on the effect of using a mobile phone while driving on road safety, focusing on the particular group of young drivers. On that purpose, a field survey is carried out in actual traffic conditions, and an appropriate setting is selected, allowing to account for different types of traffic conditions. Moreover, both traffic speeds and vehicle headways are examined as per the influence of mobile phone use while driving. This research was carried out in Athens, Greece, where a very low drivers compliance is observed, combined with a lack of systematic police enforcement of the use of mobile phones while driving.

2. Methodology and data collection

2.1 Field survey

The field survey was carried out within the campus of the National Technical University of Athens (NTUA). Surveys participants were selected among students and employees of the NTUA and were all familiar with the examined road environment. Emphasis on young individuals was also opted for, given that these individuals are more attracted by mobile phone technology, they use their mobile phone more extensively (in general and while driving), and are also a particular group as regards driving behaviour and road safety. Overall, 37 drivers of the age group 18-25 years participated in the survey, 26 males and 11 females.

A specific route was selected for the field experiment, within the NTUA Campus, as presented in Figure 1. The total length of the route was 5.9 kilometres and included two distinct parts. The first part, of length of 3.7 kilometres, lies along the Campus ring road (within points 1-2-3-4 and 7-8 in Figure 1), where traffic approximates free flow conditions. The second part, of length of 2.2 kilometres, lies in the central Campus area (within points 4-5-6 in Figure 1), which includes most of the buildings and parking areas, approaching thus interrupted flow traffic conditions, with several junctions (non traffic controlled), important pedestrian traffic and roadside parking. The total route is presented in (Figure 1).

Figure 1 to be inserted here

The field survey was carried out during July 2007, at a period where the University was still open, during the same period each day, in order to ensure typical and uniform driving conditions. Survey participants first filled out a brief questionnaire with information on their personal characteristics and their driving practices, especially as regards mobile phone use.

Then, one surveyor joined each driver participant in his or her vehicle. The surveyor was sitting at the back seat of the vehicle and used a video camera to record the entire route. A first drive on the selected route took place, during which the surveyor indicated the route to the driver, without any further communication. Then, a second drive of the exact same route took place, during which, a second surveyor called the driver on his or her mobile phone and initiated a short discussion, including questions to the driver about various trivial issues (e.g. his or her recent activities, holiday plans, other tastes and preferences etc.). This was repeated about 4 or 5 times during the entire second route.

2.2 Data processing

The data was extracted through the video recordings of the two routes. For each driver, average speed during free flow and interrupted flow traffic conditions was measured for both routes (without or with use of mobile phone) by dividing the route length to the respective travel time. Moreover, several vehicle headways were measured for each driver while driving infree flow and interrupted flow conditions for both routes. Vehicle headways were measured as the difference in time, on which the survey vehicle passed from several fixed points along the route, in relation to the vehicle ahead of it. In total, 1067 headways were measured for the 74 routes examined (two routes for each one of the 37 participants). Eventually, average vehicle headways were calculated for free flow and interrupted flow conditions on both routes.

This data was stored in a database, which was completed with data from the survey questionnaire including person age and gender, total kilometres traveled per year etc.

2.3 Analysis methods

In order to estimate the effect of using mobile phones while driving, linear regression models were examined, under the assumption that both traffic speeds and headways are continuous normally distributed response variables. However, preliminary results revealed discordances with the Gauss-Markov assumptions. A log-transformation of the two response variables was therefore implemented, leading to the following Generalized linear modeling formulation (1):

$$\text{Log } y_i = \Sigma \beta x_i + \varepsilon_i$$

Where x_i are continuous or discrete explanatory variables,
β are parameters to be estimated
and ε_i the error component $\varepsilon \sim N(0, \sigma^2)$

The results based on this formulation were significantly improved.

3. Results

3.1 Modeling vehicle speeds

Three different models were examined for vehicle speed: one for the total average speed, one for the average free flow speed and one for the average interrupted flow speed, while different explanatory variables combinations were tested for each one of the models. Explanatory variables included driver gender, driving experience, use of mobile phone, annual distance traveled and average headways, the latter one due to its obvious correlation with speed from the traffic flow theory (i.e. vehicle headways express traffic density). The variables are summarized in (Table 1).

