

Driving Exposure of Israeli Young Male Drivers within a Graduated Driver Licensing System

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Published in Transportation Research Part F 26, pp. 180-189, 2014

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Abstract

Young drivers in Israel, as in other parts of the world, are over-represented in car crashes. In an effort to reduce their crash involvement, a graduated driver licensing (GDL) system has been introduced, which requires all new drivers to be accompanied by an experienced driver for the first three months after obtaining a driving license. This study aims to characterize the driving patterns of young drivers in the accompanied driving period and immediately thereafter. We use information gathered from an in-vehicle data recorder (IVDR), which was installed in the primary vehicles driven by 217 young male drivers. It monitors all trips made with the vehicle and identifies the driver. We study the amount of driving young drivers undertake and the characteristics of the temporal and spatial distributions of these trips. We find substantial differences between the driving patterns characteristics in the two periods. These changes suggest an increase in exposure to risk in the solo period: The young drivers almost double the amount of driving they undertake in the solo period compared to the accompanied period. The amount of driving is highest immediately after the transition to solo driving, and gradually decreases in the weeks that follow. The timing of their driving time also changes as they drive much more during riskier conditions in the late evening and night hours and in more complex driving environments in built areas and on arterial and collector roads during the solo period. These results may be useful in that they can be used to generate realistic guidance to novice drivers and their accompanying drivers on required or suggested amounts of accompanied driving overall and in various situations. They may also suggest ways to refine the constraints imposed on novice drivers within the GDL program, such as on nighttime driving.

Keywords

Young drivers, driving patterns, in-vehicle data recorder (IVDR), graduated driver licensing (GDL), accompanied driving.

1. Introduction

Young drivers worldwide are involved in car crashes more than any other age group (Williams, 2003; ICBS, 2011). In Israel, the crash rate of drivers up to 19 years old is more than double that of drivers in any other age group (ICBS, 2012). This phenomenon has prompted implementation of graduated driver licensing (GDL) systems in many jurisdictions. GDL has been shown to be effective in reducing the involvement of young and novice drivers in car crashes. These reductions are commonly attributed to two factors (i) reduced exposure to risk during the GDL due to delayed licensing and the various restrictions on the novice driver, and (ii) improved driving knowledge, experience and skills through prolonged and more controlled licensure procedures (McKnight & Peck, 2002; Hedlund, Shults & Compton, 2003, 2006; Hedlund & Compton, 2004, OECD 2006, Musicant & Benjamini, 2012). Studies of GDL programs (Mayhew, Simpson & Pak, 2003; Baker, Chen & Li, 2006; Wiggins, 2005) showed that, within GDL programs, the crash rates of novice drivers are very low during the accompanied driving phase. Once the accompanied driving period ends and novice drivers begin their solo driving phase, crash rates increase dramatically and then gradually decrease over time.

In Israel, a GDL system was first implemented in 2000 and revised in November 2004 and again in July 2013. The data used in this study was collected in the period before the 2013 revisions. At that time, young adults could begin taking driving lessons at the age of 16.5 years. Driving lessons were given only by professional instructors and on specially equipped and marked vehicles. Learners were allowed to drive only during these driving lessons. A driving license was issued upon passing both theory and on-road driving tests. Students were required to attend a minimum of 28 on-road driving lessons and be 17 years or older before they could take the on-road driving test. Novice drivers that are under 24 years old were required to be accompanied by an experienced driver whenever they drive for the first three months after obtaining the driving license. An accompanying driver was required to be over 24 years old and hold a valid driving license for at least five years or be over 30 years old and hold a valid driving license for at least three years. In addition, for a period of two years after licensure, unless an experienced driver was present in the car, novice drivers that were under 21 years old were restricted to carry up to two passengers (excluding the driver) regardless of the passengers' age. There were no restrictions on nighttime driving. The regulations also did not impose a minimum requirement on the amount of driving during the accompanied driving phase. Another relevant regulation, in place since 2010, is that the BAC limit of 0.05% is

reduced to 0.01% for all drivers under the age of 24 years, regardless of their level of experience.

The July 2013 revision was partly motivated by results of this and other related studies which provided evidence to the large difference in crash risk between the accompanied and solo driving period, the relatively low extent of driving that takes place in the accompanied driving and the high extent of solo driving that young drivers undertake at night. The new regulations reduce the licensing age to 16 years and nine months, extend the accompanied driving period to six months for driving during nighttime (9pm to 6am), and add a formal requirement for a minimum of 50 accompanied driving hours (at least 20 in urban roads, 15 in interurban roads, 15 at night) within this period.

As part of the effort to evaluate the GDL program and to understand how it is implemented by the novice drivers, a study to characterize the driving exposure of young drivers during the accompanied driving period and immediately thereafter was undertaken. Crash rates of young male drivers are nearly triple that of young females (ICBS, 2012). Therefore, the study focused on male drivers only. In-vehicle data recorders (IVDR) were used to collect information on the vehicle use patterns. IVDRs are on-board devices that record information about the movement of the vehicle using a set of accelerometers and a GPS device (Correia, Iliadis, McCarron & Smlej, 2001). For the purposes of this study, the IVDR data enables us to detect the time, start and end points of trips, the routes taken and to identify the driver. Further details on the specific IVDR system used in this study can be found in Toledo, Musicant & Lotan (2008). This paper reports on the results of analysis of this data to study the following questions:

1. How much driving in terms of time and distance do novice male drivers undertake in the accompanied and solo periods and what are the distributions of these values among drivers?
2. What are the temporal distributions of the driving within the day, among the days of the week and as a function of the time that elapses from licensure in the accompanied and solo driving periods?
3. What are the distributions of the driving among built and non-built areas and among various types of roads in the accompanied and solo driving periods?

