

Evaluation of driving ability of the disabled persons in the context of the psychological activity theory

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ABBREVIATIONS

AD	Alzheimer's disease
ADHD	Attention deficit hyperactivity disorder
ADL	Activities of daily living
BI	Barthel Index
CNS	Central nervous system
DE	Driving externality
DHD	Dominant hemisphere disease
DI	Driving internality
ICD-10	International Classification of Diseases
ICF	International Classification of Functioning, Disability and Health
MMSE	Mini Mental State Examination
NDHD	Non-dominant hemisphere disease
NS	Nervous system
PD	Parkinson disease
SSS	Scandinavian Stroke Scale
TBI	Traumatic brain injury
T-LOC	Driving target multidimensional locus of control scale
TNS	Types of nervous systems
WHO	World Health Organisation

LIST OF ORIGINAL PUBLICATIONS

The present study is based on the publications below, which are referred to by their Roman numerals (I-V).

- I *Heikkilä V-M*: Metod opredelenija individual'no-psihologitseskih predposylok voditel'skoi dejatelnosti (in Russian). *Voprosy Psihologii* 1995, 6:113-121.

- II *Heikkilä V-M*, Turkka J, Korpelainen J, Kallanranta T, Summala H: Decreased driving ability in people with Parkinson's disease. *Journal of Neurology, Neurosurgery & Psychiatry* 1998, 64:325-330.

- III *Heikkilä V-M*, Korpelainen J, Turkka J, Kallanranta T, Summala H: Clinical evaluation of the driving ability in stroke patients. *Acta Neurologica Scandinavica* 1999,99:349-355.

- IV *Heikkilä V-M*: Relationships of laboratory and on-road tests for driving school students and experienced drivers. *Perceptual and Motor Skills* 2000, 90:227-235.

- V *Heikkilä V-M*, Kallanranta T: Evaluation of the driving ability in disabled persons: A practitioners' view. *Disability and Rehabilitation* 2005, 27:1029-1036.

ABSTRACT

In the future the number of the disabled drivers requiring a special evaluation of their driving ability will increase due to the ageing population, as well as the progress of adaptive technology. This places pressure on the development of the driving evaluation system.

Despite quite intensive research there is still no consensus concerning what is the factual situation in a driver evaluation (methodology), which measures should be included in an evaluation (methods), and how an evaluation has to be carried out (practise). In order to find answers to these questions we carried out empirical studies, and simultaneously elaborated upon a conceptual model for driving and a driving evaluation.

The findings of empirical studies can be condensed into the following points:

1) A driving ability defined by the on-road driving test is associated with different laboratory measures depending on the study groups. Faults in the laboratory tests predicted faults in the on-road driving test in the novice group, whereas slowness in the laboratory predicted driving faults in the experienced drivers group. 2) The Parkinson study clearly showed that even an experienced clinician cannot reliably accomplish an evaluation of a disabled person's driving ability without collaboration with other specialists. 3) The main finding of the stroke study was that the use of a multidisciplinary team as a source of information harmonises the specialists' evaluations. 4) The patient studies demonstrated that the disabled persons themselves, as well as their spouses, are as a rule not reliable evaluators. 5) From the safety point of view, perceptible operations with the control devices are not crucial, but correct mental actions which the driver carries out with the help of the control devices are of greatest importance. 6) Personality factors including higher-order needs and motives, attitudes and a degree of self-awareness, particularly a sense of illness, are decisive when evaluating a disabled person's driving ability. Personality is also the main source of resources concerning compensations for lower-order physical deficiencies and restrictions.

From work with the conceptual model we drew the following methodological conclusions: First, the driver has to be considered as a holistic subject of the activity, as a multilevel hierarchically organised system of an organism, a temperament, an individuality, and a personality where the personality is the leading subsystem from the standpoint of safety. Second, driving as a human form of a sociopractical activity, is also a hierarchically organised dynamic system. Third, in an evaluation of driving ability it is a question of matching these two hierarchically organised structures: a subject of an activity and a proper activity. Fourth, an evaluation has to be person centred but not disease-, function- or method centred.

On the basis of our study a multidisciplinary team (practitioner, driving school teacher, psychologist, occupational therapist) is recommended for use in demanding driver evaluations. Primary in a driver's evaluations is a coherent conceptual model while concrete methods of evaluations may vary. However, the on-road test must always be performed if possible.

Keywords: Driving, driving ability, subject of activity, activity theory

Tiivistelmä

Tulevaisuudessa ajokyvyn erityistutkimusta vaativien toimintarajoitteisten henkilöiden määrä tulee kasvaamaan väestön vanhenemisen ja apuvälineteknologian kehittymisen myötä. Tämä luo paineita ajokyyarvioinnin kehittämislle.

Huolimatta varsin intensiivisestä tutkimuksesta edelleenkin ei ole olemassa yhteistä näkemystä siitä, mistä ajokyyarvioinneissa on kysymys (metodologia), mitä menetelmiä ja mittoja arvioinneissa tulisi käyttää (metodit) ja miten arviointi tulisi suorittaa (käytäntö). Vastausta näihin kysymyksiin haettiin empiirisillä tutkimuksilla ja kehittämällä samanaikaisesti, empiiristä tutkimusta hyödyntäen, ajotoiminnan ja ajokyyarvioinnin käsitteellinen malli. Malli luotiin psykologisen toiminnan teoriant pohjalta.

Empiiristen tutkimusten löydökset voidaan kiteyttää seuraaviin kohtiin: 1) Ajokokeella määritelty ajokyykyisyys on yhteydessä ryhmästä riippuen erilaisiin laboratoriomittoihin. Kokemattomilla virheet laboratoriossa ennustivat virheitä ajokokeessa, kun taas kokeneilla hitaus laboratoriossa ennusti virheitä ajokokeessa. 2) Parkinson-tutkimus osoitti selkeästi, että kokenutkaan kliinikko ei kykene vajakuntoisen henkilön ajokyykyä luotettavasti arvioimaan tekemättä yhteistyötä muiden asiantuntijoiden kanssa. 3) Aivoinfarktitudkimuksen keskeinen löydös oli, että moniammatillisen tiimin käyttö informaatiolähteenä harmonisoi eri asiantuntijoiden arvioinnit. 4) Potilastutkimukset osoittivat, etteivät potilaat itse eivätkä heidän puolisonsa kykene luotettavasti ajokyykyä arvioimaan. 5) Turvallisuuden kannalta hallintalaitteilla suoritettut operaatiot eivät ole ratkaisevia, vaan keskeisessä asemassa ovat henkiset toiminnot, jotka kuljettaja toteuttaa hallintalaitteiden avulla. 6) Persoonallisuustekijät mukaan lukien korkeamman tason tarpeet, motiivit, asenteet ja itsetiedostuksen aste, etenkin sairauden tunne, ovat keskeisiä arvioitaessa toimintarajoitteisten henkilöiden ajokyykyä. Persoonallisuus on myöskin tärkein kompensatiolähde alemman asteen fyysisille rajoitteille.

Ajotoiminnan ja ajokyyarvioinnin mallintamisessa tultiin seuraavanlaisiin metodologisiin johtopäätöksiin: Ensinnäkin kuljettaja, toiminnan subjekti, on nähtävä monitasoisena hierarkisesti organisoituneena organismin, temperamentin, individin ja persoonallisuuden systeeminä persoonallisuuden ollessa turvallisuusnäkökulmasta katsottuna johtava tarkastelutaso. Toiseksi, autoilu inhimillisenä yhteiskunnallis-konkreettisenä toimintamuotona on myöskin hierarkisesti järjestäytynyt dynaaminen systeemi. Ajokyyarvioinnin

arvioinnissa on kysymys näiden kahden hierakisesti järjestäytyneen kompleksisen systeemin, toiminnan subjektin ja itse toiminnan, yhteensovittamisesta. Kolmanneksi, arvioinnin on oltava persoonalähtöinen eikä sairaus-, funktio- tai menetelmälähtöinen.

Tutkimuksemme perusteella suosittelemme moniammatillisen tiimin (lääkäri, liikenneopettaja psykologi, toimintaterapeutti) käyttöä vaativissa ajokyvyn arvioinneissa. Arviointityössä ensisijaista on johdonmukainen ja perusteltu käsitteellinen malli konkreettisten arviointimenetelmien voidessa vaihdella. Tien päällä suoritettu ajokoe on kuitenkin tehtävä aina, kun se turvallisuussyistä on mahdollista.

Avainsanat: Ajaminen, ajokyky, toiminnan subjekti, toiminnan teoria

1 INTRODUCTION

For disabled persons the possibility to drive a car is especially significant because it markedly increases their possibilities to cope with life, affording freedom of mobility independent of the help of others or public transportation. On the other hand, in Finland 300-400 persons die in traffic accidents and approximately 10 000 are injured yearly. Traffic has its risks and accidents have enormous immaterial and material expenses (see Medical aspects of fitness to drive 1995; Liikennelääketiede 1991, 2002).

Society tries to minimise traffic risk by making driving instruction obligatory, by implementing technical standards and controls, by improving the traffic environment, by enforcing traffic rules and regulations and also by controlling that drivers have sufficient abilities and skills for safe driving. The requirements regarding driving ability are stipulated in the Road Traffic Act, in the driving licence decree, and in the EU Driving License Directive (Tieliikennelaki 2006). In the act it is said that a driver is not permitted to drive if he/she has a disease, deficiency, disability, fatigue or other corresponding reason which significantly impair his/her ability to act as a driver (64 § (3.8.1990/676); decree 9 § (5.1.1996/2); (9.12.1999/1168)). So, the subject of the evaluations in the frame of a driving licence are deficiencies and potential risk factors of the driver and the aim is to find out significant driving related defects, disabilities, and restrictions of his or her driving ability.

A potential alternative way could be to construct an image of safe driving from the model of a skilled performance (Keskinen 2002). However, since the work is addressed to clinicians who often make pass/fail decisions in a 'legal' restriction-centred context we work a little bit more with deficiencies than with resources and potentials.

Traffic research, and also an evaluation of drivers, have their origin and a social order in the beginning of the 20th century when urbanisation was progressing intensely and when the number of cars was quickly increasing. This resulted in an increase of traffic accidents. In Finland the first car accident occurred in 1907 and, of course, in this very first accident the driver was intoxicated (Salovaara 1976).

1.1. Psychological factors and accident risk

1.1.1. Accident proneness

Historically, the first models of driving were developed on the basis of individual differences. Munsterberg, a central figure of the so called psychotechnique, studied tram drivers from a safety standpoint and professional suitability during the first decade of the 20th century. He underlined the significance of personality factors in such dangerous professions as tram driving. Later, Tramm (according to Kotik 1987) added attentiveness, ability to make prompt decisions, quick reactions and tolerance for fatigue to the list of needed qualifications. Marbe (1921) came forward with the famous proposal of accidents as a result of inborn factors and of critical experiences. The psychodynamic school of thought explained accident proneness with inner conflicts and unconscious motives. An accident proneness was seen as aggressiveness turned toward one's self. Psychoanalytically-orientated researchers thought that by an accident persons punish themselves (Menninger 1955). The accident proneness studies attempted to predict accidents according to relatively stable traits and basic capabilities.

The concept of accident proneness was replaced by the concept of the accident risk which is connected to a large number of different factors. Häkkinen (1958, 1979) showed in his follow-up study that accident proneness was a very permanent quality and that individual differences explained over half of the variation in accidents. There was no relationship between simple reaction time and accident rate. However, the subjects were professional drivers, i.e., the selected groups, who due to the forced-pace nature of their task cannot pace their times to the degree that private drivers can (Näätänen and Summala 1976). It would therefore not be correct to directly apply these results to non-professional drivers, who have greater freedom in planning and carrying out their driving.

1.1.2. Locus of control

The theory of locus of control have stimulated the interests of traffic researchers since the 60s. Rotter (1966) defined locus of control as a personality attribute reflecting the

degree to which a person generally perceives events to be under their own control (internal locus of control) or under the control of powerful others or other outside forces (external locus of control). It is quite understandable that an external locus of control is related to less responsible driving and accidents. However, the empirical findings have been mixed (Lajunen 1997).

According to Hoyt (1973) the locus is permanent and the external locus is firmly connected to accident risk. If this is the case, as Hoyt (1973) claims, then we are dealing with an accident prone personality. Guastello and Guastello (1986) found no direct relation between locus of control and accident involvement while Arthur, Barrett and Alexander (1991) found a positive relationship between locus of control and accidents. Montag and Comrey (1987) developed driving targeted scales for measuring 'driving internality' (DI) and 'driving externality' (DE). They found that DI and DE had a stronger relationship with safe driving than Rotter's I-E scale among new applicants for driving licenses and drivers who had been involved in a fatal motor accident. Driving externality was positively associated with fatal accidents whereas driving internality was associated with caution. Later Arthur and Doverspike (1992) reported an opposite pattern of correlation and Iversen and Rundmo (2002), as well as Guastello and Guastello (1986), did not find any correlation between locus of control and risky driving. Lajunen and Summala (1995) found that drivers scoring high in DI saw themselves as alert and careful drivers who try to predict possible risks in traffic.

Özkan and Lajunen (2005) claimed that two factor structure is too simple for identifying different attributions of causes behind traffic accidents and they developed a driving target multidimensional locus of control scale (T-LOC) with the scales of 'self', 'vehicle and environment', 'other drivers' and 'fate scale'. Their results showed that internals are more likely to be involved in accidents and to engage in risky driving than externals. The question of locus of control and driving safety still remains open and further studies are needed. However, there is support for the opinion that restricted drivers with an accentuated external locus of control are the more prominent risk group than drivers with an obvious internal locus of control.

1.1.3. Temperament and personality factors

Descriptive taxonomies of individual differences have been a tradition in personality theories since Plato and Galen. Presently, there is a near consensus among descriptive taxonomists concerning the following five fundamental dimensions of personality sometimes referred to as 'the Big 5' or 'B5' extraversion/introversion, emotional stability/instability (neuroticism), agreeableness, conscientiousness, and openness (see John 1990). There is strong agreement that the dimensions of extraversion/introversion and neuroticism/emotional stability are fundamental parts of any personality taxonomy. Associations of these dimensions with accidents are widely studied in the field of traffic psychology with the contradictory results: Fine found a significant simple relationship between extraversion and both numbers of crashes and violations in a study of 937 male students. Shaw and Sichel (1971) found bad drivers to be more extraverted but Wilson and Greensmith found no difference in the extraversion or neuroticism scores of crash-involved and crash-free drivers. Sigh reported an association between introversion and crash involvement (see Ranney 1994; Elander, West and French 1993). Loo (1979) found that when extraversion scores were broken down into sub-scales of impulsiveness and sociability, impulsiveness alone carried a relationship to risky driving. Similarly, it can be supposed that some aspects of neuroticism, like moodiness and nervousness, may increase a driver's accident risk by increasing the number of driving errors whereas other aspects of neuroticism (like being a worrier) might actually strengthen a person's concern for safety (Lajunen 2001). Thus, personality dimensions are not one-dimensional qualities regarding driving safety. Driver evaluation cannot be based on such contradictory dimensions.

In his review of studies about personality factors and driving behaviour, Beirness (1993) concluded that hostile and aggressive tendencies can influence driving behaviour in a manner that increases the likelihood of crash involvement which is also the result of the study of Lajunen and Parker (2001). Deffenbacher, Oetting and Lynch (1994) conceptualised driving anger as a personality trait related to trait anger but more context

or situation bound. It has also been found that safety orientation, i.e., emphasis on safety skills, was related to a relative lack of aggression, whereas drivers' emphasis on perceptual-motor skills ("skill orientation") was positively related to driver aggression (Lajunen and Summala 1995). It is very difficult for a person to reliably evaluate their own aggressiveness because of psychological defences. Speaking about driving anger as an activity specified personality quality sounds pseudoscientific. From the point of traffic safety anger is particularly a problem because hardly anyone can reliably estimate his or her own level of aggressiveness.

In general one can state that the individual-differences approach is primarily negative and restriction centred. Human qualities and abilities are not seen as resources but rather as their limitations. This only seems to excite researchers' interest.

1.1.4. Attention and situational awareness

Numerous studies have found significant correlation between measures of selective attention and accident involvement (e.g., Kahneman et al.1973; Owsley et al 1991). Such higher-order perceptual functions like visual search, visual speed, selective, sustained and divided attention, and visuo-spatial impairments have to be put forward as determinants of practical fitness to drive (e.g. Tant 2002). In on-road tests the largest differences between brain-injured and healthy groups also tend to occur in divided-attention situations.

According to Ranney (1994) the most consistent predictor for accident causation is selective attention. Also by Barbas and Wilde (2001) the most empirically well-established cognitive factors related to driving ability include visual attention (sustained, selective, and divided attention) and visuospatial abilities. The practical consequence is that divided attention conditions should be part of the neuropsychological and practical assessment with regard to fitness to drive (Brouwer et al 2002).

Field dependence was found to be linked to accidents (Mihal and Barrett 1976) but more recent work has failed to find a strong relationship between perceptual style and accident measures (e.g. McKenna et al 1985).

Situational awareness can be defined as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and a projection of their status in the near future (Endsley 1995).

Stanton et al (2001) write that the importance of situational awareness in maintaining safe control of an aircraft cannot be overstated. The information processing approach has been best represented by Endsley's (1995) theoretical three-level model of situational awareness. Endsley proposes that situational awareness is normally discussed in terms of system-specific subcategories, such as mode awareness, spatial awareness and time awareness.

The model of the perceptual cycle presents situational awareness as a dynamic interaction between humans and their environment. Proponents of this approach suggest that it is the context of the interaction that defines the situational awareness (Smith and Hancock 1995).

In the frame of activity theory, situational awareness is seen as only one of many components of reflective-orientational activity. The key processes that produce situational awareness are the combination of the conceptual model, the image-goal and the subjectively relevant task conditions. If what the human operator regards as subjectively relevant is misguided, then a faulty orientation to the situation can result. This may be regarded as loss of an appropriate situational awareness. Once set on this path, through which all future orientation and exploratory activity is guided, it may be difficult to re-orient the human operator to evaluate what is objectively important and develop a more realistic reflection of the situation (Bedny and Meister 1999). As with the psychological activity theoretical approach in the model, the nature of the task and the goals of the subject of an activity are underlined. So, the extent to which processes are involved is dependent on the nature of the task and on the goals of the subject. There is no doubt that situational awareness is a significant safe factor in car driving.

1.1.5. Executive functions in driving

The term executive functions refers to a variety of loosely related higher-order cognitive processes and skills like initiation, planning, hypothesis generation, concept formation, cognitive flexibility, decision making, problem solving, regulation including self-

regulation, judgement, feedback utilisation, and self-perception that are necessary for effective and contextually-appropriate behaviour (see e.g. Daigneault et al. 2002). Executive functions are high-level cognitive functions that are involved in the control and direction of lower-level functions (Stuss and Levine 2002).

Driving also involves higher mental abilities that supervise all movements and decisions taken by the driver; i.e., executive functions. So, executive functions play a crucial role in driving because this task requires a complex integration of information and supervision of multiple actions that must be adapted to environmental cues (Daigneault et al. 2002).

Despite the growing interest and literature on executive functions, a consensus on its meaning remains elusive (Perry and Hodges 1999).

1.2. Gender, age and driving experience

1.2.1. Gender

Every measure of involvement in fatal crashes recorded in the United States during the 1980s showed rates for men that were approximately double those for women (Evans 1991) and as for Finland, Laapotti (2003) concluded that female drivers are more safety orientated than male drivers. On the other hand, female drivers have more problems with vehicle handling and mastering traffic situations, while males have more problems with personal self-control in traffic.

In Finnish material, men's risks were more often linked to intentional risk taking when compared to women whereas women's were rather linked to knowledge and skills and know-how. Females were at a lower risk of crashing than males at all ages but the difference was greatest for young and inexperienced drivers; the crash liability of females was 30% less than that of males (Salo, 2003).

1.2.2. Age

Young drivers drive faster, use shorter following distances and are more likely to violate traffic lights than older drivers (Summala 1987). Greater accident risk and more deviant

driving styles are associated with being male and young (see Elander et al. 1993; Parker et al. 1995; Summala 1987). On the other hand, in Finland it has been estimated that a proportional number of traffic accidents in male drivers over 70 years old is nine times higher compared to 30-39-year-old drivers, and 13 times higher in female drivers. On the other hand young male drivers at the peak of their physical and psychomotor abilities, are the most unsafe drivers together with the elderly drivers (VALT, 1997). So, age as such does not yet tell anything about a driver's potential safety or lack of safety.

Although elderly healthy drivers may be equally as safe as younger drivers the problem is that completely healthy persons among the elderly drivers are a minority. Ageing influences driving ability through psychomotor and health restrictions, but older drivers can compensate for their reduced reaction time and steering control, for example, by reducing their speed and following at a greater distance or restricting their driving to short and familiar routes during daylight hours (see Hakamies-Blomqvist 1998; Barbas and Wilde 2001). Elderly persons also do not drive so much and therefore their personal accident risk is not very high (Laaksonen 2002).

Elderly drivers also have some advantages over their younger counterparts. These include driving experience, maturity, reduced driving exposure per year and often, the flexibility to make their trips at times and to places that they perceive as being safe. These advantages, however, are not necessarily true for all elderly drivers in all situations, especially in complex dynamic traffic situations like left turns at intersections (Daigneault et al. 2002).

Hakamies-Blomqvist (1998) remind that 'ageing' is a multidimensional concept but among traffic researchers, the word 'age' is practically always understood in its purely chronological sense, i.e., as time elapsed since birth, ignoring alternative or complementary biological, psychological, or social definitions. Ageing patterns differ greatly among individuals: Some drivers will attain any theoretical threshold values in early middle age while a few may continue as middle-aged-like drivers up to their second century. The distribution of accident risk may indeed be bimodal rather than normal; in virtue of their cautious driving style and self-critical attitude, many older persons are extremely safe drivers, while certain pathological subgroups will have functional decrements leading to considerable risk increase (ibid).

One can agree with Hakamies-Blomqvist (1998) that “while earlier research mostly was guided by the question "Why do older drivers have higher accident risk?" the alternative question "Which older drivers have higher accident risk?" has gained momentum in the 1990s”. A general finding in the literature is that faster and more deviant driving styles are associated with being male and young.

By summarising age factor in driving safety one can conclude that drivers under 25 years of age have the highest rates of crash involvement on a population and licence basis, but when the distance travelled is taken into account, rates of crash involvement for the 75 or more age group are as high as those of the youngest age group. Females have higher rates of crash involvement than males in all age groups (Ryan, Legge and Rosman 1998). Although older drivers’ accident involvement may be overly pessimistic (Hakamies-Blomqvist, Wiklund and Henriksson 2005) it is a fact that drivers are ageing and that among elderly drivers there are more driving related cognitive and health problems when compared to younger drivers. Aged drivers have an increased risk of traffic crashes in situations where the cognitive load on the driver is increased, e.g., at intersections (Harms 1991; Hakamies-Blomqvist 1993; Preusser et al 1998; Viitanen et al. 1998).

1.2.3. Experience

Generally it is difficult to separate age and experience. Both age and experience play a major role, but further analysis has indicated that the role of experience may have been overestimated (Elander et al 1993; Salo, 2003). Further, although accident risk drastically decreases during the first years of a licence but experience does not automatically mean expertise and increasing safety (Duncan, Williams and Brown 1991) as statistics indisputably show (www.tilastokeskus.fi).

The odds of a crash being at-fault decreased overall about 6% per year for 7 years after their original license date among in young adult drivers, but the decline was more than twice as fast for women as for men (Waller et al 2001). Early stages of driving are connected with the highest crash rates, but it is difficult to attribute this all to lack of skill (Summala 1987; Evans, 1991). Jonah’s (1986) conclusion that “even when one

controls for the quantity and quality of exposure to risk, young drivers are still at greatest risk of causality accident involvement”.

Rajalin and Summala (1997) studied the effects of involvement in a fatal accident on the surviving drivers' subsequent driving behaviour. Their data showed that the fatal accident affects driving behaviour, but only for a relatively short time. Most commonly, the drivers reported that the effect was limited to those circumstances and situations which led to the accident and did not generalise to safer driving practices. Even unfortunate events do not permanently change people into more safety- orientated drivers.

According to Lajunen and Summala (1995) driving experience is associated with confidence in one's own driving skills, but negatively related to concern for safety.

1.3. Diseases and driving

According to the courts of inquiry the role of diseases in the fatal accidents that occurred in Finland during 1990-2001 were marginal, only 6 %. The role of fatigue (8 %), state of mind (5 %) and functional ability (5 %) were also minor compared to speeding (17 %), intoxication (15 %), lack of knowledge and know-how (13 %) and errors in decision making and perception (10 %) when the same person may have several risk factors (Salo 2003). By the other sources the role of diseases are even more unimportant explaining only 0.1-1.0 % of the number of the fatal accidents (Medical aspects of fitness to drive 1995; Liikennelääketiede 1991, 2002). Further, it is probably often unclear when an accident is the consequence of disease and when an accident has simply occurred to a sick person (Laaksonen 2002).

Sjögren et al (1996) studied autopsied car drivers in northern Sweden over a 13-year period (n = 480, aged ≥ 18 years), who were fatally injured and died within 3 days of the crash. Almost one quarter of the drivers were found to have intrinsic medical factors. Drivers with intrinsic medical factors were often at fault, and in 6% of the drivers, intrinsic medical factors were probably the underlying cause of the crash; in 1.3% the probability was strong. In the 60-year-old and more group the, intrinsic medical factors were the underlying cause of the crash in 19% of the cases; the probability was strong in 4%.

There are exhaustive reviews about diseases and driving (e.g. Medical aspects of fitness to drive 1995; Liikennelääketiede 1991, 2002) but here cases involving evaluations of driving ability are in some way particularly difficult. Results of Dionne et al. (1995) show that diabetic truck drivers have more accidents than drivers in good health. An influence of diabetes on safe driving is difficult to evaluate by the standard short-term cross-sectional methods but a more longitudinal follow-up is needed because patients' states of variation. The number of persons suffering from diabetes is quickly increasing.

Attention deficit hyperactivity disorder (ADHD) is characterised by impairments in attention and/or impulse control, contributing to significant difficulties in social, academic and occupational functioning. Thus, it is logical to suppose that ADHD is linked to accident risk. And the results of Reimer et al. (2005) indicate that ADHD status is positively and significantly related to error, lapse and violation scores of driving. Reported driving violations and errors among ADHD subjects were mediated by age, suggesting that adults with ADHD may learn or evolve strategies to reduce their driving risks. It is highly probable that the percentage of persons suffering from ADHD syndrome will increase in driver evaluations in near future because persons with ADHD are often not capable of the sustained effort required in driving.

Alzheimer's disease (AD) is the most common cause of impaired cognitive function in the elderly. Its prevalence increases from 0.9% in the age group of 65–74 years to 26.8% among persons aged 75 years and older and affects over one third of the persons older than 85 years (Viitanen et al. 1998). AD has consequences for driving. It is likely that many of the killed aged drivers have incipient or unrecognised AD (Perry and Hodges 1999). Even though many patients with mild AD may make the road test or make it in "simple" traffic, more complicated or unexpected situations or long-lasting, "boring" performances often create problems in traffic (Adler, Rottunda and Dysken 1996; Viitanen et al. 1998). In AD attention is the first non-memory domain to be affected, before deficits in language and visuospatial functions (Perry and Hodges 1999; Solfrizzi 2002). AD patients' cognitive performance- memory, visuospatial functions and verbal capacity - is insidiously declining. Therefore, patients are usually oblivious to their disease, nor do they realise their impaired driving performance (Hunt et al 1993), nor do they seek medical examination during the early stage of the disease. Furthermore, physicians are not necessarily able to recognise cognitive impairment in

routine clinical examination (Johansson et al 1996). And with ageing the number of persons suffering from AD is increasing as well.

Traumatic brain injury (TBI) often results in perceptual, cognitive, and motor dysfunction and restrictions leading to limitations in driving. However, according to Brouwer et al (2002) only in a minority of TBI patients has the question of fitness to drive been officially considered. A total of 60% of the TBI survey participants reported that they were currently active drivers and over half of traumatic brain injury survivors had not been professionally evaluated for driving competency (Fisk et al 1997). Among them certainly are a lot of unsafe drivers.

Hernetkoski and Keskinen (1998) showed that the number of suicides and negligent drivers had increased significantly during the studied, nearly 20-year period. Also, the relative proportion of suicides had increased from 1.1% to 7.4% and the relative proportion of negligent drivers from 11.2% to 20.0%. Severe depression causes traffic risk due to self-destructive behaviour, but what else can one do besides advise avoiding unnecessary driving during times when suicidal thoughts may come into a driver's mind? Depression may also have cognitive consequences which are, for the moment, poorly studied. According to Wickens (1992), anxiety and stress can narrow attention span and limit attentional-reserve capacity.

Several health problems are likely to result in impaired driving performance, and consequently elevated crash risk. In addition, some medicines taken for different illnesses may affect driving performance apart from the effects of the health problem per se (Sagberg 2006). In 19% of fatal crashes among older drivers, medical factors which probably contributed to the crash have been found (Sjogren, Eriksson and Ostrom 1996).

