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An-Magritt S. Kummeneje

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Doctoral thesis

NTNU
Norwegian University of Science and Technology
Thesis for the Degree of
Philosophiae Doctor
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Department of Psychology

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Trondheim, December 2020

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Preface and Acknowledgements

The main aim of this thesis is to investigate how risk perception, worry, and attitudes towards traffic safety influence the behaviour of cyclists and pedestrians as road users. The thesis consists of an introductory section and three papers. The findings are based on three questionnaire surveys carried out in 2017.

The data collection for the research conducted for Study 2 was financed by the Norwegian Public Roads Administration (NPRA) as a part of the two research and development programmes 'Bedre by' and 'BEST'. I would like to thank Guro Berge, the leader of 'Bedre by' and senior advisor in NPRA, for her support and the interest in my work. The questionnaires for Study 1 and Study 3 were distributed in collaboration with the Norwegian Cyclists' Association (Syklistenes Landsforening). I would like to thank both Roar Løkken, Communications Director of the Norwegian Cyclists' Association, and Richard Liodden Sanders, former Chief of the Norwegian Cyclists' Association in Trondheim, for their interest in my research and help with distributing the questionnaires. I especially thank the 2717 survey participants who answered the questionnaires used in the research for this thesis.

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An-Magritt Steinset Kummeneje, Trondheim 8 May 2020

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Attitudes, risk perception and risk-taking behaviour among regular cyclists in Norway
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Summary

Background: In traffic safety research, cyclists and pedestrians are defined as vulnerable road users, in common with moped and motorcycle riders. Nevertheless, increasing the number of active travellers such as cyclists and pedestrians has high priority in transport policies in European countries. The use of active travel modes is seen as pro-environmental, as well as health promoting behaviour. To increase the number of active travellers, priority should be given to examining the determinants of cyclists' and pedestrian's risk perception, safety attitudes, as well as their travel and risk-taking behaviour.

Main aim: The overall aim of the research for this thesis was to examine how risk perception, worry, and attitudes towards traffic safety influenced the behaviour of cyclists and pedestrians as road users. This included both travel behaviour (walking or cycling frequency) and risk-taking behaviour.

Methods: The results of the research for this thesis are based on three different datasets collected in 2017. Study 1 was carried out among members of an Internet-based group for everyday cyclists in Trondheim Municipality, Norway. All 2240 members were invited to participate in the study by answering a self-completion online questionnaire survey, and the response rate was 13% (n = 291). The data for Study 2 were collected through telephone interviews with a representative sample of the Norwegian population (age range 15–88 years) (n = 2000). The response rate was 27%. The data for Study 3 were collected through an online questionnaire distributed through a magazine sent by post to ca 10,000 members of the Norwegian Cyclists' Association (n = 426). Only members who had used their cycle for regular trips during the last year were asked to answer the questionnaire. In total, 426 members completed the questionnaire.

Results: The results of the three studies showed that worry could be seen as an integral emotion caused by the cognitive evaluation of risk when cycling or walking. In all three studies, there were strong significant associations between worry and perceived risk. The perceived probability of consequences was found more important for worry than the judgement of the severity of consequences. The results also showed that risk perception and worry were important for cyclists' and pedestrians' behaviour in traffic, including travel behaviour (walking or cycling frequency) and risk-taking

behaviour (cyclists' risk-taking). Risk perception and worry were found most important for cycling frequency during winter (Study 1) and for walking frequency during night-time (Study 2). Respondents without access to a car perceived the risks as a pedestrian as higher than others, and worry was found more important for walking frequency for respondents without access to a car (Study 2). Geographical area of residence was found important for attitudes and risk-taking behaviour (Study 3). Respondents living in rural areas had more ideal attitudes and were less often involved in risk-taking behaviour than respondents living in urban areas, although the differences were small. Associations between cyclists' and pedestrians' perceived risk, worry, and behaviour have been investigated only to a small extent in previous studies and need further investigation.

Conclusions: The results of this thesis showed that risk perception and integral feelings of worry, influence cyclists' and pedestrian's behaviour. This includes both travel behaviour (walking or cycling frequency) and risk-taking behaviour. Attitudes towards traffic safety influence risk-taking cycling behaviour. The same attitudes were not found as important for cycling frequency.

1 Introduction

1.1 Background

Norway and Sweden are the safest countries in Europe with regard to traffic safety and in Norway the number of road deaths has been reduced by 49% between 2010 and 2017, from 210 to 106 respectively. The reduction is in line with the European Union's commitment to improve road safety by setting a target of reducing road deaths by 50% by 2020 compared with 2010 levels (Adminaite, Calinescu, Jost, Stipdonk, & Ward, 2018). However, the work to improve road safety in Europe is far from finished, and a new target to halve road deaths by 2030 compared with 2020 levels was announced by the European Commission on 17 May 2018 (Adminaite et al., 2018). In Norway, road safety policy is grounded in the a Vision Zero project, according to which all traffic safety work should be based on a vision of no fatal or serious injury accidents (Meld. St. 33, 2016–2017, p. 14) Inspired by Sweden which first introduced the project, Vision Zero was launched in Norway as part of the National Transport Plan 2002–2011 (Meld. St. 46, 1999-2000).

In traffic safety research, cyclists and pedestrians are defined as vulnerable road users, in common with moped and motorcycle riders (WHO, 2013). Nevertheless, increasing the number of active travellers such as cyclists and pedestrians has high priority in transport policies in European countries. Active travel is seen as a key solution to promote a physical active population, as well as to reduce environmental problems caused by local air and noise pollution, and carbon dioxide emissions due to fossil fuel usage. In order to reduce transport-related CO_2 emissions, the Norwegian Government has set as a target for the largest cities that all future growth in individual travel should be accommodated by walking, cycling, and public transport, and thus there should not be any growth in car traffic – the 'zero growth' goal (Meld. St. 33, 2016–2017, pp. 145-148). To achieve the targets (i.e. Vision Zero and the 'zero growth' goal) and establish safe long-term changes in transport mode use, calls for a variety of measures and enhanced knowledge of road users' preferences and choices. When choosing a mode of transport, road users take several factors into consideration, which may include risk perception and attitudes toward traffic safety. Furthermore, road users' perception of risk and their attitudes toward road safety have been found to influence risk-taking behaviour in traffic (e.g. Nordfjærn, Şimşekoğlu, Lind, Jørgensen, & Rundmo, 2014; Roche-Cerasi, Rundmo, Sigurdson, & Moe, 2013; Şimşekoğlu, Nordfjærn, & Rundmo, 2012). It is important

to take these findings into consideration when working to increase the numbers of cyclists and pedestrians and to reduce car traffic. In this thesis, I focus on the psychological risk judgements, attitudes and behaviour associated with cycling and walking in traffic environments in daily travels. Due to the aim to increase the number of active travellers in Europe, priority should be given to examining the determinants of cyclists' and pedestrian's risk perception, safety attitudes, and both their travel behaviour and risk-taking behaviour in traffic. Accordingly, this is the aim of the current thesis.

1.2 Main aims of the thesis

The overall aim of the research for this thesis was to examine how risk perception, worry, and attitudes towards traffic safety influenced the behaviour of cyclists and pedestrians as road users. This included both travel behaviour (walking and cycling frequency) and risk-taking behaviour. Figure 1 shows the conceptual model of the main variables and relationships between them examined in Papers I, II and III of this thesis.

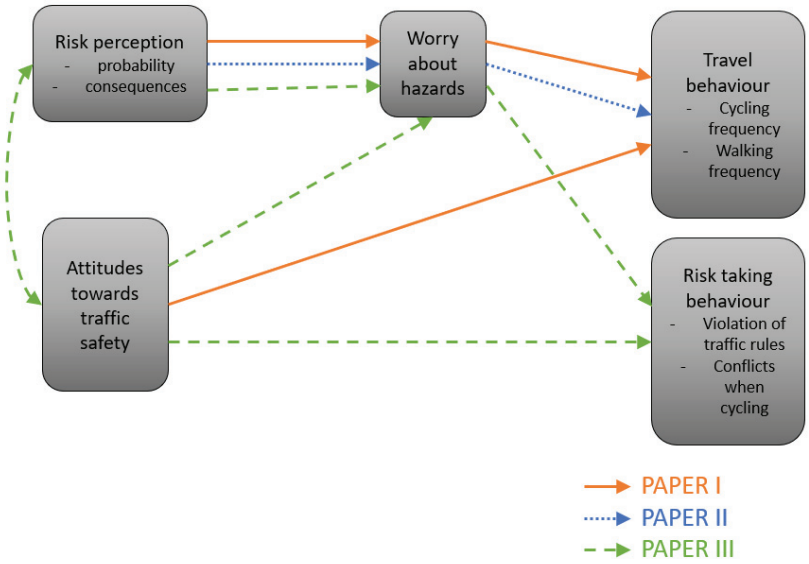

Figure 1. Conceptual model of the main variables and relationships between them examined in Papers I, II and III

Risk-taking behaviour was only studied among cyclists. Two types of cyclists' risk-taking behaviour were studied: 'violation of traffic rules when cycling' and 'conflicts with other road users when cycling' (for detailed descriptions of the concepts, see Section 1.3.1–1.3.7).

Investigating safety attitudes, risk perception and worry among cyclists and pedestrians is relevant for several reasons. *First*, all three terms may relate to people's behavioural choices. According to the risk-as-feelings approach, behaviour is influenced by the interplay between cognitive evaluations of risk and feelings (Loewenstein, Weber, Hsee, & Welch, 2001). In this thesis risk perception and safety attitudes are defined as an individual's cognitive evaluation of the risks when walking or cycling. Worry was regarded as a feeling that emerges as a result of an individual's cognitive assessment of risks and safety. Emotions often produce behavioural responses that differ from an individual's cognitive assessment of their best course of action in a given situation (Loewenstein et al., 2001). When studying road users' behaviour, both cognitive assessments and emotions are important considerations. *Second*, safety attitudes, risk perception and worry may contribute to explaining why potentially hazardous risk sources are defined as a problem for different groups in populations. Walking and cycling should be an option for everyone, and facilities for cyclists and pedestrians should be planned to include all groups in the population. It is important to study which hazards exclude people from cycling and walking during their daily travels, and which groups in the population are excluded from cycling and walking. *Third*, and finally, safety attitudes, risk perception and worry may be related to risk-taking behaviour and safety in traffic.

Paper I examines the association between risk perception, safety attitudes, and cyclists' decisions as to whether to cycle during different seasons of the year. In Norway, the share of cycling as a mode of transport is significantly higher in summer than in winter. Hence, in order to facilitate future growth in demand for cycling all year round, special focus should be directed towards risk perception in order to examine whether cyclists perceive risk differently in winter compared with in summer, and to explore any correlations between risk perception, safety attitudes, and the choice to cycle. Accordingly, Paper I investigates how people perceive risk when cycling in winter compared with summer conditions. An additional objective is to investigate the associations between perceived risk, safety attitudes, and the decision to cycle during winter and summer.

The purpose of Paper II is to investigate the association between pedestrians' risk perception and worry, and how worry influences their decision to walk as a mode

of transport for their daily travels. To my knowledge, no studies to date have solely investigated worry and risk perception among pedestrians or the associations between worry, risk perception and pedestrian behaviour. Consequently, the main aim of Paper II is to investigate what worries pedestrians, the association between their perceived risk and worry, and whether worry is associated with pedestrians' behaviour.

Risk perception, worry, and safety attitudes may not only be associated with people's decisions to walk or cycle on their daily travels. Additionally, cognitive evaluations about risk and safety as well as anticipatory feelings of worry may be related to road users' behaviour in traffic. The main aim of Paper III is to investigate whether attitudes toward traffic safety, risk perception and worry are associated with cyclists' risk-taking behaviour. The study is restricted to two types of cyclists' risk-taking behaviour: violation of traffic rules, and conflicts with other road users when cycling. The study on which Paper III is based focused on behaviour that primary influenced the probability of cyclists being involved in an accident. The use of personal protective equipment (e.g. helmets, cycling glasses, protective clothing) designed to reduce the consequences of an accident was not included in the study.

1.3 Definitions of the main concepts

1.3.1 The concept of risk

Risk is about uncertainties that might happen in the future. Risk assessments, risk analysis and accident analysis are important parts of traffic safety work. When planning, managing and maintaining roads in Norway, risk analyses are conducted to ensure safety (Håndbok V721, 2007). The Norwegian Standard NS 5814:2008, 'Krav til risikovurdering' (risk assessment requirements) defines risk as the combination of the probability and the consequence of a negative incident (NS 5814, 2008). In the international standard, ISO 12100, 2010, 'Safety of machinery — General principles for design — Risk assessment and risk reduction', risk is defined as the combination of the probability of occurrence of harm and the severity of that harm' (ISO 12100, 2010, p. 3). In the ISO definition, risk is a combination of all possible consequences that can happen and the related probability of those consequences, which includes all possible unwanted negative outcomes that may happen as a result of an activity or situation. The risk is always connected with possible incidents resulting in negative consequences that have a value for humans (Hansson, 2010; Rausand & Utne, 2009). The values may be related to individuals (e.g. life, health or welfare), the environment (e.g. air, water, animals, plants), materials (e.g. buildings, technical equipment,

infrastructure), information (e.g. confidential information, stored data), reputation (e.g. company, branding, ability to deliver), democracy, nation, and governmental system (e.g. government, parliament, lower courts) or to culture and society (e.g. cultural or historical monuments, works of art, education system, family structure). When safety experts make risk assessments, they evaluate whether the probabilities or consequences should be given the most weight. Such evaluations are value-based and influenced by the country's politics, history and culture (Rausand & Utne, 2009). Vision Zero influences Norwegian traffic safety work and attributes more weight to accidents with the most severe consequences than to less serious accidents. Even possible incidents with small probability estimates should be prioritized if the consequences could be fatal or result in serious injury when working toward Vision Zero. Vision Zero is based on the value that every human is irreplaceable. In contrast to in Sweden, suicides in traffic are not a part of the Norwegian Vision Zero. Thus, all of the above-described political and value-based decisions influence experts' risk assessments in traffic.

According to Hansson (2010), two contradictory concepts of risk are used in risk research: some researchers see risk as objective and measurable by physical facts, while others see risk as subjective and socially constructed, independently of physical facts. He argues that both views oversimplify the concept of risk and stand in the way of more sophisticated analyses of risk. Furthermore, Hansson (2010) calls the objective view of risk 'The objective risk thesis', meaning that risk can be characterized completely in terms of objective facts relating to the psychical world in calculations about possible outcomes and their probabilities. In the field of risk perception, researchers often are interested in the subjective part of the risk. This view is expressed both by Douglas and Wildavsky (1983) in their cultural theory of risk, and by Fischhoff, Slovic, Lichtenstein, Read, and Combs (1978) in their psychometric paradigm of risk perception. Douglas and Wildavsky (1983) see risk as culturally based, and an important assumption in the psychometric paradigm is that risk is inherently subjective:

> Risk does not exist 'out there', independent of our minds and cultures, waiting to be measured. Humans have invented the concept 'risk' to help them understand and cope with the dangers and uncertainties of life. There is no such thing as 'real risk' or 'objective risk'. (Slovic, 1992, p. 119)

Hansson (2010) holds the view that risk is subjective and does not refer to any objective facts of the physical world; 'The subjective risk thesis'.

According to Hansson (2010), the concept of risk is based on both facts and values, and contains both objective and subjective elements. He refers to this view as the dual risk thesis: 'An accurate and reasonably complete characterization of risk must refer to both objective facts about the physical world and to (value) statements that do not refer to objective facts about the physical world' (Hansson, 2010, p. 236). Many researchers within the field of traffic psychology and traffic safety acknowledge that risk has both a subjective element and an objective element. However, a number of researchers have chosen to subdivide objective risk and subjective risk into two different concepts. The division of risk into objective and subjective risk has frequently been repeated in the literature on risk perception in traffic (e.g. Andersson, 2011; Chaurand & Delhomme, 2013; de Blaeij & van Vuuren, 2003; Deery, 1999; Fuller, 2005; Rundmo, Nordfjærn, & Roche-Cerasi, 2013; Summala, 1988; van der Molen & Bötticher, 1988). The aforementioned literature refers to objective risk as risk calculated through statistical analyses and probability estimates of hazards that are independent of individuals' judgement of risk. Subjective risk is referred to as laypeople's judgements of risk or individuals' risk perception.

In accordance with Hansson (2010), risk and risk perception are not defined as either objective or subjective in this thesis. Rather, the assessment of risk is always based on subjective evaluations and priorities (value-based), as well as based on facts about the external world. Accordingly, both laypeople's and experts' assessments of risk have objective and subjective elements. To meet the requirements of Norwegian law, value evaluations have to be included as a part of risk and vulnerability analyses (NSM, 2019; Rausand & Utne, 2009, p. 36). One difference between laypeople's and experts' assessments of risk is the use of cognitive strategies when assessing risk. People with little knowledge about a hazard may use more heuristic strategies when judging the associated risk (Slovic, 1987; Slovic, Finucane, Peters, & MacGregor, 2007). Slovic (1987) argues that most people rely on intuitive risk judgements, in contrast to technologists' sophisticated analyses of the risks related to hazards. He uses the term 'risk assessment' for experts' risk judgements, and 'risk perception' for laypeople's judgement of risk. In the field of risk assessment and risk analysis, systematic tools have been developed for estimating risk. Several studies have shown that laypeople and experts perceive risk differently (e.g. Rowe & Wright, 2001; Siegrist & Gutscher, 2006; Wright, Bolger, & Rowe, 2002).

According to Sjöberg (1999a), specialists and the general public rarely share the same perception of risk. He argues that the difference in their perception of risk could not be explained merely by differences in knowledge about the hazard sources and the associated potential risks. Other explanations may be that experts often come from the same background (age, gender and type of education), with the same socialization of values and risk perception through their professional training and work, have the same definition of risk, share the same political ideology, have a higher level of perceived control of and familiarity with the risk source that the general public, and higher levels of trust in other experts, industries and authorities, their professional role and which values they are expected to protect in their respective roles (Sjöberg, 1999a). In some cases, the experts' professional risk assessments may conflict with their personal judgements of risk. This could, for instance, be the case if the expert personally disagrees with the national, institutional or company policy documents. For example, a traffic safety expert could disagree with the implementation of Vision Zero in traffic safety work, and personally believe that accidents with high probabilities and non-fatal injuries should be ranked as having higher risk. Another expert may believe that the loss of personal freedom is a risk that should be ranked higher in traffic safety work or believe that the protection of personal privacy should be the most important priority. In their professional work, experts calculate and assess the risk based on Vision Zero and policy defined by the Norwegian Government, the Norwegian Public Roads Administration and the Norwegian Data Protection Authority.

That laypeople and experts perceive risk differently may be overestimated as a problem when it comes to the use of private transport modes. Rundmo and Moen (2006) found that the difference in perceived probability was non-significant between experts, politicians, and laypeople concerning private transportation (including walking and cycling). A similar finding was revealed in an experimental study conducted by Kruysse and Wijlhuizen (1992). They found that experts and laypeople were equally reliable in judging traffic conflicts and that both groups perceived an equal level of risk (or dangerousness) of conflicts. According to Aldred (2016), growing evidence suggests that cyclists' perceived risk corresponds reasonable well to expert opinion (e.g. Bill, Rowe, & Ferguson, 2015; Doorley et al., 2015; Johnson, Oxley, Newstead, & Charlton, 2014; Sanders, 2013). Even though the differences in laypeople and experts perceive risk could constitute a problem when it comes to other risk sources, these differences are to a less extent relevant when it comes to the use of private transport modes.

1.3.2 Risk perception

Risk perception is a psychological concept that refers to an individual's own judgements of risk. In accordance with Sjöberg (1998) and Sjöberg, Moen, and Rundmo (2004) risk perception is defined in this thesis as people's cognitive assessment of the probability and judgment of the severity of consequences of a negative outcome. This definition is in accordance with how risk is defined within the field of risk analysis, in which experts use theoretical models to calculate and assess risk (Rausand & Utne, 2009). In the thesis, I focus on risk perception among active travellers (cyclists and pedestrians). The studied consequences of being a pedestrian included potential accidents, theft, harassment, and acts of terrorism, while the consequences for cyclists included being involved in accidents with other road users and in single accidents (e.g. falling or running off the road).

Most research on decision-making under risk has been cognitive and has influenced research on risk perception. Together with the cultural theory of risk (Douglas & Wildavsky, 1983), the psychometric paradigm of risk perception has dominated the field of risk perception research in recent decades (Sjöberg et al., 2004). The psychometric paradigm approach is characterized by the use of psychometric scaling methods to measure how characteristics of hazard sources relate to perceptions of risk, and has been used in studies of individuals' ratings of different hazard sources (Breakwell, 2007; Fischhoff et al., 1978; Slovic, 1992; Slovic, Fischhoff, & Lichtenstein, 1979).

A key article in which the approach is applied is by Fischhoff et al. (1978). The article is based on a study in which psychometric procedures were used to elicit quantitative judgements of perceived risk. In the study, the respondents were first asked to consider the risk of dying as a consequence of 30 different activities or technologies (e.g. smoking, bicycles, motor vehicles, and nuclear power). These questions were used as general measures of perceived risk. As the next step in the questionnaire, the respondents were asked to rate nine different statements for the same activities or technologies:

1. Whether people faced the risk source voluntarily (1 = voluntary; 7 = involuntary)
2. Whether death was effected immediately or delayed (1 = immediate; 7 = delayed).
3. Whether the risk level was known to the persons exposed to the risk (1 = known precisely; 7 = not known)
4. The extent to which the risk is 'known to science' (1 = known precisely;

7 = not known)

5. The level of control (measured by asking the respondents to rank their perceived level of control if they were exposed to the risks (1 = uncontrollable; 7 = controllable)
6. The newness of the risk (measured by asking respondents to rank whether they considered the risks as novel or familiar (1 = new; 7 = old).
7. The chronic versus catastrophic potential of the risk – whether the activities or technologies kill one person at a time (chronic) or a large number at once (catastrophic) (1 = chronic; 7 = catastrophic)
8. Whether the risk evoked great dread or was seen as common and could be thought about reasonably and calmly (1 = common; 7 = dread)
9. The severity of the consequences of the risk linked to the given activities or technologies (measured by asking the respondents to rate the likelihood that the consequences in the form of a mishap or illness would be fatal (1 = certain not to be fatal; 7 = certain to be fatal).

Fischhoff et al. (1978) found that the general measures of perceived risk correlated with only two of the nine items, namely dread and the severity of the consequences. In Fischhoff et al.'s study, the question measuring the latter did not ask the respondents to evaluate the severity of consequences of a negative incident. Rather the question concerned their evaluation of the likelihood or the perceived probability that a mishap or illness would be fatal. Accordingly, the question could be seen as a measure of the perceived probability of a fatal incident occurring.

Further, Fischhoff et al. (1978) found that the nine different items tended to be highly intercorrelated. By means of a principal component analysis, they found two higher-order characteristics or dimensions. The first dimension was defined as hazards judged to evoke the feeling of dread, to have catastrophic potential, to have fatal consequences, and the inequitable distribution of risks and benefits. The second dimension was defined as hazards judged to be unknown, unobservable, new, and delayed in their manifestation of harm (Slovic, 1987). Slovic (1987) argues that dread is the most important dimension for perceived risk among laypeople. Accordingly, feelings are an important dimension of perceived risk. The higher the score on this factor, the higher the perceived risk. Other feelings shown to be associated with perceived risk are worry, anticipated regret, fear, anger, outrage, and panic (for an overview of feelings associated with perceived risk, see Breakwell, 2007).

1.3.3 Affect and worry

Although early research using the psychometric paradigm showed that feelings of dread were an important factor for perceived risk (Fischhoff et al., 1978), cognitive models have since dominated risk perception and risk-taking research (Breakwell, 2007). Recently, affective processes have received increased attention. The risk-as-feelings approach highlights the role of emotions in risk decisions (Loewenstein et al., 2001). According to Loewenstein et al. (2001), two types of emotions are important for risk perception: anticipatory emotions and anticipated emotions. Anticipatory emotions are immediate visceral reactions to risk, such as worry, fear, anxiety, and dread, whereas anticipated emotions are what an individual expects to have as a consequence of a decision (e.g. anticipated regret). Furthermore, anticipatory emotions can be subdivided into integral emotions and incidental emotions. Integral emotions are caused by the decision problem itself, whereas incidental emotions are caused by other factors, such as mood (Loewenstein & Lerner, 2003). In this thesis, the associations between perceived risk and anticipatory feelings of worry about cycling and walking are examined. It is well recognized that hazards often engender worry (Breakwell, 2007). Worry is an emotional state stimulated by the anticipation of a negative outcome that is uncertain and may happen in the future. According to Breakwell (2007), by definition worry is associated with risk. In this thesis, worry is considered an anticipatory emotion and integral to the decision problem, which implies that worry is defined as a feeling that emerges as a reaction to an individual's cognitive assessment of risk. Dread and fear are other feelings that could be considered anticipatory emotions that are integral to the decision problem.

Slovic, Finucane, Peters, and MacGregor (2004) refer to 'risk as feelings' as fast, intuitive reactions to danger. They argue that such affective feelings are important for decision-making and risk perception. They define affect as 'the specific quality of "goodness" or "badness" (i) experienced as a feeling state and (ii) demarcating a positive or negative quality of a stimulus' (Slovic et al., 2007, p. 1333). Slovic et al. (2007) illustrate this with words that release feelings such as treasure or hate. They termed decisions based on such emotions the 'affect heuristic'. The affect heuristic happens fast and automatically. Heuristics are a form of cognitive strategy and problem-solving methods that use shortcuts to find solutions in complex situations, given a limited time frame or decline when solving a problem. Decisions made using a heuristic approach may not necessarily be optimal (Slovic et al., 2007). The use of heuristics is opposite to the use of reasoning, whereby people use

systematic reasoning to solve problems and find optimal solutions. Simon (1957) illustrates this in his theory of bounded rationality: people choose solutions that are 'good enough' for their purpose but could be optimized. The study of heuristics in human decision-making was developed in the 1970s and 1980s by Tversky and Kahneman (1974) and Kahneman, Slovic, and Tversky (1982). The psychometric paradigm in risk perception research has its origins in those studies (Fischhoff et al., 1978; Slovic, 1987). Affect may be regarded as anticipatory emotions and incidental to a decision problem.

Risk perception and worry are primarily of interest because they may relate to people's behavioural choices. According to the risk-as-feelings approach, such choices are influenced by the interplay between cognitive evaluations of risk and feelings. Furthermore, emotions often produce behavioural responses that differ from an individual's cognitive assessment of the best course of action. Apparently, when divergence occurs, behaviour is driven by emotional reaction, not by cognitive assessment (Loewenstein et al., 2001). Loewenstein et al. (2001) argue that in contrast to cognitive evaluations, anticipatory emotions such as worry, dread, and fear are largely insensitive to changes in probabilities. The authors refer to different experiments in which subjects were given information about probability estimates of winning a lottery, receiving an electric shock, or investing money. The experiments showed that changes in probability estimates did not influence the emotional state of the research subjects. The effect is known as the certainty effect and it supports the risk-as-feelings hypothesis, which suggests that when making behavioural choices, people will be less affected by changes in the probabilities of a negative outcome, the more the consequences themselves evoke anticipatory emotions such as worry, dread, or fear.

In contrast to the findings of Loewenstein et al. (2001), Baron, Hershey, and Kunreuther (2000) found that worry was largely affected by probability judgements, especially among laypeople, and that their respondents' desire for action largely was determined by worry and probability judgements. They used a questionnaire with a list of 32 different risks, each of them defined in terms of a cause and an outcome (e.g. injury or death from an automobile accident). For each risk, the respondent was asked (among other questions) to give probability estimates, to estimate the badness of the outcome, the number of persons affected, and how much he or she worried about the risk. A similar approach was adopted during the research for this thesis and the role of worry was investigated in addition to assessing probabilities and the severity of the consequences of an accident when cycling.

Social cognition theory and models have dominated risk perception research and there is a need for more studies that include a focus on the role of emotions in perceived risk as well as in decisions under uncertainty. However, this thesis did not aim to test the risk-as-feelings model or the nine dimensions in the psychometric paradigm. These models have been tested in studies carried out previously. According to Breakwell (2007, p. 109), 'an analysis of risk perception and decision-making that fails to consider the affect attached to a hazard, or the emotional state of the individual, is inevitably flawed.' To have a full understanding of individuals' risk assessment, both cognition and emotions should be included.

1.3.4 Attitudes towards traffic safety

In line with Fischhoff et al. (1978, p. 130), risk perception may be seen as attitudes toward risk. Other attitudes that may be related to people's behavioural choices in traffic are attitudes towards behaviour that may influence safety in traffic (attitudes towards traffic safety). To my knowledge, few studies have investigated attitudes toward traffic safety as a predictor of vulnerable road users' risk-taking behaviour. Most studies that have investigated the relationship between attitudes and behaviour among vulnerable road users have studied cyclists' helmet use (Quine, Rutter, & Arnold, 1998, 2001). However, attitudes toward traffic safety have been found important for other types of road users' risk-taking behaviour. Especially, studies of drivers have contributed to enhance our knowledge of the role of attitudes in risk-taking behaviour in traffic (e.g. Iversen & Rundmo, 2004, 2009; Nordfjærn, Jørgensen, & Rundmo, 2011; Nordfjærn, Jørgensen, & Rundmo, 2010; Parker, Manstead, Stradling, Reason, & Baxter, 1992; Åberg, 1993).

The most influential theories regarding the association between attitudes and behaviour are the theory of reasoned action (TRA) (Fishbein, 1968) and the theory of planned behaviour (TPB) (Ajzen, 1991). According to these theories, behavioural intention is influenced both by people's attitudes to specific types of behaviour and by their subjective norms. Additionally, TPB includes perceived behavioural control as a predictor of behavioural intention. TRA and TPB have been applied in studies of road users' risk-taking behaviour, which have found that road users' attitudes are positively associated with their behavioural intentions (Evans & Norman, 1998, 2003; Parker et al., 1992; Quine et al., 1998, 2001; Rosenbloom, Beigel, & Eldror, 2011; Åberg, 1993). The attitude–behaviour relation has been empirically robust in studies across different types of road users' risk-taking behaviour. Consequently, there is no need to test the entire models of TRA or TPB. However, the specific

relation between attitudes and behaviour has been relatively little studied with regard to vulnerable road users. Therefore, investigations of associations between attitudes towards safety and self-reported risk-taking behaviour when cycling is focused in the current research. Based on findings related to other travel modes than cycling, the thesis investigates whether attitudes are important for cyclists' risk-taking behaviour in urban and rural traffic environments.

1.3.5 Risk tolerance, safety priority, and risk protection

In addition to feelings and attitudes, risk tolerance, safety priority, and risk protection are important aspects of how individuals relate to risk. However, the number of studies of risk tolerance, risk protection, and safety priority among cyclists has been limited to date.

In this thesis, *risk tolerance* is defined as the extent to which individuals tolerate being exposed to risk when cycling and walking during their daily travels. Individuals may differ in their thresholds for the level of risk they find acceptable. The original impetus for the psychometric paradigm came from Starr (1969), who measured the level of risk that individuals found acceptable for different activities and found that activities that were voluntary and perceived as beneficial were tolerated more than other activities. Starr (1969) concluded that voluntariness of exposure was the key mediator of risk acceptance. In a later study conducted by Fischhoff et al. (1978), respondents were asked to judge the acceptability of the current level of risk for each of 30 different activities or technologies (including cycling). The results showed that the risk levels were less tolerated when the activities were associated with dread. Fischhoff et al. (1978) also found that higher risk levels were tolerated for voluntary activities with well-known and immediate consequences.

