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N.B.: When citing this work, cite the original article.

Original Publication:

Björn Lidestam, Anna Lundqvist and Jerker Rönnerberg, Concepts from research literature and practical assessment of risk awareness: The Swedish driving test from the perspective of cognitive psychology, 2010, TRANSPORTATION RESEARCH PART F-TRAFFIC PSYCHOLOGY AND BEHAVIOUR, (13), 6, 409-425.

<http://dx.doi.org/10.1016/j.trf.2010.06.004>

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Postprint available at: Linköping University Electronic Press

<http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-61174>

Concepts from research literature and practical assessment of risk awareness:

The Swedish driving test from the perspective of cognitive psychology

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Abstract

The Swedish driving test (SDT) was compared to theoretical concepts found in research literature (CRLs) with respect to the rated importance of the CRLs for the overall assessment of risk awareness and the five specific assessment areas used in the SDT. 116 traffic inspectors responded to questionnaires. Results show that visual search was the CRL given the highest rating, and that the assessment of risk awareness can be conceptualised as assessment of lower-order and higher-order cognitive functions. The assessment areas taxing higher-order cognitive functions were rated as most important for risk awareness, and visual search behaviour can be regarded as the best indicator of higher-order cognitive skills.

Keywords: risk assessment, risk awareness, driving, cognition, visual search, risk perception, hazard perception

1. Introduction

Risk awareness is fundamental for safe driving. If a driver is aware of present and potential risks, he or she can plan and act in order to eliminate or reduce them. Risk awareness is therefore what driving tests are intended to measure. In order to get a driving licence, the driver must demonstrate theoretical knowledge about traffic rules, be able to drive predictably in accordance with the traffic rules and in harmony with the surrounding traffic, and ultimately be able to predict and avoid risks. Some alternative and closely related terms in the literature are *risk perception*, *hazard perception*, *hazard detection*, *anticipatory attention*, and *anticipation of hazards*. Another central and closely related concept is *situation awareness*, which is defined as “perception of environmental elements in terms of time and spatial measurements, understanding their meaning and foreseeing their state in the immediate future” (Endsley, 1995, p. 36). The Swedish Driving Test (henceforth abbreviated as SDT) is intended to measure risk awareness (VVFS 1996:168; Vv 205.002). Risk awareness thus exists as a term in the practical setting of the SDT as well as in research literature on traffic safety. One question is whether well-applied experience from clinical practice and theory are in agreement with regard to how risk awareness is achieved. The driving test could possibly be supplemented with factors revealed by research. Another possibility is that theories could be revised according to practical experience in order to improve validity.

The research literature provides a large number of factors that have been scientifically validated, from many different areas within psychology. The SDT, on the other hand, seeks to assess risk awareness by using five “assessment areas” (the Swedish Road Administration, 2000; Vv 205.002), which are derived from well-applied experience from clinical practice. In turn, these assessment areas are construed by concepts that have sprung from clinical practice.

The purpose of this study was to evaluate the SDT, its assessment areas and practical concepts from the theoretical perspective of cognitive psychology. This was done by asking Swedish traffic inspectors to rate the importance of theoretical concepts relative to the five assessment areas of risk awareness.

1.1 Concepts from the SDT

Concepts from the SDT are to be found within the course plans for the driving test (VVFS 1996:168), course materials (the Swedish Road Administration, 2000) and the driving test protocol (Vv 205.002).

Risk awareness is a criterion of the SDT (the Swedish Road Administration, 2000; Vv 205.002). The assessment of risk awareness is performed by using five assessment areas, which taken together are intended to provide a valid and reliable measure of the candidate's risk awareness. All the items in the test protocol "should reflect [be permeated with] risk awareness during the assessment" (the Swedish Road Administration, 2000, p. 1). This means that risk awareness is assessed within all five assessment areas. In order for a candidate to pass the driving test, he or she must demonstrate adequate risk awareness within all the assessment areas.

The assessment areas are as follows (the Swedish Road Administration, 2000; Vv 205.002): *Speed*, which must be adapted to present circumstances; *Manoeuvring*, which is intended to assess motor skills and the candidate's ability to handle the vehicle technically; *Position*, which means the distinctiveness of intentions required during driving (the car's position on the road must signal the driver's intentions); *Traffic behaviour*, which refers to planning and rule application; and *Attention*, which refers to visual search and attention in "treacherous situations".

Other concepts, some of which also exist in the research literature related to the SDT, are used by the Swedish Road Administration (2000). For example, visual search and attention are also found within cognitive psychology and traffic psychology (e.g., Castro, 2009; Paschler, 1998; Pollatsek, Naranayanaan, Pradhan, & Fisher, 2006; Trick & Enns, 2009).

1.5 Concepts from research literature

There exist a vast number of concepts from research literature (henceforth abbreviated CRLs) on cognition and traffic psychology. An exhaustive investigation was not practically possible; so thirteen CRLs were strategically sampled, according to the following principles. Firstly, the CRLs should be designated as important for safe driving, based on either empirical findings, or on theoretical models of driving. Secondly, we wanted variation in these ratings. Therefore, some chosen CRLs should preferably yield relatively low

ratings to ensure valid and reliable data. *Strategic planning* was for this reason included as a contrast to the hypothetically more relevant concepts *automatisation* and *tactical planning*. In order to avoid potential ceiling effects, the CRLs *situation awareness*, *risk perception* and *hazard perception* were avoided, since they could be interpreted as almost synonymous with the criterion of risk awareness. Thirdly, the study was explorative. Therefore we wanted the CRLs to represent qualitatively different aspects of psychology, with regard to domains (e.g. cognitive, perceptual, personality, and social psychology) as well as to specificity (e.g. the relatively specific concept *visual search* vs. the composite concept *application of traffic rules*; or the generic concept *working memory*, vs. the subordinate concept *focused attention*). Finally, the CRLs should be as comprehensible as possible to the traffic inspectors, when presented in a questionnaire format. The thirteen CRLs are presented below. Appendix C shows the specific examples included in the questionnaire.

Working memory is a system that handles the most recently activated items of long-term memory and moves these items in and out of a temporary and short-term store (Baddeley, 2000). Driving requires a great deal of information processing and numerous decisions must be made and carried out simultaneously. Working memory is the theoretical unit that organises and processes all of this information. The working-memory capacity may theoretically determine the relative cognitive effort in traffic situations (see Brouwer & Fasotti, 1997; Groeger, 2000; Lundqvist, 2001; Recarte & Nunes, 2003, 2009; Wickens & Hollands, 1999).

Automatisation (automaticity) means that an activity that originally required attention and concentration can be carried out with much less attention (Groeger, 2000; LaBerge, 1990; Logan, 1988). Automatisation occurs as a function of practice and repetition (Anderson, 1995; LaBerge, 1990; Logan, 1988). As the skill is automatised, attention resources can be saved and used for other purposes, such as visual search (cf. operational level, Janssen, as cited in Michon, 1985; see also Matthews, Davies, Westerman, & Stammers, 2000).

Visual search refers to an active search of the visual field for targets and events, when it is uncertain when and where they may appear (Mourant & Rockwell, 1972; Paschler, 1998; Posner & DiGirolamo, 1998; Ranney, 1994; Underwood, 2007; Wickens, Alexander, Ambinder, & Martens, 2004; Wolfe, 1994). Visual search is required to detect hazards in good time and to coordinate driving with the surrounding traffic (Recarte &

Nunes, 2003, 2009; Underwood, Crundall, & Chapman, 2002). The term is also used by the Swedish Road Administration (2000).

Focused attention (selective attention) means that certain stimuli are focused on while other stimuli are ignored (Cohen, 2003; Duncan, 1999). While driving the driver needs to focus on relevant information, and ignore other information (see e.g. Hole, 2007; Lees & Lee, 2009; Trick & Enns, 2009; Trick, Enns, Mills, & Vavrik, 2004; Underwood, 2007; cf. vigilance and concentration in Groeger, 2000). Lapses in focused attention, either through inattention or distraction, cause many crashes (Neale, Dingus, Klauer, Sudweeks, & Goodman, 2005).

