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A Review of Hazard Anticipation Training Programs for Young Drivers

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Abstract

Purpose—Poor hazard anticipation skills are a risk factor associated with high motor vehicle crash rates of young drivers. A number of programs have been developed to improve these skills. The purpose of this review was to assess the empirical literature on hazard anticipation training for young drivers.

Methods—Studies were included if they: 1) included an assessment of hazard anticipation training outcomes; 2) were published between January 1, 1980 and December 31, 2013 in an English language peer-reviewed journal or conference proceeding; and 3) included at least one group that uniquely comprised a cohort of participants <21 years. Nineteen studies met inclusion criteria.

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Conflict of Interest Statement: Two authors (Pradhan, Romoser) were involved in the development and/or evaluation of one of the training programs (RAPT) described in this review.

Results—Studies used a variety of training methods including interactive computer programs, videos, simulation, commentary driving, or a combination of approaches. Training effects were predominantly measured through computer-based testing and driving simulation with eye tracking. Four studies included an on-road evaluation. Most studies evaluated short-term outcomes (immediate or few days). In all studies, young drivers showed improvement in selected hazard anticipation outcomes, but none investigated crash effects.

Conclusions—Although there is promise in existing programs, future research should include long-term follow up, evaluate crash outcomes, and assess the optimal timing of hazard anticipation training taking into account the age and experience level of young drivers.

Keywords

adolescent driver; hazard anticipation; motor vehicle crashes; teen driver; training; young driver

Introduction

Young driver crash risk increases markedly once independent driving begins, followed by a rapid decline over the first 6-12 months of driving [1-3]. The mechanisms that influence the decline in young driver crash involvement are not fully understood. Although maturation and increasing self-regulation occurs during the first year of driving [4], the pattern of decreasing crash risk bears a striking resemblance to the standard learning curve that describes the improvement over time in performance of complex cognitive tasks [1].

Hazard anticipation errors are common in crashes among adolescent drivers [5-8]. Various terms have been used in the literature to describe this aspect of driving behavior: *hazard perception, recognition, awareness, anticipation, skills,* etc. Given a lack of standard terminology, we have chosen *"hazard anticipation"* for this review to represent the broad number of terms used in the literature depicting the multiple components related to constructs of cognitive awareness, visual perception, and experiential and schema-based recognition. *Hazard anticipation* thus can be defined as a set of driver behaviors that include: awareness and knowledge of roadway risks and associated threats to driving safety; visual search that facilitates detection and recognition of elements directly or indirectly contributing to unsafe situations; prediction of emerging and latent hazards based on information from the visual scene; and execution of driving responses to avoid or minimize potential conflicts due to recognized hazards.[9-11]. Studies indicate that young novice drivers, when compared with experienced adult drivers, have poorer hazard anticipation skills with respect to proficiency, speed, and identification of hazards that are not clearly visible to a driver until the last moment [12-15]. Improvement in hazard anticipation skills is a likely contributor to crash reductions over the first few years of licensure.

A number of hazard anticipation training programs have been developed for young drivers, with the goal of accelerating the learning process in a safe environment. Some teach drivers to predict or identify critical regions of the roadway with potential or hidden risks and to generalize these to a broader set of real-world situations [15, 16]. Others attempt to improve hazard anticipation by virtually exposing young drivers to traffic hazards they might not yet have encountered in the real-world with just a few months of driving [9, 10]. Some provide feedback on performance [17, 18]. Given recent increases in the number and variety of programs – and recognition of the importance of hazard anticipation skills for young drivers – the purpose of this review was to assess the empirical literature on hazard anticipation training programs for young drivers.

Methods

Studies that described training in hazard anticipation, perception, awareness, recognition or similar terminology for young drivers were included in the review if they met the following criteria: 1) included an assessment of safety-related outcomes of a hazard anticipation training program; 2) published between January 1, 1980 and December 31, 2013 in an English language peer-reviewed journal or conference proceeding; and 3) included at least one group that uniquely comprised a cohort of study participants <21 years. This age range was chosen due to the international variation in licensure age.

