Modeling the behavior of novice young drivers during the first year after licensure

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Abstract

Novice young drivers suffer from increased crash risk that translates into over-representation in road injuries. In order to effectively confront this problem, a better understanding of the driving behavior of novice young drivers and of its determinants is needed. This study analyzes the behavior of novice young drivers within a Graduated Driver Licensing (GDL) program. Data on driving behavior of 62 novice drivers and their parents, who voluntarily participated in this experiment, were collected using in-vehicle data recorders that calculate compound risk indices as measures of the risk taking behavior of drivers. Data were used to estimate a negative binomial model to identify major determinants that affect the driving behavior of young drivers during the first year after licensure. Estimation results suggest that the risk taking behavior of young drivers is influenced by gender, sensation seeking tendency, driving behavior of their parents, amount of supervised driving and level of parental monitoring.

Keywords: Novice young drivers; Graduated Driver Licensing; In-vehicle data recorders; Sensation seeking; Negative binomial model.

1. Introduction

Novice young drivers are over-represented in road crashes and injuries, in particular during their first year of unsupervised driving (Preusser and Leaf, 2003; Williams, 2003). Several individual- and context-related factors contribute to their high crash risk. From the individual-related perspective, relevant factors include gender, as males tend to take more driving risks than females (e.g., Glendon et al., 1996; Harrè et al., 1996; Laapotti and Keskinen, 2004), personality traits, such as sensation seeking and need for control (e.g., Jonah, 1997; Taubman - Ben-Ari et al., 2004), cognitive aspects, such as a lower ability to assess driving hazards than older drivers and a higher tendency to perceive their crash risk as low (Ferguson, 2003), immaturity and driving inexperience (Williams, 2007). From the context-related perspective, relevant factors include night-time driving (Williams, 2007), low compliance with seat-belt laws (e.g., Goodwin et al., 2006; Williams, 2007), speeding (McKnight and McKnight, 2000), large cell-phone use (Foss et al., 2009; Williams, 2007), and familial or social reckless models that encourage risk taking while driving (Taubman – Ben-Ari, 2008; Taubman – Ben-Ari et al., 2004).

The dilemma surrounding novice drivers is that they need to increase their driving experience to reduce the risk of crash involvement, but the more they drive, the more they are exposed to high risks. To tackle this problem, several jurisdictions worldwide have introduced Graduated Driver Licensing (GDL) programs. These programs are designed to allow novice young drivers to obtain as much practical driving experience in real-world conditions as possible and, at the same time, to limit their exposure to high-risk situations by requiring supervision of adult drivers and limiting driving in certain situations (e.g., night-time, presence of young passengers).

In recent years, several studies analyzed the effectiveness of GDL programs in reducing novice drivers' crash rates at both the single- (e.g., Foss et al., 2001; Hallmark et al., 2008;

Hyde et al., 2005; Shope and Molnar, 2004) and the multi-jurisdictional level (e.g., Chen et al., 2006; Dee et al., 2005; Morrisey et al., 2006; Williams et al., 2005). These studies reported significant reductions in traffic fatalities or fatal crash involvement as a result of the implementation of GDL programs, and emphasized that higher effectiveness is related to higher stringency of the programs in terms of length of the supervised driving periods, constraints to night-time driving and limitations to the number of young passengers.

In addition, several studies focused on specific aspects that relate to the effectiveness of GDL programs. From the perspective of the imposed restrictions, researchers examined the impact of requirements regarding seat-belt use among drivers and passengers (e.g., Briggs et al., 2008; Goodwin and Foss, 2004; Goodwin et al., 2006), restrictions on the number of passengers to reduce the effect of social pressure from peers (e.g., Lee and Abdel-Aty, 2008; Neyens and Boyle, 2008; Preusser et al., 1998; Simons-Morton et al., 2005), night-time driving constraints to limit the exposure to the most risky conditions (e.g., Lin and Fearn, 2003; Morrisey et al., 2006; Simons-Morton and Hartos, 2003), and restrictions on cell-phone use (e.g., Foss et al., 2009; Neyens and Boyle, 2008). From the perspective of the involvement of parents in the education and the supervision of young drivers, researchers examined the importance of parental monitoring during teen driver licensing (e.g., Beck et al., 2002; Hartos et al., 2000; Simons-Morton et al., 2008; Wilson et al., 2006), motivational strategies to persuade parents to restrict novice teen driving in order to limit their exposure to risk (e.g., Simons-Morton et al., 2002; Simons-Morton et al., 2006), and relations among the driving styles of parents and offspring (e.g., Bianchi and Summala, 2004; Ferguson et al., 1996; Prato et al., 2009; Taubman - Ben-Ari et al., 2005).