The responses to these questions may be useful in several ways. The revised Israeli program and some jurisdictions elsewhere mandate that the amount of supervised driving practice,

and in some cases driving under specific conditions (e.g. nighttime, urban or non-urban roads), be reported and certified as a condition for the completion of the accompanied driving period (Scott-Parker, Watson, King & Hyde, 2012). Earlier research yielded inconclusive results regarding the impact of the amount of supervised driving experience on the crash risk for novice drivers within the GDL program (Simons-Morton et al., 2011). Regardless of its impact, knowledge of the amounts of supervised driving is useful for the design of related mandates within GDL programs. The spatial characteristics of the driving novice drivers undertake may be useful to help understand the environments and situations they will be exposed to in their solo driving. This can help design training and accompanied driving requirements that would allow the novice drivers to gain driving experience and become familiar with these environments.

2. Methods

An In-vehicle data recorder (IVDR) was installed in the primary vehicle driven by the young driver in families that participated in the experiment. The installation was performed, in most cases, shortly before the young drivers received their driving licenses. The system recorded the start and end times of all trips made with the vehicle. A special reader installed in the vehicle identified the driver by reading personal magnetic (Dallas) keys.

Participating families were recruited using media advertisements, through driving instructors, in a dedicated web site and by direct contact over the phone. The recruitment took place in a rolling fashion between July 2009 and November 2011. A preliminary screening of candidates to participate in the experiment was made to only retain male driving students or newly licensed young drivers with driving experience of up to 1.5 months from licensure. Candidates who expressed interest to participate in the study and passed the preliminary screening were asked to fill a web-based questionnaire that solicited information on further eligibility criteria: Drivers with untreated ADHD and families with no access to the internet were not eligible. Only families in which the young male drivers were expected to undertake all their driving (both accompanied and independent) in a single vehicle, and that this vehicle was also the main vehicle used by the principal accompanying person were recruited. Practically, this meant that the vehicle was either the only one in the household or the only one that the young male driver was insured to use.

In total 6290 candidates were contacted. After the preliminary screening 2380 were asked to fill the web-based questionnaire, and 872 actually did. The initial sample included 242 families with one equipped vehicle each. 25 families (10.3%) dropped out for various reasons, such as lack of cooperation, failure to pass the driving test, technical difficulties with the equipment, and sale or replacement of the vehicle. The final sample included 217 families. The start time of the participation, and the duration of the data collection period varied by family due to difficulties anticipate the date of licensure, to contact families ahead of licensure or to coordinate the installation. 108 families (50%) started collecting data within the first month after licensure, 75 families (35%) within the second month, and 32 families (15%) within the third month. On average, data was collected for 321 days within the first year for each family. 109 families (50%) provided data for over eleven months, 70 families (32%) for ten to eleven months, 23 families (11%) for nine to ten months, and the remaining 15 families (7%) for period between four and nine month. The average age at the time of licensure was 17 years and 6 months, with the youngest being 17 years old and the oldest 23 years old. 137 (63%) of the drivers were under 17 years and 6 months, 72 (33%) between 17 years and 6 months and 18 years and 6 months, and the remaining 8 (4%) over 18 years and 6 months old.

The data collection itself took place over a period covering the first year after licensure for each driver: the accompanied driving period and the first nine months of the solo driving period. Within the accompanied driving period, in 104 (48%) families both parents took part in accompanying the young driver. In 63 (29%) families only the father and in 48 (22%) only the mother accompanied the young driver. In the remaining 2 (1%) families someone else accompanied the driver. The resulting dataset covers 45,276 driving hours within 144,300 trips.

The analysis of these data focused on the amount of driving in the accompanied driving period and the solo period that followed and on the temporal and spatial characteristics of the driving. Specifically, the total number of trips and driving time in the two periods and their fractions at nighttime and weekends were compared. The distributions of these variables in the sample were also calculated. The temporal analysis examined the differences in the fraction of driving time between the accompanied and solo driving periods in the dimensions of their distribution along the time of day, weekdays, and over the weeks since licensure. The fractions of driving in the various time intervals (within days and within the week) always sum up to a unit. This type of data is referred to as allocation observations or

compositional data. Shaffer (1981) and Greer and Dunlap (1997) show that this type of data can be treated using repeated measures analysis, which deals with response outcomes measured on the same experimental unit at different times or under different conditions. In the current experiment, the repeated measures are in two dimensions: drivers were observed in two time periods: the accompanied and solo driving periods and in their allocation of driving among the various intervals. For the purpose of this analysis days were defined from 6AM to 6AM on the next day. It should also be noted that in Israel the weekend comprises of Fridays and Saturdays.

The spatial analysis examined the distributions of driving in terms of the surrounding environments between built and non-built areas, and among the various road classes (freeways, arterials, collectors, local roads). These present different driving situations and difficulties to the drivers. Built and non-built areas were defined using information from a GIS database on polygons that bound built areas. The distances traveled within built environments were measured through the spatial overlap between these polygons and the polylines defining the routes of the various trips. The GIS database also provided the base for the definitions of road classes. These are based on the functionality of various road segments:

1. Freeways provide largely uninterrupted travel between and through metropolitan areas. They are designed for high speeds and support large traffic volumes.
2. Arterials and freeways that include some at-grade intersections support large traffic volumes at high speeds.
3. Collectors provide moderate speeds and volumes. They roads commonly connect between arterials and collect traffic from local roads.
4. Local roads include streets and rural roads that have the lowest speed limits and carry low traffic.

