SUPPLEMENTAL DIGITAL CONTENT: CONTROL ANALYSES

This document contains online supplemental material for the Brief Report, “Cell Phone Use and Crash Risk: Evidence for Positive Bias” in the Journal Epidemiology.

The supplemental material consists of four control analyses:

1. *Missing GPS Data.* Days in the GPS dataset had “blank” or missing data for some vehicles, and it was not possible to determine whether that meant no driving during that day or whether the GPS unit had failed for some reason for that day. To cover both possibilities, all analyses were carried out with two methods: dropping missing days from the analysis, or counting the missing days as having no driving. This control analysis showed no effect of missing GPS data on the part-time driving amounts.

2. *Reverse Day Order.* The analyses were also done in reverse day order, with day 1 of each pair acting as the test day, and day 2 as the control day. The control analysis showed virtually no effect from reversing the day order.

3. *Driving Time per Day.* The mean driving time per day was calculated across all days and compared with other instrumented vehicle studies. The driving times in this study were comparable with other studies.

4. *Weekday vs. Weekend.* Analyses were averaged across the individual days of the week, to control for the effect for example weekdays vs. weekends because of the different amounts of driving time on those days. Some slight effects were observed on consistency if one of the two paired days was a weekend, but the main results were robust to day of week.

In sum, the results and conclusions in the brief report were robust to all the controls indicated.

1. Controls for Missing GPS Data

Some vehicles had missing GPS data for one or more days, randomly interspersed. The investigators of the GPS data collection study for Puget Sound (personal communication) said they were not able to determine whether the missing data for that day meant: (1) there was no vehicle travel; or (2) the GPS unit or storage procedures had failed for some reason. Therefore, the data were analyzed in two different ways to account for both possibilities.

For each histogram for each paired day, the main analysis (as presented in the published report) used only data where there was GPS data for both of the paired days.

This control analysis treated all the missing data as zeros (assumes no travel on that day), and redid all the analyses.

What was noteworthy is that the only thing that was different in the 100 individual paired-day histograms, and therefore in the grand mean histogram (Fig. 1 in the main report), was the size of the left-most histogram bar for 0% consistency. In the grand mean control histogram, the left-most bar became 113.3 (49.4 % of the vehicles in the histogram) instead of 81.9 (36% of vehicles in the histogram) when the missing data were treated as 0 rather than dropped from the analysis. This value of about 50% is in between the 35% non-driving in control windows estimate of Redelmeier and Tibshirani,[1] and the 64% estimate in McEvoy et al.[2]

All other histogram bars (from 1-100% driving consistency) were identical, which is logical because whether a day's travel was 0 or missing could only affect the left-most bar (0% consistency). Therefore, the "grand mean part-time driving consistency" metric in the main report holds regardless of whether missing GPS data is discarded or treated as zeros.

Counting days with missing GPS data as zeros did produce slightly lower mean driving times per day as shown in Section 3 below, but again this could not affect the main metric (the mean part-time driving consistency) because that metric is based only vehicles with at least some driving in a control window.

2. Controls for Day Order

To demonstrate robustness of the metric, the entire analysis was replicated but with reversed day order. That is, Day 1 was now treated as the surrogate for the "crash" day, and Day 2 as a surrogate for the "control" day in the case-crossover studies. The crossproducts in the numerator of Eq. 1 remain the same; the only difference is in the divisor, which is Day 2 in the main study, but Day 1 here. With the reverse day order, the mean part-time driving consistency across all vehicles with 1-100% consistency in the final mean histogram (average and standard deviation across 100 histograms) was 26.3% (95% C.I. 25.0-27.7), a negligible difference from the regular day order in the main study of 26.4% (95% C.I. 25.2%-27.6%).

3. Mean Driving Time per Day

The mean driving time for the main study across all 100 control days for all vehicles with GPS data on both days was 73.4 min (95% CI 72.0 to 74.8). For the 100 test days the mean driving time was 73.1 min (95% CI 71.9 to 74.4), a negligible difference.