These studies provide evidence that GDL programs create a relatively safe real-world learning environment. However, it is not clear what occurs during the initial months of driving to bring young drivers' crash rates down fairly dramatically (Foss, 2007). Also, these

studies often use traditional data collected through telephone interviews, self-reported questionnaires or access to driving records. However, driving records often contain incomplete or inaccurate information and do not account for differences in exposure (Ferguson et al., 1996), while self-reports are generally affected by biases of self-enhancement and social desirability (Taubman – Ben-Ari et al., 2005). More reliable data are necessary to assess driving styles and behaviors (Taubman – Ben-Ari et al., 2005).

This paper investigates the behavior of novice young drivers during the initial twelve months after licensure. This period includes the two initial phases within the Israeli GDL program. According to this program, which was enforced in 2000, teenagers are allowed to start taking on-road driving lessons with professional instructors at the age of 16.5 years. These lessons take place in specially marked vehicles that are equipped with a second set of control pedals for the instructor. The teenagers are not considered licensed at this stage, are not allowed to drive outside these lessons, and are licensed only after passing both theoretical and on-road driving tests. The theoretical test must be passed before the on-road test can be taken, but it is not needed in order to undertake the on-road driving lessons. The road test can be taken at the minimum age of 17 years and after undergoing at least 28 driving lessons. For the first three months after licensure, referred to as the accompanied driving period, the novice drivers are required to be accompanied whenever they drive by an experienced driver, who is at least 24 years old and holds a valid driving license for at least five years. In the following period, up to two years after licensure, referred to as the solo driving period, the novice drivers are allowed to take up to two passengers unless an experienced driver is present in the vehicle (for further details, see Lotan and Toledo, 2007).

The data used in the study include natural observations that were collected through in-vehicle data recorders (IVDR). The IVDR were installed in vehicles driven by novice young drivers and their family members. They continuously measured speeds and accelerations and

consequently processed these data to identify various driving maneuvers undertaken by the vehicle and to assess their severity. The identified driving maneuvers were then combined to calculate risk indices for each driver. These risk indices have been shown to have significant positive correlation with drivers' crash records (Toledo et al., 2008).

The current study investigates various factors that affect the risk taking behavior of novice young drivers, as indicated by the risk indices. The investigated factors include gender, the impact of parents through both their own driving behavior and the monitoring of their offspring's driving performance, the role of driving experience during the accompanied and solo periods and in night-time conditions, and the impact of personality traits, in particular the sensation seeking inclination. Sensation seekers tend to underestimate the likelihood of negative consequences from hazardous behavior and the threat to their own life when compared to other individuals (Weinstein, 1980; Zuckerman, 1994). Sensation seeking behavior has been shown to be positively correlated with reckless driving, car crashes, and traffic violations (e.g., Jonah, 1997; Taubman - Ben-Ari et al., 2004).

The remainder of the paper is structured as follows. Section 2 describes the participants in the study, the data collection process and the methods applied to measure and model the behavior of novice young drivers. Section 3 presents the results of a negative binomial model that uses the aforementioned factors to explain the risk indices observed for the young drivers over time. Section 4 summarizes the major findings of this study.

2. Methods

2.1. Participants

Participants in this study were selected from volunteer families of newly licensed drivers. Families were recruited by direct contact through licensing agencies, professional driving schools and advertisements in a dedicated web-site. The initial screening of the families verified that most or all the trips of the newly licensed driver would be on the vehicle

where the IVDR was installed, and that this vehicle was the main vehicle also used by the accompanying persons.

The sample used in this study consists of 62 families with novice young drivers. As this study aims to examine the behavior of novice young drivers over time and to draw conclusion on reliable data, the study sample contains young drivers who drove the equipped vehicle for at least five hours per month for a minimum of five months during the experiment. As this study intends to examine the influence of parental behavior, the study sample includes young drivers whose both parents drove the same vehicle for at least 25 hours overall during the experiment period. As this study anticipates investigating the contribution of sensation seeking, the study sample comprises novice drivers who completed the Sensation Seeking Scale questionnaire. The 62 novice young drivers, 36 males (58.1%) and 26 females (41.9%) were all 17 years old. The gender distribution in the sample is similar to that the one of the 17 years-old driver population in Israel, which is 63% males and 37% females (Israel CBS, 2007). Note also that, since participation in the study was voluntary, the sample is not otherwise representative of the Israeli young drivers' population and might be biased towards self-selection of families with high safety awareness.