The terms 'risk tolerance' and 'risk acceptance' are often used interchangeably. However, Sjöberg (1999b) argues that they are two separate concepts. Risks are less likely to be accepted and more likely to be tolerated. One may be aware of a certain risk and choose to tolerate it, even if one does not accept it. To my knowledge, few studies to date have investigated risk tolerance among cyclists and pedestrians. In a study conducted by Parkin, Wardman, and Page (2007), models were developed based on perceived cycling risk for different cycling routes and provided a measure of acceptability for those routes. Their study measured perceived risk by using video clips of cycling routes with different types of cycling infrastructure and traffic environment. The study was conducted like a hazard-detection experiment in which the respondents were asked to rate the risk on a 10-

point scale across different situations that were presented in video clips (Parkin et al., 2007). Risk acceptance was measured by asking the respondents to indicate the risk scale point at which they perceived it was too dangerous to cycle. Their models were used to show how changes in infrastructure could reduce perceived risk and make a route acceptable for cycling. The results of Parkin et al.'s (2007) study showed demographical differences in risk acceptance for cycling. Both young and elderly people rated a lower threshold for the acceptable level of risk than people in the age range 35–44 years did, and males rated a higher threshold for the acceptable level of risk than females did (Parkin et al., 2007). Other similar studies of pedestrians' or cyclists' risk acceptance in different traffic situations (e.g. gap acceptance when crossing the road) have been conducted (e.g. Lehtonen, Havia, Kovanen, Leminen, & Saure, 2016; Pawar & Patil, 2015). The definitions of risk acceptance used in these studies are not directly related to how risk tolerance is defined in this thesis. In the thesis risk tolerance related to cycling or walking overall, and not directly related to different types of traffic situations, infrastructure or traffic environment.

In this thesis, *safety priority* is investigated in two different ways: Study 1 examined the demands made to decision-makers to prioritize road safety for cyclists, and Study 3 examined the extent to which respondents prioritize their own safety when using different modes of transport (Moen & Rundmo, 2004). Safety priority relate to behavioural choices that either one has to take as an individual or that one demands that the authorities take. Both perspectives of safety priority are interesting to investigate because they could be differently associated with worry, perceived risk, safety attitudes, and risk-related behaviour. Moen (2007) studied *individuals' safety priority* when choosing different transport modes (including cycling) and found that worry and attitudes toward traffic rules were important predictors of individuals' safety priority in transport. A number of studies have investigated *demands for safety priority* or risk mitigation related to choice of mode of transport (Nordfjærn & Rundmo, 2010; Rundmo & Moen, 2006; Şimşekoğlu, Nordfjærn, & Rundmo, 2015; Sjöberg, 1999b) and some of them have included cycling and walking (Nordfjærn & Rundmo, 2010; Rundmo & Moen, 2006). Rundmo and Moen (2006) found that cycling and walking had the lowest score on demand for risk mitigation. However, the differences between the scores for the private transport modes (walking, cycling, private car, motorcycle. scooter) included in their study were small. Additionally, Rundmo and Moen (2006) found that worry was more strongly associated with demand for risk mitigation than was evaluation of consequences.

Risk protection refers to how an individual considers the possibility to protect themself against risk or to the perceived controllability of the risk. Risk protection is related to behavioural choices that could protect the individual against a risk. The perceived controllability of a risk has been found important for individuals' perception of risk, and people tend to rate a risk as lower when they think they have control over it (Higgins, St Amand, & Poole, 1997). The level of perceived control when exposed to risks is one of the nine dimensions in the studies conducted by Fischhoff et al. (1978).

Risk tolerance, safety priority, and risk protection are all terms related to situations in which the individual perceives they are exposed to risk. Whereas risk tolerance may be seen as the level of risk at which the individual tolerates exposure, safety priority relates the individual's choice or the demand for the authorities to prioritize safety. The related term risk protection refers to how individuals consider the possibility to protect themselves against risk. For example, an individual may not tolerate being exposed to risk (risk tolerance), choose to prioritize safety (individuals' safety priority), and believe that changes in behaviour may contribute to protect himself or herself against the risk (risk protection). Accordingly, in this thesis, it is hypothesized that safety priority, risk protection and risk tolerance may be correlated. Nerveless they are considered to be conceptually different. Study 1 investigated how risk tolerance and safety priority influenced cycling frequency during wintertime, Study 2 examined how risk tolerance and perceived risk protection influenced walking frequency during night-time and daytime, while Study 3 investigated how risk tolerance and safety priority affected cyclists' risk-taking behaviour.

1.3.6 Accident and assault experiences

Other aspects that could influence an individual's risk perception and worry are previous experiences of accidents and assaults. A previous study found that cyclists who had experienced an accident in the past perceived their probability of being in an accident as higher than did respondents who never had experienced an accident while cycling (Kummeneje & Rundmo, 2018). The cyclists who had experienced an accident also tended to be more worried about being involved in an accident when cycling. There were no differences in the perceived severity of consequences between the two groups. Washington, Haworth, and Schramm (2012) investigated the relationship between self-reported injuries and perceived risk of Australian cyclists, and did not find any association between injuries and perceived risk. Accordingly, in Study 2 and Study 3, the association between previous negative experiences, and risk

perception and worry on the other hand was studied. The studies also investigated whether previous negative experiences influenced pedestrians' walking frequency and cyclists' risk-taking behaviour in traffic.

1.3.7 Risk-taking cycling behaviour

A number of recently published studies have investigated cyclists' risk-taking behaviour (Fraboni, Puchades, De Angelis, Prati, & Pietrantoni, 2016; Hezaveh, Zavareh, Cherry, & Nordfjærn, 2018; Useche, Alonso, Montoro, & Esteban, 2018; Useche, Montoro, Tomas, & Cendales, 2018). In this thesis, risk-taking cycling behaviour is defined as violations of traffic rules, and/or often engaging in conflicts with other road users when cycling. Examples of violations include cycling after consuming alcohol, crossing the road against a red traffic light, and cycling while using a mobile phone. Examples of conflicts with other road users include near accidents when a cyclist has to brake hard or turn quickly to avoid collision with another road user and situations in which a cyclist fails to notice another road user.

Two questionnaires have been developed for measuring cyclists' behaviour in traffic: the Cyclist Behaviour Questionnaire (CBQ) by Useche, Montoro, et al. (2018), and the Bicycle Rider Behaviour Questionnaire (BRBQ) by Hezaveh et al. (2018). The CBQ includes questions about errors and traffic violations, as well as positive types of behaviour by cyclists. In the same questionnaire, some of the questions about errors relate to what I have defined as conflicts with other road users. The CBQ was validated by Useche, Montoro, et al. (2018), who used a sample of cyclists from 20 Spanish-speaking countries. The BRBQ includes questions about traffic violations, stunts and distractions, notice failure, control errors, and signalling violations. The questionnaire was validated by Hezaveh et al. (2018), who used a sample of Iranian cyclists and was found useful for predicting self-reported crashes. Neither the CBQ nor the BRBQ include questions about the use of safety equipment such as helmets, cycle lights, safety reflectors, and high-visibility clothing (e.g. safety vest).

Compared to drivers of motorized vehicles, there are few studies about cyclists' risk-taking behaviour. Considering the target to increase the number of cyclists, there is a need for more studies to explore factors related to cyclists' risk-taking behaviour in traffic. The purpose of Study 3 (presented in Paper III) was to investigate predictors of cyclists' risk-taking behaviour in traffic from the cyclists' perspective, primarily focusing on behaviour that influenced the probability of them being involved in an accident.

1.4 Specific aims

Paper I

The main aim of the study presented in Paper I was to investigate how people perceived risk when cycling in winter compared with in summer conditions. An additional objective was to investigate the association between perceived risk and the decision to cycle. The specific aims were as follows: (1) to examine differences in cyclists' risk perception and worry when cycling in winter and summer conditions, (2) to investigate whether cyclists' risk perception and worry were associated with their decision to cycle during wintertime, (3) to examine whether risk perception and worry were associated with their cycling frequency during wintertime, (4) to compare the role of risk perception and worry for cycling frequency during all four seasons, and (5) to examine the direct and indirect associations between risk perception, worry and cycling frequency during wintertime. Accordingly, some other potential predictors of cycling frequency were included in the analyses as independent variables, including demographics, attitudes towards traffic safety, safety priority, and risk tolerance (Figure 2).

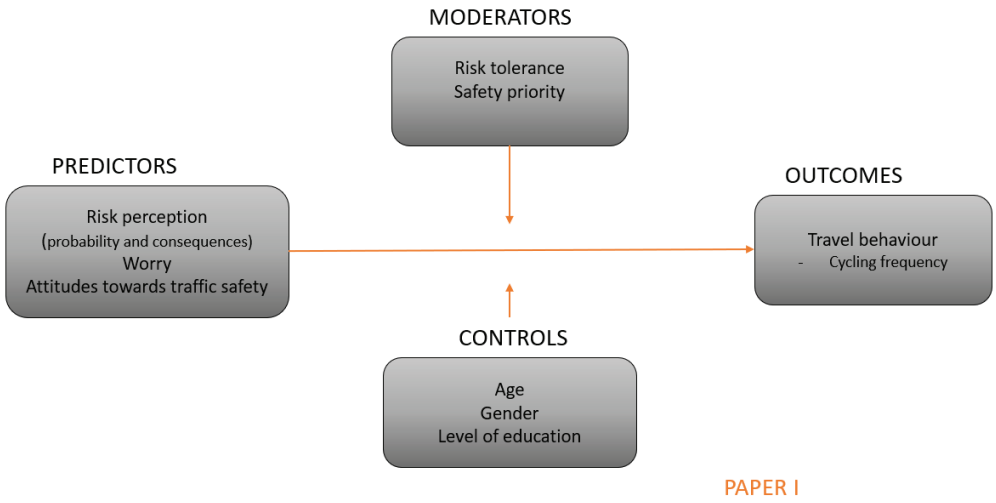

Figure 2. Variables and the relationships between them examined in Paper I

Paper II

The aim of the study presented in Paper II was to investigate what worried pedestrians, the association between their perceived risk and worry, and whether worry was associated with their decision to walk during their daily travels. The specific aims of the study were: (1) to examine differences in worry and risk perception related to being a pedestrian during night-time and daytime; (2) to investigate whether risk perception influenced worry about being a pedestrian during night-time and daytime; (3) to compare the role of risk perception in worry about being involved in an accident, and/or experiencing harassment, theft, and acts of terrorism; (4) to examine the direct and indirect associations between risk perception, risk protection, risk tolerance, previous accidents and assault experiences, and worry about being a pedestrian; and (5) to examine the association between worry and walking frequency as a pedestrian during night-time. The variables examined in Paper II are shown in Figure 3.

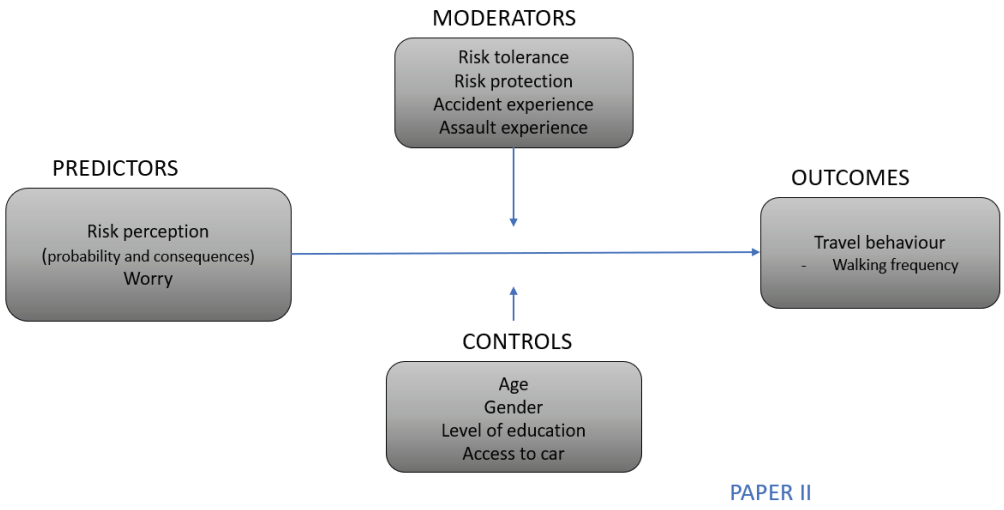

Figure 3. Variables and the relationships between them examined in Paper II

Paper III

The main aim of the study presented in Paper III was to investigate whether attitudes toward traffic safety, risk perception, worry, risk tolerance, safety priority, and previous accident involvement were associated with cyclists' risk-taking behaviour. Two types of cyclists' risk-taking behaviour were studied: (1) 'violation of traffic rules' and (2) 'conflicts when cycling'. The current study examined whether attitudes towards traffic safety and risk perception affected cyclists' behaviour in traffic to the extent that they violated traffic rules and engaged in conflicts with other road users. The examined variables and the relationships between them are shown in Figure 4.

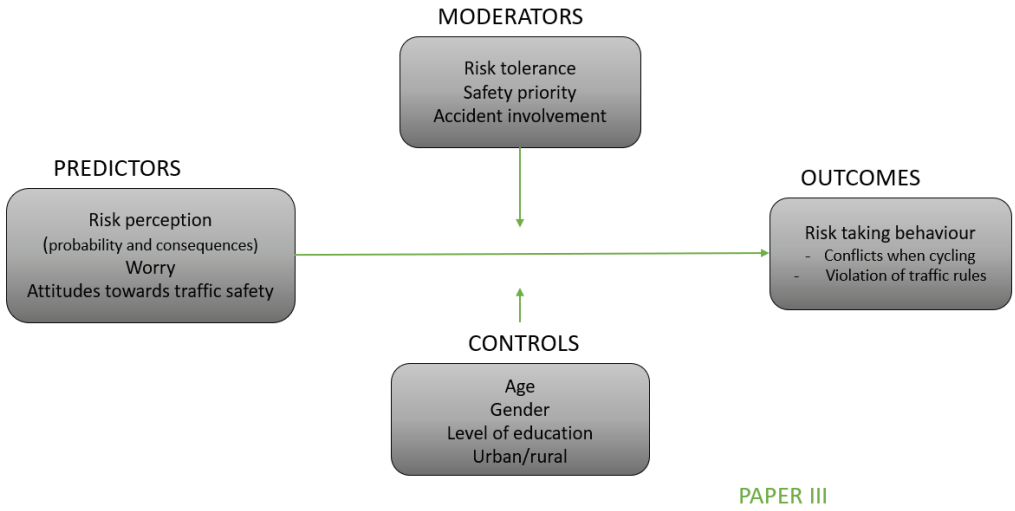

Figure 4. Variables and the relationships between them examined in Paper III

2 Method

2.1 Sampling procedures

The results of the research for this thesis are based on three different datasets collected in the beginning of 2017. Study 1 was carried out among members of an Internet-based group for everyday cyclists in Trondheim Municipality, Norway. All 2240 members were invited to participate in the study by answering a self-completion online questionnaire survey, and the response rate was 13% (n = 291). The data for Study 2 were collected through telephone interviews with a representative sample of the Norwegian population (age range 15–88 years) (n = 2000). The telephone interviews were financed by the Norwegian Public Roads Administration (NPRA) as a part of the two research and development (R&D) programmes, 'Bedre by' and 'BEST'. The data collection company NORSTAT was responsible for conducting the interviews. NORSTAT was asked to recruit respondents until they had a sample of 2000 respondents. The response rate was 27%. The data for Study 3 were collected through an online questionnaire distributed through a magazine sent by post to ca 10,000 members of the Norwegian Cyclists' Association. The address of the web page with the questionnaire was included in the written invitation to participate in the survey, which was sent together with the magazine. Only members who had used their cycle for regular trips during the last year were asked to answer the questionnaire. In total, 426 members completed the questionnaire. The surveys used in Study 1 and Study 3 were distributed in collaboration with the Norwegian Cyclists' Association.

2.2 Characteristics of the samples

The characteristics of the three samples are presented in the following.

2.2.1 Study 1

In the sample in Study 1, which comprised 291 cyclists in Trondheim Municipality, all respondents cycled on a daily basis during summer (at least 1–2 times per week). The percentages of females and males in the sample were 36% and 64% respectively. They were in the age range 20–77 years (Mean = 43.47, SD = 11.73). A total of 69% of the respondents reported that they had more than three years of university education, 19% had three years or less of university education, and 12% had received their highest level of education at upper secondary school. A total of 88% reported

their main occupation as employed, and the remaining 12% were students or pensioners. A total of 3% of the respondents reported that they did not have a driving license, and 17% did not have access to a car or to other motorized vehicles.

2.2.2 Study 2

In Study 2, which was based on a representative sample of 2000 members of the Norwegian population, the respondents were in the age range 15–88 years (Mean = 45.38, SD = 17.56), and 57% were male and 43% were female. A total of 9% of the respondents had primary or secondary school education as their highest completed education level, 34% had upper secondary school as their highest completed education level, and a high proportion of the sample (57%) had completed higher education from college or university. A total of 62% reported that they were employed or self-employed, and 10% were students. The remaining respondents were pensioners, benefit recipients, or homemakers. A total of 10% of the respondents reported that they did not have a driving license, and 13% did not have access to a car or other motorized vehicle.

2.2.3 Study 3

All respondents in Study 3, which included 426 Norwegian cyclists, reported that they cycled on a daily basis during summer (at least 1–2 times per week), and 61% reported that they cycled at least once per week during winter. There were 34% females and 66% males in the sample. Their age ranged from 18 years to 81 years (Mean = 50.59, SD = 12.61). A total of 64% of the respondents reported that they had more than three years of university education, 23% had three years or less of university education, 11% had received their highest level of education at upper secondary school, and 2% had not studied after primary school. The majority of the respondents (84%) reported that they were employed, 10% were pensioners, 2% were students, and the remaining 4% were job applicants or benefit recipients. Only 6% of the respondents reported they did not have a driving licence and 15% did not have access to a car or other motorized vehicles. A relatively small proportion of the sample (6%) reportedly lived in rural areas with less than 2000 inhabitants. Respondents in peri-urban areas with between 2000 and 20,000 inhabitants constituted 19% of the sample, whereas 24% of the sample lived in urban areas with 20,000–100,000 inhabitants. More than half of the sample (51%) lived in urban areas with between 100,000 and 700,000 inhabitants. The latter group included the

four largest cities in Norway (Oslo, Bergen, Trondheim, and Stavanger). The characteristics of the three samples are summarised in Table 1.

Table 1. Sample characteristics in Study 1, Study 2, and Study 3.

	Study 1 (n=291)	Study 2 (n=2000)	Study 3 (n=426)
Age, mean (SD)	43.47 (11.73)	45.38 (17.56)	50.59 (12.61)
Gender			
Female	36%	43%	34%
Male	64%	57%	66%
Level of education			
University, 4+ years	69%	29%	64%
University, 1-3 years	19%	28%	23%
Upper secondary school	12%	34%	11%
Primary or secondary school	–	9%	2%
Employment status			
Employed	88%	62%	84%
Student	7%	10%	2%
Other	3%	28%	14%
Driving license			
Yes	97%	90%	94%
No	3%	10%	6%
Access to car			
Yes	83%	87%	85%
No	17%	13%	15%
Geographical area of residence			
Less than 2000 inhabitants			6%
2000–20,000 inhabitants			19%
20,000–100,000 inhabitants			24%
100,000–700,000 inhabitants	100%	*	51%

* Geographical area of residence were not included as a measure. The study included a representative sampe of the Norwegian public.

2.3 Measures

An overview of the measures used during the research for this thesis is presented in Figure 5. Study 1, Study 2, and Study 3 are presented in Paper I, Paper II and Paper III of this thesis. (See Appendix for the three questionnaires used in the studies).

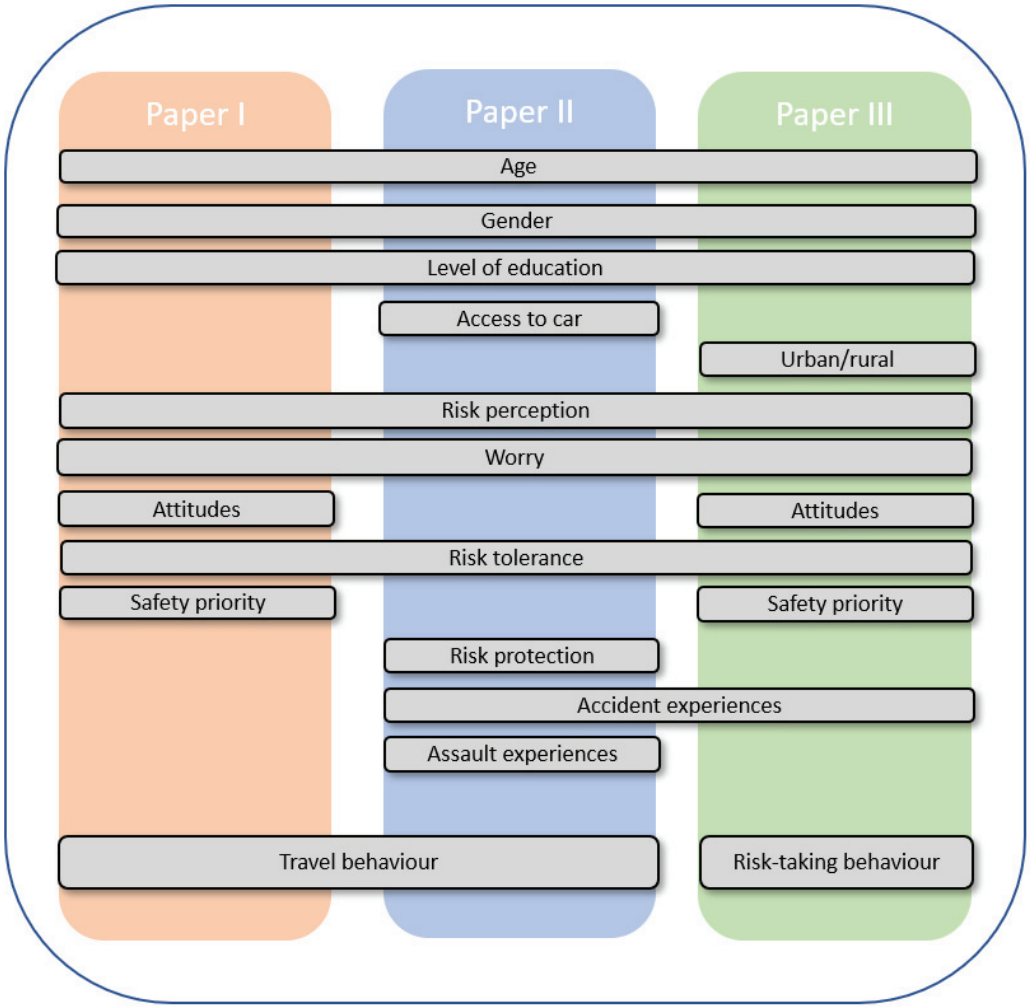

Figure 5. Overview of measures used in Paper I, Paper II and Paper III

2.3.1 Risk perception and worry

All three studies included measures on risk perception and worry about hazards as a cyclist (Study 1 and Study 3) or as a pedestrian (Study 2). To measure *risk perception*, the respondents were asked to assess their probability of experiencing different types of hazards when cycling or walking in a traffic environment, and to anticipate the severity of consequences if the named hazards were to take place. Further, in all three studies the respondents were asked to rate how *worried* they were about experiencing each of the different types of hazards when cycling or walking.

In *Study 1*, the respondents were asked to assess their probability of experiencing an accident involving injury to themselves when cycling, and to judge the severity of the consequences if such an event were to occur. The respondents were further asked to rate how worried they were about being involved in an accident involving injury when cycling.

In *Study 2*, the respondents were asked to assess their probability of experiencing four different hazards, and to judge the severity of the consequences if such a hazard were to occur. The four types of hazards were (1) traffic accidents, (2) theft, (3) harassment, and (4) acts of terrorism. The respondents were further asked to rate how worried they were about experiencing each of the four hazards as a pedestrian. All eight questions were asked twice: first with regard to walking in daytime and second with regard to walking at night.

In *Study 3*, the respondents were asked to judge the risk (probability and severity of consequences) and worry about experiencing four different types of accidents when cycling: (1) an accident involving a motorized vehicle, (2) an accident involving another cyclist, (3) an accident involving a pedestrian, and (4) a single accident (e.g. falling or running off the road).

In all three studies the probability assessments were measured on a five-point scale ranging from (1) ‘not at all probable’ to (5) ‘very probable’. The judgement of the severity of consequences was measured on a five-point scale ranging from (1) ‘not at all serious’ to (5) ‘very serious’. Worry was measured on a five-point scale ranging from (1) ‘not at all worried’ to (5) ‘very worried’.

2.3.2 Attitudes towards traffic safety

Attitudes towards traffic safety were measured by a reversed version of an instrument previously designed by Iversen and Rundmo (2004, 2009). The original instrument was designed to measure negative attitudes toward rules among car drivers. The instrument was revised in order to measure cyclists’ attitudes towards traffic safety.

The attitude instrument included statements regarding safety aspects when cycling such as rule violations, attitudes towards taking chances, and attitudes towards traffic surveillance of cyclists' behaviour. The questions about cyclists' attitudes towards traffic safety included in Study 1 and Study 3 are presented in Table 2 The table presents the questions in the same order as in the questionnaires. The respondents were asked to what extent they agreed or disagreed with different statements and to give their response on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). The instrument used in Study 1 included 13 items. In Study 3, two additional items about cycling against a red traffic light and taking chances as a cyclist were included. Items 4, 10, 11, and 12 in Table 2 were revised from Study 1 to Study 3 to make the statements clearer, easier to understand and less open to differences in interpretation.

Table 2. Items measuring attitudes toward traffic safety in Study 1 and Study 3

No.	Items	Study 1	Study 3
1	Many traffic rules for cyclists are impossible to comply with	X	X
2	Sometimes it is necessary to bend the rules as a cyclist to make sure of arriving	X	X
3	Cyclists should always follow the rules	X	X
4	Cyclists who never violate the rules do not necessarily behave more safely than others/Breaking rules does not necessarily make one a less safe cyclist compared with those who always follow the rules	X	X
5	It is no wonder that many cyclists violate traffic rules	X	X
6	The traffic rules for cyclists are too complicated to adhere to in practice	X	X
7	Many traffic rules for cyclists are unnecessary	X	X
8	There should be more traffic surveillance of cyclists	X	X
9	There should be severe punishments for cyclists who break traffic rules	X	X
10	It is not important to have road safety campaigns directed towards cyclists/It is important to have road safety campaigns directed towards cyclists	X	X
11	It is OK to bend the rules if no other road users are present/It is acceptable to break the rules as a cyclist when no others are involved	X	X
12	It is OK to cycle after drinking alcohol/It is acceptable to cycle after drinking alcohol (> 0.2‰)	X	X
13	It is more important to get ahead as a cyclist than always to follow the rules	X	X
14	It is acceptable to cycle against a red traffic light when no others are present		X
15	It is acceptable to take chances as a cyclist when only you are exposed to risk		X

To what extent do you agree or disagree with the following statements?
(1 = strongly disagree; 5 = strongly agree) X = item included

2.3.3 Risk tolerance, safety priority, and risk protection

Questions about risk tolerance were included in all three studies. *Risk tolerance* was measured by asking the respondents: ‘To what extent do you tolerate being exposed to risk when cycling?’ (Study 1 and Study 3) or ‘To what extent do you tolerate being exposed to risk as a pedestrian?’ (Study 2). The five-point evaluation scale ranged from ‘do not tolerate any risk’ to ‘tolerate the risk absolutely’. In In Study 1 the

respondents were asked to evaluate risk tolerance when cycling in winter and summer conditions. In Study 2 and Study 3 the respondents were asked to evaluate their risk tolerance as a pedestrian or cyclist in general.

In Study 1, *safety priority* was measured by asking the respondents to answer the following question: 'How important do you think it is that the authorities prioritize measures to improve safety for cyclists?' The five-point scale ranged from 'not at all important' to 'very important'. In Study 3, safety priority was measured by asking the respondents to answer the question 'To what extent do you prioritize safety as a cyclist?' on a five-point scale from 'do not prioritize safety' to 'prioritize safety absolutely'. In Study 1, the respondents were asked to evaluate their risk tolerance and safety priority both when cycling in winter conditions and summer conditions.

The question about risk protection was only included in Study 2. *Risk protection* was measured by asking the respondents 'To what extent do you think it is possible to protect yourself against risk as a pedestrian?' The five-point scale of responses ranged from 'very possible' to 'not at all possible'.

2.3.4 Accident and assault experiences

Questions about accident experience were included in Study 2 and Study 3. To measure accident experience, the respondents were asked whether they had been involved in an accident as a pedestrian or cyclist during the last two years, including single accidents (i.e. accidents with no other road users involved). If they gave a positive response, they were further asked whether other road users (e.g. cyclists, pedestrians, drivers of motorized vehicles) were involved and whether they needed medical treatment after the accident. In Study 2, the respondents were additionally asked about assault experiences. Assault experiences were measured by asking the respondents whether they had experienced being physically assaulted as a pedestrian during the last two years. If they answered 'yes' to the question, they were further asked whether they had needed medical treatment after the experience.

2.3.5 Risk-taking cycling behaviour

With regard to attitudes towards traffic safety, the measure *risk-taking cycling behaviour* was a reversed version of an instrument developed by Iversen and Rundmo (2004, 2009) to measure risk-taking behaviour among car drivers. The instrument developed as a part of the research for this thesis was revised and designed specifically for studies of cyclists. Risk-taking behaviour was measured using a 10-

item instrument for how often the respondents engaged in various risk-taking activities when cycling in traffic. The questions were about rule violations and conflicts with other road users (Table 3). The items were measured by a five-point scale: (1) Never, (2) Rarely, (3) Neither/nor, (4) Often, (5) Very often. The measures for behaviour and attitudes have shown good psychometric feasibility in previous research when used in connection with car drivers (e.g. Iversen & Rundmo, 2004; Ulleberg & Rundmo, 2003).

Table 3. Items measuring risk-taking cycling behaviour in Study 3

No.	Item
1	Cycle when using a mobile phone
2	Cycle in the dark without cycle lights
3	Cross the road when a traffic light is red
4	Use a pedestrian crossing when the light is red for pedestrians
5	Cycle after drinking alcohol (> 0.2‰)
6	Cycle against traffic in one-way streets
7	Fail to notice a vehicle approaching from a side road
8	Brake hard because a vehicle is approaching faster than expected
9	Turn quickly away from a vehicle to avoid an accident
10	Brake hard down and/or turn quickly to avoid hitting a pedestrian

How often do you do the following when cycling? (1 = never, 2 = rarely, 3 = neither/nor, 4 = often, 5 = very often)

2.3.6 Walking and cycling frequency

To measure *walking and cycling frequency*, the respondents were asked how often they usually cycled or walked during different seasons and at different times of the day. For these measurements, a six-point evaluation scale was used: 5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; and Never. Previous studies of cycle use in Norway have found the same measure appropriate (Kummeneje & Tretvik, 2015; Tretvik, 2015). In Study 1, cycling frequency was measured by asking the respondents how often they cycled each season (winter, spring, summer, and autumn). In Study 2, walking frequency was measured by asking the respondents how often they walked outside during night-time and daytime in each season (winter, spring, summer, and autumn). Respondents who answered that they had walked outside more often than monthly during night-time, were further asked

whether they sometimes walked alone (without a family member, friend or dog). A three-point evaluation scale was used: Often, Sometimes, and Never.