Both young healthy drivers and elderly drivers with cognitive and motor deficiencies are noteworthy accident risk groups. This clearly shows that such a complicated form of human performance as driving a car is only partly a biomedical function. Only a minor proportion of accidents are caused by diseases and therefore there is no grounds for disease-centeredness in driver evaluations. Considering the minor role of diseases in fatal accidents the connections between accidents and diseases have been studied very intensively. However, there are still lack of the controlled and the methodologically correct studies of the significance of the diseases to traffic safety

(Laaksonen 2002). The disease-centred studies concerning driving ability abound but, as the selected groups, they do not represent all the drivers and the findings of these studies cannot be generalised. One ought to avoid an excessive medicalisation of an evaluation of driving ability.

1.4. Visual functions and driving

Visual acuity, contrast sensitivity and visual fields are usually assessed by a medical expert. Static visual acuity continues to be used as the principal visual requirement for licensing drivers in most countries (Lamble et al 2002). Visual acuity of 0.5 (the European Union norm) is not a sufficient prerequisite for safe driving. Visual acuity is of primary importance only in some limited driving tasks which do not make a crucial difference to the overall picture of somebody's total driving ability.

According to van Zomeren et al (1988), when very specific sub-tasks of the general driving task are considered, the correlation with assessments on the impairment level are increased, and in this respect Tant (2002) wrote that it is intuitive that, for example, reading signs or reading licence plates could well be highly related to visual acuity. But then only one aspect of the driving task is considered, and thus practical fitness to drive is only partly addressed.

Abnormalities in binocularity and depth perception, contrast sensitivity, dark adaptation, glare sensitivity or colour vision could possibly increase the risk of a traffic accident (Mäntyjärvi, Juntunen and Tuppurainen 1998). Visual acuity is only very mildly associated with driving safety, and Owsley and McGwin concluded that visual perception during driving is not exclusively dependent on visual sensory function, but also on higher-order functions, which they refer to as "central processing skills" (Owsley and McGwin 1999).

An evaluation paying attention to only one, e.g., lower-order visual function, or a few factors, result necessarily results in an inadequate explanation of the variability in or in low correlation with practical fitness to drive (van Zomeren, Brouwer, Rothengatter and Snoek 1988; Tant 2002). On the basis of an analysis of driving performance it is easy to understand that such higher-level visuospatial functions as

attention (sustained and selective), vigilance and visual scanning are more relevant to safe driving than lower-level functions like visual acuity.

1.5. Compensation possibilities

Driving allows for a great deal of human and technical compensation for limitations (Coleman et al. 2002). In real situations drivers are able to make higher-level decisions that affect driving safety (Summala 1996) and by these decisions drivers can reduce influence of their limited functions and qualities. The findings of Owsley et al (2003) imply that visually-impaired older drivers at a higher risk for crash involvement may benefit from educational interventions by reducing their driving exposure and increasing their avoidance of visually challenging driving situations. Brower et al (2002) claim that slowness of information processing need not be a problem for practical fitness to drive and driving safety, as long as adequate tactical and strategical level compensations are part of a patients' repertoire.

Now a number of technological countermeasures have been proposed to reduce the incidence of accidents due to driver impairment, due to the influence of fatigue, alcohol, drugs, distraction, emotional stress, and so forth (e.g. Brookhuis et al.1997; Fukuda, Adachi, Nishida and Akutsu 1995; Qiang and Xiaojie 2002). We can anticipate that the presentation of impairment feedback will lead to behavioural adaptation, leading to changes in driver behaviour at the strategic (e.g., drivers may discontinue their "journey"), manoeuvring (e.g., drivers may reduce speed), or control levels (i.e., accuracy of vehicular input may improve) (Fairclough 2000).

So, much can be compensated for by mental and technical means. However, these adaptations are of little use to the possible accompanying higher-level cognitive, perceptual and spatial impairments (Tant 2002) nor can they be compensated for by apparently more careful behaviour on the road (Daigneault et al. 2002).

1.6. Driving skills and style

At present, driving is generally seen as being composed of driving skills and driving style (e.g. Näätänen and Summala 1976; Elander et al.1993), where driving skill is seen

to be associated with driving performance and driving style with driving behaviour (Evans 1991).

1.6.1. Driving skills

The skill model of driving was supported by early accident theories with the idea that some of us are less skilful drivers and, therefore, more prone to accident (Summala 1985). Real-world motor skill comprises both knowing and doing, and the degree of automation may be seen as an indicator of the skill. Driving skill improves with practise and training, but through experience bad habits also develop (Duncan et al. 1991; Backman 2001).

Brookhuis et al. (2003) connect driver impairment with driving skills so that driving impairment is manifested in such driving errors as following too closely, overtaking in the face of oncoming traffic, overtaking at a junction, following an overtaking vehicle too closely, changing lanes abruptly, straddling lanes and driving too fast for the circumstances.

According to Laapotti (2003) and Salo (2003) Finnish female drivers have more problems with driving skills while Finnish males' problems are associated with an overestimation of their skills, with intentional risky behaviour.

1.6.1. Driving style

First Rippon (according to Kotik 1987) noted that some pilots often made dangerous errors and he reported that they 'fly as they live' and later Tillman and Hobbes (1949) applied it to the car drivers in the well-known form: 'they drive as live'. The view is holistic underlining consistency of human behaviour in different domains. Later Evans (1991, 2002), Summala (1996) and Keskinen (1982, 1992) among others have considered driving in a wider frame than as a mere driving event.

Driving style becomes established over a period of years. Driving style is assumed to reflect choices that drivers make. These choices may reflect attitudes and beliefs of drivers. Unsafe driving styles may arise from two main sources: attitudes toward driving and level of skill and safety. According to Kuikka and Mäkinen (2003) driving skills

include judgement, control of operation, perception, decision making and motor movements, whereas driving style includes uniqueness of the character and motives, attitudes, emotional reactions and control. In multiple regression from style factors, only high driving speed remained a significant predictor of crash rate (West et al.1993; Salo 2003). Choice of speed has been shown to be consistent over time (Wasielewski 1984).

Elander et al. (1993) came to the conclusions that, first, both driving skill and driving style are related to differential crash involvement; second, speed of detecting hazards in the traffic environment and more general abilities to detect visual targets in a complex milieu and to switch attention rapidly, have been consistently related to crash frequency, independently of age, sex, and annual mileage; third, faster driving and deviant driving behaviour are associated with more frequent crashes.

The results of Ferguson et al. (2001) indicate that childrens' driving records in the first few years of licensure are related to the driving records of their parents, especially to violations. Children whose parents had three or more violations were 38% more likely to have had a violation compared with children whose parents had none. Thus, it can be supposed that driving style is connected to lifestyle and one's lifestyle depends on the lifestyle of their significant others.

Although driving skill improves with practise, the pass rate on the standard driving test falls steadily with increasing age (Maycock et al. 1991). Does this indicate possible defects in the on-road evaluations of elderly drivers?

1.7. Models of driving behaviour

1.7.1. Hierarchical models of driving behaviours

Such a human activity as driving a car is a dynamic system which constantly changes and transforms itself in the process of carrying out goal-oriented actions. Therefore behaviours and an activity have to be constantly regulated by the subject.

The simplest way to analyse driving is to divide it into subtasks, and several such lists of driving tasks have been made (e.g. McKnight and Adams 1970; Lourens 1988).

They are merely descriptive and were soon replaced by the hierarchical models which are more explanatory.

Michon's (1985) three-level cognitive control hierarchy is widely used in traffic literature. It describes driving as a hierarchy of subtasks of the strategic, tactical, and operational level (Michon 1985). Generally an operational level involves execution of basic driving operations such as steering control and brake application, demands coping with risks and is time dependent. By the lower-level perceptual and sensorimotor operations the car is held on course, and this level consists of such largely automatic action patterns as, e.g., steering, braking, and shifting. The tactical level is described as a risk-taking level, which is, on the average, time dependent or there is at least a slight time pressure. It involves in-traffic decisions like speed adaptation and use of headlights during poor visibility. Finally, on the strategic level, choice and decisions are made concerning mode of transportation, route, time of day, and so on. These decisions are usually made without time pressure and often before engaging in actual driving (Michon 1985; Molen and Bötticher 1987; Ranney 1994; Brouwer et al. 2002).

In the Rasmussen's (1987) hierarchical control model, driving behaviour is differentiated into skill-based, rule-based, and knowledge-based behaviour, and hierarchical structure is related to control errors. Later, Lehto (1991) proposed a fourth level, referred to as judgement-based behaviour. Other regulation models also exist (see e.g. Frese 1998), but let us now look a little bit closer at Rasmussen's regulation system. The main distinction between the skill-based, rule-based, and knowledge-based levels is in the degree of automation of behaviour. Drivers' behaviours are supposed to be more homogeneous and predictable at the skill-based and rule-based levels than at the knowledge-based level.

The lowest level of regulation of behaviours Rasmussen called skill level (*ibid*). It is the level of regulation of automatised skills. Information processing at this level of regulation is rapid, effortless and parallel, but the cause of automated, unconsciousness character of regulation the process of regulation is also very rigid and it is difficult to modify ineffective or harmful automatisms of activity and behaviour. The second level of regulation in Rasmussen's (*ibid*) taxonomy is called rule-based. At this level there are ready-made actions or programmes of actions and operations in memory which, however, must be adjusted to prevailing situations and circumstances. In driving this

level is, of course, important, because besides technical skills and psychomotor abilities driving requires obeying the established laws and rules for the safety of one's self and others. The third level is knowledge-based in Rasmussen's (ibid) model of regulation. Compared to the previous levels at this conscious level of regulation the regulation process is slower and constrained by limited resources of information processing capacity. Thus, when conscious regulation of activity is needed, the work is often discontinuous, inefficient and slow. Just think about driving a car for the first time.

Michon's and Rasmussen's models were later combined (Ranney 1994) to classify selected driving tasks: operational decisions take place on the skill-based level, tactical decisions on the rule-based level, and the strategic decisions on the knowledge-based level.

Parker et al. (1995) associate accidents with conscious rule-based offences and, according to activity theory, conscious actions belong in the hierarchy of a subject to the personality level. So, the findings of Parker et al. (ibid) confirm the activity theoretical view of the significance of the personality in human activities (Rubinshtein 2003) and this is also the case in evaluations of such socio-practical human activity as driving a car. Typology, however, is only a description and it does not yet explain how and why accidents occur.

All the levels of control mentioned above can be found in driving. Thus, recognition of these levels of control has relevance to the evaluation of driving ability. However, in our context, in a driver's evaluation, the theory in question completely lacks the most important level of regulation and control, namely the metacognitive level, the level of self-reflection of regulation. Normally people are aware of the strategies and tactics they use, they also know how they plan their activities, how they set their goals, how they receive and process feedback (Frese 1998), and at least to some extent they are also aware of how they make decisions. The metacognitive level is not used when rules and goals, as well as the methods of attaining the goals, of activity is known by the subject of activity. However, the metacognitive level of regulation is of greatest importance when a driver makes strategical decisions concerning his/her driving condition, planning driving routes and time. Emotions also play a significant role in regulation of such activity as driving a car. They reveal our relationship to the surrounding world, to other people and society (Bedny and Karwowski 2006). In Rasmussen's model there is

no clearly addressed place for emotions. The taxonomy of Rasmussen is not a properly hierarchical system because there are no functional links between the levels (Keskinen 2002); a higher level does not regulate a lower one.

Mikkonen and Keskinen (1980) go about characterising the problem of control and regulation of driving on the basis of ‘theory of inner models of driving behaviour’. Their theory consists of three levels of inner models: vehicle manoeuvring, mastering traffic situations and goals and context of driving. With experience and education the information a driver has about traffic situations forms to the inner models.

Then driving is regulated by these inner models. Inner models represent routes, sights, and handling of a vehicle. External factors affect driving through inner models. Consequently, the degree of development of inner models is associated with accident risk.

Later Keskinen (1996) expanded the theory of inner models by adding a fourth level: goals for life and skills for living. By this enlargement the role of motives is more heavily emphasised (Laapotti 2003). The levels interact with each other so that the higher levels direct the lower ones (Hatakka et al. 2002; Keskinen 1996). Driving experience only influences the lower levels of driving. The four level model of driver behaviour includes the following levels in order from highest to lowest: a) goals for life and skills for living, b) goals and context of driving, c) mastering traffic situations ,and d) vehicle manoeuvring. The first level offers a broader perspective for driver capacities and compensation resources. With life experience a driver may increase his or her knowledge about his or her own abilities and limitations; life itself often changes values towards more safety-directed driving, and of course, driving skills usually improve with experience. Strategy of driving reflects the content of the highest level of hierarchy which also includes elements beyond proper driving (e.g. Keskinen, 1996, Summala, 1996), whereas tactics of driving are linked to the goals of driving. In the strategic level a driver chooses the transport used, makes a decision on a trip and times a drive. Tactics of driving covers, e.g., mapping out a route of the trip.

Enlargement of the theory of the inner models done by Keskinen (1996) enables or even compels the inclusion of higher-level factors such as motives, attitudes, and values to driver evaluations. Interestingly, the idea of Mikkonen and Keskinen (1980) of the inner models as a mediator through which external stimuli and factors influence driver

behaviour, comes very close to the principle of determinism from Rubinshtein: 'External causes act through internal conditions' (Rubinshtein 2003).

Hacker (1981) specifies four levels of regulation: sensory-motor, perceptual, motivational and intellectual. There are significant differences between the levels of regulation. First, objective 'degrees of freedom' define the level of regulation that is possible. In traffic the most degrees of freedom are in the situation when a driver plans a route and time of trip. On a road degrees of freedom are limited because of traffic rules and regulations. Second, tasks and their structure vary in different levels of regulation. On lower levels – the sensory-motor and perceptual level – tasks are most often not even conscious. Third, psychological processes and operative images (a concept of Pushkin, 1965) involved in regulation differ from each other on different levels of regulation. Fourth, how detailed the programme of actions is, varies with levels of regulation. Automated programmes are rigid while intellectual ones are more flexible. According to Hacker (ibid) planning and realisation of activity are hierarchically organised so that a higher level includes lower levels which work subordinately regarding higher levels of regulation. Due to a complex nature of driving an accident may in principle results from a failure of any level of regulation. In an accident resulting from a 'human factor' the question is always focused on the failure of a driver to control and regulate an activity.

1.7.2. Functional models

Functional models as alternatives to the skill-based models include both motivational and information-processing models (Atkinson 1957; Naatanen and Summala 1974, 1976; Summala 1988; Wilde 1982; Fuller 1984).

1.7.2.1. Motivational models

Motivational models focus on "what the driver actually does" in a given traffic situation rather than on the maximum skills of a driver. One of the most important findings made in motivational studies was that on-road driving differs considerably from a driver's capabilities. A related distinction has been made between performance and behaviour (Naatanen and Summala 1976; Shinar 1978; Evans 1991; Elander, West and French

1993), where performance refers to what drivers are capable of doing, while behaviour refers to what drivers actually do on the road. Performance in laboratory tests does not necessarily predict actual driving performance. Therefore a distinction should be made between a person's maximum level of driving skill and how well drivers apply their skills. The main assumptions of these models are that driving is self-paced and that drivers select the amount of risk they are willing to tolerate in any given situation. Risk-related driving behaviour is a central issue, and the driver is seen as an active decision maker, rather than a passive responder. These models emphasise transient or situation-specific factors. The risk associated with possible outcomes is seen as the main factor influencing behaviour.

Summala (1985) argues that the driver should be seen as satisfying her/his motives in traffic, and there are also so called extra motives influencing driving behaviour. They include motives such as emotions, behavioural models, showing off, hedonistic models, and risk-taking for its own sake. According to Summala, driving behaviour has a cognitive basis, but according to his theory, however, the concepts of risk-taking and safe margins are central. Behaviour is assumed to be directly related to the level of perceived risk, which is in most cases 'calculated' to be zero. So, in normal situations the drivers do not feel a risk at all. Safety margin is defined in terms of spatial and temporal measurements, and only when the threshold for risk is exceeded, risk compensation mechanisms are called into effect to restore the risk to the zero level (Summala 1988).

1.7.2.2. Information processing models

Cognitive psychology represents the paradigm in psychology today. A primary focus of this approach is on memory. The most widely accepted theory is labelled the stage theory, based on the work of Atkinson and Shrifin (1968). The focus is on how information is stored in memory. According to this theory information is processed and stored in three stages: sensory, short-term and long-term memory. In this theory, information is thought to be processed in a serial, discontinuous manner as it moves from one stage to the next. In addition to the stage theory model of information processing, there are three more that are widely accepted: levels-of-processing theory,

parallel-distributed processing and connectionistic models as alternatives to the Atkinson-Shiffrin's stage theory. The major proposition of levels-of-processing theory is that learners utilise different levels of elaboration as they process information. There is a continuum from perception, through attention, to meaning. The theory proposes that stimuli capable of activating sensory receptors are permanently stored in memory. However, this depends on the levels of information processing and how memory functions. According to the parallel-distributed processing model information is processed simultaneously by several different subsystems of memory, rather than sequentially and serially. The connectionistic model emphasises that information is stored in multiple locations throughout the brain in the form of networks of connections: the more connections the more likely it is to be remembered (Huitt 2003). Information-processing models first study human information channel capacity and its limits but later the focus on research moved from determining the limits of processing to automaticity.

According to Ranney (1994) the problem of information processing models are that, in this context psychologists created experimental techniques using stimuli that were abstract, discontinuous, and only marginally real, and as a result, describing and explaining such continuous practical tasks such as driving, were eliminated (Ranney 1994).

Generally speaking, the advantages of functional models compared to taxonomies are, of course, their faculty to explain human activity and behaviour with the help of motives, the limitations of information processing capacity, etc. instead of only described phenomena as taxonomies and typologies do.

In driver evaluations the examination of motives is extremely important as our case study (V) excellently demonstrates. Similarly, difficulties in information processing often are accentuated by stroke, TBI and diseases affecting the CNS (III). On the other hand, examination of motives is only one phase in the procedure of the driver's evaluation, and driving is not limited to information processing only, as our models (fig. 1, 6) show.

Motivational models strongly emphasise the self-paced nature of driving. It seems that supporters of motivational models diminish the pressure drivers often experience from the side of other drivers and road users. This social pressure and prevailing norms

are factual matters but are not the only theoretical aspects of the traffic system. And pressure and norms really affect decision making at all levels. Therefore, the ability to make independent safety-related decisions is one important personality quality to examine in driver evaluations.

From the point of view of activity theory a subject indeed is seen as an active decision maker but regulation of activity must be associated with real tasks and goals of activity, with driving performance but not with perceived risks. The person's main motive is not going to be to avoid risks in traffic but to drive a car, to get from one point to another.

Driving a car sets high standards particularly for parallel and continuous information processing and regulation. Bruslinsky (1994) underlines that psyche, as the highest regulator of internal mental and external practical activities, exists as a process. From the point of view of driver evaluations this should mean abandonment of cross section studies (what) in favour of process analysis (how). One of the results of this kind of study could be a description of individual styles of activity (Merlin 1986).

1.8. Aberrant behaviours

For safety reasons one has to obey traffic rules and regulations. Deviation from rules and regulations increases accident risk. There are several classifications of aberrant behaviours such as those used in this study (see p. 44). However, the most famous classification, described by Reason et al. (1990), identified a three-fold typology of aberrant driving behaviours: lapses, errors and violations. The first type, lapses, are absent-minded behaviours with consequences mainly for the perpetrator, posing no threat to other road users. The second type, errors, are typically misjudgements and failures of observation that may be hazardous to others. The third type, violations, involve deliberate contraventions of safe driving practice. Naturally this typology has a use in traffic research.

For explanation and analysis of accidents Reason (1990) created the 'Swiss cheese model' that is widely adopted as the model for investigation of accident causation. Reason (Reason, J. Human Error. Cambridge: University Press, Cambridge 1990) made a key distinction between the active, operational errors ('unsafe acts') and the latent

(organisational) conditions. Reason (1990) stated that “systems accidents have their primary origins in the fallible decisions made by designers and high-level (corporate or plant) managerial decision makers” (p. 203). Active errors were therefore seen as symptoms or tokens of a defective system. It became the duty of incident investigators and researchers to examine the psychopathology of organisations in the search for clues.

From the point of view of a driver’s evaluation and a driving license Reason’s model has only marginal practical value because the focus of Reason’s model is in the reliability of the whole system (aviation, manufacturing plant, etc.) while in the context of a driving licence the subject is the single person. Reason’s model is system-centred while driver evaluations should be person-centred.

1.9. Theories of reasoned action and planned behaviour

There is a limited number of models which make an attempt to explain and to predict human behaviour and activity in a complex environment. Probably the most widely cited explanatory theories are the theory of the reasoned action and its successor, the theory of the planned behaviour.

According to the theory of reasoned action (Fishbein and Ajzen 1975) if people evaluated the suggested behaviour as positive (attitude), and if they think their significant others wanted them to perform the behaviour (subjective norm), this results in a higher intention (motivation) and they are more likely to perform the behaviour. Importance of significant others to driving behaviour is, particularly in youth, undoubtedly a central issue. Limitations of the theory come from the nature of the self reporting used to determine subjects’ attitudes. Self reported information is in many cases not accurate enough for determining driving ability (e.g. McKenna, Stainer and Lewis 1991; Lajunen and Summala 2003; Reimer et al. 2005). However, the most serious limitation of the theory stems from the assumption that behaviour is under volitional control. Automatisms, that are so important in driving, cannot be explained by this theory.

Later Ajzen (1985) introduced the theory of planned behaviour by adding a new component to the theory of reasoned action, ‘perceived behavioural control’. According to the theory of planned behaviour ‘attitude toward the behaviour’, ‘subjective norm’,

and 'perceived behavioural control' lead to the formation of a 'behavioural intention'. 'Perceived behavioural control' does not only affect actual behaviour directly, but also affects it indirectly through behavioural intention. Intention is determined by the individual's evaluations of the consequences, by his/her perceptions of normative pressure to perform that behaviour, and by the degree of control the individual perceives that he/she has over performance of that behaviour.

By the theory of planned behaviour the attitudes, subjective norms and perceived behavioural control predict driving style including speeding, drink-driving, close following, and risky overtaking (Lajunen 1997). The model lacks a need(s) – motive(s) – goal(s) vector and therefore the 'system' is without an energy source (need), and without the main regulator of activity (motive-goal).

Further, driving style, as a special form of activity style, is a personality attribute which has to be researched in connection to other personality factors and dimensions.

From the point of view of driver evaluations, the main limitation of the theory of planned behaviour is that it is completely based on cognitive processing. The theory overlooks all irrational factors of driving behaviour. However, a very high accident risk of young healthy male drivers clearly shows that risky behaviour depends not only on cognitive factors but on emotional and personality factors too. Because driving is only partly a cognitive task, the usability of the above-mentioned theories in driver's evaluations is limited.

1.10. Off-road and on-road tests as predictors of safe drivers

The importance of assessment of cognitive factors in the evaluation of driving abilities are stressed by many researchers. According to Stutts et al (1998) drivers who scored in the lowest 10% on the cognitive tests--Trail Making Test parts A and B, the Short Blessed Orientation Memory Concentration test of cognitive impairment, a modification of the American Association of Retired Persons 'Reaction Time' test, and a timed Traffic Sign Recognition--were approx. 1.5 times more likely to be in crashes than were drivers who scored in the highest 10%. According to Lundberg et al (1998) a combination of visuoconstructive ability, visuospatial memory and verbal episodic memory correctly classified 65.2% of the crash-involved drivers. The findings of

Coleman et al indicate that even a brief battery of neuropsychologic tests may be a useful component in the routine assessment of fitness to drive (Coleman et al. 2002).

Klavora et al (2000) found that driving fitness of elderly persons with stroke can be assessed with reasonable accuracy using off-road tests, minimising the expense and risk associated with on-road assessments in this population, and Lundberg (2003) concludes in her thesis that older drivers with demonstrated unsafe traffic behaviour should be cognitively assessed, and this should also be the case for older licence holders with medical conditions making them susceptible to cause cognitive impairments. Also the results of Daigneault et al. (2002) confirm the importance of proper assessment of cognitive processes and underscore the potential of measuring executive functions for the evaluation of driving competence of elderly persons.

Hakamies-Blomqvist et al. (1999) note that not even a heavy test battery is sufficiently sensitive to driving specific tasks in order to permit or to prohibit someone to drive a car. Fairly few studies have tested subjects both in laboratory and real-life driving, and most of these studies have used neurological patients as subjects (e.g. Galski et al, 1992; Nouri et al. 1987; Brooke et al. 1992; Fitten et al. 1995, Wolffelaar et al., 1992) and only a few studies have used healthy persons as subjects (e.g. Risser et al. 1985; Odenheimer et al.1994). Both laboratory tests and driving tests used in these studies varied to a very high degree. Efforts to create a battery of tests to predict the ability to drive reliably are still under way (Ranney 1994). Moreover, the research has still failed to identify any consistent pattern of neurological, perceptual, cognitive, motoric, or neuropsychological deficits that renders a person unfit to drive (Galski et al. 2000). Only carefully selected tests can be used to evaluate fitness to drive (Galski, Bruno and Ehle 1993). Withaar et al. (2000) note that the direct relationship between neuropsychological measures and actual driving performance is questionable. The authors point to the multiple determination of the quality of driving performance and it is noted that in many studies this has not been taken into account. Tests which successfully discriminate between brain damaged and non-brain damaged patients are not necessarily highly correlated to driving performance (e.g. van Zomeren et al. 1988). Thus, tests serving one purpose (e.g., patient-group classification), are not necessarily practical for application to driver evaluations. The need for a screening test as a first step instrument in a multi-level evaluation procedure has recently come up. De

Raedt and Ponjaert-Kristoffersen (2001a) developed a short screening battery for elderly drivers to evaluate the necessity for further referral to specialised centres. A battery consists of the Trail Making Test, Part A, a visual acuity test, a clock drawing test, and the Mini-Mental State Examination (MMSE). These results highlighted the potential value of a short screening instrument that can be used in primary health care settings. Furthermore, they noted that, at least to some extent, the predictability of car accidents by neurocognitive measurements and a road test increases when the kind of accident is specified (De Raedt and Ponjaert-Kristoffersen 2001b).

The on-road driving evaluation currently is considered the criterion index of fitness to drive; however, little information exists regarding the relation between the on-road test, actual driving records, and subjective reports of driving safety (Coleman et al 2002). Naturally, the on-road assessments have greater ecological validity than off-road evaluations including simulator tests.

The main problem with driving simulators is their low ecological validity. The examinees always know that they are in the simulator test instead of actual on-road driving and this consciousness distorts their attitudes and emotions towards the test. The extent to which an individual's performance in the simulator corresponds to actual driving behaviour is not well established (Barbas and Wilde 2001). At its best, a driving simulator is a good sensorimotor test but the majority of simulators still simulate only relatively simple skills of the eye-hand co-ordination.

1.11. Self-evaluation of driving ability

Drivers tend to overestimate their perceptual-motor and safety skills (e.g. McKenna, Stainer and Lewis 1991; Lajunen and Summala 2003) and overconfidence in driving skills results in a driver's biased sense of control in traffic leading to a high level of risk acceptance (Näätänen and Summala 1976). On the whole drivers have a general tendency to rate their driving abilities as "above average" (Delhomme 1991; Groeger and Brown 1989) and this tendency may be based on infrequent feedback from the driving task (Evans 1991). The rarity of accidents and the attribution of blame to outer factors (weather and road conditions, the behaviour of other drivers etc.), easily lead drivers to overestimate their own driving skills and ability (Reimer et al. 2005). On the

other hand driving may be perceived as an overlearnt behaviour, such as an activity of daily living, rather than a skill that requires complex cognitive ability (Coleman et al 2002).

While healthy people also tend to overestimate their driving skill and ability (Lajunen and Summala 2003), this issue is more acute among neurological patients due to particular problems, such as denial of symptoms and neglect syndrome. It is well-known that, e.g., stroke patients may have problems in recognising their own cognitive or psychomotor disorders. Particularly damage to the non-dominant hemisphere often causes anosognosia and neglect syndrome (Gainotti 1972; Hier et al.1983). In the in-person interview study by Marottoli and Richardson all participants of older individuals (n = 125) age 77 years and older rated themselves as being average or above average drivers compared to others their age, with the majority rating themselves as above average (Marottoli and Richardson 1998). Age and experience does not automatically improve one's ability to evaluate his or her driving ability.

1.12. Driving ability in the context of the Finnish law and WHO's ICF

When making pass-fail decisions in the context of a driver evaluation clinicians have to act according to law. In the decree (Finnish law 2002) it is said that driving is prohibited for persons who lack prerequisites for driving due to disease, defect, handicap, fatigue or another corresponding reason (64 § (3.8.1990/676)). Further, in decree 9 § (5.1.1996/2) it is said that a driver does not to have such defect, disease, or handicap which significantly impair his or her ability to act as a driver (91/439/ETY).

The World Health Organisation (1980) draws a clear distinction between impairment, disability, and handicap. Impairment is classified at the level of the organs, disability at the level of the individual, and handicap at the level of the social environment. This classification encourages health care professionals to examine diseases and their consequences in a wider context, that is to say, how they influence transportation, communication, living, studying and working (Talo 2001).

A prospective way of thinking about functional disabilities and restrictions provides the WHO's International Classification of Functioning, Disability and Health (ICF)

classification as a unified and standard language and framework for describing health and health-related states in a bio-psycho-social model (Talo 2001; World Health Organization 2001; Tant 2002). The ICF classifies functioning and it supplements the International Classification of Diseases (ICD-10) which provides an etiological framework. In ICF, human functioning is viewed as the outcome of an interaction between a person's physical and/or mental condition and the social and physical environment.