Table 1 to be inserted here

Preliminary modeling results revealed persistent difficulties in obtaining statistically significant results. These poor results could attributed to the fact that all participants drove the same route twice, one without using a mobile phone and another one using a mobile phone, it would be thus likely that their speed during the second route would also be affected by the better knowledge of the route. For this reason, a new field survey was carried out, with 8 new participants, for whom the process was reversed, so that they were asked to use their mobile phone on the first route and not use it on the second route.

The comparison of total average speed between the two surveys showed that average speed when using a mobile phone did not present significant differences according to the knowledge of the route (i.e. route driven first or second). However, average speed when not using a mobile phone was increased by 13% when a better knowledge of the route was involved (i.e. the route was driven second).

According to these results, it was decided to apply a correction factor for route knowledge on the initial sample of 37 participants, i.e. on the 'not using mobile phone' route speed. In particular, the average speeds of the 'not using a mobile phone' route in the initial sample were multiplied by 1.13. Following this correction, modeling results were significantly improved. The best fitting models in each case are presented in (Table 2).

Table 2 to be inserted here

In all three models, the effects of driver gender, mobile phone use and average headway are statistically significant and consistent. More specifically, women drive at lower speeds than men, both in free flow and interrupted flow conditions. Moreover, mobile phone use decreases speed in all three models. Finally, increased headways are associated with lower speeds, which is intuitive. A higher annual distance travelled increases young drivers' speed in free flow conditions, but does not appear to affect young drivers' speed in interrupted flow conditions; however, the effect is significant in the total average speed model. Free flow speed was also found to be positively affected by driving experience.

For the comparative assessment of variable effects within and across the three models, relative effects were calculated, on the basis of elasticities provided by the following formula (2):

$$e_i = (\Delta \text{Log } y_i \ / \Delta x_i) \ . \ (x_i / y_i) = \beta_i \ . \ (x_i / y_i)$$

It is noted that, although elasticities are most meaningful when comparing the effects of continuous variables, the formula was also applied for the categorical variables, as a means for the assessment of relative effects. The results for total average speed, free flow average speed and interrupted flow average speed are presented in (Table 3), in which e_i indicates the relative effect and e_i* indicates the relative effect normalized in relation to the variable with the lowest effect.

The results show that the most important effects on young drivers' speeds are those of headways, given that these two traffic measures are directly correlated. The second most important effects on young drivers' speeds are those of mobile phone use while driving. Young drivers' gender presents the smallest significant effect on speed.

Table 3 to be inserted here

(Figure 2) presents an indicative sensitivity diagram, summarizing the effects of headways, mobile phone use and gender on young drivers' total average speed. The diagram concerns male and female drivers whose annual distance travelled exceeds 10,000 kilometres. The sensitivity of total average speed to average headways is estimated for four young drivers' groups: male / female drivers using / not using their mobile phone while driving.

Mobile phone use while driving leads to reduction of vehicle speeds for both male and female young drivers. Although (Figure 2) shows only the results concerning total average speed, the effect is similar both in free flow (e.g. interurban road environment) and interrupted flow (e.g. urban road environment). Female young drivers drive at lower speeds than males, regardless of the road and traffic environment. Interestingly, male young drivers using their mobile phone while driving drive at lower speeds than female young drivers not using their mobile phone while driving. When using a mobile phone while driving, the difference in speeds between male and female young drivers is reduced; as shown in (Figure 2), the two curves corresponding to mobile phone use are closed to one another.

Figure 2 to be inserted here

3.2 Modelling vehicle headways

Following the results for young drivers' average speeds, an effort was made to develop respective models for the effects of mobile phone use on average vehicle headways. As was the case for speed, the results of the second, 'reversed' survey showed that headways during the 'not using a mobile phone' route were approximately 20% lower when this route was the second one driven, and therefore the related average headways of the initial sample were corrected accordingly by a factor of 1.20.

When testing the models, it was observed that, when explanatory variables included mobile phone use and driver characteristics, the effect of mobile phone use was statistically significant; however, models fit was rather poor, with R^2 seldom exceeding 0.25. On the other hand, when introducing average speed in the models as an explanatory variable, models fit was much improved (with R^2 reaching 0.48), however the effect of mobile phone use became non significant.