The environments and road types that drivers drive on depend also on the type of community they live in. For example, it is plausible that drivers that reside in urban areas are more likely to encounter driving in built areas compared to drivers that reside in rural areas. To account for this, the spatial analysis differentiates between three classes of home locations based on the population density (residents per squared kilometer) in the community: Rural (1000 or less residents per squared kilometer), suburban (1001 to 3300 residents per squared kilometer) and urban (over 3300 residents per squared kilometer). The repeated measures analysis was also used in this context.

The analysis was conducted using SPSS 18 (SPSS 2009).

3. Results

3.1 Amount of Driving

Table 1 presents statistics for the amount of driving in the accompanied driving period and solo driving periods. The table shows a sharp increase from the accompanied period to the solo period in the mean weekly amount of driving time from 2.47 hours to 4.31 hours (74% increase) and in the mean weekly number of trips from 6.91 to 14.02 (103% increase). The larger increase in terms of the numbers of trips drivers undertake is because, on average, the novice drivers take shorter trips in this period. Both the increases in driving time and numbers of trips are statistically significant ($t(206)=9.893$, $p<0.001$; $t(204)=11.741$, $p<0.001$, respectively). These increases were observed not only with the means but also with the other statistics reported in the table.

Table 1: Driving time and weekly number of trips

Statistic	Amount of driving time (hours/week)		Number of Trips (trips/week)		Average trip duration (minutes)	
	Accompanied	Solo	Accompanied	Solo	Accompanied	Solo
Mean	2.47	4.31	6.91	14.02	22.11	19.36
Median	2.04	3.61	5.47	11.89	21.23	18.78
Minimum	0.05	0.00	0.13	0.61	7.64	9.77
Maximum	18.73	19.42	43.11	73.39	52.41	42.30
Standard deviation	2.27	3.05	6.36	9.70	6.76	4.79

Figure 1 presents the distribution of the weekly driving time in the sample in the accompanied and solo driving periods. It can be seen that the fractions of young drivers in the ranges up to three hours per week were higher in the accompanied driving period compared to the solo driving period. This result was reversed in the ranges with higher weekly driving time, in which the fractions of drivers were higher in the solo driving period. The correlation

between the driving time that drivers took in the accompanied and solo periods is 0.490 ($p < 0.001$ $N = 206$).

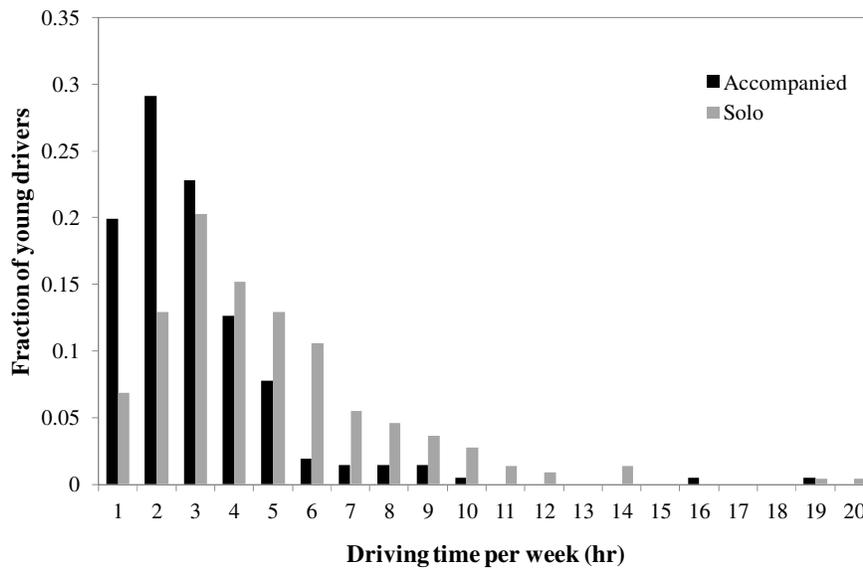


Figure 1: Distribution of weekly driving time among young drivers

Figure 2 presents the distribution of the distances traveled in trips taken by the novice drivers. The fraction of trips that are shorter, less than 10 kilometers, was higher in the solo period compared to the accompanied period.