2.3.7 Demographics

The demographic variables included age, gender (male, female), employment status, highest level of completed education, possession of a driving licence (yes, no), and motorized vehicles at their disposal (yes, no). All variables were measured using the same items in all three studies. Age was measured by year of birth, and prior to any analysis was converted to the respondents' age. Employment status was measured on a four-point scale: (1) employed; (2) student; (3) pensioner; and (4) other. Education was measured using four choices: (1) primary or lower secondary school, (2) upper secondary school, (3) three years or less of university education; and (4) more than three years of university education. Geographical area of residence was only included in Study 3 and measured on a 4-point scale: (1) less than 2000 inhabitants, (2) between 2000 and 20,000 inhabitants, (3) between 20,000 and 100,000 inhabitants, and (4) more than 100,000 inhabitants.

2.4 Statistical analysis

This section briefly presents the statistical analysis used in the research for this thesis. Descriptive statistics were in all three studies used to find the characteristics of the samples.

In *Study 1*, paired sample t-tests were used to investigate differences in risk perception (probability and consequence of being in an accident), worry, risk tolerance, and safety priority between cycling in winter conditions and summer conditions. Further, confirmatory factor analyses (CFA) were performed to test the dimensional structure of the respondents' attitudes towards traffic safety. A total of 13 items were included. A hierarchical logistic regression analysis was performed to predict whether respondents used their cycle during wintertime. In addition, four separate hierarchical linear regression analyses were performed to predict the amount of cycling done in each of the seasons. The R-squared values and the F-change values were reported for all four models. The standardized beta coefficients were reported for Model 5 and Model 6 of the analysis performed to predict cycling frequency during winter. Additional SEM analyses were performed to test the fit of the data to the linear regression models. The SEM examined path models for predicting cycling frequency during the winter season.

In *Study 2*, paired sample t-tests were used to compare differences in respondents' risk perception and worry for four different hazards (traffic accidents, theft, harassment, and acts of terrorism) between walking during night-time compared with in daytime. A SEM (structural equation modelling) analysis was performed to investigate risk perception as a predictor of worry as a pedestrian, and whether risk tolerance, risk protection, accident experience, and assault experience were associated with worry. Further, eight multiple regression analyses were performed to predict worry as a pedestrian during night-time and daytime for each of the four studied hazards (traffic accidents, theft, harassment, and acts of terrorism). Only the contribution of each predictor to the R-squared value was reported and presented in one figure for night-time and one figure for daytime. The linear regression models were used to supplement the SEM analysis, and to compare the contribution of each predictor to the R-squared value between the four hazards. Analyses of variance (ANOVAs) were performed to examine the association between worry and walking frequency during night-time in different seasons of the year. Four analyses were performed using the whole sample, as well as an additional four analyses including only respondents without access to a car. Two analyses were performed to find the association between worry and how often the respondents walked alone during night-time among respondents with access to a car and respondents without access to a car. The variables measuring worry about the four different hazards (traffic accidents, theft, harassment, and acts of terrorism) were summarized as one variable for daytime and one variable for night-time. The two variables were entered as predictor variables to examine the association between worry and behaviour.

In *Study 3*, confirmatory factor analyses (CFA) were performed to test the dimensional structure of the respondents' attitudes towards traffic safety (15 items). Exploratory factor analysis (EFA) with Varimax rotation was performed to test the dimensional structure of the respondents' risk-taking cycling behaviour (10 items). A multivariate analysis of covariance (MANCOVA) was performed to examine the differences in cyclists' attitudes towards traffic safety and risk-taking behaviour according to demographics. Two separate hierarchical linear regression analyses were performed to predict how often cyclists violated traffic rules and how often cyclists were in situations of conflict with other road users when cycling. The standardized beta coefficients, the R-squared values, and the F-change values were presented for all models. Additional SEM analyses were performed to test the fit of the data to the linear regression models. A path model examined cyclists' risk-taking behaviour. The MANCOVA was performed using general linear models (GLMs).

The main effects and interaction effects of attitudes, risk perception and worry were tested for the demographic variables age, gender, education level, and geographical area of residence. The three dimensions from the EFAs measuring attitudes and the two dimensions measuring behaviour were used as dependent variables. The demographic variables were included as fixed factors in the analysis. The variable age was subdivided into three groups: younger adults (18–39 years), middle-aged adults (40–59 years) and older adults (60–81 years). Education level was subdivided into the following groups: no university education, three years or less of university education, and more than three years of university education. Geographical area of residence was subdivided into three groups according to population size: less than 20,000 inhabitants, between 20,000 and 100,000 inhabitants, and between 100,000 and 700,000 inhabitants.

In all the factor analyses (CFA, EFA) preformed in Study 1 and Study 3, the reliability of the indices Cronbach's alpha and corrected inter-item correlations were applied to test for internal consistency. The analyses fulfilled Tabachnick and Fidell's criteria regarding an acceptable sample size (Tabachnick & Fidell, 2014).

In the SEM analyses preformed in Study 1, Study 2 and Study 3, the chi-square degrees of freedom ratio (χ^2/df), the comparative fit index (CFI), the standardized root mean square residual (SRMR), the root mean square error of approximation (RMSEA), and Hoelter's Critical N were calculated to examine the fit of the models to the data. In accordance with established criteria, a χ^2/df ratio of less than 4 (4:1), a CFI above 0.90, an SRMR of .08 or less, an RMSEA of 0.07 or less, and GFI over 0.90 were considered to indicate satisfactory fit between the model and the data. Hoelter's Critical N of 200 or better indicated a satisfactory fit.

3. Results

3.1 Paper I: Seasonal variation in risk perception and travel behaviour among cyclists in a Norwegian urban area

To reduce CO_2 emissions, as well as local air and notice pollution in urban areas, it is important that travellers maintain the use of environmentally friendly modes of transport all year around. Accordingly, the main aim of Study 1 was to examine the association between risk perception and cyclists' decision as to whether to cycle during the different seasons of the year. The target group of the study reported in Paper 1 was urban cyclists who used their cycle for their everyday travels. As expected, the results revealed seasonal differences in perceived risk and worry when cycling in winter compared with in summer conditions. The cyclists perceived the probability of being in an accident as greater when cycling in winter conditions and tended to be more worried. However, there were no differences in the perceived consequences of being involved in an accident in winter conditions and summer conditions. Furthermore, the cyclists tolerated less risk when cycling in winter conditions and thought that more priority should be given by the authorities to improve safety for cyclists who cycled in winter compared with in summer.

The results of Study 1 revealed that risk perception and worry were the most important predictors of cycling during wintertime. The same results were not found for cycling during the other seasons of the year. Risk perception was found an important predictor of both the decision to cycle and how often the cyclists cycled during wintertime. Additionally, an association was found between risk perception and worry. The respondents were more worried when cycling in winter conditions compared with when cycling in summer conditions and worry was a strong predictor of travel mode behaviour. The results showed that when the respondents' perception of risk was very low, they were not worried and hence their behaviour was not affected. Perceived risk and worry were only associated with cycling behaviour during wintertime.

A rather weak however significant association was found between attitudes towards traffic safety and how often the cyclists cycled during wintertime. Cyclists with less ideal attitudes towards traffic safety tended to cycle more often during wintertime than other cyclists. Ideal attitudes are defined on the basis of findings from previous studies (Iversen & Rundmo, 2004, 2009). Implicitly, ideal attitudes are desirable to ensure efficient traffic flow, as well as safety in traffic. Moreover, the

respondents were of the opinion that there not should be more traffic enforcements on cyclists. Additionally, gender, safety priority, and risk tolerance were found associated with cycling frequency during wintertime. As expected, females tended to perceive the risk of being in a traffic accident as higher, tended to be more worried, tolerated less risk, had more ideal attitudes towards traffic safety, and cycled less during wintertime compared with males. Cyclists who tolerated risk less and prioritized safety more than other cyclists tended to cycle less during wintertime. In conclusion, adverse weather and climate conditions, with snow, slippery roads, and darkness. in Norway during the wintertime seems to be associated with risk perception and cycling frequency. Additionally, demographic variables and psychological factors seem to be associated with use of bicycle in winter. Measures to increase the use of bicycle during wintertime should focus on the standard on the cycle paths and the use of safety equipment that can improve safety and reduce risk perception in such conditions.

3.2 Paper II: Risk perception, worry, and pedestrian behaviour in the Norwegian population

Safe environments for pedestrians are an important consideration in the work towards increasing environmentally friendly travellers, and for those who use public transport, being a pedestrian is almost always a part of their travels. Accordingly, the aim of Study 2 was to investigate the association between pedestrians' risk perception and worry, and how worry influenced pedestrians' behaviour during night-time and daytime. The study, which is reported in Paper II, included a representative sample of the Norwegian population. The study included questions about four different hazards for pedestrians: traffic accidents, harassment, theft, and acts of terrorism. As expected, pedestrians perceived their risk as higher and were more worried being exposed to all of the four asked hazards during night-time than daytime. The majority of the respondents were not worried being exposed to any of the asked hazards as a pedestrian during the daytime. By contrast, almost half of the respondents were worried about accidents, thefts, and harassments as a pedestrian during night-time, and a quarter of the respondents worried about acts of terrorism during night-time.

Structural equation modelling (SEM) revealed that risk perception was a significant predictor variable for worry as a pedestrian. Further, the results showed that respondents who had experienced an accident or assault during the last year perceived their risk of being experiencing hazards as higher than did other

respondents. Risk tolerance and risk protection were found significantly associated with perceived risk. The perceived risk increased when the participant assessed the possibility to protect themselves against the risk as small and when to a small degree they tolerated being exposed to hazards as a pedestrian.

The results revealed that worry was an important predictor of walking frequency at night-time, and how often respondents walked alone during night-time. The more worried the respondents were, the less frequently they walked. Worry was moderately associated with walking frequency during night-time in winter. The association was weaker for the other seasons of the year. No associations were found between worry and walking frequency during the daytime. Respondents without access to a car perceived the risks as a pedestrian as higher compared with respondents with access to a car. For respondents without access to a private car, the correlations between worry and walking frequency during night-time were moderate to strong for all seasons. Further, the associations between worry and never walking alone during night-time were stronger for respondents without access to a private car. In conclusion, risk perception, worry and walking frequency were positively correlated at night-time. In addition, having been previously victimised associated with perceived risk. This points to the importance of improving the overall level of security with regard to crime and safety in society. The results point to the importance of seeing walking frequency in a community context.

3.3 Paper III: Attitudes, risk perception and risk-taking behaviour among regular cyclists in Norway

Ensuring cyclists' safety in traffic is important in the work to increase the numbers of cyclists in Norway and other countries. Accordingly, the aim of Study 3 was to investigate whether attitudes toward traffic safety, risk perception, and worry were associated with cyclists' risk-taking behaviour. Two types of such behaviour were studied: (1) 'violation of traffic rules', and (2) 'conflicts with other road users when cycling'. The study was based on a sample of regular cyclists living in urban and rural areas of Norway.

The results of factor analysis revealed three main dimensions of cyclists' attitudes towards traffic safety: (1) 'Pragmatic attitudes towards rule violations', (2) 'Attitudes towards cyclist enforcement', and (3) 'Dissatisfaction with the traffic rules for cyclists'. A MANCOVA was performed to study differences in demographics (age, gender, highest level of education, and geographical area of residence) according to cyclists' attitudes and behaviour. Among the demographical variables,

only geographical area of residence was found associated with attitudes and behaviour. Cyclists living in urban areas were found to have less ideal attitudes and more often practised risk-taking behaviour compared with cyclists living in rural areas, although the differences were small.

The study also showed that risk perception and attitudes toward traffic safety were important for cyclists' risk-taking behaviour in traffic. Pragmatic attitudes towards traffic rule violations were found an important predictor of the frequency of rule violations when cycling. The more pragmatic attitudes the cyclist had towards traffic rule violations, the more often the cyclist reported to violate the rules. Attitudes towards the enforcement of traffic rules for cyclists and dissatisfaction with the traffic rules for cyclists were found to be important predictor variables of the frequency of situations involving conflicts with other road users. Cyclists with negative attitudes towards the enforcement of traffic rules who reported dissatisfaction with the traffic rules, had experienced more conflicts when cycling than others. Risk perception was found associated with conflicts between cyclists and other road users, but not with rule violations when cycling. The greater the risk was perceived to be, the more conflicts the cyclist had experienced.

The results of a linear regression analysis showed that cyclists' involvement in accidents during the last two years was associated with conflicts with other road users when cycling. Experiencing a near-miss accident was found more important than experiencing an actual accident. Cyclists who had been involved in an accident or near accident when cycling, reported less conflicts with other road users when cycling compared to those who had not experienced an accident. Accident involvement during the last two years was not found associated with the frequency of violation of traffic rules. Further, the results showed that the extent to which cyclists' prioritized safety when cycling (safety priority) and tolerated exposure to risk (risk tolerance) was associated with their risk-taking behaviour in traffic. A confirmatory factor analysis included in the SEM indicated that risk tolerance and safety priority could be seen as a part of the same dimension. Risk tolerance and safety priority were found directly associated with rule violations when cycling. The less the cyclist prioritized safety and the more they tolerated being exposed to risk, the more often he or she violated the rules. Risk tolerance and safety priority were found indirectly associated with conflicts when cycling and mediated by decreases in worry. As expected, the study showed that safety attitudes can have an impact on behaviour among cyclists. Therefore, attitude-creating measures should also be prioritized among this type of road users.

4 Discussion

4.1 General discussion

4.1.1 Risk perception and worry

One of the main aims of the research for this thesis was to examine differences in perceived risk and worry related to different contexts (time of day, season of the year) and when using different travel modes (cycling and walking). The individuals perceived higher risk and tended to be more worried when cycling in winter conditions compared with when cycling in summer conditions and when walking during night-time compared with walking during daytime. The psychometric paradigm within risk perception research served as a framework of reference for this thesis, in order to understand better how individuals perceived risk. However, the psychometric scaling methods developed in this paradigm were not applied during the research, since recent research has justified the developed set of factors applied to measure perceived risk in this paradigm. In recent research, the study of risk perception has been understood as the assessment of probability and judgement of the severity of consequences. Accordingly, these two factors have been measured by researchers. Accordingly, the two factors were measured during the research.

As mentioned in Section 1.3.2, Fischhoff et al. (1978) found that the general measures of perceived risk correlated with only two of their measured nine items, namely dread and the severity of the consequences. Dread can be defined as an anticipatory emotion and, together with the risk-as-feelings model, the psychometric paradigm contributes to highlighting the role of emotions in perceived risk. Hence, during the research for this thesis worry was treated as a measure of an anticipatory emotion related to perceived risk. The results of the present thesis support previous findings that worry is an integral emotion caused by the cognitive evaluation of risk when cycling or walking. In Studies 1–3, strong significant associations were found between worry and perceived risk. The perceived probability of consequences was more strongly associated with worry than was the judgement of the severity of consequences.

The results presented in this thesis are in contrast with claims made by Loewenstein et al. (2001), who argue that anticipatory emotions such as worry and fear are largely insensitive to changes in probabilities. As an illustration, they refer to different experiments in which subjects were given information about probability estimates for either winning a lottery, receiving an electric shock, or investing money.

The results of the experiments showed that changes in probability estimates did not influence the subjects' emotional state. The effect is known as the certainty effect and supports the risk-as-feelings hypothesis, which suggests that when making behavioural choices, people will be less affected by changes in the probabilities of a negative outcome, the more the consequences evoke anticipatory emotions such as worry or fear. The different role of probability estimates compared with the severity of consequences in walking and cycling may depend on the type of hazards. Few studies to date have focused on cyclists' and pedestrians' perceived risk and worry. In common with Baron et al. (2000), I found that worry was largely affected by probability judgements, especially among lay people, and that the respondents' desire for action was mainly determined by worry and probability judgements.

An explanation for the importance of probability estimates reported in this thesis could be that primarily the probability of being involved in an accident differs for cyclists and pedestrians in different contexts. By contrast, the perceived consequences of being involved in a traffic accident are relatively similar in different contexts. However, Study 2 showed that also for other types of hazards (theft, harassment, and terrorism), when the perceived consequences differed more between day and night, the probability estimates were important for worry.

The overall aim of the research for this thesis of this thesis was to examine how risk perception and worry influenced the behaviour of cyclists and pedestrians as road users. As argued in Section 1.1.3, risk perception and worry are primarily of interest because they may relate to people's behavioural choices. When the risk (i.e. probability or severity of consequences) is perceived as too high and causes worry, the individual is most likely to decide to take precautionary action to minimize the perceived risk. As expected, the results showed that risk assessment was important for walking and cycling behaviour in contexts in which risk was perceived as high and that worried the respondents the most. The results showed that risk perception and worry were important for the pedestrians' and cyclists' behaviour in traffic, including their travel behaviour (walking or cycling frequency) and risk-taking behaviour (cyclists' risk-taking behaviour). Risk perception and worry were found most important for cycling frequency during winter (Study 1) and for walking frequency during night-time (Study 2). The greater the risk was perceived to be and the more worried the respondent felt, the lower their walking or cycling frequency. Furthermore, it was not possible to conclude that risk assessment influenced behaviour in contexts in which the public in general perceived risks as low (in the

daytime and during summer), probably because road users experienced the risk as too small to consider changing their behaviour.

Subgroups in the population may perceive risk differently. As shown in Study 2, respondents without access to a car perceived the risks as a pedestrian as higher than respondents with access to a car. Worry was also found more important for walking frequency for respondents without access to a car. This was the case also after controlling for the demographic variables age, gender and level of education. However, the results were not controlled for geographical area of residence. The Norwegian travel survey carried out in 2018 found that 13% of the adult population did not have access to a private car (NPRA, 2019). In the capital city, 36% of the adult population did not have access to a private car (NPRA, 2019). The results of the research presented in this thesis showed a stronger significant association between worry and walking frequency among respondents without car access than among respondents with car access. One reason could be that a larger percentage of the respondents without car access lived in urban areas. Residents in urban areas are more exposed to hazards when walking in a traffic environment compared with those living in rural areas. In addition, respondents without access to a car walked more often during their daily travels than did other respondents. It seems reasonable to assume that people who are more exposed to risk are more worried than people who are exposed to risk to a small extent. It may also be that people without car access do not perceive walking in their daily travels as a voluntary choice. Starr (1969) and Fischhoff et al. (1978) argue that whether or not people face a risk source voluntarily influences their perception of risk and risk tolerance. People without access to a car have no other choice than to walk or cycle during their daily travels. If they choose to use public transport, their transport is often combined with walking or cycling.

According to the risk-as-feelings approach, behaviour is influenced by the interplay between the cognitive evaluation of risk and feelings (Loewenstein & Lerner, 2003; Loewenstein et al., 2001). When there is divergence between the cognitive evaluation and emotional reactions, it appears that behaviour is driven by anticipatory feelings. The risk-as-feeling model explains and predicts risk behaviour. Loewenstein et al. (2001) argue that the risk-as-feelings model is contrary to other models designed to predict human behaviour because it is feelings-based rather than consequence-based (e.g. as in TRA and TPB). In common with the risk-as-feeling model, the theory of reasoned action (TRA) (Fishbein, 1968) and the theory of planned behaviour (TPB) have been used to explain and predict risk-related behaviour (Ajzen, 1991). The difference between measured behavioural intention and

measured behaviour in TRA and TPB may be explained by conflicts between cognition and emotion (Kobbeltvedt & Wolff, 2009). TRA, TPB and the risk-as-feelings models were not explicitly tested in the research for this thesis, since the findings of many previous studies have supported the applicability of the approaches. Therefore, further validation of the approaches can be considered unnecessary. Rather, as models, they can be considered as frameworks of reference. The risk-as-feelings model includes cognitive evaluation of risk and feelings to explain risk-related behaviour. However, this model does not include measures of attitudes. TRA and TPB show the importance of attitudes for related behaviour. However, these models do not include feelings. Thus far in this thesis, I have shown that cognitive evaluations of attitudes and risk perception, as well as feelings are important for risk-related behaviour. Additionally, in this thesis attention is drawn to TRA and TPB in order to point out the empirically robust attitude–behaviour relation that has been shown in studies in which the theories have been applied. Also, this thesis has shown that cognitive evaluations of risk and associated worry are important for cyclists' and pedestrians' behaviour.

Models designed to predict cognitively mediated behaviour, such as the risk-as-feelings model (Loewenstein & Lerner, 2003; Loewenstein et al., 2001), TRA (Fishbein, 1968) and TPB (Ajzen, 1991) have been criticized for not including the habituation of behaviour. According to Gärling and Axhausen (2003), modes of transport used for everyday travels often become used habitually, such that travellers do not question them as a choice. Furthermore, the most socially accepted action is usually the default option for the individual. Hence, compliance with the action is not necessity experienced as decision-making. The extent to which a decision may be a decision based on cognitive evaluations and feelings may be rooted in social and cultural norms (Kobbeltvedt & Wolff, 2009). In cultural theory, cultural differences are conceived as important for perceptions of technological and environmental dangers (Douglas & Wildavsky, 1983).

According to Gatersleben (2007), private car use is important in Western cultures as a symbol of independence and freedom. To use a private car is mainly seen as the default option. Consequently, walking and cycling may be perceived more as an active choice. The results presented in this thesis support the notion that people who walk and cycle regularly evaluate risk when taking decisions about their choice of travel mode. To reach the goal of 'zero growth' in car traffic, it would be appropriate to make the use of environmentally friendly travel modes habitual and hence socially accepted and the default option for everyday travels. It is essential to

increase the amount of daily walking and cycling trips, and to establish a safe environment for cyclists and pedestrians in order to enhance the frequency of walking and cycling. The results presented in this thesis show that even everyday cyclists evaluate risk before taking the decision to cycle. Hence, road users' perceived risk and worry should be taken into consideration in the work of increasing daily cycling trips.

4.1.2 Attitudes towards traffic safety

Another part of the overall aim of the research for this thesis was to investigate how attitudes towards traffic safety influenced cycling behaviour (cycling frequency and risk-taking behaviour). Both the theory of reasoned action (TRA) (Fishbein, 1968) and theory of planned behaviour (TPB) (Ajzen, 1991) have been widely applied in studies of road users' behaviour that report that road users' attitudes were positively associated with their behavioural intentions. Both TRA and TPB have been applied to predict types of behaviour such as travel mode choice, intention to commit traffic violations, and cycle helmet use (Evans & Norman, 1998, 2003; Parker et al., 1992; Quine et al., 1998, 2001; Rosenbloom et al., 2011; Åberg, 1993). The attitudes included in the research for this thesis were related to traffic rules. The attitudes were found significant predictors of cycling frequency. They also significantly predicted cyclists' risk-taking behaviour. In addition, the attitudes significantly predicted violation of traffic rules and were found weakly associated with both conflicts when cycling and cycling frequency. However, attitudes towards traffic safety were more found more important for risk-taking behaviour than for cycling frequency. One explanation for this could be that all questions about safety attitudes were related to attitudes towards safety behaviour in traffic context and were not related directly to situations in which cycling frequency was relevant.

The results presented in this thesis show that 30% of regular cyclists had pragmatic attitudes towards rule violations and 25% were dissatisfied with the traffic rules for cyclists. Previous research of car divers attitudes, has shown that 'non-ideal' attitudes towards traffic rules were less common among car drivers (Iversen & Rundmo, 2004, 2009; Nordfjærn et al., 2011), than found among cyclists in this thesis. Thus, negative and pragmatic attitudes toward traffic safety may be more socially acceptable for cyclists than for car drivers. One reason could be that the cycling infrastructure and the traffic rules for cyclists are not sufficiently well adjusted for cyclists as road users. The results of this thesis showed that a considerable number of regular cyclists considered that many traffic rules for cyclists

were impossible to comply with (28%) and too complicated to adhere to in practice (23%). In Norway, the road infrastructure and traffic regulations are primarily planned for car drivers and pedestrians. If this is the case, the cycling infrastructure and traffic rules for cyclists need to be changed and adjusted to cyclists. As a supplement, attitude campaigns could be used to strengthen relevant authorities' communications that cyclists should be prioritized as road users. This in turn could increase road users' respect for the traffic rules for cyclists. Furthermore, campaigns may motivate people who currently do not cycle to use a cycle for their daily travels in a safe way in the future. It could be argued that attitude and information campaigns are more important for cyclists and pedestrians than for car drivers, as active road users receive little information about risk and safety in traffic compared with car drivers. In contrast to active travellers, all users of motorized vehicles need to have a driving licence, which ensures that licence holders have knowledge about traffic rules and traffic safety in general.

To my knowledge, few studies have investigated attitudes toward traffic safety as a predictor of cyclists' risk-taking behaviour. Moreover, most studies that have investigated the relationship between attitudes and behaviour among cyclists have studied helmet use (Quine et al., 1998, 2001). However, attitudes toward traffic safety have been found important for other types of road users' risk-taking behaviour (Iversen & Rundmo, 2004, 2009; Nordfjærn et al., 2011; Nordfjærn et al., 2010; Parker et al., 1992; Åberg, 1993). Based on the findings presented in this thesis and from previous research on attitudes and risk-taking behaviour, campaigns could, in addition to other countermeasures, be important to enhance safety for cyclists and pedestrians. Based on meta-studies, Elvik, Høye, Vaa, and Sørensen (2009) conclude that attitude campaigns that target attitudes towards road safety have small effects on road users' behaviour. Only four campaigns included in the meta-studies focused on cyclists and all four focused on cyclists' helmet use (Elliott, 1993). Only one of the aforementioned four meta-studies has been published in a peer-reviewed journal (DiGuiseppi, Rivara, Koepsell, & Polissar, 1989). None of the meta-studies examined by Elvik et al. (2009) were related to attitudes towards road safety and cyclists' risk-taking behaviour. Despite the conclusions from Elvik et al.'s meta-analysis of attitude campaigns (Elvik et al., 2009), the attitude–behaviour relation has been found empirically robust in studies of different types of road users' risk-taking behaviour.

4.1.3 Demographical differences

In all three studies conducted as part of the research for this thesis, age, gender and level of education were included as control variables. The results revealed demographic differences in perceived risk, worry, attitudes, and behaviour related to cycling and walking. However, the differences were small and this finding is in line with the finding by Iversen and Rundmo (2009), who found small differences in attitudes towards traffic safety related to age, gender and level of education among Norwegian car drivers. The research presented in this thesis found that, compared with males, females worried more about hazards (traffic accidents, theft, harassment, and acts of terrorism) as pedestrians, and were more worried about cycling accidents and perceived the risk of them as higher. However, the gender differences were small. Study 2 showed that demographic variables contributed to a small extent to the explained variance in worry about being a pedestrian and therefore demographics were not included in the final models. With regard to behaviour, gender was found associated with cycling frequency in winter. Female respondents cycled less than male respondents during winter. Gender was not associated with cycling frequency in the other seasons of the year, nor with risk-taking behaviour when cycling (Study 3). These findings are not in accordance with results from previous studies, which showed differences in perceptions of risk and worry related to age, gender and level of education. According to Breakwell (2007), several studies have shown that women assess the risk of different types of hazards as higher compared with males (Bord & O'Connor, 1997; Dosman, Adamowicz, & Hrudey, 2001; Gustafson, 1998; Jenkins-Smith & Silva, 1998). However, Abbott-Chapman, Denholm and Wyld (2008) found that gender differences in risk perceptions and risk-taking behaviour among Australians had narrowed significantly in recent decades. This might have been due to more focus on safety, which in turn had made both females and males more aware of risks linked to different types of hazards. Furthermore, the changes might have contributed to changes related to gender norms that made it more acceptable for males to prioritize safety and worry about the risk.

A further explanation for the narrowing in gender differences in risk-taking and risk perceptions may be that society had changed and become safer, such that both males and females had less to worry about. As a consequence, females who had previously worried the most, might have felt feel less worried. Abbott-Chapman et al. (2008), Iversen and Rundmo (2009) and Constant, Salmi, Lafont, Chiron, and Lagarde (2007) have all found that attitudes towards traffic safety and drivers' risk-taking behaviour had changed significantly to become more "ideal". The change

might have been related to the same trend in Western societies with more focus on safety and reduction in the numbers of traffic accidents. Iversen and Rundmo (2009) found a positive change related to 'attitudes towards drinking and driving' and 'attitudes towards others' careless driving' among Norwegian drivers between 2000 and 2008.

In Study 3, differences in perceived risk, worry, attitudes, and behaviour between urban and rural areas were compared to investigate the effect of geographical characteristics on risk assessment. The variable was primarily included to reveal differences in cycling infrastructure. Additionally, there may be cultural differences in attitudes and behaviour between cyclists living in urban and rural areas. Contrary to what was expected, the geographical area of residence was not found associated with the cyclists' perceived risk and worry. This might have been due to the small sample size and a small number of rural cyclists compared with urban cyclists. A relatively small proportion of the sample reported that they lived in rural areas (less than 2000 inhabitants) or peri-urban areas (2000–20,000 inhabitants) and 75% of the sample lived in urban areas. Only regular cyclists were included in the study. The finding of small numbers of rural cyclists compared with urban cyclists is in accordance with the results of the Norwegian travel survey from 2018 (Ellis, 2019). In general, the share of cycling trips in Norway increases with density-populated areas (Ellis, 2019). In the research for this thesis, the area of residence was found to be significantly associated with attitudes and risk-taking behaviour: compared with respondents living in urban areas, respondents living in rural areas had more ideal attitudes and were less often involved in risk-taking behaviour, although the differences were small.

4.2 Methodological considerations

As argued in the Introduction (Section 1.3.2), in this thesis risk perception is defined as people's cognitive assessment of probability and judgment of the severity of the consequences of a negative outcome when cycling and walking. The definition is in accordance with risk analysts' definition of risk and thus makes it easier to compare the results presented in this thesis with the results of experts' analyses of risks. Whether the same definition of risk corresponds to how people perceive risk in daily life is open for discussion (Hansson, 1999). To reduce the possibility of misinterpretation, the questionnaires did not ask the respondents about their general perception of risk when cycling or walking, and in all three questionnaires 'risk' was operationalized by measuring both the respondents' assessment of probability and the

respondents' judgment of the severity of consequences of different types hazards when cycling or walking. Whether the operationalizations of risk was in accordance with the respondents' perceived risk as cyclists and pedestrians, and whether they worried about other hazards than those they were asked about should be explored in future qualitative research.

Studies 1–3 were all based on cross-sectional surveys. One limitation of the use of cross-sectional data is that the direction of the causal relationships should be interpreted with caution. The question of whether risk perception influences cycling behaviour or vice versa is a matter for discussion. For example, it could be argued that if a person cycles often, he or she would become more familiar with traffic situations, which in turn would lower their perception of risk associated with cycling in traffic. The use of experimental research designs has an advantage in terms of determining causal relationships between variables. However, in some cases, it is not possible to use experimental designs, such as when they would be unethical or would result in testing situations that only to a little extent correspond to real-life situations (Cook et al., 1979; Shadish, Cook, & Campbell, 2002). Causal relationships between variables would be easier to detect in closed systems with few dependent and independent variables. According to Ringdal (2018), such conditions are often difficult to fulfil in social sciences. Travel behaviour, feelings and attitudes extend to a range of domains in people's lives and would be impossible to test in a controlled experimental study. However, the hypotheses tested in the analyses in the three studies conducted as part of the research for this thesis were based on previous empirical and theoretical research. Measures used to test the fit of the data to the three SEM analyses showed that the fits were acceptable for all three models. Further, the statistical tools used in the three studies, which allowed for control for demographic variables (age, gender, level of education, geographical area of residence), were associated with some of the other variables included in the analyses.