Inhibition implies reacting to certain stimuli while refraining from reacting to other stimuli (Knight & Grabowecky, 2000; see also Groeger, 2000; Stroop, 1935). Inhibition is required to prevent automatic responses when they may present risks, for example, refraining from braking hard to avoid skidding on a slippery road when the car does not have an automatic braking system (ABS). Lundqvist, Alinder, and Rönnerberg (2008) found that inhibition levels could influence a driver's competence as much as ten years after a stroke.

Interest in driving. Lundqvist and Rönnerberg (2001) concluded that interest in and motivation for safe driving are important factors for safe driving after brain injury. However, Berg (2000) concluded that interest in cars is a risk factor among young healthy drivers. Driving styles may thus be affected by both the quality and the strength of interest in driving.

Motivation may vary both qualitatively and quantitatively (i.e. in motives and strength). A number of studies have demonstrated that motivation affects driving behaviour and risk perception (Berg, 2000; Brouwer & Fasotti, 1997; Castro, 2009; Lundqvist, 2001; Matthews et al., 2000; Näätänen & Summala, 1974; Summala & Räsänen, 2000). For example, in Berg (2000), the motive to show off one's technical driving skill was only found among the young drivers who had been involved in car accidents.

Norms and social influence affect conceptions, attitudes, and behaviour (e.g., Ajzen & Fishbein, 1980) both implicitly and explicitly (Berg, 2000; Bianchi & Summala, 2004; Matthews et al., 2000; Parker, Manstead, Stradling, & Reason, 1992; Parker, Manstead, Stradling, Reason, & Baxter, 1992; Parker, Reason, Manstead, &

Stradling, 1995; Rämets & Summala, 2004; see also Groeger, 2000). Specifically, we wanted to examine the influence of assimilated norms and how drivers display them in their driving styles.

Personality refers to distinct and characteristic patterns of thoughts, emotions, and behaviour that distinguish an individual from others. Since personality is reflected in most activities, this also holds true for driving (Matthews et al., 2000; Näätänen & Summala, 1974; Ulleberg & Rundmo, 2003; see also Groeger, 2000; Hole, 2007).

Risk-taking here refers to the degree of perceived risk that a driver considers acceptable. The driver aims for a level of perceived risk that feels neither too low nor too high, according to Risk Homeostasis Theory (Wilde, 1982). Crashes among young novice drivers may in part be attributed to risk-taking (Deery, 1999; McGwin & Brown, 1999). Motivation (i.e. perceived gains and losses) is also considered to affect how great the risks a driver is ready to take (Heino, van der Molen, & Wilde, 1996; Matthews et al., 2000; McKenna & Horswill, 2006; Ulleberg & Rundmo, 2003; Wilde, 1982; see also Evans, 1991; Groeger, 2000; Hole, 2007; Näätänen & Summala, 1974).

Strategic planning refers to long-term plans for driving before actual driving, such as which time to depart and which route to take (Janssen, as cited in Michon, 1979, 1985; see also Brouwer & Fasotti, 1997; Wickens & Hollands, 1999).

Tactical planning refers to planning and controlled actions that are executed during driving (Janssen, as cited in Michon, 1979, 1985; see also Brouwer & Fasotti, 1997; Wickens & Hollands, 1999). Tactical planning affects how readily potential hazards can be detected in good time and how well driving can be coordinated with the surrounding traffic.

Application of traffic rules consists of knowledge of rules and driving behaviour. Knowledge of rules can be correct or incorrect. Driving behaviour may be in accordance with knowledge of rules, or not. Different types of errors can be made not only as a result of a lack of knowledge or misconstrued rules (Reason, 1990; Reason, Manstead, Stradling, Baxter, & Campbell, 1990; see also Brouwer & Fasotti, 1997; Parker et al., 1995), but also as a result of violating the rules (Parker, Manstead, Stradling, & Reason, 1992). Driving experience can provide better understanding of formal and informal rules in traffic (cf. Brouwer & Fasotti, 1997;

Lundqvist, 2001; Wilde, 1982). Application of traffic rules is similar to the SDT concept *rule application* (regeltillämpning, Vv 205.002; the Swedish Road Administration, 2000).

1.2 Purpose

The purpose of the study was to analyse concepts from the SDT from the perspective of cognitive psychology, and to analyse the ecological validity of CRLs in relation to driving (see Figure 1). There were four subordinate specific research questions. Firstly, how important are the assessment areas for risk awareness? Secondly, how important to risk awareness are the CRLs? Thirdly, how important to the assessment areas are the CRLs? Finally, according to which dimensions are risk awareness and the assessment areas assessed?

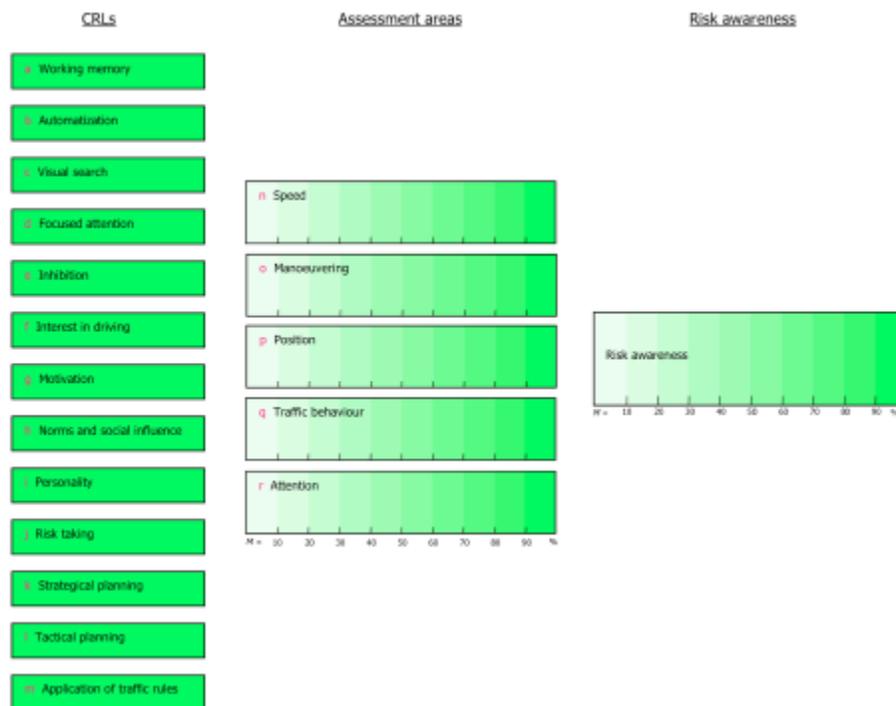


Figure 1. The CRLs, assessment areas, and risk awareness, whose reciprocal relationships were rated by the traffic inspectors.

2. Method

2.1 Literature overview

The first author (Björn Lidestam) used the database PsycINFO to search for theoretical concepts used within the research literature on driving and traffic in an effort to cover all major domains of psychology with a bearing on traffic. The search terms “driving” and “traffic” were included in all searches. Combined search strategy was used, by using for example “driving OR traffic AND visual search”. Some examples of search words for psychology terms were “psychology”, “cognition”, “cognitive”, “sensation”, “optical”, “perception”, “vision”, “visual”, “visual search”, “memory”, “memory systems”, “visual memory”, “working memory”, “personality”, “trait”, “extraversion”, “sensation seeking”, and “decision making”. The searches were iterative, in that when texts from the recent search had been read and searched for new CRLs, new searches were made based on the new CRLs, until theoretical saturation was considered to be achieved (cf. Glaser, 1978). For example, the search “[driving OR traffic] AND risk” yielded the new CRL “risk perception”, which in turn yielded “hazard perception” and “hazard detection”. Searches were also based on the traffic inspectors’ own concepts from the pilot study (see next section).