These mean driving times (calculated across a hundred days of GPS data) are slightly higher than the two days of GPS data analyzed in a Chicago dataset of 240 vehicles using similar methods in another study,[3] that had mean driving times of 68.1 min for day 1 and 70.8 min for day 2. However, the Chicago study driving time averages included 10 vehicles with known days of zero driving from driver interviews that were conducted in that study.

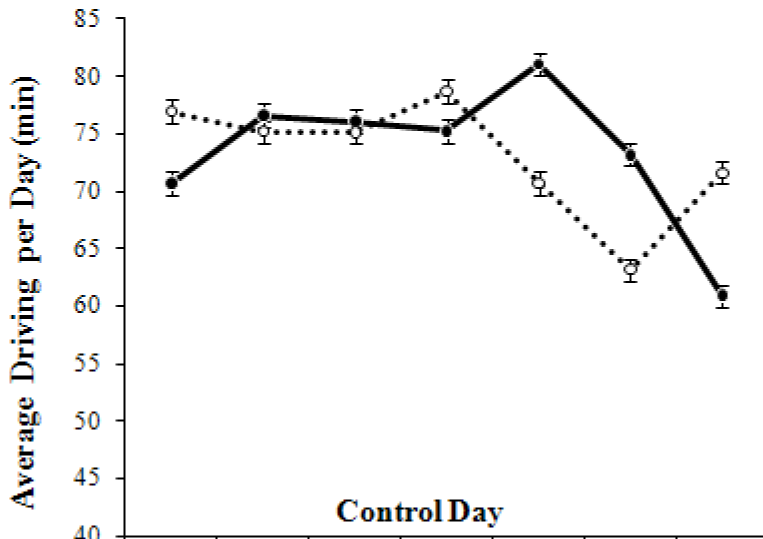
The mean driving times in the current study are slightly lower than the mean daily driving time of 84.5 minutes estimated in a study of the association between personal calls made using the OnStar hands-free calling system, and crashes severe enough to deploy an airbag.[4] The average distance estimated from the electronically reported odometer readings of 585,719 OnStar-equipped vehicles from May 2005 to May 2006 was 44.1 miles/day. This was divided by an average speed of 31.3 mph estimated from a nationwide sample of 171 instrumented GM vehicles during naturalistic driving from 1983–2009 to yield the estimated driving time of 84.5 minutes per driver, per day, about 11 minutes longer (16%) than the GPS recorded driving times of about 73 min found in the present study. The slightly lower driving time per day found with the GPS data of about 73 min per day was well within the limits of the sensitivity analysis of the relative risk vs. driving time as shown in Fig. 3 of that study.[2] The relative risk in that study would have been slightly lowered to 0.53 compared to the reported point estimate of 0.62 (CI 0.37 to 1.05) for hands-free conversation while driving if the more robust direct GPS estimate of driving time per day in the current study had been used.

The effect of driving time per day is analyzed further in the controls for day of the week in the next section.

4. Controls for Day of Week

There was a slight variation in the average driving time for weekdays vs. weekends. This driving time variation manifested itself in a slight variation in the driving consistency metric for weekdays vs. weekends.

Fig. 2 shows the variation in average driving time per day of the week for control days (solid line) and case days (dotted line) with known GPS data for the case and control days.



	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Day 1 (control)	70.7	76.6	76.1	75.3	81.1	73.2	60.9
Day 2 (case)	77.0	75.2	75.1	78.7	70.7	63.2	71.6

