Novice Driver Situation Awareness and Hazard Perception: An Exploratory Study

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Abstract
Varying definitions and approaches to the measurement of drivers' hazard perception are reviewed within a broad framework of 'novice driver competencies'; hazard perception is defined as a subset of performance elements and underlying capacities within this framework. Requirements to support the development of hazard perception training programs are discussed, identifying the need for a better understanding of developmental changes in young drivers' cognitive schemata, mental models and expectancies concerning road traffic system operations and the behaviour of other drivers. From the first in a planned series of studies to address this need, some preliminary results are presented, based on content analysis of driving commentaries by young, inexperienced drivers travelling as a passenger. Comparing commentaries recorded at night with those recorded during the day, it is tentatively suggested that the higher perceptual salience of some objects at night may tend to 'capture' attention, which might sometimes be to the detriment of overall performance. The effects of prior driving experience on the content of such commentaries are being investigated.

'Hazard Perception': conceptual framework and definitions
The relatively high crash risk of young drivers is a very well documented problem, and poor 'hazard perception' skills have been identified by many researchers as an important causal factor. However, inconsistent terminology and conceptual 'fuzziness' are recurring problems in literature on 'hazard perception'. McKenna (2000) simply said "By hazard perception I mean the ability to anticipate, the ability to read the road". This suggests that 'hazard perception' is virtually synonymous with more general situation awareness (SA), which in simple terms is "a person's perception of the relevant elements in the environment, as determined from system displays or directly by the senses" (Endsley, 1995). Endsley distinguished situation *awareness* from situation *assessment*, which she defined as "the process of achieving, acquiring, or maintaining SA", and described three hierarchical levels of SA: Level 1 = perception of the elements in the environment; Level 2 = comprehension of the current situation; Level 3 = projection of future status. When mental workload level is high, the quality of SA is likely to suffer, to an extent known in air traffic control as 'losing the picture' (Kirwan et al, cited by Sandom, 2001). This is likely to be a greater risk for inexperienced drivers whose skills have not fully developed, since other aspects of their driving task will require greater attention than for highly experienced drivers whose performance is more highly automatised.

Components of the different levels of SA can be identified in many descriptions of hazard perception. However, few definitions of hazard perception include reference to all three levels, and most have a more specific focus than SA, reflecting the idea that a hazard is a specific object or event. Hoyos (1988) defined a hazard as "the possibility that a mass, ie. a vehicle, might undergo a change in velocity or direction by colliding with a moving or non-moving object or by swerving off the road." Lerner and Rabinovich (1997) distinguished between 'actual hazards', which are situations that expose individuals to increased risk regardless of whether those risks are perceived by the individual, and 'perceived hazards', which are situations perceived by drivers as presenting increased risk. In both cases risk is the essential element underpinning whether or not something is hazardous, either in relation to *actual* risks associated with a situation (presumably determined by the accident history of that or similar situations) or in terms of a driver's perception of the risk inherent in that situation.

Consistent with the idea of a hazard being a *specific* situation, McKenna and Crick (1992) defined hazard perception as "the ability to recognise dangerous road and traffic situations", which focuses on a specific subset of situations, but they added "…or the ability to read the road", which invokes the broader ideas of SA, Levels 1 and 2. Their reference to "potentially" dangerous suggests some projection into the future, i.e. Level 3 SA. They suggested that "in psychological terms, hazard perception refers to the ability to detect potentially threatening events by the deployment of a mental model of the road network and how its various elements interact". In a similar vein, Mills et al (1998) wrote that "Hazard perception or hazard recognition is the ability to identify potentially dangerous traffic situations as they arise".