Thirteen CRLs were chosen to be included in the study, in order to represent all the major domains of psychology that had been found, while keeping the questionnaire format short enough to minimise the dropout rate. The principles for choosing CRLs were presented in the Introduction. Appendix C shows the specific examples in the questionnaire.

2.2 Pilot study: Interviews

A qualitative study (Persson, 2006) was conducted in parallel with the present quantitative study, and its results, together with the literature overview, guided the choice of CRLs for the present study. Persson (2006) examined how Swedish traffic inspectors assessed psychological (primarily cognitive) CRLs within the SDT with regard to which theoretical connections they spontaneously made in semi-structured interviews. After reviewing the results in Persson (2006), it was decided that the CRLs *prospective memory* (i.e. memory for executing an intended action, Winograd, 1988) and *fast versus slow decision-making* (i.e. heuristic vs. algorithmic

processing, respectively, cf. Kahneman & Tversky, 1972; Hunt, 1975) would not be included in the questionnaire. All 13 interviewed traffic inspectors found it difficult to comprehend these CRLs, and also found them to be irrelevant. All other CRLs from Persson (2006) were validated as good candidates for the questionnaire. *Focused attention*, *inhibition*, and *interest in driving* were chosen to be included in the questionnaire based on the literature overview and associations made by the traffic inspectors in Persson (2006).

2.4 Questionnaire construction

The questionnaire contained 197 items. The first seven items contained background variables (see Appendix B). Items 8–190 were about rated relationships between CRLs, assessment areas, and risk awareness.

The 13 CRLs were introduced with a short explanation and two contrasting examples described how a particular CRL could be manifested in a traffic situation (see Appendix C). Each CRL was examined by means of questions with a visual analogue scale marked 0–100% (see Appendix B). The first three questions for each CRL regarded the association with risk awareness and impact on a driving test. The following five questions were about how the CRL was associated with each of the five assessment areas.

Items 190–191 required the traffic inspectors to rank the importance of the CRLs for risk awareness and for the driving test. These items also served purposes of validation. Items 192–196 concerned how strongly risk awareness was associated with the assessment areas. Finally, in item 197, the traffic inspectors were asked to rate their knowledge of cognitive psychology (see Appendix B).

The questionnaire was made in two versions, A and B, with reversed orders in order to cancel out order effects. Every second questionnaire supplied was the B version. An approximately equal number of questionnaires of versions A and B were sent to each driving test office, of which 56 and 60 of each were returned.

2.5 Distribution of questionnaires

Questionnaires together with pre-stamped envelopes were sent out to the managers of all 28 driving test offices, for further distribution to all traffic inspectors in Sweden ($N = 228$, 23% women, 77% men, mean age 46.2 years). A covering letter (Appendix A) stated that the study had been sanctioned from a higher authority and the traffic inspectors were allowed time to fill in the questionnaires. The questionnaire was perceived as being rather demanding, and some participants commented that it was difficult to decide on how to answer many of the questions. A reminder and additional questionnaires were sent out. The questionnaires were sent out at the time of year when most driving tests are performed, which probably contributed to the relatively low response frequency (51%).

2.6 Participants

The number of returned questionnaires was $n = 116$. The participants were 30–67 years old ($M = 46.6$, $SD = 9.8$ years), 80% men and 20% women. They had worked as traffic inspectors for 1–35 years ($M = 8.5$, $SD = 8.5$ years). 70% ($SD = 28\%$) of them conducted driving tests only in large municipalities and 25% ($SD = 25\%$) conducted driving tests only in small municipalities (see Appendix B). The distribution of gender and mean age of the sample was on a par with the parameters of all 228 traffic inspectors; hence the sample was regarded as being representative.

2.7 Design and analyses

All variables except for the background data (gender, age, etc.) were variables within groups. The design accounted for estimations of means and correlations, and explorative factor analyses (by means of PCAs).

In order to answer research questions 1–3, means with confidence intervals were calculated for how the traffic inspectors rated the associations between CRLs, assessment areas, and risk awareness. For research question 4, PCAs with Quartimax rotation (as recommended in Stewart, 1981) and Kaiser normalisation (SPSS 11.0) were made.

3. Results and Discussion

3.1 Relationships between risk awareness, assessment areas, and CRLs

Figure 2 presents an overview of the rated associations between risk awareness, assessment areas, and CRLs, with mean ratings above 75% indicated with lines. The limit of 75% on a visual analogue scale can be considered to be a clear indication that a participant rates the association as strong (cf. an upper quartile), compared to a rating of around 50%, where hesitant and uncertain participants usually tend to mark their ratings (Patel & Davidsson, 2003).

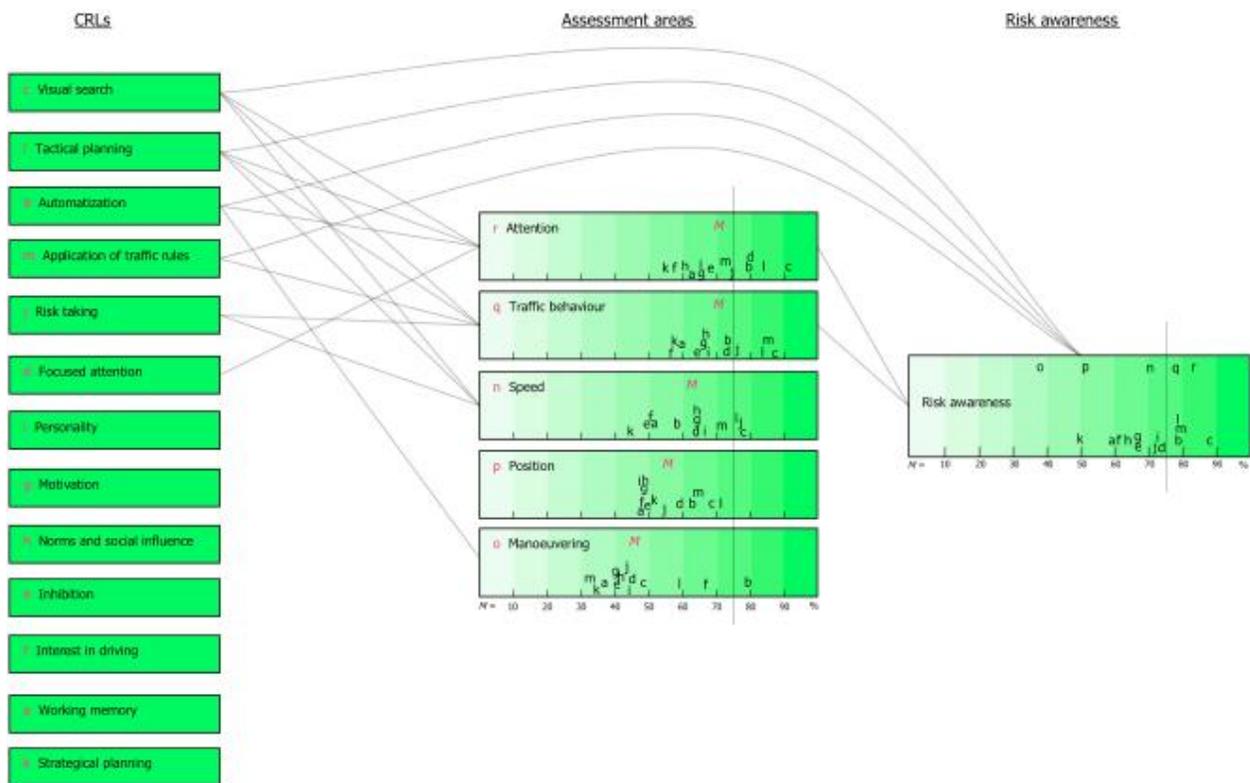


Figure 2. Means for the traffic inspectors' rated causal relationships between CRLs, assessment areas, and risk awareness. A line indicates that $M > 75\%$ for a rated relationship. Within the boxes the means for the traffic inspectors' ratings are indicated by the placement of a–q.