2.2. Measures

The driving behavior data were collected using an IVDR system developed by GreenRoadTechnology, which was installed in the vehicles of the participating families.

All trips performed by the vehicle were monitored and the driver in each trip was identified. The IVDR system recorded trip start and end times, and sensors measured speeds and accelerations at high time resolution. The IVDR employed pattern recognition algorithms to reduce the large amount of raw information to meaningful maneuvers that the driver undertook. The system defined more than 20 driving maneuvers that may be classified into four major categories (i.e., braking and accelerating, turning, lane handling and speeding).

Maneuvers are also defined by their relative direction and their level of severity (i.e., moderate, intermediate, high) on the basis of the parameters of the detailed trajectory (e.g., maneuver duration, extent of sudden changes in speed and acceleration, and the speed they are performed at).

The processed information was transmitted through wireless networks to an application server, which maintained vehicle-specific and driver-specific records. A web-based application used this data to provide drivers with feedback about their driving according to the risk indices described below. A complete description of the IVDR systems employed in this study is presented in Toledo et al. (2008).

For each family, the data collection took place over a period of twelve months starting at the time the novice driver passed the driving test. This period included both the initial three months of the accompanied driving period and the following nine months of the solo driving period. With the intention of not biasing the behavior of the participants, only minimal information was initially provided about the purpose and the capabilities of the IVDR, and no feedback at all was given about the observed driving behavior. Approximately four months after the installation, additional information about the IVDR was provided to the participants. At the same time, they received personal access codes to the web-based application that presents the data collected by the system and the calculated risk indices for all drivers in the family in order to provide parents with the opportunity to consult the driving behavior of their offspring. The access times of the family members to this feedback on the web-based application were monitored and recorded.

The records of maneuvers and their severity ratings were used to calculate composite risk indices on a monthly basis for the novice driver and the other family members driving the same vehicle. These indices are proxies for the driver's risk of involvement in car crashes and have been shown to be positively correlated with drivers' actual crash records (Toledo et

al., 2008). Risk indices are expressed as a linear function of the number and severity of the maneuvers for each driver in each month, normalized by the driving time in that month in order to account for their driving exposure:

$$R_{it} = \frac{N_{it}}{DT_{it}} = \frac{\sum_j \sum_s \beta_{js} M_{ijst}}{DT_{it}} \quad (1)$$

where R_{it} is the risk index for driver i during month t, N_{it} is the equivalent number of events for driver i during month t, which is calculated as a weighted sum of the number of maneuvers for the driver, DT_{it} is the driving time for driver i during month t, M_{ijst} is the number of maneuvers of type j and severity level s for driver i during month t, and β_{js} are weights of the maneuvers of type j and severity level s.

The thrill and adventure seeking sub-scale of the Sensation Seeking Scale (SSS-V; Zuckerman, 1994) was administered to novice young drivers in its Hebrew version, which has proven reliability and validity (Glickson and Abulafia, 1998). The thrill and adventure seeking sub-scale relates to the tendency to take part in risky physical activities that offer an intense sensation of speed or defying gravity, and has been found to correlate most strongly with reckless driving in a comprehensive review of the literature (Jonah, 1997). Accordingly, novice young drivers completed the 10 items in the thrill and adventure seeking sub-scale by choosing between two contradictory statements, one describing a situation of thrill seeking and the other unrelated to this trait. Given the high internal reliability of the sub-scale, as Cronbach's alpha is equal to 0.85, a sensation seeking score was computed by the mean responses on all items, and was assigned to each young driver. Higher scores indicate a higher level of sensation seeking by the novice young drivers.

2.3. Model

The described data were used to develop a model that aims to explain the risk taking behavior of the novice young drivers as captured by the monthly risk indices during the first

year after licensure. As noted above, risk indices are defined for a panel of M young drivers over T periods as the ratio between a count variable, corresponding to the equivalent number N_{it} of events during each monthly period, and an exposure measure, corresponding to the driving time D_{it} during the same period. They are therefore by definition non-negative rate variables, and so not normally distributed.

Following a standard procedure to model rates with count data models, a negative binomial model of the equivalent number N_{it} of monthly events is estimated. The equivalent numbers of events are converted to rates using the driving time as an offset variable and constraining the parameter of its logarithm to a unit (Wooldridge, 2006) in order to model the risk index. Random effects are introduced to account for individual heterogeneity within the model, as Hausman specification tests revealed insignificant correlations between the unobserved person-specific random effects and the regressors. In the dataset T is relatively small and so the random effects model was considered more powerful and parsimonious than the corresponding fixed effects model (Wooldridge, 2006).

