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Risk-taking behaviour: Relationship with personality and markers of heritability, and an intervention to prevent unintentional injury

UNIVERSITY OF TARTU
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Institute of Education, Faculty of Social Sciences, University of Tartu, Estonia

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TABLE OF CONTENTS

LIST OF FIGURES 8

LIST OF TABLES 8

ABBREVIATIONS 9

LIST OF ORIGINAL PUBLICATIONS 10

1. INTRODUCTION 11

2. EPIDEMIOLOGICAL BACKGROUND AND LITERATURE REVIEW OF RISK-TAKING AND PREVENTION 14
   - 2.1. The epidemiology of unintentional injuries 14
     - 2.1.1. Road traffic deaths 17
     - 2.1.2. Accidental drowning and submersions 18
     - 2.1.3. Exposure to smoke, fire and flames 20
   - 2.2. Risk-taking behaviour 22
     - 2.2.1. The role of personality-related factors in risk-taking behaviour 23
       - 2.2.1.1. Mary K. Rothbart's four dimensions of temperament 24
       - 2.2.1.2. Big Five model 24
       - 2.2.1.3. Self-esteem 25
       - 2.2.1.4. Impulsivity 26
     - 2.2.2. The role of biology in risk-taking behaviour 28
       - 2.2.2.1. The dopamine transporter gene (*DAT1*) and the VNTR polymorphism (rs28363170F) 29
       - 2.2.2.2. The serotonin transporter gene and the promoter polymorphism (5-HTTLPR; rs25531) 29
       - 2.2.2.3. Monoamine oxidases and platelet MAO activity 30
   - 2.3. Educational interventions to prevent risk-taking behaviour 31
     - 2.3.1. Cross-curricular teaching 32
     - 2.3.2. Psychological interventions to reduce risk-taking behaviour, with focus on dual-systems perspective and non-conscious factors 35
     - 2.3.3. The affective neuroscience approach and the heritable factors 37
   - 2.4. Aim and research questions 38

3. PARTICIPANTS AND METHODS 40
   - 3.1. Participants and procedure 40
     - 3.1.1. Study I (TerVe kool) 40
     - 3.1.2. Study II (ECPBHS) 40
     - 3.1.3. Study III (EPSTB) 41
   - 3.2. Methods and measurements 43
     - 3.2.1. Study I (TerVe kool) 43

3.2.1.1. Risk-taking behaviour questionnaire 43
3.2.1.2. Temperament (EATQ) 43
3.2.1.3. Self-esteem (ERSES) 43
3.2.1.4. Knowledge and skills 44
3.2.2. Study II (ECPBHS)..... 44
3.2.2.1. Traffic behaviour questionnaire 44
3.2.2.2. Personality measures 44
3.2.2.3. The Adaptive and Maladaptive Impulsivity Scale (AMIS) 44
3.2.2.4. Platelet MAO activity..... 45
3.2.2.5. Genotyping 45
3.2.3. Study III (EPSTB) 46
3.2.3.1. Intervention 46
3.2.3.2. The Adaptive and Maladaptive Impulsivity Scale (AMIS) 46
3.2.3.3. Genotyping 46
3.2.3.4. Database search 46
3.3. Statistical analysis 47
3.3.1. Study I (TerVe kool)..... 47
3.3.2. Study II (ECPBHS)..... 47
3.3.3. Study III (EPSTB) 48

4. RESULTS AND DISCUSSION 49
4.1. Safety knowledge and skills in adolescents (Study I) 49
4.2. Association of unintentional injury related risk-taking behaviour with the Rothbart's four-dimensional temperament and self-esteem (Study I)..... 50
4.3. Associations of unintentional injuries related risk-taking behaviour with the Big Five personality model and impulsivity measures..... 52
4.3.1. Associations of unintentional injuries related risk-taking behaviour with the Big Five personality model (Study II). 52
4.3.2. Association of unintentional injuries related risk-taking behaviour with impulsivity measures (Studies II and III)..... 53
4.4. Are serotonin system related measures associated with risk-taking behaviour in traffic? (Studies II and III) 54
4.5. *DAT1* VNTR polymorphism is associated with risk-taking behaviour in traffic (Study III) 55
4.6. Replication of the effect of brief psychological intervention on driving behaviour in an independent study (Study III)..... 56
4.7. Biological factors affect the efficacy of intervention (Study III) 57
4.8. Strengths and limitations and of the research design..... 58

5. MAIN RESULTS, CONCLUSIONS AND IMPLICATIONS 59
5.1. Main results and conclusions..... 59
5.2. Practical implications 60
5.3. Suggestions for future studies..... 61

REFERENCES 63
ACKNOWLEDGEMENTS 80
SUMMARY IN ESTONIAN 81
PUBLICATIONS 87
CURRICULUM VITAE 131
ELULOOKIRJELDUS 133

LIST OF FIGURES

Figure 1. Age-standardized mortality rate per 100 000. A – Transport accidents; B – Accidental drowning and submersion; C – Exposure to smoke, fire and flames (compiled after WHO, 2019) 15

Figure 2. The number of unintentional deaths in 2010–2018 in Estonia. (Compiled after Päästeamet, 2019; Maanteeamet, 2019) 16

Figure 3. Number of road traffic deaths in Estonia by the participation role (compiled after Maanteeamet, 2019) 17

Figure 4. Number of drownings by the type of water body. *2010–2013 no data (compiled after Päästeamet, 2019) 19

Figure 5. Last activity before drowning (compiled after Päästeamet, 2019) 20

Figure 6. Smoke detector installation in death ended fires (Compiled after Päästeamet, 2019) 21

Figure 7. A framework for reducing risk-taking behaviour (based on Hofmann *et al*., 2008 and Friese *et al*., 2011) 37

LIST OF TABLES

Table 1. In 2015 the age standardized mortality rates per 100,000 inhabitants (WHO Mortality Database, 2018) 12

Table 2. An overview of the samples, measurements, and methods of data analysis per study 42

ABBREVIATIONS

ASDR	Age-standardized death rate
AMIS	Adaptive and Maladaptive Impulsivity Scale
CI	Confidence intervals
CNS	Central nervous system
CTIF	International Association of Fire and Rescue Services
DAT1 VNTR	Human dopamine transporter gene variable number of tandem repeats polymorphism
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders 4th Edition
ECPBHS	Estonian Children Personality Behaviour and Health Study
ECTS	European Credit Transfer and Accumulation System
EPSTB	Estonian Psychobiological Study of Traffic Behaviour
5-HTTLPR	Serotonin transporter gene-linked polymorphic region
ICD-10	International Classification of Diseases 10th Revision
MAO	Monoamine oxidase
OR	Odds ratio
PFD	Personal flotation device
SEM	Structural equation modelling
SNP	Single nucleotide polymorphism
WHO	World Health Organization

LIST OF ORIGINAL PUBLICATIONS

I. **Luht, K.**, Klaos, M., Konstabel, K., & Eensoo, D. (2018). Personality, personal related factors and health related behaviour as predictors of pre-injury risk-taking behaviour in schoolchildren. *Proceedings Estonian Academy of Security Sciences, 17*, 7–26.

II. **Luht, K.**, Eensoo, D., Tooding, L-M., & Harro, J. (2018). The association of measures of the serotonin system, personality, alcohol use, and smoking with risk-taking traffic behavior in adolescents in a longitudinal study. *Nordic Journal of Psychiatry, 72*(1), 9–16.

III. **Luht, K.**, Tokko, T., Eensoo, D., Vaht, M., & Harro, J. (2019). Efficacy of intervention at traffic schools reducing impulsive action, and association with candidate gene variants. *Acta Neuropsychiatrica, 31*(3), 159–166.

The author contributed to the publications as follows:

Article I and Article III: participated during the preparatory stage, data collection, data analysis, formulating the research questions and writing the papers as the main author in cooperation with other authors.

Article II: participated in data analysis, formulating the research questions and writing the paper as the main author in cooperation with other authors.

1. INTRODUCTION

Injuries are an important public health issue in the whole world, having been the globally leading cause of death in males at ages 15–29 throughout the current millennium and amounting to more than 6% of total deaths. Injuries are categorized as unintentional (e.g., road traffic injuries, poisoning, drowning, falls and burns/scalds) and intentional (caused by violence). In 2016, road injuries killed 1.4, drowning 0.3 and fire-related burns more than 0.15 million people (WHO, Data and statistic, 2016). Road traffic injuries, drowning and fire-related burns together accounted for more than half of the global burden of injury deaths (WHO Mortality Database, 2018).

WHO is collecting the data of mortality and injuries based to the International Classification of Diseases 10th Revision (ICD-10) definition of external causes of morbidity and mortality. Death rate is one of the most important indicators for comparing the safety level in different countries in each timeframe. Age standardized death rate (ASDR) is a weighted (by proportion of persons in the corresponding age groups of WHO standard population) average of the age-specific mortality rates per 100, 000 persons. Nevertheless, it is important to bear in mind that the deaths that result from injuries represent only a small fraction of those injured. Many of injuries lead to hospitalization, or to aid at an emergency department, or treatment that does not involve any formal medical care; however, the event that brought them about could have ended with fatality. This idea is commonly described as the Injury Pyramid that presents the ratio of risk-taking behaviour, near miss events and injuries by severity. Risk-taking behaviour mostly does not appear as the sole cause of any incident while greatly enhances their probability.

In Europe, road traffic injuries are the most frequent causes of death in children and young people aged 5–29. Among 5–14 years olds the second leading cause of death is drowning (WHO Mortality Database, 2018) As to the situation in Estonia, the traffic, water and fire mortality rates are twice as high as in Nordic countries; nevertheless, substantially lower than in Latvia. The standardised mortality rates per 100,000 inhabitants in Estonia and its neighbouring countries in 2015 are presented in Table 1. The Estonian authorities (e.g., police, rescue service) develop and undertake educational programs on traffic, fire and water safety and have supported schools to promote safety. In the changing world with new technologies emerging, there is now a need to re-diagnose safety issues and re-plan for a new period. Estonia has set the ambitious goal to reach similar casualty rates than in Scandinavia (Päästeamet, 2016).

Table 1. In 2015 the age standardized mortality rates per 100,000 inhabitants (WHO Mortality Database, 2018).

	transport accidents	exposure to smoke, fire and flames	accidental drowning and submersion
Estonia	5.8	2.5	2.4
Finland	4.6	0.7	1.5
Latvia	10.2	3.3	4.7
Sweden	2.7	0.4	0.7

Although injuries have traditionally been regarded as random, unavoidable "accidents", in the few last decades it has generally been thought that injuries are largely preventable (Dellinger *et al.,* 2007). Everyday life decisions usually involve a balance between anticipated reward and risk. Studies demonstrate that those engaging in risk-taking behaviours are more likely to emphasise the positive consequences of their action, e.g., relaxation, excitement, and fun over the negative consequences such as injuries and social disapproval (Benthin *et al.,* 1993; Benthin *et al.,* 1995; Kuppula & Paavola, 2008). Engagement of young people in risky behaviours depends on their perception of how dangerous the situation is, or more specifically, on their perception of how dangerous that behaviour is likely to be in a given situation (Thomas *et al.,* 2007).

In Estonian national curriculum for basic schools and the national curriculum for upper secondary schools, safety is the cross-curricular topics (National curriculum for basic schools, 2018; National curriculum for upper secondary schools, 2018). "The cross-curricular topic "Health and safety" strives to shape the pupils into mentally, emotionally, socially and physically healthy members of society who are capable of leading a healthy life, behaving safely and facilitating the formation of an environment that is safe and promotes health" (National curriculum for basic schools, 2018). By the curriculum, health education is based on development of the knowledge, attitudes and social coping skills important for the pupils' health, including aspects like the awareness of their own health and safe behaviour, using knowledge, coping skills and general social skills to ensure safety, comprehend the consequences of decisions, etc. The safety topic implies that pupils are taught the following safety aspects: how to behave safely in situations of traffic, fire, water and other environmental dangers, and seek help when necessary (National curriculum for basic schools, 2018). The problem is that health education and safety topic are mostly treated as independent.

Most of the commonly applied health risk behaviour models (e.g., health belief model, theory of planned behaviour, trans-theoretical model) focus on conscious, reflective factors in describing human behaviour (Schwarzer, 2008), and these are broadly applied also in Estonia. In the last decades scientists have however increasingly paid attention to the seemingly irrational, non-conscious and unintended processes behind risk behaviours (Gibbons & Gerrard, 1995; 1997; Friese *et al*., 2011). These ideas have origins in the evolutionary development of brain and behaviour as described by affective neuroscience (MacLean, 1990; Panksepp,

1998). The focus in this thesis is on the non-conscious and unintended processes (personality and biological factors) behind risk behaviours and using this knowledge in intervention.

Interventions based on both conscious and irrational aspects of decision-making process, based on understanding of significance of differences between environmental conditions, are needed for developing a safer country.

For reducing risk-taking behaviour, it is important to place the relationship of brain and behaviour into multidisciplinary framework (Harro, 2019). The concept of affective neuroscience inspired the development of a novel intervention technique by delivery of information on the role of impulsivity in traffic together with feedback for self-recognition of personal risks so that individuals could build their own personally fitting risk reduction strategies (Paaver *et al*., 2013). (Parenthetically, the Paaver *et al*., 2013 article was selected by the Estonian Ministry of Education and Science as the annual best international paper in education research.)

While the human beings share the characteristics of their species, and the decision-making basis, including personality, is universal, specific populations are different in important ways (Khusnutdinova *et al.,* 2008), including the personality profiles (McCrae & Terraciano, 2005), and the environmental factors are very different. Mostly the co-influence of environmental and genetic factors occurs to shape behaviour (Reif & Lesch, 2003). The life curve is also important: The nature of brain growth in adolescence makes them not merely older children or younger adults, but that rather are their needs with respect to injury prevention unique (Johnson & Jones, 2011). The high risk-taking in teenager years is mostly attributed to the pubertal increase of sex hormones (Willoughby *et al*., 2013). Nonetheless, risk-taking could be the highest later, in early 20s, probably caused by the absence of supervision and increase in choices that include, e.g., driving and alcohol use (Shulman *et al*., 2016). Environment impacts on factors unique to each individual, and the nature of the interaction could change during the lifespan (Kazantseva *et al*., 2016). Injury prevention efforts should focus on phasing in risk over time paralleling maturity by focusing on peers, parents, and policymakers (Johnson & Jones, 2011).

As a consequence, environment must aggressively offer incentives for healthy behaviour, and this includes targeted intervention actions. Effective interventions during adolescence reduce the burden of health problems in adulthood (Catalano *et al*., 2012). The commonality in risk factors across problem behaviours means that interventions that address a risk factor will probably affect many problems (Catalano *et al*., 2012). Effective adolescent health programmes should include a combination of preventive policies. School based safety programs provide a great opportunity to promote healthy nutrition and physical activity because, indeed, attending a school is compulsory. In fact, a child spends more than half of his/her waking hours at school or at school-related activities on any given school day. Furthermore, what is learned at early age remains more deeply embedded in the brain. It should however be acknowledged that each brain is different.

The main aim of this doctoral study is to clarify the association of risk-taking behaviour related to unintentional injuries with personality traits and markers of heritability, and to explore the possibilities of intervention.

2. EPIDEMIOLOGICAL BACKGROUND AND LITERATURE REVIEW OF RISK-TAKING AND PREVENTION

2.1. The epidemiology of unintentional injuries

In planning of any intervention, the first phase is to deal with the identification and evaluation of the social problems that affect the quality of life of the community and its members (Green & Kreuter, 2005). Depending of the country's achieved economical level, on-going reforms, and many other aspects, the possibilities to reduce the number of unintentional injury deaths are different. Prevention comprises a number of intervention strategies, firstly classified in 1947 by Truman as three E-s (Engineering, Enforcement, Education) and nowadays usually described as the 5E (U.S. Department of Homeland Security, 2012): 1) Engineering modification (e.g., seat belt, safety seat, smoke detector, personal floating device (PFD); 2) Enforcement (e.g., prohibition of alcohol use while driving, lower ignition propensity cigarettes); 3) Education (e.g., reduction of risk-taking and impulsive decision-making); 4) Economic incentives and possibilities to invest into safer strategies; 5) Emergency response (often by responsible services). Additionally, Epidemiological analysis can help to determine and focus the specific health issues of the community and the behavioural and environmental factors involved (Green & Kreuter, 2005).

Injury rates and patterns differ from country to country, and are changing over time. Figure 1 presents accidental age standardized mortality rates (transport, drowning and fire/flames/smoke) in the Baltic and Nordic countries. In Estonia death rates by unintentional injuries are more similar to other Baltic countries, being much higher than in Nordic countries.

A **transport accident** is any accident involving a device designed primarily for, or being used for conveying persons or goods from one place to another. This includes pedestrian, pedal cyclist, motorcycle, car and other land, water, air, space and other unspecified transport accidents. Such accidents as during maintenance or repair of vehicle, or a finger crushed when shutting door of a car, or an assault by crashing of motor vehicle are however excluded (ICD-10). In 1994 the MS Estonia ferry disaster with 852 lives lost is prominently represented in statistics of Estonia and Sweden (Figure 1, Panel A). As the rates present the number of deaths per 100 000 population, the rise is bigger for Estonia than for Sweden while more Swedish lives were lost. (Bodies found later and not identified are counted as cases of drowning through several next years.) The very first National Road Safety Program was approved in Estonia in 2003 (Teede- ja sideministeerium, 2003).

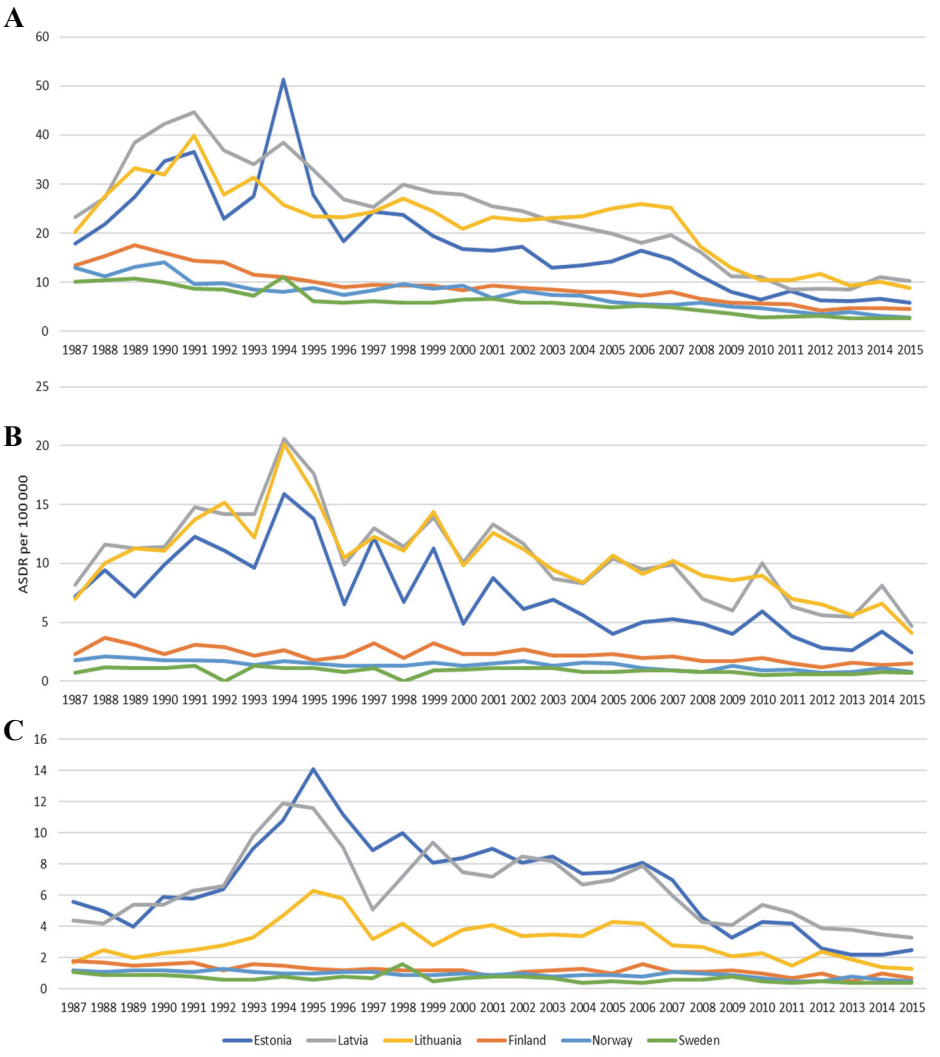

Figure 1. Age-standardized mortality rate per 100 000. A – Transport accidents; B – Accidental drowning and submersion; C – Exposure to smoke, fire and flames (compiled after WHO, 2019).