An experienced library information specialist conducted a comprehensive literature search using the following Boolean search string: (“hazard anticipation” OR “hazard perception” OR “hazard recognition” OR “risk recognition” OR “risk perception” OR “anticipation training”) AND (teen* OR you* OR novice* OR adolescen*). The following databases were included in the literature search: Transportation Research Information Database, PubMed, ISI Web of Science, PsychInfo, Psychological Abstracts, and Science Direct.

The initial keyword literature search yielded 201 unique studies. Each study was examined in two stages by two members of the research team for inclusion, first based on title and abstract, then on full paper review. Disagreements were resolved based on consensus of two reviewers. A number of studies did not provide an age range of the sample; however, studies were included if the reported mean age of study participants was <21. Eighteen studies met inclusion criteria in the initial search. Following review of personal reference collections and suggestions from peer reviewers, one additional study was identified that met inclusion criteria, bringing the total number of studies included in the review to 19. Table 1 summarizes the study design, number of training and comparison groups, sample, driving experience, training method, timing of the evaluation, and main outcome measures of these 19 studies. The following section briefly describes each study's training program, evaluation, and main results.

Results

Of the 19 studies, 11 used an interactive computer-based approach for training [9, 10, 13, 15, 16, 19-24], five used videos [12, 17, 18, 25, 26], two conducted training in a driving simulator [27, 28], and one used a combination of training methods [29]. Note, all drivers (e.g. trained group, untrained, etc.) are young drivers unless otherwise noted (e.g. “experienced” driver group).

Interactive Computer-based Approach

Act and Anticipate Hazard Perception Training (AAHPT)—A computer-based training program, AAHPT exposes young newly licensed drivers with basic vehicle handling skills to hazards they may not have encountered, with the goal of enhancing ability to anticipate these types of hazards [9, 10]. Three intervention modes were tested: active, instructional, and hybrid. During “active” training, drivers viewed short scenes of real-life driving situations and were required to press a button when they detected a hazard (no feedback about the response was provided). In “instructional,” participants had a tutorial that included both written material and video-based examples regarding hazard anticipation and they were not required to respond to hazards. “Hybrid” used a combination of active and instructional approaches [10].

Borowsky et al. [9] and Meir et al. [10] evaluated the effects of the three different modes one week after training. The study also included a group of untrained young and untrained experienced drivers. Evaluation involved a hazard perception test of 58 movie clips (button-pressing for hazard detection) with three traffic environments (residential, metropolitan and inner-city) with five categories of hazards: pedestrian behavior, obstacles on road, approaching an intersection, other vehicle behavior, and limited field of view. An eye tracker was used to detect scanning patterns during the hazard perception test. Although a large number of environments and categories were examined, improvements were found on only a few selected measures. For example, hybrid and instructional trained groups reported significantly more potential hazards involving pedestrians in residential areas than experienced or untrained young drivers [10]. Similarly, Borowsky et al. [9] found that the hybrid and instructional groups were more sensitive to the presence of pedestrians than the other groups; in addition they concluded that experienced drivers scanned for shorter periods of time (i.e. were more efficient with their scanning).

Risk Awareness and Perception Training (RAPT)—RAPT is a PC-based training program designed to teach novice drivers about various types of risks encountered while driving (particularly emerging or latent risks), and to demonstrate what behaviors minimize this risk [13, 16, 19]. RAPT includes three categories of training scenarios: “obstructions” (e.g., another vehicle is obscuring the driver's view of a pedestrian crossing): “sign ahead” (e.g., a traffic sign indicates a potential upcoming hazard that the driver cannot yet see); and “visible pedestrians and vehicles” (e.g. a vehicle immediately ahead stops to avoid hitting a pedestrian). Three versions of RAPT have been developed, differentiated by content and presentation mode. RAPT begins with instructions and initial practice, followed by pre-test, training and post-test. The pre-test includes plan-views (simplified top-down schematic views) where participants are instructed to click (with the mouse) on an area of the screen where they would need to direct attention. During training, plan-views are presented with explanations about risks, and participants are given up to four opportunities to identify areas of risk. The post-test measures risk identification, again with mouse clicks [13, 19]. In RAPT-3, perspective-view photographs are also used [23] [19].

