Are young drivers as careful as they deem? In vehicle data recorders and self reports evaluations

Gila Albert, Tsippy Lotan, Tomer Toledo, Einat Grimberg & Mariano Lasebnik

European Transport Research Review
An Open Access Journal

ISSN 1867-0717
Volume 6
Number 4

Eur. Transp. Res. Rev. (2014) 6:469-476
DOI 10.1007/s12544-014-0146-0

Springer

Eur. Transp. Res. Rev. (2014) 6:469–476
DOI 10.1007/s12544-014-0146-0

ORIGINAL PAPER

Are young drivers as careful as they deem? In vehicle data recorders and self reports evaluations

Gila Albert · Tsippy Lotan · Tomer Toledo · Einat Grimberg · Mariano Lasebnik

Received: 11 November 2013 / Accepted: 1 August 2014 / Published online: 9 August 2014

Abstract
Purpose This paper aims to explore the driving behavior of young drivers few years after licensure based on two different evaluation approaches, which are used in a complementary manner. The evaluation was done with respect to driving exposure and trip safety.
Methods The evaluation is based on two data collection approaches, which were compiled for the same trips: The first, In Vehicle Data Recorders (IVDR), which were installed in the young drivers' vehicles for a study period of 8 months. The second, Self-Reports (SR), which were provided by the young drivers at random times throughout the study period. These data have been compared and used in a complementary manner in order to provide an understanding of participants' driving behavior.
Results The results show high correlation of driving exposure which was self-reported and these obtained from IVDR. The results also indicate that young drivers clearly perceived themselves as being safer drivers than they are, according to IVDR findings. In addition variables available only in the SR e.g., the presence of passenger in the car were found to affect the trip risk level.
Conclusions The analysis obtained should be considered as exemplifying the potential of what may be accomplished and understood using these evaluation approaches.

G. Albert (✉) · M. Lasebnik
Faculty of Management of Technology, H.I.T – Holon Institute of Technology, 52 Golomb St, Holon 58102, Israel
e-mail: gila.albert1@gmail.com

T. Lotan · E. Grimberg
Or Yarok, 22 Hanagar St, Hod Hasharon 45240, Israel

T. Toledo
Faculty of Civil and Environmental Engineering, Technion - Israel Institute of Technology, Haifa 32000, Israel

Keywords In vehicle data recorders · Self-reports · Young drivers · Safety · Risk evaluation

1 Introduction

Young drivers in Israel, similar to other places across the globe, are involved in car crashes more than any other age group, as shown in Fig. 1. A "young driver" is often defined with a relatively wide age group, e.g., the ages of 17 to 24 years, but the main focus in the safety literature is on novice young drivers up to 19 years of age.

Young drivers up to the age of 19 are more affected by risk factors, such as nighttime and weekend driving, the presence of other passengers - especially teens in the car, and by negative interaction of these attributes. However, these factors have a lesser effect on young drivers between the ages of 19–24 years [10, 1, 29, 28]. Furthermore, the impact of the presence of passengers in the car on the 19–24 year-olds, for example, can be considered ambiguous and depends on socio-economic characteristics and social interactions between the driver and the passengers [10, 11]. Despite their over-representation in crashes, young drivers are often confident in their driving abilities, tend to overestimate their own driving skills, and perceive their own chances of involvement in a crash to be significantly lower than that of their peers [20, 9, 8, 25].

This paper is based on a study carried out in Israel as part of the European Community PROLOGUE project [18]. The study aims to evaluate the driving behavior of young drivers in the 19–24 age group drive, 3–4 years after licensure. The evaluation was done using two tools: In Vehicle Data Recorders (IVDR) technology and Self-Reported data (SR). More specifically, we focused on the relation between these two approaches and on the ability to use them in a complementary manner in order to improve the evaluation of driving

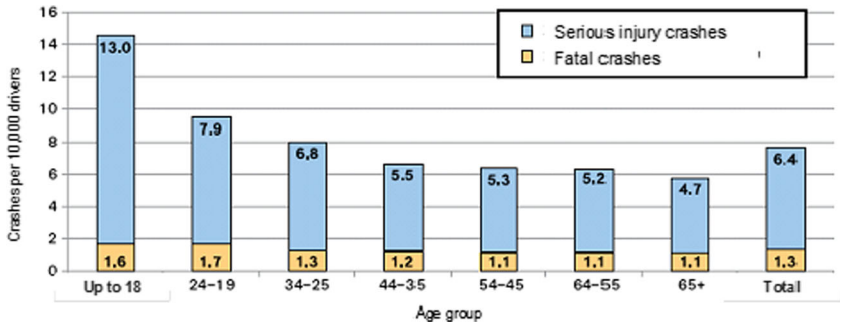

Fig. 1 Car crash rates in Israel by age group in 2009 (source: [5])

behavior. Recent literature suggests the potential strength of combining both technology-based and traditional approaches (see, for example, [4, 30]).