Accidental drowning and submersion includes drowning and submersion while in a bath-tub, swimming-pool or natural water, and other unspecified drowning and submersion. Excluded are accidents as in cataclysm, transport accidents, incl. water transport accidents (ICD-10). Most of drownings in Estonia take place in natural bodies of water, so air temperature could play an important role in the instability of accident rates (Fralick *et al.*, 2013). This tendency characterizes all countries with four seasons. Drowning prevention is very difficult to organize because the theme is not under one authority (e.g. lifeguard, Rescue Board, Police and Police and Border Guard Board). Since 2010 the Estonian Rescue Board has taken the leading role in preventing drowning and in 2011 it started water safety campaigns and placement of safety equipment at native bodies of water.

Exposure to smoke, fire and flames as a class of accidents includes the exposure to controlled or uncontrolled fire within or outside of a building or other structure, exposure to ignition of a highly flammable material, ignition or melting of nightwear, ignition or melting of other clothing and apparel, other specified smoke, fire and flames, or unspecified smoke, fire and flames. What is excluded is arson, a secondary fire resulting from explosion, and transport accidents. Economically good years during 2005 to 2008 improved the living conditions and at the same time the Estonian Rescue Board started the fire prevention work as one of the main tasks of the authority. In 2011, the lower ignition propensity standard for cigarettes was implemented in the European Union. The effect of that measure has been studied in Estonia and found to reduce the level of smoking-related fires (Saar, 2018).

Careful examination of international statistics reveals that socio-economic conditions make a big impact on the safety levels. Nevertheless, to reduce deaths caused by unintentional injuries cooperation of all partners is needed, at all levels of providing educational, and in all type of education.

Although the number of deaths is decreased in the long view, death rate by drowning, fire and road traffic in Estonia has remained stable during the last few years (Figure 2). It should however be acknowledged that the international statistics and statistics by national authorities may differs owing to variability in definitions and other considerations. For example, traffic accidents by ICD-10 include land, water, air, space and other unspecified transport accidents but traffic accidents by Traffic Act (2019) are an event in caused as a result of at least one vehicle moving on or off the road. Water transport accidents are included in both drowning and transport accidents. In case of exposure to smoke, fire and flames these could be presented differently in ICD-10 than in the Estonian rescue board statistics, because the rescue board is collecting statistic about fires.

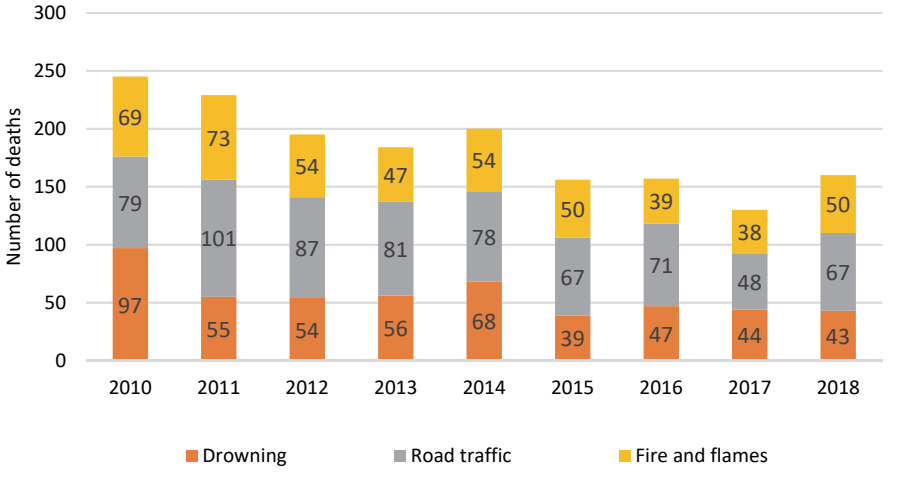

Figure 2. The number of unintentional deaths in 2010–2018 in Estonia (compiled after Päästeamet, 2019; Maanteeamet, 2019).

2.1.1. Road traffic deaths

Human **behaviour in traffic** has been an object of study since the first decades of the 20th century, driven by the increase in the use of vehicles in urban transportation and the growing involvement of drivers in automobile accidents (McKenna, 1983; Ulleberg & Rundmo, 2002).

Road traffic deaths include those among vehicle occupants, pedestrians, and cyclists. In 2018 the road traffic death rate was 5.1 per 100,000 population, representing 67 deaths. During the last five years, the male average death rate has been two and a half times as high as in females (8.6 *vs.* 3.3 per 100,000). The age distribution of vehicle occupant deaths is the lowest among children too young to drive and bike alone (<4), and the highest in teenagers and young adults aged 15–24 years. Approximately 40% of road traffic deaths are accounted for by motor vehicle drivers, and 20% are pedestrians (Figure 3). Most of pedestrians died during the crossing of road, some of them were drunk, and/or were not visible (did not use any reflector or lamp in the dark time). In case of collisions, the victims often did not use the seatbelts, drivers did not appreciate road conditions (bad weather), were negligent in crossroads, or badly fixed loading was involved. Cyclists often did not use the helmet correctly, overspeeded, or were negligent in crossroads. Some drivers had pre-existent health problems or were exhausted (Maanteeamet, 2019).

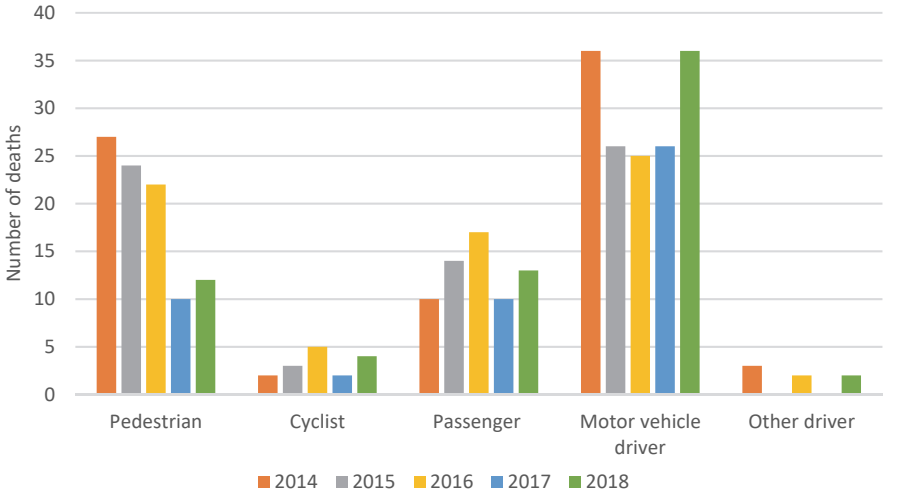

Figure 3. Number of road traffic deaths in Estonia by the participation role (compiled after Maanteeamet, 2019).

Although the most effective way for reducing the traffic deaths is modifying the infrastructure, it is very expensive and other possibilities also need to be made use of. Key risk factors to work with 5E-s (legislation with product development, education, police enforcement and punishments/cost) are speeding, drunk

driving, using the seat belt, helmet and child safety seat (Dellinger *et al.,* 2007). Road crossing pedestrians and cyclists are too often neglected by drivers. These risks have been studied in detail and found to vary by gender, area of the road (urban or rural) and behaviours (e.g., looking left and right before crossing the road, respecting the traffic lights, talking with other people and using mobile phone in traffic situations) (Razzaghi & Zolala*,* 2015). Indeed, one of the key risk factors for drivers is driving distracted by using mobile devices (Lipovac *et al.,* 2017).

Nearly every fifth death in road is caused by a **drunk driver**. Laws regulating the blood alcohol concentration (BAC) have been found effective in reducing alcohol-impaired driving (Hingson *et al*., 2000; Shults *et al.,* 2001; Wagenaar & Toomey, 2002). The Estonian Traffic Act states that "the content of alcohol in one gram of blood of the driver of a power-driven vehicle, tram or off-road vehicle must not be 0.20 milligrams or more, or 0.10 milligrams or more in one litre of breath" (Traffic Act, 2019). Another preventive method found effective in reducing alcohol-impaired driving is mass media campaigns (Elder *et al*., 2004). Every year the Estonian Road Administration together with partners conducts at least one mass media campaign to reduce alcohol-impaired driving (Maanteeamet, 2018).

Occupant safety equipment (e.g., seat belts, safety seats, helmets) is the most effective means available for injury prevention. The corresponding regulation in Estonia, the Traffic Act (Traffic Act, 2019), states that in a vehicle equipped with seat belts, a passenger must properly wear a seat belt. If a child is not tall enough to wear a seat belt provided in the vehicle, a safety device secured in accordance with the requirements of the manufacturer, and corresponding to the height and weight of the child, must be used (Traffic Act, 2019).

Using the motorcycle helmets is also effective in preventing fatal injury (Deutermann, 2004), and this also holds true for bicycles (Attewell, Glase & McFadden, 2001; Elvik & Vaa, 2004). A passenger driving on a motorcycle or a moped must wear a strapped motorcycle helmet. Similarly, cyclists and mini moped drivers aged below 16 must wear a strapped cycle helmet when riding or driving on a road (Traffic Act, 2019).

2.1.2. Accidental drowning and submersions

Drowning refers to an event in which a person's airway is immersed in a liquid medium leading to respiratory failure (Idris *et al*., 2013). There are nearby 900 lakes and more than 500 rivers in Estonia. The total length of the Estonian coastline is 3,793 km, the length of coastline of the transboundary water body, Lake Peipsi, is 175 km. Drowning takes place mostly in coastal or inland waters, less in pools and baths (Figure 4). Every year only approximately 55 formal public beaches that have supervision are opened (Terviseamet, 2019).

The overall drowning death rate was 3.3 per 100,000 population in 2018, representing 43 deaths. During the last five years (2014–2018) the male average death rate is three and a half times as high as for females (5.4 *vs.* 1.4 per 100,000).

The age distribution of deaths indicates the lowest incidence among children too young (<4) to be alone. Drowning death rates are the highest in older adults group. The second highest vulnerable group of population is older adolescents and young adults (15–24 years) (Päästeamet, 2018).

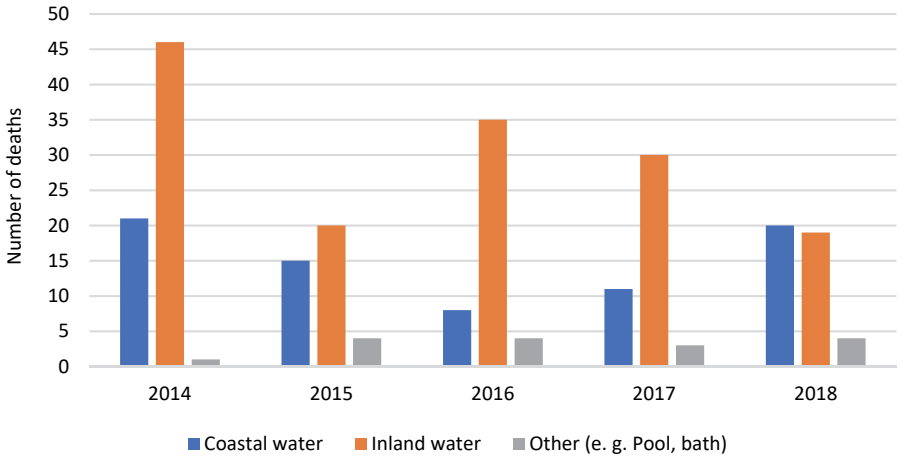

Figure 4. Number of drownings by the type of water body (compiled after Päästeamet, 2019).

Main engineering tasks to prevent drowning include building barriers that control the access to water bodies, and provision of safety equipment. Immediate access to equipment that enables quick retrieval of the drowning victim and resuscitation can increase survival and reduce neurological consequences. During last 5–6 years more than 500 swimming areas have been provided with water rescue equipment and first aid information and PFD in Estonia (Päästeamet, 2018).

People need higher awareness of water-related dangers, better swimming skills, and the awareness that close to water bodies children require adequate, close supervision by parents. Swimming ability in Estonia is defined as being able to complete the task: "jump into the water, swim 100 m freestyle, dive and take an object from the bottom of water, float 3 min and swim 100 m backstroke" (National curriculum for basic school, 2018). Swimming lessons are quite a popular drowning prevention method but caution has to be made that swimming ability in a pool may not translate to the ability to survive after an accidental fall into water: Knowing how to swim in one type of body of water (e.g. swimming pool) does not always make a child safe in another type of body of water, e.g. unguarded lakes and rivers (Brenner, 2003). The last activity before drowning was not always related with water activity that is defined as swimming, fishing or boating; these led to only about half of the drowning deaths (Figure 5). Drowning statistics also indicates that most of those who drowned while boating did not wear PFD and some of who did were not using it correctly (Päästeamet, 2019).

Enforcement should work together with education to control high-risk behaviour: This includes, e.g., limiting alcohol consumption around water activities (Smith *et al*., 2001; Leavy *et al*., 2015). Alcohol is a clear risk factor for drowning in Estonia. Almost 45% of people who drowned in 2014 to 2018 were drunk.

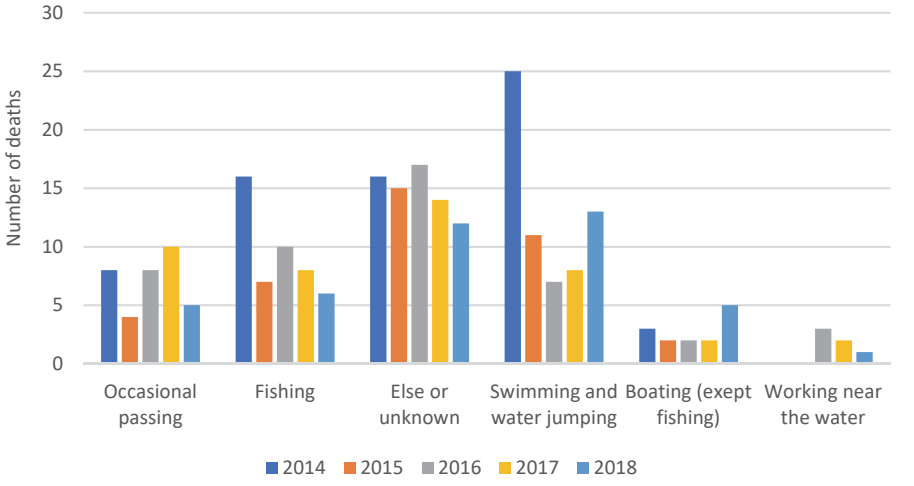

Figure 5. Last activity before drowning (compiled after Päästeamet, 2019).

In summary, the main behavioural problems associated with water survival are poor skills in case of accidental falling into the water, alcohol usage near water, and competence in using the safety equipment.

2.1.3. Exposure to smoke, fire and flames

In the beginning of the present century Estonia was one of a top three country in the world by the rate of fires and fire deaths (CTIF, 2005; 2006). During the last decades, much work has been done to reduce the number of fire deaths. The overall fire death rate in 2018 was 3.8 per 100,000 population, representing 50 deaths. During the last five years (2014–2018) the male average death rate has been more than two times higher than in females (4.8 *vs.* 2.0 per 100,000). The age distribution of deaths has been the lowest in the 15–24 age group and the highest in the elderly. In the age group 85+ the death rate is approximately 12 persons per 100,000. Smoking is the leading cause of fatal residential fires (totally 40% of fatalities), followed by negligence in using fire, electrical or heating equipment or cooking (30%). In more than 60% of cases of fire deaths alcohol had been used before the accident (Päästeamet, 2014–2018).

This Estonian statistics is consistent with reports from other countries that mostly have associated fire risk at home with personal risk-taking behaviour and negligence, including smoking (especially smoking indoors), use of alcohol and illicit drugs, cooking without surveillance, and unatttended heating systems; similarly, people at higher risk are older or very young, left alone at home, with

physical or mental special need, and possibly lower income (Barillo & Goode, 1996; Marshall *et al.,* 1998; Warda *et al.,* 1999; Leistikow *et al.,* 2008); the households may have had faulty smoke detectors (Kobes *et al,* 2008; 2010).

Smoke alarm seems to be one of the most effective strategies for preventing fatal fires. In 2009, the smoke detector legislation in owner-occupied homes was implemented in Estonia. Almost half of home fire deaths in 2014–2018 were caused by fires in properties with no smoke alarms (48%) or smoke alarms that had failed to operate (16%) (Figure 6). Legislative efforts to develop fire-safe cigarettes have shown very good effect because of the major role of reckless smoking.

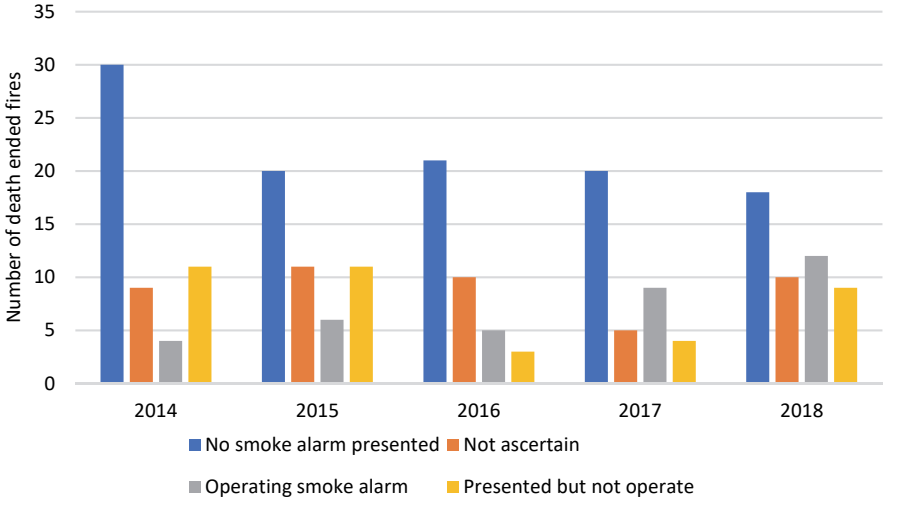

Figure 6. Smoke detector installation in death ended fires (Compiled after Päästeamet, 2019).