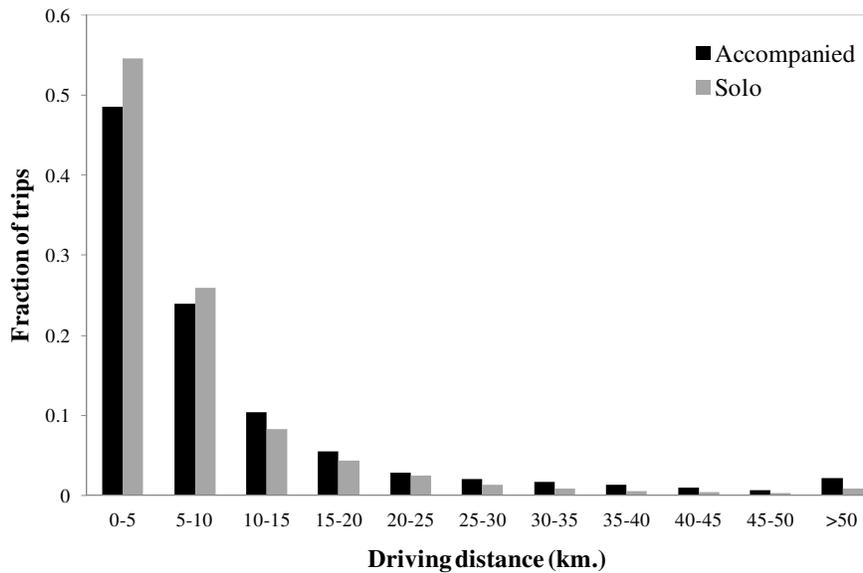


Figure 2: Distribution of the trip driving distance

Table 2 presents the mean and standard deviations of the driving time and numbers of trips in the accompanied and the solo driving periods in total and during nighttime and weekends. The p-values refer to paired t-tests for the equality of means between the two periods. As shown earlier, the total driving time (hours/week/driver) and total number of trips (trips/week/driver) are significantly higher in the solo period compared to the accompanied period. The increase in nighttime driving that the young drivers undertake is even more drastic when they start the solo driving. The percentage of nighttime driving increases by 185% when measured by driving time and 196% when measured by the number of night trips. Both are statistically significant ($t(214)=4.837$, $p<0.0001$; $t(214)=18.818$; $p<0.0001$, respectively). In contrast, the share of driving time and number of trips during the weekend was almost similar in the two periods and no significant differences were found ($t(214)=0.199$, $p=0.842$; $t(214)=1.623$ $p=0.106$, respectively).

Table 2: Amount of driving and percentages for different periods of time

Statistic		Accompanied		Solo		p-value
		Mean	SD	Mean	SD	
Driving Time	Total (hr./week/driver)	2.47	2.27	4.31	3.05	<0.0001
	% night driving (10PM – 6AM)	9.2	8.7	26.3	13.0	<0.0001
	% weekend driving (Fridays-Saturdays)	33.1	18.3	33.1	12.1	0.842
Number of Trips	Total (trips/week/driver)	6.91	6.36	14.02	9.70	<0.0001
	% night trips (10PM – 6PM)	9.4	8.5	27.8	13.2	<0.0001
	% weekend trips (Fridays - Saturdays)	30.9	16.7	32.9	11.8	0.106

3.2 Temporal characteristics

Distribution over the day

Figure 3 shows the distribution of the driving time during the day in the accompanied and solo periods. The peak driving period during the day occurs between 6-9PM during both the accompanied and solo driving periods. However, while in the accompanied driving period this is a clear peak and constitutes 24% of the driving time, the peak is flatter in the solo

driving period, with almost constant driving time from 3PM to midnight. Furthermore, once young drivers start their solo driving their driving hours shift to later in the evening and night hours (9PM – 3AM). About 30% of the driving time takes place in these hours during the solo driving period, compared to only 15% during the accompanied driving period. A repeated measures analysis was conducted in order to assess the differences between the fractions of driving time during the various periods of the day in the accompanied and solo driving periods. The interactions of the time of day periods and the licensing period were statistically significant ($F(7,198)=49.564, p<0.0001$). The fractions of driving were higher in the solo period in the nighttime (9PM – 6AM) and lower in all other time periods (6AM – 9PM). The differences between the two driving periods were statistically significant at the 95% confidence level in all time periods except Noon – 3PM.