The rest of this paper is organized as follows: the next section reviews IVDR and SR data collection approaches. Then, we present the study's Methodology, followed by the Results and their analysis. Finally, we present the discussion

2 Data collection approaches

2.1 In-vehicle data recorders (IVDR)

IVDR can be used for unobtrusive recording of driving behavior in naturalistic traffic conditions. This advanced recording equipment installed in the vehicle, tracks all trips made with it and collects trip and safety characteristics. Thus, IVDRs provide continuous monitoring of driving patterns and behavior. Based on the information collected in the database, real-time and off-line feedback can be delivered to drivers. In this role, IVDR effects to reduce the occurrence of risky behaviors have been recognized in various studies [24, 17].

The IVDR system used in this study was developed by Green Road Technologies. All trips performed by the equipped vehicle are monitored; at the beginning of each trip the driver is identified using a personal magnetic identification key. If the driver fails to identify himself/herself, the trip is recorded with no driver identification. The system incorporates four layers of information processing and its overall framework is presented in Fig. 2.

The first layer in the system is the measurement module, which uses accelerometers and a GPS receiver to collect the two-dimensional acceleration and speed of the vehicle. The acceleration information is collected at a sampling rate of 40 measurements per second. The detection layer incorporates pattern recognition algorithms to identify and classify over 20 different maneuver types in the raw measurements. The detected maneuvers are then classified into five major categories of events: braking, accelerating, turn handling, lane handling and speeding. The performance quality of the detected maneuvers is also evaluated. The analysis layer classifies the driver's profile into three categories (cautious, moderate and aggressive), based on the rate and severity of the man oeuvres they generate and on their speed profile. The final reporting layer provides feedback based on the information collected in the database.

Trips are color-coded according to their safety classification: green (moderate), yellow (intermediate) and red (aggressive). Drivers are also categorized as green, yellow and red, according to the rate of their events: green drivers perform less than 20 events per 10 driving hours, yellow drivers perform between 20 and 50 events per 10 driving hours, and red drivers perform more than 50 events per 10 driving hours. For previous studies conducted with this system and further details, see Toledo et al. [24] and Prato et al. [23].

The detailed analysis of events obtained by IVDR may provide insights on safety, especially since the relationships between safety-related events, near crashes and crashes are recognized in the safety literature (e.g., the well-established Heinrich's safety triangle and its applications, [13]). In addition, IVDR offers an accurate measure of driving exposure level, which is essential for evaluation of the risk of being involved in road crashes [12].

2.2 Self-reports (SR)

Self-reporting is an often employed tool in driver safety research. SR has many well-recognized advantages, such as its ease of use and the ability to collect large data sets relatively cheaply. However, it suffers from limitations regarding its validity as an indicator of actual behavior. Nevertheless, many studies use it, often even as the sole source of data. The drawbacks tend not to be acknowledged and it is generally assumed that SR is unbiased and that its errors are random ([26] and the accompanying references). There are two main failures that affect the validity and reliability of SR. The first is memory failure - people tend to forget, and may also have false memories of events that never actually occurred. The impact of memory failure increases with the time that passed from the time of the event being recalled. The second failure relates to cognitive/social distortions - people tend to report their actions and views in a way that they think others would