In summary, the main risk factors for fire deaths are related to negligence, smoking and alcohol usage. As mentioned earlier in the overview of epidemiology, the different aspects of prevention work by the 5E model (Engineering modification, Enforcement, Education, Economic incentives, Emergency response) are always in place. While the engineering modifications are often described as the most effective interventions, these are quite expensive and so very much related to economical possibilities. If affordable the most effective engineering modifications are enforced by law. Also, emergency response largely refers to planning at the authorities' level, and not directly applicable to the individual. Most of the educational interventions focus on conscious, reflective factors as described in e.g., health belief model or theory of planned behaviour.

For general conclusion, statistics by authorities and a number of studies (Haddon, 1968; Peden *et al.,* 2008) show that risk factors for unintentional injuries and deaths could be divided into three groups: first, human factors, comprising both demographic (e.g., age, gender) and behavioural factors (e.g., risk-taking, alcohol usage); second, vehicle/agent factors (e.g., safety equipment, type of

water), and third, environmental factors (e.g., climate, road design, distance for emergency responses. The focus of this thesis is on the human factors, with emphasis on risk-taking behaviour. Across the variety of accidents, most of health loss is owing to, in general terms, excessive risk-taking.

2.2. Risk-taking behaviour

Most health professionals acknowledge that behaviours that can have a major impact on health in adolescence and adulthood mostly develop during adolescence or even before. Risk-taking behaviour is described as "the participation in behaviour which involves potential negative consequences (or loss) not balanced in some way by perceived positive consequences or gain" (Gullone & Moore, 2000). U.S. National Library of Medicine (2019) has defined risk-taking as undertaking a task involving a challenge for achievement or a desirable goal in which there is a lack of certainty or a fear of failure. It may also include the exhibiting of certain behaviours whose outcomes may present a risk to the individual or to those associated with him or her. Mostly, risk-taking behaviour could be divided into two. First, positive, also described with terms like prosocial or adaptive, that is socially acceptable and includes constructive risks such as trying out for a sports team, enrolling in a challenging course, or initiating a new friendship. The second type, negative risk-taking behaviour is mostly illegal or dangerous behaviour such as fighting, drinking, or stealing (Duell & Steinberg, 2019). The occurrence of injuries is strongly related to risk-taking behaviour (Evans *et al.,* 2006; Duell & Steinberg, 2019). In turn, risk-taking behaviour is strongly related to both heritable factors and environment.

Usually, males are more often involved in accidents (Peden *et al.,* 2008), and many studies (Hillier & Morrongiello, 1998; Bijttebier *et al.,* 2003) have found that gender is the key factor related to risk-taking behaviour. This may be related to sex differences in personality traits (Costa *et al.,* 2001; Chapman *et al.,* 2007) and in vulnerability to environmental factors (Kovas *et al., 2016*). Risk-taking behaviour is a prime example for why interventions of accident prevention must take into account gender differences. In primary prevention (i.e., before the expression of undesired behaviour) it obviously is possible to consider gender differences but it is not thought of as mandatory in safety behaviour developing process. However, once the undesired behaviour is already expressed, in secondary prevention it is better to consider the gender differences to foster alternatives to risk-taking behaviour. Also, it is important that some processes appear earlier in girls than boys, thus there could be differences not caused by gender *per se* but the development curve (Shulman *et al*., 2016).

Specific risk-taking behaviours strongly cluster with undertaking other risk-taking activities. This has a significance for certain age periods such as adolescence: Adolescents engaging in multiple risk behaviours, such as smoking and/or drinking, are at a higher overall risk of injury (Zuckerman & Kuhlman, 2000; Pickett *et al.,* 2002; Green & Kreuter, 2005; Hutchens *et al.,* 2008; Leather, 2009;

Nordquist *et al.,* 2010; Scott-Parker *et al.,* 2013;) or risk-taking behaviour in traffic (Eensoo *et al.,* 2007). Age-dependency of risk-taking varies across different behaviours but could be highest later (during 20s) than in adolescence years (Willoughby *et al*., 2013). In their early 20s people gain access to new situations and surroundings, typically experience less supervision from adults, have more financial resources, and are afforded greater legal access to many forms of risk-taking activities (e.g., driving, alcohol) (Shulman *et al*., 2016).

For preventing unintentional injuries and deaths is important to realize the mechanism of risk-taking behaviour. Risk in decision making process is defined by three components: potential for both rewards and costs, variability in the likelihood of potential outcomes being realized, and uncertainty about the outcomes (Holton, 2004). Additionally, Jessor (1991) structured the adolescent risk-taking behaviour framework into five domains: biology /genetic, social environment, perceived environment, personality and (other) behaviour. It means that risk-taking behaviour is complex. There are many different positive and negative risk-taking behaviours (Duell & Steinberg, 2019), and each risk behaviour is affected by these factors separately and dependently on their context (Jessor, 1991). The focus in accident prevention has been on social (e.g., school-based programs) and perceived environment, and mainly based on increasing the capacity for reflective control over the behavioural impact of implicit attitudes, changing the reasoned attitudes, beliefs, and control standards. The focus of this thesis is however on the non-conscious aspects of unintentional injuries related risk-taking behaviour, such as personality and genetic factors.

2.2.1. The role of personality-related factors in risk-taking behaviour

Behavioural decisions in everyday life are influenced by personality (Zuckerman & Kuhlman, 2000). There does not appear to be a universal and simple definition for personality, but most theories state that personality is the set of psychological traits and underlying mechanisms related to behaviours, cognitions, and emotional patterns that evolve from heritable and environmental factors (Larsen & Buss, 2005). Adulthood personality could be defined as an outcome of genetic endowment into temperament and influence of individual experiences (Rothbart *et al*., 2000). Despite of much research on personality there appears to be no general consensus which theory could best be exploited for the measurement of personality. However, for the time being majority of studies either directly involves the Big Five traits or at least compares other constructs to this framework.

Thus, there are different personality trait dimensions to explain a substantial proportion of behaviour, e.g. The Five-Factor Model – Big Five (Costa & McCrae, 1989; Goldberg, 1993) Eysenck Three Traits (Eysenck & Eysenck, 1975) and some personality trait dimensions to predict specific behaviours, e.g., impulsivity that is a big player in the area of traffic safety (Paaver *et al.,* 2006), or self-esteem (Rosenberg, 1965) in the more general area of risk-taking behaviour.

Adult personality traits are believed to have a basis in temperament (Rothbart *et al.,* 2000) and because the focus of this thesis is on the unconscious aspects of risk-taking behaviour related to unintentional injuries, the temperament as the basis for personality is under investigation. Temperament has been defined as "constitutionally based individual differences in reactivity and self-regulation, in the domains of affect, activity, and attention" (Strelau, 1983). According to Rothbart & Bates (2006) temperament results from biological evolution and is determined by inborn physiological mechanisms which may be modified under environmental influences. "Temperament represents the affective, activational, and attentional core of personality, whereas personality includes much more than temperament, particularly the content of thought, skills, habits, values, defences, morals, beliefs, and social cognition" (Rothbart & Bates, 2006).

Adolescence is a time of change, time when the degree of risk-taking behaviour develops by biological, psychological, and social adaption (Berk, 2007; Livazović, 2018). Research has suggested that interventions to increase behavioural control and social confidence during the adolescence period could change the aspects of personality in adulthood (Roberts *et al.,* 2001).

2.2.1.1. Mary K. Rothbart's four dimensions of temperament

Temperament is defined as the individual differences that emerge very early in life and have a strong heritable basis (Larsen & Buss, 2005). Early references to temperament were already made by Hippocrates and Galenos. The most comprehensive studies on temperament have been done by Mary K. Rothbart who has developed a four dimension temperament scale comprising 1) Extraversion/ Surgency (reflects the degree to which a child is generally happy, active, and enjoys vocalizing and seeking stimulation); 2) Negative affectivity (reflects the degree to which a child is shy and not easily calmed); 3) Effortful control (reflects the degree to which a child can focus attention, and is not easily distracted); 4) Affiliativeness (involves warmth, love, closeness, emphatic concern, and a desire to nurture others; sometimes is used as a subscale of Effortful control) (Rothbart, 2004; Kail & Barnfield, 2014). The relationship between temperament and risk-taking behaviour related to unintentional injuries has not received hardly any attention. Evans and Rothbart (2007) have shown that dimensions of temperament are related to the Big Five personality factors (Rothbart & Ahadi, 1994; Rothbart *et al.,* 2000): The temperament dimension Negative Affectivity is related to the personality trait Neuroticism; Consciousness is associated with Effortful control; Affliativeness is related to the personality trait Openness; Extraversion/ Surgency is related to the personality trait of Extraversion.

2.2.1.2. Big Five model

The most universal and widely used construct describing personality is the **Big Five** model (Costa & McCrae, 1989; Goldberg, 1993) that includes the following traits: Extraversion or Surgency (high: talkative, extraverted, assertive, forward,

outspoken *vs.* low: shy, quiet, introverted, bashful, inhibited), Neuroticism/ Emotional Stability (high: calm, relaxed, stable *vs.* low: moody, anxious, insecure), Agreeableness (high: sympathetic, kind, warm, understanding, sincere *vs.* low: unsympathetic, unkind, harsh, cruel), Conscientiousness (high: organized, neat, orderly, practical, prompt, meticulous *vs.* low: disorganized, disorderly, careless, sloppy, impractical) and Openness or Culture or Imagination (high: creative, imaginative, intellectual *vs.* low: uncreative, unimaginative, unintellectual).

The relationship between the Big Five personality traits and unintentional injuries related risk-taking behaviour has mainly been studied in the field of traffic and not so much in the water or fire safety areas. For example, it has been shown that riskier traffic behaviour in schoolchildren (e.g., not using seat-belt in car, not using crosswalks on their way) is associated with lower scores of Conscientiousness, Agreeableness and Openness (Eensoo *et al.,* 2007). Adult female aggressive driving was associated with higher scores in Extraversion, and lower scores in Conscientiousness, Agreeableness, and Openness (Harris *et al.,* 2014). Risk-taking behaviour in traffic, e.g., reckless and angry driving style was associated with higher scores in Extraversion, and lower scores in Agreeableness and Conscientiousness (Taubman-Ben-Ari *et al.,* 2012). More conscientious teenage drivers were engaged in fewer risky driving manoeuvres and suffered fewer crashes and near-crashes (Ehsani *et al.,* 2015).

2.2.1.3. Self-esteem

Self-esteem is defined as "the extent to which one perceives oneself as relatively close to be the person one wants to be and/or as relatively distant from being the kind of person one does not want to be, with respect to person-qualities one positively and negatively values" (Block & Robins, 1993). Self-esteem is generally considered to be the degree to which a person likes, values, and accepts himself or herself (Rogers, 1951). It has been shown that subjects with lower self-esteem may engage in a greater number of general risky behaviours (e.g. unsafe sexual practices, aggressive and/or violent behaviours, rule breaking) (Auerbach & Gardiner, 2012). Babington *et al.,* (2009) found that self-esteem does not correlate with many of the risk behaviours, but adolescents who reported lower self-esteem also reported not wearing a helmet when riding a motorcycle. Considerably less attention has been focussed on investigating association between adolescents' self-esteem and their engagement in risk-taking behaviour in the domains of water and fire safety, vs self-esteem and risk-taking behaviour in traffic. Enhancing the level of self-esteem is a part of different prevention strategies, so it might be a significant factor to consider in prevention work aimed at decreasing the unintentional injuries related risk-taking behaviour. In terms of the Big Five personality model individuals with high self-esteem have been found emotionally stable, extraverted, conscientious and somewhat more agreeable and open to experience (Robins *et al*., 2001).

2.2.1.4. Impulsivity

One aspect of personality that has a major impact on risk-taking behaviour and accidents in everyday life relates to **impulsivity** (Eensoo *et al*., 2004; Barkley & Cox, 2007; Bicaksiz & Özkan, 2016; Alavi *et al.,* 2017). According to Moeller *et al*., (2001), **impulsivity** may be defined as "a predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to the negative consequences of these reactions". Impulsivity can be understood as arising from impairment of inhibitory control. Impulsivity describes poor self-control and tendency to make decisions quickly, without forethought for potential (negative) consequences (Durana & Barnes, 1993; Evenden, 1999; Moeller *et al*., 2001; Winstanley *et al*., 2006; Dalley & Roiser, 2012). However, impulsivity has been also characterized as a multidimensional construct (Evenden, 1999).

Indeed, several broadly used instruments for the measurement of impulsivity contain subscales. For example, the Barratt Impulsivity Scale has three components: motor (action without thinking), attentional (lack of focus on the task at hand), and non-planning (orientation towards the present, rather than to the future) impulsivity (Patton *et al*., 1995). Dickman (1990) made a distinction of functional impulsivity (quick decision making when it is optimal) and dysfunctional impulsivity (making quick decisions when it is not optimal).According to other impulsivity theories, behavioural impulsivity is expressed in an inability to stop reaction that has already been started, cognitive impulsivity as inability to predict the consequences of immediate and future events and delay gratification (Arce & Santisteban, 2006) and characterological attentional impulsivity with being unable to stay focused on a specific task (de Wit *et al*., 2009).

Already from this introduction it should become apparent that studies on impulsivity can be done using many different methods, and the results may therefor strongly depend on the methods applied. Most substantial studies have used approaches which include the following constructs and methods of measurement (Bevilacqua & Goldman, 2013):

- Delayed (or delay) discounting of reward; here impulsive choice is understood as preference of immediately available small reward rather than a delayed larger one.
- Risky decision-making; e.g., as measured with the computerized Balloon Analogue Test (Lejuez *et al*., 2003; subjects earn money at every mouse click as the balloon inflates, but when the balloon pops all the savings are lost) or the Iowa Gambling Test (Bechara *et al*., 1994; participants have money to win, but have to make a choice selecting a card from one of four decks on each trial selection and the result is associated with reward, some are gains and some are losses, depending on the fixed reward/loss schedule in each deck).
- Motor inhibition: cancellation of action; e.g., the Stop Signal Reaction Time task (Logan, 1994) that measures the ability to exert volitional control over a response that has already been initiated.
- Premature responding; attentional impulsivity for measuring sustained attention, e.g., the 5-choice serial reaction time task based on the Continuous

Performance Test (Rosvold *et al*., 1956; here participants view characters displayed on a computer screen and respond when the characters match a target stimulus; errors occur when the subject responds positively even though sequences do not match perfectly or responds prematurely before processing the full sequence).

- The most common method for measuring impulsivity is self-report. Popular questionnaires include the Barratt Impulsivity Scale (BIS-11; Patton *et al*., 1995); Urgency, Premeditation, Perseverance and Sensation Seeking (UPPS; Whiteside & Lynam, 2001); Impulsive Behaviour Scale (IBS; Rossotto *et al*., 1998), Karolinska Scale of Personality impulsivity subscale (KSP; Schalling, 1978), Adaptive and Maladaptive Impulsivity Scale (AMIS; Paaver *et al*., 2006; Laas *et al*., 2010), the Impulsiveness Venturesomeness and Empathy Questionnaire (I7; Eysenck *et al*., 1985), and the Lifetime History of Impulsive Behaviours (LHIB; Schmidt, 2000).

Within the Big Five personality model, aspects of impulsivity are included as the Impulsiveness subscale under Neuroticism and the Excitement seeking subscale under Extraversion (Costa & McCrae, 1989). These aspects however do not cover the whole spectrum of impulsivity, and some questionnaire items in these subscales seem less fitting for the measurement of impulsivity as they are expressed in common behaviours.

Measures obtained with different questionnaires and behavioural tests do not correlate very well, but if subjects are allocated into groups ‘‘high’’ or ‘‘low’’ on impulsivity, they can be significantly overlapping if classified based on distinct constructs (Evenden, 1999; Dom *et al*., 2006; Kirby & Finch, 2010; Dalley & Roiser, 2012).

Thus, there are several constructs and dimensions of impulsivity ranging from two (e.g., Eysenck *et al*., 1985; Dickman, 1990) to fifteen (Gerbing *et al*., 1987). Kirby and Finch (2010) included impulsivity items from nine major inventories and made a hierarchical structure of 95 self-reported impulsivity items. As a result of exploratory principal component analysis, they yielded at least 7 interpretable components: Prepared/Careful, Impetuous, Divertible, Thrill and Risk Seeking, Happy-Go-Lucky, Impatiently Pleasure Seeking, and Reserved.

Impulsivity levels differ by age. It is usually thought that impulsivity declines with age, but some aspects of it may peak during adolescence. For example, in a modified Iowa Gambling Test test (measuring the play speed in advantageous and disadvantageous decks) it was found that 14–17 years and 18–21 years olds played advantageous decks faster than younger (10–13) and older (22–25) participants (Steinberg & Chein, 2015). Self-reported impulsivity between ages of 15 to 21 decreased linearly, but no further age difference was found among individuals between 21 and 25 years of age (Quinn & Harden, 2013).

2.2.2. The role of biology in risk-taking behaviour

Risk-taking behaviour (Anokhin *et al*., 2009; Cesarini *et al*., 2009) as other behavioural constructs (Jang *et al*., 2001) including personality (Bouchard, 2009) is almost 50% heritable. Personality traits including impulsivity are based on metastable expression patterns of genes shaping the development of functional units of the central nervous system (Coccaro *et al*., 1993; Bevilacqua & Goldman, 2013; Kovas *et al.*, 2016). Genome-wide hypothesis free studies have not provided any strong candidate mechanisms for impulsivity. Studies on candidate genes have mostly focused on those that are critically important for the function of dopamine- and serotonin-releasing neurons as these are the culprits of impulse control. Genetic differences in the dopamine and serotonin systems have been suggested as potential factors underlying interindividual variability in risk taking and has a major role in impulse control and risk-taking behaviour. The relationship between different aspects are not clear, while the effect of dopaminergic manipulations strongly depends on the type of impulsivity measured, increase in the serotonergic function reduces both premature responding as well as delay discounting (Dalley & Roiser, 2012).

Dopaminergic system, which is involved in movement control, reward and pleasure seeking, behavioural and emotional inhibition, is one of the main targets in genetic studies of ADHD and aggression. Owing to their physiological role, the most explored genes have been the dopamine transporter (*DAT1*, *SLC6A3*), dopamine receptor (*DRD1, DRD2, DRD3, DRD4* and *DRD5*) and catechol O methyl transferase (*COMT*) genes (Bakker *et al*., 2005; Forbes *et al*., 2009; Zai *et al*., 2011; Hasler *et al*., 2015).

Studies on the neurobiological basis of risk-taking behaviour have most often focused on the serotonin system (Nordquist *et al*., 2010; Takahashi *et al*., 2012). What has most often been investigated both studies in humans and animals, include tryptophan levels (LeMarquand *et al*., 1998; Lauterbach *et al*., 2006), expression of several 5-HT receptor subtypes (de Boer & Koolhaas, 2005; Lauterbach *et al*., 2006), 5-HIAA concentration (Fahlke *et al*., 2002; Sher *et al*., 2005), monoamine oxidase (MAO) activity (Lesch & Merschdorf, 2000; Fahlke *et al.*, 2002; Oreland, 2004), serotonin transporter (5-HTT) activity (Praschak-Rieder *et al*., 2005; Alexandre *et al*., 2006), and a large number of relevant genotypes with particular focus on the 5-HTT gene linked polymorphism, the 5-HTTLPR (Lesch *et al*., 1996; Retz *et al*., 2004; Beitchman *et al*., 2006).