RAPT training has been evaluated immediately, within 3-5 days, and in one study, up to 12 months post training [24]. Young driver participants included learners, newly licensed (< 1 month) and more experienced licensed drivers (> 1 year). RAPT has been evaluated with high-fidelity driving simulation and on-road evaluations, primarily using an eye tracker for measuring glance location. The main outcome measures included percentage of correct glances on pre-determined locations of potential risk. RAPT studies focused on both “near” (scenarios similar to training) and "far" (scenarios different from training) transfer of effects. Results from driving simulators indicate significantly more correct glances at pre-determined areas of risk by trained than untrained drivers [21, 22], in both near and far transfer, immediately [13, 16] (e.g., near: 78% correct glances for trained v. 36% for untrained; far: 77% v. 44%) [13], and 3-5 days post training (near: 52% v. 29%; far: 53% v. 27%) [19]. In addition, Pradhan and colleagues [20] identified that although there was previous evidence that RAPT training improved hazard anticipation skills, it did not have an impact on measures of attention.

RAPT has also been evaluated in on-road settings [13, 23]. Immediately following training, young drivers had significantly more glances at critical regions than untrained young drivers (e.g. near: 79% v. 40%: far: 58% v. 38%) [13]. In one on-road evaluation up to 12 months after training, near and far transfer effects were found with RAPT-3 trained young licensed drivers, though the percent of correct glanced remained below those of experienced untrained drivers [24]. Overall, evidence from the on-road studies [13, 23] suggests similar improvements following training in comparison to RAPT simulator studies conducted in laboratories, particularly in near-transfer scenarios. Results of a larger-scale study of the effect of RAPT training on crashes are expected to be available in 2015 (personal communication, Richard Blomberg).

Fisher et al. [15] conducted a study prior to the development of RAPT which involved an evaluation of an early version of Driver ZED from the AAA Foundation for Traffic Safety (http://www.driverzed.org/). This was a PC-based program that included 80 scenarios for the participant to scan, spot, act and drive, using a computer mouse. Evaluation conducted one-week post training on a driving simulator included perceptions of, and responses to, hazards (hidden hazards, warnings to potential hazards, and situations requiring driving skill). They found that trained young drivers made maneuvers in risky scenarios that were different than untrained young drivers. For example, trained young drivers applied the brakes more often in an intersection going past a truck and maneuvered the vehicle in a more cautious manner in anticipation of a potential hazard (e.g.they pulled out farther into a roadway in order to see pedestrians that could be hidden behind a truck).

Video-based Approach

Commentary Driving—Commentary driving is a technique in which a person verbally describes what he/she is seeing, thinking, and planning to do [30]. The following studies used commentary driving in different ways, including whether commentary was provided by participants or experts.

Isler et al. [12] examined the effects of video-based participant commentary driving (training) on a video-based hazard perception dual task (outcome measure). The commentary training video included approximately 150 immediate and potential visible hazards and participants were instructed to provide verbal commentaries describing hazards they observed. The hazard perception dual task measure included the primary task of searching for hazards on video-based scenarios (detect (mouse click) with verbal identification) while performing a secondary tracking task (keep a moving target dot within a square on the screen). At baseline (pre-training) in the hazard perception dual-task, young drivers detected and identified fewer hazards, and had slower reaction times compared to experienced drivers. Immediately after commentary training, there were no differences among young trained and experienced drivers on detecting and identifying hazards. In addition, after training, young trained drivers detected and identified more hazards than untrained young drivers.