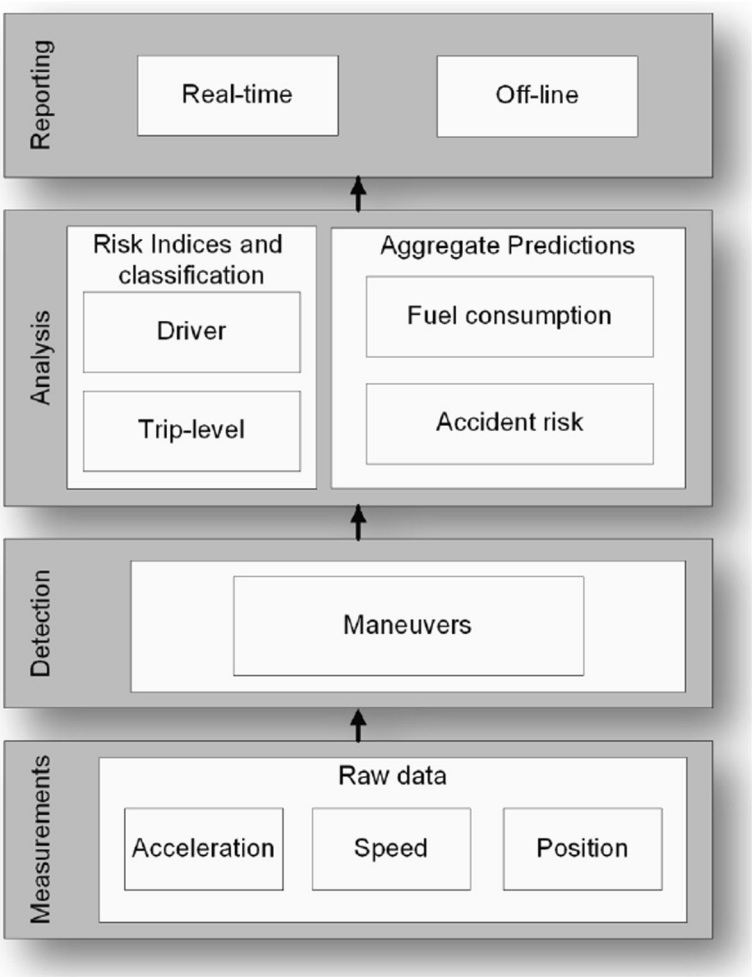

Fig. 2 Overall framework of the Green Road IVDR system

want to hear and will make a positive impression of themselves [26, 27].

In safety research, crash involvement and driving exposure are variables that are commonly derived from SR. SR crashes are especially subject to memory failure, since participants are commonly asked to recall crashes they experienced over a period of several years. To evaluate their reliability, self-reported crash involvement has been compared to official records. It should be noted that the absence of a reliable source for road crashes [14] is problematic when performing such evaluations. Wåhlberg [26] reviews numerous studies and concludes that some people forget crashes, even fairly severe ones, which they were involved in. Other drivers report crashes that never occurred. Both underreporting and over reporting of crashes at the individual level have been established. For example, McGuire [21] found that drunk drivers tend to underreport crashes. McGwin et al. [22] found that drivers self-reported crashes that could not be found in official records. Boufous et al. [2] reported that 85 % of road crashes recorded in police records during the year prior to the survey were also self-reported by young drivers. However, other studies found lower agreement between records and SR depending on characteristics of the population and the information being collected. McGwin et al. [22] found that among drivers over 60 years of age, only about two-thirds of the crashes recorded in police data for a period of 5 years were self-reported. The accuracy of self-reported near-crashes, which are much more common, is even more doubtful than that of self-reported crashes. Chapman and Underwood [6] found that 80 % of near-crashes were forgotten after two weeks.

Self-reported driving exposure also suffers from low accuracy levels compared to other driving exposure measures, and therefore seems to be rather unreliable [26]. Huebner et al. [15] found differences of over 30 % between self-reported and recorded travel distances obtained from a Car Chip (an electronic device installed in the car). Chipman [7] reported better results - a correlation of 0.86. In both studies, the period of interest was the one week prior to the self-reporting. Blanchard et al. [3] found similar results with older drivers. Overall, self-reports of travel distances were not systematically biased compared to those recorded by the Car Chips. But, individual participants tended to either under- or overestimate the weekly travel distances. Leaf et al. [16] reported that

obtaining trip-by-trip details provided the most reliable estimates of driving exposure among young drivers. Retrospective questionnaires (asking about individual trips from the previous week without forewarning) provide comparable estimates, but the overall week mileage estimates were 20–30 % lower than trip by-trip listings in most cases. [19] found large differences between IVDR measurements and similar statistics obtained through SR. Bricka et al. [4] reported on a study which considered two measures of travel intensity: survey-reported and GPS-recorded. Their findings suggest that the two survey methods complement each other and should be used in tandem.

In summary, short-recall SR are preferred and more emphasis should be put on the way the items and terms in the SR are phrased: e.g. clearly defining terms such as "slight crash", "near crash", "quality of driving style" and so on. With respect to SR, it is preferable to use phrases that are clear to all respondents and can be quantified. All SR variables should be compared whenever possible to other measures in order to achieve estimates with higher accuracy levels.