For the present thesis *DAT1* was selected a candidate for investigating associations between dopaminergic system and risk-taking behaviour, and 5-HTTLPR as the candidate for investigating associations between serotonergic system and risk-taking behaviour, because these are the two best studied genetic variations in relevant experimental as well as epidemiologocal studies.

Monoamine oxidase isoenzymes (MAO-A and MAO-B) oxidatively deaminate the neurotransmitters dopamine, noradrenaline, and serotonin (Oreland, 2004). Platelet MAO activity, that reflects capacity of serotoniniergic system (Fahlke *et*

al., 2002) has found associated with personality traits (e.g., impulsivity, extraversion) and risk-taking (e.g., different activities found in drunk drivers, pathological gamblers and criminals) (Eensoo *et al*., 2004; Oreland, 2004).

2.2.2.1. The dopamine transporter gene (DAT1) and the VNTR polymorphism (rs28363170F)

Dopaminergic system has a major role in impulse control and risk-taking behaviour (De Wit *et al*., 2002; Friedel, 2004; Thapar *et al*., 2005). The dopamine transporter is a type of membrane-spanning protein that performs the reuptake of dopamine from the synapse, thus playing a critical role in terminating dopamine neurotransmission in the CNS (Chen & Reith, 2000). The dopamine transporter is encoded by the respective gene (*DAT1/SLC6A3*). In humans, this gene is found on chromosome 5.

The human dopamine transporter gene includes a functional variable number of tandem repeats (VNTR) polymorphism (rs28363170F): the nine-repeat-allele (9R) is linked to lesser transporter activity and higher synaptic dopamine levels (Heinz *et al*., 2000; Fuke *et al*., 2001; Mill *et al*., 2002; VanNess *et al.*, 2005). Van de Giessen *et al*., (2009) and Faraone *et al*., (2014) have shown that the *DAT1* VNTR 9R allele carriers have higher striatal DAT availability than do 10-repeat (10R) allele homozygotes and this could be associated with increased risk-taking in experimental paradigms (Heitland *et al.,* 2012). This is consistent with higher self-reported impulsivity in 9R allele carriers (Forbes *et al*., 2009).

2.2.2.2. The serotonin transporter gene and the promoter polymorphism (5-HTTLPR; rs25531)

Impaired serotonin (5-HT) function has been shown to contribute to the neurobiology of impaired executive control processes and impulsive behaviours. Throughout the brain, serotonin signalling is critically dependent on the reuptake carried out by the serotonin transporter. The serotonin transporter (SERT or 5-HTT) is a type of monoamine transporter protein that transports serotonin from the synaptic cleft to the presynaptic neuron. Being the key protein in the regulation of synaptic 5-HT, the genetic variations in the 5-HTT gene have gained much attention in depression-related research. In humans the gene is found on chromosome 17. Indeed probably the overall most studied psychogenetic measure is the VNTR polymorphism in the 5-HTT gene (*SLC6A4*) promoter region, the 5-HTTLPR. This polymorphism has a long allele with 16 repeats (L) and a short allele with 14 repeats (S), whereas carrying the S-allele results in lower transcriptional activity (Heils *et al.,* 1995; Lesch *et al*., 1996).

The S-allele can increase the risk for depression (Clarke *et al*., 2010; Holmes *et al*., 2010) and suicidal behaviour (Gonda *et al*., 2011), but it is important to take environmental factors into account (Kaufman *et al.,* 2006, Sjöberg *et al*., 2006). The S-allele is also reported to be associated with negative affective

valence (Munafo *et al*., 2009) and negative emotionality (Lesch *et al*., 1996), including Neuroticism.

The short (S) allele of the serotonin transporter polymorphism has been found to increase impulsivity (Walderhaug *et al*., 2010). 5-HTTLPR polymorphism can predict response inhibition in healthy subjects (Landrø *et al*., 2015): Healthy subjects carrying the high expressive allele exhibited significantly faster inhibition of a pre-potent response as compared to the low expressive genotype, suggestive more impulsive behaviour in carriers of the low expressive genotype.

2.2.2.3. Monoamine oxidases and platelet MAO activity

Monoamine oxidases are proteins in outer mitochondrial membranes, and there are two MAO isoenzymes, named type A and B (MAO-A and MAO-B) (Chen & Shih, 1998). They oxidatively deaminate the neurotransmitters dopamine, noradrenaline, and serotonin (Oreland, 2004). Both isoenzyme forms are coded by genes on the X chromosome at Xp 11, and show 70% homology (Chen & Shih, 1998) In blood MAO-B is found in lymphocytes and platelets. Most organs express both MAO isoenzymes at some level, with the notable exception in the exclusive presence of MAO-B in platelets (O'Carroll *et al*., 1983). Platelet MAO activity has been found intra-individually stable (Murphy *et al*., 1976; Bagdy & Rihmer, 1986) but some longitudinal studies have found that individual differences are not so stable over time (Wong *et al*., 2010). Most of relevant studies have serious drawbacks, either in terms of small samples, short follow-up times or extrapolation from cross-sectional design. However, it may be assumed that in the majority of subjects' platelet MAO activity is stable for long periods of time unless any specific enzyme inhibitor is involved (Kiive *et al*., 2005; Harro & Oreland, 2016). Indeed, several twin studies have shown a high degree of heritability for platelet MAO activity (Oxenstierna *et al*., 1986; Pedersen *et al*., 1993). Harro and Oreland (2016) have suggested that platelet MAO levels reflect the impact of serotonin as a nerve growth factor during the early, fetal stage of development of the brain. Platelet MAO is not epigenetically altered by environmental impacts, while the MAO in the brain probably appears to be.

Several researchers have shown that levels of monoamine oxidase activity in platelets correlate inversely with specific personality traits such as impulsiveness (Schalling, 1978), extraversion (Spielberger & Jacobs, 1982; von Knorring *et al*., 1987; Hallman *et al*., 1996), and sensation seeking (Zuckerman, 1994). It has also been found that platelet MAO activity is lower in a variety of risk-taking groups, such as bullfighters, mountaineers, drunk drivers, pathological gamblers and criminals (Zuckerman & Kuhlman, 2000; Longato-Stadler *et al*., 2002; Eensoo *et al*., 2004; Oreland *et al*., 2007). Demir *et al*., (2002) as other researchers (von Knorring *et al*., 1985; Nilsson *et al*., 2005) have suggested platelet MAO activity as a trait marker for alcoholism, as platelet MAO activity was lowest in the Type 2 alcoholics group, significantly higher in the Type 1 group and the highest in control group. Several studies have also shown the lower platelet MAO activity in cigarette smokers (Launay *et al*., 2008). In this instance the relation appears to

be complex: Constituents of tobacco directly inhibit MAO activity (Fowler *et al*., 2003), but low platelet MAO is also predictive of future smoking (Harro *et al*., 2004).

2.3. Educational interventions to prevent risk-taking behaviour

A comprehensive, and popular, model for analysing and preventing unintentional injuries is the Haddon Matrix (Haddon, 1968). The Haddon Matrix is a framework to specify targeting of the agent, the host, and the environment (both physical and social environment) in prevention. Safety related educational interventions mostly aim at advancing knowledge and skills and modifying behaviour through the social environment and social communication-based interventions rather than by focusing on the host (the person and behavioural decisions), making the host more resistant or teaching it to disengage from the potentially harmful energy exchange. Safety communities (authorities like police, rescue service etc.) have focused more attention to the areas of the agent (i.e., safety of the vehicle or cigarettes) and the environment (i.e., roadways, smoke detectors, lifeguard) to prevent injury. Nevertheless, risk-taking behaviour, ignoring safety equipment and laws, could be the reason of death and injuries whatever the extent of action of agents and environment. Decades long research in the field of driver behaviour has collected information on the major gaps in driver knowledge and skills into one framework – Goals for Driver Education (GDE) Matrix – which in its most recent version specifies these on five levels: vehicle handling and menoeuvering, mastery of traffic situations, goals and context of driving, personal goals for life, skills for living, and the recently added fifth level – social environment (Hatakka, *et al*., 2002; Keskinen, 2014).

Earlier approaches to health education in schools have been based on the idea that if students knew about dangers and were told about the health hazards, they would avoid problem behaviour. These have commonly been known as knowledge-based models (Parcel *et al*., 2000). Knowledge is obviously a basic factor in the decision-making on healthy choices (Tarlov, 1996; Barclay & Fleming, 2003). What is less apparent is the optimal means of achieving the necessary knowledge in population. Obviously, a greater amount of supervision provides for a safer environment and enables teachers to limit the amount of negative risk-taking behaviours in which people can engage (Rosen & Peterson, 1990). However, in the provision of a level of supervision that enables teachers to support children's safety, positive risk taking is an issue that also needs to be addressed (Little, 2006). Thus, safe environment should be ensured whilst providing encouragement and support to enable children to take positive risks in order to learn new skills.

Currently empowerment models have become more popular. These are based on social psychology theories (behavioural models), focus on the learners' values,

attitudes, and feelings (affective education models) and on the idea that students must be responsible for identifying and defining the problem to be addressed and determining what action should be taken (Parcel *et al*., 2000).

Hale (2014) has suggested that targeting multiple health risk behaviours simultaneously is feasible and effective, and may be more effective and efficient than targeting a single risk behaviour. Interventions targeting adolescents can be divided into four main categories: school- family- community- and web-based. Systematic reviews suggest that in several domains of prevention school-based interventions are most common. School-based interventions could be particularly effective owing to the significance of school and peers for many risk behaviours. School climate, including student participation and engagement and teacher-student relationships, is associated with several health risk behaviours (Fletcher *et al*., 2008; Blank & Guillaume, 2009; Shepherd *et al*., 2010; Gendron *et al*., 2011).

Interventions that affect at least two levels of influence (from the list including the individual level, targeted messages at the group level, social marking at the community level, media advocacy at the policy level, and mass media campaigns at the population level) and combine behavioural and environmental components are commonly named as multilevel intervention (Bernard, 2004).

Multilevel intervention reflects a developmentally-informed approach to injury prevention because it is not entirely reliant on the skills of individual adolescents; the intervention focuses on encouragement of subjects to note situations that can prevent or lessen the consequences of errors in judgment that are a predictable part of adolescence (Johnson & Jones, 2011). School-based interventions are mostly multilevel, influencing at least the individual and group levels.

2.3.1. Cross-curricular teaching

Cross-curricular teaching and learning has a long history. Already Plato referred to the importance of linking emotional, practical and intellectual skills, in terms of combining music and movement, drama and literature, philosophy and politics. Similar ideas come with the teachings of Comenius, Rousseau, Froebel, and Pestalozzi (Barnes, 2015). In modern understanding, cross-curricular "is teaching that involves a conscious effort to apply knowledge, skills and competences to more than one subject area simultaneously with the rationale of forming autonomous citizens, solidary and responsible, intended for a democratic, inclusive and fair society" (Timmerman, 2017).

The competencies that all individuals need for personal fulfilment and development, active citizenship, social inclusion and employment are presented in The European Union Reference Framework as eight key competencies for lifelong learning (Recommendation of the European Parliament …, 2006). Key competences in Estonian national curriculums are defined as general education studies within vocational education and training. The Estonian curriculum include all of these eight and adds one competence to those set by the European reference

framework, namely the self-management competence. In Estonian national curriculum for basic schools and the national curriculum for upper secondary schools' safety is the cross-curricular topics treated in study and educational activity (National curriculum for basic schools, 2018; National curriculum for upper secondary schools, 2018). The Ministry of the Interior Development Plan suggests that teachers need professional development related to safety themes (Ministry Development Plan, 2013).

Amadio (2013) has presented an overview how national curriculum for general education are reflecting the cross-curricular/transversal topics about environmental and sustainability issues and emphasize the need for general competences/skills to be developed across the curriculum. He identified at least 71 countries/jurisdictions that include cross-curricular/transversal themes in the curriculum for general education. Environmental and sustainability issues are often a component of specific content areas and subjects but also be dealt with as a cross-curricular theme, and so this is possibly one of the most common transversal themes. All the competencies highlighted in the EU Reference Framework were highly represented (Amadio, 2013).

Cross-curricular teaching conducted in five European countries (Denmark, France, Norway, Poland and Portugal) was reviewed in the CROSSCUT survey (October 2016 to May 2017) (Timmerman, 2017). Obstacles and enablers of cross-curricular teaching were identified by teachers and school leaders during the investigations. The main enablers of cross-curricular teaching were:

- Time and space for collaboration
- Curricular flexibility and greater autonomy
- Evaluation of cross-curricular skills
- Training in cross-curricular teaching
- Mutual understanding and insight into other subjects
- Open-minded teachers

Whereas the main obstacles raised were:

- Lack of time
- Strict subject-oriented curriculum
- Lack of evaluation of cross-curricular competences
- Teachers' lack of interest and willingness
- Teachers' insecurity and unfamiliarity

Traffic safety is the only safety area that has been studied at international level as a cross-curricular topic. Indeed, education is considered an essential part of the integrated approach to traffic safety. Most of European countries have signed the UNECE's (The United Nations Economic Commission for Europe) Convention on Road Traffic (2006) where the Article 3(5bis) says: „ Contracting Parties will take the necessary measures to ensure that road safety education be provided on a systematic and continuous basis, particularly in schools at all levels". Mütze

and De Dobbeleer (2019) have recently presented an overview of Traffic Safety and Mobility Education in Europe. Safety education is offered at primary schools in all European countries. In 21 countries road safety education is included at three levels (Pre-Primary + Primary + Secondary), the most frequently used format is ordinary lessons (in 19 countries, including Estonia). In most countries (81%), the final responsibility for traffic safety education lies with the Ministry of Education, sometimes shared with other actors (e.g., Ministry of Transport, the police, another governmental agency, non-governmental organisations.

It is common across Europe that the lessons in safety topics could be offered by different entities. For example, the lessons could be taught by the teacher responsible for the class, the teacher responsible for a certain subject, or by an external expert.

Traffic safety topic is included in teacher training programmes only in Poland and Slovakia, in some other countries it depends on the college. Teachers may receive some training during the internship period. It is popular to make use of the possibility to offer teachers the safety education is periodical or non-mandatory seminars organised by a pedagogical institute/university or governmental road safety teams etc. Funded from the EU projects has been used for this purpose. Quite commonly teachers also receive from these institutions updated methodological teaching material (Mütze & De Dobbeleer, 2019).

In Estonia during the last years several activities have addressed the safety cross-curricular topic. These include: 1) Since 2017 INNOVE has created an opportunity for special continuing educational courses for developing teachers' interest and familiarity with safety areas through various projects supported by the European Social Fund. This could reduce teachers' insecurity and unfamiliarity but there are problems with course filling. 2) For evaluation of cross-curricular competences, special evaluation tools have been compiled for schools and students. 3) Also, some skills have been added to outcomes of national curriculum, e.g., swimming skills at study level I (1st to 3rd grades), together with updating the physical education curriculum since the beginning of 2018). 4) Different authorities (e.g., Police and Border Guard Board, Rescue Board) have special study programs implemented at school by an external expert (e.g., "Kaitse end ja aita teist"). Mainly those programs provide special knowledge and skills in concrete areas. More attention however needs to be paid to other aspects in the unintentional injuries related risk-taking behaviour, such as personality, genetic factors, and possibilities for psychological interventions. It could be concluded that although many different possibilities have been created, the Estonian education system will need additional efforts in safety topic, especially using the in multilevel approach.

2.3.2. Psychological interventions to reduce risk-taking behaviour, with focus on dual-systems perspective and non-conscious factors

Wasserman *et al*., (1988) has found that more highly educated people are more likely to use seat belts while driving and to wear helmets while riding on a bike than people with a lower education. On the other hand, it has been observed that safety knowledge does not necessarily lead to safer behaviour in real life situations (Briem & Bengtsson, 2000; Zeedyk *et al*., 2001; Schieber & Vegega, 2002). Together such study results would appear to suggest that provision of specific safety knowledge is less worthwhile than promotion of higher levels of education in general. However, higher education levels are not protective but rather enhance the use of specific skills, and safety instructions are a necessary precondition to prevention of excessive risks. Although knowledge on part of children may have no effect, or only a short-term effect, on risk-taking behaviour in specific settings. It belongs to the basic systematic prevention work helping to build responsible patterns of behaviours.

Abraham and Michie (2008) have identified 26 behavioural change techniques, mostly based on reflective theories like information-motivation-behavioural model; theory of reasoned action; theory of planned behaviour; social-cognitive theory; control theory and operant conditioning. The complete list also contains techniques like stress management, motivational interviewing and time management. Most of the commonly applied health risk behaviour models (e.g., health belief model, theory of planned behaviour, trans-theoretical model) focus on conscious, reflective factors in describing human behaviour (Schwarzer, 2008). However, in the last decades scientists have increasingly paid attention to the seemingly irrational, non-conscious and unintended processes behind risk behaviours (Gibbons & Gerrard, 1995; Gibbons & Gerrard, 1997; Friese *et al*., 2011). The dual-system models (e.g., Smith & DeCoster, 2000; Strack & Deutsch, 2004; Wiers *et al*., 2007) are the most widely used frameworks that integrate both reflective and impulsive aspects of health behaviour. The most influential of these, the Reflective-Impulsive Model (RIM) of Strack and Deutsch (2004), includes as its key elements both an impulsive process (rapid, and based on downstream activation by perceptual input of many associated elements) and the reflective processes (slow and based on rules, associated with reasoning, knowledge about acting, and intention). These two types of processes can activate different behavioural decision-making and thus can potentially conflict with each other (Sheeran *et al*., 2013).