McKenna, Horswill and Alexander [25] examined the effects of *expert* commentary on young driver risk taking behavior. For the expert commentary training, participants viewed video of traffic situations filmed from the point of view of the driver, accompanied by pre-recorded audio from an instructor who "referred to potentially hazardous events and how to identify them" (p. 4). Evaluation immediately after training involved viewing new traffic scenes and pressing a button when a hazard was perceived, as well as additional video-based (e.g. speed, gap acceptance) and self-report measures. Trained drivers were faster in perceiving hazards than untrained drivers (no times noted in results). In a second experiment participants were evaluated on a video-based speed test that included hazardous and less hazardous scenes. There were both main and interaction effects: for trained drivers, speed reduction was greater for hazardous scenes than less hazardous scenes.

Wetton et al. [26] compared five groups: 1) "what happens next" training, 2) expert commentary training, 3) hybrid commentary training (participant and expert commentary), 4) full training (what happens next plus hybrid commentary), and 5) untrained group. The training groups all received a video on hazard perception information and strategies. The expert commentary consisted of video scenes with pre-recorded expert commentary describing dangerous situations. The hybrid first had participant followed by expert commentary for each scene. In "what happens next" training (not the same as commentary training), participants viewed clips that cut to a black screen and were asked to generate as many possible developments that could occur in the traffic scene after the cut-point. A voiceover then identified all possibilities of what could happen next. Hazard anticipation was measured with video clips in which participants used a computer mouse to identify road users likely to be involved in a potential conflict. The full training group had the largest improvement and improved response times both immediately and at ∼1 week post training (range 6-36 days), and were significantly better than the untrained group at both time points. The "what happens next" had the least improvement. Hybrid commentary condition did not significantly improve response times over expert commentary. All training groups showed training decay at ∼1-week; for example, expert commentary and "what happens next" groups both had better response times than the untrained group immediately after training, but after one week, "what happens next" was not faster than the untrained group, but expert commentary was still faster.

Animated Video Clips—Petzoldt et al. [17, 18] tested a multimedia program designed to link theoretical driving lessons with actual driving. Participants watched short (50-70 second) animated sequences (video) from the point of view of the driver, over two sessions (delivered in one study visit for these studies). Sequences were paused at key situations, and participants were asked a multiple choice question or to mark a relevant area. Questions in the first session examined participants' understanding and predictions about the traffic scene; questions in the second session examined participants' assessment of the need for taking action, and what would be the appropriate action. During both sessions, inaccurate responses were corrected, and feedback was provided. Comparisons were made between three groups: computer-based training, paper-based training (modeled after the computer session), and untrained young drivers. Two days after training, participants were tested in a driving simulator with an eye-tracker to measure critical glance sequences and glance times for both near and far transfer. The computer-based training group glanced on the hazards sooner, and completed appropriate glance sequences faster than the paper-based or untrained groups.

Simulator Training Studies

Allen et al. [27] conducted a simulator training study with driver education students. The curriculum was broad but included eight training sessions on a low-fidelity desktop-simulator. Weekly sessions began with slides and videos describing hazardous situations and risky driving practices, followed by training drives of increasing difficulty. A post-test evaluation drive immediately followed the final training session. Compared to an untrained group, trained adolescents had fewer speed exceedances (2.2 v. 4.0), stopped at a hidden stop sign more often (73% v. 41%), and had fewer collisions with an oncoming vehicle passing in the driver's lane (0% with a collision v. 36% with a collision) [27].

SimRAPT—Vlakveld et al. [28] conducted a simulator training study using scenarios developed for RAPT, thus called SimRAPT (simulator-based risk awareness and perception training). SimRAPT focuses on latent hazards and involved error learning – situations in which the driver would have difficulty avoiding a crash. Using a low-fidelity simulator, training included 10 scenarios (seven hazard anticipation scenarios with common latent hazards and three scenarios with no hazards). Participants drove three versions of each scenario: hazard detection, error and improvement drives. In the “hazard detection drive,” hazards did not materialize initially. In the “error drive,” they materialized aggressively. This was followed by an instructional video that explained what happened and described appropriate gaze behavior. Finally, participants drove an “improvement drive” where the same hazard materialized, but less aggressively. Training was evaluated immediately afterward on an advanced high-fidelity driving simulator with eye tracker to measure gaze location. Evaluation consisted of three 10-minute drives with potential hazards. The SimRAPT group had more correct gaze location than an untrained group for both near (SimRAPT 84% correct v. untrained 57% correct) and far transfer (71% v. 54%) scenarios [28].