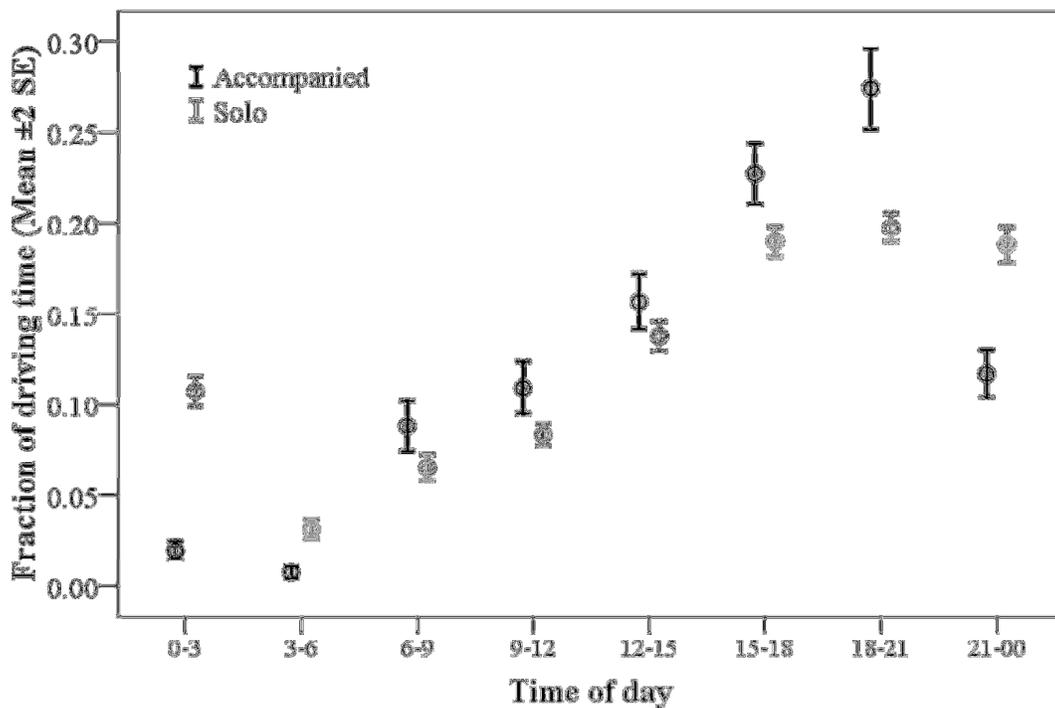


Figure 3: Distribution of driving times over the day

Distribution over the week

Figure 4 presents the distribution of the driving time over the days of the week in the accompanied and solo driving periods. The figure shows similar distributions for the accompanied and solo driving periods. The driving times split pretty much evenly among the weekdays and are higher during the weekend, and to some extent, especially in the solo driving period, on Thursdays. A repeated measure analysis did not find statistically

significant differences ($F(6,1224)=0.827, p=0.538$) in the fractions of driving time during the various days of the week between the accompanied and solo driving periods.

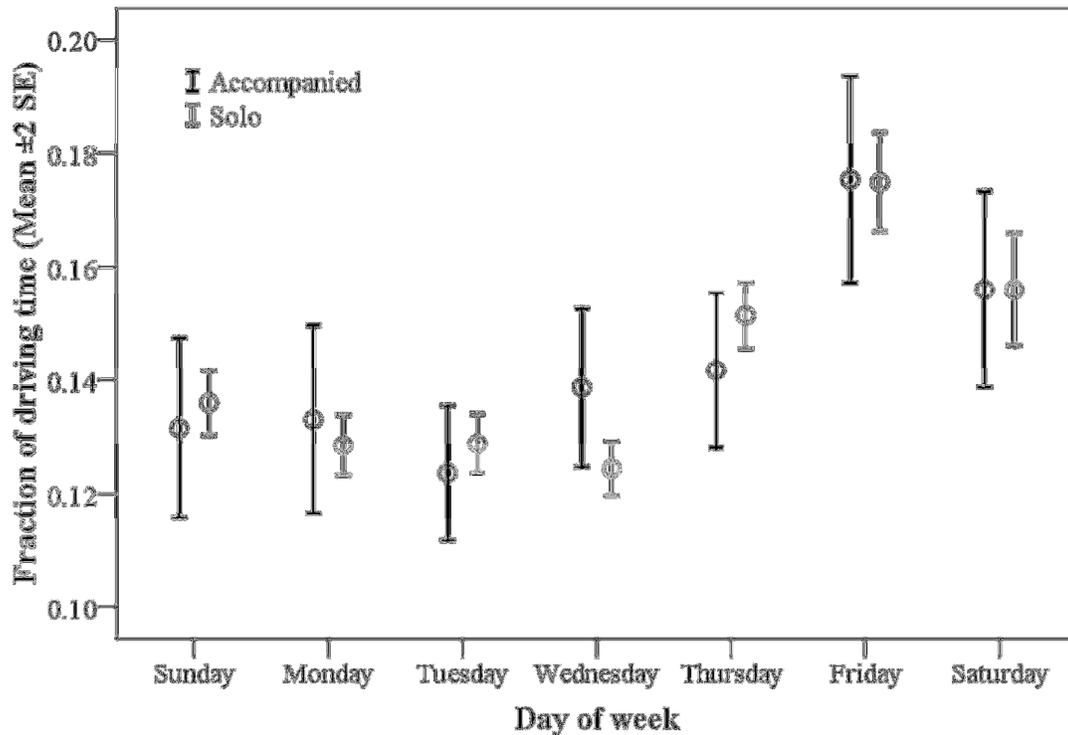


Figure 4: Distribution of driving times over the week

Distribution over the weeks from licensure

Figure 5 and Figure 6 show the distributions of number of trips and driving time, respectively, over a period of 44 weeks (10 months): the last 9 weeks (2 months) of the accompanied driving period and the first 35 weeks of the solo driving period. We did not include the initial three weeks of the accompanied period in the figures as the sample sizes for these weeks were smaller compared to later weeks due to the recruiting process (as described in section 2 above). Week 0 marks the beginning of the solo driving period. The two figures show the sharp increase in the amount of driving, both in terms of number of trips and time duration, after the transition to solo driving. Within the accompanied driving period, there is a gradual increase over time in the number of trips and the driving times observed. The amount of driving in the last week of the accompanied driving period is almost double that of the first week that was observed (week -9). Within the solo period, the largest amount of driving takes place immediately after the period has started and gradually decreases in later weeks. This may reflect the initial enthusiasm over the new independence the driver has obtained.