For this thesis, I used three datasets based on self-reported survey data designed to investigate road users' perspectives. The use of several datasets may improve the validity of research results and help researchers to gain different perspectives on the studied phenomenon. There are several benefits from studying one phenomenon using several datasets, which in turn could strengthen the results if the same results are found in all studies. In the case of Studies 1–3, all three showed that risk perception was important for behaviour. The three datasets allowed us to study the same topic in different groups of the population, and to study how risk perception and safety attitudes were associated with different types of behaviour. The

three datasets were collected sequentially, and the questionnaires were revised following feedback from the respondents and after analysing the data from the previous study.

A well-known problem associated with the use of self-reported data is the desirability bias (Krumpal, 2013; Nederhof, 1985). The bias refers to a psychological process whereby respondents respond to questions systematically in line with what they perceive is socially acceptable or in line with what they think is viewed favourably by the researchers. In the research for this thesis, desirability bias could have led to underreporting of risk-taking behaviour in traffic and overreporting of ideal attitudes towards traffic safety. Furthermore, different types of memory biases can be a problem in cases of self-reported behaviour. People tend to remember situations that involve positive emotional reactions better than they remember other situations (Walker, Skowronski, & Thompson, 2003). In the questionnaires used in Studies 1, 2 and 3, we asked the respondents about their involvement in negative incidents when cycling and walking. It is possible that the number of negative incidences when cycling and walking might have been underreported due to memory bias.

One of the main strengths of questionnaire surveys is the external validity or generalizability of the findings. When such surveys are conducted well, the findings can be generalized to the whole population under natural conditions (Weisberg, 2008). The response rate in Study 1 was 13% and the response rate in Study 2 was 27%, but it was not possible to calculate the exact response rate in Study 3. The low response rates and the problem of calculating the exact response rate in Study 3 could be regarded as a limitation of the research for this thesis. However, response rates only constitute a methodological problem if the overall sample is not representative of the target population (Krosnick, 1999). When the samples in Studies 1, 2 and 3 were compared with the target population in the Norwegian Travel Survey conducted in 2013 (Hjorthol, Engebretsen, & Uteng, 2014) and in 2018 (Ellis, 2019), we found similarities in the demographic characteristics.

5 Conclusion

This thesis adds to the current body of knowledge about risk perception and anticipatory worry, and how an individual's perception and feelings are associated with risk-related behaviour. By directing attention to anticipatory worry, the thesis highlights the importance of feelings for an individual's perception and behaviour. The perceived probability of consequences was found more important for worry than the judgement of the severity of consequences. Furthermore, it was found that risk perception and integral feelings of worry influenced cyclists' and pedestrians' behaviour (walking or cycling frequency). This thesis emphasizes that an individual's probability judgements are especially important for their anticipatory feelings and behaviour. This finding supports Baron et al.'s finding that worry was largely affected by probability judgements, and that risk related behaviour was largely determined by worry and probability judgements (Baron et al., 2000), but is in contrast to the risk-as-feelings hypothesis (Loewenstein et al., 2001), which holds that the anticipatory emotions such as worry, dread, and fear are largely insensitive to changes in probabilities. The importance of the perceived probability, as presented in this thesis, could have been embedded in the studied risk sources or the research method used. Further development of theories within the field of risk perception should take these findings into account and investigate the relative role of probability and consequences for worry and risk-related behaviour. Finally, this thesis adds knowledge about the importance of safety attitudes for risk-related behaviour, as safety attitudes were found associated with risk-taking cycling behaviour. This finding supports the empirically robust attitude–behaviour relation that has been found in previous research across different types of road users' risk-taking behaviour (Evans & Norman, 1998; Iversen & Rundmo, 2004, 2009; Nordfjærn et al., 2010; Nordfjærn, Jørgensen, & Rundmo, 2012; Nordfjærn & Şimşekoğlu, 2013; Rundmo & Ulleberg, 2000; Şimşekoğlu et al., 2012, 2015; Ulleberg & Rundmo, 2000). The same attitudes were not found as important for cycling frequency.

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Paper I

Seasonal variation in risk perception and travel behaviour among cyclists in a Norwegian urban area

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Seasonal variation in risk perception and travel behaviour among cyclists in a Norwegian urban area

Abstract

The main purpose of the article is to examine the association between risk perception and cyclists' decision as to whether to cycle during the different seasons of the year. The study on which the article is based included worry as a feeling that emerges as a result of an individual's cognitive assessment of risk, attitudes toward traffic rules, risk tolerance and safety priority. The study was based on a questionnaire survey carried out among cyclists from Trondheim Municipality in Norway (n = 291) during spring 2017. The results revealed seasonal differences in perceived risk and that risk perception was an important predictor of both the decision as to whether to cycle and the frequency of cycling during wintertime. The same results were not found for cycling during the other seasons of the year. Additionally, an association was found between risk perception and worry. The respondents were more worried when cycling in winter conditions compared with cycling in summer conditions, and worry was a strong predictor of travel mode behaviour. The authors found that when the respondents' perception of risk was very low, they were not worried and hence their behaviour was not affected. Perceived risk and worry were only associated with cycling behaviour during wintertime. These findings may be used as a guide in measures implemented to increase the number of cyclists during winter and in communications to the public about the risks linked to cycling.

Keywords: *Cycling behaviour, risk perception, worry, risk tolerance, season, attitudes towards traffic safety*

1. Introduction

In order to reduce transport-related CO_2 emissions, the Norwegian Government has set as a target for the largest cities that all future growth in individual travel should be accommodated by walking, cycling, and public transport, and thus there should not be growth in car traffic. Achieving this target calls for a variety of measures and enhanced knowledge about road users' preferences and choices in order to establish long-term changes in mode use. When choosing a mode of transport, road users take several factors into consideration, and risk perception may be one of these factors. In Norway, the share of cycling is significantly higher in summer than in winter, which leads to the following questions: Could road users' risk perception be part of the

explanation for the phenomenon? Do cyclists perceive cycling as riskier during winter? Are they more worried about cycling in winter? This article presents the results of a study of cyclists' risk perceptions of cycling during summer and winter among cyclists living in Trondheim, one of the largest cities of Norway.

After an overview of cycling in Norway, we address some challenges related to winter cycling, and cyclists' accident risk. In addition, we present theories of risk perception, worry and risk tolerance, both in general and with respect to cycling in particular. Finally, at the end of the introduction part of the article, we presents the full scope of the study.

1.1 Cycling in Norway

According to the results of the National Travel Survey carried out in Norway for the period 2013–2014 (Hjorthol et al., 2014), 75% of the population aged 13 years or older owned a bicycle. However, only 5% of all daily trips were made with bicycles. The share of cycling trips was higher among young persons aged 13–17 years compared with other age groups, 12% and 4% respectively. Also, persons with higher university education were more likely to cycle, accounted for 6% daily trips by bicycle. The gender differences were small, 4% for women and 5% for men. However, cycling trips for men were on average longer than cycling trips made by women: while the average cycling trip length was 4.1 km and lasted 17 minutes, the average trip for women was 3.2 km/16 min compared with 4.9 km/19 min for men. The highest shares of cycling trips were school trips (10%) and commuting trips (7%). The share of cycling trips also showed geographical variations: in general, the share of cycling trips increased with density-populated areas. In Trondheim, the city in which the present study took place, the overall share of cycling was 9%.

A number of policies have been recommended to reach the main goal of the Government's National Cycling Strategy (managed by the Norwegian Public Roads Administration), and they stated that cycling should constitute 8% of all daily trips by 2023. Among the policies, special emphasis has been placed on the provision of a coherent network of cycle paths, the development of main road networks for cyclists, and safe routes to school (Statens vegvesen, 2012). Trondheim has set the ambitious target of becoming the best city for cycling in Norway, with the priority given to building new infrastructure for cyclists in the city. Since 2014, more than 30 km of new dedicated infrastructure for bicycles has been built, as well as a high number of parking facilities for bicycles in the city centre (Miljøpakken, 2016).

Cycling during the winter season is a specific challenge in Norway due to adverse climate conditions, with snow, slippery roads, and darkness. In Trondheim, the temperature during wintertime (December–February) is on average minus 2.5 °Celsius. During December and January, the sun rises at 10:00 and sets at around 15:00. During spring and autumn too, the temperatures often fall below zero. The seasonal variations are reflected in the use of bicycles for daily travel. During the summer months, 7% of daily trips in Norway are cycling trips compared with only 2% during the winter months. Local travel surveys conducted in Trondheim have revealed cycling shares ranging from 3% to 13% across the seasons (Miljøpakken, 2018). Previous studies have found that high-standard road clearance operations in winter positively affect people's decision to cycle (Svorstøl et al., 2017). In Trondheim, the removal of snow and ice are given high priority on the main road network for the benefit of cyclists. No more than 1 cm of snow is allowed to accumulate before removal, as the strategy is to provide clear surfaces all year round (Miljøpakken, no date).

Both international and Norwegian studies of road safety with respect to cycling have recently been reviewed by Høye (2017). The review indicates that the youngest and the oldest cyclists, as well as male cyclists are at higher risk than other cyclist groups. Winter conditions with snow and ice-covered surfaces were found to increase the accident risk. The studies are ambiguous with regard to whether winter conditions lead to accidents that are more severe (Doherty et al., 2000; Melhuus et al., 2015; Rolfsman et al., 2012). Although the number of bicycle accidents has decreased in the last decades in Norway, when estimates of underreported accidents are included, the accident risk for cycling (number of injuries and fatalities per km travelled) is estimated as 20–25 times as high compared with travelling by car (Bjørnskau, 2015).

1.2 Risk perception, risk tolerance, and the feeling of worry

The psychometric paradigm has dominated the field of risk perception research over the recent decades (Sjöberg et al., 2004). The approach is characterized by the use of psychometric scaling methods to measure how characteristics of risk sources relate to perceptions of risk (Breakwell, 2007; Fischhoff et al., 1978; Slovic, 1992). In their classic study, Fischhoff et al. (1978) used psychometric procedures to elicit quantitative judgements of perceived risk. To measure perceived risk, their respondents were asked to consider the risk of dying as a consequence of 30 different activities or technologies (e.g. smoking, bicycles, motor vehicles, and nuclear power).

Additionally, nine different dimensions were measured for the same activities or technologies. The first one was whether people faced the risk source voluntary. The second dimension was whether death was effected immediately or delayed. The third dimension was whether the risk level was known by the person. The fourth dimension was about the chronic versus the catastrophic potential of the risk – whether the activities or technologies kill one person at a time (chronic) or a large number at once (catastrophic). The fifth dimension was whether the risk evoke great dread or if it is seen as common. The sixth dimension of the risk was the severity of the consequences of risk-taking (i.e. the likelihood that the consequences will be fatal). The seventh question concerned to the extent to which the risk is known in science (measured by asking respondents to rank whether the risk level was known precisely or not known to science). The eighth characteristic was about the level of control (the respondents were asked to rank their perceived level of control if they were exposed to the risks). The last dimension concerned the newness of the risk (the respondents were asked to rank whether they considered the risks as novel or familiar). Fischhoff et al. (1978) found that perceived risk correlated only with the severity of the consequences and dread, and not with any of the other dimensions. However, in accordance with recommendations by Breakwell (2007), studies carried out during recent years have used assessments of probability and judgments of the severity of consequences as indicators of perceived risk (Moen and Rundmo, 2006; Nordfjærn et al., 2014a; Roche-Cerasi et al., 2013; Rundmo and Moen, 2006). Consequently, perception of risk can be measured by the two factors ‘assessments of probability’ and ‘judgments of the severity of consequences’ of an accident occurring when performing an activity. According to Sjöberg et al. (2004), risk perception can be defined as people’s cognitive assessment of risk along these two dimensions.

Backer-Grondahl et al. (2009) considered the feeling of worry as an ecological measure of risk perception. However, the inclusion of feelings in the concept of risk perception is not in accordance other studies. Thus, in the present article, risk perception is defined as a purely cognitive assessment of probabilities and judgement of severity of consequences of a particular adverse event (Rundmo, 2002; Sjöberg 1998).

Risk tolerance is another important aspect of how individuals relate to risk. Individuals may differ in their thresholds for the level of risk they find acceptable. The original impetus for the psychometric paradigm came from Starr (1969), in his effort to answer the question ‘How safe is safe enough?’ He measured the level of risk that individuals found acceptable for different activities, and found that activities

that were voluntary and perceived as beneficial were tolerated more than other activities. In a later study conducted by Fischhoff et al. (1978), respondents were asked to judge the acceptable level of risk associated with different activities or technologies, and the authors found that risk was less tolerated when the activities were associated with dread. They also found that higher risk levels were tolerated for voluntary activities with well-known and immediate consequences.

The terms 'acceptance' and 'tolerance' are often used synonymously. However, Sjöberg (1999) argues that risk tolerance and risk acceptance are two separate concepts. Risks are less likely to be accepted, and more likely to be tolerated. One may be aware of a certain risk and choose to tolerate it, even if one does not accept it. In the present study, we investigated risk tolerance among cyclists.

Cognitive models have dominated risk perception and decision-making research, but recently affective processes have received increased attention (Breakwell, 2007). The risk-as-feeling approach highlights the role of anticipatory and anticipated emotions for risk perception (Loewenstein et al., 2001). Anticipatory emotions are immediate visceral reactions to risk, such as worry, fear, anxiety, and dread, whereas anticipated emotions are emotions that the individual expects to have as a consequence of a decision. There are two types of anticipatory emotions: integral emotions and incidental emotions. Integral emotions are caused by the decision problem itself, whereas incidental emotions are caused by other factors, such as mood (Loewenstein and Lerner, 2003). In this article, worry is considered as an anticipatory emotion and integral to the decision problem, which implies that worry is defined as a feeling that emerges as a reaction to the individual's cognitive assessment of risk. Accordingly, the aim of this article is to examine the association between perceived risk and anticipatory feeling of worry about cycling.

Risk perception and worry are primarily of interest because they may relate to people's behavioural choices. According to the risk-as-feeling approach, behaviour is influenced by the interplay between cognitive evaluations of risk and feelings. Further, emotions often produce behavioural responses that differ from the individual's cognitive assessment of the best course of action. When divergence occurs, it appears that behaviour is driven by emotional reaction, not by cognitive assessment (Loewenstein et al., 2001). Loewenstein et al. (2001) argue that in contrast to cognitive evaluations, anticipatory emotions such as worry and fear are largely insensitive to changes in probabilities. As an illustration, they refer to different experiments in which subjects were given information about probability estimates for winning a lottery, receiving an electric shock, or investing money. The experiments

showed that changes in probability estimates did not influence the emotional state of the research subjects. The effect is known as the certainty effect, and it supports the risk-as-feeling hypothesis, which suggests that when making behavioural choices, people will be less affected by changes in probabilities of negative outcome, the more the consequences themselves evoke anticipatory emotions such as worry or fear.

Contrary to the findings of Loewenstein et al. (2001), Baron et al. (2000) found that worry was largely affected by probability judgements, especially among lay persons, and that their participants' desire for action largely was determined by worry and probability judgements. They used a questionnaire with a list of 32 different risks, each of them defined in terms of a cause and an outcome (e.g. injury or death from an automobile accident). For each risk, the respondent was asked (among other questions) to give probability estimates, to estimate the badness of the outcome, the number of persons affected, and how much he or she worried about the risk. A similar approach was adopted in the present study, and investigated the role of worry in addition to assessing probabilities and the severity of the consequences of an accident when cycling.

1.3 Risk perception, risk tolerance, and the feeling of worry among cyclists

The study of risk perception among cyclists has received little attention to date (Chaurand and Delhomme, 2013). Much of the research in this field has been conducted to aid engineers and planners in designing and improving infrastructure for cyclists. In most of these studies, cyclists were asked to rate their overall risk perception of a route described by video clips, simulations, or surveys. Manton et al. (2016) used mental mapping to study cyclists' risk perception. The respondents were asked to draw their regular route with different colours according to their perception of safety and risk. All the studies of risk perception among cyclists have in common to focus of perceptions on either the road infrastructure or the traffic (Lawsonet al., 2013). Some researchers have investigated cyclists' risk perceptions relating to specific roads (Llorca et al., 2017), crossings, and roundabouts (Moller and Hels, 2008).

According to our knowledge, no studies to date have solely investigated risk perception among cyclists from a psychometric approach. However, previous studies have examined risk perception related to different travel modes. Moen and Rundmo (2006) and Oltedal and Rundmo (2007) included cycling as well as other travel modes when investigating risk perception. The respondents' perceived probability of being involved in an accident was found to be higher when cycling compared with when

using other travel modes. However, the severity of the consequences of a bicycle accident was judged as lower. Another interesting finding was that the respondents reported they were more worried about experiencing an accident when cycling, compared with when travelling with other modes of transport.

Studies on risk perception are however difficult to compare due to the different ways used to measure the perceived risk. According to Cristea and Delhomme (2016), some studies measured only the probability of involvement in an accident, not the perceived consequences if an accident were to occur. Frings et al. (2012) and Moller and Hels (2008) asked their respondents to evaluate risk without asking about the probability or consequence of risk. Backer-Grondahl et al. (2009) used worry as an ecological measure of risk perception.

Previously, researchers found differences in perception of risk and worry due to age, gender, and education. According to Breakwell (2007), several studies found that, compared with men, women in general assessed risks as higher (Bord and O'Connor, 1997; Dosman et al., 2001; Gustafson, 1998; Jenkins-Smith and Silva, 1998). Women are more concerned about traffic risks than are men (Moen and Rundmo, 2006), although data suggest that traffic risk measured by injuries and fatalities is lower for women (Melhuus et al, 2015). Lawson et al. (2013) studied gender differences in cyclists' perceptions of safety, and found that both males and females more often described cycling as less safe than driving, and that older women perceived cycling as less safe than did younger women. Manton et al. (2016) found that females perceived their regularly used cycling route as more dangerous than did men. Moen and Rundmo (2006) found that, in contrast to women, men scored lower on their perceptions of probability, on expected consequences, and on worry. They also found that individuals below the age of 25 years regarded the consequences of accidents as the least serious and were the least worried when travelling by private modes of transport (including bicycles). The same age group perceived the probability of being in an accident as the highest among all age groups. Individuals with a university degree perceived the same risk as lower than did others and were less worried about being involved in an accident.

To date, few studies have measured risk tolerance among cyclists. Parkin et al. (2007) developed a model based on a risk threshold and provided a measure of acceptability of different cycling routes. The model demonstrated how different infrastructure layouts lead to a reduction in the perceived risk and make the route acceptable for cyclists. Parkin et al.'s model also showed that young and elderly

people considered cycling less acceptable than did people in the age group of 35–44 years, and that males considered cycling more acceptable than did females.

1.4 Travel mode choice and demand for safety

A number of studies have investigated demands for safety priority or risk mitigation related to choice of mode of transport (Nordfjærn and Rundmo, 2010; Rundmo and Moen, 2006; Şimşekoğlu et al., 2015; Sjöberg, 1999), and some of them have included cycling (Nordfjærn and Rundmo, 2010). Nordfjærn and Rundmo (2010) found that in Norway, the demand for risk mitigation and priorities related to transport safety increased significantly between 2004 and 2008. Demand for risk mitigation can be defined as the public's demands for decision-makers to reduce specific sources of transport risks (Moen and Rundmo, 2004). In the present study, we defined the demand for safety priority as demands made by the public to decision-makers to prioritize road safety for cyclists.

Furthermore, attitudes towards traffic safety have been found important for road user behaviour (Iversen and Rundmo, 2004, 2009; Nordfjærn and Şimşekoğlu, 2013). In the present study, we hypothesized that also attitudes affect cyclists' behaviour, such as their frequency of bicycle use. In this article, we focus on how attitudes towards traffic safety, risk tolerance, safety priority, risk perception, and worry are associated with the choice to use a bicycle as a mode of transport.

1.5 Aims of the study

The Governmental target for the largest Norwegian cities, that all future growth in individual travel should be accommodated by walking, cycling, and the use of public transport, calls for more knowledge about factors affecting mode choice. In order to facilitate future growth in demand for cycling all year around, special focus should be directed towards risk perception, to examine whether cyclists perceive that the risk of cycling in winter is different compared with cycling in summer, and to explore any correlations between risk perception and the choice to travel by bicycle. Consequently, the main aim of the present study was to investigate how people perceived risk when cycling in winter compared with summer conditions. An additional objective was to investigate the association between perceived risk and the decision to cycle.

The specific aims were as follows: (1) to examine differences in cyclists' risk perception and worry when cycling in winter and summer conditions, (2) to investigate whether cyclists' risk perceptions and worry were related to their decision

to cycle during wintertime, (3) to examine whether risk perception and worry were associated with cycling frequency during wintertime, (4) to compare the role of risk perception and worry for cycling frequency during all four seasons, and (5) to examine the direct and indirect associations between risk perception, worry, and cycling frequency during wintertime. Additionally, some other potential predictors for cycling frequency were included in the analyses as independent variables, namely demographics, attitudes towards traffic safety, safety priority, and risk tolerance.

2. Methods

2.1 Sample

The study was based on a questionnaire survey that was completed online through a website for cyclists in Trondheim Municipality in Norway during spring 2017. In 2017, the website had 2240 members. We invited all members to participate in the study, and the response rate was 13% (n = 291). All respondents reported that they cycled on a daily basis during summer. There were 36% females and 64% males in the sample. Their age ranged from 20 years to 77 years (M = 43.47, SD = 11.73). A total of 69% of the respondents reported they had more than three years of university education, 19% had three years or less of university education, and 11% had received their highest level of education at upper secondary school. A total of 88% reported that they were employed; the remaining 12% were students or pensioners. A total of 3% of the respondents reported that they did not have a driving license, and 17% did not have access to a car or to other motorized vehicles.

2.2. Questionnaire and measure instruments

The questionnaire (see Appendix) asked the respondents to evaluate the probability of being injured in an accident when cycling and the severity of its consequences, their worry about being injured in an accident, risk tolerance, and safety priority when cycling in winter and summer conditions. Winter and summer conditions referred to the cycling conditions, not the season. Winter conditions refer to conditions with temperatures below zero degrees Celsius and when there is the potential for snow and ice, whereas summer conditions refer to conditions when the temperature is above zero degree Celsius. This definition was well understood by the respondents who answered the questionnaire, and is clearly defined in the Norwegian language – *vinterføre* versus *sommerføre*. The questionnaire also contained questions about attitudes towards traffic safety, frequencies of cycling during the four seasons, age,

gender, employment status, highest level of completed education, driving licence, and motorized vehicles at the respondents' disposal.

To measure risk perception, the respondents were asked to assess their probability of experiencing an accident that involved injury when cycling, and to judge the severity of the consequences if such an event were to occur. The scale for measuring the probability assessments was a five-point evaluation scale ranging from 'not at all probable' to 'very probable'. For the judgement of severity of the consequences, the scale ranged from 'not at all serious' to 'very serious'. The respondents were also asked to rate how worried they were about being involved in an accident when cycling, and the measurement scale ranged from 'not at all worried' to 'very worried'. To measure risk tolerance, the respondents were asked the following question: 'To what extent do you tolerate being exposed to risk when cycling?' The five-point evaluation scale ranged from 'tolerate the risk absolutely' to 'do not tolerate any risk'. To measure safety priority, the respondents were asked to assess the following question: 'How important do you think it is that the authorities prioritize measures to improve safety for cyclists?' The five-point scale ranged from 'not at all important' to 'very important'.

Attitudes towards traffic safety were measured by a 13-item instrument (Moen and Rundmo, 2006; Nordfjærn et al., 2014b). We tested a revised version that we especially designed for cyclists. The respondents were asked to what extent they agreed or disagreed with 13 different statements and give their responses on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree).

In addition, the respondents were asked how often they cycled each season (winter, spring, summer, and autumn). For this measurement, a six-point evaluation scale was applied: 5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; and Never. Previous studies of bicycle use in Norway have found the same measure appropriate (Kummeneje and Tretvik, 2015; Tretvik, 2015).

2.3 Statistical procedures

Confirmatory factor analysis (CFA) was conducted to test the dimensional structure of the respondents' attitudes towards traffic safety. A two-dimensional factor structure was included, and nine indicators were used to measure the factors. The analysis fulfilled Tabachnick and Fidell's criteria for an acceptable sample size (Tabachnick and Fidell, 2014). To test internal consistency, the reliability of the indices Cronbach's alpha and corrected inter-item correlations were applied. Paired sample t-tests were used to investigate differences in risk perception (probability and

consequence of being in an accident), worry, risk tolerance, and safety priority, between cycling in winter conditions and summer conditions. To predict whether respondents used their bicycle during wintertime, a hierarchical logistic regression analysis was carried out. In addition, hierarchical regression analysis was used to predict the amount of cycling done in all seasons.

To test the fit of the data to the regression model, additional structural equation modelling (SEM) was done. To examine the fit of the model to the data, the root mean square error of approximation (RMSEA) and the comparative fit index (CFI) were used. In addition, the chi-square degrees of freedom ratio were calculated. (χ^2/df). In accordance with established criteria, an RMSEA of 0.07 or less was considered to indicate satisfactory fit between the model and the data. A CFI above 0.90 was considered to indicate satisfactory fit. The same was the case for an X^2/df ratio of 4:1. Standard criteria were used for the evaluation of RMSEA and critical N.

3. Results

3.1 Risk perception for winter and summer conditions

The paired sampled t-tests showed significant differences in the respondents' assessment of risk during winter and summer cycling conditions. This was also the case for the subjective assessments of the probability of an accident ($t = 5.837$, $p < 0.001$) and for how worried the responents were being in an accident ($t = 6.786$, $p < 0.001$). The respondents perceived greater risks for cycling in winter conditions compared with cycling in summer conditions. However, it is interesting to note that there were no significant seasonal differences in the respondents' judgements of the severity of the consequences if an accident were to occur. Further, there were significant differences in risk tolerance ($t = 3.585$, $p < 0.001$) as well as priority given to safety ($t = -2.134$, $p < 0.05$). A high score on risk tolerance indicated low risk tolerance, and similarly a high score on priority given to safety indicated low priority. Table 1 shows that the respondents tolerated less risk when cycling in winter compared with cycling in summer conditions, and that they thought more priority should be given to safety when cycling in winter conditions compared with when cycling in summer conditions.

Table 1: Differences in risk perception when cycling in winter and summer conditions

	Winter cycling conditions		Summer cycling conditions		t-value
	Mean	SD	Mean	SD	(Sig. 2-tailed)
Probability	2.98	1.099	2.67	1.013	5.837***
Consequence	3.24	.999	3.28	.952	-.980
Worry	2.65	1.230	2.29	1.030	6.786***
Risk tolerance	2.66	1.117	2.49	1.044	3.585***
Safety priority	4.52	.935	4.58	.950	-2.134*

*p <.05, **p <.01, ***p <.001

The standard deviations for all variables were relatively high and there were variations in the respondents' perceptions of risk for both cycling in summer conditions and cycling in winter conditions.

3.2 Dimensional structure of attitudes towards traffic safety among cyclists

Table 2 shows the results of a confirmatory factor analysis (CFA) for the 9-item measure of cyclists' attitudes towards traffic safety. Four of the original 13 items were excluded during the factor analysis because they did not load, thus resulting in two dimensions. The first dimension was called 'Attitudes towards traffic rules' and consisted of six items related to the respondent's evaluation of violations of the rules for pragmatic reasons, based on statements such as 'The traffic rules for cyclists are too complicated to adhere to in practice' and 'Many traffic rules for cyclists are unnecessary'. The second dimension was called 'Attitudes towards controlling cyclists' and was measured by three items, based on statements such as 'There should be more traffic surveillance for cyclists' and 'There should be severe punishments for cyclists who break traffic rules'. Two of the items in the dimension 'Attitudes controlling cyclists' were inverted before conducting the analysis (see Table 3). As shown in Table 2, the tested measurement instrument had feasible reliability (Cronbach's $\alpha = 0.831$ and 0.632). The SEM showed that the fit of the model to the data was satisfactory ($\chi^2/df = 3.52$, RMSEA = 0.095, CFI = 0.95, SRMR = 0.057, Critical N = 139.03). However, although the RMSEA was above the criteria of 0.07, all other fit measures were fully in accordance with accepted criteria.

Table 2: Reliability and internal consistency and fit statistics of the model

Dimensions	Number of items	Mean	SD	Cron-bach's α	Corrected inter-item correlation, max, min	Average corrected inter-item correlation
Attitudes towards traffic rules	6	2.84	.801	.831	.685, .498	.603
Attitudes towards controlling cyclists	3	2.73	.729	.632	.687, .221	.456

The mean scores and standard deviations for the factors (Table 2) showed that the cyclists in the sample scored higher on the dimension 'Attitudes towards traffic rules' than on 'Attitudes towards controlling cyclists'. There were more statistical variations in the first dimension than in the second dimension.

A considerable number of cyclists reported attitudes that were not ideal. Ideal attitudes were those that disagreed with the statements. Table 3 shows that 30% of the respondents agreed on what were not ideal attitudes towards traffic safety. This concerned attitudes towards both traffic rules and controlling cyclists. In addition, a relatively large percentage of the respondents reported that they neither agreed nor disagreed with statements indicating ideal attitudes towards traffic safety. However, it is interesting to note that 43% of the respondents were in agreement in items showing ideal attitudes towards traffic rules and 46% had ideal attitudes towards controlling cyclists. A total of 50% of the respondents wanted more traffic surveillance for cyclists and 67% wanted more traffic safety campaigns to be implemented. Only 22% wanted punishments for cyclists who broke traffic rules.

Table 3: Dimensions of cyclists' attitudes towards traffic safety (%)

	Disagree	Neither agree/nor disagree	Agree
Attitudes towards traffic rules	**43**	**28**	**30**
It is no wonder that many cyclists violate traffic rules	25	31	44
Many traffic rules for cyclists are impossible to comply with	45	26	29
The traffic rules for cyclists are too complicated to adhere to in practice	50	27	23
Sometimes it is necessary to bend the rules as a cyclist to make sure of arriving	34	20	46
It is more important to get ahead as a cyclist than always to follow the rules	63	20	17
Many traffic rules for cyclists are unnecessary	38	44	18
Attitudes towards controlling cyclists	**46**	**23**	**31**
There should be more traffic surveillance for cyclists (inverted)	50	23	27
There should be severe punishments for cyclists who break traffic rules (inverted)	22	28	50
It is not important to have road safety campaigns directed towards cyclists	67	18	16

3.3 Predictors of the decision to cycle during the winter season

Table 4 shows the results of a logistic regression analysis performed to identify winter cyclists. The independent variables were entered in six blocks, respectively demographics, attitudes (towards traffic safety), risk tolerance, priority given to safety, risk perception, and worry. Table 4 shows the Block χ^2 values after each block was entered, and the result after all of the blocks were entered (full model).