Multiple Method Approach

Isler et al. [29] used a multi-faceted, complex training program that involved a 5-day training (4-6 hours per day) at a “Driver Training Research Camp.” Group 1 received higher-order training with on-road participant commentary, video-based hazard perception training (computer), on-road self-evaluation exercises, and focus group discussions to improve situational awareness, visual search, and hazard anticipation. Group 2 received vehicle handling skill training by a professional instructor. Group 3 received no training. Outcomes were measured by an on-road assessment, hazard perception test (watching a video and providing commentary), and self-report questionnaires. The group that received higher-order training showed improvement in visual search and a composite driving measure from the on-road assessment. They also showed an improvement in the percentage of hazards detected on the hazard perception test.

Discussion

This critical review included 19 peer-reviewed studies evaluating hazard anticipation training programs for young drivers. The training programs, outcomes measures, study designs, length of follow-up, and level of driving experience among participants varied across studies. All studies reported some type of positive training effect on young drivers' hazard anticipation behavior. Despite promise of hazard anticipation training, the limitations and methodological issues with previous studies provide important direction for future research.

Sample size was a common limitation. Many studies included less than 20 participants per group. Sample size can be constrained by logistics and costs associated with the use of high-fidelity driving simulators, participant recruitment, training and follow-up. However, larger samples are needed to determine generalizability of training effects. In addition, many studies did not clearly report descriptive statistics for age and amount of driving experience (or length of licensure) of participants. Other demographic characteristics were also largely lacking. Overall, more information about participants is needed to understand effects of training programs across populations.

Improved reporting on driving experience can help better distinguish between age and experience, which are too often conflated in the “young” driver literature. The distinction between age and inexperience is critical to understanding and addressing crash risks of novice drivers, thus studies must precisely address this issue. Hazard anticipation training is presumably intended for beginning drivers, yet many studies did not focus just on beginners. Study samples ranged from learners taking driver education, to young drivers with a year or more of driving experience, and some studies combined learners and licensed groups in their sample [12, 26] (see Table 1). Only a few described how the sample was an appropriate target of the selected training program, or how the training program was intended to address specific skill-deficits of the sample. Hazard anticipation training is unlikely to be helpful for all drivers who may be “young.” For example, a novice adolescent driver who has not mastered basic vehicle handling skills may not benefit from advanced training [9, 10]. Similarly, advanced training may not be helpful for a young driver who has already been driving unsupervised for a year or more. Future studies evaluating hazard anticipation training programs should examine effects on those drivers who are most likely to need, or benefit from, this kind of training. Moreover, studies must provide a clear description of how the training matches the needs of the sample.

Several studies demonstrated that training effects can be seen in both near and far transfer scenarios (e.g. [16, 19]); however, it is not clear if hazard anticipation skills learned in a laboratory generalize to “real world” driving, especially in potentially high-risk situations such as driving at night or with multiple peer passengers. Four studies included an on-road component [13, 23, 24, 29] with gaze location as an outcome measure. As previously noted, the similarities between simulator laboratory and on-road results in the RAPT studies are encouraging [13, 23]. Isler et al [29] also found their weeklong “training camp” improved on-road assessment outcomes, but this time-intensive training approach would likely be extremely difficult to replicate and scale to a larger sample. Even assuming that training effects translate to “real world” situations, no studies have evaluated the effects of training programs on young driver crash outcomes. Moreover, no studies have used naturalistic observational methods, such as in-vehicle cameras, to measure driving behaviors of study participants outside of the laboratory. An examination of actual real-world driving and crash outcomes is needed to identify whether training effects extend beyond the laboratory.