What is an ability to drive from the perspective of the WHO's ICF classification? In terms of the ICF, practical fitness to drive is defined on the activity (formerly disability) level, and is evaluated accordingly (Tant 2002). Unfitness to drive is therefore conceptually an activity limitation. It is thus recognised that fitness to drive is as closely related to learnt driving skills and compensatory behaviours as to medical status. This is in contrast to the traditional medical concept of fitness to drive, which is only related to impairments. The on-road test is situated on the activity level, as it is an assessment of actual driving ability presented by the client. In contrast, medical fitness to drive is a decision based on medical information (for example visual acuity or visual field extent), not on actual driving performance. Tant (ibid) pointed out that the restriction based on medical unfitness to drive bypasses the activity level in the framework. Consequently, an ability-to-drive decision should be based on the on-road driving test which is an activity level indicator. Using ICF terminology, an interaction of lower-order impairment and environmental factors including legal aspects, results in a participation restriction or prospect, namely being refused to drive a car or being permitted to acquire a driving license.

1.13. Résumé of the literature review

af Wåhlberg (2003) writes that the current research into psychological accident predictors is fraught with methodological deficiencies: the question of culpability, the use of self-reported crash data, crash definitions, the mixing of predictor variables of different types (e.g., sex and personality), the lack of replications of many studies, how to handle the exposure problem, sub-groupings other than culpability, etc. He says that research has been rather individualistic concerning the variables and methods chosen.

The search for psychological predictors of accidents has not been very successful. Further he asks whether there is really such a thing as stable, measurable individual behaviour in the traffic environment, which is the same thing as reliability over time of the measurement made. Very few traffic researchers seem to have paid any attention to the question of the reliability/stability of their accident predictors, as such calculations are seldom reported or discussed.

Hauer argued (2004) that the pervasive use of tests of significance as statistical ritual impedes the accumulation of knowledge and is unfit for use. The uncritical application of null hypothesis significance testing may easily lead to the misinterpretation of data and often leads to the subversion of reason and of science. Further, use of tests of significance has directed research toward the lower-order measurable phenomena. Therefore, less attention has paid to the higher-order factors. This ritualistic use of statistical methods as an exclusive scientific criterion has led to the situation that there is an ocean of formally correct studies with minor information in traffic literature.

A self-report in a different form is the main traffic research method. However, reliance on self-report of driving safety is methodologically questionable because patients may have a poor awareness of their deficits and may misrepresent their driving behaviour (Coleman et al. 2002). Self-reports are not reliable methods for collecting accident related information (McGwin Jr., Owsley and Ball 1998).

Diseases are often accompanied by psychological denial of their physical and mental restrictions or via depression a person may devaluate his or her residual abilities. Thus, diseases often distort patients' self-concept which is the basis of sound self-evaluation. Risks accumulate when weakened cognitive and sensorimotor functions are unified with denial of one's symptoms or diseases and/or overestimation of one's abilities.

Generally speaking health plays only a minor role in traffic safety (e.g. Medical aspects of fitness to drive 1995) and driving ability is only partly the biomedical object of the research. However, traffic literature is abound with epidemiological studies of accident causation. The findings of these empirical studies are often contradictory and confusing (Ranney 1994), and in general, these studies with the selected groups have little to offer a practical driver evaluation with concrete unique individuals. Moreover,

Galski et al. (2000) note that there has been misunderstanding concerning the role of medical examination in evaluation of driving ability. This misunderstanding is based on the incorrect supposition that medical expertise automatically qualifies practitioners to evaluate driving ability and leads to overestimation of the role of clinical examination in evaluations. Overestimation of the role of clinical examination has led to a groundless medicalisation of the evaluation of driving ability.

In Europe there are no universally agreed upon criteria for invoking the assessment process, no standardisation regarding the specific medical conditions requiring assessment, no standardisation in the scheduling of the assessment process, no universally agreed upon and validated set of tests or tools to measure the functional skills necessary for driving, lack of knowledge regarding guidelines and standards related to specific driving-relevant functional deficits (Hakamies-Blomqvist, Henriksson and Heikkinen 1999; Sommer et al. 2003). Among traffic researchers there is widely accepted view that driving ability evaluation procedures are too deficit related. More compensation and capacity-related evaluation procedures are needed (De Raedt and Ponjaert-Kristoffersen 2000). In Finland the procedure of an evaluation is disjointed depending on the researcher's individual context and on methods used in evaluations.

The literature shows that accidents are difficult to predict using off-road tests (for a review of performance tests, see Wetherell 1996), and although performance tests have been extensively used to predict impaired driving, the validity of these tests is rarely studied or even questioned. Further, the problem here is that performance in laboratory tests does not necessarily predict actual driving performance but a distinction should be made between a person's maximum level of skill and how well drivers apply their skills (Näätänen and Summala 1974, 1976; Summala 1988; Evans 1991; Elander, West and French 1993). It is easy to determine the pattern of tests which distinguishes patients from the healthy controls, but it is much more a demanding task to determine the tests which distinguish safe drivers from unsafe ones.

Well-known instrumental problems are related to non task specificity of traditional psychological tests. Studies with adequate neuropsychological assessment typically lack adequate outcome measures for driving safety or have an extremely brief follow-up. Often, the tests have been brief, largely neglecting important domains such as executive

functioning and the patient's awareness of deficit (Coleman et al 2002). According to Solfrizzi (2002) there are problems defining whether age-related cognitive decline is an expression of normal ageing or preclinical dementia.

Executive functions are undoubtedly of most importance in such a complicated form of an activity as driving. Most studies in which neuropsychological assessment was found not to be useful for predicting driving safety failed to include measures of higher-order executive functioning. (Coleman et al. 2002). These higher-level cognitive functions involved in the control and regulation of lower cognitive operations, are clinically assessed by a small battery of tests that, on the basis of putative sensitivity to frontal damage, are referred to as "frontal." Support for the validity of this claim is variable. In general, modern cognitive neuroscience findings have failed to penetrate clinical assessment of executive functions (Stuss and Levine 2002). Thus, there are yet no reliable methods for measuring executive functions.

There is also a surprising lack of widely accepted measures for sustained attention (detection of targets over a prolonged time period) in traditional clinical neuropsychology. And, though, almost all driving test patterns include a work memory test, few widely used tasks seek to directly assess working memory per se. Digit span or spatial span tasks are important for determining working memory storage capacity, but do not provide information relating to rehearsal or executive control (Stuss and Levine 2002). Digit span does not measure actual work memory but a volume of short term memory.

The on-road tests are attractive in their seeming ability to address task-specific characteristics of driving. However, these tests are also limited in their ability to predict actual driving behaviour. Both theoretical and practical concerns have been raised. First, there is a limitless number of combinations of traffic situations and therefore it is even, in principle, impossible to confirm whether a driver copes with every traffic situation or not only using a driving test (Ojala and Meriläinen 2003). Second, on-road driving evaluations have also been strongly criticised for lack of objectivity and reliability, exemplified in the relatively high accident rates for young drivers who pass the on-road test for licensure and absence of standardisation in conducting on-road evaluations. Further, the pass rate on the standard driving test falls steadily with increasing age (Galski et al. 2000; Fox et al. 1998). Third, on-road tests are also considered dangerous,

often have unknown reliability and objectivity, and are costly in terms of time, money and energy (Galski, Bruno and Ehle 1992; Barbas and Wilde 2001). They require expensive equipment and specially trained evaluators, and carry high liability (Klavora et al 2000). Fourth, because driving is an overlearned behaviour, a standard road test may be insufficient for uncovering the unpredictable and complex situations in which disabled individuals may have the most difficulty. Fifth, driving school teachers are used to working with young persons which may bias their evaluations of the older drivers.

A comprehensive model of driving behaviour that predicts both crash-causing behaviours and everyday driving has yet not to be developed (Ranney 1994), and it is easy to agree with Summala (2005) when he writes that truly functional models which predict road user behaviour on road is needed in traffic psychology.

The main question in the context of driver evaluation is: Who is a driver? Surprisingly this question remains without an answer in light of the traffic literature and with it there is a lack of a proper basis of the evaluations of driving ability, as well. Regardless of generally and officially accepted fact of the significance of the driver for road safety, it seems that traffic researchers have practically not systematically studied their conception of a human being. However, according to Rauhala there are always some preconceptions of the fundamental character of the subject of the research and this ontological solution always shall be made. If the researcher does not make this ontological solution in regard to Man's nature, then in the last analysis, his or her hypotheses and research methods dictate this ontological conclusion regarding Man's nature for the researcher (Rauhala 1978, 1983). This appears to be the case in traffic research and the result is that traffic research is predominantly behaviouristic where the tasks of the research are mainly human reactions and responses to different stimuli.

The prevailing behaviourism and functionalism in psychology generally, and particularly in traffic psychology, has led to the loss of a real subject of an activity, a concrete human being. The subject of activity, a driver, is replaced in traffic psychology with his reactions and responses, motivation, cognition, emotion, attentiveness, etc., and furthermore, a personality is reduced to some traits or dimensions which are only a few variables among others variables. This is a considerable limitation from the standpoint of driver evaluation. It can be concluded that the traffic researchers' predominant

conception of Man bears the stamp of naturalism, mechanism, and fragmentarism and by this conception of Man it is impossible to organise a qualified driver's evaluations.

Traffic safety claims that the drivers who are clearly dangerous to other road users and to themselves have to be excised from traffic as drivers, but on the other hand, one should allow the possibility to drive to all those disabled persons who have sufficient physical and mental qualifications to act as drivers. And, progress in adaptive technology affords an ever-increasing number of disabled persons the opportunity to succeed as a driver. Therefore, there is a continuous and an increasing need for an evaluation of driving ability. A driving licence, regardless of whether we see it as a right or privilege, can be forbidden only because of closely argued proof. All disabled persons ought to have the possibility for a high-quality evaluation of their driving ability.

Safe driving requires the complex interaction of physical, psychomotor, cognitive, emotional, and personality attributes regardless of a driver's age, sex, driving experience and health. So, one can agree that there are some psycho-physiological requirements common to all the drivers but it seems that the consensus ends here.

Ability to drive evaluation procedures need to be clearly defined, however this is now not the case. Ranney (1994) noted that there is no comprehensive model of driving behaviour, and as far as models of an evaluation of driving ability are concerned the situation is possibly even more open and uncertain. Performance tests have been extensively used to predict impaired driving (Wetherell 1996), but the research has failed to identify any consistent pattern of neurological, perceptual, cognitive, motor, or neuropsychological deficits that renders a person unfit to drive (Galski et al 2000). Disease-centred studies concerning driving ability abound but, as selected groups, they do not represent all the drivers and the findings of these studies cannot be generalised. There are no standards for the conduct of driving evaluations, no normative data relevant to a person's performance on individual tests or evaluation as a whole on which to base pass/fail decisions and no guidelines for interpretation of test results. Further, there has been no consensus among clinicians about which tests and measures should be included in a standard assessment nor any accepted guidelines for determining who should pass/fail a comprehensive driving evaluation (Galski et al. 2000, see also Barbas & Wilde 2001; Hakamies-Blomqvist et al. 1999; Hopewell 2002). So, there is no

consensus about what an evaluation of driving ability has to include and how an evaluation has to be carried out.

The British Psychological Society stated (2001) on neuropsychological deficits and ability to drive, that “a complete account of driving would ultimately require a comprehensive understanding of the whole of human behaviour in terms of this very broad array of variables, which as present are far from complete.” For making this possible an evaluator could orient in this ‘very broad array of variables’ the conceptual and functional models are needed along with empirical materials.

2 AIMS OF THE STUDY

The general aim is to develop model for practitioners and other professionals, who have to take a stand on driving ability of their patients. This is made on the basis of empirical materials and psychological activity theory.

The aim of the study with the young driver school female students and the experienced middle-aged male drivers (I, II) was mainly methodological: how off-road laboratory tests and on-road driving test work in different driver groups.

The studies with the patient groups (III, IV) were aimed at showing how concordant or discordant the conclusions on the patients' driving ability made by the different evaluators were -- examinees themselves, their spouses, medical doctors, a psychologist, an occupational advisor, a driving school teacher -- on the basis of their knowledge and the methods in their use.

In case study (V) the aim was to describe, in detail by the help of some cases, how and on which basis decisions in clinical driver evaluation can be made in the context of the psychological activity theory.

3 STUDY DESIGN, MATERIAL AND RESULTS

3.1. Study design

Two basically different case-control methodologies have been used to determine the relative risk associated with medical conditions. The most common approach is to select drivers with a certain condition (cases) and compare their risk with that of drivers without the same condition (controls), often matching the cases and controls on background factors. The alternative approach is in a way inverse to the first one. Instead of selecting cases on the basis of medical diagnosis and estimating their crash involvement, cases are selected on the basis of crash involvement, and the prevalence of the medical condition among the crash-involved drivers is compared to that of a control group (Schlesselman 1982). Our material is of the previous type.

The study design was the same in the groups of the students, experienced drivers and the Parkinson's disease patients: the same driving school instructor evaluated driving ability using the on-road driving test (criterion), to which the evaluations made by the specialists and the examinees themselves were compared. Finally all evaluations were carried out on a ten-degree scale where the number 10 indicated excellent driving ability and the number 4 and below indicated a negative mark concerning the ability to drive. Evaluations were conducted without any interaction between the evaluators. In the Parkinson group patients' ability to drive was estimated by the neurologist purely on the basis of a clinical examination whereas in the stroke group the neurologist based his evaluation on a clinical examination and on the findings of the neurological multidisciplinary rehabilitation team. The evaluations of the controls were carried out in the same way as the patients' evaluation except that instead of the neurologist there was a vocational rehabilitation counsellor. The psychologist's estimation of ability to drive was based on the test results and an interview; the driving instructor made estimations according to the official driving test used in Finland (1992). The patients (II, III) and their spouses (III) also estimated driving ability using the same scale. Furthermore, examinees evaluated their own performance in laboratory tests using the scale:

1 = poor; 2 = fair; 3 = satisfactory and 4 = excellent.

The on-road driving test was not carried out in the stroke group primarily for safety reasons due to patients' physical, sensorimotor and cognitive restrictions. Moreover, arrangement of the on-road driving test often would have required many individual alterations to the car and therefore was out of question in the group's study.

3.2. On-road and off-road tests

Tant (2002) wrote that the prognostic validity of even a practical driving test cannot be taken for granted. The judgement given by a driving instructor or traffic expert is subjective in nature. To reduce this rater bias in our studies, a structured protocol was used. The on-road test was performed both in urban and rural surroundings on a standard and relatively difficult route. The time of day or weather conditions did not vary noticeably. The time needed to cover the route was approximately 45 min.

In the protocol, driving performance is classified into 7 factors: 1) observation, 2) speed and its regulation, 3) merging, 4) staying in a lane, 5) obeying driving orders, 6) obeying traffic guidance, and 7) keeping a safe distance from other road users. These 7 factors are observed in 10 traffic situations: 1) start, 2) driving in traffic flow, 3) changing a lane, 4) action in a pedestrian crossing, 5) turning to the right, 6) turning to the left, 7) crossing a lane, 8) overtaking, 9) driving on the highway and 10) parking/stopping. Errors in these traffic events were classified into three categories: minor errors, significant faults, and serious offences. Handling a car was evaluated separately according to the following three point scale: good, satisfactory, and poor. Examples of disqualifying driver errors were: driving in oncoming traffic, disobeying traffic lights, turn into improper lane, and severe speeding.

In the first study with students and experienced drivers, all three categories of errors – minor errors, significant faults, and serious offences -- were registered. In the experienced group a great number of 'faults' seems to mean a greater number of 'offences' too ($p < 0.01$). This connection was not so pronounced in the student group but the trend was the same. However, the 'minor errors' did not correlate with 'faults' or 'offences' in the student nor the experienced group. Our results confirmed findings that there is not a path from minor 'errors' to real risks (Parker et al. 1995; Reason et al. 1990; Parker et al. 1995; Reimer et al. 2005). Due to lack of a real connection between

minor errors and risk-related driving characteristics, minor errors were excluded from the later studies.

Psychological examination included a structured interview and computer aided laboratory tests. The laboratory test package varied by the groups so that it was the widest in the first study with the students and the experienced drivers but was reduced after experience and theoretical analysis and consideration (appendix No 2). The briefest test package was in the stroke group where cognitive and psychomotor restrictions limited a selection of the tests.

Although there an almost significant correlation between the simulator tracking task and the on-road driving test's faults, the simulator was excluded because of the low ecological validity, and second, it did not bring any additional value to that of an information processing test or to the other tests.

Although the scale of neurosis of the Eysenck's test was strongly linked to the faults of the on-road driving test (paper I), the Eysenck's inventory was also excluded because in the group of the experienced drivers the results were contradictory. Moreover, the scales of Eysenck's inventory are basically problematic in the context of driving. There are quite different requirements for drivers on the highway at night than at rush hours in big cities; neuroticism means carefulness, extraversion also means dependence on outer stimuli for the maintenance of the level of an activity of the brain. So, at the beginning of the study (I and II) there were 119 test variables but the number of variables was reduced to 65 on the basis of statistical analysis and deliberation (the statistical methods used in the different studies is demonstrated in appendix No 1).

Finally five tests were proved to be genuinely driving related: visual short-term memory, flexibility of visual perception, vigilance, complex choice reaction test and information processing capacity. These were selected for the studies with the Parkinson's disease and stroke patients. However, an information processing test proved to be too demanding for most of the stroke patients, and was also excluded from their test package.

3.3. Study subjects and main findings

The study groups consisted of the young female student drivers group, experienced middle-aged men, two patients groups (stroke and Parkinson), and the cases which

illustrate problems met in the practice of evaluating driving ability. The group of the middle-aged men with good traffic records served as a control group for the student and the patient groups.

3.3.1. Study I-II: Driving school students and healthy experienced drivers

The studies involving the young and inexperienced female driving school students and the experienced middle-aged men was a preliminary one and its aim was not only to compare these groups to each other, but also to test and develop an on-road driving test as a criterion, and to determine relevant tests for future studies involving disabled persons of the different patient groups. All the members of both groups had no traffic related health problems.

The results of the comparison of young and the middle-aged drivers are surprising and paradoxical: with experience the number of serious faults and offences in the on-road-driving tests increased (see table 1, paper I; table 1, paper II). The difference in the number of the faults is significant ($p < .001$). The results may be explained by the fact that the driving school students are still undergoing a learning period with regard to driving, and therefore they experienced the on-road driving test as a challenging task. This is reflected in their driving style and attitudes: They drove as well as they could. On the other hand the experienced drivers have fallen into routines and conform to the "everyday" rules of traffic rather than to the written regulations. Therefore skill-related laboratory tests predicted actual driving to be worse in the group of experienced drivers than in the inexperienced drivers who tried to drive as well as they could.

In the student group there was a clear connection between skills of handling a car and 'faults' ($p < 0.001$) whereas this is lacking in the experienced group. Uncertainty and lack of practice in handling a car seems to increase the number of dangerous 'faults' of perception and decision making. For the inexperienced drivers handling a car is still a challenging task, whereas for experienced drivers manoeuvring a car is largely automated (e.g. Summala 1996; Keskinen et al. 2000).

Along with experience, automated routines allow some deviations from traffic rules in the name of flexibility (Duncan et al 1991; Lajunen and Summala 1995). Thus, we can suppose that the students' driving performance corresponded to their real skill level

whereas the outcome of the driving tests of the experienced drivers rather reflected their affective-motivational dimensions, attitudes, tendency to overestimate their own driving skills, and tendency to underestimate the driving test (Näätänen and Summala 1976). Personality factors seem to be even more influential in driving compared to skills in the groups of experienced drivers. It is noteworthy that most persons needing the thorough driver evaluation are experienced drivers and in this group the style factors are underlined.

Our results show that ‘faults’ and ‘offences’ belong to the same group of the phenomena. One can suppose that faults, offences and accidents form a pyramid where faults are at the bottom, offences or conflicts in the middle, and accidents on the top. The most suitable variable for evaluations of driving ability seems to be faults, i.e., quite serious mistakes. Offences are naturally important for evaluations, but as a rare event, they have the same well-known limitations as accidents as a criterion have (see, Näätänen and Summala 1976), whereas minor errors seem to be related rather to automated routines than with safety.

In the novice group, Eysenck’s neuroticism scale is significantly connected ($p < 0.01$) and the psychotism scale is moderately ($p < 0.05$) connected to the driving test’s faults. Further, in the same group the lie scale is significantly connected ($p < 0.01$) and the extroversion scale is moderately ($p < 0.05$) connected to the offences of the driving test. In the experienced drivers group there were no significant connections between the questionnaire scales and the on-road driving test variables. Moreover, some correlations were completely opposite in these two groups. Thus, although there were some significant correlation between Eysenck’s Personality questionnaire and the on-road driving test, these connections were mixed and confused and they appeared only in the novice group.

The main findings of these studies are, first, that on-road driving can be explained by the skill-related cognitive and sensorimotor laboratory tests more exhaustively in the novice group than in the experienced drivers group, and second, faults in the laboratory tests predicted faults in the on-road driving test in the novice group whereas slowness in the laboratory predicted driving faults in the experienced drivers group.

3.3.2. Study III: Parkinson group (PD)

In the PD group the disease indicators such as duration of the disease, the Hoehn and Yahr scale and MMSE were not driving related and the medication (Levodopa) had only a weak connection with the on-road driving test. Further, in the PD group there was no connection between annual mileage or the total mileage or the on-road driving test results.

In the on-road driving test the PD patients committed significantly more risky faults ($p < 0.05$) and offences ($p < 0.01$) than the controls did. Problems appeared above all in urban areas but the patients and controls did not differ from each other in highway driving.

The laboratory tests – particularly the information processing capacity test -- unambiguously distinguished PD patients from controls; the differences being most significant in the number of the correct, correct and within the time correct responses in the information processing test ($p < 0.0001$), in the number of correct responses in the choice reaction test ($p < 0.001$) and in the visual memory test's latencies ($p < 0.01$). Slowness and correctness in the information processing test (correct and within the given time responses) have a very significant connection ($p < 0.001$) with offences in the on-road test. Consequently, serious offences and conflicts in the road seem to be linked especially to cognitive slowness in the PD group.

In the patient group the connection between the laboratory test and the driving test's faults was the most pronounced in the visual perception test (correct responses, $p < 0.001$), and in the information processing test (omitted stimuli, $p < 0.001$). Just a bit looser, but still very significant, was the connection between the faults and correct responses in the vigilance test ($p < 0.01$) and in the choice reaction test ($p < 0.01$). Both correctness and quickness in laboratory tests predicted success in the on-road driving test in the PD group evaluated by the number of the risky-faults.

A neurologist's evaluations of the patients suffering from PD was based on clinical observations and they were significantly more optimistic than the driving instructor's evaluations ($p < 0.001$) and psychologist's ones were based on the interview and the laboratory test ($p < 0.001$). There was no connection between the evaluations of the

neurologist and the instructor, nor between the neurologist and the psychologist evaluations, whereas neurologist and the patient evaluations were similar, strongly overestimated in light of the criterion.

Our study with PD clearly showed that evaluating a disabled persons' driving ability is such a complicated task that even an experienced clinician cannot accomplish it without the support of other specialists and driving-related methods.

3.3.3. Study IV: Stroke group

In the stroke group age, driving experience and duration of the onset were not connected with the laboratory tests. A low score in the Scandinavian Stroke Scale (SSS) and in the Barthel Index (BI) scale were associated with the wrong responses in the vigilance test ($p < 0.01$). Thus, these questionnaires were sensitive to the patients' inattention problem caused by monotony and a low-stimuli situation. Attentiveness and vigilance is a necessary condition for many ADL functions, and on the other hand, ADL functions, of course, tell us something about a person's possibilities to act as a driver.

The neurologist and the traffic psychologist both independently estimated 60 percent (12 out of 20) of the stroke patients as being incapable of driving whereas the patients themselves evaluated only 10 percent (2 out of 20), and the spouses 25 percent (5 out of 20) being incapable of driving. Neither the neurologist's nor the psychologist's evaluations were correlated with the patients' own evaluations which were very optimistic (mean 7.2 ± 1.8 in the 10-point estimation scale) as were the evaluations of the spouses (6.2 ± 2.3) compared to the neurologist's (4.8 ± 1.9) and the psychologist's evaluation (4.3 ± 2.5). The neurologist's and psychologist's evaluations were along the same lines ($p < 0.001$), the hit rate of evaluations being 75%. So, the patients systematically overestimated their driving ability compared to the instructor's and the psychologist's evaluations.

Variation in views regarding stroke patients' driving ability was wide as it was in the PD group.

There were only two cases in which all four evaluators agreed on the subjects disability to drive. In four cases the psychologist and neurologist considered the examinee as being unable to drive but both the patients and their spouse considered the examinee as

being able to drive. The patients had a tendency to overestimate both their laboratory performance and driving ability.

Because driving has many elements of time pressure, slowed information processing can be a problem, particularly in extreme situations (Brouwer et al 2002). This was the case in our stroke group. In our study the laboratory tests efficiently distinguished the stroke patients from the controls especially by sensorimotor tasks (table 2, study III). Our stroke patients were very significantly slower ($p < 0.001$) in visual perception and they responded markedly slower in the visual memory task ($p < 0.01$) compared to the controls. The number of the correct responses in the choice reaction test was also markedly lower in the patient group compared to the control group.

The results of the non-dominant hemisphere group (NDHD) were inferior to those of the dominant hemisphere group (DHD) in every variable of the driving related tests. However, the groups differed significantly from each other only in the visual memory test: DHD patients responded both faster ($p < 0.05$) and more reliably ($p < 0.05$) than NDHD patients. So, the visual memory test was the most sensitive method for the localisation of the damage at the level of cerebral hemispheres.

Patients with a non-dominant hemisphere lesion have more problems in driving related cognitive and sensorimotor functions.

In the stroke study the clinician using all the materials of the neurological rehabilitation team evaluated driving ability of his patients in the same way as the psychologist did using the task-specific laboratory tests and driving related interview.

Stroke patients form one of the most important groups needing a multidisciplinary team evaluation. From a safety and practical point of view, stroke patients' driving ability has to be normally assessed without a behind-the-wheel driving test but a decision regarding driving ability has to be made solely on the basis of laboratory tests and a driving related interview. Tests used in the evaluation of the stroke patients' driving ability have to be sufficiently difficult and versatile including at least the tests of visual perception, vigilance, visual short term memory, choice reaction and, if possible, information processing (both parallel and sequential) capacity in a complex situation.

Measures of a reduced speed of mental processing were found to be the most discriminating variables for driving. In particular, the patients had limitations in speed

and flexibility of visual processing, which is one of the basic functions needed in driving. Thus, stroke is a clear risk factor in traffic, and driving ability should always be evaluated after a stroke.

3.3.4. Study V: Case study

An analysis of motives reveals what an activity it is question about; what is the leading activity? Our ultimate motives very often remain subconscious and the existence of extra motives (Näätänen and Summala 1976) is a matter concerning all drivers but not only younger ones to which they are most often linked. An 'extra motive' is extra only to an outside observer. For the driver it is always a genuine impetus, moving force, of an activity. Often driving is just a means to reach something important which has nothing to do with moving from point A to point B. The fact that the ultimate motive often is not conscious, doesn't necessarily mean anything to safe driving, but if driving performance is actually directed by delusions or hallucinations, as was a case in our study, then there is a sufficient reason to intervene in the matter. A person suffering from delusions or having hallucinations has no place in traffic as a driver. In our case the examinee's ability to understand the inner and the outer realities was insufficient, whereas the level of operations was intact. A motive defines the activity and distorted motives can even be the exclusion criterion for driving as in cases of mentally handicapped persons. Due to incorrect motives the structure of an activity can be broken up not only in cases of psychosis but, e.g., in frontal lobe syndromes too.

A high education level, as our case study shows, may easily mislead practitioners and clinicians especially when they are working without the help of special research methods. In the clinical examination the covered mental deficiencies are difficult or even impossible to determine. In this case it was of central importance to uncover the significant contradiction between the examinee's apparent coherent behaviour in the interview and his tested cognitive and motor functions.

From a safety standpoint it is not appropriate that a driver's limited mental capacity is bound by lower-level operations. If a driver has to focus too much on operations when driving they become the real goal of performance instead of proper and safe goal-directed driving. This is often the case in stroke and TBI patients. One stroke patient in

our case study was evaluated as being unable to drive because a large number of previous operations were raised to the level of conscious actions due to general mental and cognitive regression. Now operations significantly loaded cognitive capacity when the examinee's capacity to learn was markedly reduced.

In another case (a middle-aged man, who as the result of an inborn anomaly, lacks their left hand completely and whose right hand is a short stump with one single finger) all the deficiencies were found to be on the level of operations while all higher level mental functions were intact. It was concluded that the examinee had all personal, cognitive, and motor presuppositions to act as a driver. In the previous evaluations he was prohibited to drive due to these striking physical restrictions. Possibilities to compensate for physical restrictions with the help of good cognitive capacity and the flexible personality were ignored.

We all are in some degree blind in regard to ourselves and therefore it is unrealistic to suppose that all the handicapped and disabled drivers, even in principle, were able to correctly decide when it is time for them to stop driving a car. This was seen in the both patient groups as it was in the cases. Often they consider themselves as good drivers even when they have massive driving related neurological and neuropsychological deficiencies.

Relatives have significant information regarding the patient's driving history, and in our experience, children often were the initiators in making referrals to a driving evaluation. They also had a realistic view of their parents' driving ability. If possible, the relatives of the patient should always be included in the procedure of an evaluation. Families may be invaluable in helping the person to accept the negative conclusion concerning his or her driving ability. Coleman writes that the bases on which significant others form their opinions are particularly important in affecting the safety of these patients and others who share the road with them (Coleman et al. 2002).