The model is specified as follows:

$$E\left[\ln\left(R_{it}\right)\right] = E\left[\ln\left(\frac{N_{it}}{D_{it}}\right)\right] = \beta' X_{it} + u_i \tag{2}$$

$$E\left[\ln\left(N_{it}\right)\right] = \ln\left(D_{it}\right) + \beta' X_{it} + u_i \tag{3}$$

where X_{it} and β are vectors of explanatory variables and the corresponding parameters, and u_i are individual-specific terms. Given this model specification, the interpretation of the estimated parameters β is similar to the interpretation for any econometric model from a qualitative perspective, and is measured with the computation of the incidence rate ratios (IRR) of each independent variable from a quantitative perspective.

Risk indices were calculated for an unbalanced panel of 533 observations for the 62 young drivers over the 12 months, as some young drivers did not drive the equipped vehicle

during all the months. The complete unbalanced panel was used for model estimation as it yields consistent and unbiased estimators (Wooldridge, 2006).

This random effects negative binomial model derives from a standard Poisson model with a parameter λ_{it} that depends on the explanatory variables X_{it} and the individual-specific terms u_i. Under the assumption that $\exp(u_i)$ follows a Gamma distribution, the Poisson parameter λ_{it} is Gamma distributed with parameters (γ_{it}, θ_i), where $\gamma_{it} = D_{it}\, exp(\beta' X_{it})$ and θ_i varies across individuals.

In order to allow the ratio of the mean to the standard deviation of the Poisson parameter to vary across individuals, Hausman et al. (1984) assume conveniently that the ratio $\theta_i / (1+\theta_i)$ follows a Beta distribution with parameters (a,b). This assumption yields a closed form expression for the unconditional joint probability density for the observations of the same individual over time:

$$p\left(N_{i1},...,N_{iT}\left|X_{i1},...,X_{it}\right.\right)=\frac{\Gamma(a+b)\Gamma\left(a+\sum_{t=1}^{T}\gamma_{it}\right)\Gamma\left(b+\sum_{t=1}^{T}N_{it}\right)}{\Gamma(a)\Gamma(b)\Gamma\left(a+\sum_{t=1}^{T}\gamma_{it}+b+\sum_{t=1}^{T}N_{it}\right)}\prod_{t=1}^{T}\frac{\Gamma\left(\gamma_{it}+N_{it}\right)}{\Gamma\left(\gamma_{it}\right)\Gamma\left(N_{it}+1\right)} \qquad (4)$$

3. Results

3.1. Data analysis

During the twelve-month period, the 36 male and 26 female young drivers were monitored over a total of almost 8 000 driving hours in which they recorded over 41 000 maneuvers with intermediate or high severity ratings. During the same period, the parents of the young drivers recorded about 10 000 driving hours and 30 000 maneuvers.

Figure 1 presents the average number of driving hours in each of the twelve months after licensure for male and female novice drivers. Male young drivers acquire more driving experience during the accompanied period, as on average they drive 24.4 hours (SD = 4.2 hours) over the three months, compared to 15.8 hours (SD = 2.0 hours) driven by females.

Note that the Israeli GDL program does not prescribe a minimum amount of driving hours during the accompanied period. The supervised driving experience provided to the novice drivers in the sample is somewhat lower compared to the minimum requirements of 30-50 driving hours over six months adopted by most U.S. jurisdictions, and much lower compared to the 120 hours recommended by the Australian program. Males also drive more during the solo period, with an average of 19.4 hours per month (SD=2.1 hours), compared to 14.7 hours (SD=1.9) driven by females.

The characteristics of trips also change after the transition from accompanied to solo driving. For male young drivers, their average number increases from 17.8 (SD = 3.4) to 57.3 (SD = 7.6) trips per month, while their average duration decreases from 27.3 (SD = 1.5) to 20.3 (SD = 1.3) minutes. For female young drivers, their average number raises from 12.9 (SD = 2.2) to 45.2 (SD = 6.0) trips per month, while their average duration declines from 24.5 (SD = 1.3) to 19.6 (SD = 1.3) minutes.