Outcome measures were predominately short-term, and they varied across studies. To date, there has been an almost exclusive focus on evaluation immediately or within one week of training. Only one study assessed longer-term effects of training [24]. Although not without challenges, long-term follow up can help identify whether the effects of training are sustained over time. In particular, it is important to understand how training fits within the context of a young driver's growing experience behind the wheel, where natural exposure to hazards may in and of itself provide learning opportunities for young drivers. A diverse and sometimes large number of hazard anticipation outcomes were used in studies, with report of success based on improvement in just a few select measures. Registration of trials on ClinicalTrials.gov would aid in reporting of pre-defined outcome measures of clinical trials. Lastly, beyond studies conducted with the same training program (e.g. RAPT or AAHPT), outcome measures are not easily compared across studies. It is difficult to compare efficacy or effectiveness of different training programs without common measures, such as a standardized hazard perception test, simulated drives with pre-defined eye glance measures, or on-road protocols.

Limitations of this Review

The strict inclusion criteria for this review may have excluded important studies. For example, a number of training studies were not included because they did not meet age criteria (e.g., Crundall et al. [30] included 17-25 year olds; Wang et al. [31] included participants with a mean age 23.1). We were unable to include a study by Chapman et al. [32] examining the effects of a training video on novice driver scanning patterns over the first year of driving, because participant age was not reported. Likewise, publications where peer-review could not be verified, such as some conference proceedings and government reports, were also excluded from the review.

Recommendations and Research Needs

Future research should include long-term follow up measures, including crash outcomes, and examine hazard anticipation training effects on young drivers most likely in need of this kind of training. Long-term follow up can address two major gaps: assessing the relationship of hazard anticipation training to young driver crash risk, and understanding whether training effects can persist over time. Moreover, although studies included young drivers at different stages of the licensing process, no study followed a cohort of young drivers to assess the effectiveness of training during the learner period, at the beginning of independent licensure, at 6-months, or 12-months. Evaluation at multiple time points would provide a clearer picture of how hazard anticipation training contributes to crash reduction during the early period of high-risk driving. Much of the peer-reviewed published research has focused on assessment through behaviors such as eye glance location, driving performance, and button pushes. Future studies might consider heart rate, respiratory response, pupil dilation, and other physiological measures that are more automatic or involuntary than button pressing, which may be a useful indicator of the implicit understanding of the underlying processes related to hazard anticipation [33]

Conclusion

Hazard anticipation errors are common in the crashes of young drivers [5-8]. Consequently, programs that accelerate the acquisition of hazard anticipation skills in a safe environment could be an important tool for reducing the high crash rates of newly licensed drivers. A number of training programs and interventions have been shown to improve hazard anticipation in the laboratory, and a few demonstrate these skills translate to on-road assessments. However, more research is needed to determine how well these acquired hazard anticipation skills are retained over the long-term and whether training decreases subsequent crashes. The question of how hazard anticipation skills improve – whether by experience behind the wheel, training, or some combination – has yet to be fully explored.

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Implications and Contributions

A number of hazard anticipation training programs have been developed for young drivers. This review indicates that many of these programs have demonstrated improvements in selected hazard anticipation outcomes, predominately measured immediately after training. More research is needed to determine effectiveness on long-term outcomes, crashes, and optimal timing of program delivery.