According to Withaar (2000) "fitness to drive implies three criteria: to have the perceptual, cognitive and motor abilities needed to drive a car; to have a weak probability of losing control suddenly and unpredictably during driving and to have the needed social responsibility (attitudes) and social judgement during driving". In our case study one examinee did not meet any of these requirements. Nevertheless, he regarded himself as a good and safe driver. There are, in clinical practice, many persons

of this kind who definitely need a thorough driver evaluation and who must stop driving. On the other hand, their evaluation is usually problem-free because their inability to drive is easy to prove.

3.4. Summary of empirical materials

Summarising the empirical material we can first note that in the student groups mistakes predicted mistakes when in the experienced group slowness in the laboratory predicted mistakes on the road. Second, the students' performance reflected their skill level while the experienced drivers applied their normal driving style which does not necessarily comply with all traffic rules to every detail. Third, both stroke and Parkinson's patients significantly overestimated their driving ability compared to the evaluations of the experts. Fourth, in the PD group disease indicators including medication had no connection with the on-road driving test whereas many of the laboratory tests were driving related: flexibility of visual perception, information processing capacity, vigilance, and choice reaction time were associated with faults during the on-road test. Both correctness and quickness in laboratory tests predicted success in the on-road driving test in the PD group. In the stroke group the poor scores on the SSS and on the BI were associated with vigilance problems and therefore they were also indirectly associated with driving. Lesions of the non-dominant hemisphere affect driving related abilities more than those in the dominant hemisphere. Fifth, even an experienced clinician cannot evaluate reliably patients' driving ability on the basis of an interview and medical findings whereas a neurological rehabilitation team seems to be a reliable evaluator. Sixth, spouses are not reliable evaluators but they may be an important informant and they can help a person to accept the prohibition of driving. Seventh, faults and offences seem to belong to the same group of the higher-level phenomena. Eighth, both mental and technical compensation possibilities are wide at the level of operations whereas deficiencies in the level of higher-level actions often caused inability to drive.

Case studies brought something significant into focus that statistical studies cannot do. The real cases clearly showed deficiencies of the narrow evaluation methods and the frames and compel us to develop our own conceptual model. The views about driver

evaluation presented here are based specifically on our empirical studies and cases, practise on the whole.

The important conclusion which one can draw from our empirical materials is that a reliable evaluation of driving ability of the disabled persons on the basis of health information and clinical interview is not possible to carry out.

Although there are correlation between laboratory tests and an on-road driving test, an evaluation cannot rely only on laboratory measures because especially the experienced drivers – the main group of driver evaluations -- do not drive according to their maximum cognitive and sensorimotor potentials, but rather how they are motivated and used to driving. Personality qualities define how the skills are used by the person.

Our examinees, particularly stroke patients, had severe health restrictions which are clearly manifested in poor laboratory results. However, in the practise of clinical driver evaluations the patients' restrictions are mostly not so prominent and one cannot make conclusions regarding driving ability on the basis of exceptionally poor laboratory measures, as was the case in our patient groups. It is seldom that the final outcome can be based merely on laboratory test results.

Besides motives and over-learned routines there are also other intermediaries between laboratory measures and driving test measures which may seriously affect everyday driving. They are such personality and cognitive factors as self-concept, self-esteem, emotional stability/instability, adaptation to one's physical and mental restrictions, recognition of one's own limitations and resources etc.

In the stroke and TBI groups there are, due to functional restrictions, significant limitations in laboratory methods which can be used.

Our findings confirm the conclusion of Freund et al (2005) that elderly drivers assign high ratings to their driving performance, even in the presence of suspected skill decline. Further, the patients were also not able to evaluate their own laboratory performance sufficiently reliably and most of all they had problems in the evaluation of their capacity for paying attention. The discrepancy between the norm data and the patients' view is very prominent. Their mean z-score indicates that 98 % of the general population performs better than patients while the patients themselves thought they managed well in the vigilance test. This may result from the apparent ease of the

vigilance test, and obviously driving a car is considered by stroke patients as being easy to manage as well. Patient's relatives are also most often not reliable evaluators.

For a high-quality evaluation, evaluators need substantial knowledge about driving performance and special driving-related research methods. The procedure used in our empirical studies proved to be passable but in order to meet the requirements of the systems analysis, the proper conceptual model of the drivers and driving is needed.

4 DRIVING A CAR IN THE CONTEXT OF ACTIVITY THEORY

In traffic literature there is a widely used dichotomy of driving skill-driving style (Elander et al. 1993) which corresponds to the driving performance-driving behaviour dichotomy (Evans 1991), where performance refers to what drivers are capable of doing, while behaviour refers to what drivers actually do on the road (Näätänen and Summala 1976; Shinar 1978; Evans 1991). This dichotomy is, of course, very useful and of most importance to traffic research. However, the major problem of empirical traffic psychology is that there a clear enough distinction has not been made between an animals' behaviour and man's activity. Therefore empirical human research is still predominantly behaviouristic, and study design directly or indirectly follows a stimulus-response (S-R) pattern originally created for the examination of conditional reflexes of animals. Here the distinction between behaviour and activity is underlined.

A human being fundamentally differs from an animal in many respects: a person has self-consciousness, only people can set themselves conscious goals, people can transmit cultural heritage and historical achievement to the next generations. More concretely: when moving in the environment a person does react to stimulus as an animal does but rather acts with material and mental objects, a person does not only have to adapt to the environment but, if necessary, changes it to one that is suitable to them. A person lives in the world of historically developed artefacts where they orient themselves with the help of material and mental signs.

Behaviour is a series of motor reactions: it is perceptible movements, expressions, gestures and voice, etc. It is a visible part of an interaction between an organism and an environment, whereas human activity (*tätigkeit, dejatel'nost*) applies exclusively to a human being. Activity has a social and historical basis (Bruslinkij 1994; Rubinshtein 2003) and it is an object-oriented, artefact-mediated and socially formed system (Bedny and Karwowski 2004).

The psychological theory of activity, mainly its Rubinshteinian line, has been, from the very beginning (see paper I), one of the main components of the undersigned's theory-in-use (Argyris 1976) despite my own experience as a clinical and traffic

psychologist. The frame of reference described below partly directed the carrying out of the empirical studies: partly it is the result of those studies.

4.1. Rudiments of activity theory

Activity theory is a theoretical framework for studying different forms of human praxis. It is a theory with a high level of generality that can be applied in different domains. Activity theory was developed as a psychological theory, but now attracts a wide audience of specialists including philosophers, anthropologists, educators, and linguists (Bedny and Karwowski 2006).

Basov as early as in 1931 suggested replacing the notion of behavior with the notion of *deytel'nost*, which is best translated into English as “activity” (Bedny and Karwowski 2006). The psychological theory of activity (Abul'hanova-Slavskaja 1980a, 1980b; Asmolov 1983, 1986; Bedny and Karwowski 2004; Bruslinkij 1987, 1991, 1992, 1994; Ivanova 1987; Lektorsky 1990; Lomov 1979, 1981, 1984, 1986; Solntseva 1987; Wertsch 1976), originates in works of Rubinshtein (1959, 1989, 2003) and Leontjev (1978, 1981). Vygotsky developed a sociocultural determinism of mind, but not of object-oriented, socially mediated, individual activity. Sociocultural theory and activity theory share some features, but are not regarded as the same (Bedny and Karwowski 2004). This is a generally shared view among Russian scientists (e.g. Lomov 1984; Yaroshevsky 1985) and it differs from the Western understanding of the identity of sociocultural theory and activity theory (Engestrom 2000). While Engestrom, in his own theory of developmental work research, (1995) aspires to multi-voicesness (Engestrom 1991), he grows away from the principles and views of classical psychological theory of activity. In the dissertation at hand we try to stay firmly in the way marked by classics of the activity theory.

Activity determines the specificity interaction of conscious subjects with the external world. During this interaction, human mental processes evolve (Bedny and Meister 1997; Bedny and Karwowski 2006). From this follows the unity of consciousness and activity. Rubinshtein formulated this fundamental principle of activity theory, the unity of consciousness and activity, as early as 1922 (Rubinshtein 1986, 2003).

The term activity refers to human mobilisation around conscious goals in a concrete, external world. Inasmuch as only humans can establish conscious goals, only humans can be the subjects of activity. This emphasis on conscious goals in activity theory implies that human activity develops less from human biology, than from human history and culture (Bedny and Karwowski 2004). Behaviour is a biological concept whereas activity is a historical and cultural one. According to activity theory, the human mind develops from historically contextualized, object-practical activity (Bedny et al. 2001). Conscious goal-directed activity determines the genesis and structure of human psyche (Leontjev 1978). Rubinshtein (2003) underlines that a human being not only expresses him/herself in an activity but psyche is forming and developing during activity too. A human being is a cause and effect of himself/herself by way of his or her activity (Rubinshtein 1959). So, activity is inextricably linked with internal psychological processes and consciousness. In activity cognition, behaviour and motivation are integrated and organised by the mechanism of self-regulation toward achieving a conscious goal (Bedny and Karwowski 2004).

Activity is always an activity of some concrete person or persons. A subject of an activity can be an individual or a collective set of individuals. There is no subjectless activity nor a subject of an activity without a conscious goal (Heikkilä 1997, 1998). Activity is characterised by any form of subject-object relations, regardless of the vector of direction, and whether the object is situated inside or outside of the subject (Lomov 1984). The object of an activity refers to an object that has been modified by the subject according to the required goal of activity. And objects, which may be either material or ideal, determine the nature of human actions. (Bedny and Karwowski 2006). The activity is social by its very nature and it is directed towards object (material or ideal) and it is mediated by artefacts (tools, language, schemata etc.). Strongly simplified, one can define a process of a subject's activity as a movement from the goal to the result by the help of the mental or material means. According to Tikhomirov (1984) the goal is considered a conscious mental representation of a future result connected with a motive. Goals are cognitive, informational components of activity (Bedny and Karwowski 2006).

In the frame of the psychological activity theory a human being is not studied in an S-R environment but in the world of objects where he or she is living as an active

player. An object of the research of driving performance shall not be reactions but actions and an activity. Further, the object towards a human activity is directed is historically developed (Leontjev 1978). Driving a car has its history too and without understanding this history it is impossible to understand driving now.

An activity is a holistic process of interaction between a human being and his/her environment and an aim of activity is not only adaptation to an environment -- as it is seen in the frame of behaviour -- but also an active influence on surroundings by the help of the mental and cultural tools (Vygotskij 1978). As distinguished from physiological reactions any human activity and even its very simplest actions always contain some psychological elements and an activity is regulated from the very beginning by these psychological elements (Rubinshtein 2003).

A system is a set of interdependent elements that is organised and mobilised around a specific purpose or goal (Bedny, Seglin and Meister 2000). This is the case in such a human activity as driving. Activity theoretical research is a systemic approach too. The structural or systemic-structural approach may also be used when the structure of the activity system is underlined as in Leontjev (Heikkilä 1997, 1998). From the systemic-structural perspective, activity can be defined as a goal-directed system, in which cognition, behavior, and motivation are integrated and organized by a mechanism of self-regulation toward achieving as conscious goal (Bedny and Meister 1997). Any activity has recursive loop structure, organized according to the principles of self-regulation in which feedback mechanisms that evaluate performance are decisive (Anokhin 1962; Bernstein 1966; Bedny and Karwowski 2006).

During activity human create artificial objects that are a necessary precondition for the development of internal cognitive processes. The inner mental world of human beings is not naturally given, but mediated by artificial objects produced from human activity (Rubinshtein 1935; Leont'ev 1947). So, activity is a multidimensional and multifaceted system, which should be considered to be historically developed, socially formed and culturally mediated.

The concept of mediation is of most importance to the theory of activity. Human activity is mediated by a number of tools, culturally established instruments, both external and internal (Vygotskij 1978). The purpose of those tools is to help people to regulate, to control and to develop their own activity. Physical tools such as vehicles

extend our physical abilities while psychological tools like concepts and inner models extend our mental abilities. Driving a car is a good example of a cultural product. The artefacts mediating driving include signs, schemata, inner models, instruments, aids, etc.

Artefacts are there for us when we are introduced into a certain activity, but they are also a product of our own activity, and as such they are constantly changing through the activity. During a driving activity the rules, an environment and a vehicle are given whereas a driver's inner models and mental tools constantly develop with experience. And these inner models and mental tools are the main subject of a driver's evaluation. Further, these models and tools are constantly changing and develop with a changing activity. So, the subject of our study is really dynamic.

There is two approaches to the study of activity. One may be considered through individual psychological perspectives and the other in terms of cultural-historical perspectives. The first approach considers activity to be an attribute of individuals under which the individual is an agent of activity. The second approach points toward a formulation of activity not only as an individual trait but as normative standards for activity that transcend separate individuals. In this latter perspective one emerges not so much as an agent but as a subject adjusting and adapting to the normative standards and requirements of activity (Schedrovitsky 1995, Bedny and Karwowski 2004). When a driver begins the activity of driving, the minimum factors involved are: an instrument, i.e., a vehicle, an environment, and traffic regulations. The task of a driver is first to absorb this historically developed form of an activity. This is a subject of driving schools. And traffic -- a vehicle, environment and traffic rules -- are now quite different compared to those of some 50 years ago. Consequently, the requirements for driving are quite different now than, say, 50 years ago and in the future the requirements for drivers will constantly change. In order to draw a general view of driving a car as a social-practical form of human activity, both individual and cultural-historical approaches are needed. In driver's evaluation, however, individual psychological perspectives are of most importance. Ontologically the most important points associated with activity theory are, first, that activity theory does not allow a subject of activity, in our context a driver, to be reduced to a reaction machine, an information processor, a risk calculator or some other narrow, one-dimensional aspect, but a subject has to be considered as a real person of his/her activity. Second, a subject is thought to act in the world of objects instead of

stimuli. Third, activity is at its core always social and mediated by cultural and mental tools whereas behaviour is a biological frame of a human being. Fourth, activity has to be seen as a constantly developing system. Fifth, the main element, a system organiser (Judin 1978), is always the subject of activity, in our context of study, a driver.

Regardless of the major importance of the concept of activity, one has to remember that psyche is not equal to activity (Lomov 1984). The category of activity has to be considered together with other basic categories such as a personality, reflection, self-regulation and social interaction.

4.2. Unit of analysis

When we study the procedural components of activity, the selection of proper units of activity is decisive (Bedny and Karwowski 2006). Meaning and signs as a result and tools of activity cannot be an unit of analysis of activity (Rubinshtein 1958; Leont'ev 1977) nor can the activity be simultaneously the object of study and an unit of this study (Lomov 1984; Heikkilä 1997, 1998).

The main prerequisite for choosing the unit of analysis, is that the selected unit retains the features of the whole (Rubinshtein 1958; Vygotsky 1962). Such a unit is action (Rubinshtein 1958; Leont'ev 1997). Actions are derived from particular motives and are directed toward a specific goal of action (Bruslinsky 1987). So, the final goal of activity has to be distinguished from the intermediate goals of actions. Action fulfils an intermediate subgoal of activity. Consequently motives of each action and overall motivation for the activity must be distinguished. They may or may not coincide (Platonov 19872). The goal of action should be distinguished from the goal of a task or an activity in general (Bedny and Karwowski 2006).

An unit of an analysis of driving activity and driving ability has to be one that is high-order enough because lower-order elementary level factors do not include psychological elements necessary for regulation and control of driving and then they do not have a real relation to driving activity. Therefore, according to an activity theory the unit of an analysis of driving activity has to be an action but not an operation. An action because it has a real connection to a goal and motive of driving.

The on-road test used in our studies produces just action level driving events and as actions they have a real link to driving performance as a human form of activity. In handling a car the matter is operations, i.e., the lowest level of the elements in human activity. Problems met at this level often can be solved by technology, even in severe cases.

4.3. Functional model of driving a car

Hakkarainen (1989) writes that “the study of human activity is complicated, because the object of study cannot be immediately observed. Only elements and their immediate relations can be observed”. Therefore an activity like driving can be understood and evaluated only with the help of a model.

From the point of view driver evaluation, a substantial failing of traffic literature is the lack of a distinctly defined subject. Therefore the particular aim of this study is to model the subject of driving, a driver. On the other hand, a driver’s potentials and limitations have to be able to be compared to requirements of the driving tasks. So, the functional model includes both the driver and the driving subsystems using a hierarchical structure. In an evaluation of driving ability it is a question of matching these two hierarchically organised systems: the subject of performance and the performance itself (figure 1.).

In the process of activity there is always a moment of creativity (Rubinshtein 2003). Therefore human activity is highly dynamic process and the functional model one has also to understand as a set of function blocks which are used variously depending on internal and external conditions of activity and on the results self-regulation. So, the number of blocks is constant, but their content and degree of involvement in driving activity varies case by case.

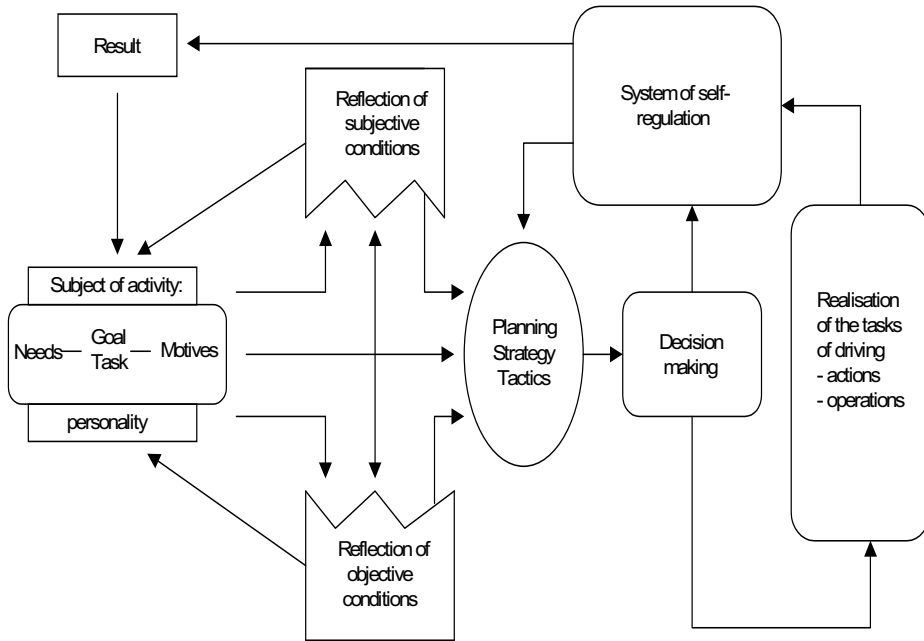


Figure 1. The macro-level functional model of driving activity.

The blocks are the subject of activity, reflection of internal subjective and external objective conditions of activity, planning, decision making, realisation and regulation of driving ¹.

4.3.1. Subject of an activity

The main question of the study is: Who is a driver? By nature a human being is a bio-social being (Yarosevsky 1974,1976). However, one has to underline that a subject of activity is not psyche but a human being who has needs to satisfy, who has psychological processes and qualities, a human being who acts and interacts with other people. The subject of activity, here a driver, is viewed as a multisystemic hierarchically

¹ Subject- subject relations are not presented in the model.

organised bio-social creature where psyche is the main regulator of human activity and behaviour (Lomov 1984). An individual who performs in accordance with conscious goals and tasks embedded in the goals, is the subject of an activity. The subject is an agent with accumulated historical and social experience (Bedny and Karwowski 2006). In driving a car drivers represents themselves as a social being and development of driving activity is mainly determined by the society, not by an individual driver. On the other hand, development of a subject of an activity depends on a driver him/herself and on the driving education system as well.

The subject of driving is the holistic multilevel and multisystemic human being where the level of personality is the leading and dominant factor, according to Judin (1978), the formator of the system. In this sense a driver evaluation is, at its core, a personality examination. Personality always appears in human activities (Rubinshtein 2003) but it is not a product of an activity. By the process of objectivation a personality gives to an activity its personal form (Abulhanova-Slavskaja 1980). And personality factors associated with accident risk are highly constant as Häkkinen (1958, 1979) clearly showed in his follow-up studies.

An organism, a temperament, individuality and a personality form a unity of viewpoints on a human being. Individuality is seen as the core of a personality forming its uniqueness. This unity contains both the formal-dynamic and content aspects. In the model an organism and a temperament represent the former and an individuality and a personality the latter aspect (Heikkilä 1995a, 1995b, 1996). These subsystems are relatively independent and quite different laws and principles act at the biological level than work at the levels of personality and individuality. An organism, and partly temperament, as biologically-based, formal-dynamic aspects, are relatively stable and measurable systems, whereas a socially determined and constantly developing personality and an individuality can only be evaluated and described in the context of the activities of other people and society.

The place to become a real subject of his or her driving activity is in the above mentioned multilevel hierarchical structure of the human being. A safe driver is an active, conscious subject of his or her own driving activity; a subject who adheres to established rule-governed behaviours established for the safety of one's self and others (Reimer et al. 2005). Being a subject of his/her activity means that a person consciously

acts within his/her capabilities. Becoming a subject is an inner movement of the elements of a multilevel and multi-systemic structure and a distribution of energy and power between the subsystems (Heikkilä 1994, 1995a, 1995b). The more cognisant subject a driver is, the more reliable he/she is as a driver.

4.3.1.1. An organism and biological limits and potentials of a man

On the level of an organism, a human being is considered as a representative of the species Homo Sapiens. This categorisation defines the levels of physiological potentials, anatomical characteristics, sensory capacity, health condition and other biological factors common to humans.

Here the limits and potentials of a human kind's functional capacity are defined.

By biological nature a human being is a slowly moving diurnal animal with senses and reaction speeds intended for the speed of walking or a running (Laaksonen 1991). In driving we artificially exceed our biological limits and from this point of view accidents are a quite normal result of a performance which is against our nature. A car is a good example of how humankind has exceeded, by the help of technology, their biological limits, and in some cases with the fatal consequences.

A human being regulates his or her activity by psyche but there are no psychological processes, states or qualities outside the organism, outside the CNS (Lomov 1984). In driving the brain is without doubt the most important organ.

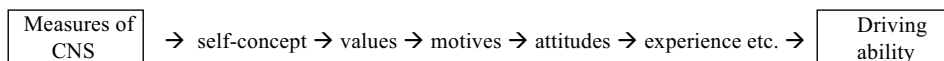


Figure 2.

However, there is not any simple correspondence between the brain and driving, but the final outcomes of the driving are affected by many factors (Figure 3). Thus, e.g., from

neuropsychological tests one cannot make direct conclusion on driving ability. From these factors affecting driving only a part can be localised directly in the brain whereas a part is in one's net of relationships rather than in the CNS.

Individual differences in the CNS have been intensively studied particularly in the Russian neurophysiological school since Pavlov introduced the concept of the types of nervous systems (TNS) or the types of higher nervous activity to science. According to Pavlov the configuration of the basic properties of the nervous processes constitutes the TNS. Three basic properties of the nervous system according to Pavlov are the strength of the nervous system, equilibrium of excitation and inhibition processes and mobility of nervous processes (see e.g. Gray 1964; Nebylitsin and Gray 1972). The strength of a nervous system may be defined as the endurance of the nervous system in the face of continuous (or frequently) repeated excitation. The mobility of the nervous processes seems suitable for denoting the property characterised by the speed of transformation of nervous processes (Teplov 1972). Basic properties of the CNS have been linked to such driving related factors as vigilance (Pushkin 1972), flexibility and endurance (Gurevich et al., 1975), tolerance of monotony (Stepanova and Rozdestvenskaja 1986) and capacity to act as professional drivers (Klyagin et al. 1977). In our test pattern, the test of vigilance clearly measures tolerance or endurance (strength) of the NS towards monotony, and the tests of information.

4.3.1.2. Temperament and dynamics of psychological processes

Temperament acts as an intermediary link between an organism and a personality. Temperament strongly depends on qualities of the CNS and it is coupled with the biological basis of a human being. Temperament can be seen as the psychological manifestation of a general type of a higher nervous system where the properties of the CNS form the neural structure of temperament (Strelau 1983).

Temperament is the whole of the individual differences characterising dynamics and emotionality of a person's activity and behaviour. The qualities of a temperament are quite stable elements compared to some other psychological characteristics. As a formal-dynamics level of psyche, in temperament there is not such 'content' elements as

attitudes, interests and motives which develop in communication and interaction with other people.

Eysenck (1967) studied two continua (extrovert - introvert and stable - unstable), plotting his results in four quadrants which might represent the four temperaments. Eysenck's constructs have been fundamental concerns for many years and have been the basis for descriptive, as well as non-biological, theories of motivation and learning. Eysenck's theory is most frequently used in temperament dimensions in traffic research, as well according to Cloninger's psychobiological model of personality, temperament can be described by four genetically independent dimensions— novelty seeking , harm avoidance , reward dependence, and persistence (Cloninger et al. 1993).

Individual differences in temperament dimensions cause differential sensitivities to specific classes of stimuli and environmental cues, leading to differential affective states. The characteristics of sensation seeking, extraversion, and impulsivity may be referred to as action-oriented temperament dimensions.

Rusalov (1985) outlines temperament in the following way: 1) it is not related to the content of an activity but reflects the formal side of an activity, 2) it characterises the dynamics of the subject in his/her relations with the world, 3) it is universal, 4) it manifests itself in early childhood, 5) it is permanent, and 6) it correlates with the basic properties of the NS and with other biological subsystems like hormonal regulation.

As dynamic and emotional aspect of personality, the driving tempo and rhythm, in other words driving style, depend substantially on temperament characteristics. Temperament is another basis of driving style besides a personality and in that way may in some cases have indirect effects on driving ability. However, there is not a direct connection between temperament and driving ability in the frame of “legal” driver evaluation.

4.3.1.3. Personality and ability to realise, act and communicate

The famous adage ‘man drives as he lives’ (Tillmann and Hobbs 1949), means that people express their personality behind the wheel. A worrier is a worrier at home and behind the wheel, a prudent person is cautious in traffic and at work. In the words of Evans (2002) ”a crash risk relates to factors at the very core of human personality”.

Personality factors have an impact on road accidents through their effects on actual driving-related performance.

So, what is human personality? Use of the term personality is so broad that a coherent, simple and unambiguous definition for it cannot be made. A personality is kind of an umbrella term under which there is room for a large number of a most different views and research methods (Pervin 1989). Pervin (2003) defines a personality as the complex organisation of cognitions, affects, and behaviours that gives direction and pattern (coherence) to a person's life. Like the body, personality consists of both structures and processes and reflects both nature (genes) and nurture (experience). In addition, personality includes the effects of the past, including memories of the past, as well as constructions of the present and future. Such a system cannot be but flexible and dynamic. A personality is not a bunch of inflexible and unchangeable traits, like trait theories, the dominating frame of reference of traffic psychology, claims.

Criticizing Vygotsky's cultural-historical theory, Rubinshtein argues that psychological characteristics of the individual are not completely derived from the social environment (Bedny and Karwowski 2006). The schema from social to individual, from external to internal, does not take into consideration enough a human being as an active subject of his/her activity (Bruslinsky A.V, 1991-92) . According to Rubinshtein (1957, 2003), the external world never directly determined internal, mental activity but through the mediation of internal conditions. And the personality can be understood as a system of those internal conditions, through which all external influences are mediated. The personality is the whole of the inner conditions by which all the outer influences are refracted (ibid). These internal conditions include personal experience, hereditary predisposition, properties of CNS, characteristics of temperament, abilities, and prevailing state of the subject. Therefore, Bedny and Karwowski (2006) note, that the origin of consciousness cannot be reduced to internalization of the social. Further they write about internalization that it is not the transformation of the external into internal, but rather the changing interrelationship between the internal and external in human activity (ibid).

According to Rubinshtein (2003) the aspect of a subject which realises and in which is realised the unity of consciousness and activity, is a personality. And, the human being's basic way of existing is to do so be a conscious and active being, a

subject of consciousness and activity (Rubinshtein 2003). Abul'hanova-Slavskaja (1989) defines a personality as a triadic unity: what a man wants, what a man is able to do and what a man is. What a person wants appears in his or her orientation, needs, attitudes, and ideals; What a person is able to do is manifested in his or her abilities and talents; What a person is turns out in his or her inclinations crystallised in character. It is important to understand that a personality is not a moment or a product of an activity as mechanistic activity theorists claim, but quite the contrary, a personality is a basis of an activity and a social interaction. When activities of life are separated into a social interaction, a goal-directed activity, and experience then we can define a personality as a subject of a consciousness, activity, and communication and a way of experience (Heikkilä, 1994, 1995). According to Rubinshtein (1959) a realisation of all psychological processes depends on a personality and there is not a single psychological phenomenon which could be understood separate from personality.

A human being as a personality constantly exceeds his or her current limits. A personality is not any kind of final photogenic frozen entity which one can measure and accurately observe but a personality is always something more than the sum of its parts. A personality is always forming and developing. A personality can be seen as the sum of a man's all central relationships: a relation to himself, to other people, to goal-directed activity (play, education and work) and relation to a society and to its rules and norms.

When a formal-dynamic aspect of the psyche crystallises into temperament a personality is mainly a concept of content. Biology indirectly affects personality being the natural basis of temperament and abilities but personality comprises values, interests, motives, attitudes and all social relations of a human being. And according to Elander et al. (1993) attitude and aptitude of the driver are the criteria used for understanding driving problems. Further, in driving a personality becomes apparent in driving style which comprises selection of speed, driving tempo and willingness to violate traffic regulations (Rajalin and Keskinen 2002).