The above definitions of hazard perception refer to the *identification* of hazards (discerning whether or not a hazard is present) rather than to assessing the level of risk they may represent. However, Deery and Love (1996) defined hazard perception as "the process of identifying hazardous objects and events in the traffic system and quantifying their dangerous potential." Their definition replaces McKenna and Crick's "reading the road" element with "quantifying their dangerous potential", thus retaining focus on a specific hazard, with the additional notion of assessing risk level. 'Risk' is often mentioned in relation to hazard perception, and sometimes appears to be conflated with hazard. In an earlier paper, Brown and Groeger (1988) defined risk perception as "the detection by drivers of any shortfall in their ability to avoid realizing the potential of immediate task and environmental hazards". Or, to paraphrase their own wording elsewhere in the same paper: "risk perception" refers to the driver's ability to detect hazards, to assess their own ability to deal with the hazards and to compare the results of these assessments in order to determine whether or not they are able to cope with the hazard confronting them.

The following definitions have been adopted for the present project. They are similar to those arrived at by Haworth et al (2000, p.10), based on their useful review of this topic, except that in their definition of a hazard, they excluded situations where the risk "is beyond the immediate control of the driver in question".

Risk: the *probability* of a negative outcome, in this case a road accident, weighted according to the severity of the negative outcome, and most usefully expressed as per some meaningful denominator (e.g. crashes per 1000 kilometres driven for a certain class of driver).

Risk factor: a general condition that increases the likelihood of an accident (e.g. driver inexperience, slippery road), that can be mitigated by general countermeasures and by driver counter-strategies.

Hazard: a specific, defined object, event or situation that increases probability of an accident in its immediate spatial and temporal vicinity; the risk associated with a hazard can be mitigated by drivers' perception of, and possible avoidance response to, the hazard.

Hazard perception: the process whereby a road user notices the presence of a hazard.

Risk perception: the individual driver's impression of the risk level associated with a hazard or risk factor. Hazards vary in their perceived *risk*, which may be influenced both by the nature of the hazard, and by the driver's perception of their own competence, particularly their competence to cope with the specific hazard.

Risk assessment: the process whereby a road user assesses the riskiness of a driving situation.

Risk assessment is seen as a conscious process. As defined here, it would not usually occur at the operational and tactical levels of driving performance, and only occasionally at the strategic level (Michon, 1985; van der Molen & Botticher, 1988), since drivers do not often *consciously assess* risks while driving (unless required to do so by a researcher). Both hazard perception and risk perception, as defined above, occur routinely at all levels, particularly the operational and strategic. The level of attentional resources allocated to these perceptual tasks can usefully be considered within the framework of 'recognition primed' decision making (Klein, 1997). This type of decision occurs at an early stage of information processing, based on very rapid comparisons of sensory information patterns with existing cognitive schemata and mental models. By this means, experienced drivers (i.e. those with well-developed cognitive schemata and mental models concerning driving) are able to perceive and act upon traffic situations more rapidly, using less attention, than very inexperienced drivers. In normal circumstances, an experienced driver's SA and driving performance would presumably be based on such processes, although some types of hazard and higher levels of perceived risk might demand more attention. Conclusions from empirical research on drivers' perceptual performance are briefly outlined in the following section, with emphasis on differences related to amount of driving experience.

'Hazard perception' performance: research evidence

Maycock and Forsyth (1997) investigated relationships between licence test errors made by a large cohort of U.K. novice drivers, and their accidents during the following three years. Errors of 'awareness and anticipation' were found to be the strongest accident predictors for both men and women. Such errors included: *inadequate observations* or precautions before emerging from a junction, or while reversing, or while turning in the road, or before starting the engine, or before moving off; *insufficient notice taken* of approaching traffic, or the signals of other road users, or pedestrian crossing lights; and *inadequate anticipation* of the actions of cyclists, pedestrians on a crossing, or other drivers. Laboratory research by Groeger and colleagues (e.g. Groeger & Chapman, 1996) on the development of young drivers' judgements and understanding of the road traffic environment obtained results consistent with these on-road observations. Based on driver responses to a 'Judgement of Traffic Scenes' task, they identified three 'metafactors' characterising drivers' perceptual performance, which they labelled Danger, Difficulty and Abnormality. Differentiation of judgements of traffic scenes in terms of these three factors was not present in drivers with less than 1000 miles driving experience, and was only well differentiated in drivers with 6000 miles or more.