Table 1

Description of Reviewed Studies

Study	Study design and Method for Young Driver Group Assignment	Group comparisons	Young driver age and driving experience	Training[a]	Evaluation timeline	Outcomes measured using:				
						Eye tracker	Simulator	On-Road	PC or video response	Self-report
Allen et al., 2011 (27)	2 groups Pre-post test Assignment method not described	1 Trained 1 Untrained[b] (Total n=67)	Driver education students, Age: 14-17	Desktop simulator-based driving instruction program (~8-weeks) with targeted education about hazardous situations	End of training		X			
Borowsky et al., 2012 (9) **and Meir et al., 2014** (10)	5 groups Training followed by post-test Assignment based on demographics and sensation seeking scores	3 Young trained --Active --Instructional --Hybrid 1 Young untrained (Total young: n=40) 1 Experienced untrained (n=21)	Learner permit, Mean 1.7 months experience, Age: 17-18	Computer-based AAHPT (Active, Instructional, Hybrid) (1.5 hrs)	1-week post training	X			X	
Fisher et al., 2002 (15)	3 groups Training followed by post-test Assignment method not described	1 Young trained (n=15) 1 Young untrained (n=15) 1 Experienced untrained (n=15)	Driver education students, Age: 16-17	The AAA Foundation Driver-ZED program (1.5 hrs)	1-week post training		X			
Fisher et al., 2007 (13)	Both experiments: 2 groups Training followed by post-test Random assignment	Experiment 1 – on road 1 Trained (n=12) 1 Untrained (n=12) Experiment 2 – simulator 1 Trained (n=6)	Licensed 1+ year, Age: 18-21	Computer-based RAPT-Version 3 (45 min)	End of training	X	X	X		

Study	Study design and Method for Young Driver Group Assignment	Group comparisons	Young driver age and driving experience	Training[a]	Evaluation timeline	Outcomes measured using:				
						Eye tracker	Simulator	On-Road	PC or video response	Self-report
		1 Untrained (n=6)								
Isler et al., 2011 (29)	3 groups Pre-post test Random assignment	2 Trained: --higher-order skills (n=12) --vehicle handling skills (n=12) 1 Untrained (n=12)	Licensed, Age: 15-18	Embedded in a 5 day "Driver Training Research Camp." Higher order: Road commentary, PC-based exercises, on-road training and focus group. Vehicle handling: Training in vehicle handling skills.	1-2 days post training			X	X	X
Isler, et al., 2009 (12)	4 groups Pre-post test Random assignment	1 Young trained (n=8) 2 Young untrained (n=16) 1 Experienced trained (n=8)	Learner and Licensed, Mean 1.5 years experience, Age: 18-19	Participant road commentary training	End of training				X	
McKenna et al., 2006 (25)	Both experiments: 2 groups Training followed by post-test Random assignment	Experiment 1 1 Trained (n=46) 1 Untrained (n=45) Experiment 2 (Total n=145) 1 Trained 1 Untrained	Exp 1: Mean 1.5 years licensed Mean age=18.9 Exp 2: Mean 1.8 years licensed Mean age=19.2	Expert commentary driving (21 min)	End of training				X	X
Petzoldt, et al., 2013 (17)	3 groups Training followed by post-test Assignment method not described	2 Trained --computer-based (n=12) --paper-based (n=13) 1 Untrained (n=11)	Students in driving school, Mean age=17.4	Computer-based: Animated video clips of traffic scenes with questions about potential risks in each	2 days post training	X	X			

Study	Study design and Method for Young Driver Group Assignment	Group comparisons	Young driver age and driving experience	Training[a]	Evaluation timeline	Outcomes measured using:				
						Eye tracker	Simulator	On-Road	PC or video response	Self-report
				scene (two 40 min sessions). scene (two 40 min sessions). <u>Paper-based:</u> Similar to computer-based training except static images were used (two 25 min sessions)						
Petzoldt et al., 2013 (18)	3 groups Training followed by post-test Assignment method not described	1 Young trained (n=12) 1 Young untrained (n=11) 1 Experienced untrained (n=13)	Students in driving school, Trained: Mean age=18.3 Untrained: Mean age=17.2	Computer-based animated video clips of traffic scenes with questions about potential risks in each scene (two 40 min sessions).	2 days post training	X	X			
Pollastek et al., 2006 (16)	2 groups Training followed by post-test Random assignment	1 Trained (n=24) 1 Untrained (n=24)	Learners permit, 1-5 months experience Trained: Mean age=16.6 Untrained: Mean age=16.4	Computer-based RAPT-Version 1 (90 min)	End of training	X	X			
Pradhan et al., 2005 (21)	2 groups Training followed by post-test Groups recruited separately	1 Trained (n=12) 1 Untrained (n=12)	Learners permit, Trained: Mean age=16.7 Untrained: Mean age=16.4	Computer-based RAPT-Version 1 (90 min)	3-5 days post training	X	X			
Pradhan et al., 2006 (19)	2 groups Training followed by post-test. Random assignment	1 Trained (n=16) 1 Untrained (n=16)	Learners permit, Trained: Mean age=16.9 Untrained: Mean age=16.5	Computer-based RAPT-Version 1 (90 min)	3-5 days post training	X	X			
Pradhan et al., 2009 (20)	3 groups Training followed by post-test Random assignment	1 Young trained (n=11) 1 Young untrained (n=12) 1 Untrained experienced (n=11)	Driver education students, Age: 16-18	Computer-based RAPT-Version 3 (45 min)	End of training				X	