When evaluating driving ability one has to take into consideration that personality disorders always mean in some relation inflexibility in behaviour, and together with other mental or physical restrictions, they may seriously affect driving. Certain personality characteristics such as low tension tolerance, immaturity, and paranoid

conditions are risk factors for traffic crashes. It is noteworthy that a diagnosis of antisocial personality disorder includes reckless driving (DSM III).

A personality is a continuously changing system with enormous developmental capacity, and therefore a personality is the main source of competence. Personality qualities such as cognitive flexibility, planning capacities, adaptability to inner and outer changes are important for maintaining driving ability when driver's own prerequisites are reduced. These qualities are crucial for a competence evaluation .

Our findings and practice clearly show that a flexible person with good self-knowledge tolerates much more driving related restrictions than a rigid person with limited self-knowledge. Most of the young risky male drivers mature into safe ordinary middle-aged drivers on the basis of the developing capacity of their personality.

Personality becomes particularly central in borderline cases when there is one or more problematic factors affecting driving but which alone do not cause inability to drive. If the dominating personality trait is, e.g., impulsiveness or rigidity, such a person for safety reasons tolerates less driving-related cognitive or other deficiencies compared with a balanced or flexible person. The personality of the driver is decisive: all the test results and the clinical findings have to be judged in relation to the personality of the driver.

4.3.1.4. An individuality and style of life and activity

At the core of personality lies an individuality. By an individuality one refers to a very core of personality considered as an unique creature. Individuality means individual variation in the structure common to all persons. Individuality is manifested in individual style of life and activity (Merlin 1986). Basically a driving style is always unique and individual. An individual style of activity depends not only on individual differences in objective requirements but of an activity as well. One can drive a car individually but only within certain limits of the common rules. Individual style of activity is not only a possibility but all activity always is individual and unique because every person has his or her unique genotype and history through which all outer influences are reflected (Rubinshtein 2003). Individual driving style develops on the basis of temperament and personality and therefore it represents both dynamic and

qualitative aspects of driving. An individual style of activity is a descriptive level of human reality. Of course this concerns driving style too. According to Elander, West and French (1993) hasty decision making, antisocial and inappropriate motives and norms of behaviour contribute to a dangerous driving style.

4.3.2. Inducing elements of activity and their relations to the tasks and goals

A need provides the initial stimulus for an activity, which first stimulates a behaviour aimed at finding an object capable of satisfying the need that has arisen. A need is an inner state of a person, whereas an object which can satisfy a need is outside of the person. Besides biological, material, mental and social needs there are so called quasi-needs too. They are idols and ideas which particularly influence young drivers' driving behaviour.

Driving symbolises independence and autonomy in our society (Reimer et al. 2005). Driving satisfies, in addition to transportation, the need to maintain autonomy and the possibility to drive may markedly support the self-esteem of a person.

Needs that induce human activity directed to attain certain goals are called motives (Petrovsky 1986). In the ability to direct the search lies the regulative function of motives (Kotik 1978). Thus, needs are the impetus for activity whereas motives are its directive force.

In an analysis of motives one has to exceed the individual level because different groups of people have different motives. The motives of the young drivers certainly differ from those of the elderly drivers (Summala 1987).

When a suitable object for a need is found, it transforms into the goal of an activity and an objectless activity turns into a concrete goal-directed activity to reach an already conscious goal

(Kotik 1978). In activity theory a goal is a conscious mental representation of humans' own activity in conjunction with a motive (Bedny and Karwowski 2006).

Besides its real existence, the chosen object now begins to live in the mind of the person as a target-image, that is to say, a motive. When a goal of an activity is defined the plan to reach the goal is actualised. A target-image directs a selection and

integration of information during the execution of an activity. From outside one can set requirements for a subject but a goal of activity of a subject forms himself. A goal is an ideal vision of the result of an activity and there simply does not exist a non-goal-directed or unmotivated human activity. The motive defines the kind of activity in question. Drivers driving one after the other on the same road are executing quite different activities. Perhaps one is on a shopping trip, another is calming down by driving after contention, and third escaping his fictional persecutors as was the case in our study (V).

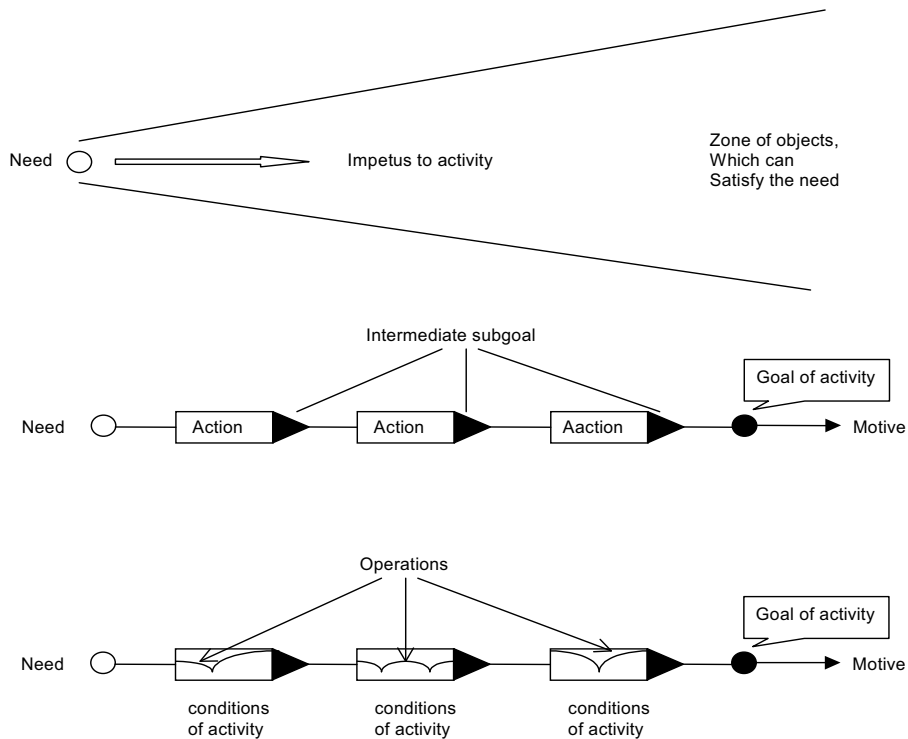


Figure 3. Genesis and development of activity according to Kotik (1978).

The vector motive-goal points out the direction of an activity and the force mobilised by the subject toward its realisation (Lomov 1984). This vector defines

dynamics of the psychological process and what a person sees, remembers, thinks, etc. The vector motive-goal is the main regulator mechanism of a driving activity.

Human lives can be conceptualized as an ongoing attempt to solve tasks or problems. The task is a specific kind of activity, which comprises different actions and operations and present by itself as a complicated system. Accordingly, the task can be considered as the basic object of study. A task is unity of the goal and conditions of its achievement (Psihologitseskij Slovar 1983). Tasks may also be definend as a logically organized system of mental and behavioural actions, directed toward an ultimate task-goal. In contrast to cognitive psychology in activity theory the task is a situation which requires achievment of a goal in specific conditions. Hence the task in activity theory includes motivational components (Rubinshtein 1973; Leont'ev 1977; Bedny and Karwowski 2006).

A goal is a conscious mental representation of humans' own activity in conjunction with a motive. Goals are cognitive, informational components of activity, that may be contrasted with motives, or motivation in general. Motives are energetic components of an activity. The more intense the motive, the greater the effort to reach the conscious goal. Motive-goals create a vector that lends goal-directed activity its directedness.

According to Shadrikov (1982) a goal appears in two aspects: an ideal vision of the results of an activity, and as a target level. The goal is considered as a conscious mental representation of the future results of one' s own actions that are connected with a motive. Simplistically put, motives, methods of performance and goal directed behaviour as a whole can be formulated consciously or unconsciously, but the goal of an activity is always conscious (Bedny, Seglin and Meister 2000). To be precise, at least some aspect of a goal always has to be conscious.

One has to distinguish final and intermediate goals from each other. The goal of action should be distinguished from the goal of a task or an activity in general (Bruslinskij 1987). By performing a logically organised sequence of actions, subjects achieve intermediate goals of actions and then goals of task or activity in general (Bedny and Karwowski 2004).

Satisfaction or nonsatisfaction of diverse needs is conveyed by affects and emotions that in turn may induce activity (Bedny and Karwowski 2006). Emotions are associated

with needs and interests expresses to us whether they are satisfied or not. Our emotions hold in memory works as motives and regulators of driving. Depending on a mark of an emotion it either inhibits or provides motives for participating in an activity.

In driving emotional memory plays an important role. Emotional experiences give an activity its basic accent. In traffic there are aggressive, balanced, depressed, cheerful drivers whose mode of an activity is regulated by their basic emotional accent. Transplacement of any unpleasant memories into current driving situation from the person's driving history, is possible.

4.3.3. Reflection of internal and external conditions of driving

Reflection is a particular kind of interaction among phenomenon in which the reflected object preserves its topological structure within a systematic reflective medium (Platanov 1982). Psychological reflection is the individual's active and complex process of adaptation and capturing internal and external reality.

Correct recognition of internal (subjective) and external (objective) conditions of driving affect organisation, planning and regulation of driving activity. The dynamic reflection of inner and outer conditions of activity contains logico-conceptual, imaginative, conscious and unconscious components which enable individuals to develop mental models of external events (Bedny and Meister 1999; Stanton et al. 2001).

4.3.3.1. Reflection of internal subjective conditions of driving

The frontal lobes, in particular the frontal poles, are involved in uniquely human capacities, including self-awareness and mental time travel (Stuss and Levine 2002). Self-awareness of deficits is considered a component of executive functioning (Burgess et al. 1998) and it is thought to play an essential role in self-judgement regarding fitness to drive (Coleman et al. 2002). Denial of one's symptoms and serious deficits is always a significant risk factor for safe driving.

Cognitive and psychomotor flexibility is of the most importance for safe driving, and many diseases and disorders especially affect flexibility of mental processes. For

explaining the degree of flexibility of higher mental functions, complex multitask tests have to be used instead of the narrow 'one-channel' and one-factor tests. In general, measures of frontal and executive functions, which are linked to the skills at higher task levels of driving, are essential in evaluations of driving ability and measurement of an information-processing capacity is the central issue in evaluation of neurological patients' driving ability. Our patient groups had considerable difficulties in perceptual flexibility and vigilance tests, and they were unable to perceive themselves or their defects in these functions (III-V).

4.3.3.2. Reflection of external objective conditions of driving

Drivers do not merely react to stimuli, but rather a driver must actively extract the required information from the traffic environment and interprets it according to the requirements of the goal.

The information processing of a driver may be controlled or automated. Controlled processing requires significant conscious effort whereas automatic processing requires less mental effort and concentration of attention. Therefore, whenever possible, in the name of the saving of psychological energy, drivers prefer to automatic processing.

Safe driving performance requires unimpaired cognitive functions, including perception, decision-making, information processing (reasoning, memory), selective, sustained, and divided attention and vigilance (Elander et al. 1993; French et al. 1993; Ranney 1994; Summala 1996, Daigneault et al. 2002). Selective attention refers to the ability to screen out irrelevant stimuli whereas sustained attention or vigilance may be defined as the ability to focus attention on a task over unbroken periods of time (Perry and Hodges 1999; Wilkins et al. 1987). Arousal is the state needed to remain vigilant.

Information processing while driving has some specialities. First, in driving, information is obtained partly from the control devices, partly from the external environment, and perception and information processing goes side by side as a decision making and also executive action. Second, thinking while driving always has some temporal limits within the contexts where a driver has to act. Third, the price of

decisions may be very high. The above described form of practical thinking is called operative thinking in the activity theory (Pushkin 1966).

Visuospatial abilities are crucial for safe driving, and in this respect division of labour between hemispheres plays an important role in driving as well. In the stroke study both the psychologist and the neurologist evaluated the patients with the non-dominant hemisphere lesion as being unable to drive a car more often compared to the patients with the dominant hemisphere lesion. The result is logical when the specialisation between cerebral hemispheres and the demands of driving is taken into consideration. It might not be merely by chance that five out of the sample of six actively driving stroke patients had a lesion in the dominant hemisphere, while only one had a lesion in the non-dominant hemisphere.

It is a very general finding that perceptual and psychomotor processes take significantly more time after TBI. Because driving has many elements of time pressure, slowed information processing can be a problem, particularly when very extreme (Brouwer et al. 2002). This was also the case in our stroke patients. In our study the laboratory tests efficiently distinguished the stroke patients from the controls especially in terms of sensorimotor speed (table 2, study III).

Brain injury and the stroke patients can often be characterised as one-channel persons with significant limitations of simultaneous information processing and they are also often slow in sequential processing. The same kind of problems in information-processing were met with in the mentally-deficient persons in our practise.

In our patient groups measures of reduced speed of mental processing were found to be the most discriminating variables for driving. In particular, the patients had limitations in speed and flexibility of visual processing, which is one of the basic functions needed in driving.

4.3.4. Planning in driving

With actualisation of the goal, the plan is immediately formed in the person's

consciousness (Miller, Galanter and Pribram 1960), and the plan consists of a series of successive actions each of them aimed at performing a single step in reaching an intermediary result on the way to the final goal of activity (Kotik 1978).

Departing from the goal, which reflects the future result, in the plan the strategy and the tactic of achieving the goal is reflected (Lomov 1984). The plan is made on the basis of analysis of subjective and objective conditions of driving and it is formed in a driver's mind during the period of anticipation. The plan organises actions in time and place.

Without a plan it is impossible to connect different actions to the united system and to the activity. And an activity is organised in different ways depending on the plan. Roughly simplified one may suppose that there are three levels of the plans:

- flexible plan: possible changes in internal and external conditions of driving activity is anticipated.
- rigid plan: unpredictable situations and events disorient activity
- no plan: a driver responds and acts in traffic without a systematic plan

Planning is connected with personality factors, intelligence, experience, and executive control functions. The term executive control functions has been applied to a set of higher-order cognitive processes that control, integrate, organise and maintain other cognitive abilities (Pohjasvaara et al. 2002). Specifically, the term has been used to describe a group of cognitive actions like dealing with novelty, planning and implementing strategies for performance, monitoring and controlling performance, using feedback to adjust future responding and correct errors, strategic control of memory search plans, allocation of attention and inhibiting task-irrelevant information, mental flexibility, set maintenance and set shifting (Rabbitt 1997). Planning deficits are associated with lesions to the right dorsolateral prefrontal cortex (Burgess et al. 2000).

Drivers having accidents made more errors that reflect mental rigidity (perseverative errors, flexibility problems, etc.) and had poorer ability to plan and solve problems (Daigneault et al. 2002). Task complexity can affect which regions of the frontal lobes are involved. As a general rule for some processes, the more complex the function, the more frontal brain regions involved (Stuss and Levine 2002). Thus executive functions are of most importance in non-routine, in non-automated tasks, such

as driving a car on non-familiar roads. There are good reasons to suppose that patients with damages to frontal areas often have problems in driving.

4.3.5. Decision making in driving

The process of decision making consists of perceiving of problem situation, forming different hypotheses, evaluation of hypotheses, and selecting the hypothesis.

Drivers make decisions consciously and unconsciously during different stages of the driving event. It can be an automated or voluntary process. Operations are normally selected automatically by a driver whereas actions are selected consciously.

Strategy of driving reflects the content of the highest level of hierarchy which also includes elements beyond proper driving (e.g., Keskinen 1996), whereas tactics of driving are linked to the goals of driving. At the strategic level, a driver chooses the transport used, makes a decision on the trip and times a drive (Summala 1996). Tactics of driving cover, e.g., mapping out of the route of the trip.

Tendency to commit driving violations, fast driving, and lack of thoroughness in decision making have been reliably shown to be associated with increased accident risk (West, Elander and French 1991), and French et al. (1993) found that the connection between these factors does not depend on age, sex or experience.

It is possible to classify decisions in terms of the informational processes involved and nature of the situation in which decisions are made. For example, Fogel (see Bedny and Meister 1997) classified decisions as deductive (e.g. following learned operating procedures with little uncertainty), abductive (determining causal factors and how to proceed in a situation involving at least some uncertainty), inductive (requiring the integration of multiple parameters and utilization of a mental model of a system), and prognostic (decisions requiring the forecasting of transformations in the initial situation).

Decision making is a very individual act where individual differences are clearly manifested and decision making style depends on personality qualities. If decision making is divided into forming of hypotheses (HF) and control measures (CM) then we get the following ways of decision making which reflect a driver's individual differences (Kulytkin and Suhobsckaja 1971):

- HF >> CM impulsive decisions
- HF > CM risk decisions
- HF = CM balanced decisions
- HF < CM cautious decisions
- HF << CM inert decisions

From a safety standpoint, the group of impulsive drivers are the most problematic whereas from the point of traffic fluency the group of the inert drivers easily form 'blocks of traffic' who may unintentionally cause rear-ender accidents by their overcautious driving style.

According to our studies, a hasty and incorrect style in which an activity was done in the laboratory seems to mean an increasing number of errors in traffic. Well-timed decisions are crucial for safe and fluent driving.

Our findings indicate that decision making errors in the choice reaction test are positively connected to faults of the on-road test. Decision making errors are shown in hurrying and this may cause faults on the road.

4.3.6. Actions and operations as units of an activity

The study of activity structure at the individual-psychological stage of analysis presupposes the study of mental and practical actions of the individuals, their logical organization, and the study of the self-regulation mechanism (Bedny and Karwowski 2006).

Activity is always an activity of some concrete person or persons, i.e. a collective subject. There is no subjectless activity. And only a real subject may have mental and physiological resources needed in planning and execution of human activity. An abstract structure has not such resources and qualities.

Rubinshtein decomposes activity into major components, namely, motive, goal, action, and operation. Similar components were also described by Leont'ev (1947) (activity-action-operation and correspondingly motive-goal-conditions). Later Leont'ev (1977, 1978) and Zinchenko (1961) drew the conclusion that external and internal activities are to some extent isomorphic. This view is, however, criticized by many activity theorists (see Bedny and Karwowski 2006).

Psychologically the most essential components of a goal-directed activity besides that of the subject of activity are an action (in contrast to a reactions and movements) and operations in their interrelationship with the goal, motive, and conditions of activity of the subject (Bruslinskij 1987; Gameso and Domashenko 1986; Kotik 1978; Leontjev 1978; Lomov 1977). Actions are fundamental elements through which one can recreate holistic activity. Each action has separate conscious goals that must be reached to attain the overall goal of the task (Bedny, Seglin and Meister 2000). Since action is organised as a self-regulated system, the starting point of any action is the moment when the goal for the action is formulated or accepted, and the action is completed when the individual achieves the conscious goal of the action and evaluates the result of the action in terms of the established goal (Bedny, Seglin and Meister 2000; Bedny and Karwowski 2004).

An activity is always directed toward the final goal and actions are carried out according to the same motives as an activity, but they are directed toward intermediate goals whereas operations are subordinate to the conditions of an activity.

An action differs from a reaction in that it has a different kind of relation to the object. For a reaction, an object is only a stimulus, i.e., the external reason or an impulse causing it. In contrast to a reaction, an action is an act of activity directed not to a stimulus, but at the object and goal.

An action is different not only from reactions but also from activity, primarily because of its different relationship to the subject. An action becomes a deed to the extent that it begins to be regulated by more or less cognisable relations toward the acting subject and toward other people as subjects and, in particular, as self-awareness evolves. The same activity can be carried out with different actions, and the same action can be a component of different activities (Bruslinskij 1987).

Actions have both an intentional aspect, i.e., what one has to reach, and an operational one, i.e., by which means the result is achieved. An operational aspect of an action is related to the lowest level of a hierarchy of activity and operations depend on conditions and circumstances but not on goals.

The system of an activity as a whole is dynamic and it continually evolves. Activity constantly changes and transforms itself in the process of carrying out a concrete goal-directed activity: an action becomes an operation when its goal is changed, and action is able to become an activity when a motive is changed (Leontjev 1978).

According to Bedny and Karwowski (2006) an action can be described in terms of a recursive loop structure. Since action is organized as a self-regulated system, the starting point of any action is the moment when the goal of the action is formulated or accepted (figure 4).

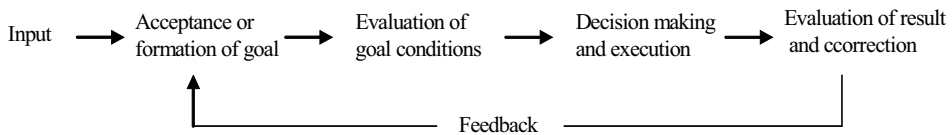


Figure 4. Simplified model of action as a one-loop system.

Actions are the result of historical development. From this point of view, actions are prior to the subject who first has to learn and internalizase the action and only then he/she is able to carry it out. Each object, e.g. a car or its control devices have spesific to them actions, and traffic is governed by laws and social norms and values. Actions are as if embedded in a such man-machine system as driving a car. Moreover, tools and instruments used in executing actions have their own developmental history too. Driving a car has more than a centenarian history.

An action may be formulated in terms of the object of action, the tools of an action, the goal of action and the subject of an action. Actions are the result of social-historical development. Each object has spesific associated actions, governed by social norms and values. Actions are facilitated by tools that similarly possess a history and cultural context (Bedny and Karwowski 2004). Actions shall be one of the main subjects of the driver's evaluation. In the theory of activity different methods of classification of mental and practical actions are used (Dushkov et al.1986; Bedny 1987; Bedny et al. 2000). The simplest way to classify actions is to divide them into external and internal ones. Regarding mental actions, they may be classified according to psychological processes to sensory, perceptual, information processing and mnestic actions. Every

action has a practical, i.e., motor component. When we are observing, our eyes are moving, when thinking, organs of articulation always move to some extent. Galperin (1979) divided actions into the following categories: orientation, executive and control/corrective. When the detailed information concerning the functioning of actions is needed, a classification depending upon the nature of the object of actions can be useful (Lomov 1986; Bedny and Karwowski 2004): object-practical actions, object-mental actions, sign-practical actions performed with real signs and sign-mental actions that are performed mentally by manipulating symbols (Figure 5.).

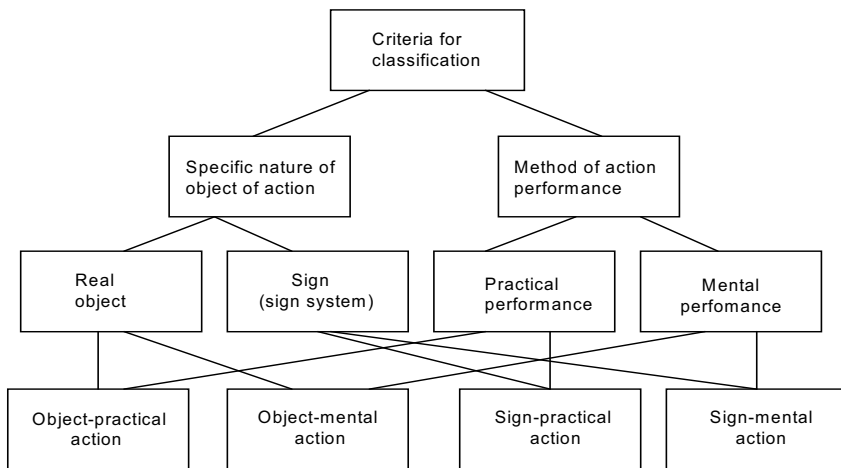


Figure 5. Classifications of actions according to Lomov (1986) and Bedny & Karwowski (2006).

Actions performed by the subject of activity through their skeletal-muscular system that changes the state of objects in the external world, or as in the case of driving a car, change the parameters of the control devices, are called object-practical-actions. Object-mental actions are performed mentally by the subject of activity with images of objects. In driving object-mental actions are related to planning and strategy as well self-regulation with different kinds of inner models.

Sign-practical actions are performed by the subject of activity with real signs receiving them from different devices and sources. In driving this means receiving information from the traffic environment (traffic signs and instructions, winker and brake lights of other's cars, etc.) and from the instrument panel (speedometer, tachometer, etc.). Sign-mental actions are mentally carried out by the subject of activity by manipulating and processing symbolic information received from different devices. The information concerning the functioning of these mental actions or cognitive blocks of driving activity is obtained from off-road and on-roads tasks.

Actions associated with different driving subtasks are, e.g., decision making concerning the moment of overtaking, changing a line, crossing a junction, etc., timing of different manoeuvring (turning, shifting, braking, etc.), observing instruments and traffic signs, selective observation in general, maintaining vigilance, identification of significant objects and observing using rear-view mirrors.

As Lomov (1984) pointed out, there are actions executed with concrete objects and there are ideal actions, which are associated with sign systems. However, any activity includes both "material" and "ideal" actions. All physical activity has its "inner side" (Lomov 1984).

Actions can be also divided into reactive and proactive. Reactive actions depend on features of the objective situations; proactive actions, which are determined largely by personality characteristics, usually take place in nonstructured, complex, and indeterminate situations (Bedny and Meister 1997). For safety reason, drivers have to be able to carry out proactive actions too. For their evaluation behind-the-wheel test is needed.

Activity and actions can also be evaluated by their meaning and sense where meanings are objective and sense is subjective depending on the motive behind the action (Leontjev 1978). Motives can be 'only known' or 'really effective' ones (Leontjev 1981). Apparent similar actions may have different senses depending on what each are trying to achieve by these actions.

Operations are a technical part of actions and they do not have an independent goal but are subordinated to the goal of the current action (Kotik 1987). The driving operations are already partly substituted by technology or they are made easier to carry out (automatic transmission, speed regulator, servo systems, etc.) and in the long run

information technology shall take care of a continually increasing part of control and also execution operations while the higher-level mental actions will stay under a driver's control.

According to Leont'ev (1977), actions become automated and unconscious operations during training and repetition. Both mental and motor operations are initially conscious but by repetition they shall first be abbreviated and then they become step by step unconscious. Leontjev (1978) illustrates the process of the transformation of actions into operations using driving a car as the example: "Initially every operation, such as shifting gears, is formed as an action subordinated specifically to this goal and has its own conscious "orientation basis" (Leontjev refers here to Galperin, vmh). Subsequently this action is included in another action, for example, changing the speed of the car. Now shifting gears becomes one of the methods for attaining the goal, the operation that effects the change is speed, and shifting gears now ceases to be accomplished as a specific goal-oriented process: Its goal is not isolated. For the consciousness of the driver, shifting gears in normal circumstances is as if it did not exist. He does something else: He moves the car from a place, climbs steep grades, driver the car fast, stops at a given place, etc. Actually this operation of shifting gears may, as is known, be removed entirely from the activity of the driver and be carried out automatically. Generally, the fate of the operation sooner or later becomes the function of the machine".

Total mileage is very important for the degree of automatisisation of driving tasks. To learn safe driving, an individual must develop standardised actions, and on the other hand, an individually flexible driving style too.

The closed driving test is a good method for an examination of operations and to examine how well the person has become adjusted to his or her deficiencies and aid devices. An action-operation analysis shows how stressful driving a car is for drivers: the greater part of the driving tasks that are at the level of conscious actions, the more loading driving is. However, the final decisions must be made on the level of actions because they have a real connection to the motives and goals of driving.

4.3.7. Self-regulation of driving

Driving activity is not a stable, unchangeable structure but it constantly changes and transforms itself in the process of carrying out goal-oriented actions. Therefore a driver has to regulate his or her driving performance. Regulation of driving is the process of consolidation of objective requirements and automated processes. The regulator of driving is a driver, a subject of an activity, and driving, despite the numerous technical innovations, is still based on self-regulations. Driving safety is actually equivalent to the state of self-regulation. Consequently, psyche as the highest system of regulation, is the basic element of driving ability.

In driving the role of self-regulation can hardly be overestimated. In accidents most often the underlying cause is the failure of self-regulation, that is to say, a human factor. Without self-regulation there is no flexibility or adaptability in human activity, and the more degrees of freedom there are, the more important the role of self-regulation is for success and the result of an activity.

For the subject, the relation to the object is just that, a relation, and hence it specifically regulates all activity. The subject regulates his or her activity by psyche, especially by consciousness, and driving is not an exception. Psyche works as a regulator especially as a process, because psyche is forming, reforming and developing all the time through interaction with people and the environment. According to Bruslinkij (1989) the main form of existence of psyche is a process. And psyche as a process constantly regulates activity, i.e., regulation has to be understood as non-disjunctive parallel processing (Bruslinskij 1994).

All external activities also have intrinsically psychological components by the help of which a subject of an activity regulates external activity (Rubinshtein 1973). Generally, this immanence of psychological elements in every motor action, enables regulation of a practical activity such as driving, too. So, juxtaposition of external and internal aspects of an activity is fruitless and erroneous because psyche as a regulator of an activity is included in all external activity (Rubinshtein 2003). Studying an executive part of an activity separately from its psychological basis (an action as an image), inevitably leads to a mechanical view of human activity.

The fact that driving is a practical form of human activity but not theoretical, does not mean that its regulation should somehow be easier to carry out than the theoretical form of the activity, rather the contrary, because in driving there is limited time resources for decision making and regulation. Driving is in most cases to some extent force-paced: one has to obey traffic signs and rules, in traffic flow one has to drive at a certain speed for the sake of traffic fluency, etc. Social pressure on the road is substantial and only few can stand up to it. If in intellectual activity one can test hypotheses and decisions in principle unendingly, a driver most often performs here and now situations where everything has to work on the first attempt while immaterial and material costs of a wrong decision may be very high. This in turn increases emotionality in regulation of driving.