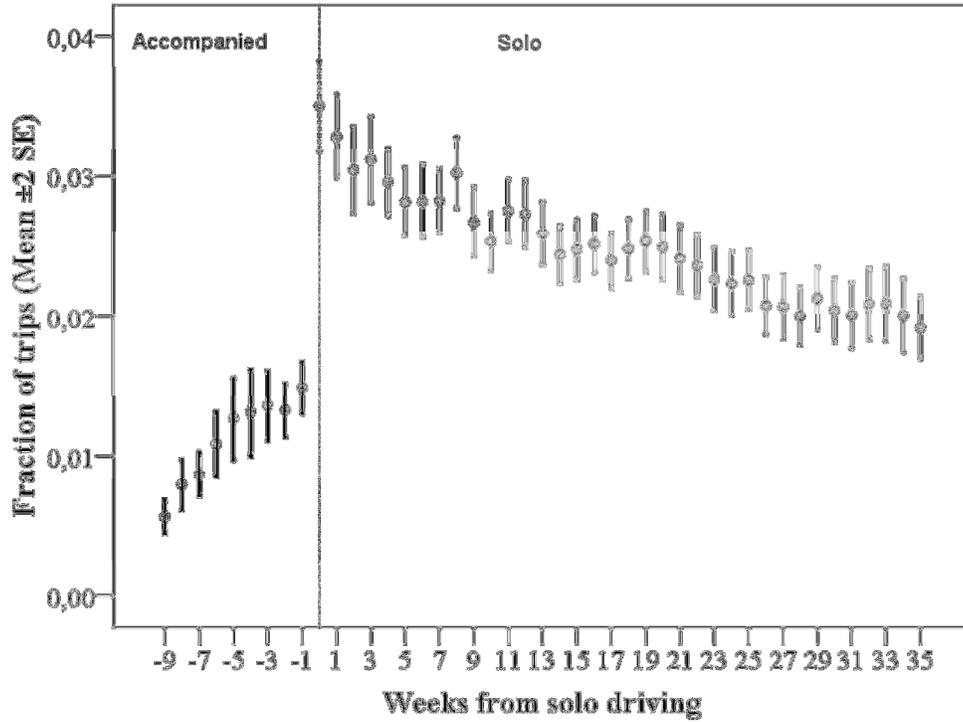


Figure 5: Fractions of trips over the weeks since licensure

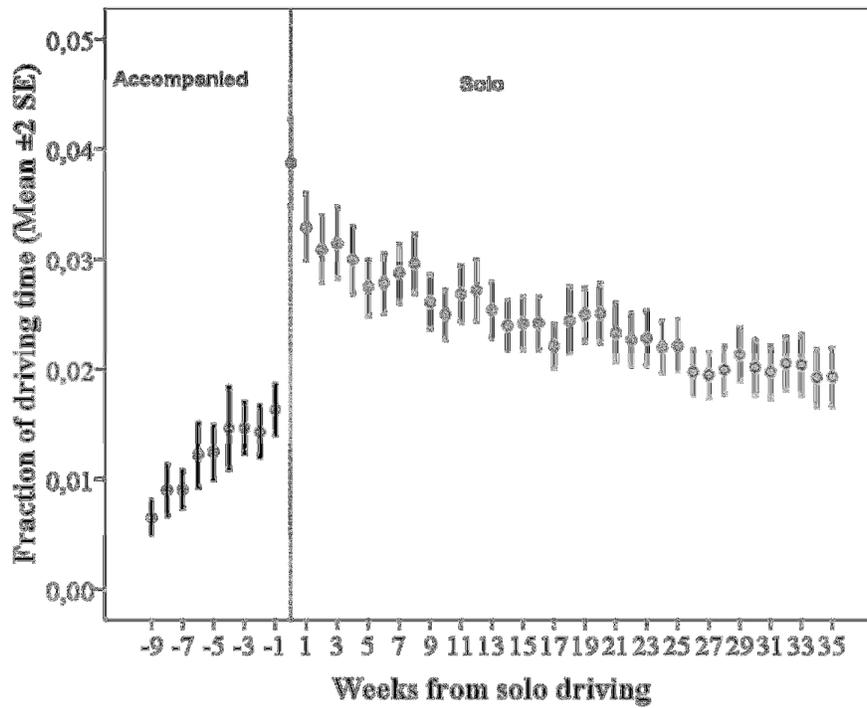


Figure 6: Fraction of driving times over the weeks since licensure

3.3 Spatial characteristics

The results are shown in Figure 7. Overall, over 80% of the driving distance takes place in built areas. As expected, this fraction is highest in urban communities and lowest in rural communities. A repeated measures analysis, taking into account the home location type as a confounding variable, showed that the impact of the home location on the fraction of distance traveled in built and non-built areas is significant ($F(2,190)=33.559$, $p<0.001$). In all the three home location types, the fraction of distance traveled in built areas is higher in the solo period compared to the accompanied period. A repeated measure analysis showed that, overall, both the effect of the time period and the interaction of the time period and the residence type are significant ($F(1, 190)=23.521$, $p<0.001$, and $F(2, 190)=3.037$, $p=0.050$, respectively).