Table 4: Predictors of cyclists' decision to cycle during wintertime (full model). Dependent variable 1 = cycle at least 1–2 times per week, 0 = cycle monthly, rarely, or never

	Block χ^2 (df)	B	Wald	Odds ratio
Block 1: Demographics	13.73 (3)**			
Gender (male = 0, female = 1)		0.36	.90	0.70
Age		.00	0.05	1.00
Education		0.36	1.98	1.44
Block 2: Attitudes	1.70 (2)			
Attitudes towards traffic rules		0.36	2.40	1.44
Attitudes towards controlling cyclists		0.28	1.22	1.32
Block 3: Risk tolerance	43.05 (2)***			
Risk tolerance, winter conditions		-1.09	13.42***	0.34
Risk tolerance, summer conditions		0.70	5.59*	2.01
Block 4: Safety priority	9.64 (2)**			
Safety priority, winter conditions		0.55	2.29	1.74
Safety priority, summer conditions		0.54	1.54	1.74
Block 5: Risk perception	9.85 (4)*			
Probability, winter conditions		-0.07	0.06	1.71
Probability, summer conditions		-0.09	0.09	0.93
Consequence, winter conditions		-0.24	0.77	0.92
Consequence, summer conditions		0.50	2.61	0.079
Block 6: Emotions	12.81 (2)**			
Worry, winter conditions		-0.64	6.29*	1.65
Worry, summer conditions		-0.04	0.03	0.53
Cox & Snell's R^2	0.29			
Nagelkerke's R^2	0.42			

*p <.05, **p <.01, ***p <.001

Demographics (gender, age, and education level) were entered as controlling variables in the analysis as the first block (Block $\chi^2 = 13.73$, $p < 0.01$, Cox & Snell's $R^2 = 0.05$, Nagelkerke's $R^2 = 0.07$). Gender was found to be a significant predictor variable ($B = -1.01$, Wald = 12.01, $p < 0.001$). Female respondents cycled less often than male respondents during wintertime. Age and educational level were not found to be associated with whether the cyclists used their bicycle during wintertime.

Attitudes towards traffic safety were not found significantly related to whether cyclists used their bicycle during winter. Adding risk tolerance significantly improved the model (Block $\chi^2 = 43.05$, $p < 0.001$, Δ Cox & Snell's $R^2 = 0.14$, Δ Nagelkerke's $R^2 = 0.20$). Risk tolerance for cycling in winter conditions increased the likelihood of cyclists using their bicycle during the wintertime. In addition, risk tolerance for cycling in summer conditions decreased their likelihood of cycling during wintertime. Next, the role of priority given to safety was investigated, which significantly improved the model (Block $\chi^2 = 9.64$, $p < 0.01$, Δ Cox & Snell's $R^2 = 0.02$, Δ Nagelkerke's $R^2 = 0.04$). The variables measuring safety priority significantly influenced whether the respondents used their bicycle during the wintertime. Additionally, risk perception significantly improved the model. However, the improvements to the model were modest with regard to probability assessments and to judgments of the severity of consequences (Block $\chi^2 = 9.85$, $p < 0.05$, Δ Cox &Snell's $R^2 = 0.03$, Δ Nagelkerke's $R^2 = 0.04$).

Finally, worry was added to the model and was found as an important predictor variable of winter cycling (Block $\chi^2 = 12.81$, $p < 0.01$, Δ Cox & Snell's $R^2 = 0.04$, Nagelkerke's $R^2 = 0.06$). Worry about cycling in winter conditions reduced cyclists' likelihood of cycling during winter. Thus, the results of the final block of the analysis showed that risk tolerance and worry were especially important for whether the respondents used their bicycle during the winter season. Additionally, perceived risk, priority given to safety, and gender were related to bicycle use during the wintertime. All of these variables lost prediction power after all of the blocks were entered into the model. This may indicate that these predictor variables had an indirect effect on the respondents' decision to cycle during wintertime.

3.4 Predictors for cycling frequency during the winter season

Respondents who used their bicycle during the wintertime were asked about the frequency of bicycle use. Accordingly, the next step in the analysis was to examine how the same group of predictors used in the logistic regression analysis predicted the frequency of bicycle use among that group. The independent variables were entered into the analysis in six blocks. The two final steps are presented in Table 5. In total, the predictor variables explained an acceptable percentage of variance ($R^2 = 0.32$).

Table 5: Dimensions of cycling frequency during winter (standardized beta coefficient). The table shows the two final steps (Model 5 and 6).

	Model 5	Model 6
Block 1: Demographics		
Gender (male = 0, female = 1)	-.12*	-.11
Age	.05	.04
Education	.05	.07
Block 2: Attitudes		
Attitudes towards traffic rules	.13*	.12*
Attitudes towards controlling cyclists	.06	.07
Block 3: Risk tolerance		
Risk tolerance, winter conditions	-.45***	-.35***
Risk tolerance, summer conditions	.28***	.22*
Block 4: Safety priority		
Safety priority, winter conditions	.17*	.14
Safety priority, summer conditions	.01	.05
Block 5: Risk perception		
Probability, winter conditions	-.18*	-.06
Probability, summer conditions	.07	.03
Consequence, winter conditions	-.20*	-.15
Consequence, summer conditions	.15	.15
Block 6: Emotions		
Worry, winter conditions		-.29**
Worry, summer conditions		.06
R^2	.28	.32
F Change	4.294**	6.236**

*p <.05 **p <.01, ***p <.001

Among the demographic variables, only gender was found to be associated with cycling frequency in wintertime. Female respondents cycled less than male respondents during wintertime. The results showed that risk tolerance in both winter and summer conditions was the most important predictor of cycling frequency. The more the cyclists tolerated exposure to risk when cycling in winter condition, the more they cycled during the winter season. We found the opposite case for risk tolerance when cycling in summer conditions: the less the cyclists tolerated exposure to risk when cycling in summer conditions, the more they cycled during the winter.

Additionally, safety priority was found to be related to cycling frequency during wintertime. The more important the respondent thought it was to prioritized safety for cyclists in winter conditions, the more they cycled during wintertime. When risk perception was added to the model, the explained variance significantly improved (Table 5). The less the cyclists perceived the probability being in an accident and the less serious they perceived the severity of consequences, the more they cycled during wintertime.

Additionally, worry related to cycling in winter conditions was found to be an important predictor of cycling frequency. The more worried the cyclists were, the less they used their bicycle during the winter season. Attitudes towards traffic rules were found to significantly influence bicycle use when the other variables were included in the model. When worry was included in the model, the risk-perception predictors (probability and severity of consequences) decreased significantly. This may indicate an association between the factors measuring worry and perceived risk, and that perceived risk could have an indirect effect on behaviour. Gender seemed to be a good predictor for cycling frequency as long as worry was not included in the model. This result may be related to gender differences in worry.

3.5 Predictors of cycling frequency during all seasons of the year

The next step in the analysis was to predict and compare cycling across all seasons. Four hierarchical multiple regression analyses were performed and the results are summarized in Table 6.

The model explained the largest amount of the variance in cycling frequency during winter ($R2 = 0.32$). The model was least successful in explaining cycling frequency during summer ($R2 = 0.09$). Thus, we did not find the model a good fit for predicting cycling frequency during summer. The model explained an identical amount of variance in cycling frequency during spring ($R2 = 0.15$) and autumn ($R2 = 0.15$). During these two seasons, both risk tolerance and risk perception were significantly associated with frequency of cycling.

To summarize, the results showed that risk perception was significantly associated with cycling frequency during winter. However, perceived risk was not strongly related to cycling frequency during the other seasons. Additionally, worry was found important for cycling frequency, but only during winter.

Table 6: Predictors of cycling frequency in winter, spring, summer, and autumn

	Winter		Spring		Summer		Autumn	
	R^2	F Change	R^2	F Change	R^2	F Change	R^2	F Change
Block 1: Demographics	.07	6.738***	.01	1.042	.02	2.056	.02	1.631
Block 2: Attitudes	.08	1.859	.02	1.182	.04	1.913	.04	2.727
Block 3: Risk tolerance	.22	21.979***	.07	6.393**	.05	2.371	.06	3.188*
Block 4: Safety priority	.23	3.026*	.08	1.330	.06	.686	.07	.422
Block 5: Risk perception	.28	4.294**	.13	4.049**	.08	1.726	.14	5.797***
Block 6: Worry	.32	6.236**	.15	1.914	.09	.849	.15	1.281

*p <.05, **p <.01, ***p <.001

3.6 Model for predicting cycling frequency during the winter season

We examined a path model for predicting frequency of cycling during the winter season (Figure 1), which included both direct and indirect associations between risk perception (probability and consequence), worry, risk tolerance, attitudes towards safety, gender, and priority given to safety. Gender and safety priority were included as exogenous variables in the model. Risk perception, worry, risk tolerance, and attitudes towards safety were entered as mediating variables. The aim of the model was to predict cycling frequency during the winter season, which therefore was the endogenous variable. Due to lack of success in explaining cycling frequency during summer, autumn, and spring, the analysis was restricted to cycling during winter.

As shown in Figure 1, worry was the strongest predictor of cycling frequency (B = -0.33): the more worried the respondents were, the lower was their cycling frequency. Other significant direct predictors of cycling frequency were safety priority (B = 0.18), risk tolerance (B = -0.15), and gender (B = -0.14). There was also a small but significant direct association between attitudes towards safety (B = 0.07) and cycling frequency. Risk perception was indirectly associated with cycling frequency by worry. The assessment of the probability of an accident (B = 0.44) contributed more to the variation in worry than did the perceived severity of

consequences (B = 0.23).The model explained 38% of the variance in worry and 26% of the variance in cycling frequency. The fit of the model to the data was acceptable ($\chi 2/df = 0.97$, CFI = 0.99, SRMR = 0.038).

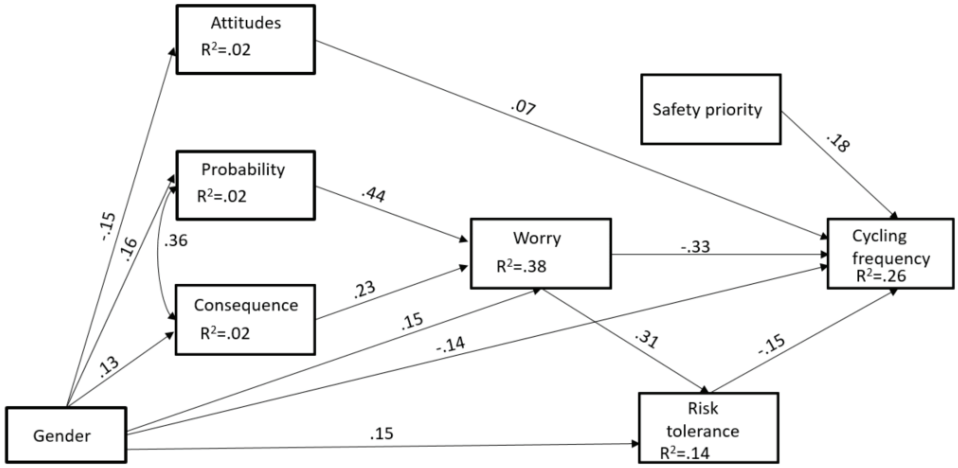

Figure 1: Heuristic path model for predicting cycling frequency during the winter season

4. Discussion

4.1 General discussion

The results showed seasonal differences in cyclists' perceptions of risk and worry when cycling. Their perception of risk was higher and they tended to be more worried about being involved in an accident when cycling in winter conditions compared with cycling in summer conditions. There were no differences in the perceived severity of consequences. With darkness and with icy and snowy roads in Norway, it is natural that cycling in winter may be perceived as a bigger challenge than in summer, and the probability of being involved in an accident in winter was judged to be higher. One reason why the consequences were not perceived as increased might have been that the type of accidents the cyclists imagined they could be involved in did not differ with winter and summer conditions. Novelty and familiarity associated with risk have been found to influence how people assess risk (Fischhoff et al., 1978). People perceptions of risks they are familiar with, may be lower than their perceptions of unknown risks. Most cyclists in Norway have experienced cycling in summer

conditions, but fewer have experienced cycling in winter conditions, and this may influence how they perceive seasonal differences in risks.

Most of the serious accidents among cyclists in Norway happen during the summertime (Melhuus et al., 2015). One reason for this may be enhanced risk exposure, since more people cycle during the summer, resulting in higher numbers of accidents. Another explanation could be that people who cycle during the winter often cycle during all seasons of the year. It may be argued that such cyclists are more experienced and safer in traffic than cyclists who only cycle during the summer. It is interesting to note that in our study the respondents assessed the risk of being involved in an accident as higher when cycling in winter condition than in summer conditions, although very few cycling accidents happen during the winter months. One explanation for fewer registered cycling accidents in winter might be that cyclists perceive the risk of being involved in an accident as high and therefore are more cautious when cycling in winter conditions.

The results showed that risk perception and worry were important factors in cyclists' decisions to cycle during the winter season. The assessment of risk had less influence on cycling frequency during the other seasons of the year. One possible explanation for this is that in general there is a very low perception of risk when cycling in summer conditions and that a cyclist has to experience that the risk is above their threshold before it will influence their behaviour. Finally, our findings showed that worry could be seen as an anticipatory integral emotion caused by the cognitive evaluation of risk, which is in accordance with findings by Loewenstein et al. (2001). The results showed that worry (as an emotion) influenced cycling frequency during the winter season. If the risk of being injured in a cycling accident was perceived as low, the cyclists tended to be less worried and worry did not influence their choice about whether to cycle. This difference emerged when cycling during winter was compared with cycling during the other seasons. The present study did not aim to investigate the role of anticipated emotions.

A further interesting finding was that women tended to tolerate risk less than did men and they were more worried and perceived the risk of accident as higher compared with men. This finding corresponds to findings from previous research (Breakwell, 2007; Moen and Rundmo, 2006). Attitudes towards traffic rules had a small effect on cycling frequency during wintertime when controlled for the other variables in the analysis. Women had more ideal attitudes towards traffic rules than did men. In previous research, attitudes towards traffic rules have been found

associated with risk-taking behaviour in traffic (Iversen and Rundmo, 2004, 2009; Nordfjærn and Şimşekoğlu, 2013).

4.2 Methodological discussion

The response rate the present study was low and can been seen as a limitation. Relatively low response rates are common in transport population studies (e.g. Backer-Grondahl et al., 2009; Castanier et al., 2012; Moan, 2013) probably partially due to the low immediate personal salience of the research topic (Galea and Tracy, 2007). Furthermore, web surveys have been found to have lower response rates compared with postal surveys (Shih and Xitao, 2008). However, low response rates do not necessary constitute a methodological problem. This is only the case if the overall sample is not representative of the target population (Krosnick, 1999). The target group of the present study was cyclists who cycled on a daily base. We assumed that people who often cycled visited the web page (i.e. where the respondents were recruited) more often than did those who cycled less often. It is natural to assume that users of the web page who never cycled or rarely cycled, would have had little interest in visiting the web page with discussions on topics related to cycling (i.e. cycling conditions, weather, closed roads, infrastructure, maintenance of the roads). When we compared the study sample with the target population we found similarities in the demographic characteristics. In the present study, 69% of the respondents reported they had more than three years of university education. This finding is in accordance with one reported by Hjorthol et al. (2014), who found that persons with university education cycled more than others did. Hjorthol et al. (2014) fount no gender differences in cycling activity among Norwegians, which is in contrast with the present study were 65% of the sample were men.

According to Iversen and Rundmo (2002), it is important to consider the social and situational context of risk assessments. For example, media coverage of related topics could influence how a population assesses risk. In Norway, cycling accidents account for 10% of people killed and injured in traffic (Statistics Norway, 2017). There has been little media focus on cycling accidents compared with other types of road accidents. The media not only cover traffic accidents, but also politicians, road authorities, and researchers, who communicate their views on the risks of cycling to the public. For example, the Norwegian Public Roads Administration communicates information about safety winter cycling in the media. Thus, interesting topics for future research are the way the media, road authorities, and researchers influence cyclists' risk perceptions in general, and particularly how

cyclists' perceptions of risk are influenced by whether they cycle in different seasonal conditions.

Worry was in the present study found to be a consequence of risk perception. As well as being a consequence of perceived risk, people's risk perceptions may be influenced by feelings. However, the present study did not intend to investigate the role of anticipated affect. For future research, it would be interesting to investigate whether the emotional state of cyclists influences their perception of risk. Another interesting future research path would be to explore how different winter operational standards and procedures affect risk perception among cyclists. Other than accidents, perceived risk when cycling in winter conditions may be influence by factors such as discomfort (even extreme discomfort) and the potential for adverse health impacts of cycling in winter conditions. We did not study these factors, but they would be worth considering in future research.

The results of the present study may be transferable to other places in Norway that have similar weather conditions during the year as Trondheim, and to other countries with snow and darkness during the winter months. Trondheim has the highest number of daily cyclists in Norway and a comprehensive focus on winter cycling. Other places in Norway where fewer trips are made on bicycles may benefit from the results from Trondheim with respect to increasing the numbers of cyclists.

5. Conclusions

The present study have shown that there are seasonal differences in how cyclists perceive the risk and how worried they are about being involved in an accident. As expected, cyclists perceived the latter risk as higher and were more worried being in an accident when cycling in winter conditions compared with when cycling summer conditions. Structural equation modelling showed that risk perception was a significant predictor of worry, and worry predicted cycling frequency during the winter season.

The results of our study contribute to an understanding of why cyclists cycle less during the winter than in other seasons of the year. From a pro-environmental perspective, it is important that people who use bicycles for their daily travels do not change to motorized modes of transport during the winter season. Campaigns aimed at increasing the number of cyclists could be ineffective if they do not take into account that the risk of being involved in an accident is perceived differently for the different seasons of the year. When encouraging people to cycle more often, it is important to bear in mind that not only should bicycles be safe to use. Bicycles should

also be perceived as safe to use by the road users. To increase the number of winter cyclists, it is important to take into account that there were no seasonal differences in the perceived severity of the consequences of involvement in an accident, and that the respondents perceived the probability of being in an accident as higher when cycling in winter conditions than in summer conditions, although fewer accidents occur during winter. This result may be a starting point to guide governments when planning interventions and public health sensitization programmes.

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Appendix

Questionnaire about risk perception and travel behaviour among cyclists

1. Have you used your bicycle once or more during the last year? (yes; no)

If you have answered that you have used your bicycle once or more during the last year:

2. How often do you cycle during …
    a. Winter (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
    b. Spring (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
    c. Summer (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
    d. Autumn (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
3. How probable do you think it is that you will experience an accident with injury when cycling in …
    a. Winter conditions (1 = not at all probable; 5 = very probable)
    b. Summer conditions (1 = not at all probable; 5 = very probable)
4. If you experienced an accident, how serious do you think the consequences would be when cycling in …
    a. Winter conditions (1 = not at all serious; 5 = very serious)
    b. Summer conditions (1 = not at all serious; 5 = very serious)
5. How worried are you being involved in an accident when cycling in …
    a. Winter conditions (1 = not at all worried; 5 = very worried)
    b. Summer conditions (1 = not at all worried; 5 = very worried)
6. To what extent do you tolerate being exposed to risk when cycling in …
    a. Winter conditions (1 = tolerate the risk absolutely; 5 = do not tolerate any risk)
    b. Summer conditions (1 = tolerate the risk absolutely; 5 = do not tolerate any risk)
7. How important do you think it is that the authorities prioritize measures to improve safety for cyclists cycling in …
    a. Winter conditions (1 = not at all important; 5 = very important)

   b. Summer conditions (1 = not at all important; 5 = very important)
8. To what extent do you agree or disagree with the following statements? (1 = strongly disagree; 5 = strongly agree)
   a. Many traffic rules for cyclists are impossible to comply with
   b. Sometimes it is necessary to bend the rules as a cyclist to make sure of arriving
   c. Cyclists should always follow the rules
   d. Cyclists who never violate the rules do not necessarily behave more safely than others
   e. It is no wonder that many cyclists violate traffic rules
   f. The traffic rules for cyclists are too complicated to adhere to in practice
   g. Many traffic rules for cyclists are unnecessary
   h. There should be more traffic surveillance for cyclists
   i. There should be severe punishments for cyclists who break traffic rules
   j. It is not important to have road safety campaigns directed towards cyclists
   k. It is OK to bend the rules if no other road users are present
   l. It is OK to cycle after drinking alcohol
   m. It is more important to get ahead as a cyclist than always to follow the rules
9. Gender? (male; female)
10. Year of birth? (year)
11. Highest level of education completed? (1 = primary or lower secondary school; 2 = upper secondary school; 3 =three years or less of university education; 4 = more than three years of university education)
12. Employment status? (1 = employed; 2 = student; 3 = pensioner; 4 = other)
13. Do you have a driving licence? (yes; no)
14. Do you have a motorized vehicle at your disposal? (yes; no)

Paper II

Risk perception, worry, and pedestrian behaviour in the Norwegian population.

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Risk perception, worry, and pedestrian behaviour in the Norwegian population

Abstract
The aim of the study was to investigate the association between pedestrians' risk perception and worry, and how worry influence pedestrians' behaviour. Worry is regarded as a feeling that emerges as a result of an individual's cognitive assessment of risk. The study was based on a questionnaire survey carried out among a representative sample (n = 2000) of the Norwegian population. The results showed differences in how people perceived risk and how worried they were about being exposed to different hazards (traffic accident, harassment, theft, and terrorism) as a pedestrian during night-time and daytime. As expected, pedestrians perceived their risk as higher and were more worried being exposed to hazards during night-time than in daytime. Structural equation modelling (SEM) revealed that risk perception was a significant predictor variable for worry during both night-time and daytime. Additionally, worry was found to influence pedestrian behaviour. Worry was moderately associated with walking frequency during night-time, and how often individuals walked alone outdoors during night-time. These associations were stronger for people without access to a private car. No associations were found between worry and walking frequency during daytime. The results of the study contribute to the understanding of the association between pedestrians' risk perceptions and worry, and how worry influence walking frequency. From both a pro-environmental and a health promoting perspective, it is important that people choose to walk or cycle for their daily travels.

Keywords: *worry, risk perception, risk tolerance, traffic accidents, pedestrian behaviour, night-time*

1. Introduction

In traffic safety research, pedestrians are defined as vulnerable road users, in common with cyclists and motorcyclists, because they have the highest risk in traffic compared with all other road users (Peden et al. 2004). Nevertheless, active travel, such as walking and cycling, is given high priority in European transport policy. Active travel is seen as a key solution to solve health problems in the population and to reduce environmental problems, both local air pollution and carbon dioxide emissions due to fossil fuel usage. Due to the risk factors and the aim to increase the numbers of people using active transport, priority should be given to examining pedestrians' risk

perception and worry. Consequently, the aim of the present study was to investigate what worried pedestrians, the association between their perceived risk and worry, and whether worry is associated with the decision to walk for daily travels.

1.1 Aims of the study

The specific aims of the study were as follows: (1) to examine differences in worry and risk perception related to being a pedestrian during night-time and daytime; (2) to examine the direct and indirect associations between risk perception, risk protection, risk tolerance, previous accidents and assault experiences, and worry being a pedestrian; (3) to compare the role of risk perception in worry about being involved in an accident, and/or experiencing harassment, theft, and terrorism; (4) to examine the association between worry and walking frequency as a pedestrian during night-time.

1.2 Risk perception and worry

Social cognition theory and models have dominated risk perception research and there is a need for more studies that include a focus on the role of emotions in perceived risk as well as in decisions under uncertainty. According to Breakwell (2007), 'an analysis of risk perception and decision-making that fails to consider the affect attached to a hazard, or the emotional state of the individual, is inevitably flawed.' To have a full understanding of individuals' risk assessment, both cognition and emotions should be included in research.

Affective processes have received increased attention in risk perception research. The risk-as-feeling approach highlights the role of emotions, e.g. worry, in risk decisions (Loewenstein et al. 2001). This approach distinguishes between two types of emotions that are important for risk perception: anticipatory and anticipated emotions. Anticipatory emotions are immediate visceral reactions to risk, such as worry, fear, anxiety, and dread. Anticipated emotions are those that the individual expects to feel as a consequence of a decision. There are two types of anticipatory emotions: integral emotions and incidental emotions. Integral emotions are caused by the decision problem itself, whereas incidental emotions are caused by other factors, such as mood (Loewenstein and Lerner 2003).

It is well recognized that hazards often engender worry. Worry is an emotional state that is stimulated by the anticipation of a negative outcome that is uncertain and may happen in the future. According to Breakwell (2007) worry is by definition associated with risk. In this article, worry is conceived as an anticipatory

emotion and integral to the decision problem, which implies that worry is defined as a feeling that emerges as a reaction to the individual's cognitive assessment of risk. Accordingly, in this article, we aim to examine the association between people's perceived risk and anticipatory feelings of worry as pedestrians.

Risk perception and worry are primarily interesting because they may be related to people's behavioural choices. According to the risk-as-feeling approach, behaviour is influenced by the interplay between cognitive evaluations of risk and feelings. Further, emotions often produce behavioural responses that differ from the individual's cognitive assessment of the best course of action. When such divergence occurs, it appears that behaviour is driven by emotional reactions, not by the cognitive assessment (Loewenstein et al. 2001). Loewenstein et al. (2001) argue that in contrast to cognitive evaluations, anticipatory emotions such as worry and fear are largely insensitive to changes in probabilities. To illustrate this, they refer to different experiments in which subjects were given information about probability estimates for winning a lottery, receiving an electric shock, or investing money. The results of the experiments showed that changes in probability estimates did not influence the emotional state of the research subjects. This effect is known as the certainty effect, and it supports the risk-as-feeling hypothesis, which suggests that people will be less insensitive to probability variations in emotional outcomes than other outcomes.

In contrast to the findings of Loewenstein et al. (2001), Baron et al. (2000) found that worry was largely affected by probability judgements, especially among laypersons, and that the desire for action was mainly determined by worry and probability judgements. Their study included 32 different risk sources, each of which was defined in terms of a cause and outcome (e.g. injury or death from an automobile accident). For each risk, the respondent was asked (among other questions) to give probability estimates, to estimate the badness of the outcome, number of persons affected, and evaluate how much he or she worried about the risk. Accordingly, in the present study, we investigated the role of the probability assessments, the assessments of severity of the consequences and the feeling of worry.

Several studies of parental worry about children as pedestrians have been conducted (Peterson et al. 1990, Salmon et al. 2007, Mammen et al. 2012). Mammen et al. (2012) investigated differences in parental worry about children's school travel. They found out that parents who escorted their children to school worried more than other parents about the possibility of strangers and bullies approaching their child and the traffic volume around the school. Salmon et al. (2007) found an association between the child's use of active transport to school and parents' concern that their

child may be injured in a road accident. Peterson et al. (1990) investigated parents' feelings of worry about different types of injury, including their children being injured by a motor vehicle when walking. Overall, the results showed that parents reported low feelings of worry about injuries.

Rosenbloom et al. (2011) investigated risk perception in relation to the possibility of sustaining an injury when crossing the road while in a fatigued state compared with a non-fatigued state. They divided their sample randomly into two groups, and participants in one group were asked one question about their perceived risk of being involved in a road accident after a sleepless night. Participants in the other group had the same question but without the last part of the sentence, 'after a sleepless night'. No differences in perceived risk were found between the two groups.

In contrast to studies that have examined road crashes, few studies have focused on the association between built environments and perceived risk. In their study, Kononov et al. (2007) argued for using data about road users perceived risk, as well as calculated risk in transport planning. They found that crash data only provided accident frequency and allowed for severity comparisons, but did not provide any information about the nature of the studied safety problem. Cho et al. (2009) examined how perceived risk and accident rates are related to each other, to built-environment characteristics, and to pedestrians' and cyclists' safety. Their results showed that residents who lived in low density-single residential neighborhoods were more likely to perceive their neighborhood as dangerous relative to residents of compact, mixed-use neighborhoods, even though the latter exhibited higher actual crash rates. Painter (1996) studied pedestrians' feelings of fear and about street use after dark. She found that street lightning might lead to a reduction in fears of crime and might increase pedestrians' use of streets after dark. Rankavat and Tiwari (2016) examined pedestrians' perception of convenience and safety while crossing the road in Delhi. Their study showed the use of zebra crossings were positively correlated with convenience perception and not correlated with safety perception.

Several previous studies have examined risk perception and worry related to accidents in relation to travel mode. For instance, Moen and Rundmo (2006), Oltedal and Rundmo (2007) and Roche-Cerasi et al. (2013) included walking as well as other travel modes when investigating perceptions of risk and worry. Both Moen and Rundmo (2006) and Oltedal and Rundmo (2007) found that their respondents reported they were less worried about being in an accident as a pedestrian compared with using other private travel modes. The respondents also perceived the probability

of being in an accident as the lowest as a pedestrian compared with the other private transport modes about which they were asked (car, motorcycle, scooter, bicycle). Another interesting finding from the two aforementioned studies was that the respondents reported that the consequences of being in an accident were greater when walking than when cycling, but still lower than when using motorized transport modes. Roche-Cerasi et al. (2013) also included respondents' risk perception of and worry about experiencing a terrorist attack and experiencing physical assault, as well as accidents. They compared differences in risk perception and worry regarding the use of private travel modes (including pedestrians) and public travel modes, and did not solely examine pedestrians. The results of the study showed that the respondents perceived the probability as higher and the consequences if being involved in an accident as greater, and were more worried about being involved in an accident when using private travel modes than when using public modes of transport. The respondents were more worried about experiencing violence when using public travel modes than when using private travel modes. Kummeneje et al. (2019) have studied risk perception and worry when cycling, and seasonal cycling behaviour. They found that risk perception and worry were strong predictors of cycling frequency during wintertime. To the authors of the present article's knowledge, no studies to date have solely investigated worry and risk perception among pedestrians, and the associations between worry, risk perception and pedestrian behaviour.

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1.3 Risk tolerance, risk protection, and previous experiences

It is important to investigate how risk is tolerated by individuals, and to what extent they think they can protect themselves against the risk. Individuals may differ in their thresholds for the degree of risk they find acceptable. The original impetus for the psychometric paradigm came from Starr (1969), in his effort to answer the question 'How safe is safe enough?' He measured the level of risk that individuals found acceptable for different activities, and found that activities that were voluntary and perceived as beneficial were tolerated more than other activities. In a study conducted by Fischhoff et al. (1978), respondents were asked to judge the acceptable level of risk associated with different activities or technologies. The researchers found that risk was less tolerated when the activities were associated with dread. Fischhoff et al. (1978) also found that higher risk levels were tolerated for voluntary activities with well-known and immediate consequences.

Risk protection refers to how the individual considers the possibility to protect himself or herself against risk. The perceived controllability of the risk has

previously found important for individuals' perception of risk (Higgins et al. 1997), and people tend to rate a risk as lower when they think they have control over it. Previous experience of accidents and assaults can influence the individual's perceived risk and feeling of worry. This was found in a study that we conducted out recently (Kummeneje and Rundmo 2018). Kummeneje and Rundmo (2018) found that individuals that had experienced an accident as a cyclist perceived the risk of being in an accident as higher than did the other individuals. They also tended to be more worried about being involved in an accident when cycling. Accordingly, in this article, we hypothesize that risk tolerance, risk protection, and previous negative experiences are associated with risk perception and worry.

2 Methods

2.1. Sample

The study was based on a telephone questionnaire survey carried out among a randomly selected sample of the Norwegian population aged 15 years or older. The data collection was carried out in spring 2017. The final sample was a representative sample of the Norwegian public and included 2000 respondents. The response rate was 27%. There were 43% females and 57% males in the sample. The respondents' age was in the ranged from 15 years to 88 years (mean = 45.38, standard deviation = 17.56). A total of 28% of the respondents reported they had more than three years of university education, 29% had three years or less of university education, 35% had received their highest level of education at upper secondary school, and 9% had primary or secondary school as their highest level of education. A total of 62% reported that they were employed or self-employed, and 10% were students. The remaining respondents were pensioners, benefit recipients, or homemakers. A total of 10% of the respondents reported that they did not have a driving license, and 13% did not have access to a car or other motorized vehicle.