Hofmann and co-workers (2008) described the health risk-taking reduction in dual-systems perspective as a combination of three components (Figure 7):

a) Changing contents of the reflective system. The reflective system is mostly based on consequences of decision-making processes, in particular the knowledge about the available behavioural options, probabilities, and consequences (Strack & Deutsch, 2004). The aim of interventions at increasing capacity for

reflective control over the behavioural impact of implicit attitudes, change the reasoned attitudes, beliefs, and control standards (e.g., through processes of cognitive restructuring, health education, or by persuasion which is the most popular intervention category). Most effective have been the interventions targeting alcohol abuse related such as motivational interviewing and personalized normative feedback (Carey *et al*., 2007), as well as brief motivational interviewing, active aftercare, multidimensional family therapy, and brief intervention with adolescent and parent (Tripodi *et al*., 2010).

b) Directly changing impulsive reactions (Friese *et al*., 2011):
   - Changing automatic associations which often form as a result of repeated pairings of an object with positive and negative affect (Houben *et al*., 2010). Houben *et al.,* (2010) used a go/no-go task that consistently paired alcohol related cues with a stopping response to strengthen the ability to inhibit responses to alcohol-related stimuli in heavy drinking college students. They used the implicit association test (IAT; Greenwald *et al.,*1998), a computerized classification task during which participants must classify stimuli into two target categories (e.g., alcohol and soft drinks) and two affective attribute categories (e.g., positive and negative). Such interventions should be particularly effective for individuals with low motivation or ability to control (Friese *et al.,* 2008).
   - Changing attentional biases by successful attention control, e.g., Attention Bias Modification Treatment (ABMT; MacLeod *et al*., 2002). Some stimuli attract and/or capture attention more strongly than others. Interventions try to train individuals to direct their attention away from potentially harmful stimuli (e.g., alcohol) towards harmless, neutral stimuli (e.g., soft drinks). For example, one intervention used a visual-probe task where the probe consistently appeared behind the neutral stimulus and attention thus had to be directed away from the substance-related cues; this was found to reduce motivation to drink alcohol (Field & Eastwood, 2005). Another technique used is the implementation of intentions described as if–then plans that link critical situational cues to a goal-directed behaviour in the format of if(cue)–then(response) (Gollwitzer & Sheeran, 2006).
   - Changing approach tendencies. The corresponding theory says that automatic associations activate approach and avoidance tendencies toward the stimuli and re-training the approach–avoidance tendencies could be feasible. Experimentally this is often assessed by pulling or pushing a joystick upon seeing a stimulus belonging to a certain category (Chen & Bargh, 1999). Study participants have been trained to approach healthy and to avoid unhealthy stimuli (e.g., Wiers *et al*., 2011); similar is the stop-signal training in which subjects learn to inhibit behavioural responses to tempting stimuli (e.g., Houben & Jansen, 2011; van Koningsbruggen *et al*., 2014).

c) create situational and dispositional circumstances that are conducive for effective self-regulation of health goals (e.g., by increasing self-monitoring, self-efficiency, coping skills, control capacity or control motivation). This could be a part of both types (i.e., a and b) of interventions (Friese *et al*., 2011; van Koningsbruggen *et al*., 2014).

Figure 7. A framework for reducing risk-taking behaviour (based on Hofmann *et al*., 2008 and Friese *et al*., 2011).

Dual-system based interventions to improve health behaviour are widely used mainly in areas like eating, drinking, smoking, and physical exercise, but also for other health related behaviours.

2.3.3. The affective neuroscience approach and the heritable factors

Thus, irrational, non-conscious and unintended processes lurk behind risk-taking behaviours (Gibbons & Gerrard, 1995; Gibbons & Gerrard, 1997; Friese *et al*., 2011). These have their origins in the evolutionary development of brain and behaviour as described by affective neuroscience (MacLean, 1990; Panksepp, 1998). In brief, emotive-motivational systems emerged for rapid and efficient stimulus processing, direction of attention and focusing coherent behavioural responses without the need of involvement of "higher" cognitive processing. Such responses may not always be beneficial to the individual but are helpful for the survival of the species in ambivalent environments. Naturally, these primal emotive activities can be modified by cognitive control, but not always in real time. The complexity of the regulation of motivation and emotion could be described by means of differentiating three levels of organization: *Primary-process (sub-neocortical)* as emotional (e.g., emotion action system), homeostatic (e.g., hunger) and sensory (e.g., pleasurable feelings) affects; *Secondary-process (*learning) as classical conditioning, instrumental and operant and

emotional habits; *Tertiary affects and neocortical "awareness" functions* as cognitive executive functions like thoughts and planning, emotional ruminations and regulations and at last "free will" or intention-to act (Panksepp, 1998; 2010).

The concept of affective neuroscience has inspired the development of a novel intervention technique that was applied in the Estonian Psychobiological Study of Traffic Behaviour (EPSTB) (Paaver *et al*., 2013). A brief intervention was aimed at delivering information on risk-taking proneness together with self-recognition of personal risks so individual could build their own personally fitting risk reduction strategies. Trained psychologists administered the intervention at traffic schools in the format of a session composed of a lecture (45 min) and group work (45 min). The lecture focused on three topics: (1) the idea of impulsivity as a personality feature and information processing style that is largely biologically determined and can lead to risky behaviour in traffic; (2) different types of impulsivity, how they are related to risk-taking and how to recognize impulsive tendencies in oneself; and (3) potential situational factors triggering impulsive behaviour and encouragement of subjects to note situations in which they behave impulsively or take risks. In groups, participants completed a task of: (1) identifying the psychological factors involved in real-life traffic accident cases and (2) estimating their own risk for this kind of traffic accident and generating ideas of ways to decrease this risk. The intervention was found to be highly effective as compared to control group (Paaver *et al*., 2013; Eensoo *et al.,* 2018). This intervention could be classified as an educational intervention (as described in section 2.3. in the present thesis), and would fit into the cross-curricular integrated of basic school curriculum (as discussed in section 2.3.1). It is also essentially a psychological intervention (section 2.3.2), that is compatible with the dual-system model.

It may however be an issue of importance for the perspective of the eventual implementation of this intervention method that in the first trial the intervention was administrated by trained psychologists. Thus, we can not be certain of the effectiveness of such an intervention if it were conducted by e.g., the regular teachers in driving schools.

2.4. Aim and research questions

The main aim of this doctoral study is to clarify the association of risk-taking behaviour related to unintentional injuries with personality traits and markers of heritability, and to explore the possibilities of intervention.

To reach this aim, the following **research questions** were posed:

1) How are adolescents' knowledge and skills involved in risk-taking activities in the safety domains?
2) How is risk-taking behaviour related to unintentional injuries associated with the Rothbart's four-dimensional temperament and with self-esteem?

3) How is risk-taking behaviour related to unintentional injuries associated with traits of the Big Five personality model and impulsivity measures in longitudinal study?
4) How are serotonin system index measures like platelet MAO activity and the 5-HTTLPR polymorphism associated with risk-taking behaviour in traffic?
5) How is the *DAT1* VNTR polymorphism associated with risk-taking behaviour in traffic?
6) Is the effect of brief psychological intervention on novice drivers' driving behaviour replicable in an independent study, and can "teaching the teachers" approach be effective used?
7) Do the biological factors under investigation affect the efficacy of the intervention?

To answer the research questions, three studies were conducted. The first question is addressed in Study I, the second in Study II, the third in Study III, the fourth in Studies II and III, the fifth in Study III, the sixth in Studies II and III, and the seventh in Study III. The three studies correspond to the three articles included in the dissertation.

3. PARTICIPANTS AND METHODS

3.1. Participants and procedure

Different samples were used in Studies I–III. Table 2 provides an overview of the samples, measurements, and methods of data analysis per study. All three studies were approved by the Research Ethics Committee of the University of Tartu.

3.1.1. Study I (TerVe kool)

This study was a part of the project "Health promotion effectiveness in schools in Estonia", on different behavioural risks to the health, health related behaviour in schoolchildren, and associations with social and physical environmental factors. It was carried out on a random sample of sixth-grade students in the four biggest counties of Estonia (Harju, Tartu, Pärnu and Ida-Viru). For the sampling, in each of the four counties all schools were divided into three groups: Estonian-based city schools, Russian-based city schools, and rural schools. A two-stage sampling technique was implemented. At the first stage a random selection of schools was made from primary sampling units (12) from each stratum, totally 78 schools; 52 schools agreed to participate. At the second stage, one of all the possible sixth grades was selected by a simple random sampling method. The study was carried out during the school year 2012/2013 and the sample of the study included 1033 sixth-grade schoolchildren (response rate was 82.6%). The study is based on the data of the Estonian language school sample (n = 699) with a mean age of 12.8 (SD = 0.4) years; 49.4% of subjects were males, and 72.1% were from city schools.

Adolescents filled in web-based self-reported questionnaires in a classroom at school. Before the study, children and parents signed an informed consent form. Every child received his/her unique study code. While the students were completing the questionnaires, only a research assistant was present. This was to ensure confidential and independent responding, and to provide assistance to the children if necessary. No school representative was present.

3.1.2. Study II (ECPBHS)

This analysis was performed on the data of children of the Estonian cohort of the European Youth Heart Study conducted in 1998/99, which was later incorporated into the longitudinal Estonian Children Personality Behaviour and Health Study. The Estonian sample of the European Youth Heart Study was a random sample of 25 schools from the Tartu County, selected using cluster sampling (urban and rural schools with younger and older children from Estonian and Russian language schools) and probability proportional to school size. All children from grades 3 and 9 were invited to participate. Parents and children gave their written

consent. The present analysis was conducted on the younger cohort of the ECPBHS. The total number of subjects in the original sampling in 1998/99 was 583 in this cohort, age 9.6 years (SD=0.5). Traffic behaviour was assessed during the follow-up studies that took place in autumn 2004 (n=483, 222 boys and 261 girls, mean age 15.3, SD=0.5) and in autumn 2007 (n=454, 202 boys and 252 girls, mean age 18.3, SD=0.5 years) (Harro *et al*., 2001; Tomson *et al*., 2011).

Before the study, children and parents (if the children were under the age 18) signed the informed consent form. Self-administered questionnaires were filled and blood samples were collected in the laboratory conditions.

3.1.3. Study III (EPSTB)

For the re-evaluation of the effect of a brief intervention (Paaver *et al.*, 2013), a new sample was formed of driving-school students at twenty driving schools. Groups attending from January 2013 to February 2014 were assigned to the intervention and control condition. The study comprised in total 1441 subjects (participation rate 82.5%; mean age 22.5 ± 7.9 years; 43.3% male). The intervention group included 321 (44%) males and 416 (56%) females, and the control group 303 (43%) males and 401 (57%) females.

A study team member introduced the study at the driving school, participants signed the informed consent forms and the saliva samples were collected. Every first group of students was assigned to the intervention condition and every second group was assigned to the control condition. After recruitment, subjects in intervention group participated in the brief psychological intervention. All subjects completed web-based self-report forms.

Table 2. An overview of the samples, measurements, and methods of data analysis per study.

Study	Sample	Measures	Data analysis methods
Study I (TerVe kool)	n=699; Estonian language school sixth-grade schoolchildren (216 boys, 253 girls); mean age 12.8 (SD = 0.4) years	Questionnaires: Risk-taking behaviour, Knowledge, Skills, Tobacco and alcohol use, Temperament (EATQ-R), Self-esteem (ERSES)	Correlation analysis Logistic regression analyses Structural equation modelling (SEM) AMOS
Study II (ECPBHS)	First stage n=483; 222 boys and 261 girls; mean age 15.3, SD=0.5 Second stage (same sample three years later) n=454; 202 boys and 252 girls; mean age 18.3, SD=0.5 years	Self-reported questionnaires: Traffic behaviour, Personality measures (NEO-PI-R; Estonian Brief Big Five Inventory), Adaptive and Maladaptive Impulsivity Scale (AMIS), Smoking status and alcohol use Venous blood: Activity of the enzyme monoamine oxidase (MAO), Functional polymorphism of the serotonin transporter gene (5-HTTLPR)	Independent-samples t-test Pearson's Chi-square test Generalized linear model with repeated measures
Study III (EPSTB)	n= 1441; driving-school students; mean age 22.5 ± 7.9 years Intervention group n=737; 321 males, 416 females, Control group n=704; 303 males, 401 females	Self-reported questionnaires: Tobacco and alcohol use, Adaptive and Maladaptive Impulsivity Scale (AMIS) Saliva samples Functional dopamine transporter gene polymorphism (*DAT1* VNTR) Functional serotonin transporter gene polymorphism (5-HTTLPR) Database search Traffic offenses and crashes	Independent-samples t-test Pearson's Chi-square test Survival analysis (Kaplan-Mayer estimates) Cox regression analyses

3.2. Methods and measurements

3.2.1. Study I (TerVe kool)

3.2.1.1. Risk-taking behaviour questionnaire

Web-based self-reports were filled in to describe behaviour during the last 12 months in the domains of traffic, water and fire safety. Responses were on a 5-point scale ranging from *never* to *very often* in each domain. The measurement traffic safety behaviour included 7 items, some of them reversed (Cronbach's α=0.70, mean score 4.24), for example "Do you use your seatbelt in the backseat while riding in a car?" (Eensoo *et al*., 2007). In case of water safety, 3 items were used (Cronbach's α=0.73, mean score 3.02), for example "Have you jumped head first into water?" (McCool *et al*., 2009). Fire safety behaviour was assessed with only one question (mean score 3.93) "Have you played with matches, lighters, or else?" (Fessler, 2006). Cronbach's α was 0.6 between the behaviour measures of traffic, water, and fire safety. The total risk-taking score was obtained by summing up the behaviour measures of the three safety domains.

For comparing subjects (n = 670) by different risk levels, they were divided into three risk groups according to the 25th and 75th percentile values of the total risk-taking score: low (n = 151; 22.5%), medium (n = 360; 53.7%), and high-risk (n = 159; 23.7%) groups.

3.2.1.2. Temperament (EATQ)

Early Adolescent Temperament Questionnaire – Revised (EATQ-R) (Capaldi & Rothbart, 1992; Hsu, 2011) was used for the evaluation of schoolchildren's temperament. This is the most used questionnaire for measuring temperament in adolescents. Items were rated on a 5-point scale ranging from *almost always untrue of you* to *almost always true of you.* The structure of four factor EATQ-R was used. The effortful control scale consists of 18 items (Cronbach's α = 0.72), for example "When someone tells me to stop doing something, it is easy for me to stop ". The extraversion/surgency scale has 15 items (Cronbach's α = 0.68), e.g., "I enjoy going to places where there are big crowds and lots of excitement". The negative affectivity scale consists of 18 items (Cronbach's α = 0.80), e.g., "I get upset if I am not able to do a task really well". The affiliativeness scale has 16 items (Cronbach's α = 0.83), e.g., "I enjoy exchanging hugs with people I like".

3.2.1.3. Self-esteem (ERSES)

Self-esteem was assessed with the Estonian version of the Rosenberg Self-Esteem Scale (Pullmann & Allik, 2000). Eight questions (Cronbach's α = 0.66) like: "I am able to do things as well as most other students" were asked. Items were rated on a 5-point scale ranging from *strongly disagree* to *strongly agree*. The ratings were summed, with negative statements reverse coded. Higher score represented a higher level of self-esteem.

3.2.1.4. Knowledge and skills

Multiple choice questions concerning knowledge about topics related to traffic, fire and water safety were with one correct answer. The correct answer rate was standardized on a 100-point scale. Traffic safety knowledge was assessed with 9 items, e.g., "How should you cross the road after leaving the bus?", water safety knowledge with 8 items, e.g., "Are you allowed to be in a boat without a life-jacket?", and fire safety knowledge with 20 items, e.g., "What is most dangerous for humans in case of fire?"

Skills in the three domains of safety were assessed with questions; "Do you have a bicycle driver's license?" (yes and no), "How far can you swim?" (400 m or more – yes and less than 400 m – no), "Can you make a campfire?" (yes and no).

3.2.2. Study II (ECPBHS)

3.2.2.1. Traffic behaviour questionnaire

Traffic behaviour was assessed by self-administered questionnaires and filled in during the laboratory visit. Traffic behaviour questionnaire filled in at the age of 15 consisted of seven items, e.g., "frequency of using pedestrian crossings on the way to school" (Eensoo *et al*., 2007). At 18 years two further questions," the frequency of using a helmet while cycling' and "frequency of using a helmet while riding on motorbike", were added. Frequency was measured on a 5-point scale ranging from *always* to *never*. Traffic risk score was obtained as previously described (Eensoo *et al*., 2007) while higher score referred to higher risk-taking behaviour: the items were transformed into z-scores (separately for boys and girls), and summed; low- and high-traffic behaviour risk groups were formed, dividing subjects on the basis of the 75-percentile value of the traffic risk score (separately for boys and girls and separately at ages 15 and 18). Valid data about risk-taking behaviour in traffic were available for 472 subjects at age 15 and for 443 subjects at age 18.

3.2.2.2. Personality measures

Personality traits of the five-factor model (Big Five: Neuroticism, Extraversion, Openness, Agreeableness, Conscientiousness) were measured at age 15 with a 240-item personality inventory and at age 18 with a short 60-item questionnaire; both instruments provide a valid and convergent description of the traits (Mõttus *et al*., 2006; Konstabel *et al*., 2012).

3.2.2.3. The Adaptive and Maladaptive Impulsivity Scale (AMIS)

To measure impulsivity, we used the Adaptive and Maladaptive Impulsivity Scale (AMIS) (Paaver *et al*., 2006; Laas *et al*., 2010), which is based on the construct of functional *vs.* dysfunctional impulsivity of Dickman (1990) and

includes modified facets of the Dickman's questionnaire as well as modified Impulsiveness subscale under Neuroticism and Excitement seeking subscale under Extraversion scale of NEO-PI (Costa & McCrae, 1989). AMIS measures four different facets of impulsivity: fast decision-making and excitement seeking as facets of adaptive impulsivity, and thoughtlessness and disinhibition as facets of maladaptive impulsivity (Eensoo *et al*., 2007). Each facet was measured by 6 items on 5-point Likert scale.

3.2.2.4. Platelet MAO activity

Platelet MAO activity was measured in platelet-rich plasma with a radioenzymatic method as previously described (Harro *et al*., 2001). After thawing, the samples were sonificated four times for 10 s each, and estimation of the enzyme activity performed by incubation at 37 ºC for 4 min with ^{14}C-labeled beta-phenylethylamine as the substrate. All samples were blindly analysed in duplicate and corrected using a reference sample. Platelet MAO activity is expressed as nanomoles of beta-phenylethylamine oxidized per 10 to the tenth power platelets per minute. In the analysis of associations with risk-taking traffic behaviour, z-scores of platelet MAO activity at ages 15 and 18 were used. Pearson correlation between the two measurements was 0.64 ($p<0.0001$). Smoking status was taken into account in the analysis as a confounding factor of platelet MAO activity (Eensoo *et al*., 2004).

3.2.2.5. Genotyping

Genomic DNA was extracted from whole blood samples using QIAamp Midi Kit (Qiagen). Genotyping for 5-HTTLPR triallelic classification was performed according to Anchordoquy *et al*., (2003) with minor modifications (Tomson *et al*., 2011). Genotyping was done in two stages. First all subjects were genotyped for the 5-HTTLPR VNTR polymorphism, then SNP rs25531 (A→G). The polymorphic region was amplified using the primers 5-HTTLPR-F: 5′-6FAM-ATG CCA GCA CCT AAC CCC TAA TGT-3′ and 5-HTTLPR-R: 5′-GGA CCG CAA GGT GGG CGG GA-3′. Then SNP rs25531(A→G) was determined as described in detail elsewhere (Tomson *et al*., 2011).

Triallelic genotypes were categorized according to the level of expression of 5-HT transporter mRNA: the low-expressing genotypes as s'/s', l_A/s and l_A/l_G as l'/s', and the high-expressing genotype l'/l'.

3.2.3. Study III (EPSTB)

3.2.3.1. Intervention

The intervention „Reducing Impulsive Action in Traffic" (Paaver *et al*., 2013; Eensoo *et al*., 2018) consisted of a lecture (45 min) and group work (45 min) as previously described. This intervention was theoretically guided by the affective neuroscience concept (Panksepp, 1998) and aimed at acknowledgement of personal impulsive tendencies, so that subjects of intervention could build their own strategies to reduce personal risk. Lectures were carried out and the group work conducted by regular teachers of the driving schools, who had previously been trained in a tailor-made 2 ECTS point course at the University of Tartu to carry out the intervention

3.2.3.2. The Adaptive and Maladaptive Impulsivity Scale (AMIS)

To measure different facets of impulsivity The Adaptive and Maladaptive Impulsivity Scale was used (see 3.2.2.3 above).