As a rule there is time pressure towards operations when driving in traffic flow whereas at least some subtask-related actions, although they are mentally more complicated than operation, are in principle free of time pressure (e.g., decision to overtake, functioning at the ordinary crossroads). When activity is highly automated, the planning and the evaluation of results are extremely abridged. Then the process of regulation occurs unconsciously at the level of operations (Mikkonen and Keskinen 1980; Hacker 1981). However, these operations can be raised to a conscious level, for example in the case of functional disability or diseases.

Psychological self-regulative systems provide the integration of cognitive, executive, evaluative and emotional-motivational components of activity. During an individual's self-regulative process, the programme of self-regulation, criteria of self-regulation and even the goal of self-regulation may be changed. Self-regulation is a process that supplies co-ordination among the various psychological functions in accordance with a specific goal (Bedny, Seglin and Meister 2000).

Regulation of driving is affected by conditions of a subject (fatigue, emotions, intoxication, etc.), attitudes, and abilities. On the other hand regulation in itself is the process of producing such specific conditions as set (Uznadze 1966) and situative awareness (Endsley 1995, Stanton 2001).

The set creates a predisposition to processing information in a particular way or a predisposition to performing particular actions (Uznadze 1986). The set is an internal state of a person which unconsciously determines the purposefulness of human

behaviour. The transformation of the conscious goal into an unconscious set when attention shifts to new tasks allows the subject to return quickly to the formerly interrupted task. Goals are the only components of self-regulation that have to be conscious during self-regulation (Bedny and Karwowski 2006).

Levels of self-regulations are relationship of personality and the world, task-related regulations and regulations of his or her own condition. Self-regulation includes conscious and unconscious levels where the former level is linked to actions and the latter to operations.

Relationship of personality and the world are manifested in values and attitudes. Strategic-level decisions are partly value-based, e.g., choice of a car. Attitudes toward other people and societal norms are directly connected to driving safety. Task-related regulation can be divided into senso-perceptive, imaginary, and verbal-logistic levels (Lomov 1984). In driving the two previous are central. Partly regulation of driving is carried out automatically because a part of motives may be unconscious and operations are automated.

In driving the role of the internal models are crucial. In regulation we consciously or unconsciously compare here and now situations and results of our performance to inner models (Keskinen et al. 1992), i.e., conceptual models and operative schemes (Pushkin 1965). These inner models can be tested and observed to some degree in the course of the behind-the-wheel driving test.

Task-related regulation begins by forming an image of the task. A driver compares this image with previous solutions made by him/her in similar situations. In this process of comparison the view of degree of difficulty of the task is formulated and at the same time mobilisation of energy takes place. The more important a task the more a driver mobilises energy to its solution. The objective significance and personal sense of the task is directed to the use of man's psychological and physiological capacity (figure 6).

When driving we consciously or unconsciously compare here and now situations and results of our performance to inner models, i.e., conceptual and operative models. Inner models are ideal models of how an activity has to be realised. A conceptual model is a cognitive map including all the traffic-related information and experience the driver has obtained. Operative schemes comprise programmes of series of operations and

knowledge of control devices (Pushkin 1965). And, in all human systems there is a feedback loop from the results of performance to the subject of activity.

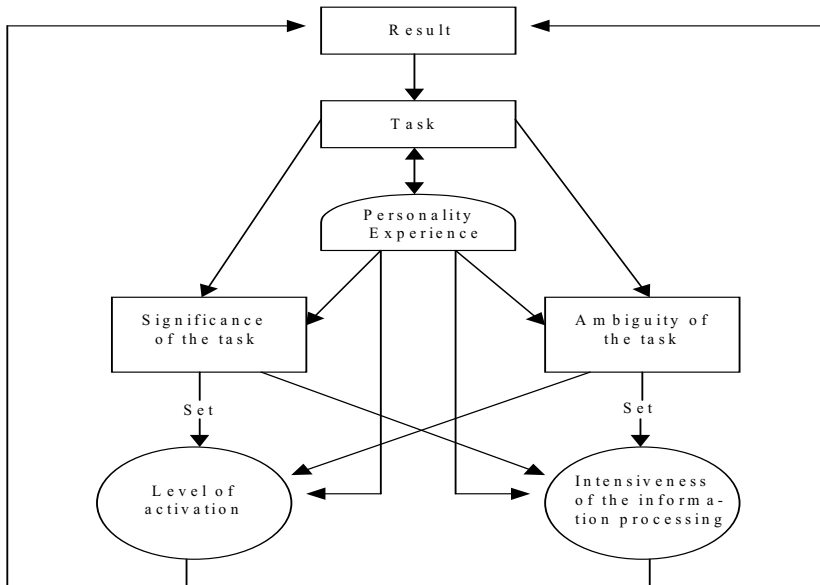


Figure 6. Regulation of activity (Kotik 1978).

Driving is in some degree a self-paced performance but this aspect seems to be overestimated at least to some extent in the case of driving in traffic flow. In traffic all the drivers have to adjust to the given driving rhythm and tempo. This does not directly depend on traffic regulation but on social pressure. In traffic, besides traffic regulations there is group dynamics within which a diver has to act. And one has to underline that these invisible boundaries exist objectively and nobody can avoid them.

4.4. Abilities in activity

In the dissertation the main question focuses on abilities. Therefore it is appropriate to provide some theoretical points of view concerning abilities.

An ability is an individual characteristic. The essence of the term ability is that the person can perform the task now, no further training is needed (Dictionary of psychology 1985). Second, the abilities are individual differences linked to success in some activities and they are not similar to skills or knowledge but on these depend how easily or difficulty they are adopted (Teplov 1985). Third, the abilities are not innate as their anatomical and physiological prerequisites. Fourth, the abilities are connected to development and the development of a human being is development of his or her abilities, too. Abilities not only manifest themselves in activities but they also develop in activities. Since abilities are connected with development then they do not exist outside development (Rubinshtein 1989; Bruslinsky 1982). There are not abilities outside the corresponding activities. Thus, there are no common innate driving abilities.

Consequently, in principle it is even impossible to study the driving ability of a person who does not yet have driving experience. As far as not yet licensed persons with handicaps or chronic illnesses are concerned the question is about general emotional, cognitive, sensorimotor and personality qualifications for safe driving but not about actual driving ability. There is no ability to act outside the corresponding form of activity. For them the decision had to be made whether to go to the driving school or not. Abilities become rusty without practise and in the case of a long interruption in driving a re-educational course is highly recommend.

When trying to decide where driving ability is localised a concept of the functional system is useful (Anohin 1975). The functional system is understood as a dynamic organisation which selectively associates both central and peripheral sections for a good result. Even a relatively simple movement forms a complicated functional system including sensory and kinesthetic impulses. In driving we are dealing with a complex biosocial activity which is impossible to be localised to some limited section of CNS or an organism. Therefore one cannot measure driving ability in the same way that muscular strength is measured by isometric devices, or in the way that volume of working memory is measured by the digit span test. Because abilities are connected with a development and activity, a process-centred approach is needed where the process is emphasised besides the result. In a process-centred evaluation there should be a focus on describing a style of an activity instead of the cross-section diagnosis.

5 EVALUATION OF DRIVING ABILITY

The requirements regarding driving ability are stipulated in the Road traffic act (Tieliikennelaki 2006). By law, refusal of driving requires proof that an examinee has a significant driving-related restriction(s). However, WHO's ICF encourages looking at driving with a wider perspective. It seems that the future of driver evaluations is drawn in ICF. Therefore driving and driving ability are considered here in a wider perspective than the valid Finnish traffic law provides.

Evaluation of the driving ability of disabled persons is a demanding task that carries a great deal of responsibility. Both false positive and false negative decisions have undesirable consequences. False positive decisions may lead to unsafe driving, even to accidents, which cause enormous immaterial and material expenses for a driver him/herself and for the third parties. On the other hand false negative decisions mean unjustifiable restriction of persons' independence.

5.1. General views and recommendations on driver evaluations

The crux of the problem lays in the definition of driving a car as a social form of human activity in a man-machine or man-technology environment. The complexity of the phenomenon of the ability to drive a car underlines the importance of the interplay of social, psychological, environmental, medical, and technical factors.

Driving as a social performance with universal traffic regulations sets some psycho-physiological requirements common to all the drivers regardless of the driver's age, sex, driving experience and health. So, in order to be a safe driver, one must satisfy some basic common physiological and psychological requirements. These common requirements are the basis of an evaluation. Procedure of a driver evaluation is described in the figure 8.

Both a driver and driving are hierarchical systems and there are oceans of connections between these systems, and in a driver evaluation only a few of them can be studied. Therefore it is so important what level of hierarchy of a human being and driving activity is chosen for an evaluation. The outcomes of an evaluation depend on what levels of hierarchy of a human being and driving performance we take as the

objects of the examination: an organism and motor operations, a temperament and dynamics of cognitive and sensorimotor processes, an individuality and style of life and activity, or a personality and goal-directed activity as whole. If organism and motor operations are chose to represent a drivers and driving, as the case often is, then we have only deal with biological and mechanical phenomena and laws whereas traffic is first and foremost the social form of activity and social interaction which does not open in an organism-operation level. Thus, the methodological decision of the frame where we examine the driver has to be made first.

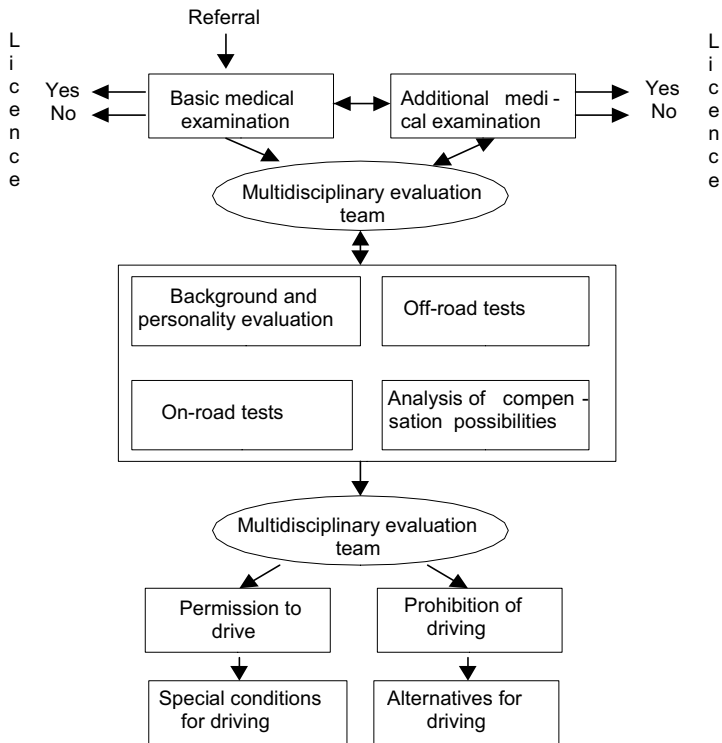


Figure 8. Prosedure of a driver evaluation.

There are persons suffering from diseases causing functional conditions which require a quite a long observation time until their real ability for safe driving can be reliably defined. Then a process-centred approach is needed. Diabetes mellitus and

sleeping disorders like appnea are examples of those. The question is how and who shall make an evaluation. That kind of an evaluation could be quite expensive.

To some extent a driver can always compensate for lower psychophysiological deficiencies by drawing on higher level resources: by anticipation one can compensate for reduced motor speed, by judgement one can avoid difficult traffic situations, by the active movements of the head a driver can compensate for minor visual field deficiencies etc. So, from the point of compensation an examination of the higher-order abilities is of most importance. However, permanently lost higher psychological functions such as missing judgement, inadequate self-awareness including lack of a sense of illness, cannot be compensated for. They all lead to degradation of driving performance and often cause abandonment of driving. People with poor executive functions generally have reduced adaptive capability.

The technical possibilities of the compensation are solved on the basis of an examination of the condition of a driver's motor functions. Additional traffic related tests and examinations may be required: fine motor tests to find out suitable adaptive devices, muscular strength tests for defining the level of the servo, the balance test in a sitting position etc.

For most handicapped persons a car can be adapted to their physical requirements, as our case in point a man who has only one functioning finger in his upper limbs, excellently shows. Intelligent transport system technologies such as route navigation and intelligent cruise control are coming into wider use, and they can reduce disabled persons' mental load while driving.

There is a multitude of bio-psycho-social factors influencing safe driving; driving is a multisystem object of study. Therefore a multidisciplinary team evaluation is needed. Composition of such an evaluation team could be a (traffic) physician, a (traffic) psychologist, an occupational therapist with expertise in adaptive technology, and a driving-school teacher. Medical and psychological prerequisites for driving are defined by an interview, questionnaires and laboratory tests whereas an evaluation of practical ability to drive has to be performance based. Since practical ability to drive is based on the behind-the-wheel driving test, the role of the driving-school teacher, as an expert of driving performance and education, has to be central to the evaluation team.

As we pointed up (IV, V) crucial for safe driving are not perceptible operations with the control devices but correct mental actions (object-mental and sign-practical actions) which the driver carries out with the help of control devices. Just these higher-level mental actions shall be the main subject of the driver's evaluation. In driver's evaluations we have to take a step away from the testing of the low-order motor operations towards higher-level mental actions, and away from concentration in perceptible conditions towards identification of the covert personality and cognitive qualities of a driver.

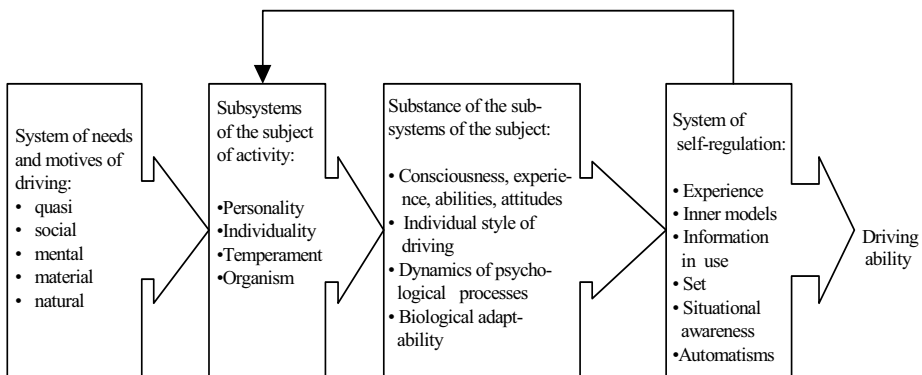


Figure 7. Main elements of driving ability.

It is so important to know what motives are behind driving activity. Is a licence needed for commuting? The leading activity is anything but a self-evident fact and one always has to discover it especially. Pathologically distorted motivational bases of activity may lead to prohibition of driving.

Besides transportation, driving satisfies important social and emotional needs and therefore driving and a driver evaluation too, is taken very seriously by road users. Therefore an evaluation situation may be emotionally charged. By pass/fail decisions experts take an attitude far beyond the actual driving of a car. However, safety consideration always have to be primary.

The subject of driving activity is the driver but not any of his or her single functions, organs or skills. An evaluation of driving ability should be subject-centred instead of disease-, handicap- or disability-centred, nor should it be test-centred. In driving, all the levels of a human being – an organism, a temperament, and a personality including an individuality – are involved. Thus, an evaluation of driving ability is a driver evaluation where a driver is considered as a multilevel hierarchical system (picture 2). A person's functioning as a driver is conceived as a dynamic interaction between levels of an organism, temperament, personality and individuality as the core of a personality. In this hierarchy a personality is 'a formator of a system' (Judin 1978).

As mentioned above several times, how well or bad a driver uses his or her potential depends on personality factors. The more consciousness is involved in driving, the more the driver is the real subject of his or her driving performance and behaviour. Therefore, finally driving ability is manifested on the level of a personality which is, in the last analysis, responsible for driving safety. The important personality dimensions which one has to take into consideration when evaluating driving ability are 'balanced – impulsive', 'responsible – irresponsible', 'confident – unconfident', 'flexible – rigid', 'mature – immature', 'good self-control – bad self-control'.

Diseases always alter a person's self-concept and this alteration may also affect self-evaluation. Under or overestimation of one's residual capacity is a common phenomenon among disabled persons. In this part of an evaluation the help of relatives is most often needed. In a driver's evaluation of disabled people it is very important to examine how the person in question has come to terms with his or her handicap. The closed driving test is a good method for an examination of motor functions and to examine how well the person has become adjusted to his or her deficiencies and aid devices. Generally, the driving simulators and the closed-road tests are proper methods for evaluating an operational level of driving performance.

Safe driving requires that a driver is aware of his or her abilities and restrictions as well as the driver has to correctly comprehend traffic situations and conditions. A driver's ability to correctly reflect on his or her internal driving conditions always has to be evaluated. The risk for crashes may be moderated by personality qualities and higher-order cognitive abilities. However, permanently lost higher psychological functions such as missing judgement, inadequate self-awareness including lack of a

sense of illness, lack of being able to simultaneously process information etc., cannot be compensated for. They all lead to degradation of driving performance and often cause abandonment of driving. People with poor executive functions generally have reduced adaptive capability. Denial of one's symptoms is always a significant risk factor for safe driving, and may be a criterion for exclusion from driving.

In activity theory, the concept of action is fundamental. Cognitive qualifications for safe driving are defined precisely at the level of actions. Deficiencies in the level of higher-level actions, but not operations, most often caused disability. In driving performance cognitive functions, especially perception, attention (selective, sustained, and divided), vigilance, planning, decision-making, and parallel information processing are emphasised. These psychological functions are not considered to be on the pathological level.

Measures of executive functions, which are linked to the skills at higher task levels of driving, are essential in evaluations of driving ability. During an evaluation one has to determine what a driver's abilities to plan his or her driving events are, to formulate adequate task-goals of driving. Goal formation is influenced by needs and motives and therefore goal formation is also often an emotionally charged process. At the strategic level a driver chooses the transport used, decides on a trip and times driving. Tactics of driving covers. e.g.. mapping out the route of a trip. Information about an examinee's planning abilities can be obtained either directly with the help of a driving test or indirectly by laboratory tests and an interview. An examinee could be asked, e.g., to plan the driving route from point A to point B. The limitations of a driver's intelligence culminates in the strategy and tactics of driving.

A plan takes shape during driving tasks which a driver solves by mental and practical actions and operations. In traffic situations such tasks are, for example, obeying driving orders and guidance, regulation of speed, keeping a safe distance away from other road users, action at an intersection and junction, action at a pedestrian crossing, turning right or left, driving with traffic flow and on the highway, staying in and changing lanes, merging, overtaking, and starting/parking/stopping. Tasks connecting to one's own conditions are, e.g., a continuous evaluation of one's own driving ability, maintaining a high enough activation level and emotional balance. The second question related to actions and operations is: how is the examinee's mental

capacity distributed between operation and actions? Is there enough free energy and capacity to carry out higher-order actions or is the capacity bound to lower-order operations.

The decision making process can be balanced or unbalanced in the way of impulsiveness or inertness. If the driver's decision making reaches a pathological level of impulsiveness or inertness it causes inability to drive a car safely enough.

Driving a car is a self-regulative system and the role of self-regulation can hardly be overestimated. Safe driving requires especially well functioning self-regulation in all levels of regulations. Self-regulation of driving performance and self-regulation of self during driving. Safety totally depends on the state of a driver's self-regulation. The problem here is that regulation difficulties appear mostly in unexpected situations. Therefore one's actual ability to regulate driving is difficult to predict and examine even using the on-road test because genuinely unexpected and dangerous traffic situations are almost impossible to demonstrate due to safety and ethical reasons. A conclusion concerning regulative abilities is based on all direct and indirect information that an evaluator has on hand.

5.2. Questions for evaluators

Questions which have to be solved in an evaluation arising from the models presented above (figures 1. and 7.) are follows:

- What are the examinee's needs and motives for driving?
- What is a driver's leading system in the hierarchical structure of the subject of activity: organism, temperament, personality ?
- Is the examinee able to correctly reflect on the internal and external driving conditions?
- Is the examinee able to correctly plan his or her driving activity?
- Is the examinee able to carry out proactive actions during driving?
- How does the examinee master driving related object-practical, object-mental, and sign-practical actions?

- Is the examinee uncommonly impulsive/inert or sufficiently flexible in his/her decision making?
- Is the examinee capable of making corrections to his or her driving performance through a feedback loop?

5.3. The point of law: are there significant driving related health restrictions?

In Finnish legal regulations the ability to drive is a medico-legal term which is defined in terms of minimal functional requirements, and in this context ability or disability to drive is associated with defect, disease and impairments. Thus, in a clinical examination concerning legal permission or prohibition to drive a car, medico-legal aspects are underlined. From the point of view of Finnish law (2006) the question for the evaluators is: is there a defect, a disease, or an impairment which *significantly* impairs a person's ability to act as a driver? And as to defects and impairments, they are most often described only as such lower-order factors as visual acuity, presence of seizure disorders and functioning of the skeletomuscular system.

The explanatory document of the WHO defines the impairment as 'any loss or abnormality of psychological, physiological or anatomical structure or function', and disability as 'any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered for a human being' (WHO 1980). Impairment includes those parts or systems of the body which do not work properly, and disability centres on those things that people cannot do, primarily basic skills of everyday living. Handicap refers to difficulties in carrying out social roles.

A physical impairment results from anatomical anomalies or physiological dysfunctions which are demonstrable by medically acceptable clinical and laboratory diagnostic techniques. The grounding of the definition of driving ability in health and driving disability in the clinical concepts of disease, impairment, and handicap outlines an angle of examination so narrow that the real cornerstones of safe driving remain outside of the focus. It falsely assumes a direct correspondence between physiological

processes and functional abilities. Physicians can attest to impairment, but they cannot identify inability to drive; that is the province of traffic related on-road and off-road researchers.

Below are some cases when there is good justification to suppose that an examinee may have significant driving related restrictions:

- Lack of a sense of illness or his/her sense of reality is distorted.
- When an examinee's level of alertness and attentiveness fluctuates considerably during the laboratory tests.
- When driving related laboratory measures of perceptual, frontal and executive functions are 2-3 standard deviations below the mean or below the lower quarter in a representative sample of the examinee's own group, and these deviant functions cannot be compensated for by others.

Besides health-related problems there are also other things indicating possibly significant problems in driving:

- Several culpable accidents or near-by-accidents in the recent past have occurred but a driver has not learnt anything from the events.
- When close relatives refuse to ride with an examinee and/or when the close relative is an initiator in an evaluation process, this according to our experience, most often was indicative of significant problems in driving.

The complexity of the phenomenon of the ability to drive a car underlines the importance of the interplay of social, psychological, environmental, medical, and technical factors.

5.4. Possible sources of bias in evaluations

It is inevitable, that we make errors when judging other people. There are some common evaluating errors such as the 'halo effect', which implies that the evaluator makes multiple generalizations based on one positive or negative characteristic to other ones, e.g., an intelligent person is also seen to be more conscientious (Pulakos et al.

1986). This ‘halo effect’, as our study with the patients suffering from Parkinson disease shows, is particularly possible in clinical studies carried out without ‘objective’ methods. The leniency/severity error means that some people tend to be generally more positive while others tend to give more negative ratings. Central tendency errors mean that raters only use the midpoints of a scale, rather than the extremes (Guion 1965). Finally, the similar-to-me-error (Wexley and Yukl 1977) occurs when evaluators tend to give better ratings when the personality of an examinee is similar to theirs. All these common types of evaluating errors may occur in driver evaluations. However, as for the driver’s evaluation, there are also some specific types of decision making errors.

The main type of decision making error in driver’s evaluation can be called ‘an error of a level’. This refers to a lack of a sufficient differentiation between the phenomena of the biological, psychological and social subsystems of a human being. Natural scientists are prone to consider all human factors depending only on a biological or physiological level. In traffic literature there are plenty of studies where driving is reduced to an organism-operations level and in this context only a behaviouristic approach is possible. From the point of view of driving ability such things as a driver’s ability to recognise his or her restrictions and strengths, even in principle cannot be defined in an organism-operation frame.

The second type of error, associated with the first one, is ignorance of the higher-order mediators (inner models, self-concept, motives, attitudes, interests etc.) between the factors of the CNS and driving activity.

The third type of error is connected to the prevailing paradigm to see a human being mainly as only a processor of information. Well-functioning cognition is an important, but not a sufficient, precondition for safe driving as traffic research involving healthy young drivers unambiguously proves.

Fourth, driving is emotionally charged and this also has an effect on the evaluators and the evaluation as well. Emotions may easily bias results in positive or negative direction. Professionalism is lost when an evaluator begins to work as an examinee’s counsel for the defence.

The fifth type of evaluation errors are connected to research methods. The limitations of the clinical evaluation were clearly seen in our study with the Parkinson’s disease patients (study III). A driver’s evaluation requires special research methods. The

common psychological paper-pencil tests and inventories are not driving-related, therefore more complicated tests which load, e.g., parallel information processes are needed.

Sixth, a sufficient difference is not always made between permanent, changing, and transient resources and conditions, e.g., acute fatigue may be overemphasised in conclusions in the case of diabetes. One can avoid this bias by stretching an evaluation over a longer period.

6 LIMITATIONS OF THE STUDY

Some methodological limitations of this study should be acknowledged. First, the empirical material is relatively limited. Although all the specialists involved in the studies were highly experienced, only one specialist was used in each category. Therefore more evaluators in each category (clinicians, psychologists, driving instructors) should be included in further research.

The main concept of the study, an activity, also has a limited field of application. Communication cannot be explained in the framework of activity because S-O-relations do not reach interrelations between human beings. S-S-relations cannot be explained by actions following each other but the matter is rather in mutual influence (Lomov 1984). Actually traffic users continually influence each other directly (blinker, horn, headlights, gestures etc.) or indirectly (acceleration, braking, changing lane, etc.). Traffic is really the field of interaction, the large system of communication, and without a concept of communication it is impossible to properly comprehend a driver's performance. However, regardless of the importance of the concept of the communication for understanding road users' behaviour, in the frame of a driver's evaluation most often it is enough to make a rough estimate of an examinee's emotions and attitudes towards other people and traffic rules.

From the standpoint of an analysis and an evaluation of human activity and behaviour, such important factors as psychological defences, identity, role, small and large group dynamics and style of activity and interaction, have only been dealt with superficially in the study or they are totally ignored.

The study of the skilled performance and skilled drivers would diversify the picture of driving abilities.

In traffic persons unknown to each other satisfy their needs for movement and other needs within the framework of mutually accepted rules. Although a traffic situation is supposed to include traffic users it seldom is seen as genuinely interactive and dynamic. Subject-subject (S-S) relations open quite a new view compared to subject-object relations (S-O) where a driver's performance is mostly seen as handling of a vehicle and traffic situation. An activity is social by its very nature because our activity is always

linked to the activities of other people. However, social interaction in its full extent was not the topic of this dissertation.

7 CONCLUSIONS

No matter how primitive or how sophisticated techniques are, the resulting judgements on driving ability are still only the product of an expert evaluation.

Both drivers and driving activity have a hierarchical structure and in driver evaluations it is a question of the matching of these two hierarchical systems with each other.

When evaluating driving ability one has not to reduce driving to a series of elementary motor operations nor should a driver be reduced to an organism, a reaction machine, a processor of information, to emotions or motives or to a risk calculator.

Safe driving is mainly dependent on higher psychological factors such as self-awareness, motivation, attitudes, planning, decision making and situational awareness.

An evaluation has to be person centred instead of diagnosis centred. Actually, driving ability is manifested in the level of personality.

The functional system of driving comprises the interactive blocks of the subject of activity, reflection of internal and external conditions of activity, planning, decision making, realisation of the plans, regulation of driving activity and feedback. An evaluation of driving ability is an evaluation of these blocks.

An evaluation of driving ability includes methods of measurement (mainly at the level of an organism), evaluation (at the level of temperament and personality) and description (at the level of personality and individuality).

A thorough evaluation must always include the behind-the-wheel test because the final conclusion of driving ability or disability, whenever possible, has to be based on practical ability to drive.

A personality is a continuously changing system with enormous developmental capacity, and therefore a personality is the main source of competence too. Personality qualities such as cognitive flexibility, planning capacities and adaptability to internal and external changes are important for maintaining driving ability when a driver's own prerequisites are reduced. These qualities are crucial from the point of compensation possibilities.

There are no abilities beyond a corresponding activity. Therefore abilities rust without practise and in the case of a long interruption in driving a re-educational course is recommend. Medical and rehabilitation personnel should more actively recommend driving lessons for their clients.

An evaluation of driving ability is a complex, multilevel, and multiphase process which can be compared to an evaluation of work ability and this type of research requires a multidisciplinary approach and special expertise in this field of human activity. An evaluation requires team-work and the role of driving instructors has to be central in the team since they have professional knowledge of driving activity.

8 DISCUSSION

The majority of the drivers still would not need any kind of evaluation of driving ability. Nor are there problems in conclusions concerning driving ability when there is some single exclusion factor like insufficient eyesight, continual attacks, severe neglect, or significant perceptual disorders. However, in most cases there is no single exclusion factor but several traffic-related constant, changing, and/or fluid factors depending on a person's physical and mental condition. It should be reasonable to use the scanty resources for a careful examination of driving ability of potentially problematic persons instead of healthy ones. However, there are still no jointly agreed upon criteria for when an evaluation by a team of experts is needed. Now it is time for thorough discussion of those criteria.