From a review of research evidence, Mayhew and Simpson (1995) identified seven driver 'competencies' that are important influences on crash risk, four of which are primarily perceptual or cognitive: (1) visual search/ scanning strategies that provide effective and efficient monitoring of the driving environment and, in particular, the use of peripheral vision; (2) hazard perception – the ability to detect, recognise and respond to potential hazards; (3) risk assessment; (4) decision-making. Another – the ability to integrate and coordinate these and other skills effectively so that several can be carried out simultaneously – has important cognitive components, and the ability to control attention allocation has been identified as a significant problem for young drivers (Regan, Triggs & Deery, 1998). Regarding perceptual deficiencies, Mayhew and Simpson (1996) concluded:

> "Novice young drivers are less aware of hazards in the environment and are less likely than older experienced drivers to identify moving objects as hazards. As a consequence, it takes novice drivers longer to respond to a hazard … Their problems with detecting hazards likely relates to the fact that their search and

scan abilities are less developed than those of more experienced drivers. The novice driver may not have fully developed the use of peripheral vision and because they have a smaller range of scanning of the roadway than experienced drivers, they can fail to detect hazards in the environment." (Mayhew & Simpson, 1996, p.4)

Lonero et al (1995) characterised driver information processing and response selection in terms of a series of stages, including: *detection* (visual scanning, detecting path deviation); *perception* (seeing with understanding, potential hazard recognition); and *evaluation* (risk assessment, other users' expectancies, attribution bias). Mayhew and Simpson (above) attributed young drivers' poor hazard perception primarily to deficiencies in the process of detection (inadequate searching and scanning; less use of peripheral vision) rather than to deficiencies in perception or evaluation. Lynam and Twisk (1995), however, gave greater emphasis to the second and third of Lonero et al's three stages.

More recent UK research has investigated relationships between young drivers' visual scanning behaviour, available attentional resources and perception of traffic situations (e.g. Underwood & Chapman, 1998; Crundall et al, 1999; Underwood, 2000). They have documented ways in which novice driver visual search patterns differ from those of more experienced drivers, finding a reduction in the attentional resources available to novice drivers for perception of information in the periphery of the visual field, compared to more experienced drivers. It appears that a significant factor underlying these differences is that experienced drivers have a lower demand for foveal attentional resources, due to their more automatised level of skill development. That is, the 'useful field of view' is evidently smaller in inexperienced drivers, just as it is among those older drivers who experience deterioration in their information processing capacity (e.g. Owsley et al, 1998).

Young driver testing and training

Many people see improved driver training and/or testing as possible means of reducing young drivers' crash risk. However, driver training and licensing programs throughout the world currently focus primarily on road law knowledge and vehicle control skills, despite evidence that deficiencies in perceptual and cognitive aspects of driving performance are important contributors to young driver crashes.

Various forms of perceptual testing have been developed by researchers over the past few decades (Haworth et al, 2000; Macdonald, 1987, Sexton, 2000), although very few licensing systems incorporate such tests. Development of the VicRoads hazard perception test (HPT) commenced in 1989 and was introduced as a driver licensing requirement in 1996 (Drummond, 2000; Haworth et al, 2000); similar forms of test have recently been implemented as part of the Western Australia and New South Wales driver licensing systems (Shanks, 2002). Low scores on the Victorian HPT have been associated with higher involvement in fatal and serious crashes during the subsequent 12 month period (Congdon, 1999). There is little value in introducing such testing if it is not associated with an improvement in the related skill levels of novice drivers. Macdonald (1987) recommended that a hazard perception test should be introduced as part of a graduated licensing process, and that this should be accompanied by the development of hazard perception training. As yet there are no systematic programs to facilitate the development of perceptual and cognitive skills, although it is has been established that performance on some HPTs can be improved by specific training (Haworth et al, 2000; McKenna & Crick, 1997; Sexton, 2000). For example, Mills et al (1998) reported positive outcomes from two to four hours of training on-road assessment entailed the learner having to verbally identify any hazardous situations as soon as they occurred. It was concluded that "it is possible to improve the hazard perception skills of novice drivers by training".