Descriptive statistics and 95% confidence intervals for means are presented in tables. Table 1 displays ratings of assessment areas on risk awareness (research question 1); Table 2 shows ratings of CRLs on risk

awareness (research question 2); and Tables 3–7 present ratings of the importance of the CRLs on the assessment areas (research question 3).

(Table 1 in about here)

3.1.1 Rated importance of the assessment areas for risk awareness

As indicated in Figure 2 and Table 1, attention and traffic behaviour, followed by speed, are most important for risk awareness. Position and manoeuvring are rated as less relevant. High risk awareness requires the candidate to fulfil all five assessment areas (the Swedish Road Administration, 2000; Vv 205.002). The results indicate that manoeuvring and position are necessary but not sufficient prerequisites for good risk awareness. Manoeuvring requires automatised technical handling of the car, that is, basic skills required for mastering other assessment areas. Maintaining attention and good traffic behaviour and controlling speed all require complex skills. The driver should not have to pay attention to the handling of the vehicle, but should be able to detect and interpret the flow of information in the traffic, including potential hazards. Thus, manoeuvring and position can be viewed as less important and will be revealed in more complex abilities (cf. VVFS 2006:21). The results also indicate that the traffic inspectors do not rate any single assessment area to be sufficient for assessing risk awareness, but attention, traffic behaviour, and speed taken together can possibly be viewed as sufficient.

In sum, position and manoeuvring can be regarded as skills that are necessary but not sufficient for safe driving, while attention, traffic behaviour and speed can be regarded as measures of higher-order skills that enable safe driving. The results suggest that the driving test primarily assesses these higher-order skills, and thus validates the SDT (Vv 205.002). Risk awareness is the highest-order skill that the SDT is designed to assess (the Swedish Road Administration, 2000), and three assessment areas can be regarded to capture risk awareness well, according to traffic inspectors.

(Table 2 in about here)

3.1.2 Importance of the CRLs for risk awareness

From Figure 2 and Table 2 it is evident that visual search (Mourant & Rockwell, 1972; Paschler, 1998) is the CRL that is rated as most important for risk awareness and it is also rated as being more important than any of the assessment areas. This might be explained by the traffic inspectors' rich experience of the concept in their training and practical work. Theoretically, visual search is the (overt) behaviour that is directly governed by attention, which can be inferred from eye and head movements. Visual search was also defined as applied attention by traffic inspectors in Persson (2006). It is one of the few concepts for observable behaviour in the driving test. Most other concepts describe characteristics that must be inferred, such as cognition and personality. For example, when assessing 'traffic behaviour', observable behaviour can be the product of several cognitive processes. Not stopping at a stop sign can be the result of conscious rule violation, lack of knowledge about the rule, or lack of attention (cf. Reason, 1990). Conversely, when a gaze in the direction of an object does not guarantee that a driver candidate actually perceives the object, or perceives it correctly, perception of the object as a potential risk is indicated by reduced speed and adjusted positioning of the vehicle.

Figure 2 and Table 2 also show that application of traffic rules, tactical planning, and automatization are equally important for risk awareness. Application of traffic rules (cf. rule application, Vv 205.002) is crucial for traffic safety behaviour and risk awareness, since lapses, mistakes, and violations (Reason, 1990; Wickens et al., 2004) increase the risk of traffic incidents. Inherent in the assessment of rule application is the drawing of conclusions about different types of decisions and actions. It is not easy to draw valid conclusions about risk awareness by mere observation. A complementary verbal account may be needed in order to assess the candidate's decision-making. Tactical planning (Janssen, as cited in Michon, 1979, 1985) is also considered central to risk awareness. Impaired tactical planning can affect interaction with other road users, and impair risk perception when the driver experiences time pressure. Traffic inspectors must assess higher-order cognitive processes; a task that may be difficult to carry out just from observation. Again, verbal reports from the candidate would therefore aid valid conclusions about tactical planning and other higher-order cognitive

processes. Automatisation (Groeger, 2000; LaBerge, 1990; Logan, 1988) is also a theoretical prerequisite for risk awareness, since automated driving skills enable full attention to be directed to the surrounding traffic. Without automatised driving routines (cf. manoeuvring) the driver does not have spare cognitive capacity to perform the more taxing higher-order cognitive processes required for attention, traffic behaviour and speed, and ultimately risk awareness.

In sum, no special attention should be required to manoeuvre a car. The more attentional resources that are available for scanning and interpreting the traffic surroundings for potential risks, the better the risk perception. It should be noted that most driving tests are taken by candidates who have relatively little experience of driving. Experience and automatisation were associated with each other by several traffic inspectors in Persson (2006).

As expected, strategic planning (Janssen, as cited in Michon, 1979, 1985) was rated as least important for risk awareness since it is not assessed in the driving test. Strategic planning was included as a contrast to other CRLs, especially tactical planning and automatisation. The results imply that the traffic inspectors define risk awareness as a quality on a tactical level (cf. Janssen, as cited in Michon, 1979, 1985).

(Tables 3–7 in about here)

3.1.3 Importance of the CRLs for assessment areas

Attention. Visual search, tactical planning, focused attention, and automatisation were most important for attention. Strategic planning and interest in driving were rated as least important (Figure 2 & Table 3).

Traffic behaviour. Visual search, application of traffic rules, and tactical planning received the highest ratings for traffic behaviour. Interest in driving, strategic planning and working memory had the lowest ratings (Figure 2 & Table 4).

Speed. Visual search, low risk-taking, tactical planning, and application of traffic rules were rated as most important while strategic planning was the least important (Figure 2 & Table 5).

Position. Position was not very strongly associated with any of the CRLs. The highest ratings were given to tactical planning, visual search, application of traffic rules, and automatisisation. Means for the concepts rated as least important for position were all below 50%: working memory, personality, interest in driving, motivation, norms and social influence (Figure 2 & Table 6).

Manoeuvring. Manoeuvring was strongly associated with automatisisation, followed by interest in driving. Application of traffic rules and strategic planning were rated as least important for manoeuvring (Figure 2 & Table 7).

Overall, the ratings of how important the CRLs were for the assessment areas follow a distinct pattern: the more important the CRLs were for a specific assessment area, the more important this assessment area was for risk awareness (see Figure 2). This corroborates the importance of the CRLs given the highest ratings. The combined CRL ratings were highest for attention and traffic behaviour, which in turn were rated highest for risk awareness. This strengthens the notion that risk awareness is best assessed according to the more complex abilities that attention and risk awareness are intended to capture.

Visual search and tactical planning were rated as important for attention, traffic behaviour and speed. Automatisisation was also an important component, since it is a necessary basic skill. Application of traffic rules was important for the complex skills associated with traffic behaviour, attention and speed. Low risk-taking was also important for the complex skills associated with speed, traffic behaviour and attention.

In sum, the rated importance of the CRLs, in view of the five assessment areas, follow the same pattern as their rated importance for risk awareness. Visual search, tactical planning, automatisisation, application of traffic rules, (low) risk-taking, and focused attention were rated as most important for both risk awareness and the assessment areas. These CRLs can therefore be claimed to have good ecological validity for the SDT.

3.2 Dimensions for assessment

In order to study further the relationships between the CRLs, assessment areas, and risk awareness, exploratory PCAs were performed. The purpose was to reveal dimensions by which (a) risk awareness can be assessed based on assessment areas; (b) risk awareness can be assessed based on CRLs; and (c) assessment

areas can be assessed based on CRLs. Figure 3 shows these dimensions (i.e. factors) which were sought in the fourth specific research question.