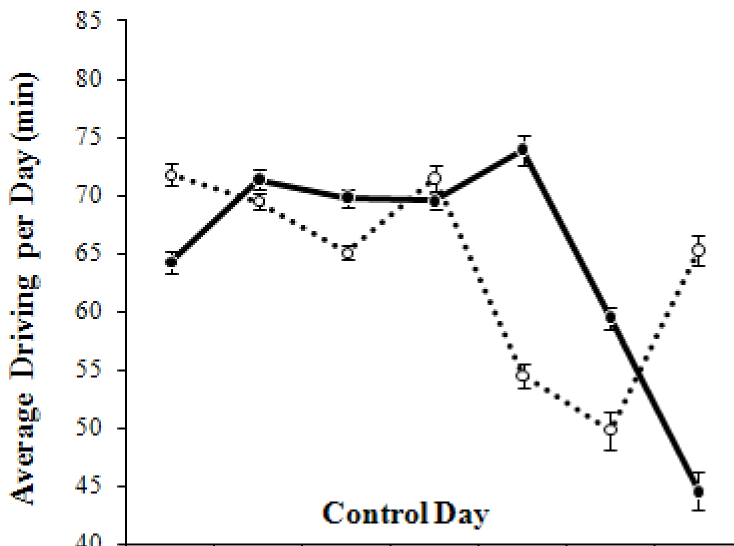
FIGURE 2. The horizontal axes are the day of the week for the control day. The vertical axes are the average driving minutes per day across all the vehicles. The solid lines are the driving minutes for the control day and the dotted lines for the case day, for days with known GPS data.

Fig. 2 shows that the average driving times for weekend days tended to be lower than weekdays, as is plausible. The weekend control days are the last two points on the solid line (marked Sat and Sun). The shortest driving time occurred on a Sunday for the control days (60.9 min) and the longest on a Friday (81.1 min).

For the case days (dotted line), the weekend days occurred when the control day was a Friday or a Saturday. The shortest driving time for the case days occurred on a Sunday (63.2 min, with a Saturday control day), and the longest driving time on a Friday (78.7 min, with a Thursday control day).

Fig. 3 gives the variation in average driving time per day of the week when missing GPS data treated as zeros (no driving). The average driving times are smaller than in Fig. 2 where missing GPS data were excluded, because days with no GPS data are counted in Fig. 3 as zero driving time for that day (see Section 1 above). The pattern of variation of the mean driving team across days of the week for control and case days is identical to Fig. 2.

Because there was no way of determining whether missing GPS data has a true zero driving time for that day, or the GPS unit had failed for some reason (see Section 1), the actual driving minutes per day are likely somewhere in between the values shown in Figs. 2 and 3.



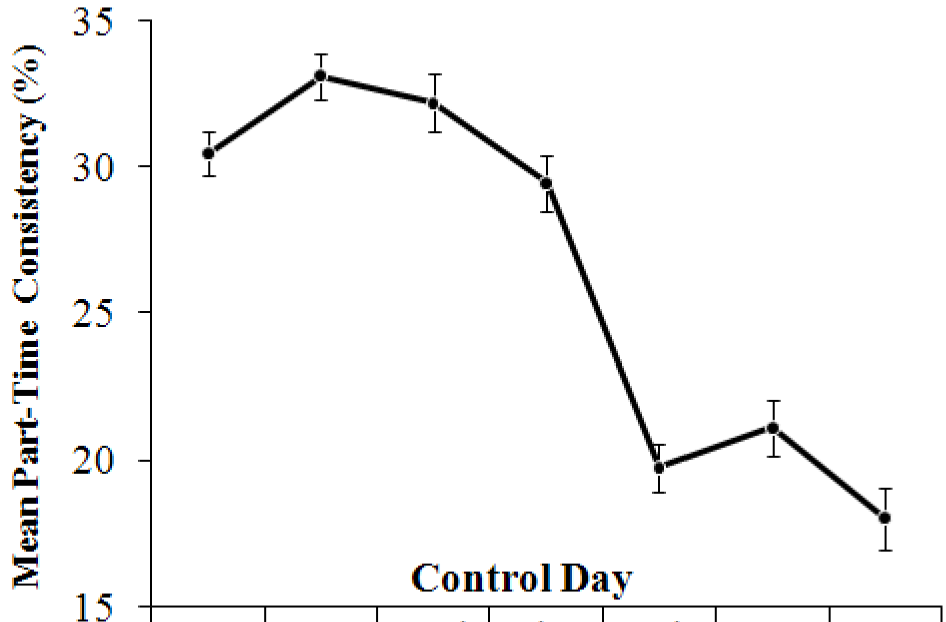
	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Day 1 (control)	64.2	71.3	69.8	69.5	73.9	59.5	44.5
Day 2 (case)	71.8	69.5	65.1	71.5	54.5	49.8	65.3