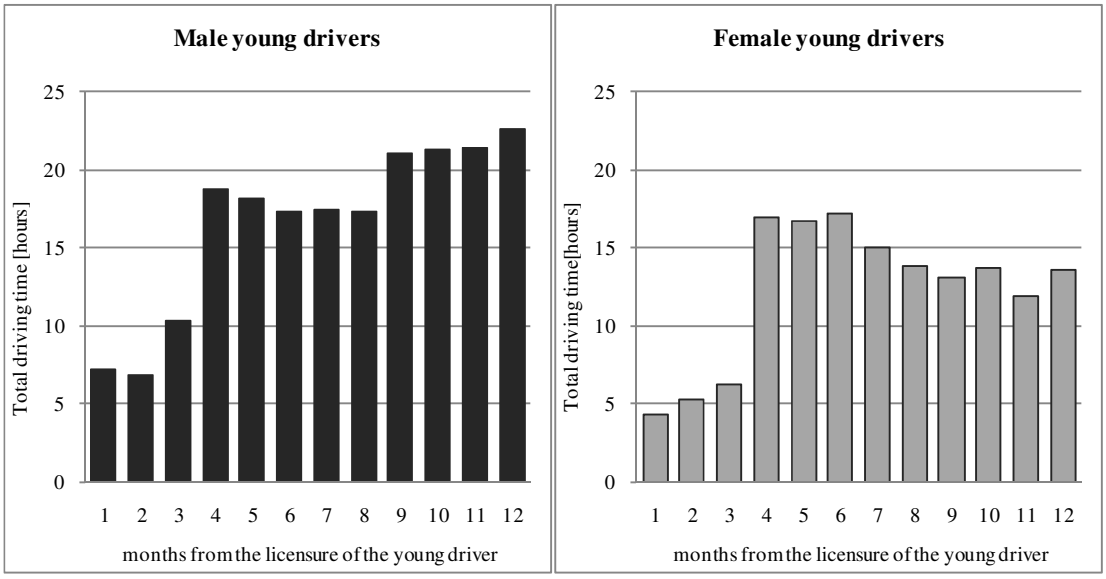

Figure 1. Distribution of driving hours over time

Figure 2 illustrates the average night-time (between 10pm and 6am) monthly driving hours in each of the twelve months after licensure for male and female novice drivers. Males

acquire twice as much driving experience at night during the accompanied period with an average of 2.1 hours (SD = 0.4 hours) total in the three months compared to 1.1 hours (SD = 0.2 hours) for females. Note that the Israeli GDL program neither prescribes a minimum amount of night-time driving hours during the accompanied period nor imposes any restriction on night-time driving in the solo period. During the nine months of the solo period, the night-time driving hours are significantly higher and make up a large portion of the overall driving time: 34% for males and 26% for female young drivers. At the same time, the average trip length is about 25% shorter compared to the accompanied period.