3 Methodology

3.1 Participants

Study participants drove their own or family vehicles on their regular, uninterrupted trips in various driving conditions and locations. The vehicles were all equipped with Green Road IVDR systems. All trips were monitored. Participants and other family members using the same vehicles were asked to identify themselves using a magnetic (Dallas) key at the beginning of each trip. Participants' family members also received magnetic keys. However, only the participants were explicitly required to identify themselves.

Subjects were recruited from a participants' pool of novice young drivers who took part in a study conducted in Israel between the years 2006–2007 (for more details about this study of novice young drivers, see [19, 24, 23]). Those who agreed to participate again were screened for vehicle availability and sufficient driving experience. It should be noted that since participants took part in a previous study that used the same system, they were all familiar with the technology and associated terminology.

32 young drivers participated in this study. 21 participants (66 %) were male and 11 (34 %) were female. Their average age at the beginning of the current study was 20.5±0.5 years. The majority of participants (75 %) were in the midst of their regular military service during most of the time in which the study took place (a national mandatory military service exists for young Israelis, beginning at the age of 18 and continuing for 2–3 years). Therefore, their use of the family car was assumed from the beginning not to be intensive. Generally, their driving occurred during their free time. On average, participants had received their driving license 40.0± 6.6 months prior to the re-installation of the IVDR systems. Three out of the 32 participants reported that they had been involved, as drivers, in road crashes that resulted in injuries since obtaining their licenses. All respondents reported that the crash was not their fault.

3.2 Experimental design

The overall study period was 8 months. The experimental design followed a three-stage structure. The first stage lasted for 2.5 months immediately after the IVDR installation. During this "blind" stage, participants did not receive any feedback from the IVDR. The second stage lasted 3.5 months. In this stage, participants received feedback by way of web-based reports and in-vehicle display. The results reported in this paper do not use data from this period since it is ineffective to ask participants to self-report data while feedback is available. Finally, a two-month cooling-off stage was employed, during which participants continued to drive with the IVDR, but did not receive any feedback.

A self-reported questionnaire was also developed for this study. The questionnaire was Internet-based. Invitations to complete the questionnaire were sent to participants by email. The questionnaire included a self-reported trip diary for a short recall period of 48 hours. The 48-hour reporting period was used in order to reduce memory failure. As mentioned, to assure that the SR was done only based on the participants perspective, it was administered in the two period in which drivers did not receive any feedback, that is, only during the first and last stages of the study. Each participant was asked to complete these diaries about five times at randomly selected times within the blind and cool off stages of the experiment. The information requested for each trip included the following items:

1. Date.
2. Start and end time of the trip.
3. Purpose of the trip chosen from a menu. Options were work, education, leisure, errands and other.
4. Number of passengers in the vehicle.
5. Number of risk events that occurred during the trip.
6. Overall assessment of the level of crash risk in the trip.

With the exception of the trip purpose and the presence of passengers, all data items may be compared to those found in the IVDR data. The definition of the risk events and the overall risk level was based on those of the IVDR, which the participants were familiar with. In addition, the questionnaire collected information on the socio-economic characteristics of participants.

4 Results

4.1 Summary statistics

More than 37,000 trips were monitored by the IVDRs. In 40 % of the trips, the driver was identified. However, as mentioned before, only participants (and not other family members) were required to identify themselves when driving. Overall, 3,424 trips were associated with the 32 participants during the blind and cool-off periods that did not involve any feedback. This amounts to an average of 1.02 trips per day for each driver. This relatively low rate may be explained, as noted earlier, by the limitations imposed by their military service. TABLE 1 presents summary statistics of the trips the participants undertook. These trips are used in the analysis that follows.

4.2 Association of IVDR and SR data

The comparison of IVDR and SR data was done with respect to driving exposure and trip risk level. The self-reported data that was compiled for specific days in the stages without feedback were compared to the data collected by the IVDR for the same days. First, self-reported trips were matched with trips recorded by the IVDR. The matching was done requiring at least a partial time overlap. In cases that a self-reported trip could not be related to a specific trip undertaken by the young driver, a matching trip was sought within the unidentified trips for the same vehicle.