A basic problem in developing such training is our poor understanding of the precise aspects of drivers' perceptual and cognitive competencies that are being assessed by the current Victorian HPT, and the poor definition of constructs which an ideal HPT *should* assess. Related to this, exactly which aspects of perceptual competency should be the target of driver training? Groeger and colleagues identified Danger, Difficulty and Abnormality as dimensions of their test, but it is not known how generalisable these factors are, or how they relate to hazard perception per se (Groeger & Chapman, 1996). Difficulty, for example, seems likely to be related to cognitive factors, particularly the driver's level of 'spare' attentional capacity (e.g. Proctor & Van Zandt, 1994, ch.9), rather than to perception, per se. Overall, there is little evidence of how best to accelerate the rate at which 'hazard perception' skills develop in novice drivers.

In accord with guidelines for effective training of high performance tasks such as driving (e.g. Proctor & Van Zandt, 1994; Schneider, 1985), Macdonald (1998. (p.13) suggested 'part-task' practice of "situation and hazard awareness" by pre-learners and learner drivers, as part of a proposed competency-based novice driver training and assessment program. Data from the present project is intended to support this proposal by specifying training goals to facilitate the development of learner drivers' "accurate schemata, mental models and expectancies concerning road traffic system operations and behaviour of other drivers" in terms of specific performance descriptions and evaluation criteria (see Table 1). The conceptual framework for the project is depicted in Table 1, in which the various components of 'hazard perception' are presented within a broader framework of novice

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driver competencies, drawing on frameworks of Macdonald & Scott (1993), Austroads (1995) and Macdonald (1998). Dark grey-highlighted, asterisked items represent components of hazard perception; items lightly greyed and not asterisked represent underlying capacities or closely associated competencies.

Table 1: 'Hazard perception' as a subset of driver capacities and competencies (drawing on the AustRoads novice driver competencies working model, 1995).
* Shaded items represent aspects of 'hazard perception'; underlying capacities and closely related factors are more lightly shaded.

GENERAL ATTRIBUTE-BASED CAPACITIES
Underlie most human activities, including driving. Apply to both novice and experienced drivers. Assumed to be adequately developed by driver licensing age.

Knowledge	**Sensory & Perceptual Capacities**	**Cognitive Capacities**	**Physical Capacities & Psychomotor Coordination**
Formal knowledge of the general nature of the driving task and driver limitations (to facilitate the acquisition of performance based competencies). Knowledge of general strategies facilitating reduced exposure to crash risk (e.g. re drinking behaviour).	Adequate vision (most driving-relevant information is visual). Adequate hearing, touch. Perceptual skills underpinning capacity to predict trajectories and arrival times of moving objects	Information processing capacity and rate; working memory capacity Level of attentional resources and attentional control: – to divide attention between concurrent task components – to maintain attentional focus, resisting distractions – to sustain concentration for extended periods.	Physical strength & endurance Postural flexibility Coordination; simple tracking and motor control skills.

DRIVING-SPECIFIC 'COMPETENCIES'

Knowledge, Schemata & Strategic Performance	**Perceptual/Cognitive Performance**	**Vehicle Control Performance**
Knowledge of formal road laws *** Accurate schemata, mental models and expectancies concerning road traffic system operations and behaviour of other drivers –** supporting more automatised perceptual/cognitive performance Realistic understanding of own driving-related competencies and limitations (i.e. accurate 'calibration') Implement driving-specific strategies to reduce exposure to crash risk, e.g. via drink/driving behaviour, fatigue management, route choice, trip planning.	*** Maintain efficient visual searching/ scanning of the environment (using vehicle lights as required).** *** Based on mental models and expectancies, 'read' traffic situations, maintain high situation awareness** *** Within the broader context of situation awareness, identify 'hazards' (specific, higher risk situations) in good time.** Based on situation awareness and perception of specific hazards, together with personal 'calibration' and perceived risk level, select appropriate driving responses. Allocate attentional resources in accord with driving task demands, sustaining vigilance as required.	Change speed or lateral position smoothly Maintain safety margins by appropriate: – speed for conditions – lateral position within lane or carriageway. – position in relation to stationary objects/vehicles Control vehicle smoothly and accurately during low-speed manoeuvres Use vehicle horn and turn indicators as required.