There is an enormous quantity of studies attempting to explain crash risk by the factors of the low or even by the very low level - simple reaction time, eye-hand co-ordination etc. -- which even in principle can explain only a very minor part of a driver's accident risk . Traffic psychological studies lack of a concrete human being including all of his or her needs, motives, attitudes, abilities and deficiencies as well. Instead of the whole concrete human being there we meet the abstractions of Man or the abstract Men. By the abstractions of Man we mean the way to study a human being through narrow operationalised traits or qualities, and by abstract Men we mean selected one-dimensional patient groups. In the real world there are no abstractions of the man nor the abstract men behind the wheel, but multidimensional and often also multiproblematic persons with their concrete needs and desires.

Importance of a personality for safety has been underlined for decades. Therefore it is astonishing how uncritically the concept of personality is used in traffic literature. Generally, one does not even bother to try to define it. There are numerous perspective alternatives among personality theories but traffic research seems to stick to the trait theory though its limitations and weaknesses are well-known (Pervin 2003). Probably the reason that the trait theory is used is because it meets the standards of statistics. In traffic research the methods seem to lead the research instead of the methods being selected from the subject of the research.

As numerous studies show, young healthy drivers as well as elderly drivers with cognitive and motor deficiencies, are noteworthy accident risk groups. This clearly shows that safe driving depends only partly on biomedical functions and only a minor number of accidents are caused by reasons of health. Therefore, one should avoid an excessive medicalisation of the evaluation of driving ability. Further, driving is only partly a cognitive task and therefore one should avoid neuropsychologisation too.

Statistical significance, of course, plays an important role when measuring sensorimotor and cognitive qualifications of driving ability, but, however, when speaking about an evaluation of significant driving related restrictions we are not dealing with an absolute scale but the significance has to be evaluated only in a relation to some other concepts. One such concept is predictability. One aspect of deviant driving is how well or poorly other road users can predict the driver's decisions and performance behind the wheel. Just in this context of a confidence principle we have to try to define driving related restrictions and laboratory test results. The predictability or unpredictability of one's driving behaviour always has to be showed, when possible, by the on-road test or by an activity based test. The safe driver's driving performance is predictable and predictability of driving means confidence. Thus, the principle of confidence is a useful tool in decision making.

In traffic research there is a lack of such basic psychological concepts as a defence mechanism and group dynamics, and partly a role, temperament, self-concept, will, need, etc. How can one, for example, examine functional capacity of a chronically sick or handicapped person without studying his or her defence mechanism? Of course it is impossible. However, in traffic literature one's unawareness of deficit(s) is almost always considered only as a neuropsychological syndrome (neglect) but hardly ever as a manifestation of a person's defensiveness though both organic neglect and emotional defensiveness may be equally fatal to road users. Physiologising of psychology leads to naturalism and along with it psyche disappears from psychology as has happened in American and Russian behaviourism at the beginning of the last century. By the disappearing of psyche from psychology, we then lose the main regulator of human activity and behaviour. It is to say: we lose a human being from the field of research.

There is a proposal for a pan-European evaluation model with a standardised set of tests for assessment (Sommer et al 2003) but this is hardly a correct and appropriate

way to organise driver evaluations. First, traffic conditions widely vary in different countries as do driving cultures. For instance it is a quite a different task to drive to work in sparsely populated northern Finland than in urbanised central Europe. In the former case, safe driving primarily requires good vigilance and tolerance of monotony whereas in the latter case a divided and selective attention is emphasised. The main thing here is to understand what the main question in driver evaluations should be, then to standardise an evaluation. There are several correct and valid ways to carry out a driver evaluation. Further, a standard is very likely to retard progress in traffic research rather than raise the level of the research.

Individual differences in driving are determined, to a certain degree, by the properties of the nervous system, but presently it is unclear how these properties of the CNS manifest themselves during driving activity in different situations and driving conditions. In theory one could determine the manifestations of the strength-weakness parameter of CNS in fatigue, sense threshold, vigilance and attention, and consequently, in different traffic situations and conditions as well. This may be a prospective field of research.

A driving licence, regardless of whether we see it as right or privilege, can be forbidden only by closely argued evidence. All disabled persons ought to have the possibility for a high-quality evaluation of their driving ability. An evaluation of patient's capacity and possibilities to move, including possibilities to act as a driver, should be an essential part of a holistic rehabilitation examination. At its best, a driver evaluation is a rehabilitation intervention where experts, together with an examinee and, if possible, with his or her close relatives, investigate and plan an examinee's prerequisites and possibilities of movement.

The ability to drive is an individual quality and disability just highlights the individuality of a person. Individuality should be more clearly in sight in the terms of the licence than it does at the moment. There should be a possibility to stipulate different individual conditions for drivers depending on their slight deficiencies which do not signify an inability to drive but which may influence driving in certain circumstances.

When a driver's activity is studied as an individual activity in the 'driver-car-environment' system and the subject of the analysis is the driver's actions and

operations, then the results of the analysis are perception errors, speeding, too narrow safety margins, etc. This is the paradigm. However, though driving a car is a goal-directed activity, not even the goal of an activity can be understood without an analysis of interrelations between individuals because other people have a central role in the forming of a goal (Lomov 1979, 1984; Abulhanova-Slavskaja 1980). Traffic is co-operation and a each driver's activity depends on others' activity. In a social interaction a communicative function of a psyche is highlighted when cognitive and regulative functions are more subject-centred. In a social interaction a common goal unifies the separated people in the group. A net of communication, a matrix according to Foulkes (1973), transform individuals into a group, individual road users into traffic, i.e., to a large group. When driving is studied as communication and social interaction between road users then the subject of the research should be group dynamics, communication net, style of communication and role-behaviour. Until now this is a poorly studied area of research.

In the last analysis in evaluations of driving ability it is the question of the values favoured by the society, and evaluators make value-based decisions when permitting or prohibiting someone to drive a car. To put it simply, the dilemma may be formulated: is the licence a right or a privilege? Costs of the consequences of false positive decisions are high. Thus, a main criterion in decision making must always be a person's own safety and the safety of others.

Biological, psychological, social and technical approaches all provide unique perspectives to the field of evaluation of driving ability. In the next decade the challenge of driving ability research is to integrate these many separate foci.

APPENDICES

Appendix No 1. Statistical methods used in the studies

Methods	Study
Methods for testing group differences	
Student's t-test (parametric)	III, IV
Mann-Whitney U-test (non-parametric)	I, II, III, IV
z-score	III, IV
Multivariate methods	
Pearson's product moment correlation coefficient	I, II, III, IV
Spearman's rank correlation coefficient	III, IV
Stepwise regression analysis	I, III,
Hit rate accuracy	
Fisher's P	IV

Appendix No 2. The evaluation methods used in studies.

Method	Paper I	Paper II	Paper III	Paper IV	Paper
Traffic-related interview	X	X	X	X	X
Willingness to take risk	X	X			
Traffic attitude test	X	X			
Eysenck's personality test	X	X			
Anxiety questionnaire	X	X			
MMSE			X		
Hoehn and Yahr scale			X		
Scandinavian Stroke Scale				X	
Barthel index				X	
Self-evaluation of laboratory test			X	X	X
Self-evaluation of driving ability	X	X	X	X	X
Spouse's evaluation of driving ability				X	X ²
Non-verbal intelligence test	X	X			X ¹
Visual short term memory	X	X	X	X	X
Speed and distance estimation	X	X			
Continuous attention	X	X			
Vigilance	X	X	X	X	X
Flexibility of perception	X	X	X	X	X
Simple choice reaction time	X	X			
Complex choice reaction time	X	X	X	X	X
Information processing capacity	X	X	X		X ²
Driving simulator, tracking test	X	X			
Isometric strength measure of the limbs ?					X ¹
Fine motor of the hands ?					X ¹
Close-road-driving test					X ¹²
On-road-driving test	X	X	X		X ²

¹ If needed

² If possible

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REFERENCES

Abul'hanova-Slavskaja KA: Kategorija dejatel'nosti v sovetsoj psihologii. Psihologitskij zurnal 1980,4:11-28.

Abul'hanova-Slavskaja KA: Dejatel'nost i psihologija litšnosti Nauka, Moskva, 1980b.

Abulhanova-Slavskaja KA: Printsip subjekta v filosofsko-psihologitseskoj kontseptsii S.L. Rubinshteina. Teoksessa: Sergej Leonidovits Rubinshtein: Otserki, vospominanija, materialy. Moskva Nauka 1989.

Adler G, Rottunda SJ and Dysken MW: The driver with dementia. A review of the literature, Am. J. Geriatr. Psychiatry 1996,4.

Anohin PK: Otšerki po fiziologii funkšionalnyh sistem. Moskva 1975.

Anonymous. Driving after stroke. Lancet 1987;ii:901-902.

af Wählberg AE: Some methodological deficiencies in studies on traffic accident predictors. Accident Analysis & Prevention 2003, 35:473-486.

Ajzen I And Fishbein M: Understanding Attitudes and Predicting Social Behavior. Amazon 1980.

Ajzen I: From intentions to actions. In Kuhn and Beckman (eds) Action-control: From cognition to behavior. Heidelberg: Springer 1985.

Allen TM, Lunenfeldt H and Alexander GJ: Driver information needs, Highway Research Records 1971, 366:102 -115.

Alexander R A and Barrett GV: Relationship between perceptual style and responses to visual motion under active and passive viewing conditions. Journal of Applied Psychology 1975,60:507-512.

Argyris C: Theories of action that inhibit individual learning. American Psychologist 1976,31:638-654.

Arthur Jr W, Barret GV and Alexander RA: Prediction of vehicular accident involvement: A meta-analysis. Human performance 1991,4:89-105.

Arthur Jr W and Doverspike D: Locus of control and auditory selective attention as predictors of driving accident involvement: A comparative longitudinal investigation. *Journal of safety research* 1992,23:73-80.

Asmolov AG: Osnovnye printsipi psihologitseskoj teorii dejatelnosti. In: A.N. Leontjev i sovremennaja psihologija. Izdatelstvo moskovskogo universiteta, 1983.

Asmolov AG: Basic principles of analysis in the theory of activity. *Soviet psychology* 1986,24: 78-102.

Atkinson J: Motivational determinants of risk-taking behavior. *Psychol. Rev* 1957,64:359-371.

Atkinson R and Shiffrin R: Human memory: A proposed system and its control processes. In K Spence and Spence (Eds.). *The psychology of learning and motivation: Advances in research and theory* (Vol. 2). New York: Academic Press 1968.

Backman M: Driving skill: The role of car control behavior. - *Annales Universitatis Turkuensis* 2001, B 247.

Barbas NR and Wilde EA: Competency issues in dementia: Medical decision making, driving, and independent living. *Journal of geriatric psychiatry and neurology* 2001,14:199-212.

Bedny G, Meister D: *The Russian Theory of Activity: Current Applications to Design and Learning*. Lawrence Erlbaum Associates, London 1990.

Bedny G and Meister D: Theory of activity and situation awareness. *Int. J. Cognitive Ergonomics* 1999,3:63-72.

Bedny GZ, Seglin MH and Meister D: Activity theory: history, research and application. *Theor. Issues In Ergon. Sci.* 2000,1:168-206.

Bedny GZ and Karwowski WA: Methodology for systemic-structural analysis and design of manual-based manufacturing operations, *Human Factors and Ergonomics in manufacturing* 2001,11:233-255.

Bedny GZ and Karwowski W: Activity theory as a basis for the study of work. *Ergonomics* 2004,47:134-153.

Bedny GZ and Karwowski W: *A systemic-structural theory of activity. Applications to human performance and work design*. Taylor & Francis 2006.

Bennet KM, Waterman C, Scarpa M and Castiello U: Covert visuospatial attentional mechanisms in Parkinson's disease. *Brain* 1995, 118:153-66.

Berger JT, Rosner F, Kark P and Bennett AJ: Reporting by physicians of impaired drivers and potentially impaired drivers. *J Gen Intern Med* 2000, 15:667-672.

Bloxham CA, Dick DJ and Moore M: Reaction times and attention in Parkinson's disease. *J Neurol Neurosurg Psychiatry* 1987, 50/9:1178-83.

Bradley VA, Welch JL and Dick DJ: Visuospatial working memory in Parkinson's disease. *J. Neurol Neurosurg Psychiatry* 1989, 52/11:1228-35

Brendemuhl D, Schmidt U and Schenk N: Driving behaviour of elderly motorists in standardized test runs under road traffic conditions. In: Rothengatter, T. de Bruin (eds). *Road user behaviour. Theory and research.* Van Gorcum 1988.

Brooke MM, Questad KA, Patterson DR and Valois TA: Driving evaluation after traumatic brain injury. *American Journal of Physical Medicine and Rehabilitation* 1992,71:177-182.

Brookhuis K, De Waard D, Peters B and Bekiaris E: SAVE –System for Detection of Driver Impairment and Emergency Handling–. *IATSS Research* 1998,22:37-42.

Brouwer W, Rothengatter JA and van Wolfelaar PC: Compensatory potential in elderly drivers. In: Rothengatter, T. de Bruin (eds). *Road user behaviour. Theory and research.* Van Gorcum 1988.

Brouwer WH and Withaar FK: Fitness to drive after traumatic brain injury. *Neuropsychol Rehabil.* 1997,7:177–193.

Brouwer WH, Withaar FK, Tant ML and van Zomeren AH: Attention and Driving in Traumatic Brain Injury: A Question of Coping with Time-Pressure. *J Head Trauma Rehabil* 2002,17:1–15.

Brown RG, Marsden CD: Cognitive function in Parkinson's disease: from description to theory. *Trends Neurosci* 1990, 13/1:21-29.

Bruslinkij AV: Vzaimosvjaz protsessualnogo in litsostnogo aspektov myslenija. *Teoksessa: Myslenija: protsess, dejatel'nost, obsenije.* Nauka. 1982.

Bruslinsky AV: Activity, action, and mind as process. *Soviet Psychology* 1987,4:60-81.

- Bruslinkij AV: Problema subjekta v psihologitseskoj nauke. Psihologitseskij zurnal 1991,6:3-11.
- Bruslinkij AV: S.L.Rubinshtein. Osnovopoloznik dejatel'nostogo podhoda v psihologitseskoj nauke. In: Sergej Leonidovits Rubinshtein : Otšerki, vospominanija, materialy. Nauka, Moskva, 1989.
- Bruslinkij AV: Problemy psihologii subjekta. Rossiiskaja akademija nauk, Institut psihologii. Moskva 1994.
- Bukasa B, Risser R (ed): Die verkehrspsychologischen verfahren im Rahmen der fahreignungsdiagnostik. Wien: Literas Universitätsverlag, Austria:1985.
- Burgess P, Alderman N, Evans J, Emslie H and Wilson B: The ecological validity of tests of executive function. J Int Neuropsychol Soc 1998,4:547-58.
- Cattell RB: Personality and learning theory. Vol. 1. N.Y. Springer. 1979.
- Cattell RB and Scheier IH: Handbook for the Ipat Anxiety Scale Questionnaire. Institute for Personality and Ability Testing. Illinois, USA 1963.
- Cerella J: Ageing and information-processing rate. In J.E. Birren & K.W. Schaie (Eds.), Handbook of the psychology of aging. San Diego,CA: Academic Press 1990.
- Charles M: Poser Automobile Driving Fitness and Neurological Impairment. Journal of Neuropsychiatry 5/3:342-348.
- Cloninger CR, Przybeck TR and Svrakic DM: A psychobiological model of temperament and character. Archives of General Psychiatry 1993,50:975-990.
- Cooper JA and Sagar HJ: Incidental and intentional recall in Parkinson's disease: an account based on diminished attentional resources. J Clin Exp Neuropsychol 1993,15/5:713-31.
- Cooper JA, Sagar HJ, Tiddwell P and Jordan N: Slowed central processing in simple and go/no-go reaction time tasks in Parkinson's disease. Brain 1994,117:517-29.
- Cooper JA, Sagar HJ and Sullivan EV: Short-term memory and temporal ordering in early Parkinson's disease: effects of disease chronicity and medication. Neuropsychologia 1993,31/9:933-49.
- Coleman RD, Rapport LJ, Ergh TC, Hanks RA, Ricker JH and Millis SR: Predictors of Driving Outcome After Traumatic Brain Injury. Arch Phys Med Rehabil 2002,83:1415-22.

Daigneault G, Joly P and Frigon J-Y: Executive Functions in the Evaluation of Accident Risk of Older Drivers. *Journal of Clinical and Experimental Neuropsychology* 2002,24:221-238.

Daum I and Quinn N: Reaction times and visuospatial processing in Parkinson's disease. *J Clin Exp Neuropsychol* 1991,13:972-82.

Deffenbacher JL, Oetting ER and Lynch RS: Development of a Driving Anger Scale. *Psychological Reports* 1994,74:83-91.

Delhomme P: Comparing one's driving with others': assessment of abilities and frequency of offences. Evidence for a superior conformity of self-bias? *Accident Analysis and Prevention* 1991;23:493-508.

De Raedt R and Ponjaert-Kristoffersen I: Short Cognitive/Neuropsychological Test Battery for First-Tier Fitness-To-Drive Assessment of Older Adults. *The Clinical Neuropsychologist* 2001,15:329-336.

De Raedt R and Ponjaert-Kristoffersen I: Predicting at-fault car accidents of older drivers. *Accident Analysis and Prevention* 2001,33:809-819.

De Raedt R and Ponjaert-Kristoffersen I: Can strategic and tactical compensation reduce crash risk in older drivers? *Age and Ageing* 2000, 29:517-521.

Dictionary of psychology. Penguin Books, 1985.

Dionne G, Desjardins D, Laberge-Nadeau C and Maag U: Medical conditions, risk exposure, and truck drivers' accidents: An analysis with count data regression models. *Accident Analysis & Prevention* 1995,27:295-305.

Driving school curriculum for driver education. Vehicle administration centre Helsinki:1989,1992.

Dubinsky RM, Gray C, Husted MA, Busenbark K, Vetere-Overfield B, Wiltfong D, Parrish D and Koller WC: Driving in Parkinson's disease. *Neurology* April 1991:517-520.

Duncan J, Williams P and Brown I. Components of driving skill. Experience does not mean expertise, *Ergonomics* 1991, 34:919-937.

Elander J, West RJ, French DJ. Behavioral correlates of individual differences in road-traffic crash risk: An examination of methods and findings. *Psychol Bull* 1993,113:279-294.

Endlsey MR: Toward a theory of situation awareness in dynamic-systems. *Hum. Factors* 1995,37:32–64.

Engestrom Y: Activity theory and individual and social transformation. *Activity Theory* 1991 (7/8):6-17.

Engeström Y: Kehittävä työntutkimus. Perusteita, tuloksia ja haasteita. Helsinki 1995.

Engestrom Y: Activity theory as a framework for analysis and design of work. *Ergonomics* 2000,43:960–974.

Eysenck HJ: The biological basis of personality. Springfield (illinois): Thomas, 1967.

Eysenck HJ and Eysenck SB: Manual of the Eysenck Personality Questionnaire. London: Hodder & Stoughton 1975.

Evans L: Traffic Safety and the Driver. New York: Van Nostrand Reinhold, 1991.

Evans L: Traffic crashes. *American scientist* 2002,May-June:244-253.

Fairclough SH: The Influence of Impairment Feedback on Driver Behavior: A Simulator Study. *Transportation human factors* 2000,2:229–246.

Ferguson SA, Williams AF, Chapline JF, Reinfurt DW and De Leonardis DM: Relationship of parent driving records to the driving records of their children. *Accident Analysis & Prevention* 2001,33:229-234.

Fisk GD and Owsley C: Driving following stroke: a survey. Paper presented in Transportation Research Board, 76th Annual Meeting, January 12-16, 1997, Washington, D.C.

Fitten LJ, Perryman KM, Wilkinson CJ, Little RJ, Burns MM, Pachnana N, Mervis JR, Malmgren R, Siembieda DW and Ganzell S: Alzheimer and vascular dementias and driving. A prospective road and laboratory study. *JAMA: Journal of American Medical Association* 1995,273:1360-1365.

Foulkes SH and Antony EJ: Group psychotherapy. The psychoanalytic approach. Penguin Books, London 1973.

Fox GK, Bowden SC and Smith DS: On-road assessment of driving competence after brain impairment: Review of current practice and recommendations for a standardized examination. *Arch Phys Med Rehabil.* 1998,79:1288–1296.

French DJ, West RJ, Elander J and Wilding JM: Decision-making style, driving style, and self-reported involvement in road traffic accident. *Ergonomics* 1993,36:627-644.

Freund B, Colgrove LA, Burke BL and McLeod R: Self-rated driving performance among elderly drivers referred for driving evaluation. *Accid. Anal. Prev.* 2005, 37:613-618.

Frese M: Work and organizational psychology. In Eysenk M. (Eds): *Psychology. An integrated approach.* Pearson Prentice Hall 1998.

Fukuda J, Adachi K, Nishida M and Akutsu E: Development of driver's drowsiness detection technology. *Toyota Technical Review* 1995,45:34-40.

Fuller RA: conceptualization of driving behaviour as threat avoidance. *Ergonomics* 1984, 27:1139-1155.

Fuller R: Towards a general theory of driver behaviour. *Accident Analysis and Prevention* 2005,37:461-472.

Gainotti G: Emotional behavior and hemispheric side of the lesion. *Cortex* 1972,8:41-55.

Galperin PJ: *Johdatus psykologiaan. Kansankulttuuri.* Helsinki 1979

Galski T, Bruno RL and Ehle HT: Driving after cerebral damage: a model with implications for evaluation. *American Journal of Occupational Therapy* 1992,46:324-332.

Galski T, Holly E, McDonald MA and Mackevich J: Evaluating fitness to drive after cerebral injury: Basic issues and recommendations for medical and legal communities. *Journal of head trauma and rehabilitation* 2000,15: 895-908.

Gameso MB and Domashenko IA: *Atlas po psihologii.* Izdatelstvo Prosvishchie, Moskva 1986.

Gray JA: *Pavlov's typology.* Pergamon Press, Oxford 1964.

Groeger JA and Brown I D: Assessing one's own and others' driving ability: Influences of sex, age, and experience. *Accident Analysis and Prevention* 1989,21:155-168.

Gronin-Golomb A, Gorkin S and Growdon JH: Impaired problem solving in Parkinson's disease: impact of a set shifting deficit. *Neuropsychologia* 1994,32/5:579-93.

Guastello SJ and Guastello DD: The relationship between the locus of control concept and involvement in traffic accidents. *Journal of Psychology: Interdisciplinary and Applied* 1986,120:293-297.

Guion RM: *Personnel Testing*. New York: McGraw-Hill 1965.

Gully SM, Whitney DJ and Vanosdall FE: Prediction of police officers' traffic accident involvement using behavioral observations. *Accident Analysis and Prevention*, 1995,27:355-362.

Gurevich KM, Klyagin VS and Serkov MI: The diagnosis of individual psychological traits of drivers in relations to professional reliability. In: Gurevich KM and Lubovsky VI. (Eds). *Psychological diagnosis: Problems and methods*. SSSR Academy of Pedagogical Sciences. Moscow 1975.

Haapasalo J: Factor structures of the Eysenck Personality Questionnaire and Zuckerman's Sensation Seeking Scale in Finland. *Reports from department of psychology* 1990:311. Jyväskylä: University of Jyväskylä.

Hacker W: *Allgemeine Arbeits- und Ingenieurpsychologie: psychische Struktur und Regulation von Arbeits-tätigkeiten*. Deutscher Verlag der Wissenschaften, Berlin 1978.

Hacker W: *Yleinen työpsykologia*. Weilin & Göös. Espoo 1981.

Hakamies-Blomqvist L: Fatal accidents of older drivers, *Accid. Anal. Prev.* 1993,25:19–27.

Hakamies-Blomqvist L: Older drivers' accident risk: conceptual and methodological issues. *Accid. Anal. and Prev.* 1998,30:293-297.

Hakamies-Blomqvist L, Henriksson P and Heikkinen S: Diagnostisk testning av äldre bilförare. *Fordonsförvaltnings-centralens utredningar* 1/1999. Helsingfors.

Hakamies-Blomqvist L, Wiklund M and Henriksson P: Predicting older drivers' accident involvement – Smeed's law revisited. *Accid. Anal. Prev* 2005,37:675-680.

Hakkarainen P: Problems of analyzing human activity. *Journal of activity theory*, 1989,3:13-21.

Harms L: Variation in drivers' cognitive load. Effects of driving through village areas and rural intersections, *Ergonomics* 1991,34:151–160.

Hatakka M, Keskinen E, Gregersen NP, Glad A and Hernetkoski K: From control of the vehicle to personal self-control; broadening the perspectives to driver education. - Transportation Research Part F: Traffic Psychology and Behaviour 2002,5:201-215.

Hauer E: The harm done by tests of significance. Accident Analysis & Prevention 2004,36:495-500.

Heikkilä V-M: Kokonaisvaltaisuus kuntoutustoiminnassa. Osa1: Kokonaisvaltaisen kuntoutuksen tarpeesta ja edellytyksistä. Kuntoutus 3/1994.

Heikkilä V-M: Kokonaisvaltaisuus kuntoutustoiminnassa. Osa 2: Kuntoutujakeskeinen toimintamalli. Kuntoutus 1/1995.

Heikkilä V-M: Kokonaisvaltaisuus kuntoutustoiminnassa. Osa 3: Kokonaisvaltaisuus kuntoutuskursseilla. Kuntoutus 2/1995.

Heikkilä V-M: On the concept and dynamics of work ability. Kuntoutus 1/1996.

Heikkilä V-M: Activity theory versus activity theory. Part 1.: Structure-centred activity theory. Psykologia 1997,5:324-333.

Heikkilä V-M: Activity theory versus activity theory. Part 2: Subject-centred activity theory. Psykologia 1998,1:11-18.

Hernetkoski K and Keskinen E: Self-destruction in Finnish motor traffic accidents in 1974–19921. Accident Analysis & Prevention 1998, 30:697-704.

Hier DB, Mondlock J and Caplan LR: Behavioral abnormalities after right hemisphere stroke. Neurology 1983,33:337-344.

Hopewell CA: Driving assessment issues for practicing clinicians. Journal of head trauma and rehabilitation. 2002,17:48-61.

Hoyt MF: Internal-external control and beliefs about automobile travel. Journal of research in personality 1973,7:288-293.

Huitt WG: Educational Psychology Interactive: The information processing approach to cognition Verkkodokumentti: 2003.

Hunt JC, Morris D, Edwards BS and Wilson: Driving performance in persons with mild senile dementia of the Alzheimer type, *J. Am. Geriatr. Soc.* 1993, 41:747–753.

Häkkinen S: Traffic accidents and driver characteristics. (Scientific Researches No. 13): Finland's Institute of Technology, 1958.

Häkkinen S: Traffic accidents and professional driver characteristics: a follow-up study. *Accident Analysis and Prevention* 1979,11:7-18.

Ivanova E.M: Osnovy psihologitseskogo izuzenija professional'noj dejatel'nosti. Izdatel'stvo MGU, Moskva 1987.

Iversen H and Rundmo T: Personality, risk behaviour and accident involvement among Norwegian drivers. *Personality and Individual Differences* 2002, 33:1251-1263.

Jahanshani M, Brown RG and Marsden CD: Simple and choice reaction time and use of advance information for motor preparation in Parkinson's disease. *Brain* 1992,115:539-64.

Jaroshevsky MG: Psihologija v XX stoletii. Politizdat, Moskva, 1974.

Jaroshevsky MG: Istorija psihologii. Mysl, Moskva 1976.

Jaroshevsky MG: Istorija psihologii. Mysl, Moskva 1985.

Johansson K, Bronge L, Persson A, Seideman M and Viitanen M: Can a physician recognise an older driver with increased crash risk potential? *J.Am.Geriatr.Soc.*1996, 44:1198–1204.

John OP: The "Big Five" factor taxonomy: Dimensions of personality in the natural language and in questionnaires. In LA Pervin (Eds.), *Handbook of personality: Theory and research*. New York: Guilford 1990.

Jonah BA: Accident risk and risk-taking behaviour among young drivers. *Accident Analysis and Prevention* 1986,18:255 - 271.

Jones RD and Donaldson IM: Fractionation of visuoperceptual dysfunction in Parkinson's disease. *J Neurol Sci* 1995,131(1):43-50.

Judin EG: Sistemnij podhod in prontosip dejatel'nosti. Moskva. Nauka 1978.

Kahneman D, Ben-Ishai R and Lotan M: Relation of a test of attention to road accidents. *Journal of applied psychology* 1973,58:113-115.

Kaptelinin V and Nardi BA: Activity theory: Basic concepts and applications. CHI 97 Electronic Publications: Tutorials.

Karttunen R and Hakkinen S: Road Accident Investigation Teams in Finland. Helsinki: University of Technology 1986.

Keskinen E: Inhimillinen tekijä liikenteessä. Turun yliopisto, psykologian tutkimuksia. 59, Turku 1982.

Keskinen E, Hatakka M and Katila A: Inner models as a basis for traffic behaviour. *Journal of Traffic Medicine* 1992,20:147-152.

Keskinen E: Why young drivers have more accidents? Reports of the First Interdisciplinary Conference 12-14 December 1994 in Cologne, *Berichte der Bundesanstalt für Strassenwesen: Mensch und Sicherheit, Heft M 52, Bergisch Gladbach* 1996.

Keskinen E, Hatakka M, Laapotti S, Katila A. and Peräaho M: Driver behaviour as a hierarchical system. In T. Rothengatter (ed) *ICTTP 2000 Proceedings, selected papers*.