FIGURE 3. Same legend as Fig. 2 except that the driving minutes when all GPS data are missing for a day, is given a value of 0 minutes of driving on that day.

Fig. 4 shows the effect of the day of the week on the mean driving consistency. (Because these data are the means across the consistency amounts from 1% to 100% and do not include the vehicles with 0% consistency, the graph is the same whether the days with missing GPS data are dropped from the analysis or treated as zeros as per Section 1 above).

In Fig. 4, for the “Fri” control day, the case day is on a Saturday; for the “Sat” control day, the case day is on Sunday; and for the “Sun” control day, the case day is on Monday, etc. Clearly, when at least one of the days in a day-pair is on a weekend the three right-most points in Fig. 4), the mean part-time driving consistency decreases. This result suggests a positive correlation between driving consistency and the duration of driving: the more driving in a day-pair (whether on a case or control day), the greater the driving consistency. This result is intuitive if one considers that as the minutes in a day fill up with driving, it is more likely that some of those minutes will overlap with driving on another day.

Note that this variation of the mean part-time consistency with the day of the week does not affect the main results or conclusions of this report. A crash can happen on any day of the week at any time. By simply taking the average driving exposures across all days of the week, the data as analyzed correctly reflect the actual amount of driving exposure that a large cohort of drivers would face, and the amount of day-to-day consistency that they would exhibit given that amount of driving exposure.



	Mon	Tue	Wed	Thu	Fri	Sat	Sun
% Consistency	30.4	33.1	32.2	29.4	19.7	21.1	18.0

FIGURE 4. The horizontal axis is the day of the week for the control day. The vertical axis is the average part-time driving overlap across each day of the week as shown, across all vehicles. The error bars are the 95% confidence limits.

This association between driving time and consistency is illustrated in another way in Fig. 5, which plots the amount of consistency as predicted by the amount of driving on the control day (the graph is similar if the horizontal axis is made the case day instead of the control day). The symbols are assigned according to the particular paired days as shown in the legend. The day-pairs comprised of two weekdays are shown as is a weekend day.

A regression line between all the points is shown, with a correlation of 0.314, which is statistically significant (n = 100, p = 0.001). It indicates that vehicles with heavier travel on the control day tend to have a slightly higher percent consistency, as shown by the regression line.

At first glance, this correlation might be suspected of being an artifact, attributable to the difference between the weekend and weekday travel patterns rather than their durations (note that the regression line through all the 100 points almost perfectly divides the weekday vs. weekend symbols). When the data are stratified into weekday vs. weekend groups however, the correlations within each subgroup re still statistically significant. Using only data points with all weekday driving (the filled black circles), the correlation between minutes of driving on the control day and the mean part-time driving consistency is 0.319 (n = 48, p = 0.015). For data points with at least one weekend in the pair (open symbols), the correlation is 0.463 (n = 42, p = 0.002). Hence, the overall variation of the consistency amounts with minutes of driving is a result of the amounts of driving and not just different temporal patterns of driving on weekdays vs. weekends.

Because these data are the means across only the part-time consistency amounts from 1% to 100%, they do not include vehicles with 0% consistency (no overlap of control day driving with the case day driving). Hence, the graph is identical regardless of whether the days with missing GPS data are dropped from the analysis or treated as zeros, so this effect is robust with respect to missing GPS data.