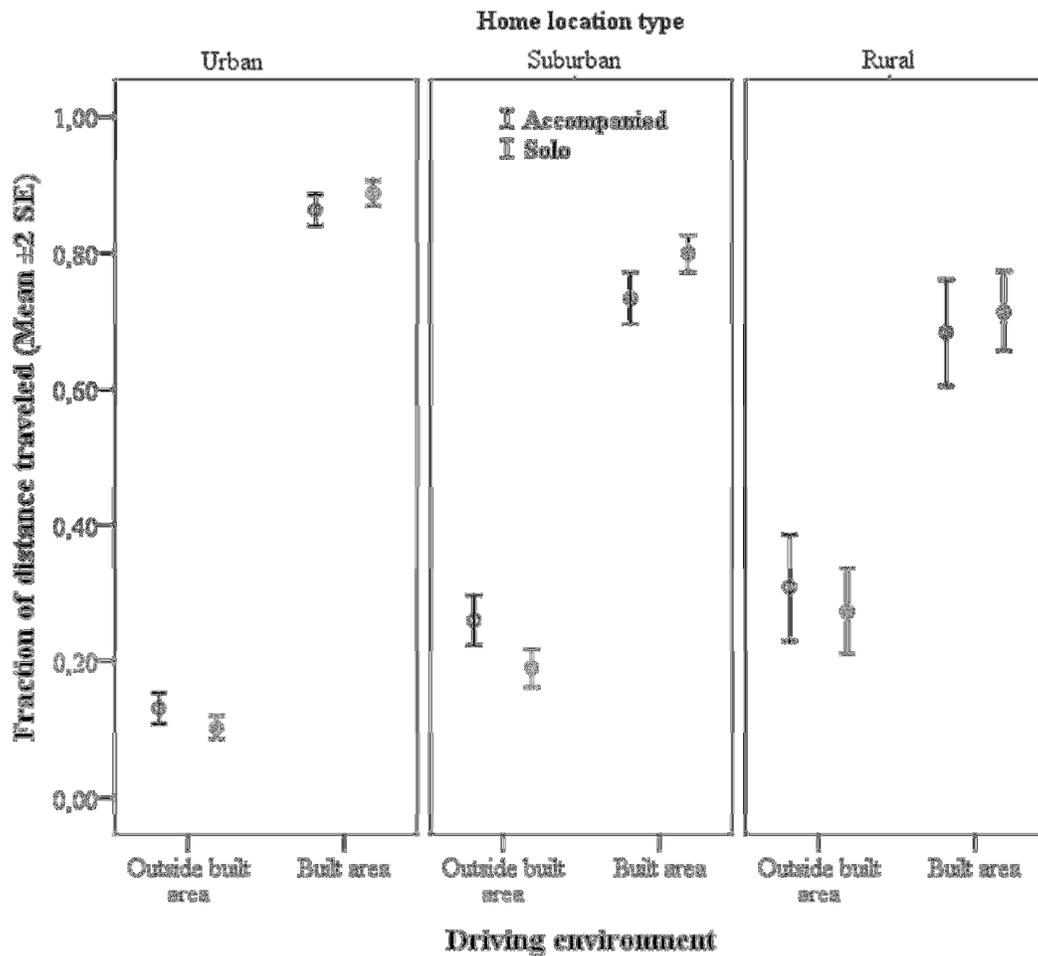


Figure 7: Distribution of distance traveled between built and non-built areas by home location type

Error! Reference source not found. presents the distribution of the driving distance among the four road classes by home location type. Overall, the exposure of the novice young drivers to different classes of roads changes between the accompanied and the solo driving periods. Drivers undertake more of their driving on arterials and collectors in the solo period compared to the accompanied period, and less on local roads. A repeated measures analysis showed that the overall effect is statistically significant ($F(3,564)=13.034, p<0.001$).

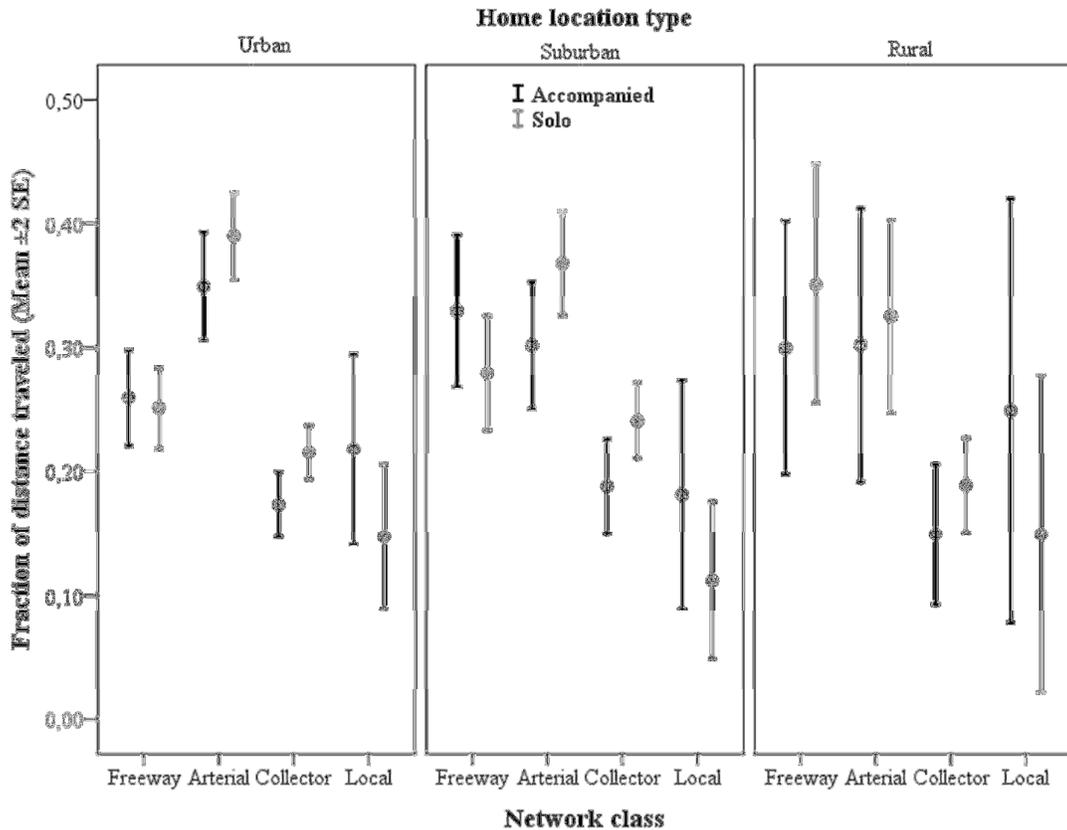


Figure 8: Distribution of distance traveled among road classes by home location type