2.2 Questionnaire and measure instruments

The questionnaire (see Appendix A) asked the respondents to evaluate their perception of risk and worry about being involved in an accident, as well as non-accidental risks (theft, harassment, and acts of terrorism) as a pedestrian during night-time and daytime. Additionally, they were asked about how they tolerated being exposed to risk (risk tolerance) as a pedestrian, and to what extent they thought it was possible to protect themselves against the risk (risk protection). The questionnaire also contained questions about the respondents' age, gender, employment status,

highest level of completed education, driving licence, motorized vehicles at their disposal, walking frequency, and their accident and assault experiences as a pedestrian.

To measure risk perception, the respondents were asked to assess their probability of experiencing four different hazards (accident, theft, harassment, or acts of terrorism), and to judge the severity of the consequences if such an event were to take place. The scale for measuring the probability assessments was a five-point evaluation scale ranging from 'not at all probable' to 'very probable'. For the judgement of severity of the consequences, the scale ranged from 'not at all serious' to 'very serious'. To measure worry, the respondents were asked to rate how worried they were about experiencing each of the four hazards as a pedestrian, and the measurement scale ranged from 'not at all worried' to 'very worried'. To measure risk tolerance, the respondents were asked: 'To what extent do you tolerate being exposed to risk as a pedestrian?' The five-point evaluation scale ranged from 'tolerate the risk absolutely' to 'do not tolerate any risk'. To measure risk protection, the respondents were asked: 'To what extent do you think it is possible to protect yourself against risk as a pedestrian?' The five-point scale ranged from 'very possible' to 'not at all possible'.

To measure walking frequency, the respondents were asked how often they walk outside during night-time and daytime each season (winter, spring, summer, and autumn). For this measurement, a six-point evaluation scale was applied: 5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; and Never. Previous studies have found the same measure appropriate (Kummeneje and Tretvik 2015, Kummeneje and Rundmo 2018, Kummeneje et al. 2019). The respondents that answered that they more than monthly walk outside during night-time, were further asked if they walk alone (without a family member, friend or dog). A three-point evaluation scale was applied: Often; Sometimes; and Never.

To measure accident experience, the respondents were asked whether they had been involved in an accident as a pedestrian during the last two years, including single accidents (i.e. accidents with no other road users involved). If they reported being in an accident, they were further asked whether other road users (e.g. cyclist, pedestrian, motorized vehicle) were involved and whether they needed medical treatment after the accident. To measure assault experiences, the respondents were asked whether they had experienced being physically assaulted as a pedestrian during the last two years. If they answered 'yes' to this question, they were further asked whether they had needed medical treatment after the experience.

2.3 Statistical analysis

Paired sample t-tests were used to compare the respondents' risk perception (perceived probability and severity of consequence) and worry as a pedestrian during night-time and daytime. Structural equation modelling (SEM) was done to predict worry about being a pedestrian during night-time and daytime. To examine the fit of the model to the data, the Root Mean Square Error of Approximation (RMSEA), the Standardized Root Mean Square Residual (SRMR), and a comparative fit index (CFI) were used. In addition, the Chi-square degrees of freedom ratio were calculated (χ^2/df). A RMSEA of 0.07 or less was considered to indicate a satisfactory fit between the model and the data. For SRMR, a value below .08 is considered a good fit. A CFI above 0.90 was considered indicative of a satisfactory fit. The same was the case for an χ^2/df ratio of 4:1. Eight multiple regression analyses were used to predict worry as a pedestrian during night-time and daytime for each of the four different hazards (accident, theft, harassment, and acts of terrorism). The multiple regression analyses are used as exploratory analyses for further research. In the multiple regression analysis, all the variables that originally was hypnotized as predictor variables are reported. The predictor variables were entered into the models with an enter procedure. The calculation of the contribution of each predictor to the R-square value was as follows:

$$R^2 \cdot 100\% = \sum_{i=1}^{6} \beta \cdot r \cdot 100\%$$

β is the standardized beta coefficient, r is the Pearson's r correlation.

The variables measuring worry about the four different hazards were summarized to one variable for daytime and another variable for night-time. These variables were used to examine the association between worry and behaviour. Four different ANOVAs (analyses of variance) were conducted to examine the association between worry and walking frequency during night-time in different seasons of the year. An additional ANOVA analysis was conducted to find the association between worry and how often the respondents walked alone during night-time.

3 Results

3.1 Worry as a pedestrian during night-time and daytime

The results presented in Table 1a show differences in how worried the respondents were about being a pedestrian during night-time and daytime. They were more worried about experiencing an accident, theft, harassment, and terrorism as a pedestrian during night-time than in daytime. The majority of the respondents (78-84%) reported they were not worried about being exposed to a hazard as a pedestrian during daytime. By contrast, between 53–74% of the respondents reported they were not worried about the hazards as a pedestrian during night-time.

Table 1a: Worry experienced as a pedestrian during night-time and daytime (%), Worried, high (5-3), Worried, low (2), Not worried (1), n=2000

	Accident		Theft		Harassment		Terrorism	
	Night	Day	Night	Day	Night	Day	Night	Day
Worried, high	22	9	20	5	19	6	14	7
Worried, low	26	13	24	11	21	10	12	9
Not worried	53	78	55	84	59	84	74	84

Comparatively more respondents felt worried about being involved in an accident as a pedestrian than about experiencing the other three hazards (theft, harassment, and terrorism), both in night-time (48%) and daytime (22%). There were small differences in their worry about experiencing theft (16%), harassment (16%), or terrorism (16%) during daytime. By contrast, for night-time, the results showed that 44% of the respondents felt worried about experiencing theft, 40% about harassment, and 26% about terrorism. It is interesting to note that for night-time, the respondents reported they were least worried about experiencing acts of terrorism. After accidents, daytime acts of terrorism worried them the most. Table 1b shows the mean values in the respondents' assessment of risk and worry being a pedestrian during daytime and night-time.

The paired sampled t-test showed significant differences in the respondents' perceived risk and worry for all four hazards. The respondents perceived the risk associated with being a pedestrian during night-time as greater than during daytime. This was the case for both the subjective assessment of the probability and the respondents' judgement of the severity of consequences. Further, the results revealed that the judgement of the severity of consequences had relatively high scores compared with the probability assessments. This was the case for all four hazards.

The incident with the highest perceived probability was being involved in a traffic accident during night-time, while experiencing acts of terrorism during daytime was perceived as least probable. The severity of consequences was judged as most serious for experiencing acts of terrorism during night-time, and least serious for being harassed during day-time. The standard deviations for all of the variables were relatively high and revealed variations in the respondents' perceived risk and worry. With regard to worry and the probability assessment scores, the variations were higher for daytime than for night-time.

Table 1b: Differences in worry and risk perception as a pedestrian during night-time and daytime, 1 = not at all probable; 5 = very probable / 1 = not at all serious; 5 = very serious / 1 = not at all worried; 5 = very worried, n=2000

		Worry		Probability		Consequence	
		Mean	SD	Mean	SD	Mean	SD
Accident	Night	1.82	1.036	2.16	1.015	2.99	1.252
	Day	1.37	.788	1.68	.928	2.90	1.270
	t-value (sig. 2-tailed)	-24.450***		-22.817***		-4.109***	
Theft	Night	1.77	1.010	1.98	1.040	2.64	1.218
	Day	1.26	.670	1.40	.750	2.26	1.150
	t-value (sig. 2-tailed)	-27.683***		-28.616***		-17.860***	
Harassment	Night	1.74	1.038	1.94	1.103	2.50	1.279
	Day	1.26	.665	1.42	.786	2.05	1.136
	t-value (sig. 2-tailed)	-25.819***		-26.217***		-23.103***	
Terrorism	Night	1.51	1.000	1.41	.814	3.20	1.648
	Day	1.29	.761	1.24	.634	3.10	1.686
	t-value (sig. 2-tailed)	-13.337***		-11.731***		-5.122***	

*p < .05 **p < .01, ***p < .001

3.2 Model for predicting worry about being a pedestrian during night-time and daytime

Next, we examined a model for predicting worry about being a pedestrian during night-time and daytime (Figure 3), which included both direct and indirect associations between risk perception, worry, previous experiences, risk protection, and risk tolerance. Demographics contributed very little to the explained variance and were not included in the model. Overall, the model explained an acceptable proportion of the variance in worry about being a pedestrian during night-time (R^2 = .81) and during daytime (R^2 = .64).

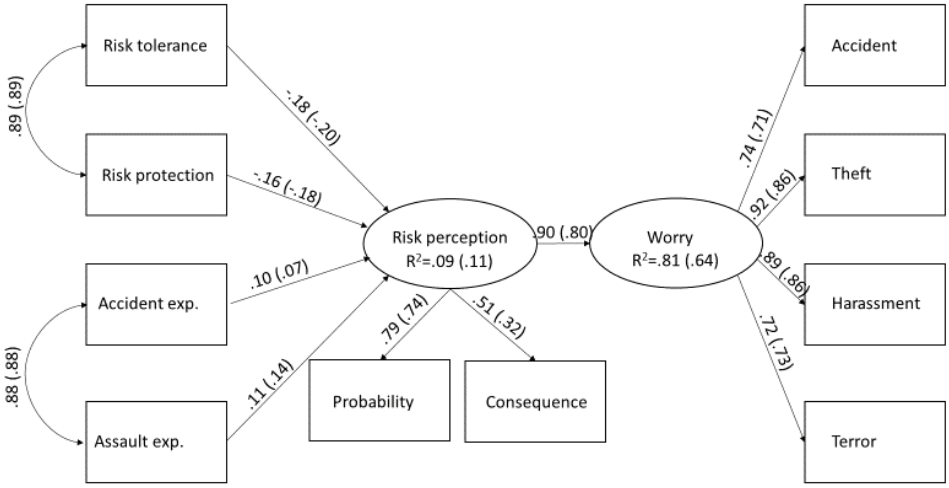

Figure 1: Heuristic path model for predicting worry as a pedestrian during night-time (daytime), n=2000
χ^2/df = 3.994, RMSEA = .039, CFI = .991, SRMR = .019
(χ^2/df = 4.366, RMSEA = .041, CFI = .986, SRMR = .023)

As shown in Figure 3, risk perception was a strong predictor of worry about being a pedestrian during both night-time and daytime. Risk tolerance, risk protection, accident experience, and assault experience were indirectly associated with worry. The results showed that individuals that had experienced an accident or assault as a pedestrian during the last two years, perceived their risk of being involved in a negative incident as higher than did the other individuals. Both accident experience (night-time β = .10; daytime β = .07) and assault experience (night-time β = .11; daytime β = .14) significantly influenced the perceived risk being a pedestrian during

night-time and daytime. Risk protection and risk tolerance were found to be significantly related to perceived risk when being a pedestrian during night-time and daytime. The perceived risk increased when the respondent assessed the possibility of protecting himself or herself against the risk as small (night-time $\beta = -.20$; daytime $\beta = -.18$). The more the respondent tolerated being exposed to risk, the lower they perceived the risk when exposed to hazards as a pedestrian (night-time $\beta = -.18$; daytime $\beta = -.16$). The associations between risk tolerance and risk protection were found to be significant, which indicates that people who experience that they can protect themselves against risk will tolerate more risk. There was also a significant association between accident experience and assault experience, which indicates that people who have been involved in an accident as a pedestrian have more often also experienced assault as a pedestrian than have others. The fit of the model to the data was acceptable both for night-time ($\chi^2/df = 3.994$, RMSEA = .039, CFI = .991, SRMR = .019) and daytime ($\chi^2/df = 4.366$, RMSEA = .041, CFI = .986, SRMR = .023).

3.3 Predictors of worry about being involved in an accident or incidents of harassment, theft, or terrorism

Exploratory analyses were conducted to investigate the contribution of the six predictor variables previously included in the SEM (see Figure 1). Worry was entered into the analyses as a latent exogenous variable. Eight multiple regression analysis were carried out in order to examine the explained variance related to worry about each of the four types of hazards (accident, harassment, theft, and terrorism) separately. The first four analyses (see Figure 2) aimed at predicting worry being a pedestrian during night-time. The last four analyses (see Figure 3) aimed at predicting worry being a pedestrian during daytime. The figures show the contribution of each predictor to the R-square value. All eight models explained an acceptable amount of variance in worry (R^2 between .33 and .23).

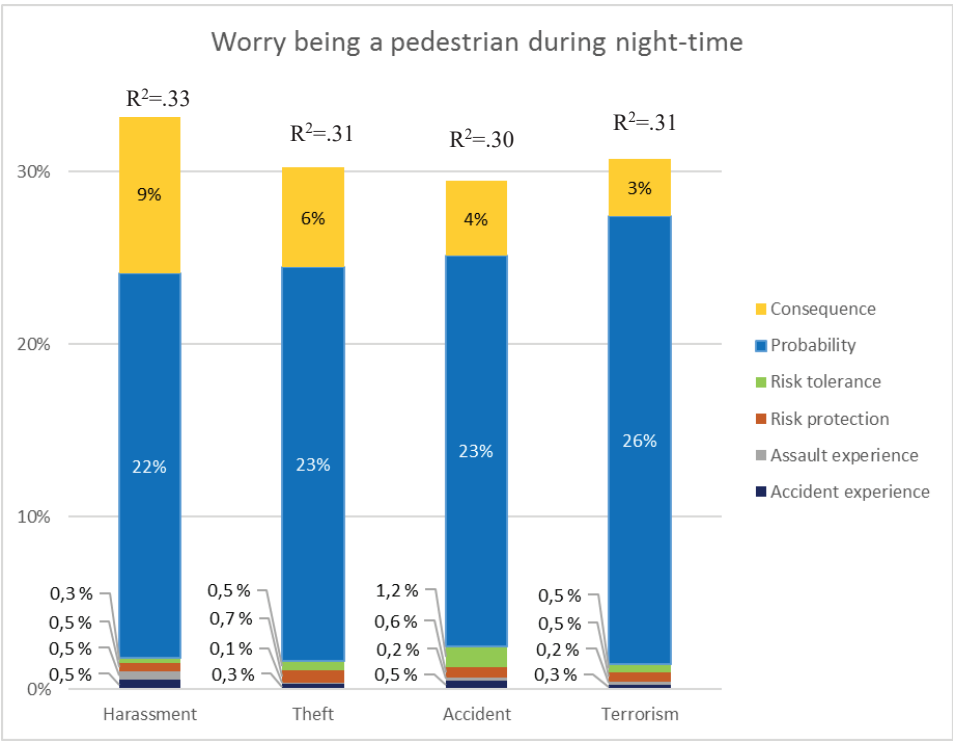

Figure 2: Predictors of worry about being involved in incidents of harassment, theft, traffic accident, and terrorism as a pedestrian during night-time, the contribution of each predictor to the R-square value, n=2000
*p < .05 **p < .01, ***p < .001, NS = non-signifiant

The model was better for predicting worry about being a pedestrian during night-time than during daytime. The model explained the largest amount of the variance in worry about experiencing harassment during night-time (R^2 =.33), and the model was least successful in explaining worry about theft during daytime (R^2 = .23).

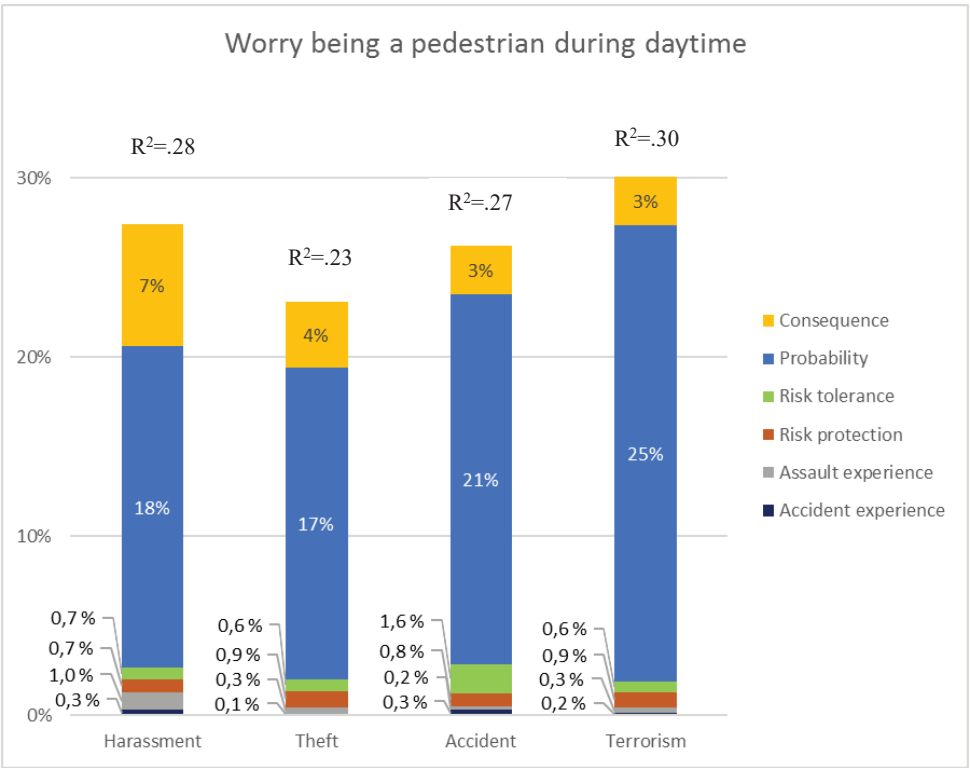

Figure 3: Predictors of worry about being involved in incident of harassment, theft, traffic accident, and terrorism as a pedestrian during daytime, the contribution of each predictor to the R-square value, n=2000

*p < .05 **p < .01, ***p < .001, NS = non-signifiant

The assessment of the probability of being involved in an adverse event was found to be the most important predictor of worry in all of the models. The probability estimates explained between 17% (theft during daytime) and 26% (terrorism during night-time) of the variance in worry. The judgment of severity of consequences was the second most important predictor of worry in the models. Severity of consequences was most important for predicting worry about harassment during both night-time (9%) and daytime (7%), and least important for predicting worry about being exposed to acts of terrorism during night-time (3%) and daytime (3%).

Further, the results showed that risk protection and risk tolerance were related to worry. For all four hazards, there were small differences in the influence of risk protection and risk tolerance between night-time and daytime. Risk tolerance was a more important predictor of worry about being involved in an accident (1% during

night-time, 2% during daytime) compared with experiencing the other three hazards. For all of the hazards, risk protection was shown to be a more important predictor of worry about being a pedestrian during daytime (0.7–0.9%) than during night-time (0.5–0.7%).

Additionally, previous experiences influenced worry, but were less important than were the other predictors. Accident experience was a more important predictor of worry about being a pedestrian during night-time compared with during daytime, especially with regard to being involved in an accident (0.5% during night-time, 0.3% during daytime) or experiencing harassment (0.5% during night-time, 0.3% during daytime). Assault experience was associated with worry about being harassed during daytime (0.5% during night-time, 1.0% during daytime), but was only to a low degree important for worry about experiencing or being involved in other types of hazards.

In preliminary analyses, we controlled for demographic variables. Gender was shown to be the most important predictor among the demographic variables for worry about being a pedestrian (1–2% of the explained variance). Education level was shown to be associated with worry about experiencing terror attack (0.9% during night-time, 0.6% during daytime), but was not as important as for the other three types of hazard. Age was most important for worry about being involved in an accident (0.8%) and experiencing theft (0.9%) during night-time, and not as important as for other types of hazards. Overall, the results showed that demographic variables to a little extent contributed to the explained variance in worry and demographics were not included in the final models (Figure 2 and Figure 3).

To summarize, the results showed that risk perception was strongly related to worry for all four hazards (accident, harassment, theft, and terrorism), both during night-time and daytime. Especially, the probability estimates were important for worry about being a pedestrian, but the perceived severity of consequences was as well highly important for worry about being a pedestrian.

3.4 The association between worry and behaviour

According the results from the SEM models, worry about ‘accidents’, ‘harassment’, ‘theft’, and ‘terrorism’ could be seen as part of the same factor. All of the four variables have strong factor loadings. Accordingly, the variables measuring worry about the four different hazards were summarized to one variable for daytime and another variable for night-time. Worry was shown to be associated with how often the respondents chose to walk to their travel destinations during night-time, and whether they chose to walk alone. We did not find the same correlation between

worry and walking frequency during daytime. Table 2 shows the association between worry and walking frequency during night-time for the different seasons of the year. The whole sample is included in the results. The more worried the respondents were, the less frequently they walked.

Table 2: Worry about being a pedestrian during night-time, and walking frequency, scale from 4 to 20, 4 = not at all worried of any of the four hazards; 5 = very worried about all four hazards, n = 2000

		Worry, night-time			Cohen's d		
		Mean	SD	N	1-2	1-3	2-3
Winter	1 Daily	5.91	3.031	264	-.21	-.41	-.22
	2 Weekly	6.57	3.197	1159			
	3 Rarely	7.35	3.996	577			
	F (sig.)	18.341***					
Spring	1 Daily	6.07	3.067	359	-.20	-.31	-.13
	2 Weekly	6.72	3.329	1211			
	3 Rarely	7.18	3.998	430			
	F (sig.)	10.288***					
Summer	1 Daily	6.40	3.307	486	-.10	-.19	-.10
	2 Weekly	6.73	3.367	1208			
	3 Rarely	7.09	3.967	306			
	F (sig.)	3.896*					
Autumn	1 Daily	6.05	3.113	324	-.20	-.33	-.15
	2 Weekly	6.69	3.309	1260			
	3 Rarely	7.26	4.019	416			
	F (sig.)	11.252***					

*p < .05 **p < .01, ***p < .001

Table 2 shows that worry was weakly to moderately associated with walking frequency during night-time for all four seasons. Worry was most important for walking frequency during winter and least important for walking frequency during summer. Table 3 shows the association between worry and walking frequency during night-time for respondents who did not have access to a car.

Table 3: Worry about being a pedestrian during night-time, and walking frequency (no car), scale from 4 to 20, 4 = not at all worried of any of the four hazards; 20 = very worried about all four hazards, n = 297

		Worry, night-time			Cohen's d		
		Mean	SD	N	1-2	1-3	2-3
Winter	1 Daily	6.67	3.42576	54	-.24	-.59	-.40
	2 Weekly	7.48	3.42835	186			
	3 Rarely	9.16	4.92729	57			
	F (sig.)	6.624**					
Spring	1 Daily	6.78	3.43643	72	-.23	-.62	-.43
	2 Weekly	7.59	3.52246	184			
	3 Rarely	9.49	5.09962	41			
	F (sig.)	6.872***					
Summer	1 Daily	7.27	3.70838	104	-.08	-.49	-.43
	2 Weekly	7.56	3.53473	163			
	3 Rarely	9.47	5.21095	30			
	F (sig.)	4.008*					
Autumn	1 Daily	6.98	3.57012	64	-.15	-.56	-.44
	2 Weekly	7.53	3.51033	196			
	3 Rarely	9.49	5.22080	37			
	F (sig.)	5.483**					

*p < .05 **p < .01, ***p < .001

Table 4: Worry about being a pedestrian during night-time, and walking alone, scale from 4 to 20, 4 = not at all worried of any of the four hazards; 20 = very worried about all four hazards,

		Worry, night-time			Cohen's d		
		Mean	SD	N	1-2	1-3	2-3
All	1 Often	6.36	3.217	907	-.13	-.27	-.17
n = 1845	2 Some times	6.78	3.246	681			
	3 Never	7.41	4.087	257			
	F (sig.)	10.504***					
No car	1 Often	7.30	3.653	160	-.07	-.63	-.58
n = 283	2 Some times	7.55	3.444	98			
	3 Never	9.92	4.600	25			
	F (sig.)	5.308**					

*p < .05 **p < .01, ***p < .001

Worry was more important for walking frequency for respondents without a car, and the correlations were stronger for all four seasons compared with respondents who had a car at their disposal. Those who reported that they walked outdoors during night-time were further asked whether they walked alone. The results for all who responded 'yes' to walking alone and who did not have an access to a car are presented in Table 4.

Worry about being a pedestrian was important for respondents who chose to walk alone during night-time. When all respondents were included in the analysis, the correlations were significant but weak. For individuals without an access to a car the correlations between worry and never walking alone during night-time were moderate to strong.

4 Discussion

The results showed that worry could be seen as an anticipatory integral emotion caused by the cognitive evaluation of risk. This finding is in accordance with findings by Loewenstein et al. (2001). There was a significant strong association between risk perception and worry. The exploratory regression analysis showed that the perceived probability of being exposed to a hazard was a more important predictor variable of worry than the judgement of the severity of consequences. This finding is in accordance with the finding made by Baron, Hershey, and Kunreuther (2000), but in contrast to Loewenstein et al. (2001) that argue that the perceived severity of consequences is a more significant predictor variable for emotions such as worry. However, the role of subjective assessments of probability and severity of consequences may depend on the type of risk source evaluated. Previous studies have not focused on pedestrians, and the association between risk perception and worry among pedestrians has not been examined previously. The results of the present study indicate that the majority of Norwegians perceive the risk of being a pedestrian as low. If the probability estimates are low, it is conceivable that individuals give less attention to their perception of the severity of consequences. This could be a reason for the strong association we found between the probability estimates and worry. Further research should clarify the relationship between probability and severity of consequence estimates, and worry.

In the present study, both risk perception and worry seemed to have been influenced by external factors (accident involvement and assault experience), as expected. This is in accordions with Kummeneje and Rundmo (2018) that found that individuals that had experienced a bicycle accident during the last two years

perceived their risk as higher and tended to be more worried about being involved in an accident when cycling than did other individuals. In the present study, it was not asked about the date of the incidents. It is reasonable to assume that the more recent the individual has experienced assault or been involved in an accident, the higher they would perceive the risk of the same incident happening again. These associations were not possible to test in the present study, but would be worth studying in future research.

The results showed a moderate association between worry and behaviour. Worry was measured in relation to accidents and three different security problems (harassment, theft, and terrorism). The type of anticipatory worry that was measured consider these specific factors. On the other side, behaviour was measured as how often the respondents walk in general. With these conditions, strong correlations were not expected. A moderate negative association between worry and walking frequency was found, as expected. In general, the group without access to a car is more worried about being exposed to the risk being as a pedestrian than others. A possible explanation for this may be that people that are more exposed to the risk will be more worried than people that to a little extend are being exposed to the same risk. Individuals without access to a car are also walking more often on their daily travels than others. A further interesting finding was that the association between worry and walking frequency during night-time was stronger for individuals without access to a car. Those who have no car and answered that they rarely walk outdoors during night-time is a group who severely worried about walking at night. This group worry more about hazards being a pedestrian than the general public. Sever worry in this group results in rarely walking outside at night. From the results we cannot conclude that not having access to a car results in more worry in this group because they to a little extend are being exposed to the risk being a pedestrian. The results show that the proportion of the group that answer that they sometimes walk alone at night is bigger in the group that does not have a car compared to the whole sample. Individuals without access to a car are more dependent of safe environment for pedestrians than others because they have no choice about being exposed to risk while on their daily travels. Because they do not have access to a car, most of them have no other choice than walk at night sometimes even though they worry about hazards. There is a need for more research to explain the association between worry as a pedestrian and access to a car.

Worry was found especially important for walking frequency during night-time in winter. Hence, measures such as better street lighting may increase the

number of pedestrians in certain areas. Measures that reduce pedestrians' feelings of worry about being involved in an accident could be separate pathways for vulnerable road users. This might reduce pedestrians' perceived probability of being involved in an accident. Earlier research has shown that some people perceive themselves as less likely to experience something negative compared with others (Moen and Rundmo 2005), and it is therefore reasonable to assume that people will tolerate less risk exposure for persons for whom they are responsible, such as children. Measures that reduce vulnerable road users' perception of risk could also influence where children use active transport modes, and reduce the numbers of parents who drive their children to school.

Two methodological issues should be focused in future research. The first relates to the scales used to measure risk tolerance (risk acceptance) and risk protection. These variables are usually measured on a relative scale where the respondents are asked to compare different types of risks (e.g. risk tolerance or risk protection related to different modes of transport, different types of hazards, or different conditions) (e.g. Moen and Rundmo 2004, Kummeneje et al. 2019). In the present study the respondents were only asked one question about risk tolerance and one question about risk protection. A one question scale might be more open to interpretation by different respondents than a relative scale. The second methodological issue relates to the measurement of worry. The variables measuring worry about being a pedestrian were measured with Likert-type five-point scales. The use of such scales does not fully satisfy the requirements of criterion variables in multiple regression analysis. However, Likert-type scales with five or more categories are often used as criterion variables in survey research analysing measurements of subjective judgements (Norman 2010, Sullivan and Artino Jr 2013). This should be an issue more suitable for basic measurement research than for applied research in the area of transport safety and security.

The response rate of the present study was low (27%). Relatively low response rates are common in transport population studies (e.g. Backer-Grondahl et al. 2009, Castanier et al. 2012, Moan 2013) probably partially due to the low immediate personal salience of the research topic (Galea and Tracy 2007). However, low response rates only constitute a methodological problem if the overall sample is not representative of the target population (Krosnick 1999). Demographic characteristics were compared with the Statistics Norway (2015) registry that showed that there were no serious violations between our sample and the population. The youngest age group (15-29 years) were slightly underrepresented compared with

other age groups, and females were underrepresented relative to males. When we compared the study sample with the National Travel Survey (Hjorthol et al. 2014) we found similarities in the demographic characteristics. In the present study, 10% of the respondents reported that they did not have a driving license, and 13% did not have a motorized vehicle at their disposal. This finding is in accordance with the one reported by Hjorthol et al. (2014) that found that 91% of the Norwegian population have a driving license and that 88% of the population have access to a car or other motorized vehicle.

Conclusions

The present study has shown that the respondents perceived their risk as higher and tended to be more worried about hazards (accidents, harassment, theft, and terrorism) as pedestrians during night-time than during daytime. Furthermore, the results showed that previous accident involvement and assault experience had an indirect effect on worry. Respondents who had previous experience of being involved an accident or had experienced assault perceived the risk of walking as higher than respondents without these experiences, and tended to be more worried being exposed to hazards. Both risk tolerance and risk protection were associated with risk perception, which in turn influenced how worried the respondents felt about being pedestrians. Finally, the results showed that worry influenced how often the respondents walked outdoors during night-time. We did not find the same correlation between worry and walking frequency during day-time as we found for night-time. This association was stronger for individuals without access to a car.

The results of our study contribute to the understanding of the association between risk perceptions of and worry about being a pedestrian, and how worry influences walking frequency. From a pro-environmental perspective as well as a health promoting perspective, it is important that people choose to walk or cycle for their daily travels. The results of our study of worry about being a pedestrian may be important in the work with increasing the frequency of such behaviour. Interventions that aim to include all transport users could be ineffective if they do not take into account that the risk of being exposed to a hazard is perceived differently between different groups in the population. It is especially important to reduce the perceived risk and worry for people without access to a car. People who are dependent on public transport are also dependent on a safe environment for pedestrians.