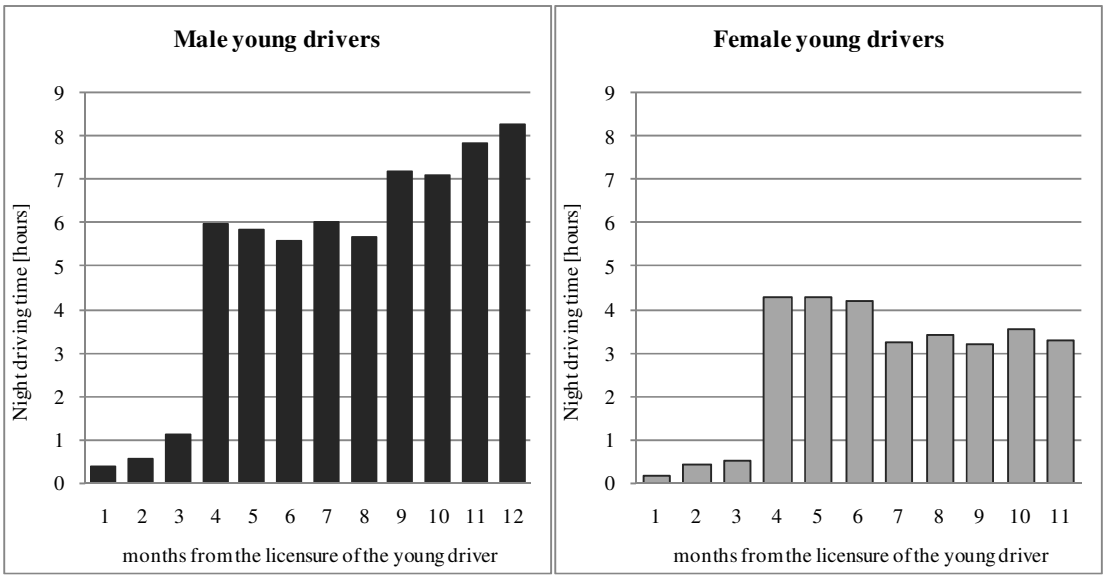

Figure 2. Distribution of night-time driving hours over time

Figure 3 presents the average risk indices for the novice drivers and their parents during the twelve months period. Risk indices vary significantly over time for both male and female novice drivers. Specifically, low values are observed during the accompanied driving period, and a steep increase is noticed after the transition to the solo period. After feedback is provided to the families for the first time around the fourth or fifth month, the average risk indices seem to decrease substantially. In the following period, while risk indices increase again for males, the decrease is sustained over time for females. Overall, male novice drivers

exhibit higher average risk indices compared to females. All novice drivers score higher in the risk indices compared to their parents in the solo driving period. Interestingly, the average risk indices of the parents do not change during the twelve-month period, which indicates that the driving styles of the parents are well established, a trait obviously not observed among the young drivers.

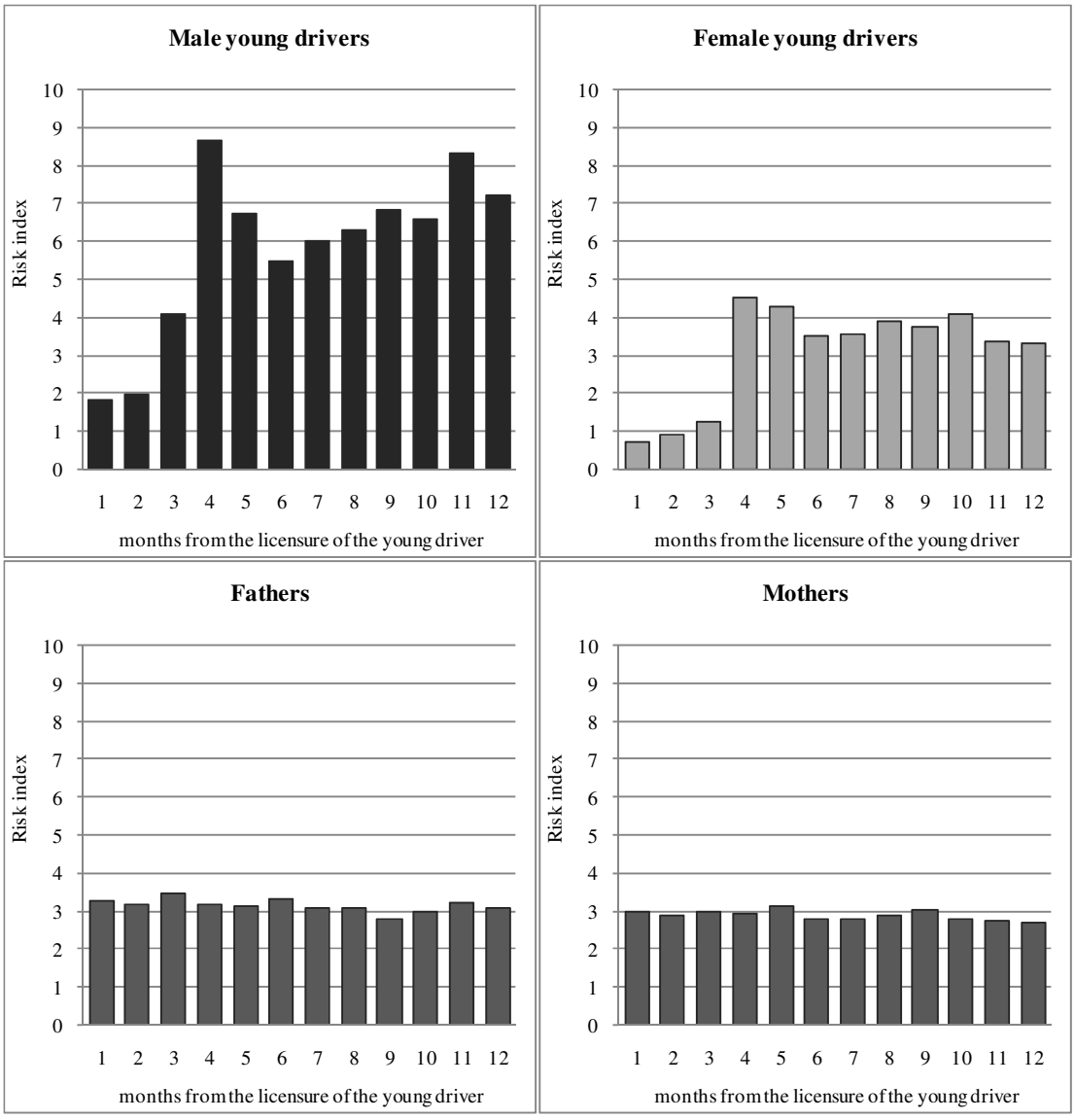

Figure 3. Distribution of risk indices over time

The feedback was available to the novice drivers and their families in 236 of the total of 533 observed household-months. The web pages holding the driving records were accessed in