(Figure 3 in about here)

3.2.1 Dimensions for risk awareness from assessment areas

Two factors emerged from the assessment areas (see Figure 3). The largest and most important factor was denoted *higher-order skills* and explained 52% of the variance in risk awareness. It consists of traffic behaviour, attention and speed, all of which require complex cognitive abilities. A second factor, called *lower-order skills*, was a result of manoeuvring and position, and explained 31% of the variance. These results are in congruence with the importance of assessment areas for risk awareness, and imply that risk awareness requires higher-order skills, and that basic skills are necessary but not sufficient for risk awareness.

3.2.2 Dimensions for risk awareness from CRLs

Four factors emerged from the 13 CRLs (see Figure 3). The factor *motivation and capacity to avoid risk* was a result of focused attention, motivation, inhibition and strategic planning, and explained 19% of the variance. *Visual search and tactics* was a result of visual search, tactical planning, and automatised, and also explained 19% of the variance. The same CRLs were also rated as most important for risk awareness from the five assessment areas. A third factor, *interaction in traffic*, was a result of personality, norms and social influence, risk-taking, and working memory, with 16% variance accounted for. Finally, the factor *interest and rule application* was a result of interest in driving and application of traffic rules, with 9% explained variance.

In sum, the two factors resulting from the assessment areas explained 83% of the variance in total, which implies that risk awareness can be reasonably well assessed as “higher-order” and “lower-order” skills. The factor obtained from traffic behaviour, attention and speed (i.e., higher-order skills) explained the largest proportion of variance in ratings of how much risk awareness depends on the assessment areas. As separate variables, the same three assessment areas also obtained the highest importance ratings for risk awareness. On

the other hand, the CRLs did not provide as good a basis for assessment of risk awareness, since only 63% of the variance was explained. What is more, each factor yielded a small proportion of explained variance. The apparent difference in explained variance between factors based on assessment areas and factors based on CRLs suggests that the traffic inspectors regard risk awareness to be best assessed by compound measures of the five assessment areas, rather than by a larger number of tests designed to measure more specific skills. There may also exist aspects that are difficult to define and verbalise that the traffic inspectors can however perceive intuitively thanks to experience.

3.2.3 Dimensions for assessment areas from CRLs

The factors of assessment areas from CRLs summed up to between 55% and 65% of explained variance (see Figure 3). This suggests that the assessment areas cannot be completely explained from the factors formed by the traffic inspectors' understanding of the CRLs, which also appeared to be the case for explaining risk awareness from CRLs. Again, there may be aspects assessed in the driving test that the CRLs do not cover.

4. Conclusions

The present study yielded two main answers to the question of how congruent the research literature and the SDT are with regard to identifying psychological factors underlying safe driving.

Those assessment areas that require higher-order cognition were rated to be most important for risk awareness. Higher-order cognitive skills required for attention, traffic behaviour, and speed are most important for risk awareness. Attention and experience were also spontaneously mentioned as important for safe driving by the majority of traffic inspectors interviewed in Persson (2006). Long driving experience can enable a driver to recognise traffic situations (i.e. schemas and traffic insight), and thereby facilitate the focus of attention on the most important aspects of the present traffic situation (Brouwer & Withaar, 1997; Chapman & Underwood, 1998; Duncan, Williams, & Brown, 1991; Quimby & Watts, 1981). The assessment areas that require higher-order cognitive skills also gave rise to the factor that explained most variance (52%) in the CA. Besides, the

assessment areas manoeuvring and position assess lower-order skills. They were rated as less important for risk awareness, and gave rise to a factor that explained considerably less variance (31%). Hence, they are necessary but not sufficient for risk awareness in that the higher-order cognitive skills require these basic skills. To conclude, the results show that the SDT primarily assesses higher-order cognitive skills required for risk awareness and risk awareness is conceptually the highest-order cognitive skill, since it requires mastery of all assessment areas (Vv 205.002; the Swedish Road Administration, 2000).

Visual search may be used as a valid and reliable indicator of risk awareness. The CRL given the highest rating was visual search. Visual search can be assessed with a minimum of conclusions about cognitive processes. Also, the majority of traffic inspectors associated visual search with risk awareness, attention and planning in Persson (2006). Visual search was rated as the most important concept for risk awareness and the assessment areas. Thus, it appears to have the best ecological validity of all concepts studied and is an observable behaviour directly and clearly governed by attention, which is subjected to risk awareness, which in turn is closely related to risk perception and risk detection. Visual search is also germane to the concept of anticipatory attention, proposed by Lundqvist and Rönnerberg (2001) to be a key factor in successful adaptation of brain-injured drivers.

The conclusion is thus that visual search is a concept that should be emphasised both theoretically and in practice, since it can be claimed to be the observable behaviour directly governed by risk (i.e. hazard) perception. The other CRLs were also validated with high ratings in the context of driving safety: tactical planning (Janssen, as cited in Michon, 1979, 1985; see also Brouwer & Fasotti, 1997; Wickens & Hollands, 1999); automatisisation (LaBerge, 1990; Matthews et al., 2000; Michon, 1979, 1985); application of traffic rules (Brouwer & Fasotti, 1997; Parker et al., 1995; Parker, Manstead, Stradling, & Reason, 1992; also cf. rule application, the Swedish Road Administration, 2000); risk-taking (cf. target risk, Wilde, 1982); focused attention (Cohen, 2003; Duncan, 1999); and personality (Matthews et al., 2000; Näätänen & Summala, 1974). Strategic planning (Janssen, as cited in Michon, 1985) was the CRL given the lowest rating, as expected, since it is not assessed in the SDT.

References

- Anderson, J. R. (1995). *Learning and memory: An integrated approach*. New York: Wiley.
- Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. Englewood Cliffs, NJ: Prentice-Hall.
- Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, 4, 417–423.
- Berg, H.-Y. (2000). *Unga förare med olycka och unga förare utan olycka: Vilka likheter och skillnader finns? En intervjuundersökning of 25 förare* [Young drivers with accidents and young drivers without accidents: Which similarities and differences exist?]. VTI rapport 458.
- Bianchi, A., & Summala, H. (2004). The “genetics” of driving behavior: Parents’ driving style predicts their children’s driving style. *Accident Analysis & Prevention*, 36, 655–659.
- Brouwer, W., & Fasotti, L. (1997). Planning en regulatie. In B. G. Deelman, P. A. T. M. Eling, E. De Haan, A. Jennekens, & A. H. Van Zomeren (Eds.), *Klinische neuropsychologie* (pp. 145–163). Amsterdam: Boom.
- Brouwer W. H., & Withaar F. K. (1997). Fitness to drive after traumatic brain injury. *Neuropsychological Rehabilitation*, 7, 177–193.
- Castro, C. (2009). Visual demands and driving. In C. Castro (Ed.), *Human factors of visual and cognitive performance in driving*. Boca Raton, FL: CRC Press.
- Chapman, P. R., & Underwood, G. (1998). Visual search of driving situations: Danger and experience. *Perception*, 27, 951–964.
- Cohen, A. (2003). Selective attention. In L. Nadel (Ed.), *Encyclopedia of cognitive science, Vol. 3: Mental models – Signal detection theory* (pp. 1033–1037). London: Nature Publishing Group.
- Deery, H. A. (1999). Hazard and risk perception among young novice drivers. *Journal of Safety Research*, 30, 225–236.
- Duncan, J. (1999). Attention. In R. A. Wilson & F. C. Keil (Eds.), *The MIT encyclopedia of the cognitive sciences* (pp. 39–41). Cambridge, MA: MIT Press.