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Appendix A

Questionnaire about risk perception, worry, and travel behaviour among pedestrians

1. How often do you walk outside during daytime in …
    a. Winter (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
    b. Spring (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
    c. Summer (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
    d. Autumn (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
2. How often do you walk outside during night-time in …
    a. Winter (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
    b. Spring (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
    c. Summer (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
    d. Autumn (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
3. The respondents that answered that they more than monthly walk outside during night-time, were further asked: How often do you walk outside during night-time alone (without a family member, friend or dog)? (Often; Sometimes; Never)
4. How probable do you think it is that you will experience the following hazards when walking in daytime…
    a. Accident (1 = not at all probable; 5 = very probable)
    b. Theft (1 = not at all probable; 5 = very probable)
    c. Harassment (1 = not at all probable; 5 = very probable)
    d. Acts of terrorism (1 = not at all probable; 5 = very probable)
5. How probable do you think it is that you will experience the following hazards when walking in night-time…
    a. Accident (1 = not at all probable; 5 = very probable)
    b. Theft (1 = not at all probable; 5 = very probable)

c. Harassment (1 = not at all probable; 5 = very probable)
d. Acts of terrorism (1 = not at all probable; 5 = very probable)

6. If you experienced the following hazards, how serious do you think the consequences would be when walking in daytime …
   a. Accident (1 = not at all serious; 5 = very serious)
   b. Theft (1 = not at all serious; 5 = very serious)
   c. Harassment (1 = not at all serious; 5 = very serious)
   d. Acts of terrorism (1 = not at all serious; 5 = very serious)
7. If you experienced the following hazards, how serious do you think the consequences would be when walking in night-time …
   a. Accident (1 = not at all serious; 5 = very serious)
   b. Theft (1 = not at all serious; 5 = very serious)
   c. Harassment (1 = not at all serious; 5 = very serious)
   d. Acts of terrorism (1 = not at all serious; 5 = very serious)
8. How worried are you being involved in the following hazards when walking in daytime…
   a. Accident (1 = not at all worried; 5 = very worried)
   b. Theft (1 = not at all worried; 5 = very worried)
   c. Harassment (1 = not at all worried; 5 = very worried)
   d. Acts of terrorism (1 = not at all worried; 5 = very worried)
9. How worried are you being involved in the following hazards when walking in night-time…
   a. Accident (1 = not at all worried; 5 = very worried)
   b. Theft (1 = not at all worried; 5 = very worried)
   c. Harassment (1 = not at all worried; 5 = very worried)
   d. Acts of terrorism (1 = not at all worried; 5 = very worried)
10. To what extent do you tolerate being exposed to risk as a pedestrian? (1 = tolerate the risk absolutely; 5 = do not tolerate any risk)
11. To what extent do you think it is possible to protect yourself against risk as a pedestrian? (1 = very possible; 5 = not at all possible)
12. Have you been involved in an accident as a pedestrian during the last two years? (yes; no)

    If ‘yes':

    a. Were other road users involved in the accident(s)? (e.g. cyclist, pedestrian, motorized vehicle)
    b. Did you need medical treatment after the accident(s)? (yes; no)

13. Have you experienced being physically assaulted as a pedestrian during the last two years? (yes; no)

    If ‘yes':

    a. Did you need medical treatment after the experience(s)? (yes; no)
14. Gender? (male; female)
15. Year of birth? (year)
16. Highest level of education completed? (1 = primary or lower secondary school; 2 = upper secondary school; 3 =three years or less of university education; 4 = more than three years of university education)
17. Employment status? (1 = employed; 2 = student; 3 = pensioner; 4 = other)
18. Do you have a driving licence? (yes; no)
19. Do you have a motorized vehicle at your disposal? (yes; no)

Paper III

Attitudes, risk perception and risk-taking behaviour among regular cyclists in Norway

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Attitudes, risk perception and risk-taking behaviour among regular cyclists in Norway

Abstract

The main aim of the study was to investigate whether attitudes toward traffic safety, risk perception, worry, risk tolerance, safety priority, and accident involvement are associated with cyclists' risk-taking behaviour. Two types of cyclists' risk-taking behaviour were studied: (1) 'violation of traffic rules, and (2) 'conflicts with other road users when cycling'. The study was based on a questionnaire survey carried out in 2017 among regular cyclists in Norway (n = 426). The results revealed that cyclists' risk-taking behaviour was influenced by their attitudes, risk perception, and accident involvement. Pragmatic attitudes toward traffic rule violations and safety priority were found to be important predictors of the frequency of rule violations when cycling. Attitudes towards the enforcement of traffic rules for cyclists and dissatisfaction with the traffic rules for cyclists were found to be important predictors for the frequency of situations involving conflicts with other road users. Risk perception and accident involvement were found to be associated with conflicts with other road users, but not with rule violations when cycling. The findings show that risk perception and attitudes toward traffic safety are important for cyclists' risk-taking behaviour in traffic. The road infrastructure and the traffic regulations are primarily planned for car drivers and pedestrians. If cyclists' attitudes are to be changed, the cycling infrastructure and traffic rules for cyclists would need to be adjusted to cyclists as road users. When building new infrastructure and implementing new safety measures for cyclists, it is important to include attitude campaigns, as well as communications to the public about safety and the risks linked to cycling. Attitude campaigns could be used to strengthen the authorities' communications that cyclists are prioritized as road users.

Keywords: *Cycling behaviour; Risk-taking; Traffic safety attitudes; Risk perception; Worry; Risk tolerance*

1. Introduction

In traffic safety research, cyclists are defined as vulnerable road users, in common with pedestrians, moped, and motorcycle riders, because they have the highest risk in traffic compared with other road users (Peden et al., 2004). Further, cyclists often share the road with motorized vehicles, yet the wearing of cycle helmet is optional in

almost all countries and cyclists usually wear little personal protection equipment. If an accident between a cyclist and a motorized vehicle occurs, the consequences are often most serious for the cyclist. Nevertheless, active travel, such as cycling and walking, is given high priority in European transport policy. Active travel is seen as a key solution to both solve health problems in the population and environmental problems caused by local air and noise pollution, and carbon dioxide emissions due to fossil fuel usage. Due to the risk factors and the aim to increase the number of cyclists in Europe, priority should be given to examining the determinants of cyclists' risk-taking behaviour in traffic.

The main aim of the study on which this article is based was to investigate whether attitudes toward traffic safety, risk perception, worry, risk tolerance, safety priority, and previous accident involvement are associated with cyclists' risk-taking behaviour. Two types of cyclists' risk-taking behaviour were studied: (1) 'violation of traffic rules' and (2) 'conflicts when cycling'. We hypothesized that attitudes towards traffic safety and risk perception affect cyclists' behaviour in traffic, to the extent that they violate traffic rules, and engage in conflicts with other road users.

1.1 Cycling in Norway

According to the Norwegian National Travel survey from 2018 (Ellis, 2019), only 5% of all daily trips are made on cycles. The share of cycling trips was higher among young persons in the age group 13–17 years than those in other age groups: 11% and 5% respectively. Persons with a university education were more likely to cycle than those without a university education: an overall share of 7% daily trips by bicycle were made by persons with a university education. Also, there were gender differences, with shares of 4% and 6% respectively for females and males. The highest shares of cycling trips were among trips to school (10%) and commuting trips (8%). The share of cycling trips also showed geographical variations. In general, the share of cycling trips increased with increasing population density. In the same way as for car drivers, it is illegal for cyclists in Norway to cycle through a red traffic light and to cycle against the traffic on one-way streets (if not otherwise signposted as legal for cyclists). According the law, it is illegal for a person to use a cycle if they are not in a condition fit to do so in a safe manner, whether due to alcohol or any other intoxicating or sedating substance, or due to illness or tiredness, or due to any other circumstances (Vegtrafikkloven, 1965, §21). In contrast to drivers of motorized vehicles, there is no defined legal limit for blood alcohol concentration (BAC) level with respect to cycling. For drivers of motorized vehicles, it is illegal to drive with a

BAC level above 0.2 ‰ (Vegtrafikkloven, 1965, §22). For drivers of motorized vehicles, it is illegal to use a handheld mobile phone when driving. This is not defined as illegal when cycling. It is mandatory for cyclists to use a cycle light when cycling after dark, but it is not mandatory to wear a helmet when cycling.

A number of policies have been recommended to reach the main goal of the National Cycling Strategy, according to which cycling should constitute 8% of all daily trips by 2023. Among the policies, special emphasis has been placed on the provision of a coherent network of cycle paths, the development of main road networks for cyclists, and the establishment of routes to schools (Norwegian Public Roads Administration, 2012). There are 93,870 km of public roads (Statistics Norway, 2013), of which 5850 km have infrastructure designed for cycling (Norwegian Public Roads Administration, 2012). These include roads with foot and cycle paths, cycle paths with designated parts for pedestrians, roads with cycle lanes, and roads that are used by both cyclists and drivers (Norwegian Public Roads Administration, 2012). Additionally, there are private roads with infrastructure designed for cycling. Foot and cycle paths that are shared by cyclists and pedestrians constitute the most common cycling infrastructure in Norway, and have been commonly built since the beginning of the 1970s (Norwegian Public Roads Administration, 1976). Separate cycle lanes for cyclists have become more common in recent decades, primarily in the biggest cities and in the peripheral areas of those cities (Norwegian Public Roads Administration, 2012). In Norway, it has been legal to cycle on pavements since 1978. Cyclists can choose whether to cycle on the pavements and adjust their behaviour in relation to pedestrians or to cycle on the road and follow the rules that apply to drivers. If a cyclist chooses to use the pavement, they have to dismount before crossing a pedestrian crossing.

1.2 Cyclists' risk-taking behaviour

A number of recently published studies have investigated cyclists' risk-taking behaviour (Fraboni, Puchades, De Angelis, Prati, & Pietrantoni, 2016; Hezaveh, Zavareh, Cherry, & Nordfjærn, 2018; Useche, Alonso, Montoro, & Esteban, 2018; Useche, Alonso, Montoro, & Tomas, 2019; Useche, Montoro, Sanmartin, & Alonso, 2019; Useche, Montoro, Tomas, & Cendales, 2018). Risk-taking behaviours included in these studies were violation of traffic rules, errors when cycling, notice failures, different types of red-light behaviour, and distractions of cyclists. In this article, risk-taking cycling behaviour is defined as violation of traffic rules, and/or often having conflicts with other road users when cycling. Examples of violations include cycling

after consuming alcohol (above the legal limit), crossing the road on a red traffic light, and cycling while using a mobile phone. Examples of conflicts with other road users include near accidents when the cyclist has to brake hard or turn quickly to avoid collision with another road user, and situations when the cyclist fails to notice another road user.

Two questionnaires have been developed for measuring cyclists' behaviour in traffic: the Cyclist Behaviour Questionnaire (CBQ) by Useche et al. (2018), and the Bicycle Rider Behaviour Questionnaire (BRBQ) by Hezaveh et al. (2018). The CBQ includes questions about errors and traffic violations, as well as positive types of behaviour by cyclists. CBQ was validated by Useche et al. (2018) by using a sample of cyclists from 20 Spanish-speaking countries. The BRBQ includes questions about traffic violations, stunts and distractions, notice failure, control errors, and signalling violations. BRBQ was validated by Hezaveh et al. (2018) by using a sample of Iranian bicyclists and was found useful for predicting self-reported crashes.

In line with our study, both CBQ and BRBQ includes questions about traffic violations when cycling. In all three questionnaires, the violations include cycling under the influence of alcohol, cycling against a red traffic light, and cycling against the direction of traffic. In line with the BRBQ, our study included questions about mobile phone use when cycling. Mobile phone use was not included in the CBQ. The use of safety equipment such as helmets, cycle lights, safety reflectors, and high-visibility clothing (e.g. safety vest) was not included in either the BRBQ or the CBQ. In our study, cycling in the dark without cycle lights was included as a traffic violation.

The questions defined as notice failure in the BRBQ and some of the questions defined as errors in the CBQ are related to the question we have defined as conflicts when cycling. Half of the CBQ includes questions about errors and most of those questions are about experiences of conflicts with other road users (pedestrians, cyclists, vehicles). Additionally, CBQ includes questions about errors as a result of road conditions and as a result of the use of the cycle brakes. Only 5 of 34 questions in the BRBQ are related to conflicts with other road users (notice failures). In contrast to our study, the BRBQ has more questions about cyclists' conflicts with pedestrians and fewer questions about cyclists' conflicts with vehicles.

There is a need for more studies to explore factors related to cyclists' risk-taking behaviour in traffic from the cyclists' perspective. The purpose of our study was to investigate predictors of cyclists' risk-taking behaviour in traffic from the

cyclists' perspective, primarily focusing on behaviour that influences the probability of being involved in an accident.

1.3 Attitudes toward traffic safety

In this article, attitudes toward traffic safety are related to attitudes toward traffic rules and rule violations. To our knowledge, few studies have investigated attitudes toward traffic safety as a predictor of cyclists' risk-taking behaviour, and most studies that have investigated the relationship between attitudes and behaviour among cyclists have studied helmet use (Quine et al., 1998, 2001). However, attitudes toward traffic safety have been found important for other types of road users' risk-taking behaviour. Especially, studies of car drivers have contributed to enhance our knowledge of the role of attitudes in road users' risk-taking behaviour (e.g. Aberg, 1993; Iversen & Rundmo, 2004, 2009; Nordfjærn, Jørgensen, & Rundmo, 2010, 2011; Parker, Manstead, Stradling, Reason, & Baxter, 1992). The most influential theories regarding the association between attitudes and behaviour are the theory of reasoned action (TRA) (Fishbein, 1968) and the theory of planned behaviour (TPB) (Ajzen, 1991). According to both theories, behavioural intention is influenced by people's attitudes to specific types of behaviour and by their subjective norms. Additionally, TPB includes perceived behavioural control as a predictor of behavioural intention. TRA and TPB have been applied in studies of road users' risk-taking behaviour, which have found that road users' attitudes are positively associated with their behavioural intentions (Aberg, 1993; Evans & Norman, 1998, 2003; Parker et al., 1992; Quine et al., 1998, 2001; Rosenbloom, Beigel, & Eldror, 2011).

The attitude–behaviour relation has been empirically robust in studies across different types of road users' risk-taking behaviour. However, this relation has been relatively little studied with regard to cyclists. Therefore, priority should be given to investigations into associations between cyclists' attitudes towards safety and self-reported risk-taking behaviour when cycling. Based on findings for other travel modes, we hypothesize that attitudes are important for cyclists' risk-taking behaviour. Since in many studies attitudes have been found to influence behaviour, we included safety attitudes as one of the predictors of cyclists' risk-taking behaviour in our study.

A significant association has been found between motives for cycling and the provision of infrastructure, the cycling environment, and individual choice. (Mertens et al., 2017; Mertens et al., 2016; Nielsen, Olafsson, Carstensen, & Skov-Petersen, 2013). It follows that infrastructure and cycling environment probably also influence attitudes toward traffic safety among cyclists and risk-taking cycling behaviour.

Furthermore, the balance between the motives for cycling as a matter of individual choice and cyclists' dependence on infrastructure may be affected by whether basic cycling infrastructure is available (de Geus, De Bourdeaudhuij, Jannes, & Meeusen, 2008; de Geus et al., 2019). One study of risk-taking behaviour and attitudes among Norwegian car drivers revealed that drivers who lived in rural areas had less ideal driver attitudes compared with drivers who lived in urban areas (Nordfjærn et al., 2010). Due to differences between urban and rural areas in Norway with regard to cycling infrastructure and traffic environments, we hypothesized that cyclists who lived in rural areas would differ from those who lived in urban areas in terms of their safety attitudes and their amount of risk-taking behaviour in traffic.

1.4 Risk perception and worry

In line with safety attitudes, both risk perception and worry are primarily of interest because they relate to people's risk-taking behaviour. The psychometric paradigm (Slovic, 1992; Slovic, Fischhoff, & Lichtenstein, 1979) has dominated the field of risk perception research in recent decades (Sjöberg, Moen, & Rundmo, 2004). The approach is characterized by the use of psychometric scaling methods to measure how the characteristics of risk sources relate to perceptions of risk (Breakwell, 2007; Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Slovic, 1992). Fischhoff et al. (1978) used psychometric procedures to elicit quantitative judgements of perceived risk. To measure perceived risk, the respondents were asked to consider the risk of dying as a consequence of 30 different activities or technologies (e.g. smoking, bicycles, motor vehicles, and nuclear power) and to order and rate them. After rating the risks, the respondents were asked to rate each of the same activities and technologies on nine dimensions that previously have been found to be associated with levels of perceived risk. By investigating these relations by means of a second order factor analysis, Fischhoff et al. (1978) found two higher order characteristics or factors: unknown risk and dread. Studies carried out recent years have used assessment of probability and judgment of severity of consequences as indicators of perceived risk (Kummeneje, Ryeng, & Rundmo, 2019; Moen & Rundmo, 2006; Nordfjærn, Şimşekoğlu, Lind, Jørgensen, & Rundmo, 2014; Roche-Cerasi, Rundmo, Sigurdson, & Moe, 2013; Rundmo & Moen, 2006; Sjöberg et al., 2004). Consequently, we measured perception of risk by measuring the respondents' assessment of probability and judgment of severity of consequences. According to Sjöberg et al. (2004), risk perception can be defined as people's cognitive evaluation of risk on these two dimensions.

Emotions often produce behavioural responses that differ from an individual's cognitive assessment of the best course of action (Loewenstein, Weber, Hsee, & Welch, 2001). According to the risk-as-feeling approach, behaviour is influenced by the interplay between cognitive evaluation of risk and feelings. The approach distinguishes between anticipatory and anticipated emotions. Anticipatory emotions are immediate visceral reactions to risk, such as worry, fear, anxiety, and dread. Anticipated emotions are emotions that an individual expects to have as a consequence of a decision. Anticipatory emotions are further divided in two types: integral emotions and incidental emotions. Integral emotions are caused by the decision problem itself, whereas incidental emotions are caused by other factors, such as mood (Loewenstein et al., 2001). In the present study worry is defined as an anticipatory emotion and integral to the decision problem, which implies that worry is defined as a feeling that emerges as a reaction to an individual's cognitive assessment of risk.

Several earlier studies compared risk perception and worry related to different travel modes. Rundmo and Moen (2006) and Oltedal and Rundmo (2007) included cycling as well as other travel modes when investigating perceptions of risk. Relative to other modes, the probability of being in an accident was judged to be greater when cycling was compared with other travel modes. However, the level of the severity of the consequences when cycling was judged to be low. In the above-mentioned studies, cycling was one of several studied travel modes. According to Chaurand and Delhomme (2013), the study of risk perception related to cycling has received relatively little attention and few studies have solely investigated risk perception and anticipatory feelings (e.g. worry, fear, anxiety, and dread) related to cycling. In a recent study, risk perception and worry were found to be important predictors of both the decision to cycle and the frequency of cycling during wintertime (Kummeneje et al., 2019). In a separate study, researchers investigated risk perception among frequent and infrequent cyclists in a city environment (Lehtonen, Havia, Kovanen, Leminen, & Saure, 2016). The study was conducted as a traffic signal detection experiment, by showing the participants video clips and asking them to detect hazards. The cognitive estimate of risk was measured asking the participants to evaluate the caution level of each of the detected hazard on a scale from 1 to 100. Frequent cyclists detected more hazards than infrequent cyclists did, but the two groups did not differ in their overall level of cognitive risk assessment (Lehtonen et al., 2016). Hazard perception and cognitively estimated risk perception

are not directly related. Nevertheless, the study by Lehtonen et al. (2016) found an association between perception of hazards and cycling behaviour.

Furthermore, studies of perceptions and feelings of risk linked to travel mode can be difficult to compare, due to different measurement methods (Kummeneje et al., 2019). In most studies of cyclists' risk perception, cyclists have been asked to rate their overall risk perception of a route described in video clips, simulations, or surveys. In all of these studies, cyclists' perception of the road infrastructure or traffic was in focus (Lawson, Pakrashi, Ghosh, & Szeto, 2013; Llorca, Angel-Domenech, Agustin-Gomez, & Garcia, 2017; Manton, Rau, Fahy, Sheahan, & Clifford, 2016; Moller & Hels, 2008).

The studies mentioned above in this section all found that perceived risk and worry were important for different types of cycling behaviour. To our knowledge, no studies have investigated how risk perception and feelings influence cyclists' risk-taking behaviour. Therefore, the purpose of our study was to examine the association between perceived risk and the anticipatory feeling of worry about cycling, and how risk perception and worry were associated with cyclists' risk-taking behaviour. We hypothesize that perceived risk and worry influence cyclists' risk-taking behaviour.

1.5 Risk tolerance and safety priority

Risk tolerance can be defined as the extent to which individuals tolerate being exposed to risk when using different modes of transport. Risk tolerance and acceptance are often used synonymously. Parkin, Wardman, and Page (2007) developed a model based on a risk threshold and provided a measure of acceptability of different cycling routes. The authors used the model to show how different infrastructure reduced perceived risk and made a route acceptable for cycling. The results of Parkin et al.'s study showed that both young and elderly people considered cycling less acceptable than people in the age range 35–44 years did, and that males considered cycling more acceptable than females did (Parkin et al., 2007).

Risk tolerance and safety priority are related. Moreover, both terms relate to situations in which the individual perceives they are exposed to risk. Whereas risk tolerance could be seen as the risk threshold to which the individual tolerates exposure, safety priority relates to the individual's behavioural choices and the decision-making processes. Safety priority can be defined as the extent to which individuals prioritize safety when using different modes of transport (Moen & Rundmo, 2004). To prioritize safety is a choice that the individual has to make regarding, for example, the safest route, the use of safety equipment, and cautious

cycling behaviour. Further, the individual has to believe that their behaviour will reduce the risk to which they are exposed. The number of studies of risk tolerance and safety priority among cyclists is to date limited. Some studies have investigated safety priority related to the use of different transport modes (Nordfjærn & Rundmo, 2010; Rundmo & Moen, 2006; Şimşekoğlu, Nordfjærn, & Rundmo, 2015). Nordfjærn and Rundmo (2010) also included cycling. Kummeneje et al. (2019) found that risk tolerance and safety priority influenced cycling frequency during wintertime. We expected that safety priority and risk tolerance also should affect cyclists' risk-taking behaviour and therefore examined in the study on which this article is based.

1.6 Accident involvement

A study conducted recently, found that previous experience of accidents was associated with a cyclist's perception of risk and feeling of worry (Kummeneje & Rundmo, 2018). Individuals that had experienced an accident while cycling perceived their probability of being in an accident as higher than did individuals who never had experienced an accident while cycling. They also tended to be more worried about being involved in an accident when cycling. There were no differences in the perceived severity of consequences between the two groups. The correlation between accident involvement and behaviour was not part of the study. Washington, Haworth, & Schramm (2012) investigated the relationship between self-reported injuries and perceived risk of Australian cyclists, and did not find any association between injuries and perceived risk. Perceived risk was measured by asking the respondents to compare safety when cycling with safety when driving a car. Whether this is a measure of cyclists' risk perception could be a matter for discussion. Washington et al. (2012) also found an association between self-reported injury and behaviour (e.g. helmet use, cycling speed). Accordingly, in the study on which this article is based, we examine whether accident involvement is associated with cyclists' risk-taking behaviour.

1.7 Aims of the study

The specific aims of the study were as follows: (1) to examine demographic differences in attitudes towards traffic safety and risk-taking behaviour among cyclists (according to age, gender, level of education, and geographical area of residence); (2) to investigate whether cyclists' attitudes, risk perceptions, worry, risk tolerance, safety priority, and accident involvement were related to traffic rule violations when cycling; (3) to investigate whether cyclists' attitudes, risk

perceptions, worry, risk tolerance, safety priority, and accident involvement were related to conflicts when cycling; (4) to examine the direct and indirect associations between attitudes towards traffic safety, risk perception, worry, risk tolerance, safety priority, geographical area of residence, and cyclists' risk-taking behaviour.

2. Method

2.1 Sample

We administered a self-completion online questionnaire survey in 2017. The questionnaire was distributed in collaboration with the Norwegian Cyclists' Association (Syklistenes Landsforening). An invitation to participate in the survey was distributed through a magazine sent by post to ca. 10,000 members of the Norwegian Cyclists' Association. The second page of the magazine included a description of the study and an Internet address, where the respondents were asked to answer an online questionnaire about cycling. Only members who had used their bicycle for regular trips during the last year were asked to answer the questionnaire. There were three main reasons for including in the sample only cyclists who had used their bicycle for regular trips during the last year. First, cyclists in this group are the most experienced and most familiar with the local cycling infrastructure and cycling facilities. Second, this group of cyclists mainly cycle to and from their work place and/or school during the peak traffic times. They often cycle in areas with high traffic density and they interact with other road users to a greater extent than do cyclists in other groups. The third reason for including only cyclists who had used their bicycle for regular trips during the last year in the sample related to memory when reporting behaviour in traffic. To recall behaviour could be a difficult cognitive task. Hence, to obtain accurate data about risk-taking cycling behaviour, we wanted to include cyclists whose memory was fresh. In total, 426 members completed the questionnaire. All respondents reported that they cycled at least once per week during summer, and 61% reported that they cycled at least once per week during winter. There were 34% females and 66% males in the sample. Their age ranged from 18 years to 81 years (Mean = 50.59, SD = 12.61). A total of 64% of the respondents reported that they had more than three years of university education, 23% had three years or less of university education, 11% had received their highest level of education at upper secondary school, and 2% had not studied after primary school. The majority of the respondents (84%) reported that they were employed, 10% were pensioners, 2% were students, and the remaining 4% were job applicants or benefit recipients. Only 6% of the respondents reported they did not have a driving licence and 15% did not have

access to a car or other motorized vehicles. A relatively small proportion of the sample (6%) reported they lived in rural areas with less than 2000 inhabitants. Respondents in peri-urban areas with between 2000 and 20,000 inhabitants constituted 19% of the sample, whereas 24% of the sample lived in urban areas with 20,000–100,000 inhabitants. More than half of the sample (51%) lived in urban areas with between 100,000 and 700,000 inhabitants. The latter group included the four largest cities in Norway. To investigate the ecological validity of the sample, the education levels, age patterns, gender and geographical spread were compared between the sample and the Norwegian national travel survey 2018 (Ellis, 2019) and the Norwegian cycling surveys (Kummeneje & Tretvik, 2015; Tretvik, 2015) (see section 4).

2.3 Questionnaire and measure instruments

The questionnaire asked the respondents to evaluate their perception of risk and worry about being involved in accidents with other road users and in single accidents (e.g. falling or running off the road). Additionally, they were asked about how they tolerated being exposed to risk (risk tolerance) as a cyclist and to what extent they prioritized safety when cycling (safety priority). Further, the respondents were asked about their attitudes toward traffic safety and risk-taking behaviour. The questionnaire also contained questions about the respondents' age, gender, employment status, highest level of completed education, possession of a driving licence, motorized vehicles at their disposal, and geographical area of residence. Geographical area of residence was measured on a 4-point scale: (1) Less than 2000 inhabitants, (2) Between 2000 and 20,000 inhabitants, (3) Between 20,000 and 100,000 inhabitants, and (4) More than 100,000 inhabitants. This variable was primarily intended to represent differences in the levels of cycling infrastructure. Additionally, there may be cultural differences in attitudes and behaviour between cyclists living in urban and rural areas.

To measure risk perception, the respondents were asked to assess their probability of experiencing four different types of accidents when cycling, and then to anticipate the severity of consequences if such an event were to take place. The four types of cycling accidents were (1) an accident involving a motorized vehicle, (2) an accident involving another cyclist, (3) an accident involving a pedestrian, and (4) a single accident (e.g. falling or running off the road). The probability assessment was measured on a five-point scale ranging from 'not at all probable' to 'very probable'. For judgement of severity of consequences, the scale ranged from 'not at

all serious' to 'very serious'. Furthermore, the respondents were asked to rate how worried they were about experiencing each of the above-mentioned four types of accidents when cycling, measured on a five-point scale from 'not at all worried' to 'very worried'. To measure risk tolerance, the respondents were asked the following question: 'To what extent do you tolerate being exposed to risk when cycling?' The five-point evaluation scale ranged from 'do not tolerate any risk' to 'tolerate the risk absolutely'. Safety priority was measured with the following question: 'To what extent do you prioritize safety as a cyclist?' The five-point evaluation scale ranged from 'do not prioritize safety' to 'prioritize safety absolutely'.

The measures of cycling behaviour and attitudes were revised versions of instruments developed by Iversen and Rundmo (2004, 2009) to measures behaviour and attitudes among car drivers. We tested versions of the instruments that we had designed specifically for cyclists, with specific focus on violations when cycling in a Norwegian context. Attitudes towards traffic safety were measured by a 15-item instrument. A similar version of the instrument with 13 items has been tested earlier (Kummeneje et al., 2019). The respondents were asked to what extent they agreed or disagreed with different statements and to give their response on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). The attitude instrument included statements regarding safety aspects when cycling, such as rule violations and attitudes towards taking chances, as well as attitudes towards traffic surveillance of cyclists' behaviour (see Table 2 for questions about cyclists' attitudes towards traffic safety). Risk-taking behaviour was measured by a 9-items instrument for how often the respondents engaged in various risk-taking activities when cycling in traffic. The questions were about rule violations and conflicts with other road users (e.g. cycling with an illegal level of alcohol in their body, cycling through a red traffic light, braking hard or turning quickly when cycling to avoid accidents) (Table 4). The items were measured by a five-point Likert-type scale: (1) Never, (2) Rarely, (3) Neither/nor, (4) Often, (5) Very often. The measures for behaviour and attitudes have shown good psychometric feasibility in previous research when used in research on car drivers (e.g. Iversen & Rundmo, 2004; Ulleberg & Rundmo, 2003).

2.4 Statistical analysis

Exploratory factor analysis (EFA) with Varimax-rotation was first conducted to test the dimensional structure of the respondents' behaviour and attitudes toward traffic safety. A three-dimensional factor analysis with nine indicators was used to measure attitudes. A two-dimensional factor analysis with ten indicators was used to measure

behaviour. To test for internal consistency, the reliability of the indices Cronbach's alpha and corrected inter-item correlations were applied. An additional exploratory factor analysis with structural equation modelling (SEM) was performed to examine the fit of the data to the models. The chi-square degrees of freedom ratio (χ^2/df), the root mean square error of approximation (RMSEA), the goodness of fit index (GFI), the comparative fit index (CFI), Holter's Critical N, and the standardized root mean square residual (SRMR) were calculated to test the fit between the model and the data. In accordance with established criteria, a χ^2/df-ratio of less than 4 (4:1), an RMSEA of 0.07 or less, a GFI over 0.90, a CFI above 0.90, and an SRMR of .08 or less were considered to indicate satisfactory fit between the model and the data. The analysis fulfilled Tabachnick and Fidell's criteria for an acceptable sample size (Tabachnick and Fidell, 2014).

Multivariate analysis of covariance (MANCOVA) was conducted using General Linear Models (GLMs). The main effects and interaction effects of attitudes, risk perception and worry were tested for the demographic variables age, gender, education level, and geographical area of residence. The three dimensions from the EFA measuring attitudes, and the two dimensions measuring behaviour, were used as dependent variables. The demographic variables were included as fixed factors in the analysis. Age was divided into the three groups: younger adults (18–39 years), middle-aged (40–59 years) and older adults (60–81 years). Education level was divided into the following groups: no university education, three years or less of university education, and more than three years of university education. Geographical area of residence was divided into three groups: less than 20,000 inhabitants, between 20,000 and 100,000 inhabitants, and between 100,000 and 700,000 inhabitants.

Hierarchical regression analyses were used to predict how often the cyclists violate traffic rules, and to predict how often the cyclists are in situations with conflicts with other road users when cycling. Additional SEM was done to test the fit of the data to the regression mode. Also, χ^2/df-ratio, CFI, GFI, and RMSEA were used to test the fit of the data to the model χ^2/df-ratio, CFI, GFI, and RMSEA, as done for the other SEM analysis.