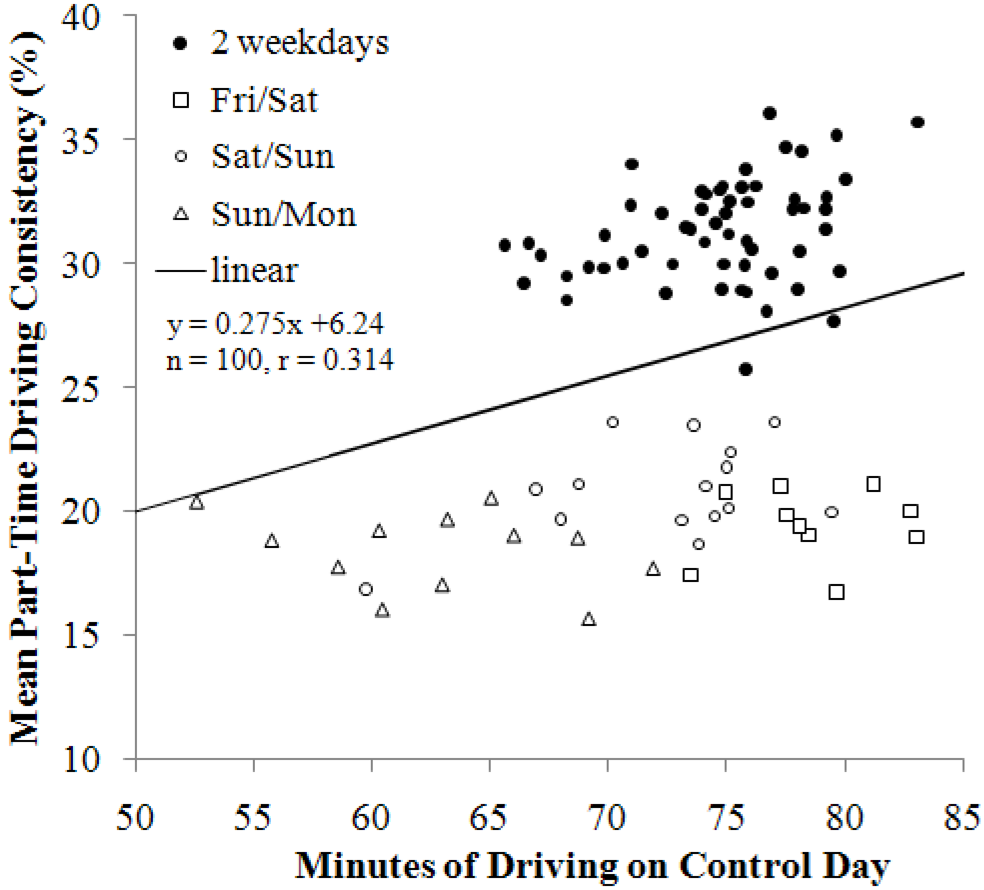


FIGURE 5. Correlation between driving consistency and minutes of driving on control day. The horizontal axis is the minutes of driving on the control day. The vertical axis is the mean part-time driving consistency. Each of the 100 points represents the mean part-time driving consistency across all vehicles with GPS data for both days of a day-pair. Day-pairs with all weekdays (Mon-Thu control days) are the solid circles; day-pairs that include at least one weekend are given by open symbols.

In short, Fig. 5 shows that there is a tendency for lower driving amounts to be associated with lower consistency. Note also that less day-to-day driving consistency lowers the relative risk estimate, due to adjustments for driving consistency bias, as shown in the main report. These two findings together logically lead to the hypothesis that relative risk after adjustment for driving consistency will tend to be lower for those drivers who have relatively smaller amounts of driving time per day (or smaller distances driven). A finding of a lower relative risk for crashes associated with cell phone use for those with lower amounts of driving distance, has been reported by Laberge-Nadeau et al.[5] in a logistic-normal regression model based on data from 1998-2000 in Quebec, Canada, consisting of 36,078 driver questionnaires, cell phone billing records, and reported crashes.

References

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