This may be initially attributed to the strong correlation between speed and mobile phone use, making that the effect of mobile phone use on average vehicle headways is totally included in the effect of speed. Additionally, the fact that the effect of mobile phone use on headways is significant in a model not including speed, but non significant in a model including speed, may also be interpreted as an unclear effect of mobile phone use on average vehicle headways.

It is also worth mentioning that mobile phone use was consistently found to increase vehicle headways in all modelling attempts. This finding is in accordance with some existing findings and may be explained by the reduced speed associated with mobile phone use while driving. Overall, it can be said that mobile phone use while driving leads to reduced speeds and increased vehicle headways, corresponding to drivers efforts to compensate for the distraction caused by the use of mobile phone while driving. It is possible that, if data was available on minimum headways or headways variability, it might be easier to draw conclusions on the effect of mobile phone use on headways.

4. Discussion

Most existing research efforts on the effect of mobile phone use while driving on drivers' behaviour are based on either driving simulator experiments or stated preference surveys. This research contributes to the identification and validation of the effects of using a mobile phone while driving on drivers' speed and headways, by using data from a field experiment, where vehicle speeds and headways were measured for a group of young drivers partly using their mobile phone while driving in actual road and traffic conditions.

Modelling results showed that mobile phone use leads to lower average speeds by approximately 15%, both in free flow and in interrupted flow conditions. Moreover, an increase of average headways of approximately 25% was measured from the data on drivers using their mobile phone. However, this increase of vehicle headways could not be statistically validated, as the effect of speed on headways appears to be predominant.

Mobile phone use results in similar reductions of speeds for male and female drivers, regardless of their annual distance travelled. Male drivers drive at higher speeds than female drivers, except when comparing male drivers using their mobile phone with female drivers not using their mobile phone.

From a traffic engineering viewpoint, mobile phone use appears to have a negative effect on traffic flow. In particular, lower vehicle speeds and higher vehicle headways, at a given road section during a given time period, and with given road conditions and traffic control features, should lead to a reduction of traffic capacity.

On the other hand, form a road safety view point, mobile phone use may also have important, but less straightforward effects. Reduced speeds and increased vehicle headways during mobile phone use may have some positive effects on road safety, given that drivers may have more time to react to an unexpected situation. Moreover, driving at lower speeds reduced the risk of serious injury or fatality when involved in a road accident. Nevertheless, mobile phone use while driving can by no means be consider to favour road safety, given that several studies confirm an important distraction of drivers using their mobile phone, which may lead to increased risk of provoking or failing to avoid a road accident.

The conclusions of the present research can be considered to be quite representative of either a suburban / rural road environment, with low traffic volumes and densities, or a typical urban setting, according to the two types of road environment on which the filed experiment took place. Nevertheless, a University Campus area is still an approximation of the conditions described above. A larger scale experiment is under way in actual urban traffic conditions, in which instead of in-vehicle measurements, roadside radar measurements of speeds and headways are foreseen. Moreover, the analysis should be extended to all driver age groups. Finally, comparing stated preference data with actual data on of mobile phone use while driving may provide additional insight on drivers' attitude and behaviour as per the effects of using mobile phones while driving.

References

Alm H., Nilsson L. 1995. The effects of a mobile telephone task on driver behaviour in a car following situation. *Accident Analysis and Prevention* 27 (5), 707-715.

Chen, Y.-L. 2007. Driver personality characteristics related to self-reported accident involvement and mobile phone use while driving. *Safety Science* 45 (8), 823-831.

Gras M.E., Cunill M., Sullman M.J.M., Planes M., Aymerich M., Font-Mayolas S. 2007. Mobile phone use while driving in a sample of Spanish university workers. *Accident Analysis and Prevention* 39, 347-355.

Haigney D.E., Taylor R. G., Westerman S. J. 2000. Concurrent mobile phone use and driving performance : task demand characteristics and compensatory processes. *Transportation Research, Part F: Traffic Psychology and Behavior* 3 (3), 113-121.

Kahneman, D. 1973. *Attention and Effort*. Englewood Cliffs, NJ: Prentice-Hall.

Karekla X., Kontodima E. 2008. *Impact of mobile phone use on vehicle speed*. Diploma Thesis. National Technical University of Athens, School of Civil Engineering, Department of Transportation Planning and Engineering.

Laberge-Nadeau C., Maag U., Bellavance F., Lapierre S.D, Desjardins D., Messier S., Saïdi A. 2003. Wireless telephones and the risk of road crashes. *Accident Analysis and Prevention* 35, 649-660.