- Duncan, J., Williams, P., & Brown, I. (1991). Components of driving skill: Experience does not mean expertise. *Ergonomics*, *34*, 919–937.
- Endsley, M. R. (1995). Towards a theory of situation awareness in dynamic systems. *Human Factors*, *37*, 32–64.
- Evans, L. (1991). *Traffic safety and the driver*. New York: Van Nostrand Reinhold.
- Glaser, B. G. (1978). *Theoretical sensitivity: Advances in the methodology of grounded theory*. Mill Valley, CA: Sociology Press.
- Groeger, J. (2000). *Understanding driving: Applying cognitive psychology to a complex everyday task*. Hove, England: Psychology Press.
- Heino, A., van der Molen, H. H., & Wilde, G. J. S. (1996). Risk perception, risk taking, accident involvement and the need for stimulation. *Safety Science*, *22*, 35–48.
- Hole, G. (2007). *The psychology of driving*. Mahwah, NJ: Lawrence Erlbaum.
- Hunt, E. B. (1975). *Artificial intelligence*. New York: Academic Press.
- Knight, R. T., & Grabowecky, M. (2000). Prefrontal cortex, time, and consciousness. In M. S. Gazzaniga (Ed.), *The new cognitive neurosciences* (2nd ed.), pp. 623–631. Cambridge, MA: MIT Press.
- LaBerge, D. (1990). Attention. *Psychological Science*, *1*, 156–162.
- Lees, M. N., & Lee, J. D. (2009). Enhancing safety by augmenting information acquisition in the driving environment. In C. Castro (Ed.), *Human factors of visual and cognitive performance in driving*. Boca Raton, FL: CRC Press.
- Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review*, *95*, 492–527.
- Lundqvist, A. (2001). Cognitive functions in drivers with brain injury: Anticipation and adaptation (Doctoral dissertation, Linköping University, 2003). *Linköping University Medical Dissertations*, *678*.
- Lundqvist, A., Alinder, J., & Rönnerberg, J. (2008). Factors influencing driving 10 years after brain injury. *Brain Injury*, *22*, 295–304.
- Lundqvist, A., & Rönnerberg, J. (2001). Driving problems and adaptive driving behavior after brain injury: A qualitative assessment. *Neuropsychological Rehabilitation*, *11*, 171–185.

- Matthews, G., Davies, D. R., Westerman, S. J., & Stammers, R. B. (2000). *Human performance: Cognition, stress and individual differences*. East Sussex, England: Psychology Press.
- McGwin, G., & Brown, D. B. (1999). Characteristics of traffic crashes among young, middle-aged, and older drivers. *Accident Analysis and Prevention, 31*, 181–198.
- McKenna, F. P., & Horswill, M. S. (2006). Risk taking from the participant's perspective: The case of driving and accident risk. *Health Psychology, 25*, 163–170.
- Michon, J. A. (1979). *Dealing with danger*. Summary report of a workshop in the Traffic Research Center, State University, Groningen, The Netherlands.
- Michon, J. A. (1985). A critical view of driver behavior models. What do we know, what should we do? In L. Evans & R. Schwing (Eds.), *Human behavior and traffic safety*. New York: Plenum Press.
- Mourant, R., and Rockwell, T. (1972). Strategies of visual search by novice and experienced drivers. *Human Factors, 14*, 325–335.
- Neale, V. L., Dingus, T. A., Klauer, G. S., Sudweeks, J., & Goodman, M. (2005). *An overview of the 100-car naturalistic study and findings* (DOT HS Publication 05-0400). Retrieved April 23, 2010, from http://www.nhtsa.dot.gov/staticfiles/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/Driver%20Distraction/100Car_ESV05summary.pdf
- Näätänen, R., & Summala, H. (1974). A model for the role of motivational factors in drivers' decision-making. *Accident Analysis & Prevention, 6*, 243–261.
- Parker, D., Manstead, A. S., Stradling, S. G., & Reason, J. T. (1992). Determinants of intention to commit driving violations. *Accident Analysis & Prevention, 24*, 117–131.
- Parker, D., Manstead, A. S., Stradling, S. G., Reason, J. T., & Baxter, J. S. (1992). Intention to commit driving violations: An application of the theory of planned behavior. *Journal of Applied Psychology, 77*, 94–101.
- Parker, D., Reason, J. T., Manstead, A. S. R., & Stradling, S. G. (1995). Driving errors, driving violations and accident involvement. *Ergonomics, 38*, 1036–1048.
- Pashler, H. (1998). *The psychology of attention*. Cambridge, USA: MIT Press.

- Patel, R., & Davidsson, B. (2003). *Forskningsmetodikens grunder: Att planera, genomföra och rapportera en undersökning* (3rd ed.) [The basics of research methods: To plan, conduct, and report a study]. Lund, Sweden: Studentlitteratur.
- Persson, L. (2006). *Riskmedvetande som beteende: Trafikinspektörers bedömning of kognition i bilkörning* [Risk awareness as behaviour: Traffic inspectors' assessment of cognition in driving]. Master of Science thesis, Department of Computer Science, Linköping University. Retrieved April 23, 2010, from <http://www.diva-portal.org/liu/abstract.xsql?dbid=7656>
- Pollatsek, A., Narayanaan, V., Pradhan, A., & Fisher, D. L. (2006). Using eye movements to evaluate a PC-based risk awareness and perception training program on a driving simulator. *Human Factors*, 48, 447–464.
- Posner, M. I., & DiGirolamo, G. J. (1998). Executive attention: Conflict, target detection and cognitive control. In R. Parasuraman (Ed.), *The attentive brain* (pp. 401–423). Cambridge, MA: MIT Press.
- Quimby, A. R., & Watts, G. R. (1981). Human factors and driving performance (Transport and Road Research Laboratory Rep. No. 1004). Crowthorne, England: Transport and Road Research Laboratory.
- Reason, J. (1990). *Human error*. Cambridge, England: Cambridge University Press.
- Reason, J. T., Manstead, A., Stradling, S., Baxter, J., & Campbell, K. (1990). Errors and violations on the roads: A real distinction? *Ergonomics*, 33, 1315–1332.
- Recarte, M. A., & Nunes, L. M. (2003). Mental workload while driving: Effects on visual search, discrimination, and decision making. *Journal of Experimental Psychology: Applied*, 9, 119–137.
- Recarte, M. A., & Nunes, L. M. (2009). Driver distractions. In C. Castro (Ed.), *Human factors of visual and cognitive performance in driving*. Boca Raton, FL: CRC Press.
- Rämet, T., & Summala H. (2004). *Young drivers' and their parents' driving habits and attitudes* [Abstract]. Retrieved April 23, 2010, from <http://www.psyko.helsinki.fi/PSYKO/Psykolog.nsf/13a1f7abe43a8c7ac2256f9b00386701/7bc2cfdfe30b8583c2256f9c002b8357?OpenDocument>
- Stewart, D. W. (1981). The application and misapplication of factor analysis in marketing research. *Journal of Marketing Research*, 18, 51–62.

- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18, 643–662.
- Summala, H., & Räsänen, M. (2000). Top-down and bottom-up processes in driver behavior at roundabouts and crossroads. *Transportation Human Factors*, 2, 29–37.
- Trick, L. M., & Enns, J. T. (2009). A two-dimensional framework for understanding the role of attentional selection in driving. In C. Castro (Ed.), *Human factors of visual and cognitive performance in driving*. Boca Raton, FL: CRC Press.
- Trick, L. M., Enns, J., Mills, J., & Vavrik, J. (2004). Paying attention behind the wheel: A framework for studying the role of selective attention in driving. *Theoretical Issues in Ergonomic Science*, 5, 385–424.
- Ulleberg, P., & Rundmo, T. (2003). Personality, attitudes and risk perception as predictors of risky driving behaviour among young drivers. *Safety Science*, 41, 427–443.
- Underwood, G. (2007). Visual attention and the transition from novice to advanced driver. *Ergonomics*, 50, 1235–1249.
- Underwood, G., Crundall, D., & Chapman, P. (2002). Selective searching while driving: The role of experience in hazard detection and general surveillance. *Ergonomics*, 45, 1–12.
- Wickens, C. D., Alexander, A. L., Ambinder, M. S., & Martens, M. (2004). The role of highlighting in visual search through maps. *Spatial Vision*, 17, 373–388.
- Wickens, C. D., & Hollands, J. G. (1999). *Engineering psychology and human performance* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.
- Wilde, G. J. S. (1982). The theory of risk homeostasis: Implications for society, and health risk analysis. *Risk Analysis*, 2, 209–225.
- Winograd, E. (1988). *Some observations on prospective remembering*. In M. M. Gruneberg, P. E. Morris & R. N. Sykes (Eds.), *Practical Aspects of Memory: Current Research and Issues* (Vol. 2, pp. 348–353). Chichester: Wiley.
- Wolfe, J. M. (1994). Guided search 2.0: A revised model of visual search. *Psychonomic Bulletin & Review*, 1, 202–238.