3.2.3.3. Genotyping

Saliva samples (2 ml) were obtained from 1341 subjects (93.1% of total sample) using the SalivaGene® Collection module II (STRATEC Molecular GmbH). DNA was extracted from the samples using the NucleoSpin® Blood method (MACHEREY-NAGEL GmbH & Co KG) designed for extracting genomic DNA from various body fluids.

Genotyping for the triallelic classification of the 5-HTTLPR polymorphism was performed as described above (see 3.2.2.5).

The *DAT1* (*SLC6A3*) VNTR was genotyped by following the analytical method by Anchordoquy *et al*., (2003) as described in detail by Maksimov *et al*., (2005). The olymorphic region (rs28363170F) was amplified using the primers 5′ /56-FAM/TGT GGT GTA GGG AAC GGC CTG AG 3′ and 5′ CTT CCT GGA GGT CAC GGC TCA AGG 3′ for *DAT1* 3′UTR VNTR. The VNTR repeat numbers range from 6 to 11, with 9 and 10-repeat alleles being the most common. Genotype frequencies were in the Hardy–Weinberg equilibrium. We compared the 9-repeat carriers (9R/9R and 9R/10R; n=502; 38.9%) and 10-repeat (10R/10R) homozygotes (n=810; 60.4%); subjects who had a rare VNTR genotype (10R/11R, 6R/10R; n=29) were excluded from the analysis.

3.2.3.4. Database search

Traffic offenses and crashes were monitored in the period of 01.01.2014 – 01.01.2017. Information about subjects obtaining the driving licence was received from the Estonian Road Administration. Police and Border Guard Board database was used for collecting information about violations in traffic including drunk

driving (penalties for drunk driving with an estimated blood alcohol level of 0.2‰ or more) and speed limit exceeding. Data on traffic accidents were received from the Traffic Insurance Fund database. Accidents in which the subject was at fault were classified as active and other accidents as passive. Subjects with occurrence of either recorded traffic offence or a collision were classified into the high general traffic risk group. From 278 subjects with high general traffic risk (occurrence of either a recorded traffic offence or a collision) 23 (8.3%) were also drunk drivers and 179 (64.4%) subjects with violations.

3.3. Statistical analysis

Data were analysed using the IBM SPSS (version 22.0, Chicago, IL), IBM SPSS AMOS and SAS (version 9.4 SAS Inc., Cary, NC) softwares. An overview of the data analysis methods applied during Studies I, II, and III is given in Table 2.

3.3.1. Study I (TerVe kool)

Pre-injury risk-taking behaviour was the dependent variable. Participants were divided into three groups by their level of risk-taking behaviour. Simple multinominal logistic regression analyses were used to clarify associations between risk levels and independent variables.

For clarifying the relationship between pre-injury risk-taking behaviour, personality, personal related factors, and health related behaviour in a complex manner, SEM was used by AMOS. First, all independent variables significantly associated with pre-injury risk-taking behaviour by simple multinominal logistic regression analyses were included into the model directly and also gender. Variables with non-significant associations were removed from the model. Values of $p<0.05$ were considered statistically significant.

3.3.2. Study II (ECPBHS)

To compare the level of platelet MAO activity at ages 15 and 18, the paired-samples t-test was used. To explore the time changes in age 15–18 years in the effect of different factors on traffic behaviour, a generalized linear model with repeated measures was used; the quasi-likelihood under the Independence model criterion (QIC) statistics was used for comparing fit models (SAS Institute, 2008). In our models, each subject with repeated measurements at age 15 and 18 years constituted one unit of consideration; subjects were identified by their study code; repeated measures identified by the variable of research year; traffic risk group, smoking status, alcohol use, personality variables and platelet MAO activity were time-dependent variables, and gender and 5-HTTLPR time-independent variables. Because Neuroticism and Extraversion had no significant effect on traffic

behaviour in a previous analysis (Eensoo *et al.*, 2007) and both include elements of impulsivity measured by AMIS, we included only Openness, Agreeableness and Conscientiousness of the Big Five construct together with Adaptive impulsivity and Maladaptive impulsivity from AMIS into the overall models. For the generalized linear models, the personality measures were categorized using the 25^{th} (Openness, Agreeableness, Conscientiousness) or 75^{th} (Adaptive impulsivity, Maladaptive impulsivity) percentile value to respective low- and high-scoring groups. This approach was preferred because exploratory analyses had revealed that risk-taking behaviour was in non-linear relationship with the personality measures. Value of $p<0.05$ was considered statistically significant.

3.3.3. Study III (EPSTB)

In Study III, probabilities of non-occurrence of traffic accidents and/or general traffic risk (survival probabilities) were compared by survival analysis (Kaplan-Mayer estimates) between control and intervention groups. Cox regression analysis was used to investigate the effect of different variables upon the traffic accidents and on general traffic risk.

4. RESULTS AND DISCUSSION

Adolescents engage in multiple risks (Zuckerman & Kuhlman, 2000; Pickett *et al*., 2002; Green & Kreuter, 2005;). While risk behaviours all are shaped by multiple factors such as genes or personality, each risk behaviour is affected by these factors in distinct manner, and is furthermore dependent on the environmental context (Jessor, 1991).

In Study I, self-reports were used to describe behaviour during the last 12 months in the domains of traffic, water, and fire safety. The mean scores of risk-taking behaviours (see Study I, Table 1) were highest in the traffic safety area where indeed the risk-taking behaviour could be usually illegal. Cronbach's α was 0.6 between the behaviour measures of traffic, water, and fire safety. For clarifying the relationship between unintentional injury related risk-taking behaviour in traffic, water, and fire safety domains with gender, four-factor temperament, self-esteem, safety knowledge and skills, tobacco and alcohol usage, structural equation models (SEM) were used. First, all independent variables significantly associated with risk-taking behaviour by simple multinominal logistic regression analyses were included into the model directly, and also gender through all the independent variables. Variables with non-significant associations were removed from the model. The best model explained all three domains at a rather similar level ($n = 699$; NFI and CFI >0.90; RMSEA <0.06), therefore the total risk-taking score was calculated and used in further analysis (see Study I, Table 1 and 3). The results show that in case of unintentional injury related risk-taking behaviour the different risk behaviours could be explained through the same factors.

In Study II a self-reported traffic behaviour questionnaire was filled in at the age of 15 and 18 in order to clarify whether risk-taking behaviour is persistent in late adolescence. The Pearson correlation coefficient between traffic risk scores showed a positive relationship (0.43; $p<0.0001$) at ages 15 and 18, suggestive of significant while by no means complete persistence of risk-taking behaviour.

In Study III data about violations in traffic from Police and Border Guard Board database and about traffic accidents from the Traffic Insurance Fund database were used. In the group of 1441 participants of the second intervention study of the EPSTB, there were 278 subjects with high general traffic risk (occurrence of either a recorded traffic offence or a collision) including 23 drunk drivers (only one of them was female) and 99 speed-exceeders (21 female) within the 3-year study period.

4.1. Safety knowledge and skills in adolescents (Study I)

Students were requested to answer the questions on knowing the rules of fire, water and traffic safety (Study I, Table 3). Lower knowledge predicted higher likelihood for risk-taking behaviour related to unintentional injuries (Study I,

Table 4). Some earlier studies have presented contradictory associations between knowledge and risk-taking behaviour: Zeedyk *et al*., (2001) found that better knowledge did not play a role in risk-taking behaviour; Cook & Bellis (2001) found that the relationship between knowledge and risk-taking is complex and that people who had taken more risks tended to perceive their behaviours as less risky. It is explained by the theory that knowledge alone does not guarantee correct behaviour, but could assist in carrying out an intended behaviour. "Before acting people need to know why they should act, what actions they needed, when or under what circumstances, how to do it and where" (Green & Kreuter, 2005). It can be concluded that knowledge is the basis of behaviour and our study confirmed it.

In our study 63.4% of students reported that they can make a campfire, but only 38.5% had a bicycle driver's license and 18.7% could swim 400 m or more. This suggests quite a low level of skills among 6-th grade schoolchildren. Additionally, higher skills score predicted higher likelihood for risk-taking behaviour related to unintentional injuries (Study I, Table 4). In a previous study higher self-reported driving skills but lower scores in safety skills were related to higher risks in traffic (Eensoo *et al.*, 2010). Self-reported skills are often overestimated and could predict risk-taking behaviour in traffic or other situations (Sümer *et al.*, 2006; Eensoo *et al.,* 2010; Avamidis & Butterly, 2012).

If adolescents already have basic safety knowledge and skills, then they should have the capacity to modify their behaviour to be safer and healthier (Peden *et al*., 2008). However, it is known for traffic behaviour that experience and age is a factor: Younger drivers exhibit less considerate driving and overestimate their skills more (Eensoo *et al*., 2007; Taubman-Ben-Ari *et al*., 2012; Harris *et al.,* 2014). Inconsiderate driving poses a major risk for others, thus a recommendation for intervention in schoolchildren on the agreeableness aspects of personality to enhance cooperative, trusting, and courteous behaviour has been made to promote prosocial driving (Harris *et al*., 2014).

4.2. Association of unintentional injury related risk-taking behaviour with the Rothbart's four-dimensional temperament and self-esteem (Study I)

For clarifying associations between unintentional injury related risk-taking behaviour with Rothbart's four-dimensional temperament in schoolchildren first a simple multinominal logistic regression analysis was used. Results show that students with higher extraversion/surgency, negative affectivity and lower effortful control were more likely in the high- and medium-risk groups as compared to the low-risk group. Students who reported lower affiliativeness belonged more likely to the high-risk group (Study I, Table 4).

These results are essentially in line with other studies. High-surgency children have been found to be more socially outgoing as being more involved in group

play with peers (Kochanska & Radke-Yarrow, 1992; Rubin *et al*., 1995; Rimm-Kaufman & Kagan, 2005), but it has also been shown that high-surgency children are more aggressive (Berdan *et al.,* 2008; Dollar & Stiffer, 2012) and hyperactive (Berdan *et al*., 2008). Higher surgency may put children at greater risk for externalizing problems (e.g., hitting, biting) but lower surgency may be associated with internalizing problems (e.g., fearful, withdrawn) (Northerner *et al.*, 2017).

Higher negative affectivity level can be characteristic for risk-takers in early childhood (Gartstein *et al*., 2012; Northerner *et al.,* 2017). Negative affectivity has been found to predict both internalizing and externalizing behaviours as well as sleep problems (Northerner *et al.,* 2017). Children with high negative affectivity become easily frustrated, which can lead to a pattern of anger, irritability, or aggression (Berdan *et al*., 2008).

In the present study lower effortful control predicted higher risk-taking activities. Researchers have found that children with low effortful control tend to be at risk for social, moral, emotional, and psychological problems (Caspi *et al*., 1995; Eisenberg *et al*., 2010). Effortful control plays a central role in the self-regulation of emotion and related processes (Rothbart *et al.*, 2000) and is one of the main targets for planning intervention to reduce risk-taking behaviour. The capacity for effortful control is believed to increase markedly in the preschool years and may continue to develop into adulthood (Leon-Carrion *et al*., 2004; Carlson, 2005). Affiliativeness, sometimes considered as part of effortful control, was used separately in this study and found to significantly distinguish the high-risk group from the low-risk group in terms of their risk-taking behaviour.

Structural equation modelling (SEM) revealed that of all temperament measures lower effortful control and higher extraversion/surgency were the strongest predictors (Study I, Figure 1) of higher risk-taking behaviour. Of other factors included in the analysis only gender remained significant. The risk-taking score was significantly higher in boys compared to girls; in girls, higher risk-taking score was mediated by extraversion/surgency while this was not the case with boys. The SEM results are in line with earlier trait-by-trait studies that suggest that impact of some temperamental aspects is balancing others, like negative affectivity and low effortful control (Northerner *et al.,* 2017).

Also, some temperament aspects develop earlier than others, and their role in risk-taking behaviour could be revealed later and depending on the environment (Dollar & Stiffer, 2012; Northerner *et al.,* 2017). It is important to find ways to stimulate temperament trait development at home, and in school-age children also outside of the home (Eisenberg *et al*., 2010). It has been shown that different emotion regulation strategies, e.g., active distraction, social support seeking, information gathering, self-soothing, and avoidance behaviours could help to develop safer behaviour (Eisenberg *et al*., 1995; Raver *et al*., 1999; Silk *et al*., 2006). It could be concluded that although there are different temperament traits associated with risk-taking behaviour, it could also be possible to help children to avoid the risks by developing their social competence and emotion regulation skills.

In this study, lower self-esteem did not predict higher risk-taking behaviour (Study I, Table 4). Mostly it has been shown that lower level of self-esteem predicts problem behaviour, especially the externalisation of problems like aggression, anger and hostility (Donnellan *et al*., 2005), antisocial behaviour (Dumont & Provost, 1999), cigarette smoking (Carvajal *et al*., 2000) and substance use (Wheeler, 2010). Unrealistically high self-esteem is also linked with aggression and criminal behaviour (Baumeister *et al.*, 1996). Studies on self-esteem and risk-taking behaviour have produced contradictory findings. However, these inconsistencies are mostly explained by cultural differences in socially acceptable risky behaviours *vs.* maladaptive risky behaviours (Özmen & Sümer, 2011). It is possible that associations with lower self-esteem and risk-taking behaviours were not revealed in the present study because some of the measured risky behaviours could be considered socially acceptable (e.g., not wearing a helmet while cycling).

4.3. Associations of unintentional injuries related risk-taking behaviour with the Big Five personality model and impulsivity measures

4.3.1. Associations of unintentional injuries related risk-taking behaviour with the Big Five personality model (Study II).

Using the Big Five personality model it was found that the subjects with lower Agreeableness and, specifically, boys with lower Openness, were more prone to risk taking in traffic during adolescence (Study II, Tables 2 and 3). These results are consistent with the results in the earlier cross-sectional analysis (Eensoo *et al.,* 2007) as well as with the work of other authors (Taubman-Ben-Ari *et al.,* 2012; Anitei *et al.,* 2014; Harris, *et al.,* 2014), where lower Agreeableness and/or Openness have been significantly associated with risks.

Agreeableness is associated with different humane aspects of personality, e.g., being altruistic, empathic, tolerant, generous and gentle (McCrae & John, 1992). Subjects with a high score in agreeableness tend to practice careful driving style, those with a low score often drive in an angry, reckless, anxious and desolate way (Taubman-Ben-Ari *et al.,* 2012). Similarly, Dahlen *et al.,* (2012) have shown that drivers reporting low agreeableness drive more aggressively, while Taubman-Ben-Ari *et al*., (2012) have found that lower agreeableness is associated with anxious driving style.

Openness corresponds to aesthetic appreciation, aesthetic sensitivity, open-mindedness and self-actualization, personal growth and development (McCrae & John, 1992). Drivers who score lower in openness could be characterized as more aggressive, anxious, hostile (Taubman-Ben-Ari *et al*., 2012) and with reckless driving style (Dahlen & White, 2006; Ehsani *et al.,* 2015).

Previously, lower Conscientiousness was found to predict risk-taking behaviour in traffic in young drivers (Taubman-Ben-Ari *et al.,* 2012) and the present findings suggest this may generalize to all traffic behaviour at even younger age.

Previous studies have reported the effect of various psychosocial interventions, such as cognitive–behavioural therapy, supportive/humanistic- or psychoanalytic interventions (Roberts *et al*., 2017). Here the intervention consisted of an intensive phase (8 weekly 2.5-hour sessions, plus an all-day session between the sixth and seventh weekly session) and a maintenance phase (10 monthly 2.5-hour sessions following the eighth weekly session) of rather extensive training. In a different type of study, social-skill training program for recovering substance abusers led to increases in agreeableness, conscientiousness, and emotional stability in a 6-week program (Piedmont, 2001), and Jackson *et al*., (2012) reported that a 16-week home-based intervention aimed to increase cognitive ability in older adults also changed openness to experience. The meta-analysis by Roberts *et al.,* (2017) on 207 studies (of these, 35 experimental studies) with a total of 357 samples (many studies included separate results for multiple samples) published or completed between 1959 and 2013 concluded that indeed personality traits also appear to be amenable to intervention. Interventions lasting less than 4 weeks tended to have small effects but interventions that lasted longer than 8 weeks did not induce further personality change (Roberts *et al.,* 2017).

4.3.2. Association of unintentional injuries related risk-taking behaviour with impulsivity measures (Studies II and III)

For clarifying the association between unintentional injury related risk-taking behaviour with impulsivity we used the adaptive and maladaptive impulsivity constructs. Higher maladaptive impulsivity was associated with risk-taking behaviour in traffic in the total sample, and especially in boys (Study II, Tables 2 and 3) throughout adolescence. In turn, adaptive impulsivity (fast decision making and excitement seeking) was higher in the high traffic risk group as formed on the basis of objective databases (Study III, Table 3).

Association of impulsivity with risk-taking behaviour in traffic has been studied by numerous researchers (Paaver *et al*., 2006; Barkley & Cox, 2007; Alavi *et al*., 2017; review by Bicaksiz & Özkan, 2016) and the vast majority of the studies has reported significant relationships between impulsivity and the driving outcomes (Bıçaksız & Özkan, 2016). While both basic impulsivity aspects characterize the tendency to act with less forethought than average, adaptive or functional impulsivity, by definition, can be the optimal way of responding, and high maladaptive or dysfunctional impulsivity may with high probability lead to negative consequences (Dickman, 1990). Pearson *et al*., (2013) have found that in college students both adaptive and maladaptive sides of impulsivity could enhance self-reported risk-taking in driving behaviour, and injuries. Rather similar results were reported by Eensoo *et al*., (2007) where high traffic risk in schoolchildren was associated with higher adaptive (Excitement seeking) and maladaptive impulsivity

(Disinhibition and Thoughtlessness). These two aspects of impulsivity may however relate differently to distinct traffic behaviours: In an adult car driving population high-risk speed limit exceeders had higher scores in adaptive impulsivity and less so in maladaptive impulsivity, but drunk drivers only had higher scores in maladaptive impulsivity (Paaver *et al.*, 2006). Indeed, maladaptive impulsivity describes inability to plan one's actions thoroughly, leading to negative consequences (Dickman, 1990), and drunk driving may be considered an extreme in failed planning.

These results show that impulsivity, both adaptive and maladaptive, is a significant predictor for risk-taking behaviour in traffic. Interventions to reduce traffic accidents should target individual differences in risks caused by impulsivity. It is important to recognize impulsive tendencies in oneself, see how different aspects of impulsivity are related to risk-taking, and to take note of situations in which one behaves impulsively or take risks (Paaver *et al*., 2013).

4.4. Are serotonin system related measures associated with risk-taking behaviour in traffic? (Studies II and III)

In the study on adolescents (Study II) platelet MAO activity was measured twice, at ages 15 and 18, and Pearson correlation between the two measurements was 0.64 ($p<0.0001$), suggestive of relative intra-individual stability at this age period. Compared to 15-year olds, platelet MAO activity was about 10% higher at the age of 18 years, and this increase, if comparing the subjects with platelet MAO activity measured at both ages, was statistically significant (Study II, Table 1). It has been thought since the classic works (e.g., Murphy *et al.,* 1976), that MAO activity is a relatively stable measure; however these studies have been cross-sectional (e.g., Bridge *et al.,* 1985), on small samples (e.g., Bagdy & Rihmer, 1986) or with short inter-measurement interval (e.g., Murphy *et al.,* 1976). Longer studies have shown that in the majority of participants platelet MAO activity is rather persistent, but in a significant minority a noticeable change in MAO activity has occurred (Kiive *et al*., 2005; Harro & Oreland, 2016;). Girls had higher platelet MAO activity than boys both at 15 and 18 years (Study II, Table 1) that is consistent with the results of previous studies (e.g., Murphy, 1970).