Present research project
Research is in progress to document the "schemata, mental models and expectancies concerning road traffic system operations and behaviour of other drivers" of young pre-learners and of young learner/probationary drivers of differing levels of experience. To date, only a preliminary data set has been collected and analysed, as described below.

Subjects. Ages ranged from 18 to 28 years. Amount of driving experience ranged from nil to at least two years, with estimated distance driven ranging up to 90,000kms.

Procedure. Each subject provided an oral commentary about the driving task, traffic situation and road environment from the imagined perspective of a driver, as s/he was driven around both an 8km and a 13 km route through the suburbs of Adelaide, once during the day and once at night (order balanced over subjects). Subjects were asked to describe "the things that you see that you think a good driver would notice while they are driving". Commentaries were tape recorded, transcribed, and coded with particular reference to potential 'hazards' using the NUD*IST software program, to provide a coherent description of the nature of their 'awareness' during the drives.

Data coding. At this preliminary stage, coding categories were developed in a purely 'data driven' way. An initial coding pass generated a basic hierarchical structure. Top level coding categories included: 'road geography' (references to things on or about the road itself); 'roadside geography' (references to the road environment, including objects there), 'road users and their behaviour' (all types of road user, traffic flow characteristics), vision and visibility issues, and driving itself (planning, navigation, manoeuvring, attention deployment, speed choice, road rules, performance of other drivers, aspects of task difficulty and consequences of errors). Second and third passes added detail and depth, focusing on 'road users' and 'driving' categories, including driver cognitive processes relating to task demands and attention deployment.

Results. The primary purpose of this study was to trial the data collection and analysis system, rather than to investigate particular hypotheses. However, an interesting difference was observed between day and night commentaries. For a set of 61 types of comment[1], paired comparisons of day versus night showed that there were more frequent comments at night (n = 46) than during the day (n = 15). The types of comment that were less common at night tended to fall into three groups, referring to: things less often present at night (cyclists, buses, animals); things less perceptually salient at night due to the lower lighting level (road width, road shape, road topography, non-signalised intersections, pedestrian crossings, roadside objects); and comments of a reflective nature that were probably not directly triggered by sensory input (referring to various difficulties, driving task demands, complex manoeuvres, car control, aspects of the commentary itself, etc). All other types of comment were more frequent at night. It may be that at night, the relatively higher perceptual salience of illuminated objects (traffic signals, illuminated signs, vehicles in the immediate vicinity) demands a higher proportion of attention than during the day. Drivers' information processing at night might be characterised by a more 'bottom up' (sensory input-driven) and less 'top down' (cognition-driven) emphasis, compared with during the day. At least, it seems plausible that at night, attention is more prone to 'capture' by objects and events with high perceptual salience. In some circumstances, this might result in inadequate attentional resources being devoted to more safety-critical aspects of the driving task, particularly in the case of inexperienced drivers.

This suggestion from the present small set of data will be investigated in a larger study, as will the nature of differences between commentaries of drivers with different levels of driving experience, ranging from pre-learners to fully licensed drivers with over five years of experience. The commentary coding system will be developed further to explore possible differences related to Groeger and Chapman's triad of hazard assessment criteria: danger, difficulty and abnormality. Subsequent studies may investigate relationships between the quality of individual commentaries and performance on a formal test of 'hazard perception', such as the VicRoads HPT.

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[1] 61 was the full number of categories at that level of the coding 'tree'; this was the most detailed level which provided sufficient numbers of responses to support meaningful comparisons.

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