4.2.1 Driving exposure

In the Initial blind stage, 16 participants self-reported that they did not drive at all. The other 16 participants self-reported a total of 109 trips. 50 of the trips (46 %), by 12 participants, were successfully matched. In the cool-off stage, 7 participants self-reported that they did not drive at all. The other 25 participants self-reported a total of 194 trips. 106 of the trips (54 %), by 17 participants, were successfully matched. The most common reason for not matching trips was missing self-reported data (e.g., date, start or end time).

Table 1 Characteristics of the trips undertaken by the participants

	Blind stage	Cool-off stage
No. of trips	1,859	1,565
Total driving time (hrs.)	846.2	601.1
Average trip duration (min.)	27.3	23.0
SD of trip duration (min.)	22.8	22.1

In the blind stage, the total duration of the matched trips was 1,487 minutes according to the IVDR and 1,742 minutes according to the SR. The average trip duration was 31.6± 39.1 minutes according to the IVDR and 36.9±45.3 minutes according to the SR. The correlation between the total driving times at the level of individuals was 0.96. Four participants (33 %) underestimated their total travel time, while eight (67 %) overestimated it.

In the cool-off stage, the total duration of the matched trips was 2,746 minutes according to the IVDR and 2,795 minutes according to the SR. The average trip duration was 26.8± 21.6 minutes according to the IVDR and 27.3±16.0 minutes according to the SR. The correlation between the total driving times at the level of individuals was 0.90. Six participants (35 %) underestimated their travel time, while 11 (65 %) overestimated it.

4.2.2 Risk assessment

For the comparison with respect to the trip risk assessment, the categorization of the trips into three risk levels: high (red), intermediate (yellow) or moderate (green) was used. In the initial blind stage, the IVDR risk classifications were higher (indicating a higher risk level) than the SR in 47 % of the trips. The categories were equal in 45 % of the trips. The risk category recorded by the IVDR was lower than the self-reported one in only 8 % of the trips. In the cool-off stage, risk levels reported by the IVDR were higher than the SR in 30 % of the cases and equal in 70 % of the cases. There were no cases in which the IVDR reported a lower risk level.

The overall risk evaluation scores (RES) of the young drivers, as obtained by IVDR and SR, were calculated. To conduct statistical comparisons, we converted the original ordinal scale obtain from the IVDR (a scale of 1–3 where "green" trips are rate 1, "yellow" trips are rate 2 and "red" trips are rate 3) to an interval scale, ranging from 0 to 1, with lower values indicating safer driving behavior. In addition, drivers were also categorized as moderate (green), intermediate (yellow) or aggressive (red) using the category thresholds. These thresholds obtained from IVDR methodology, where 20 events per an hour of driving indicate a "green" driver, 20–50 events per an hour of driving indicate a "yellow" driver and more than 50 events per an hour of driving indicate a "red" driver. Based on the discussed above values of up to 0.2 are categorized as low-risk drivers (green), $0.2 \leq RES < 0.5$ indicates intermediate driving (yellow), and values of over 0.5 indicate aggressive driving (red).

In the blind stage, the average risk indices that were obtained from the IVDR and SR were 0.465 and 0.185, respectively. In the cool-off stage, the same average risk indices were 0.270 and 0.035, respectively.

These results suggest two important insights. First, the risk indices are significantly lower in the cool-off stage compared

to the blind stage. This may indicate that the feedback provided in the experiment had an effect on the driving behavior. Second, participants significantly perceived that their level of risk was lower compared to the IVDR estimates.

To illustrate this trend, the comparison of the perceived RES of each participant to the RES calculated from the IVDR in the "cooling-off" stage is shown in Fig. 3. In the figure, the bar for each participant represents his or her average RES based on the IVDR risk levels, whilst the bar's color is coded according to the RES based on self-reported risk levels (green for low risk, yellow for intermediate and red for high). The horizontal lines represent the cut-off value of RES, e.g., the red line means that participants with bars above it exhibit an aggressive driving.

The figure indicates that 6 out of the 14 participants perceived themselves, in general, to be safer drivers than they are according to the IVDR data (e.g. participants with a RES of 0.85–0.90 according to the IVDR are certainly "red" but perceived themselves as "yellow"). Seven participants classified themselves similarly to the IVDR. Only one self-reported a higher risk level compared to the IVDR (i.e., this participant with a RES of 0.04 according to the IVDR is certainly "green" but perceived himself/herself as "yellow".