It was found that low platelet MAO activity predicted high-risk traffic behaviour through late adolescence (Study II, Tables 2–4). In the studies on *MAOA* genotype, it has been repeated found that male and female brain and behaviours are very different with regard to *MAOA* × life events interaction (Harro & Oreland, 2016). For *MAOB* the molecular genetics has not revealed yet any polymorphisms with strong explanatory power so similar studies remain a future aim. It should however be borne in mind that platelet MAO is likely to reflect past events and not be under similar epigenetic load by psychological stress as the corresponding genes in the nerve celles.

The serotonin transporter 5-HTTLPR genotype has previously been associated with higher expression of impulsive behaviour. As the original in vitro experiments had shown that the long allele of the 5-HTT gene has a more efficient promoter than the short allele and that the l/s or s/s genotype cells did not differ in this regard, we also compared the s'– allele carriers with the l'/l' homozygotes. In the population-representative birth cohort sample, only in boys carrying the 5-HTTLPR s'-allele was a significant association found with higher risk-taking behaviour in traffic through late adolescence (Study II, Table 2). 5-HTTLPR genotype had however no significant predictive effect of general traffic risk and traffic accidents, neither in the total sample (Study III, Table 3) nor if stratified by gender.

Conclusively, platelet MAO activity was found to be associated with risk-taking behaviour in girls and the 5-HTTLPR polymorphism in boys. It could be speculating that risk-taking behaviour in males and females is regulated by the serotonin system by different molecular mechanisms, at least during adolescence.

4.5. *DAT1* VNTR polymorphism is associated with risk-taking behaviour in traffic (Study III)

For clarifying the association between unintentional injury related risk-taking behaviour with dopamine system we compared the *DAT1* VNTR 9-repeat carriers (9R/9R and 9R/10R; n=502; 38.9%) and 10-repeat (10R/10R) homozygotes (n=810; 60.4%). The results revealed that the *DAT1* VNTR genotype was associated with traffic behaviour (Study III, Table 3), *DAT1* VNTR 9R carriers were more likely in the high general traffic risk group than 10R/10R homozygotes. *DAT1* VNTR genotype associated with traffic behaviour in males but not in females, these were male 9R allele carriers who belonged more frequently to the high general traffic risk group (OR = 1.46; 95% CI = 1.02–2.10), and had more frequently been driving drunk (OR = 2.89; 95%; CI= 1.12–7.47) compared to 10R/10R homozygotes. In females there was rather a tendency for the 10R homozygotes to have higher traffic risk (Study III, Figure 2). Studies on impulsivity/risk-taking behaviour and *DAT1* VNTR have been quite varied in approach, and controversial in outcome. Fagundo *et al.,* (2014) found that 9R homozygotes had better cognitive flexibility performance than 10R carriers but no significant association with inhibition response performance in pathological gamblers. Heitland *et al*., (2012) reported a tendency for more risk taking in *DAT1* VNTR 9R carriers within the sample of 60 healthy female subjects using a gambling task. Similarly, Forbes *et al*., (2009) reported that 9R carriers had higher scores of Barratt Impulsiveness Scale in a group of 89 adult volunteers. Congdon *et al.,* (2008) measured in 119 healthy adults impulsivity as the behavioural inhibition during the Stop-signal task and found that 10R homozygotes could have poorer inhibitory control but did not find significant differences on any subscale of the BIS-11 between allele or genotype groups. The most recent

longitudinal study of Tokko *et al.,* (2019), based on real-life statistics, has shown that 9R carriers could be involved in more traffic accidents by their own fault compared to 10R homozygotes. While the variability in literature may suggest heterogeneity in constructs, the real-life evidence suggests that the genotype merits further study to understand its role in behaviour.

Conclusively, these results suggest that the dopaminergic function, as exemplified be the *DAT1* VNTR genotype, is a significant factor for risk-taking behaviour in traffic.

4.6. Replication of the effect of brief psychological intervention on driving behaviour in an independent study (Study III)

Effortful control and extraversion/surgency are the characteristics most consistently associated with unintentional injury related risk-taking behaviour (Study I), and these two temperament dimensions are related to impulsivity. Higher maladaptive impulsivity, lower agreeableness and openness are associated with unintentional injury related risk-taking behaviour (Study II). Earlier studies (Deffenbacher *et al*., 2000; Piedmont, 2001; Krasner *et al*., 2009) have shown that life skill trainings could change the role of personality in risk-taking behaviour and so could underlie effective intervention strategies for reducing risks. Earlier research by our group had demonstrated that brief intervention sessions, led by psychologists, that were integrated into the driving education program and focused on impulsivity as a personal psychological risk factor may be effective for improving traffic safety (Paaver *et al*., 2013). So, the aim of the study described in Study III was an independent re-evaluation of the effect of the intervention, but as conducted by driving school teachers.

Driving school students were divided into intervention (n=704) and control (n=737) groups. Control and intervention groups did not differ by gender, age, education, income, or impulsivity measures. According to the Road Administration database the control and intervention groups did not differ significantly in any respect with regard to the obtaining of driving license. The intervention group had significantly less traffic accidents, and the general traffic risk (occurrence of either traffic offence or a collision) was less by about a quarter than in control group (Study III, Table 2). Both male and female intervention groups had significantly lower general traffic risk than controls, and intervention reduced the occurrence of both active and passive accidents in females. According to the survival analysis, participants of the intervention group were significantly less likely to fall into the general traffic risk group or become involved in traffic accidents during the three-year study period (Study III, Figure 1). Both male and female intervention groups had significantly lower general traffic risk than control group, and intervention reduced the occurrence of both active and passive accidents in females.

In the original intervention study (Paaver *et al*., 2013; Eensoo *et al*., 2018) the intervention sessions were conducted by trained psychologists. In the present study the intervention was conducted by regular teachers of the driving schools, who had previously been trained to carry out the intervention in a tailor-made course (2 European Credit Transfer and Accumulation System (ECTS) points) at the University of Tartu. Thus, intervention could be effectively delivered even if the teachers had participated in a brief specific course, and in principle it could be possible for every schoolteacher, even during the regular curriculum. As the impulsive aspects are similar in different risk-taking areas, e.g., traffic, alcohol usage, aggressive behaviour, the intervention focused on the different facets of impulsivity could avoid much of unintentional injuries during adolescence and adulthood. Knowledge about accident factors but also information about the role of impulsive behaviour could be a cross-curricula theme, and self-monitoring and self-regulation skills have to be established during the school years.

4.7. Biological factors affect the efficacy of intervention (Study III)

We investigated the effect of the *DAT1* VNTR polymorphism and the 5-HTTLPR polymorphism on efficacy of the brief psychological intervention on novice drivers. The intervention effect was independent of genotype in males, but in females associated with the *DAT1* VNTR and 5-HTTLPR genotypes. The proportions of females with high general traffic risk, and traffic accidents, including passive and active traffic accidents were significantly lower in *DAT1* VNTR 10R/10R homozygotes after intervention (Study III, Figure 2). Also in female 5-HTTLPR s'-allele carriers the lowest proportion of traffic accidents and general traffic risk were observed after intervention: for traffic accidents ($\chi 2=(3)8.70$; $p=0.034$) and for the general traffic risk ($\chi 2=(3)7.91$; $p=0.048$) (Study III; Table 4).

Thus, regarding the *DAT1* VNTR genotype, the intervention was most effective in female 10R homozygotes. Heitland *et al.,* (2012) has found decreased risk-taking following gains using a gambling test in 10R carriers. Regarding the 5-HTTLPR, the results of our study are again compatible with Heitland *et al.,* (2012) who found that female 5HTTLPR s'-allele carriers had a decreased risk taking after repeatedly taking a gambling task. Thus, female s-allele carriers appeared to learn faster the risks and adjust their behaviour more flexibly.

4.8. Strengths and limitations and of the research design

Risk-taking varies across different behaviours and situations during the lifespan, and by behaviour and situation the contribution of conscious and non-conscious aspects also vary. In this dissertation three different samples have been studied, in different ages, which is both a strength and a limitation: The dissertation thus covers a large variety of factors, but can not characterize them all in each sample. Study samples were big enough for making reliable conclusions: Study I had 699 participants at the mean age 12.8, Study II 483 participants at the first stage (mean age 15.3 y) and 454 participants in second stage (mean age (18.3 y) and Study III with 737 participants in intervention group and 704 in control group (mean age 22.5 y).

A weakness in the studies on which this dissertation is based is the use of several questionnaires that were self-administered. Self-reports facilitate collection of information from large samples but raise the possibility of biasing the relationship between the independent and dependent variables (Podsakoff *et al*., 2003). It is acknowledged that socially not desirable behaviours tend to go underreported.

5. MAIN RESULTS, CONCLUSIONS AND IMPLICATIONS

5.1. Main results and conclusions

This dissertation aimed to clarify the association of risk-taking behaviour related to unintentional injuries with personality traits and markers of heritability, and to explore the possibilities of intervention.

The studies I–III have led to the following answers to the seven research questions:

1) Study I showed that **lower safety knowledge** and **higher skills** predicted higher likelihood for **risk-taking behaviour** related to unintentional injuries. It can be reiterated that knowledge is the basis of behaviour, and the results of our study are consistent with this view. Safety topics in curriculum (how to behave safely in situations of traffic, fire, water and other environmental dangers, and seek help when necessary) are needed. Nevertheless, it is important to realize that knowledge alone does not guarantee correct behaviour, while it could assist in carrying out an intended behaviour. Indicators such as possessing bicycle driver's license, or ability to swim a normative distance revealed quite a low level of presence of skills among 6-th grade schoolchildren. So, additional provision of training in safety skills would be necessary.
2) Based on Study I it can be concluded that lower **effortful control** and higher **extraversion/surgency** of the Rothbart's four-dimensional temperament scale is associated with risk-taking behaviour. It can also be concluded that although there are different temperament traits associated with risk-taking behaviour, it could be possible to help children avoid the risks by developing their social competence and emotion regulation skills. Finally, **self-esteem was not associated** with unintentional injuries related risk-taking behaviour in sixth grade students.
3) Study II showed that of the Big Five personality traits, **lower Agreeableness** and **Openness** predicted higher unintentional injuries related risk-taking behaviour longitudinally in schoolchildren from ages 15 to 18 years. Higher **maladaptive impulsivity** was also associated with higher risk-taking behaviour in traffic during adolescence. In Study III conducted in novice drivers, instead higher **adaptive impulsivity** predicted high general traffic risk (occurrence of either traffic offence or a collision).
4) Study II showed that the marker of low capacity of the serotonin system, **low platelet MAO activity,** predicted high-risk traffic behaviour through late adolescence, especially in females. Male **5-HTTLPR s'-allele** carriers were more likely to belong to the high-risk traffic behaviour group compared to the l'/l' homozygotes through late adolescence. In Study III the 5-HTTLPR genotype had however no significant predicting effect on risk-taking behaviour in novice drivers. Conclusively, platelet MAO activity was found to be

associated with risk-taking behaviour in girls and the 5-HTTLPR polymorphism in boys. It could be speculating that risk-taking behaviour in males and females is regulated by the serotonin system by different molecular mechanisms, at least during adolescence.

5) Study III showed that ***DAT1* VNTR 9R** carriers were more likely to present high general traffic risk than *DAT1* VNTR 10R/10R homozygotes. By gender this association and the association with drunk driving appeared significant only in males. Conclusively, these results suggest that the dopaminergic function, as exemplified be the *DAT1* VNTR genotype, is a significant factor for risk-taking behaviour in traffic.
6) Study III showed that after intervention subjects had almost a quarter less traffic accidents (especially among females) and lower general traffic risk (occurrence of either traffic offence or a collision) in novice drivers. The **effectiveness of the intervention „Reducing Impulsive Action in Traffic“** was independently confirmed, and the "teaching the teachers" approach found effective. Thus, intervention could be effectively delivered even if the teachers have participated only in a brief targeted course, and in principle it could be possible for every schoolteacher, even during the regular curriculum.
7) Study III also showed that the intervention was most effective in female *DAT1* VNTR 10R/10R homozygotes and in female 5-HTTLPR s' allele carriers. Thus, females with these functional gene variants learned the risks faster and adjusted their behaviour more flexibly, and this finding illustrates the **individual differences** that exist in response to interventions.

5.2. Practical implications

Based on the empirical findings, several recommendations could be made for teachers, curriculum and learning material developers, and policy makers.

Teachers:

- In order to help children behave safely in situations of traffic, fire, water and other environmental dangers, it is important to increase in teachers the skills to identify the psychological factors involved in real-life accident cases and to aid children in the estimation of their own risks. Recognition of the role of non-conscious and unintended mental processes in risk behaviours and accidents is helpful.
- Develop self-monitoring and self-regulation skills in schoolchildren.
- Discussion with students of how temperament traits are related to risk-taking and how to recognize riskier tendencies in oneself could be beneficial. Everybody could act safely but may have different preferred ways to decrease their risk. The skill to estimate own risk of accidents and to recognize risky situations can reduce the occurrence of accidents. Also, protected risk taking as such can

be beneficial in development, but it is important to provide safe environment for learning such new skills.

- As the risks brought about by impulsive acts occur in different risk-taking areas, e.g., traffic, alcohol usage, aggressive behaviour, an intervention that focused on the different facets of impulsivity could avoid much of unintentional injuries during adolescence and adulthood. Knowledge about accident factors but also information about the role of impulsive behaviour could be a cross-curricula theme, and self-monitoring and self-regulation skills must be established during the school years.
- Teach that risk-taking behaviour, incl. ignoring safety equipment and laws, could be the reason of death and injuries.
- It could also be possible to help children to avoid the risks by developing social competence and emotion regulation skills.
- It should be acknowledged that risk-taking behaviour has hereditary aspects, and that such impact of heredity should not be treated as fateful but rather as a factor that shapes behaviour together with environmental factors such as experience. Genetic differences are potential factors underlying interindividual variability in risk taking and have a major role in impulse control and risk-taking behaviour.

Curriculum and learning material developers and trainees:

- Treating safety as a cross-curricular theme would offer the possibility to address relevant knowledge, skills and competences in several subject areas in a multidisciplinary manner (e.g., study of speed in physics can refer to safety in traffic; chemistry of fuels to fire risk at home; risk-taking behaviour to psychological risks).
- Training for the teachers about different personality risk factor traits and their relations to risk-taking aspects that are largely biologically determined and can lead to risky behaviour in traffic, water and fire safety.
- Create the materials about real-life accident cases for recognizing the potential situational factors triggering impulsive behaviour.

Policy makers:

- Consider possibilities to promote responsible social environment that facilitates the reduction of problematic risk-taking behaviour and enhances cooperative, trusting, and courteous behaviour.

5.3. Suggestions for future studies

This research has raised many questions in need of further investigation. It is recommended that further research is undertaken in the following areas:

The first suggestion for further studies would be to further examine whether and how the brief psychological intervention on impulsive risk-taking behaviour

can be applied in other settings. For that it is needed to teach teachers how to deliver information on risk-taking proneness to schoolchildren and how to manage group works for self-recognition of personal risks, so schoolchildren could build their own personally fitting risk reduction strategies.

Further data collection and analyses of other markers is required to detail the link between risk-taking behaviour, and the dopaminergic and serotonin systems.

It could also be possible to help children to avoid the risks by developing social competence and emotion regulation skills.

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SUMMARY IN ESTONIAN

Riskeeriv käitumine: seosed isiksuse ja pärilikkusega ning sekkumine vigastuste ennetamiseks

Vigastussurmade näitajad on viimastel aastatel taasiseseisvunud Eestis jõudnud stabiilsele tasemele, olles siiski oluliselt kõrgemad kui Põhjamaades. Tulekahjudes hukkunute standardiseeritud suremuskordaja (SDR) 100 000 elaniku kohta oli 2015 aastal Eestis 2,5 ja Lätis 3,3, kuid samal ajal Soomes 0,7 ja Rootsis 0,4. Samuti oli Eestis uppumiste SDR (2,4) 2015 aastal suurem kui Soomes (1,5) ja Rootsis (0,7), aga siiski väiksem kui Lätis (10,2) (WHO Mortality Database, 2018). Tuginedes liikluses, tulekahjudes ning vees toimunud õnnetusjuhtumite analüüsile ning ka teaduskirjanduses levinud arusaamadele, saab välja tuua, et enamuse juhtumite tekkes on olnud oluline roll riskeerival käitumisel (nt sõidukiiruse ületamine, alkoholijoobes liikluses või veekogude juures olemine, suitsetades magama jäämine, tule järelvalveta jätmine, turvavarustuse mittekasutamine väikestes veesõidukites).

Riskide võtmist on kirjeldatud kui olukorda, mille lahendamisel on võimalus õnnestumiseks, aga ka ebaõnnestumiseks (Gullone & Moore, 2000). Longituudsed uuringud on tõestanud, et teismeliseeas läbi viidud sekkumised (näiteks enesekontrolli tõhustamine, sotsiaalsete oskuste arendamine) mõjutavad käitumist hilisemas eas (Roberts *et al*., 2001). Teismeliste seas ennetustöö tegemiseks on kõige levinum koht kool ning teadmised on ennetustöö aluseks (Tarlov, 1996; Barclay & Fleming 2003). Siiski on selgelt välja toodud, et vaid teadmistele suunatud programmid ei pruugi kujundada ohutut käitumist (Briem & Bengtsson; 2000; Zeedyk *et al*., 2001; Schieber & Vegega, 2002).

Tervise edendamisel on olnud kasutusel tervisekäitumise mudelid (nt tervise uskumuste mudel, trans-teoreetiline mudel), mis keskenduvad inimese käitumise teadlikele aspektidele (Schwarzer, 2008). Samas viimastel kümnenditel on aga leitud, et riskikäitumise uurimisel ei piisa vaid teadlike/teadvustatud valikute uurimisest, vaid tuleb tegeleda ka otsuste langetamisega seotud irratsionaalsete, tahtmatute ja teadvustamatute protsessidega (Gibbons & Gerrard, 1995; 1997; Friese *et al*., 2011). Peamiselt on kasutusele jäänud peegeldav-impulsiivne mudel (Strack & Deutsch, 2004), mille kohaselt põhineb käitumine üheltpoolt aeglastel, kaalutletud ning teadmistel ja oskustel baseeruvatel teadlikel protsessidel ning teisalt mõjutavad käitumist kiired impulsiivsed protsessid. Riskide võtmise vähendamiseks tuleb lisaks eelnimetatud kahele poolele võtta arvesse ka konkreetset situatsiooni ning valmisoleku asjaolusid (nt enesejuhtimine, jäljendamis- ja kontrollioskused) (Hofmann *et al*., 2008; Sheeran *et al*., 2013). On välja toodud, et aju arengust tingituna erinevates arenguetappides on vaja sekkumise planeerimisel arvestada sihtrühma arengutaseme eripäradega (Johnson & Jones, 2011).