Vv 205.002. (n.d.). *Beslut om utfärdande of körkort/ bevis om körkort* [Decision on issuing of driving licence/warrant for driving licence]. Driver-test protocol, Vv 205.002 (U11) 03-05. The Swedish Road Administration.

VVFS 1996:168 (2006-07-10). *Vägverkets föreskrifter for kursplaner, behörighet B* [The Swedish Road Administration's instructions for course plans, competence B]. The Swedish Road Administration. Retrieved April 23, 2010, from <http://www20.vv.se/vvfs/pdf/1996nr168.pdf>

VVFS 2006:21 (n.d.). *Vägverkets föreskrifter om ändring i föreskrifterna (VVFS 2004:110) om kursplaner, behörighet B* [The Swedish Road Administration's instructions for changes in the instructions for course plans, competence B]. The Swedish Road Administration. Retrieved April 23, 2010, from <http://www20.vv.se/vvfs/pdf/2006nr021.pdf>

The Swedish Road Administration (2000). *Kriterier for provpunkter: Standardiserat körprov* [Criteria for test items: Standardized driving test]. Document provided by The Swedish Road Administration.

Figure Captions

Figure 3. Factors by which risk awareness and the five assessment areas are assessed, as yielded by seven PCAs. The proportion of explained variance per factor is presented within parentheses after the names of each factor; the total proportion of explained variance is presented according to each assessment area and to risk awareness.

Appendix A. Introduction to the questionnaire

The questions regard how different areas and concepts within psychology are associated with risk awareness and its five assessment areas for the driving test. Each block of questions is introduced by a short description of the specific concept, and with examples of how the quality that the concept describes can vary between people and situations. You are requested to tick on the 0% to 100% line to indicate your rating. You will also be asked to compare different groups of drivers with each other. The questionnaire is about driving tests for licences to drive cars.

The examples are constructed in the following way:

Each is an extreme example of how [the quality described by the CRL] can be manifested.

- (1) An example of when [the quality described by the CRL] is in one way, i.e. it functions well, and
- (2) An example of when it is in another way, i.e. it malfunctions.

The only difference between every pair of examples is the specific capacity. In all other respects the people are identical. All examples are about Eva and Sara, and Peter and Johan. If the comparison is about attention, then you are to imagine that Eva has good attention skills, whereas Sara does not. With regard to speed, manoeuvring, position, traffic behaviour, and all other capacities, Eva and Sara are identical.

The concepts being studied are taken from the bases of assessment for the driving test and from psychological research. These are the concepts being studied: ...

Appendix B. Questionnaire items

Gender

() Male

() Female

Year of birth

19.....

How many years have you been a traffic inspector?

..... years

How many courses for further development have you taken within the Swedish Road Administration?

.....

Which driving test office do you belong to?

.....

How large is the proportion of driving tests you rate that you conduct in small municipalities, where the traffic environment only has two or fewer sets of traffic lights and two or fewer multiple-lane streets in the town?

..... %

How large is the proportion of driving tests you rate that you conduct in large municipalities, where the traffic environment has five or more sets of traffic lights and five or more multiple-lane streets in the town?

..... %

How much does [the quality described by the CRL] affect risk awareness in driving tests?

Not at all **0%** ————— **100%** Entirely

How much do you consider [the quality described by the CRL] in driving tests?

Not at all **0%** ————— **100%** Entirely

How often do driver candidates have problems at driving tests due to deficiencies in [the quality described by the CRL]?

Not at all **0%** ————— **100%** Entirely

How much does [the quality described by the CRL] affect the assessment areas?

Speed

Not at all **0%** ————— **100%** Entirely

Manoeuvring

Not at all **0%** ————— **100%** Entirely

Position

Not at all **0%** ————— **100%** Entirely

Traffic behaviour

Not at all **0%** ————— **100%** Entirely

Attention

Not at all **0%** ————— **100%** Entirely

How much does risk awareness depend upon each assessment area for the driving test?

To what extent does risk awareness depend upon *speed*?

Not at all **0%** ————— **100%** Entirely

To what extent does risk awareness depend upon *manoeuvring*?

Not at all **0%** ————— **100%** Entirely

To what extent does risk awareness depend upon *position*?

Not at all **0%** ————— **100%** Entirely

To what extent does risk awareness depend upon *traffic behaviour*?

Not at all **0%** ————— **100%** Entirely

To what extent does risk awareness depend upon *attention*?

Not at all **0%** ————— **100%** Entirely

If you disregard this questionnaire, rate your own knowledge about cognition.

0% ————— **100%**

I have never heard about cognition

I already know a lot about cognition

Appendix C. Explanations and examples of the CRLs

(Order as in version A of the questionnaire; version B had reversed order.)

Strategic planning

Strategic planning means that a plan is made well in advance: *whether* to drive, whether it has been decided to drive, then *when* to drive, and *which route* to take. An example of strategic planning is when you ask the driver candidate to drive to a certain location, without saying how to get there.

Examples:

Eva is good at strategic planning for her drive to work. When she drives to work, she takes the road with the least traffic in order to avoid the traffic jam that often occurs during the rush hour in the mornings. She knows that the road with less traffic takes less time to drive along, even though it is longer. However, in the evenings, when there is less traffic, she always takes the shortest route, since it is faster in the evenings.

Sara is bad at strategic planning for her drive to work. When she drives to work she always takes the shortest way, even though it takes more time due to traffic jams. She does not take into consideration that there is an alternative route that is longer but takes less time during rush hour.

Tactical planning

Tactical planning is the planning that is made during driving, and with a rather short time horizon.

Examples:

Peter is good at tactical planning for his driving. When he approaches a crossing, he slows down in good time, shifts to a lower gear, and directs his attention toward the traffic in and around the crossing. He therefore also follows the traffic rhythm well.

Johan is bad at tactical planning for his driving. He slows down very late when he approaches a crossing, is late shifting to a lower gear and directs his attention toward the traffic in and around the crossing. Therefore he does not follow the traffic rhythm well.

Automatisation

Some behaviour and actions are so well learnt that they can be carried out without the need to think about how they can be performed. Other behaviour and actions, that are less well learnt, may require more attention in order to be carried out. An example of an action that usually becomes automatised in drivers is gear shifting.

Examples:

For Peter gear shifting is an automatised action. He can therefore direct his full attention to the surrounding traffic and to reading and remembering what is written on the traffic signs that he passes. Also, he does not get disturbed if someone talks to him when he is driving in city traffic.

For Johan gear shifting is not automatised. Some of his attention is therefore needed for shifting gears, and he has grave difficulties simultaneously paying attention to surrounding traffic, reading and remembering what is written on the traffic signs that he drives past. He also easily gets disturbed if someone talks to him when he is driving in city traffic.

Working memory

Humans can only handle a limited amount of information at a time, and this information is temporarily stored and processed in a working memory. Working memory is for example used when a new and unfamiliar phone number is retained until it has been dialled. Another example is to use mental arithmetic for solving $28 + 36$. Then you may need to first calculate a part sum, keep this part sum in memory while calculating the second part sum, and finally adding the two part sums (i.e., $20 + 30 = 50$; $8 + 6 = 14$; $50 + 14 = 64$).