4.3 The impact of trip purpose and presence of passengers on the risk level

One of the potential advantages of using different data sources is the ability to obtain complementary information, which is often not available from a single source. In this section, we evaluate the effect of two variables that were available only in the SR data - trip purpose (specifically, leisure trips) and presence of passengers – on the trip risk level, as estimated by the IVDR.

The data used for this evaluation includes all the 156 trips (50 in the "blind profile" stage and 106 in the "cooling-off" stage) that were matched between the IVDR and SR. The data was pooled in order to increase the number of relevant observations in each case. The drivers reported that 40 (26 %) of the trips were for leisure purposes and that passengers were present in the vehicle in 81 (52 %) of the trips. The IVDR classified 91 (61 %) of the trips as moderate (green), 25 (16 %) as intermediate (yellow) and 35 (23 %) as aggressive (red).

Figure 4 shows the distribution of trip risk level classification for all trips, for leisure trips and for trips in which passengers were present in the vehicle.

The figure indicates that there is no significant difference in the distribution of trip safety levels between all trips and trips made for recreation purposes. Furthermore, we found in the analysis that similar share (approximately one-quarter) of the trips at each safety level are recreational in nature. These findings may suggest that there is no impact of recreational purposes on the trip's risk level. This result is not in line with the known negative effect of recreation on young drivers' behavior; however, as mentioned before, one explanation for this might be the maturity level of the sample population, which leads to results that are more expected among older drivers regarding the impact of recreation. It seems that the unique characteristics of the sample population, e.g., maturity, also provide an explanation for this result.

In regard the impact of the presence of passengers in the car on safety level the figure indicates that there is a difference in the distribution of trip safety levels between all trips and trips where passengers are presented in the vehicle. Furthermore, we found in the analysis that there is a significant higher share of trips with "green" safety level when passengers are presented in the vehicle compare to trips with"green" safety level without passengers. These results which may suggest that the