Discussion & Conclusions

Analysis of the IVDR data indicates significant differences between the behavior of young drivers in the accompanied and the solo driving periods in terms of the amount and temporal characteristics of the trips they make. Young drivers roughly double the amount of driving they undertake in the solo period compared to the accompanied period. The amount of driving is highest immediately after the transition to solo driving, and gradually decreases in the weeks that follow. On average, the young drivers drive a total of 32 hours during the

accompanied period. This significantly raises their experience level of young drivers, as they may be able to obtain their driving license with as little as 28 hours of driving instruction. Nevertheless, the driving experience young drivers have accumulated by the end of the accompanied driving period still falls short of desired values required by the new Israeli rules and recommended by jurisdictions in other countries: Most US jurisdictions require 50 hours, whereas Victoria, Australia requires 120 hours (e.g. NSW, 2011; NHTSA, 2012). The correlation between the driving times in the accompanied and solo period did not show a very strong link between the extents of driving that takes place in the two periods. Thus, there are some young drivers who drive very little during the three months accompanied period, and so gain very little experience before the solo driving period. The extreme case in the sample was a driver that drove only 0.6 hr/week in the accompanied period, but 9.8 hr/week in the solo period.

The most striking difference between the characteristics of the driving in the two periods is that the young drivers get little experience in night driving during the accompanied period, but drive much more during late evening and night hours in the solo period. This effect is amplified by the sharp increase in the total driving time from the accompanied driving to the solo period. Thus, young drivers who have gained little experience in night driving during the accompanied driving period undertake significant night driving once they are in the solo period (an average of 1.3 hours per week). This result may be affected by the daily activity patterns of the young drivers. It should also be noted that the young participants in this study did not own their vehicles, but drove the family vehicle. Thus, the availability of the vehicle to them was also affected by the activities of other members of the family. The activity patterns of both the young drivers and the accompanying parents may also be underlying the higher fractions of weekend driving compared to weekdays in both the accompanied and solo period. The increase in the fraction of driving on Thursdays (which in Israel marks the end of the working week) in the solo driving period may also be related to the activity patterns of the young drivers and to higher availability of the family vehicle to them at this time.

The young drivers also drive more of their time in built areas and on arterial and collector roads during the solo period. All these differences are statistically significant, and in some cases very substantial. These results indicate that the exposure to risk increases substantially in the solo period both in terms of extent of driving and in that the young drivers drive in riskier conditions during nights and in more complex driving environments in built areas and on arterial and collector roads.

The recent changes to the Israeli licensing system that were described earlier attempt to mitigate this issue: The requirement for nighttime accompanied driving has been extended from three to six months and a formal requirement for a minimum amount of nighttime accompanied driving was added. Formal requirements for a minimum total accompanied driving hours, and specifically in urban and interurban roads were also established in order to guide novice drivers and their accompanying drivers. The expectation that these measures will result in lower crash rates by young drivers is supported by Ehsani et al. (2013) who studied the effects of similar measures taken in various US jurisdictions. Specifically, they found that both extending the accompanied period and establishing minimum driving requirements contributed to lower crash rates. We hope to repeat the current study in future research to evaluate the effect of the changes in the licensing system on the exposure of the young drivers. The present study demonstrates the capability of IVDR systems to collect detailed and objective data on driving exposure.

Previous exposure studies (e.g. Ehsani et al. 2010) used travel diaries or self-reports, which may be subject to substantial biases in the reporting, for example due to forgetting. In the past, the costs associated with IVDR data collection dictated use of small samples over relatively short periods of time. As the technologies mature and become cheaper, conducting large scale data collection efforts at a reasonable cost is increasingly feasible. Still, the use of technology for data collection is not without limitations. In the current study, all the data was collected automatically without communication with the drivers. This greatly simplifies the data collection process. However, as a result, the data does not include any information on driving that the young driver undertook in other vehicles. Erroneous or missing driver identification may also negatively affect the accuracy of the data. Other data items that may be of interest, such as the identity of the accompanying driver, presence of passengers in the vehicle and trip purposes, also could not be collected in this mode. One way to extend the data items that may be collected is to add sensors to the data collection system. For example, an in-cab camera can be used to detect the driver and presence of passengers or a cellphone detector may be used to identify use patterns within the car. This approach results in expensive and more intrusive systems. The data collected also requires substantial data processing. This approach is adopted in the 100-vehicle naturalistic study (Dingus et al. 2006) and similar other studies. Another way to overcome these limitations, but keep the system simple and relatively cheap, is to base the data collection on a combination of the objective IVDR-based data collection of the location and temporal variables with web-based

or other interfaces that will be used to solicit the additional information that the system cannot collect. This way, the technology collects objective and reliable data, helps keep the effort required from participants low, and frees their time to provide other data items.

Another limitation is that the sample used in the study may not be representative of young male drivers' population in Israel. It is likely that it is biased towards self-selection of families with high awareness and willingness to participate. Therefore, a future challenge is to convince families with lower awareness for safety to participate in this type of activities.

Acknowledgement

We thank two anonymous referees for valuable comments. This research was sponsored by the Research Fund of Israel Insurance Association.

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