162 of these household-months. In 49.4% of the cases only the parents accessed the feedback, in 22.2% only the young drivers consulted their driving history and in 28.4% both the novice drivers and parents engaged in this activity.

4.2. Model estimates

Risk indices R_{it}, and accordingly the number of equivalent events N_{it} and the driving times D_{it}, were extracted from the driving history recorded by the IVDR for each driver during each month. The random effects negative binomial model was estimated with the monthly risk indices collected by the IVDR as the dependent variable and transformed accordingly to the formulation in presented in section 2.3. Table 1 provides a description of the explanatory variables X_{it}.

Table 1 Explanatory variables of the negative binomial model

Variable	Values	mean	st.dev.
$male_i$	1 if young driver *i* is male, 0 otherwise	0.58	0.49
$sensationseeking_i$	sensation seeking index of young driver *i*	1.64	0.27
$solo_t$	1 if month *t* is during the solo period, 0 otherwise	0.79	0.41
$riskindexfather_i$	log of the average risk index of the father of young driver *i*	3.23	3.43
$riskindexmother_i$	log of the average risk index of the mother of young driver *i*	2.89	2.31
$feedbackteen_{it}$	1 if young driver *i* accesses alone the feedback web-site in month *t*, 0 otherwise	0.07	0.25
$feedbackteenparents_{it}$	1 if both young driver *i* and the parents access the feedback web-site in month *t*, 0 otherwise	0.09	0.28
$drivexpacc_{it}$	log of cumulative driving experience in hours at month *t* for young driver *i*, accumulated during the accompanied period	13.14	11.47
$drivexpdaysolo_{it}$	log of cumulative driving experience in hours at month *t* for young driver *i*, accumulated during the solo period at day (6am - 22pm)	37.78	42.40
$drivexpnightsolo_{it}$	log of cumulative driving experience in hours at month *t* for young driver *i*, accumulated during the solo period at night (22pm – 6am)	16.68	22.09

Parameter estimates of the random effects negative binomial model are presented in Table 2. Values of the IRR for each variable are reported to interpret the variables. If the IRR of a given variable is more than 1.0, then an increase in the value of the variable is associated with an increase in the value of the risk index. Conversely, if the IRR is less than 1.0, an increase in the value of the variable is associated with a decrease in the value of the risk index. Note that Hausman et al. (1984) do not provide rules for the interpretation of the distribution of the hyper-parameters *a* and *b* of the beta distribution, apart from the fact that values close to zero would be difficult to comprehend. The parameters of the beta distribution simply indicate that the ratio $\theta_i / (1+\theta_i)$ has a small mean and a large variance.

Table 2 Random effects negative binomial model

	estimate	t-statistic	p-value	IRR
male	0.542	6.81	0.0000	1.719
solo	0.376	2.85	0.0043	1.456
sensationseeking	0.356	2.38	0.0173	1.428
riskindexfather	0.345	7.70	0.0000	1.412
riskindexmother	0.373	6.34	0.0000	1.452
feedbackteen	0.189	1.64	0.1012	1.208
feedbackteenparents	-0.157	-2.06	0.0393	0.855
driveexpacc	-0.129	-3.65	0.0002	0.879
drivexpdaysolo	-0.043	-1.22	0.2231	0.958
drivexpnightsolo	0.156	4.41	0.0000	1.169
constant	-0.320	-3.18	0.0014	
offset (monthdrivingtime)	1.000	fixed		
a	1.699	3.70	0.0002	
b	16.276	3.43	0.0006	
Observations	533			
Log-Likelihood	-2344.68			
Restricted Log-Likelihood [a]	-11308.53			
Chi-Square	17927.70	(df = 1, p = 0.0000)		

[a] Log-Likelihood of the Poisson model with the same explanatory variables

As expected, estimation results show that males have higher risk indices and unsupervised driving affects the risk propensity of young drivers. This result confirms the suggestion of the graphical representation of risk indices in Figure 3. The IRR of the variable indicating that a month is during the solo driving period suggests that the risky behavior increases once novice drivers complete their obligations of being accompanied after three months. Also, this result confirms the indication of the graphical representation of risk indices in Figure 3. The IRR of the sensation seeking score indicates that young drivers that are higher sensation seekers tend to exhibit a more risky behavior. The IRR of the variables expressing the risk indices of fathers and mothers implies that risk-prone behavior of the parents is reflected into higher risk indices for the young drivers.