Ohutus on üks osa Euroopa Liidu Nõukogu soovitustest võtmepädevuste kohta elukestvas õppes, põhikooli ja gümnaasiumi riiklikes õppekavades on neid nimetatud kui üldpädevused. Konkreetsemalt on ohutuse teemat riiklikus õppekavas

käsitletud läbiva teemana, mis realiseerub õppekeskkonna kujundamises, aineõppes, valikainete valikul, loovtöödes, klassivälises õppetegevuses ja huviringide ning projekti-põhistes tegevustes (Põhikooli riiklik õppekava, 2018).

Igapäevaelu käitumuslikud otsused on mõjutatud isiksusest (Zuckerman & Kuhlman, 2000). Täiskasvanu isiksuse olemust on selgitatud kui kooslust geneetilisest eelsoodumusest ja isiklikest kogemustest (Rothbart *et al*., 2000). Ei ole ühtset definitsiooni isiksusele, detailsema määratluse järgi on isiksus kogum tunde-, mõtte- ja käitumismustritest, mis määravad inimese käitumise elulistes olukordades ning mis areneb välja pärilikest ja keskkondlikest teguritest (Larsen & Buss, 2005). Isiksuslikke tegureid (sealhulgas juba varajases eas väljenduv temperament ja väljakujunenud isiksuse omadused) on väga palju uuritud ning kasutusel on mitmeid erinevaid konstruktne ja mõõdikuid. Ei ole konsensuslikku otsust, milline on parim mõõdik, kuid enamiku konstruktide puhul on mitmeid uuringuid, mis võrdlevad näitajaid ühe levinuma konstruktiga, milleks on isiksuse viie-faktoriline konstrukt e. Suur Viisik (avatus kogemusele, meelekindlus, ekstravertsus, koostöövalmidus ja neurootilisus). Käesolevas töös on 15–18 aastase õpilaste longituudsel uurimisel kasutatud Suure Viisiku konstrukti, nooremate kooliõpilaste uuringus kasutati temperamendi küsimustikku ning spetsiifiliste isiksuseomanduste hindamiseks kasutati impulsiivsuse ja enesehinnangu küsimustikke.

Käesoleva väitekirja eesmärgiks oli selgitada riskeeriva käitumise seoseid isiksuslike ja pärilike teguritega ning selgitada riskeeriva käitumise ennetamiseks läbiviidud sekkumise efektiivsust.

Eesmärgi täitmiseks püstitati järgmised uurimisküsimused:

1) Kuidas on noorukite teadmised ja oskused seotud riskide võtmisega liikluse-, vee- ja tulega seotud tegevustes?
2) Kuidas on riskeeriv käitumine seotud Rothbarti neljamõõtmelise temperamendi näitajatega ning enesehinnanguga?
3) Kuidas on riskeeriv käitumine seotud Suure Viisiku isiksuseomaduste- ning impulsiivsusega longituuduuringus?
4) Kuidas on serotoniinisüsteemi toimimise näitajad nagu vereliistakute MAO aktiivsus ja 5-HTTLPR polümorfism seotud riskeeriva käitumisega liikluses?
5) Kuidas on dopamiinisüsteemi toimimise näitaja *DAT1* VNTR polümorfism seotud riskeeriva käitumisega liikluses?
6) Kas lühikese psühholoogilise sekkumise mõju algajate autojuhtide käitumisele liikluses on kordusuuringus samuti efektiivne ja kas autokoolide õpetajate väljaõppe meetod on tõhusalt kasutatav?
7) Kas uuritud bioloogilised tegurid mõjutavad sekkumise tõhusust?

Käesoleva doktoritöö empiiriline osa põhineb järgnevate teadusprojektide valimitel:

1) Tervisedenduse tulemuslikkus Eesti koolides (I uuring – TerVE kool). Valimisse kuulus 699 eesti keelsete koolide kuuenda klassi õpilased (216 poissi ja 253 tüdrukut) keskmise vanusega 12,8 aastat.

2) Eesti Laste Isiksuse Käitumise ja Terviseuuring (II uuring – ELIKTU). Uuringus kasutati kahe mõõtmise tulemusi samadel lastel keskmise vanusega 15,3 aastat (222 poissi ja 261 tüdrukut ja 18,3 aastat (202 poissi ja 252 tüdrukut).
3) Vigastuste ja riskeeriva käitumise ennetamiseks teaduspõhiste meetmete väljatöötamine ning rakendamine (III uuring – TerVE VIGA). Valimisse kuulusid 1441 autokoolide õpilast keskmise vanusega 22,5 aastat, moodustati sekkumisegrupp suurusega 737 õppurit (321meest ja 416 naist) ning kontrollgrupp 704 õppuriga (303 meest ja 401 naist).

Teadmiste ja oskuste osas on varasemad uuringud toonud välja vastakaid tulemusi (Cook & Bellis, 2001; Zeedyk *et al*., 2001), kuid üldiselt on teadmised käsitletavad kui eeldus ohutu käitumise kujundamisel, sest enne käitumisotsuse tegemist vajab inimene informatsiooni, kuidas peaks käituma ning millised mõjud võivad käitumisotsusel olla (Tarlov, 1996; Barclay & Fleming 2003; Green & Kreuter 2005). Valdavalt on erinevate koolituste raames antud õpilastele teadmisi erinevatest ohtudest ja õpetatud ohutut käitumist. Kooliõpilaste uuringus mõõdeti õpilaste teadmisi seoses tule, vee- ja liiklusohutusega. Kõrge riskikäitumisega gruppi kuulunud õpilastel olid teistega võrreldes oluliselt madalamad teadmised (I uuring). Sõltuvalt omandatud oskustest võib oskuste mõju riskeerivale käitumisele olla erinev, näiteks võivad algajad juhid oma oskusi üle hinnata (Eensoo *et al*., 2007; Taubman-Ben-Ari *et al*., 2012; Harris *et al.,* 2014). Sarnane tulemus ilmnes ka kooliõpilaste uuringus, kus riskeerivamat käitumist raporteerinud õpilased hindasid oma oskusi oluliselt kõrgemalt (I uuring). Kuna teadmised on ohutusõppe baasosa, tuleb sellealaseid teadmisi õpilastele anda, kuid teadmised üksinda ei taga veel ohutut käitumist ning seetõttu on vajalikud mitmed erinevad tegevused. Õpetades mingit uut oskust (nt ujumine, rattasõit) on vajalik lisaks oskustele õpetada enda ja teiste tegevuse märkamist erinevates olukordades, kus käitumisoskusele lisaks peab arvestama ohutusega (nt väliveekogus ujudes, rattaga liikluses sõites). Seega õpetades uusi oskusi tuleb õpetada ka oskustega kaasnevaid ohutuse põhimõtteid.

Selgitamaks, kuidas kooliõpilaste riskeeriv käitumine on seotud temperamendi ja enesehinnanguga, kasutati teadusprojekti TerVE kool eestikeelsete koolide 6. klasside õpilaste andmeid. Isiksuseomadustega hea võrreldavuse ja suhteliselt laia kasutusega on Mary K. Rothbart ja kaasautorite (Rothbart, 2004; Kail & Barnfield, 2011) poolt välja töötatud varajase noorukiea temperamendi küsimustik EATQ. EATQ 4 faktorilise struktuuri põhiskaaladeks on tahteline kontroll, ekstravertsus, negatiivne afektiivsus ja kuulumine. I uuringu struktuurivõrrandite analüüsi tulemustest selgus, et riskeerivamalt käituvad õpilased, kellel on madalam tahteline kontroll ja kõrgem ekstravertsus. Samas tahtmatute vigastustega seotud riskeeriv käitumine ei olnud oluliselt seotud enesehinnanguga. Kuna riskeeriva käitumise puhul võib sõltuvalt situatsioonist olla suurem või väiksem osatähtsus teadlikult tehtud otsustel, siis on oluline, et õpilased oskaksid oma käitumist analüüsida ning tunneksid oma nõrkusi. Korduvate situatsiooniharjutustega on võimalik arendada kaitsemehhanisme selliselt, et reaalsesse olukorda sattudes võetakse vastu ohutumad otsused. Koolidel on võimalus luua keskkond,

kus suurema ekstravertsusega õpilased saaksid ennast ohutult ja turvaliselt välja elada, et ei oleks ahvatlust käituda riskeerivalt näiteks liikluses.

Riskeeriva liikluskäitumise seoste selgitamiseks suure viisiku isiksuseomaduste ning impulsiivsusega longituudselt kasutati Eesti laste isiksuse, käitumise ja tervise uuringu (ELIKTU) noorema kohordi andmeid vanuses 15 ja 18 aastat. Isiksuslikke eripärasid hinnati Suure Viisiku mudeli skaaladega: avatus kogemusele, meelekindlus, ekstravertsus, sotsiaalsus ja neurootilisus. II uuringu tulemustest selgus, et longituudselt teismelise-ea jooksul võtavad liikluses rohkem riske madalama sotsiaalsuse ja avatusega (eriti poiste hulgas) uuritavad. Siinkohal saab anda praktilisi soovitusi õpilaste sotsiaalsuse arendamiseks sotsiaalsete oskuste arendamise kaudu; õpetajatel on oluline roll, et arendada õpilaste sotsiaalseid oskuseid läbivalt kõikide õppeainete kaudu ning ka spetsiifiliselt erinevate riskikäitumise olukordade kaudu.

Üks isiksuse aspekt, mida väga selgelt seostatakse riskide võtmise ja õnnetustesse sattumisega on impulsiivsus (Eensoo *et al*., 2004; Barkley & Cox, 2007; Bicaksiz & Özkan, 2016; Alavi *et al.,* 2017). Isiksuse omadusena on impulsiivsus mitmetahuline ning selle hindamiseks on palju erinevaid konstrukte. Käesolevas töös on kasutatud adaptiivse ja maladaptiivse impulsiivsuse skaalat (AMIS) alaskaaladega: kiire otsustamise stiil, erutusihalus, mõtlematus ja pidurdamatus (Eensoo *et al*., 2004; Paaver *et al*., 2006). ELIKTU valimil selgus, et kõrgem maladaptiivne impulsiivsus (mõtlematus ja pidurdamatus) kirjeldab suuremat riskide võtmist liikluses teismelise-ea jooksul (II uuring). Selgitades riskeeriva liikluskäitumise seost impulsiivsusega algajatel autojuhtidel ilmnes, et kõrgem adaptiivne impulsiivsus ennustas kõrgemat riskide võtmist liikluses (III uuring). Tulemused näitavad, et nii adaptiivne kui ka maladaptiivne impulsiivsus on olulised riskeeriva käitumise ennustajad liikluses. Kuna riskeeriva käitumisega seotud otsused mõjutavad inimest kogu eluea jooksul (sõltudes nii teismelise huvist ja uudishimust kõike proovida kui ka vanemas eas võimalustest tegeleda asjadega, mis nooremana ei olnud võimalikud), siis on vajalik oma käitumise analüüsimine erinevates situatsioonides igas vanuses inimestele. Kui käitumises ilmneb oht liigsete riskide võtmiseks, on kõigil võimalik välja töötada endale sobiv kaitsestrateegia käitumises, et hoida ära kriitilises olukorras impulsiivselt tehtavat ohtlikku otsust. Abiks saavad siin olla psühholoogid ja psühholoogiliste sekkumiste läbiviijad.

Uuringutes on näidatud, et riskeeriv käitumine (Anokhin *et al*., 2009; Cesarini *et al.,* 2009) ja isiksuseomadused (Jang *et al*., 2001; Oreland, 2004) on suures ulatuses bioloogilise eelsoodumusega. Siiski on käitumise kujunemisel oluline roll ka keskkondlikel teguritel (Kaufman *et al.,* 2006; Sjöberg *et al*., 2006), mistõttu võivad käitumuslike näitajate ja bioloogiliste tegurite vahelised seosed erinevate valimite puhul anda erisuguseid tulemusi. Üldiselt on riskeerivat käitumist ning impulsiivsust seostatud aju serotoniini- ja dopamiinisüsteemidega (Dalley & Roiser, 2012). Impulsiivsuse bioloogilise markerina on tuntud vereliistakute monoamiinide oksüdaasi (MAO) aktiivsus, mis korreleerub aju serotoniinineuronite aktiivsusega. Uuringutes on näidatud, et vereliistakute MAO aktiivsus on oluliselt madalam erinevates riskivalt käituvates rühmades, nt sõidukit

alkoholijoobes juhtinud, mägironijad, hasartmängurid, kriminaalid, härjavõitlejad (Zuckerman & Kuhlman, 2000; Longato-Stadler *et al*., 2002; Eensoo *et al*., 2004; Oreland *et al*., 2007). ELIKTU (II uuring) valimil selgus, et madalam MAO aktiivsus ennustab suuremat riskide võtmist liikluses hilis-teismelise-ea jooksul (eriti naistel), mis näitab et riskikäitumine liikluses on seotud serotoniinisüsteemi madalama aktiivsusega teismelise eas. Serotoniini transporti ajus kontrollib serotoniini transporter (5-HTT). Kõige enam on uuringutes kasutatud 5-HTT geeni (*SLC6A4*) promootorregiooni funktsionaalset polümorfismi (5-HTTLPR), millel on kaks alleelivarianti: lühike alleel (s-alleel) ja pikk alleel (l-alleel) (Heils *et al.,* 1995; Lesch *et al*., 1996). S-alleeli kandlust on näiteks seostatud suurema depressiooniriskiga (Clarke *et al*., 2010; Holmes *et al*., 2010), suitsiidse käitumise (Gonda *et al*., 2011) ja kõrgema impulsiivsusega (Walderhaug *et al*., 2010). Longituudses uuringus ilmnes, et poisid, kellel on 5-HTTLPR s'-alleeli kandlus, võtavad rohkem riske liikluses kui l'/l' homosügoodid hilis-teismelise-eas (II uuring). Algajatel autojuhtidel 5-HTTLPR seost käitumisega liikluses ei ilmnenud (III uuring).

Sarnaselt serotoniinile omab olulist rolli impulsside kontrollimisel ja riskide võtmises dopamiinergiline süsteem (De Wit *et al*., 2002; Friedel, 2004; Thapar *et al*., 2005; Fried *et al*., 2006). Inimese dopamiini transporteri geen (*DAT1*) sisaldab varieeruva arvuga tandeemse kordusega (R) polümorfisme (rs28363170F), levinuimad on 9R ja 10R. 9R alleeli kandlust on seostatud suurema riskide võtmisega (Forbes *et al*., 2009; Heitland *et al.,* 2012). Dopamiinitransporteri genotüübi mõju uuriti autokoolide uuringus (Study III), kus *DAT1* VNTR 9R kandjatel ilmnes kõrgem üldine liiklusrisk kui *DAT1* VNTR 10R/10R homosügootidel. Seega nii serotoniini- kui ka dopamiinisüsteem on seotud vigastustele eelneva riskeeriva käitumisega, kuid seose tugevus võib olenevalt vanusest olla erinev. Päriliku eelsoodumuse tähenduse õpetamisel näiteks inimeseõpetuses või bioloogias on mõeldav põhikooli ainekavas käsitleda aju ehitust ja virgatsainete toimimist ning seda, et aju toimimine ja käitumine sõltub geneetilisest eelsoodumusest. Samas geneetilise eelsoodumuse avaldumine on suuresti mõjustatud nii varasemast kui ka hetkekeskkonnast.

Varasemalt on näidatud, et autokoolides B-kategooria juhiloa taotlejate väljaõppe jooksul psühholoogide poolt läbiviidud sekkumine impulsiivse käitumise ennetamiseks liikluses on efektiivne (Paaver *et al*., 2013; Eensoo *et al*., 2018). III uuringus koolitati esmalt autokoolide õpetajaid sekkumist läbi viima. Seejärel viidi pooltes uuringus osalenud autokoolide B-kategooria juhiloa taotlejate õppegruppides läbi sekkumine: sekkumisrühmas osales 737 ning kontrollrühmas 704 uuritavat. Kolme aasta vaatlusperioodi jooksul sattusid sekkumises osalenud õpilased oluliselt vähem liiklusõnnetustesse ning neil oli madalam liiklusrisk (liiklusõnnetuse või õigusrikkumise esinemine liikluses) kui kontrollrühmal. Kuna interventsiooni mõju võib sõltuda inimese vastuvõtlikkusest välistele mõjuritele (Heitland *et al.,* 2012), uuriti sekkumisuuringus sekkumise efektiivsuse seoseid funktsionaalsete geenipolümorfismidega 5-HTTLPR ja *DAT1* VNTR-ga. III uuringu tulemused näitasid, et sekkumise mõju on suurem naistel *DAT1* VNTR 10R/10R homosügootidel ja 5-HTTLPR s'-alleeli kandjatel (III uuring).

Sekkumise efektiivsus tõestas, et riskeerivat käitumist põhjustavate isiksuse ja bioloogiliste näitajaid tundes on võimalik seda koolis õpetajate poolt käsitleda nii, et viia läbi efektiivseid sekkumisi. Seetõttu võiks psühholoogilise sekkumise läbiviimiseks vastava ettevalmistuse lisada õpetajakoolitusse või täiendkoolitusse.

Väitekirja põhjal saab välja tuua mitmeid ettepanekuid vigastustele eelneva riskeeriva käitumise vähendamiseks. Lisaks erinevate ohtudega seotud teadmistele on vajalik õpetada õpilasi hindama oma isiklike tegurite seost riskide võtmisega. Selleks on hea kasutada toimunud sündmuste analüüsi ning lasta hinnata enda käitumist sellises olukorras ja otsida võimalusi, kuidas riske vähendada. On vajalik harjutada ja läbi mängida erinevaid situatsioone, et suurendada teadvustatud käitumise rolli otsustusprotsessis ning vähendada seeläbi teadvustamata ja impulsiivse otsutamise mõju.

Kuna riskeeriv käitumine on seotud nõrkade sotsiaalsete oskustega, siis on vajalik arendada ka erinevate tegevuste (nt auto juhtimine, koduohutus) juures teiste inimestega arvestamise oskust. Seetõttu ei piisa vaid tehniliste oskuste arendamisest (nt jalgratta või auto juhtimine, lõkke tegemine, ujumisoskus), vaid on vajalik arendada selle tegevusega seotud ohutusalaseid (hinnata situatsioonist tulenevaid ohte) ja sotsiaalseid (nt enesekontroll, teistega arvestamine) oskuseid.

Õpetajakoolituses on oluline, et õpetajad omandaksid teadmised erinevatest isiklikest (psühholoogilised, bioloogilised) riskiteguritest ja nende seostest riskeeriva käitumisega (nt liikluses, vees ning tuleohutuses), riskide hindamise meetoditest ning eneseregulatsiooni oskuste arendamisest.

Riiklikul tasandil on vajalik arendada tugisüsteeme probleemsete riskeerivalt käituvate inimestega tegelemiseks ning arendada erinevate koostööpartnerite vahelist koostööd.

Kokkuvõttes, uuringute tulemused näitavad, et kuigi nii bioloogilised tegurid nagu serotoniini- ja dopamiinisüsteemi näitajad kui ka temperament ja isiksuseomadused ning teadmised ja oskused omavad olulist rolli tahtmatute vigastustega seotud riskide võtmisel, on siiski võimalik riskeerivat käitumist ennetada lühikese sekkumisega ning seda ka siis, kui sekkumist viivad läbi selleks ettevalmistatud õpetajad.

PUBLICATIONS

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