Study	Study design and Method for Young Driver Group Assignment	Group comparisons	Young driver age and driving experience	Training[a]	Evaluation timeline	Outcomes measured using:				
						Eye tracker	Simulator	On-Road	PC or video response	Self-report
Pradhan et al., 2007 (22)	2 groups Training followed by post-test Random assignment	1 Trained (n=12) 1 Untrained (n=12)	Leaners permit, 1-5 months experience (Pollastek et al. 2006 (16) subsample)	Computer-based RAPT-Version 1 (90 min)	End of training	X	X			
Pradhan et al., 2009 (23)	2 groups Training followed by post-test Random assignment	1 Trained (n=12) 1 Untrained (n=12)	Licensed 1+ year, Age: 18-21	Computer-based RAPT-Version 3 (45 min)	End of training	X		X		
Taylor et al., 2011 (24)	3 groups Training followed by 2 post-tests Random assignment	1 Young trained (n=15) 1 Young untrained (n=13) 1 Experienced untrained (n=15)	Licensed ~1 month, Age: 16-18	Computer-based RAPT-Version 3 (45 min)	Immediately and roughly 8 months post training	X		X		
Vlakveld et al., 2011 (28)	2 groups Training followed by post-test Random assignment	1 Trained (n=18) 1 Untrained (n=18)	Licensed 1+ years, Trained: Mean age=19.4 Untrained: Mean age=19.1	SimRAPT (Simulator RAPT training) (40 min – 1 hour)	End of training	X	X			
Wetton et al., 2013 (26)	5 groups Pre-2-post tests Random assignment	4 Trained: --Expert commentary training --Hybrid commentary --What happens next training --Full training 1 Untrained (Total n=233)	Learner and licensed, Mean 1.7 years experience, Mean age=18.2	<u>All groups:</u> Video describing strategies to improve hazard perception. <u>Expert commentary:</u> Video of road scenes with expert commentary. <u>Hybrid commentary:</u> Self-generated commentary, followed by expert commentary. <u>What happens next:</u> Self-generated predictions of	Immediately and 10 days post training				X	

Study	Study design and Method for Young Driver Group Assignment	Group comparisons	Young driver age and driving experience	Training[a]	Evaluation timeline	Outcomes measured using:				
						Eye tracker	Simulator	On-Road	PC or video response	Self-report
				what happens next in a driving scene, followed by expert description of all possibilities. what happens next in a driving scene, followed by expert description of all possibilities. what happens next in a driving scene, followed by expert description of all possibilities. what happens next in a driving scene, followed by expert description of all possibilities. what happens next in a driving scene, followed by expert description of all possibilities. what happens next in a driving scene, followed by expert description of all possibilities. what happens next in a driving scene, followed by expert description of all possibilities. Full training: All groups hazard perception video, hybrid commentary and what happens next. (All groups ~35 min)						

Note:

[a]See main text for more detailed descriptions of trainings.

[b]Originally consisted of two control groups (no educational materials and educational materials via slides), combined for analysis.