The access to the feedback provided by the system also affects the risk indices of the young drivers. According to the model estimates and the IRR, risk indices decrease when parents monitor the driving behavior of their children, but increase, even though not significantly, when young drivers enter the website to check their own driving records. Most probably, parents who consult the feedback about their children's driving performances tend to monitor their young drivers more carefully and perhaps to impose restrictions on their behavior. On the contrary, young drivers whose driving records are not consulted by parents are not keen to modifying their behavior. These findings show that, most likely, parents who are more active in monitoring their children while involving them in the process obtain better results in terms of risky behavior mitigation with respect to parents who prefer not to interest them and, obviously, to parents who are not engaged in checking the driving behavior of their offspring.

Also the amount of driving experience accumulated during the accompanied and the solo period is related to the risk indices of the young drivers. The IRR of the variables expressing driving experience show that acquiring more hours of supervised driving

contributes to reducing the risk indices. In contrast, risk indices of young drivers who drive more hours in the solo period tend to increase with respect to risk indices of those who drive less. On the one hand, this result seems to indicate the importance of augmenting supervised driving experience as opposed to unsupervised driving to reduce risk-prone behavior. On the other hand, this finding appears to suggest that gaining more experience in the initial year after licensure does not reduce risk indices. Specifically, the model in Table 2 clarifies this point with a distinction between day-time and night-time driving. In the accompanied driving period, the more experience is acquired, the better is the risk index reduction for young drivers, regardless of the period during day in which supervision is provided. In the solo driving period, the problem seems related to the drastic increase in night-time driving hours. As young drivers are mostly inexperienced since they acquired little to none night-time experience in the initial three months after licensure, their risk indices are strongly affected by their risky behavior between 10 pm and 6 am.

5. Summary and conclusions

This paper examines several relevant factors that contribute to the behavior of novice young drivers in the first year after licensure. Data were collected using IVDR systems that continuously monitor the vehicles of the families participating in the study. These measurements provide objective observations of driving behavior and are used to calculate risk indices that have been previously shown to be positively correlated with the risk of crash involvement. Random effects negative binomial models are estimated to explain the monthly risk indices and estimation results help to provide insights into relevant determinants that affect these risk indices.

Results confirm that male young drivers constitute a more severe problem than female young drivers, a well-known result in the existing literature that reports higher risk propensity in male drivers (e.g., Glendon et al., 1996; Harrè et al., 1996; Laapotti and Keskinen, 2004).

Also, results show that a higher level of experience acquired during the supervised period implies lower risk indices in the solo period.

Higher sensation seeking individuals appear also more inclined toward risky behavior and most likely exhibit this tendency after being allowed to drive without supervision. This finding confirms previous results cited in the literature that shows sensation seeking behavior to be positively correlated with reckless driving (e.g., Jonah, 1997; Taubman - Ben-Ari et al., 2004).

Importantly, results stress the role of parents in influencing the driving behavior of the novice young drivers. This is evident in both the connection between risk indices of parents and their children, and the evident impact of levels of parental monitoring. From the parental correlation perspective, high risk indices of the parents are reflected into higher risk indices for the young drivers, a result that reinforces previous findings about intra-familial correspondence of driving styles (e.g., Bianchi and Summala, 2004; Prato et al., 2009; Taubman - Ben-Ari et al., 2005). From the parental monitoring perspective, lower risk indices of the young drivers are related to active involvement of the parents in checking the driving behavior of their offspring, a result that confirms previous findings about the effect of parental monitoring on adolescent problematic driving (e.g., Hartos et al., 2000; Hartos et al., 2002).

Thus, parents should be encouraged to provide positive driving behavior modeling, actively monitor the behavior of their young drivers while involving them in the process, and tailor family policies to discourage risky behaviors that potentially lead to car crashes. Furthermore, parents should also have an important role in increasing the amount of supervised driving the novice drivers undertake, in particular with specific efforts at night that might reduce the subsequent tendency to risky behavior. This finding may also imply that policies should be designed to extend the accompanied driving period and propose

minimum requirements for supervised driving hours with the aim to reduce crash risks of young drivers.

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