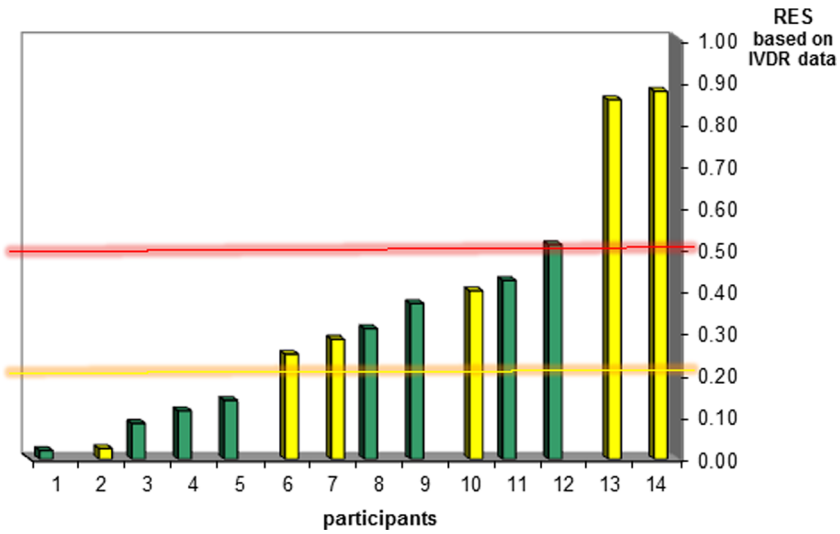

Fig. 3 Risk evaluation scores measured by IVDR and SR

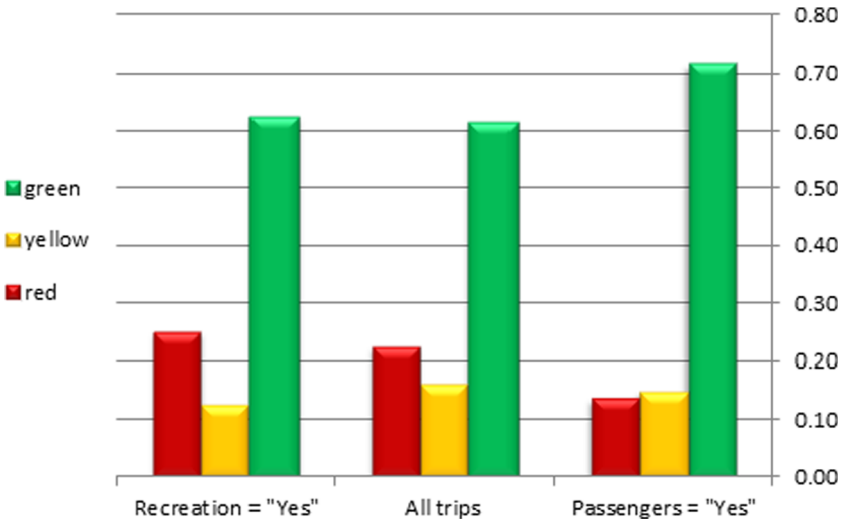

Fig. 4 The distribution of trip risk level classification

presence of passengers in the car may have a positive impact on trip risk levels are contradictory to most safety literature regarding the impact of the presence of passengers on young drivers' behavior. However, as mentioned in the introduction, it is recognized that the negative impact of the presence of passengers is relaxed among relatively older young drivers and even a positive impact was found in some studies. In addition, it should be noted that it was not revealed in the SR who the passengers were; they may be, for example, the parents, who have a moderating impact on risky driving style.

5 Discussion

This paper presents an evaluation, based on IVDR and SR data, of the driving behavior of young drivers with 3–4 years of driving experience. To the best of our knowledge, this is the first attempt which focuses on evaluating the overall risk level of relatively "experienced" young drivers based on these two evaluation approaches.

Most of the results of this study are based on a combination of IVDR and SR and contribute to demonstrate the strength of analyses that use these two approaches in a complementary manner. The comparison of driving exposure data revealed that substantial differences may be observed between the two approaches even if drivers are asked to recall their trips for only a short time period. While the results demonstrate the problems associated with the accuracy of SR, they also highlight the difficulties that may arise with IVDR data collection, and in particular in regard obtaining complete and correct driver identification. More effort should be put into this problem.

When considering the results, it is important to take into account that the analyses are based on a relatively small sample of 32 participants, which is by no means representative of young drivers. The status of the participants– a large fraction of them engaged in doing their military service – has an influence on their exposure patterns in a way that may be unique to their situation. In addition, the sample is likely to be biased towards individuals and families that have a high level of awareness and positive attitudes towards traffic safety, since they agreed to participate once again in a safety research study. This may explain that, as generally opposed to the common safety literature about young drivers, "recreation" negative effect was not obtained. In addition, the presence of passengers in the car was found to positively affect the trip risk level. These finding are not typical for young drivers.

Overall, the participants' perception of their own safety behavior as indicated from the SR indicated that they perceived themselves as safer drivers than they are, according to the IVDR data. This finding is in line with the safety literature reported over self- confidence of young drivers who tend to overestimate their own driving skills. This perception may be also influenced by self-concept and other factors. Their driving exposure reports were reasonably accurate whereas the literature is not distinct about the dependability of self-reported driving exposure. Similar to previous researches, the results suggested that young drivers did improve their driving behavior while driving with IVDR: their risk evaluation score was significantly safer in the final "cool-off" stage compared to the initial "blind profile" stage, based on the two evaluation approaches.

As discussed earlier, the results should be considered with respect to the sample's unique characteristics. The results cannot be generalized and should be treated with caution due to the limitations of the study sample, and should be further investigated. However, the methodology for the data analysis may have wider use. IVDR technology is a valuable tool in understanding driving patterns and behavior. Combining it with other data sources, such as SR, can improve the validity and reliability of the data and enhance our understanding of drivers' behavior and risks. The analysis results obtained in this trial should be considered as exemplifying the potential of what may be done with this kind of data.

Acknowledgment This research was funded by the EC FP7 PROLOGUE project. The authors would like to thank Prof. Shalom Hakkert for his valuable suggestions.