Keskinen E: Taitojen oppiminen ja opettaminen. - Teoksessa Niemi, P. & Keskinen, E. (toim.), *Taitavan toiminnan psykologia*. Turun yliopiston psykologian laitoksen oppimateriaaleja 2, 2002, Hakapaino Oy, Helsinki.

Kisser R und Brandstätter Ch: Test für reaktive Stress-Toleranz. In Bukasa B., Risser R. (ed.): *Die verkehrspsychologischen verfahren im Rahmen der fahreignungsdiagnostik*. Literas Universitätsverlag Austria:1985.

Klavora P, Heslegrave RJ and Young M: Driving skills in elderly persons with stroke: comparison of two new assessment options. *Arch Phys Med Rehabil* 2000,81:701-5.

Klyagin VS, Gordeyeva AK and Muldarov VK: Individual characteristics of the regulative activity of the central nervous system and their manifestations in indicators of a car drivers' reliability. In: Gurevich K.M., Syerda Yu.L. (Eds). *Problems of psychological diagnosis: Theory and practice*. Research pedagogical institute ESSR. Tallin 1977.

Kotik MA: *Psihologija bezopasnosti*. Tallin, Vilgus 1987.

Kotik MA: Kurs inzenernoj psihologii. Valgus, Tallin 1978.

Kuikka P and Mäkinen T: Vanhemman kuljettajan kognitio ja ajokyky. Suomen lääkärilehti 48/2003.

Kulyutkin YN and Suhobskaja GS: individualnye razlitsija v myslitel'noi dejatel'nosti vzsroslyh utsashsihsja. Pedagogika 1971.

Kuljettajatutkinnon ajokokeen arviointi. Autorekisterikeskus. Helsinki 1992.

Laapotti S: What are young female drivers made of? Differences in attitudes, exposure, offences and accidents between young female and male drivers. Annales Universitatis Turkuensis B 264 2003.

Laaksonen H: Sairauksien ja iän yleinen merkitys liikenneturvallisuudelle. In: Liikennelääketiede. (Toim. Karkola K, Muller K, Ojala M.). Duodecim. Gummerus Kirjapaino Oy, Jyväskylä 2002.

Lajunen T: Personality factors, driving style and traffic safety. Reports 31:1997. University of Helsinki. Traffic research unit.

Lajunen T: Personality and accident liability: are extroversion, neuroticism and psychoticism related to traffic and occupational fatalities?. Personality and Individual Differences 2001,31:1365-1373.

Lajunen T and Summala H: Driving experience, and skill and safety-motive dimensions in drivers' self-assessment. Personality and Individual Differences 1995,19:307-318.

Lajunen T, Corry A, Summala H, Hartley L: Impression management and self-deception in traffic behaviour inventories. Personality and Individual Differences 1997,22:341-353.

Lajunen T and Parker D: Are aggressive people aggressive drivers? A study of the relationship between self-reported general aggressiveness, driver anger and aggressive driving. Accident Analysis and Prevention 2001,33:243-255.

Lajunen T and Summala H: Can we trust self-reports of driving? Effects of impression management on Driver Behaviour Questionnaire responses. Transportation Research 2003,6: 97-107.

Lamble D, Summala H and Hyvärinen L: Driving performance of drivers with impaired central visual field acuity. Accident Analysis and Prevention 2002,34:711-716.

Lagh-Smith J, Wade DT, Hewer RL: Driving after stroke. J R Soc Med 1986,79:200-203.

Leeman CP, Cohen MA, Parkas V: Should a pshychiatrist report a bus driver's alcohol and drug abuse? An ethical dilemma. *General Hospital Psychiatry* 2001,23:333-336.

Lehto MR: A proposed conceptual model of human behavior and its implications for the design of product warnings. *Perceptual and Motor Skills* 1991, 73:595-611.

Lektorsky VA: *Activity: Theories, methodology and problems*. Orlando: Paul M. Deutsch Press 1990.

Leontjev AN: *Activity. Consciousness. Personality*. Englewood Cliffs, NJ, Prentice Hall, 1978.

Leontjev AN: *Problems of the Development of Mind*. Moscow: Progress Publishers, 1981.

Leskinen M and Hirvonen P: Koulutettavuus raskaan autokaluston kuljettajaksi. *Työterveyslaitoksen tutkimuksia* 1979 No 139.

Lings S and Jensen PB: Driving after stroke: a controlled laboratory investigation. *International Disability Studies* 1991,13:74-82.

Lings S and Dupont E: Driving with Parkinson's disease. *Acta Neurol Scand* 1992,86:33-39.

Liikennelääketiede. Suomen Liikennelääketieteen yhdistys Ry. Forssan Kustannus Ky 1991.

Liikennelääketiede. (Toim. Karkola K., Muller K., Ojala M.). Duodecim. Gummerus Kirjapaino Oy, Jyväskylä 2002.

Liikennevakuutuskeskus (VALT). Vakuutusyhtiöiden liikennevahinkotilastoja eri vuosilta.

Linnoila M and Mattila MJ: Drug interaction on psychomotor skills related to driving: Diazepam and Alcohol. *European Journal of Clinical Pharmacology* 1973,5:186-194.

Lomov BF: *Osnovy inzenernoj psihologii*. Vysaja shkola, Moskva 1977.

Lomov BF: Kategorija obtšenija i dejatel'nosti v psihologii. *Voprosy Filosofii* 1979,8:34-47.

Lomov BF: K probleme dejatel'nosti v psihologii. *Psihologitseskij zurnal* 1981,5:3-22.

Lomov BF: *Metodologitseskije i teoretitšeskije problemy psihologii*. Nauka, Moskva 1984.

Lomov BF: Dejatel'nost operatora v sisteme "tšelovek-mašina". Teoksessa: Osnovy inženernoj psihologii (red. Lomov B.F) Vysšaja skola, Moskva 1986.

Loo R: Role of primary personality factors in the perception of traffic signs and driver violations and accidents. *Accid. Anal. Prev.* 1979,11:125–127.

Lourens P: Psychogenesis of incorrect driving behaviour. Traffic Research Centre, University of Groningen, the Netherlands 1988.

Lundberg C: Older drivers with cognitive impairments : issues of detection and assessment. Doctoral dissertation, Karolinska Institutet 2003.

Lundberg C, Hakamies-Blomqvist L, Almkvist O and Johansson K: Impairments of some cognitive functions are common in crash-involved older drivers *Accid. Anal. and Prev.* 1998,30:371-377.

Madeley P, Hulley JL, Wildgust H and Mindham RHS: Parkinson' s disease and driving ability. *Journal of Neurology, Neurosurgery and Psychiatry* 1990,53:580-582.

Mahoney FI, Barthel DW: Functional evaluation: The Barthel Index. *Maryland State Med J* 1965,14:61-65.

Marbe K: *Praktische Psychologie der Unfall und Betriebsschaden.* Munchen-Berlin, 1921.

Marottoli RA: and Richardson ED. Confidence in, and self-rating of, driving ability among older drivers. *Accid. Anal. and Prev.* 1998,30:331-336.

Maycock G, Lockwood C and Lester J: The accident liability of car drivers. TRL Research report RR 315. Transport research laboratory, Crowthorne 1991.

Mazer BL, Korner-Bitensky NA and Sofer S: Predicting ability to drive after stroke. *Arch Phys Med Rehabil* 1998,79:743-50.

McGwin Jr G, Owsley C and Ball K: Identifying crash involvement among older drivers: agreement between self-report and state records. *Accident Analysis & Prevention* 1998,30:781-791.

McKenna FP, Duncan J and Brown ID: Cognitive abilities and safety on the road: A re-examination of individual differences in dichotic listening and search for embedded figures. *Ergonomics* 1985, 29:649-663.

McKenna FP, Stainer RA and Lewis C: Factors underlying illusory self-assessment of driving skills in males and females. *Accident Anal. Prev.*1991,23:45–52.

McKenna FP and Myers LB: Illusory self-assessments. Can they be reduced? *British Journal of Psychology* 1997,88:39-51.

McKnight AJ and Adams BB: Driver education task analysis. Volume I-II. AlexandriaVA: Human resources research organisation. Final report, 1970.

McLay P: The Parkinsonian and driving. *Int. Disabil. Studies* 11:50-51.

Medical aspects of fitness to drive. A guide for medical practitioners. The Medical Commission on Accident Prevention. London 1995.

Menninger K: *Itseään tuhoava ihminen*. Otava, Helsinki 1955.

Merlin VS: *Otserk integralnogo issledovanija individualnosti*. Pedagogika 1986.

Michon JA: A critical view of driver behaviour models: what do we know, what should we do? In L. Evans and R. C. Schwing (eds), *Human Behavior and Traffic Safety* (New York: Plenum, 1985).

Mihal WL and Barrett GV: Individual differences in perceptual information processing and their relation to automobile accident involvement. *J Appl Psychol.*1976,61:229-33.

Mikkonen V and Keskinen E: *Sisäisten mallien teoria liikennekäyttäytymisessä [Internal models in the control of traffic behaviour]*. General psychology monographs, No. B1. University of Helsinki, General psychology 1980.

Miller M, Galanter E and Pribram KH: *Plans and the structure of behavior*. New York: Holt, Rinehart and Winston, 1960.

Molen van der and Bötticher AM: A hierarchical risk model for traffic participants. Special issue: risky decision-making in transport operations. *Ergonomics*, 1988,31:537-555.

Montag I and Comrey AL: Internality and externality as correlates of involvement in fatal driving accidents. *Journal of applied psychology* 1987,72:339-343.

Moskowitz H, Burns MM and Williams AF: Skills performance at low blood alcohol levels. *Journal of Studies on Alcohol* 1985,46:482-485.

Münsterberg G: Grunzüge der Psychotechnik. Leipzig. 1920.

Mäntyjärvi M, Juntunen V and Tuppurainen K: Visual functions of drivers involved in traffic accidents. *Accident Analysis & Prevention* 1998,31:121-124.

Nakashima K, Shimoyama R and Takahashi K: Paired choice reaction tasks in patients with Parkinson's disease. *Acta Neurol Scand* 1993, 87/3:178-83.

Nebylytsyn VD and Gray JA (eds): *Biological basis of individual behavior*. N.Y., L.: Academ. Press 1972.

Nouri F: Fitness to drive and the general practitioner. *International Disability Studies* 1988,10:101-103.

Nouri FM, Tinson DJ and Lincoln NB: Cognitive ability and driving after stroke. *International Disability Studies* 1987,9:110-115.

Nouri FM and Lincoln NB: Predicting driving performance after stroke. *BMJ* 1993,21:482-483.

Näätänen R and Summala H: A model for the role of motivational factors in drivers' decision-making. *Accident Analysis and Prevention* 1974,6:243-261.

Näätänen R and Summala H: *Road-user behavior and traffic accidents*. Amsterdam and New York: North-Holland/American Elsevier, 1976.

OECD scientific expert group. *Behavioral adaptations to changes in the road transport systems*. 2001.

Odenheimer GL, Beaudet M, Jette AM., Albert MS, Grande L and Minaker KL: Performance-based driving evaluation of the elderly driver: safety, reliability, and validity. *J. Gerontol.* 49/4 1994.

Ojala Mand Meriläinen V: Käytännön ajokoe ja ajosimulaattoritutkimus. In: *Liikennelääketiede*. (Toim. Karkola K., Muller K., Ojala M.). Duodecim. Gummerus Kirjapaino Oy, Jyväskylä 2002.

Owen AM, Beksinska M, James M, Leigh PN, Summers BA, Marsden CD, Quinn NP, Sahakian BJ and Robbins TW: Visuospatial memory deficits at different stages of Parkinson's disease. *Neuropsychologia* 1993,31/7:627-44.

Owsley C, Ball K, Sloane ME, Roenker DL and Bruni JR: Visual/cognitive correlates of vehicle accidents in older drivers. *Psychol Ageing* 1991,6:403-415.

Owsley C and McGwin G Jr: Vision impairment and driving. *Survey of Ophthalmology* 1999,43:535-550.

Owsley C, Stalvey BT and Phillips JM: The efficacy of an educational intervention in promoting self-regulation among high-risk older drivers. *Accident Analysis & Prevention* 2003,35:393-400.

Parker D, Reason JT, Manstead ASR and Stradling SG: Driving errors, driving violations and accident involvement. *Ergonomics* 1995,38:1036–1048.

Parker D, West R, Stradling S and Manstead ASR: Behavioral characteristics and involvement in different types of traffic accident. *Accid. Anal. Prev.* 1995,27:571–581.

Payne TR: S.L. Rubinstein and the Philosophical Foundations of Soviet Psychology. Dordrecht-Holland, D. Reidel 1968.

Perry RJ and Hodges JR: Attention and executive deficits in Alzheimer's disease. A critical review. *Brain* 1999,122:383–404.

Pervin LA (Ed.): *Handbook of Personality: theory and research*. New York: Guilford 1990.

Pervin LA: *The science of personality*. Second edition. Oxford university press. N.Y, Oxford 2003.

Petrovsky V. (Ed): *Obshaja psihologija*. Moscow 1986.

Pillon B, Dubois B, Bonnet AM, Esteguy M, Guimaraes J, Vigouret JM, Lhermitte F and Agid Y: Cognitive slowing in Parkinson's disease fails to respond to levodopa treatment: the 15-objects test. *Neurology* 1989,39/6:762-768.

Platonov KK: *System of psychology and theory of reflection*. Moscow 1982.

Poewe W, Berger W, Benke T and Schelosky L: High-speed memory scanning in Parkinson's disease: adverse effects of levodopa. *Ann Neurol* 1991,29/6:670-673.

Popova NE: Prognozirovanie individualnoi uspesnosti voditelskoi dejatelnosti. *Psihologitseskij zurnal* 1986,4:66-72.

Poser CM: Automobile Driving Fitness and Neurological Impairment. *Journal of Neuropsychiatry* 5/3:342-348.

Preusser DF, Williams AF, Ferguson SA, Ulemer RG and Weinstein HB: Fatal crash risk for older drivers at intersections. *Accid. Anal. and Prev.* 1998,30:151-159.

Priddy DA, Johnson P and Lam CS: Driving after a severe head injury. *Brain Injury* 1990,4:267-272.

Pulakos ED, Schmitt N and Ostroff CA: warning about the use of a standard deviations across dimensions within rates to measure halo. *Journal of Applied Psychology* 1986,71:29-32.

Pushkin VN: Operative thinking in Large Systems. Moscow 1965.

Pushkin VN: Vigilance as a function of strength of the nervous system. In: Nebylytsyn, V.D. and Gray, J.A (eds). *Biological basis of individual behavior*. N.Y., L.; Academ. press, 1972.

Qiang Ji and Xiaojie Yang: Real-time eye, gaze, and face pose tracking for monitoring driver vigilance Source. *Real-Time Imaging* 2002,8:357-377.

Rajalin S and Summala H: What surviving drivers learn from a fatal road accident *Accid. Anal. and Prev.* 1997,29:277-283.

Rajalin S and Keskinen E: Ihmisen liikennekäyttäytyminen. In: *Liikennelääketiede*. (Toim. Karkola K., Muller K., Ojala M.). Duodecim. Gummerus Kirjapaino Oy, Jyväskylä 2002.

Ranney TA: Models of driving behavior: a review of their evolution. *Accident Analysis and Prevention* 1994,26:733-750.

Rasmussen J: The definition of human error and a taxonomy for technical design. In J. Rasmussen, K. Duncan, J. Leplat (Eds.) *New technology and human error*. Chichester, UK: Wiley 1987.

Rauhala L: Erilaisista käsitesysteemeistä ihmisen kokonaisuuden tutkimisessa. Teoksessa: *Psykiatrian ja filosofian rajamailla*. *Psychiatria Fennica* 1978.

Rauhala L: *Ihmiskäsitys ihmistyössä*. Gaudeamus 1983.

Ravits-Sherbo: Genetitseskie aspekty psihologitseskoj diagnostiki. In: Gurevits, K.M. (ed): *Psihologitseskaja diagnostika: problemy i issledovanija*. Moskva 1981.

Reason JT., Manstead, A., Stradling, S., Baxter, J. and Campbell, K: Errors and violations on the roads: a real distinction?. *Ergonomics* 1990,33:1315-1332.

- Reimer B, D'Ambrosio LA, Gilbert J, Coughlin JF, Biederman J, Surman C, Fried R and Alear M: Behavior differences in drivers with attention deficit hyperactivity disorder: The driving behaviour questionnaire. *Accident Analysis & Prevention* 2005,37:996-1004.
- Revonsuo A, Portin R, Koivikko L, Rinne JO and Rinne UK: Slowing of Information Processing in Parkinson's Disease. *Brain and Cognition* 1993,21:87-110.
- Risser R, Schidt L, Brandstatter C, Bukasa B and Wenniger U: Traffic-Psychological Tests and Criteria of Driver Behaviour. First results of a validation-study. Wien: Austrian Road Safety Board, 1985.
- Risser R, Schidt L. Brandstatter C, Bukasa B and Wenniger U: Traffic-Psychological Tests and Criteria of Driver Behaviour. First results of a validationstudy. Austria: 1985.
- Richards M, Cote LJ, Stern Y: The relationship between visuospatial ability and perceptual motor function in Parkinson's disease. *J Neurol Neurosurg Psychiatry* 1993,56/4:400-6.
- Rotter JB: Generalized expectancies for internal versus external control of reinforcement. *Psychological Monographs* 1966,80:1-28.
- Rubahin VF: Prinjatje resenija v dejatel'nosti operatora. In: *Osnovy inženernoj psihologii* (red. Lomov, B.F.). Moskva 1977.
- Rubinshtein SL: *Printzipty i puti razvitija psihologii*. Izdatel'stvo Akademii Nauk, Moskva 1959.
- Rubinstein SL: *Grundlagen der allgemeinen Psychologie*. Berlin, Volk und Wissen 1977.
- Rubinshtein SL: *Osnovy obščestvennoj psihologii*. Pedagogika, Moskva 1989.
- Rubinshtein SL: *Bytie i soznanije. Tselovek i mir*. Piter, 2003.
- Rusalov VM: O prirode temperamenta i ego meste v strukture individualnyh svoistv tseloveka, *Vopr. Psih.* 1985,1:19-32.
- Russ MO and Seger L: The effect of task complexity on reaction times in memory scanning and visual discrimination in Parkinson's disease. *Neuropsychologia* 1995,33:561-75.
- Ryan GA, Legge M and Rosman D: Age related changes in drivers' crash risk and crash type. *Accid. Anal. and Prev.* 1998,30:379-387.

Sagberg F: Driver health and crash involvement: A case-control study. *Accident Analysis and Prevention* 2006,38:28-34.

Salo I and Keskinen E: Riskikuljettajat ja kuljettajien riskit. Kuolemaan johtaneet moottoriajoneuvonnettomuudet Suomessa vuosina 1990-2001. Liikenne- ja viestintäministeriön mietintöjä ja muistioita B28/2003. Helsinki 2003.

Salovaara E. Talja – Liikenneturva ry 1935-1973. Vammala 1976.

Scandinavian Stroke Study Group. Multicenter trial of hemodilution in ischemic stroke: background and study protocol. *Stroke* 1985,16:885-890.

Schneider W and Shiffrin RM: Controlled and automatic human information processing: detection, search, and attention. *Psychol Rev* 1977,84:1-66.

Shadrikov BD: Problemy sistemogeneza professionalnoi dejatelnosti. Nauka 1982.

Shaw L and Sichel H: Accident proneness research in the occurrence, causation and prevention of road accidents. *International series of monographs in experimental psychology*. Vol 11. 1971.

Shchedrovitsky CP: Selective work. Moscow 1995.

Shinar D: *Psychology on the road*. New York:Wiley, 1978.

Simpson CS, Klein GJ, Brennan FJ, Krahn AD, Yee R and Skanes AC: Impact of a mandatory physician reporting system for cardiac patients potentially unfit to drive. *Can J Cardiol* 2000,16:1257-63.

Sjogren H, Eriksson A and Ostrom M: Role of disease in initiating the crashes of fatally injured drivers, *Accid. Anal. Prev.* 1996,28:307-314.

Smith K and Hancock PA: Situation awareness is adaptive, externally directed consciousness. *Human Factors* 1995,37:137-148.

Solfrizzi V, Panza F, Torres F, Capurso C, D'Introno A, Colacicco AM and Capurso A: Selective Attention Skills in Differentiating between Alzheimer's Disease and Normal Aging *J Geriatr Psychiatry Neurol* 2002,15:99-109.

Sommer SM, Arno P, Strypsten M, Eeckhout G and Rothermel S: On-road Assessment methodology and Reference road test. AGILE Deliverable 4.3. December 2003.

Solntseva GN: Struktura i reguljatsija dejatel'nosti s pozitivno strukturnofunktional'nogo analiza. Teoksessa: Bolkov AM, Mikadze JB and Solntseva GN. Dejatel'nost: struktura i reguljatsija. Izdatelstvo Moskovskogo universiteta 1987.

Stanton NA, Chambers PRG and Piggott J: Situational awareness and safety. *Safety Science* 2001, 39:189–204.

Stepanova LP, Rozdestvenskaja VI: Osobennosti rabotaspasobnosti v uslovijah monotonnoj dejatel'nosti. *Voprosy psihologii* 1986,3:121-127.

Strelau J: Temperament, personality, activity. Academic Press. London, New York, etc. 1983.

Strelau J: The concepts of arousal and arousability as used in temperament studies. In JE Bates & TD Wachs (Eds.), *Temperament: Individual differences at the interface of biology and behavior* (pp. 117-41). Washington, D.C.: American Psychological Association 1994.

Stuss DT, Totha JP, Franchia D, Alexander MP, Tipper S and Craika FIM: Dissociation of attentional processes in patients with focal frontal and posterior lesions. *Neuropsychologia* 1999,37:1005-27.

Stuss DT and Levine B: Adult clinical neuropsychology: Lessons from Studies of the Frontal Lobes. *Annu. Rev. Psychol.* 2002,53:401–33.

Stutts JC, Stewart JR and Martell C: Cognitive test performance and crash risk in an older driver population. *Accid. Anal. and Prev.* 1998,30:337-346.

Suhodolsky GV: Ponjatijana sistema psihologitseskoj teorii dejatel'nosti. *Psihologitseskij zurnal* 1981,3:12-24.

Sullivan EV and Sagar HJ: Nonverbal recognition and recency discrimination deficits in Parkinson's disease and Alzheimer's disease. *Brain* 1989,112:1503-17.

Sundet K, Goffeng L and Hoff E: To drive or not to drive: Neuropsychological assessment of driver's license among stroke patients. *Scand J Psychol* 1995,36:47-58.

Summala H. Modelling driver behavior: A pessimistic prediction? In Evans, L. and Schwing, R.C. (eds) *Human behavior and traffic safety*. New York:Plenum 1985.

Summala H: Young driver accidents: risk taking or failure of skills? *Alcohol, Drugs and Driving* 1987,3:79-91.

Summala H: Risk control is not risk adjustment: the zero-risk theory of driver behaviour and its implications. *Ergonomics* 1988,31:491-506.

Summala H: Accident risk and driver behaviour. *Safety Science* 1996,22:103-117.

Summala H: Hierarchical model of behavioural adaptation and traffic accidents. In: Rothengatter, T. and Vaya, E.C. (Eds.) *Traffic and transport psychology. Theory and application*. Pergamon, Elsevier Science, U.K. 1997.

Summala H: Traffic psychology theories: Towards understanding driving behaviour and safety efforts. In *Traffic and transport psychology* (Underwood, G. Ed.). Elsevier Ltd. 2005.

Summala H, Pasanen E, Räsänen M and Sievänen J: Bicycle accidents and drivers' visual search at left and right turns. *Accident Analysis and Prevention* 1996,28:147-153.

Svenson O: Are we all less risky and more skilful than our fellow drivers? *Acta Psychologica* 1981,47:143-148.

Talo S (ed.): *Functioning – from the frame of reference to assessment and measurement*. Turku: The Social Insurance Institution, Finland. Social security and health reports 49, 2001.

Tant M: *Visual performance in homonymous hemianopia : assessment, training and driving*. University of Groningen 2002.

Teplov BM: *Izbrannye trudy*. Pedagogika, Moskva 1953.

Teplov BM: The problem of types of human higher nervous activity and methods of determining them. In: Nebylytsyn, V.D. and Gray, J.A (eds). *Biological basis of individual behavior*. N.Y.; L.: Academ. press, 1972.

Tieliikennelaki. Suomen säädöskokoelma 267/1981, muutettu. 676/1990, 429/1996, 1242/1997 ja 546/1999; Ajokorttiasetus. Suomen säädöskokoelma 845/1990, muutettu. 2/1996 ja 1243/1997; Euroopan Yhteisön direktiivi yhteisön ajokortista (91/439/ETY); Neuvoston direktiivin (91/439/ETY) liite III: Moottoriajoneuvon kuljettamiseen vaadittavaa fyysistä ja henkistä terveyttä koskevat vähimmäisvaatimukset.

Tikhomirov OK: Psihologija myslenija. Moskovskij Universitet 1984.

Tillmann WA and Hobbs GE: The Accident-Prone Automobile Driver - a Study of the Psychiatric and Social Background. *American Journal of Psychiatry* 1949,106:321-331.

Tolman CW: The basic vocabulary of activity theory. *Activity theory* 1988 (1): 14-20. Vainio, A., Ollila, J., Matikainen, E., Rosenberg, P., & Kalso, E. Driving ability in cancer patients receiving long-term morphine analgesia. *Lancet* 1995,346:667-670.

Van Winsum W and Brouwer W: Time headway in car following and operational performance during unexpected braking. *Perceptual and Motor Skills* 1997,84:1247-1257.

Van Zomeren A, Brouwer W and Minderhoud J: Acquired brain damage and driving: a review. *Arch Phys Med Rehabil* 1987,68:697-705.

Van Zomeren A., Brouwer W, Rothengatter, JA and Snoek JW: Fitness to drive a car after recovery from severe head injury. *Arch Phys Med Rehabil.* 1988,69:90-96.

Venda BF, Rotnberg RV and Ulihanjan GC: Psihologitseskie faktory nadeznosti upravljenija avtomobilami i problema obsnenija mezdu voditeljami. *Psihologitseskij zurnal* 1983,(4).

Vienna Test System. Computer-aided diagnostics and therapy. Dr. G. Schuhfried Ges.m.b.H., Mödling, Austria, 1991.

Viitanen M, Johansson K, Bogdanovic N, Berkowicz A, Druid H, Eriksson A, Krantz P, Laaksonen H, Sandler H, Saukko P, Thiblin I, Winblad B and Kalimo H: Alzheimer changes are common in aged drivers killed in single car crashes and at intersections. *Forensic Science International* 96,1998:115-127.

Vollrath M, Meilinger T and Krüger H-P: How the presence of passengers influences the risk of a collision with another vehicle. *Accident Analysis & Prevention* 2002,34:649-654.

Vygotsky LS: *Mind in society : the development of higher psychological processes.* Cambridge: Harvard U.P., 1978.

Waller PF, Elliott MR, Shope JT, Raghunathan TE and Little RJA: Changes in young adult offence and crash patterns over time. *Accident Analysis and Prevention* 2001,33:117-128.

Wasielewski P: Speed as a measure of driver risk: Observed speed versus driver and vehicle characteristics. *Accident analysis and prevention* 1984,16:89-103.

- Wertsch JV (Ed): The concept of activity in soviet psychology. Armonk, NY: M.E. Sharpe, Inc. 1979.
- West R, Elander J and French D: Decision making personality and driving style as correlates of individual crash risk. TRRL Contractors Report No. 309. Transport and Road Research Laboratory Contractors Report. Crowthome, Berkshire, U.K.: Transport and Road Research Laboratory, 1991.
- West R, French D, Kemp R and Elander J: Direct observation of driving, self reports of driver behaviour, and accident involvement. *Ergonomics* 1993,36:557-567.
- Wetherell A: Performance tests. *Environmental Health Perspectives* 1996,104:247-273.
- Wexley KN and Yukl GA: *Organizational Behaviour and Personnel Psychology*. Homewood, IL:Richard D.Irvin 1977.
- WHO. International classification of impairments, disabilities, and handicaps. Geneva: World Health Organization, 1980.
- Wickens CD: *Engineering psychology and human performance* (2 edit) New York: Harper Collins 1992.
- Wilde GJS: The theory of Risk Homeostasis: Implications for Safety and Health. *Risk Analysis*, 1982,2:209-225.
- Withaar: Divided attention and driving: the effects of ageing and brain injury. Published doctoral dissertation. Leeuwarden, the Netherlands, 2000.
- Wolffelaar P, van Zomeren E, Brouwer W and Rothengatter T: Assessment of fitness to drive of brain damaged persons *Teoksessa Road user behaviour: Theory and research*, Rothengatter T., de Bruin (ed.) Van Gorcum 1992.
- Wright MJ, Burns RJ, Geffen GM and Geffen LB: Covert orientation of visual attention in Parkinson's disease: an impairment in the maintenance of attention. *Neuropsychologia* 1990, 28/2:151-9.
- Zimmerman P, Sprengelmeyer R, Fimm B and Wallesch CW: Cognitive slowing in decision tasks in early and advanced Parkinson's disease. *Brain Cogn* 1992,18:60-69.
- Özkan T and Lajunen T: Multidimensional Traffic Locus of Control Scale (T-LOC): factor structure and relationship to risky driving. *Personality and Individual Differences* 2005, 38:533-545.