Lam L.T. 2002. Distractions and the risk of car crash injury: The effect of drivers' age. *Journal of Safety Research* 33 (3), 411-419.

McKnight A.J., McKnight A.S. 1993. The effect of mobile phone use upon driver attention. *Accident Analysis and Prevention* 25, 259-265.

Nowakowski C., Friedman D., Green P. 2001. *Cell phone ring suppression and HUD Caller ID: Effectiveness in reducing momentary driver distraction under varying workload levels*. Technical Report UMTRI 2001-29, October 2001, Available on-line: http://www.umich.edu/~driving/publications/UMTRI-2001-29.pdf [Accessed Jul. 28, 2008].

Ranney T., Watson G.S., Mazzae E.N., Papelis Y.E. 2004. *Examination of the distraction effects of wireless phone interfaces using the National advanced driving simulator*. Preliminary Report No DOT 809 737, NHTSA, Virginia, April 2004. Available on-line:

http://www.nhtsa.gov/staticfiles/DOT/NHTSA/NRD/Multimedia/PDFs/VRTC/ca/capubs/Wireless1F_PrelimReport.pdf [Accessed Jul. 28, 2008].

Redelmeier, D.A., Tibshirani R.J. 1997. Association between Cellular-Telephone Calls and Motor Vehicle Collisions. *New England Journal of Medicine* 336 (7), 453-458.

Rosenbloom T. 2006. Driving performance while using cell phones: An observational study. *Journal of Safety Research* 37, 207-212.

Strayer D.L., Drews F.A. 2001. *Effects of cell phone conversations on younger and older drivers*.University of Utah, Salt Lake City. Available on-line: http://www.psych.utah.edu/AppliedCognitionLab/Aging.pdf [Accessed Jul.28, 2008].

Törnos J.E.B., Bolling A.K. 2005. Mobile phone use - Effects of handheld and handsfree phones on driving performance. *Accident Analysis and Prevention* 37, 902-909.

Wilcox S.D. 2004. Comparison of driving in a simulated environment while using the cell phone with and without a headset. Published in *Design Science*, 2 August 2004. Available on-line: http://www.natarus.com/safedriving/NatarusSafeDrivingPressKit_06-03-05.pdf, p. 13.

Figure 1. Field survey area and routes

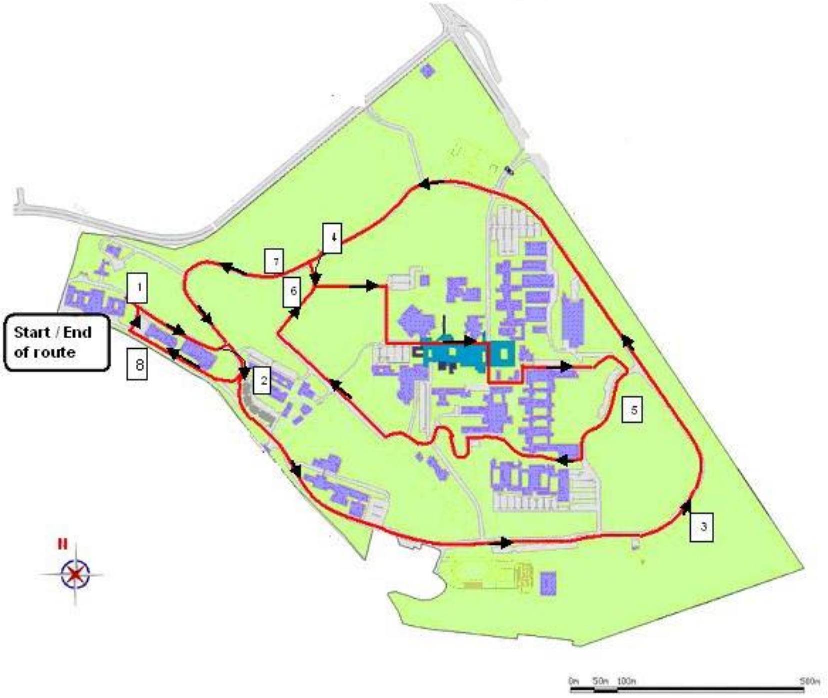

Figure 2. Sensitivity of average speed to average headway per driver gender and mobile phone use