References

1. Åkerstedt T, Kecklund G (2001) Age, gender and early morning highway accidents. European Sleep Research Society 10:105–110
2. Boufous, S., Ivers, R., Senserrick, T., Stevenson, M., Norton, R. and Williamson, A. (2010). Accuracy of self-report of on-road crashes and traffic offences in a cohort of young drivers: The DRIVE study. *Injury Prevention*.
3. Blanchard RA, Myers AM, Porter MM (2010) Correspondence between self-reported and objective measures of driving exposure and patterns in older drivers. Accident Analysis & Prevention 42: 523–529
4. Bricka SG, Sen S, Paleti R, Bhat CR (2012) An analysis of the factors influencing differences in survey-reported and GPS-recorded trips. Transportaion Reseach C 21:67–88
5. CBS (2010). Traffic accidents with casualties, Israel Central Bureau of Statistics, Ministry of Transport, Jerusalem, Israel.
6. Chapman P, Underwood G (2000) Forgetting near-accidents: the roles of severity, culpability and experience in the poor recall of dangerous driving situations. Appl Cogn Psychol 14:31–44
7. Chipman ML (1982) The role of exposure, experience and demerit point levels in the risk of collusion. Accident Analysis & Prevention 14:475–483
8. Deery HA (1999) Hazard and risk perception among young novice drivers. J Saf Res 30(4):225–236
9. Dejoy DM (1992) An examination of gender differences in traffic accident risk perception. Accident Analysis & Prevention 24(3): 237–246
10. Doherty ST, Andrey JC, MacGegor C (1998) The situational risk of young drivers: the influence of passengers, time of the day, and day of week on accident rates. Accident Analysis & Prevention 30:22–45
11. Engström I, Gregersen NP, Granström K, Nyberg A (2008) Young drivers - Reduced crash risk with passengers in the vehicle. Accident Analysis & Prevention 40(1):341–348
12. Evans, L. (1991). *Traffic Safety and the Driver.* Van Nostrand Reinhold, NY.
13. Heinrich, H.W. (1931). *Industrial Accident Prevention: A Scientific Approach*. McGraw-Hill.
14. Hauer E, Hakkert S (1988) Extent and some implications of incomplete accident reporting. Transp Res Rec 1185:1–10
15. Huebner KD, Porter MM, Marshall SC (2006) Validation of an electronic device for measuring driving exposure. Traffic Injury Prevention 7:76–80
16. Leaf WA, Simons-Morton BG, Hartos JL, Shabanova Northrup V (2008) Driving miles estimates by teen drivers: how accurate are they? Injury Prevention 14:59–61
17. Lerner N, Jenness J, Singer J, Klauer S, Lee S, Donath M, Manser M, Ward N (2010) An exploration of vehicle-based monitoring of novice teen drivers. Final Report. NHTSA, Report No. DOT HS 811 333, Washington
18. Lotan, T., Albert, G., Ben-Bassat, T., Ganor, D., Grimberg, E., Musicant, O., Hakkert, S. and Toledo T. (2011). *Israeli Field Trial*. PROLOGUE - PROmoting real Life Observations for Gaining Understanding of road user behaviour in Europe. Deliverable D3.2. European Commission, Seventh Framework Programme Theme 7 Transport. Or Yarok, Hod Hasharon, Israel.
19. Lotan T, Toledo T (2007) Driving patterns of young drivers within a graduated driver licensing system. *Compendium of papers of the 86th annual meeting*. Transportation Research Board, Washington
20. Matthews ML, Moran AR (1986) Age differences in male drivers' perception of accident risk: the role of perceived driving ability. Accident Analysis &Prevention 18(4):299–313
21. McGuire FL (1976) The validity of accident and violation criteria in the study of drinking drivers. J Saf Res 8:46–47
22. McGwin G, Owsle C, Ball K (1998) Identifying crash involvement among older drivers: agreement between self-report and state records. Accid Anal Prev 30:781–791
23. Prato CG, Toledo T, Lotan T, Taubman-Ben-Ari O (2010) Modeling the behavior of novice young drivers during the first year after licensure. Accident Analysis & Prevention 42(2):480–486
24. Toledo T, Musicant O, Lotan T (2008) In-vehicle data recorders for monitoring and feedback on drivers' behavior. Transp Res C 16:320–331
25. Ulleberg P, Rundmoo T (2003) Personality, attitudes and risk perception as predictors of risky driving behavior among young drivers. Saf Sci 41:427–443
26. Wåhlberg, A. A. (2009). Driver behaviour and accident research methodology: Unresolved problems. Chap 2. pp. 17–64. MPG Books Group, UK.
27. Wåhlberg AA, Dorn L, Kline T (2010) The effect of social desirability on self-reported and recorded road traffic accidents. Transport Res F: Traffic Psychol Behav 13(2):106–114
28. Williams AF (2003) Teenage drivers: patterns of risk. J Saf Res 24:5–15
29. Williams AF, Ferguson SA (2002) Rationale for graduated licensing and the risks it should address. Injury Prevention 8(II):9–16
30. Zhao N, Mehler B, Reimer B, D'Ambrosio L, Mehler A, Coughlin J (2012) Exploring the relationship between the driving behavior questionnaire and objective measures of highway driving behavior. Compendium of Papers of the 91th Annual Meeting, Transportation Research Board, Washington