Examples:

Eva has high working-memory capacity. Therefore she has no difficulties simultaneously having an interesting discussion with her passenger, keeping her eyes on the traffic, and remembering the directions that she was given just before departure. Eva's attention on the traffic thus does not risk suffering from discussions with her passenger or from thinking about the directions.

Sara has low working-memory capacity. Therefore it is difficult for her to simultaneously have an interesting discussion with her passenger, keep her eyes on the traffic, and remember the directions that

she was given just before departure. Sara's attention on the traffic thus risks suffering from discussions with her passenger and from thinking about the directions.

Inhibition

Inhibition refers to the ability not to react to events and stimuli that would otherwise elicit automatic responses.

Examples:

Eva has good capacity for inhibiting responses. She sees when the traffic light changes to green in the next lane, but her right foot is still on the brake pedal. A moment later when she drives and meets traffic, and with traffic just behind her, she sees an empty plastic bag blown by the wind into the street in front of her car. She has no difficulties managing to refrain from turning the steering wheel or from braking.

Sara has bad capacity for inhibiting responses. She sees when the traffic light changes to green in the next lane, and automatically moves her foot from the brake pedal to the accelerator pedal before she stops herself from accelerating. A moment later when she drives and meets traffic, and with traffic just behind her, she sees an empty plastic bag blown by the wind into the street in front of her car. She reflexively turns to the left and nearly collides with a car in the other lane.

Focused attention

Humans have limited attention capacity. As a consequence, attention is directed differently depending on what is perceived as most important or most interesting at the moment. Focused attention is the ability to resist distractions, to sort out irrelevant information, and to pay attention only to what is important for the task at hand.

Examples:

Peter's ability to focus his attention is good. Therefore he can keep his attention on his car and the variation in traffic around him, even though his three children are in the car, having a noisy discussion and waving their hands wildly.

Johan's ability to focus his attention is bad. When he drives and his three children are having a noisy discussion and waving their hands wildly, it is therefore difficult for him to focus on his car and the surrounding traffic.

Visual search

Visual search refers to how gaze and visual attention is directed toward the surroundings. From a risk-awareness point of view, good visual search means that gaze is active and mainly directed toward potential hazards far ahead, but that there is also regular scanning for hazards behind and alongside the car. Visual search may be claimed to serve the purpose of keeping the driver aware of how the surroundings look at the moment and change over time.

Examples:

Eva has excellent visual search. Her gaze is constantly searching for potential hazards ahead of the car. She is at the same time aware of what is happening around her car, since she is good at reacting to changes in her peripheral field of vision. When Eva turns to the right, and a cyclist approaches from the cycle path crossing the road, she has already noticed the cyclist a long time ago. She therefore calmly slows down and lets the cyclist pass without risk.

Sara has bad visual search. Her gaze is rather fixed on the roadway ten metres ahead of the car, when it is not directed at the speedometer. She is not at all aware of what is happening alongside and behind her car, which among other things is due to the fact that she is not good at reacting to changes in her peripheral field of vision. When Sara turns to the right and a cyclist approaches from the cycle path crossing the road, she almost hits the cyclist, who is forced to brake in panic.

Motivation

There can be qualitatively *different* motives for doing something. There can also be *different strengths* in motivation for doing something.

Examples:

Eva has worked as an ambulance paramedic and seen many people with traffic injuries. For this reason she is strongly motivated not to take any risks in traffic. She is also motivated to drive smoothly and not

faster than the speed limits, since she wants to save money on fuel. She also reasons that she would not save more than a negligible amount of time by driving faster.

Sara has neither worked as an ambulance paramedic nor seen people with traffic injuries. She is on the other hand motivated to drive aggressively and much faster than the speed limits, since she very much appreciates the feeling of driving fast in her sporty car. She also reasons that “time is money”. Sara thinks that the thrill and joy of driving fast, together with the time that she gains, make up for an increased risk of getting speeding fines.

Risk-taking

People are prepared to take risks of different sizes and have different levels of awareness when it comes to perceiving whether a risk may be excessively hazardous, even though they have the same understanding of how great or small the risk is. It can be conceived that driver A is prepared to be exposed to no more than a virtually non-existent risk of running off the road when there is slippery road surface, while driver B is prepared to be exposed to as much as a five per cent risk of running off the road. This difference in risk-taking could result in driver B driving 10 km/h faster than driver A.

Examples:

Eva has a low limit for accepting risks. She always keeps within speed limits, and when there is bad visibility, a winding or slippery road, she slows down. She drives calmly and is careful to keep the proper distance to the vehicle ahead of her, with regard taken to speed and the condition of the road surface. Eva does all of this to maintain the same low level of risk – she does not accept an increase in the risk of an accident.

Sara has a high limit for accepting risks. She seldom keeps within speed limits, and when there is bad visibility, a winding or slippery road, she prefers not to slow down. She drives aggressively and does not keep the proper distance to the vehicle ahead of her, without regard to speed and road surface conditions. Eva accepts that the risk of an accident increases as a result of worse visibility, worse road conditions, higher speed, and shorter distances.

Personality

Personality refers to the rather stable patterns of thought, emotion, and behaviour that people have, both over time and situations.

Examples:

Peter is a calm and stable person who is not sensation-seeking. He prefers the calmness of known situations to adventure and situations that go with a bang. When Peter drives, he prefers to drive slowly. He also always drives smoothly, calmly, and with great margins for error [safety margins].

Johan is a restless and impulsive person who is sensation-seeking. He prefers adventures and likes things to go with a bang. He easily gets bored with the calmness of known situations. When Johan drives, he likes to drive fast. He also always drives aggressively, restlessly, and with small margins for error [safety margins].

Norms and social influence

Norms and social influence refer to how one is affected by others, by one's conceptions about others' opinions, and by motivation to live up to others' expectations.

Examples:

Peter drives alone in his car. He thinks that people who are reasonable above all want to minimise risks in traffic by keeping within speed limits and by maintaining good cooperation with other road users. He himself tries to be a good example in traffic with regard to adaptation of speed and cooperation.

Johan drives with his two best friends in the car. He thinks that what is most important to tough guys like himself is to drive fast and that the driving should reflect a high level of technical skill. He thinks that it is good to demonstrate this by driving closely behind other vehicles and by often overtaking with small time margins. He also likes to impress his friends with his driving, and therefore drives fast, aggressively, and shows off his technical skills.

Interest in driving

People may differ in how much interest they have in driving as an activity, and they may be interested in driving for different reasons.

Examples:

Peter is very interested in driving. For him driving is a way of life – he finds joy and pleasure in sitting behind the wheel and sensing that he is in control of a well-functioning car. He likes to drive for sheer joy, and prefers to drive rather than sit in the passenger seat.

Johan is rather uninterested in driving and drives because he is not in a position to commute by public transport or go by bike. For him driving is merely a way of getting from one place to another. He never drives for sheer joy, and he may just as well sit in the passenger seat.

Application of traffic rules

How traffic rules are applied depend in part upon the knowledge about the rules, and in part upon how the knowledge is used. Errors and violations may thus result from a lack of knowledge of rules, application of the wrong rule in a particular situation, or that the rule is wilfully violated.

Examples:

Eva has good knowledge about the traffic rules and when which rule applies. She seldom makes mistakes and lapses with regard to application of traffic rules, and she never commits violations of traffic rules. The few mistakes she makes, and the few lapses she has, are of mild character.

Sara has little knowledge about the traffic rules and when which rule applies. She often makes mistakes and lapses with regard to application of traffic rules, and she also often commits violations of traffic rules. Sara's mistakes, lapses, and violations are of both mild and grave character.

Acknowledgements

The study was financed by the Traffic Medicine Council of the Swedish Road Administration. We thank Henrik Söderqvist for assistance with data collection; Per-Olof Nilsson for help with contacts and for valuable comments; Hans-Yngve Berg and Lars Englund for valuable comments; and the 116 traffic inspectors who answered the extensive questionnaire for their kind participation.