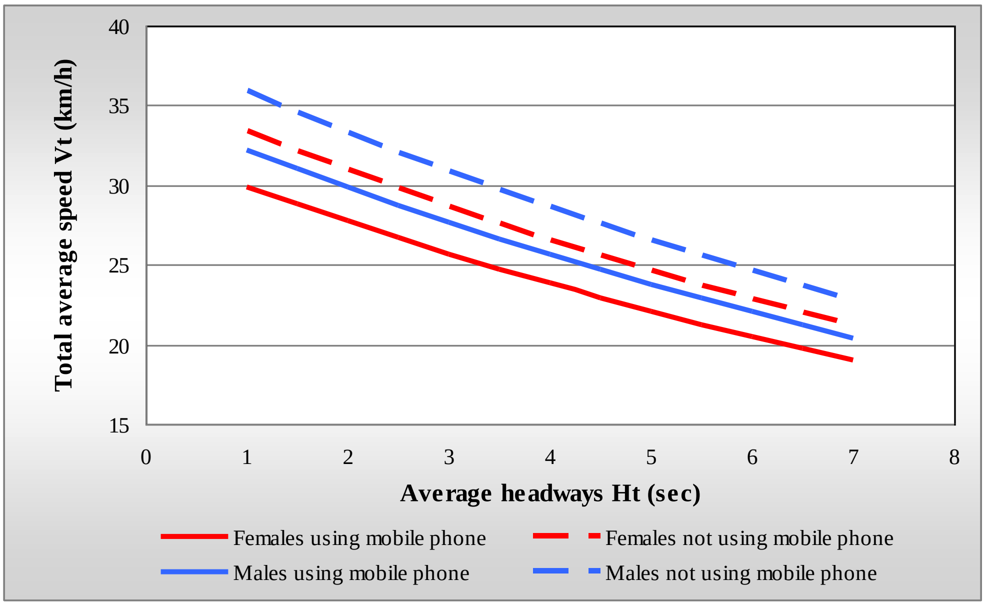

Table 1. Summary of Variables and Values

Variables	Type	Values
Total average speed (V_t)	Continuous	km / h
Free flow speed (V_f)	Continuous	km / h
Interrupted flow speed (V_i)	Continuous	km / h
Average headways (H_t)	Continuous	sec
Driver age	Discrete	0: 19-23 / 1: 24-35
Gender	Discrete	0: male / 1: female
Driving experience	Discrete	0: 0-4 years / 1: >4 years
Annual distance traveled	Discrete	0: 0-10,000 km / 1: >10,000 km
Mobile phone use	Discrete	0: no / 1: yes

Table 2. Best fitting models for vehicle speed

	Total average speed (Log V_t)		**Free flow average speed (Log V_f)**		**Interrupted flow average speed (Log V_i)**	
Variable	**β**	**t-test**	**β**	**t-test**	**β**	**t-test**
Constant	1.568	83.046	1.574	77.213	1.495	70.867
Gender	-0.032	-2.671	-0.028	-1.901	-0.050	-3.248
Annual Distance	0.020	1.861	0.032	2.295	-	-
Mobile phone use	-0.047	-3.909	-0.049	2.447	-0.063	-4.241
Average headways	-0.033	-5.123	-0.023	-3.512	-0.026	3.540
Driving experience	-	-	0.03	1.808	-	-
R^2	0.609		0.517		0.568	

Table 3. Relative variable effects on speed (elasticities)

Variable	**Total average speed (V_t)**			**Free flow average speed (V_f)**			**Interrupted flow average speed (V_i)**		
	β_i	**Relative effect**		**β_i**	**Relative effect**		**β_i**	**Relative effect**	
		e_i	**e_i^***		**e_i**	**e_i^***		**e_i**	**e_i^***
Mobile phone use	-0.047	0.017	2.46	-0.049	0.017	3.12	-0.063	0.023	1.97
Gender	-0.032	0.007	1.00	-0.028	0.005	1.00	-0.050	0.012	1.00
Driving experience	-	-	-	0.030	0.010	1.79	-	-	-
Annual distance	0.020	0.008	1.12	+0.032	0.012	2.15	-	-	-
Average headways	-0.033	0.069	10.33	-0.023	0.047	8.81	-0.026	0.059	5.08