3 Results

3.1 Dimensional structure of attitudes toward traffic safety and risk-taking behaviour

Table 1 shows the result of the three-dimensional exploratory factor analysis (EFA) with the 9-item measure of cyclists' attitudes toward traffic safety. In the analysis, six of the originally 15 measured items were excluded because they did not load (see all

items in the Appendix). The first dimension, ‘Pragmatic attitudes towards rule violations’, consisted of five items related to each respondent’s evaluation of rule violations for pragmatic reasons, such as ‘It is acceptable to cycle [when the lights are] on red when no others are present’ and ‘Breaking rules does not necessarily make one a less safe cyclist compared with those who always follow the rules’. The second dimension was ‘Attitudes towards cyclist enforcement’ and was measured by two items related to traffic surveillance and punishments for cyclists who break traffic rules. The third dimension, ‘Dissatisfaction with the traffic rules for cyclists’ was measured by two items related to attitudes, namely that the traffic rules for cyclists are too complicated and impossible to comply with. As shown in Table 1, the tested measurement instrument had feasible reliability (Cronbach’s α = .749, .804, and .693). SEM showed that the fit of the model to the data was satisfactory ($\chi^2/df = 2.927$, RMSEA = .067, GFI = .96, CFI = .96, SRMR=.045). The mean scores and standard deviations of the factors listed in Table 1 show that the cyclists in the sample reported a higher score on the dimension ‘Attitudes towards cyclist enforcement’ than on the dimensions ‘Pragmatic attitudes towards rule violations’ and ‘Dissatisfaction with the traffic rules'. There were more statistical variations in the second dimension compared with the other two dimensions.

Table 1: Cyclists' attitudes towards traffic safety, reliability, and internal consistency and fit statistics of the model

Dimensions	Number of items	Mean (SD)	Cronbach's α	Average corrected inter-item correlation	Corrected inter-item correlation, max, min
Pragmatic attitudes towards rule violations	5	2.74 (.798)	.75	.37	.66, .18
Attitudes towards cyclist enforcement	2	2.51 (.832)	.80	.67	.67, .67
Dissatisfaction with the traffic rules	2	2.75 (.985)	.69	.53	.53, .53
	$\chi 2$/df-ratio 2.927	RMSEA .067	GFI .96	CFI .96	SRMR .045

Ratings given on a 5-point scale: (1) Strongly disagree, (2) Disagree, (3) Neither agree/nor disagree, (4) Agree, (5) Strongly agree

Table 2 presents the share of cyclists who agreed or disagreed with the statements related to attitudes towards traffic safety. Cyclists with ideal attitudes disagreed with the statements in the first and the third dimensions and disagreed with the statements in the second dimension. The results of the second dimension are shown inverted in Table 2 to make the results easier to compare. Ideal attitudes are defined on the basis of results and findings from previous studies of the association between attitudes and safe behaviour (Iversen & Rundmo, 2004, 2009). In the research project to which those studies related, an expert committee was appointed and its members defined what attitudes should be considered as ideal. Implicitly, ideal attitudes are desirable in traffic planning to ensure traffic flow and safety in traffic.

Table 2: Dimensions of cyclists' attitudes towards traffic safety (%)

	Disagree (ideal)	Neither agree/ nor disagree	Agree (non-ideal)
Pragmatic attitudes towards rule violations	**47**	**23**	**30**
It is acceptable to break the rules as a cyclist when no others are involved	40	31	29
It is acceptable to cycle on red when no others are present	40	19	41
It is acceptable to take chances as a cyclist when only you are exposed to risk	68	19	13
Breaking rules does not necessarily make you a less safe cyclist compared with those who always follow the rules	32	25	43
It is acceptable to cycle after drinking alcohol (< 0.2 ‰)	54	24	22
Attitudes towards cyclist enforcement	**32**	**31**	**37**
There should be more traffic surveillance for cyclists (inverted)	43	28	29
There should be severe punishments for cyclists who break traffic rules (inverted)	20	34	46
Dissatisfaction with the traffic rules	**46**	**29**	**25**
Many traffic rules for cyclists are impossible to comply with	44	28	28
The traffic rules for cyclists are too complicated to adhere to in practice	47	30	23

Ratings given on a 5-point scale from (1–2) Disagree, (3) Neither agree/nor disagree, (4–5) Agree
Mean values in bold

A noteworthy number of cyclists reported attitudes that were not ideal. As shown in Table 2, 30% of the respondents agreed in pragmatic attitudes towards traffic safety, about 37% of the respondents had negative attitudes towards the enforcement of traffic rules for cyclists, and 25% reported dissatisfaction with the traffic rules for cyclists. Among the items in the first dimension, two items had notably less ideal attitudes than the others. More than 40% of the cyclists considered it acceptable to

cycle through red traffic lights when no road users were present and that breaking the rules did not necessarily makes someone a less safe cyclist compared with those who always follow the rules. A total of 20% of the sample wanted more severe punishments for cyclists who break traffic rules, and 43% of the cyclists wanted more traffic surveillance of cyclists. It is interesting to note that a considerable number of the respondents considered that many traffic rules for cyclists were impossible to comply with (28%) and too complicated to adhere to in practice (23%).

Table 3: Risk-taking behaviour, reliability, and internal consistency and fit statistics of the model

Dimensions	Number of items	Mean (SD)	Cron-bach's α	Average corrected inter-item correlation	Corrected inter-item correlation, max, min
Violation of traffic rules	6	1.66 (.553)	.683	.273	.624, .155
Conflicts when cycling	4	1.99 (.604)	.663	.330	.431, .184
	χ^2/df-ratio	RMSEA	GFI	CFI	SRMR
	4.015	.092	.93	.87	.065

Ratings given on a 5-point scale: (1) Never, (2) Rarely, (3) Neither/nor, (4) Often, (5) Very often

Table 3 shows the results of the two-dimensional exploratory factor analysis (EFA) with the 9-item measure of cyclists' risk-taking behaviour. The first dimension, 'Violation of traffic rules', consisted of six items related to rule violation when cycling, such as 'cross the road on a red traffic light' and 'cycle after drinking alcohol (an illegal level)'. The second dimension, 'Conflicts when cycling', consisted of four items related to conflicts with other road users, such as 'Fail to note a vehicle approaching from a side road', and 'brake hard down and/or turn fast to avoid hitting a pedestrian'. The items in the second dimension measure risk-taking behaviour that is not necessarily intentional or the caused by the cyclist. As shown in Table 3, the tested measurement instrument had feasible reliability (Cronbach's α = .683, and .663). SEM showed that the fit of the model to the data was satisfactory (χ^2/df = 4.02, RMSEA = .092, GFI = .93, CFI = .87, SRMR =.065). However, the RMSEA was

above the criteria of .07, but the other fit measures were all in accordance with acceptable criteria.

Table 4: Dimensions of cyclists' risk-taking behaviour (%)

	Rarely	Neither rarely/nor often	Often
Violation of traffic rules	**82**	**13**	**5**
Cycle when using mobile phone	93	5	2
Cycle in the dark without cycle light	96	3	1
Cross the road on a red traffic light	78	14	8
Use a pedestrian crossing on a red light for pedestrians	73	17	10
Cycle after drinking alcohol (< 0.2 ‰)	84	14	2
Cycle against traffic in one-way streets	68	25	7
Conflicts when cycling	**74**	**19**	**7**
Fail to note a vehicle approaching from a side road	91	8	1
Brake hard because a vehicle is approaching faster than expected	81	17	2
Turn quickly away from a vehicle to avoid an accident	44	36	20
Brake hard and/or turn quickly to avoid hitting a pedestrian	80	15	5

Ratings given on a 5-point scale: (1–2) Rarely or never, (3) Neither/nor, (4–5) Often
Mean values in bold

Table 4 shows the respondents' reported times they had been involved in different types of risk-taking behaviour when cycling. Only 5% reported they had often violated the traffic rules, and 7% reported they had often had conflicts with other road users when cycling. Among the items in the first dimension, three types of rule violations stand out as more common. One in ten cyclists reported that they had often used pedestrian crossings on a red light for pedestrians, 8% had often crossed the road when a traffic light was red, and 7% had often cycled against traffic in one-way streets. In the second dimension, one item is noteworthy: 20% of the respondents reported that they had often turned quickly away from vehicles to avoid accidents.

3.2 Demographic differences in attitudes towards traffic safety and risk-taking behaviour

A MANCOVA was performed to study differences in cyclists' attitudes towards traffic safety and risk-taking behaviour with respect to demographics. Table 5 shows the results of the analysis and presents F-values for the full model.

Additionally, Table 5 shows the mean values and standard deviations for geographical area of residence for each factor. The results revealed that cyclists living in urban areas had less ideal attitudes compared with cyclists in rural areas, and more often practised risk-taking behaviour when cycling. However, the differences were small, especially with regard to 'attitudes towards cyclist enforcement'. The statistical variations in such attitudes were relatively high.

The analysis showed demographic differences in three of the five dependent variables. Among the attitude factors, there were demographic differences in 'pragmatic attitudes towards rule violations' ($F = 1.526$, $p < .05$), and 'attitudes towards cyclist enforcement' ($F = 1.468$, $p < .05$). With regard to behaviour, there were demographic differences in how often the cyclists violated the traffic rules ($F=1.791$, $p < .05$). The differences in negative attitudes towards traffic rules ($F=.975$, $p > .05$) and conflicts when cycling ($F = 1.167$, $p > 0.5$) were not significantly related to the demographic variables in the analysis.

Among the demographic variables, only geographical area of residence was found to be associated with attitudes and behaviour ($\lambda = .94$, $p < .05$). Age ($\lambda = .97$, $p > .05$), gender ($\lambda = .97$, $p > .05$) and level of education ($\lambda = .98$, $p > .05$) were not found to be significantly associated, and descriptive statistics related to these variables are not presented in Table 5. An interaction effect was found between gender and geographical area of residence ($\lambda = .93$, $p < .05$), but not for any of the other variables.

Table 5: Attitudes towards traffic safety and risk-taking behaviour among cyclists (MANCOVA)

	Geographical area of residence						Corrected Model
Measures	Less than 20,000 inhabitants (1-2)		20,000–100,000 inhabitants (3)		100,000–700,000 inhabitants (4)		F-value
Attitudes	Mean	SD	Mean	SD	Mean	SD	
Pragmatic attitudes towards rule violations	2.54	.765	2.58	.766	2.91	.811	1.526*
Attitudes towards cyclist enforcement	2.94	1.091	3.12	.987	3.14	1.067	1.468*
Dissatisfaction with the traffic rules	2.57	.966	2.68	.935	2.86	.987	.975
Behaviour							
Violation of traffic rules	1.45	.399	1.52	.428	1.83	.611	1.791**
Conflicts when cycling	1.87	.585	2.07	.550	2.01	.624	1.167
Wilks' λ	.943, sig.< .05						

Attitudes measured on a 5-point scale: (1) Strongly disagree, (2) Disagree, (3) Neither agree/nor disagree, (4) Agree, (5) Strongly agree

Behaviour measured on a 5-point scale: (1) Never, (2) Rarely, (3) Neither/nor, (4) Often, (5) Very often

Geographical area of residence measured on a 4-point scale: (1) Less than 2000 inhabitants, (2) Between 2000 and 20,000 inhabitants, (3) Between 20,000 and 100,000 inhabitants, (4) More than 100,000 inhabitants

*p < .05, **p < .01, ***p < .001

3.3 Predictors of traffic rule violations when cycling

The next step in the analysis was to examine what influenced cyclists' risk-taking behaviour. Table 6 shows the results of a linear regression analysis performed to predict how often the cyclists violate traffic rules.

Table 6: Predictors of cyclists' violation of traffic rules (standardized beta coefficient)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Block 1: Demographics						
Age	-.12*	-.06	-.07	-.07	-.06	-.06
Gender (male = 0, female = 1)	-.05	-.08*	-.09*	-.09*	-.07	-.06
Education	.14**	.04	.05	.05	.04	.04
Urban/rural	.23***	.15***	.15***	.15**	.15**	.14**
Block 2: Attitudes						
Pragmatic attitudes towards rule violations		.55***	.55***	.55***	.514***	.516***
Attitudes towards cyclist enforcement		-.07	-.08	-.08	-.07	-.08
Dissatisfaction with the traffic rules		.02	.01	.03	.03	.02
Block 3: Risk perception						
Probability – single accident			.02	-.00	-.00	.01
Probability – pedestrian			-.01	-.04	-.02	-.02
Probability – another cyclist			.04	.07	.05	.05
Probability – motorized vehicle			-.05	-.07	-.05	-.05
Consequence – single accident			-.05	-.07	-.05	-.05
Consequence – pedestrian			.06	.04	.04	.04
Consequence – another cyclist			-.04	-.01	-.01	-.01
Consequence – motorized vehicle			.05	.03	.03	.03

Block 4: Worry						
Worry – single accident				.05	.04	.04
Worry – another cyclist				.07	.07	.07
Worry – pedestrian				-.09	-.10	-.10
Worry – motorized vehicle				.01	.05	.05
Block 5: Tolerance and priority						
Risk tolerance					-.03	-.02
Safety priority					-.10*	-.10*
Block 6: Accident involvement						
Involved in accident						-.03
Near accident						-.02
R^2	.11	.43	.44	.45	.46	.46
F Change	10.863***	61.886***	.407	1.147	2.864	.397

Dependent variables 1–5: 1 = never violate the rule, 5 = very often violate the rule
*p < .05, **p < .01, ***p < .001

The independent variables were entered into the model in six blocks: demographics, attitudes towards traffic safety, risk perception, worry, risk tolerance and safety priority, and accident involvement. In total, the predictor variables explained an acceptable percentage of variance (R^2 = .46). Among the demographic variables, age (β = .12), level of education (β = .14) and geographical area (β = .23) were found to be associated with violation of traffic rules when cycling. Young cyclists, cyclists with higher levels of education, and cyclists in urban areas tended to break the rules more often others did. After entering the second block (attitudes), the association between gender and traffic rule violations became significant but weak (β = .08). The results showed that that pragmatic attitudes toward rule violations were the most important predictor of rule violation when cycling (ΔR^2 = .32). Cyclists with pragmatic attitudes toward rule violations violated the rules more often than other cyclists did. 'Dissatisfaction with the traffic rules' and 'attitudes towards cyclist enforcement' were not found to be good predictors of rule violations when cycling. Risk perception, worry, risk tolerance, and accident involvement were not associated

with rule violations when cycling. Further, the results showed that safety priority was associated with how often the cyclists violated the rules (β = -.10). The less the cyclists prioritized safety when cycling, the more they violated the rules when cycling.

3.4 Predictors of conflicts when cycling

The respondents were asked questions about a second type of risk-taking behaviour: conflicts when cycling. Accordingly, the next step in the analysis was to examine how the same group of predictors predicted conflicts when cycling. The results are presented in Table 7.

In total, the predictor variables explained an acceptable percentage of variance (R^2 = .35). None of the demographic variables were found to be associated with conflicts when cycling. Adding the second block (attitudes) into the model resulted in a significant change in the explained variance (ΔR^2 = .08). In contrast to the first model, 'attitudes towards cyclist enforcement' (β = .18) and 'dissatisfaction with the traffic rules' (β = .24) were associated with conflicts when cycling. Risk perception was entered as the third block and found to be the most important predictor of conflicts when cycling (ΔR^2 = .18). Both the perceived probability of being involved in an accident with another cyclist (β = .15) and with a motorized vehicle (β = .20) were associated with conflicts when cycling. The perceived consequences of accidents were not found to be associated with conflicts when cycling. Adding worry, risk tolerance and safety priority to the model did not result in a significant change in the explained variance. Entering the last block, accident involvement, into the model gave a significant change in the explained variance (ΔR^2 = .06). Experiencing a near accident (β = .26) was found to be more important for conflicts when cycling than being involved in an accident during the last two years (β = .09).

Table 7: Predictors of cyclists' conflicts with other road users when cycling (standardized beta coefficient)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Block 1: Demographics						
Age	-.08	-.07	.00	.00	.00	.03
Gender (male = 0, female = 1)	-.07	-.05	-.06	-.08	-.08	-.06
Education	.01	.01	.02	.02	.02	.02
Urban/rural	.09	.05	.02	.02	.02	.00
Block 2: Attitudes						
Pragmatic attitudes towards rule violations		.08	.08	.09	.09	.09
Attitudes towards cyclist enforcement		.18**	.11*	.11*	.11*	.08
Dissatisfaction with the traffic rules		.24***	.16**	.14**	.14**	.11*
Block 3: Risk perception						
Probability – single accident			-.08	-.09	-.09	-.06
Probability – pedestrian			-.12	-.11	-.11	-.14*
Probability – another cyclist			-.15*	-.10*	-.10	-.07
Probability – motorized vehicle			-.20**	-.20**	-.20**	-.16*
Consequence – single accident			-.01	-.00	.00	-.01
Consequence – pedestrian			.06	.06	.06	.03
Consequence – another cyclist			-.02	.01	.01	.00
Consequence – motorized vehicle			-.02	.00	-.00	.02

Block 4: Worry						
Worry – single accident				.03	.03	.01
Worry – another cyclist				-.02	-.02	-.03
Worry – pedestrian				-.09	-.09	-.08
Worry – motorized vehicle				-.05	-.05	.01
Block 5: Tolerance and priority						
Risk tolerance					.01	.04
Safety priority					-.03	-.02
Block 6: Accident involvement						
Involved in accident						-.09*
Near accident						-.26***
R^2	.02	.10	.28	.29	.29	.35
F Change	1.909	10.078***	9.711***	1.015	.104	17.004***

Dependent variables 1–5: 1 = never conflict, 5 = very often conflict
*p < .05, **p < .01, ***p < .001

3.5 Model for predicting cyclists' risk-taking behaviour

Figure 1 shows the results of an SEM analysis for prediction of cyclists' risk-taking behaviour. The model includes both direct and indirect association between attitudes, risk perception, worry, risk tolerance, safety priority, and type of geographical area. Only risk perception and worry related to being involved in accident with motorized vehicle were included in the model; the reason was that accidents that involved motorized vehicles were the type of accidents that the respondents perceived as the greatest risk and worried about the most. Geographical area for cycling was included as exogenous variable in the model. Attitudes towards traffic safety, risk perception, worry, risk tolerance, and priority of safety were included as mediation variables. Both types of cyclists' risk-taking behaviour were included in the model: (1) 'violation of traffic rules', and (2) 'conflicts when cycling'. These were included as endogenous variables in the model. The fit of the model to the data was satisfactory (χ^2/df = 2.763, RMSEA = .068, GFI = .96,
CFI = .93, SRMR = .062).

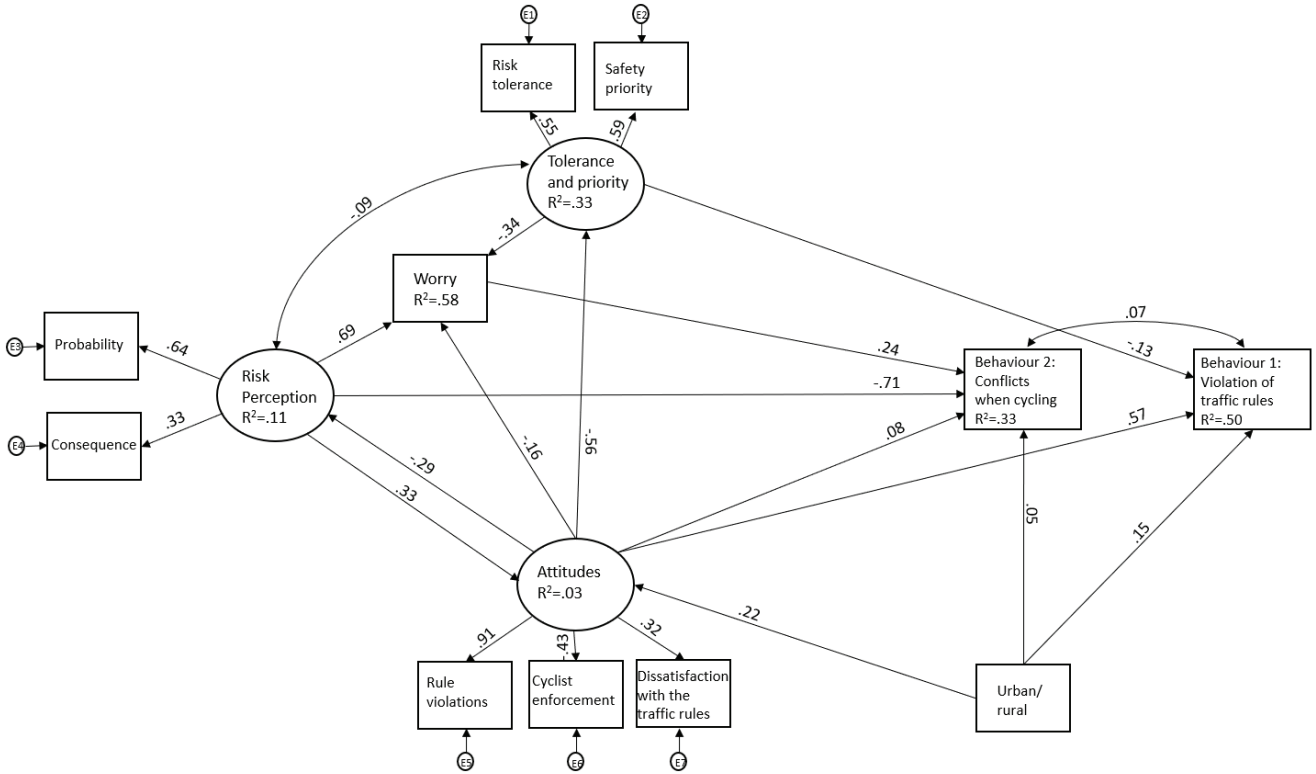

Figure 1: Heuristic path model for predicting cyclists' risk-taking behaviour

χ^2/df = 2.763, RMSEA = .068, GFI = .96, CFI = .93, Holter's Critical N = 226.89, SRMR = .062

As shown in Figure 1, the model explained 50% of the variance in violation of traffic rules, and 33% of the variance in conflicts when cycling. The strongest predictor of violating the traffic rules when cycling was attitudes toward traffic safety (β = .57). Other significant direct predictors of rule violation were risk tolerance and safety priority (β = -.13) and geographical area for cycling (β = .15). Risk perception was indirectly associated with rule violation by attitudes, and risk tolerance and safety priority. With regard to conflicts when cycling, risk perception was found to be the strongest predictor (β = -.71). The greater the risk was perceived, the more conflicts the cyclist had experienced. Furthermore, worry (β = .24) was found to be a strong direct predictor of conflicts when cycling. There were also small but significant direct associations between both attitudes (β = .08) and geographical area (β = .05), and conflicts when cycling. Risk tolerance and safety priority were indirectly associated with conflicts when cycling and mediated by decreases in worry. The model explained 58% of the variance in worry, 33% of the variance in risk tolerance and safety priority, 11% of the variance in risk perception, and 3% of the variance in attitudes towards traffic safety.

4. Discussion

4.1 General discussion

Although many researchers have concluded that attitudes are important for behaviour, few studies have investigated this relationship with regard to cycling. The results of our study showed the importance of studying cyclists' attitudes towards traffic safety and that their attitudes are important predictor variables for their risk-taking behaviour. As expected, we found an association between attitudes toward rule violations and behaviour related to rule violations. Pragmatic attitudes towards rule violations constituted the most important factor to explain how often cyclists violated the rules. One explanation could be that cyclists who think it is acceptable to break the rules have a lower threshold for breaking the rules compared with other cyclists. Furthermore, the results showed that Norwegian road users who were regular cyclists had more pragmatic attitudes towards rule violations and were more dissatisfied with the traffic rules than were car drivers (Iversen & Rundmo, 2004). One explanation for this could be that the road infrastructure and traffic regulations are primarily planned for car drivers and pedestrians. Although the Norwegian Public Roads Administration (2012) has increased its focus on improving the infrastructure for cyclists, on most roads in Norway cyclists either have to use the pavements or cycle on the road with motorized vehicles. Pragmatic attitudes towards rule violations and

dissatisfaction with the traffic rules could be explained by cyclist's previous experiences when cycling, the cycling infrastructure, their interactions with other road users, and media communications and/or conversations with friends and family. However, further investigations are needed in order to draw more decisive conclusions.

Although, almost two-thirds of the cyclists had pragmatic attitudes toward rule violations, relatively few cyclists reported that they themselves violated the rules. The most commonly reported traffic violations were related to crossing the road against a red traffic light. Nearly half (41%) of the cyclists argued that it was acceptable to cross the road against a red traffic light, but only 8% did so on a regular basis. Cyclists sometimes experience that when they cycle on the road and come to a crossing, the traffic light fails to turn green because the traffic light sensors only register motor vehicles. This could be seen as a communication from the government that cyclists are not prioritized as road users in traffic planning. Norwegian cyclists have regularly complained in the media about traffic lights with sensors that do not register cyclists. This may result in less respect for traffic lights among cyclists. However, the Norwegian Public Roads Administration (2018) is working on solving the problem. Additionally, new infrastructure for cyclists and new measures to increase the number of people who cycle as a means of transport are currently being implemented in Norway. (Norwegian Public Roads Administration, 2012). Violation of traffic rules were also found related to safety priority. Cyclists who violated the traffic rules more often than other cyclists, did not differ in their perception of risk or worry about accident when cycling compared with cyclists who more often followed the rules. This may indicate that cyclists have the same understanding of the risks related to breaking the law when cycling but differ in the extent to which they prioritize safety when cycling. The fact that the road authorities have started to focus on cycling as a travel mode will most likely change cyclists' attitudes, safety priority, and risk-taking behaviour in traffic.

Dissatisfaction with traffic rules was associated with the number of conflicts experienced when cycling. A possible explanation could be that dissatisfaction with the rules is associated with confusion about the rules or problems with following the existing rules, which result in more conflicts with other road users when cycling. We did not asked about which type of traffic rules the cyclists were dissatisfied with, which could have included rules such as giving way to other road users when cycling over crossings or on roundabouts, overtaking when cycling on the road when motorized vehicles are present, or rules related to the use of foot and cycle paths.

About one-quarter of the cyclists reported that they were dissatisfied with the traffic rules for cyclists. Reducing the levels of such dissatisfaction might contribute to reducing the number of conflicts between cyclists and other road users. This could be achieved by changing the rules and making the rules more appropriate with respect to cyclists' needs. Additionally, there is a need to investigate in depth which type of traffic rules cyclists are dissatisfied with, and the association between their dissatisfaction and conflicts when cycling.

As we hypothesized, cyclists' risk perception was significantly related to conflicts with other road users when cycling. The perceived probability of being involved in an accident with a motorized vehicle was significantly associated with conflicts when cycling. However, the perceived probability of being involved in other types of accidents (single accident, with a pedestrian, with another cyclists) was not associated with conflicts when cycling. A possible explanation is that a relatively small share of the cyclists perceived the risk of the other types of accidents (i.e. about which they were questioned) as high. Previous research has revealed that low probability estimates often are associated with low levels of perceived severity of consequences (Nordfjærn & Rundmo, 2015). It follows that cyclists who perceive the severity of consequences of an accident as low are least likely to change their behaviour. From this assumption, it is natural to assume that the association between risk perception and amount of conflicts when cycling is weak. In our study, the distribution of the answers related to worry was often skewed. Most cyclists perceived the risk as negligible and therefore risk was unlikely to have influenced their behaviour.

Geographical area of residence was found to influence attitudes toward traffic rules and cyclists' risk-taking behaviour. Individuals living in urban areas had less ideal attitudes and more risk-taking behaviour when cycling compared with cyclist who lived in rural areas. This finding may have been embedded in geographical characteristics, differences in road infrastructure, and differences in traffic density between urban and rural areas. Cyclists in urban areas face more complex traffic situations, with more crossings and possibly more conflicts with other road users, which may result in different cycling behaviour. However, the differences in attitudes and behaviour between cyclists living in urban and cyclists living in rural areas were small.

It could be argued that the type of risk-taking behaviour that we analysed did not increase the risks for cyclists or lead to more accidents involving cyclists. Nevertheless, it is natural to assume that the more the situations involving conflicts

with other road users a cyclist experiences, the more the risk of their involvement in accidents will increase. The traffic rules and traffic regulation are set to increase traffic safety and to ensure traffic flow. We assume that cyclists who never or rarely violate the rules are safer than are other cyclists. In the study we chose to define attitudes as either ideal or non-ideal. As mentioned in the Results section (3.1), ideal attitudes are desirable in traffic planning to ensure traffic flow and safety in traffic. Although previous studies have defined attitudes as ideal (Iversen & Rundmo, 2004, 2009), the use of the term 'ideal' in the context of cyclists' attitudes towards traffic safety should be discussed. Additionally, there is a need for further investigation of whether the risk-taking behaviour and safety attitudes discussed in this article are associated with safety in traffic.

The results of the study show that it would be worth considering having more campaigns that target cyclists' attitudes towards road safety. The study showed that the importance of attitudes and risk perception varied across different types of behaviour. Attitudes were more important for violation of traffic rules, while risk perception was more important for conflicts when cycling. Hence, when designing safety campaigns aimed at influencing cyclists' attitudes, it is important to keep in mind what type of risk-taking behaviour it is desirable to change, as this would affect whether the campaign should focus primarily on changing cyclists' perceptions of risk or their attitudes toward traffic safety. However. it could be discussed whether too much focus on risk may prevent people from starting to cycle, which would not be in line with sustainable transport. Additionally, attitudes toward traffic safety communicated in informal social settings could prevent people from cycling. Carefully designed attitude and information campaigns about traffic safety for cyclists, could contribute into positive attitude change, without worrying people and discouraging them from cycling. The effect of such measures should be thoroughly evaluated.

4.2 Limitations of the study

It was not possible to calculate the exact response rate and this could be seen as a limitation of the study. However, calculating the exact response rate only constitutes a methodological problem if the overall sample is not representative of the target population (Krosnick, 1999). In our study, the target group was cyclists who had used their bicycle for regular trips. All respondents in the sample reported that they cycled at least once per week during summer. We can assume that people who often cycle also read the Norwegian Cyclists' Association's magazine (through which the

respondents were recruited) more often than others did. When our study sample was compared with the target population in the Norwegian National Travel Survey 2018 (Ellis, 2019), we found similarities in the demographic characteristics. In total, 64% of the respondents reported they had more than three years of university education – a finding that is in accordance with the finding made by Ellis (2019) that persons with a long period of university education cycled more than others did. More than half of the sample lived in urban areas with between 100,000 and 700,000 inhabitants. This finding is similarly in accordance with the finding made by Ellis (2019) that people living in urban areas used their bicycle for daily travels more often than others did. The results of Norwegian surveys that have collected data about cycling in the cities show that about two-thirds of participants who answered that they had used their cycle during the last year had cycled at least once per week during the summer months (Kummeneje & Tretvik, 2015; Tretvik, 2015). Ellis (2019) found a higher rate of cycling activity among males than among females. This finding is supported by the results of our study, which showed that 66% of the sample was male. The analyses in our study controlled for demographic differences.

Only cyclists who had used their bicycle for regular trips during the last year were asked to answer the questionnaire. This could be seen as a limitation of the study in terms of interpretation of the results. It is possible that such a group is potentially on the tail of the distribution of cyclists (and road users) in terms of many of the variables examined in this study. A design with a wider range of cycling frequency might have provided different results. For example, the lack of importance of gender might have reflected the censored sample. At the same time, as mentioned in the method section in this article, the purpose of the study was primarily to focus on and investigate cyclists who had used their bicycle for regular trips. The reason was that the group comprises the most experienced cyclists, who are most familiar with the local cycling infrastructure and cycling facilities, and mainly cycle during the peak hours of the day with high traffic density.

The methods used in the study were based on cross-sectional survey data. The methods that could be used to analyse such data did not enable us to draw any conclusions about causal relationships. More studies with an experimental design are needed to investigate causal relationships. Nevertheless, the fit statistics from the study shows that the data fitted the theoretical models that were investigated. Furthermore, the results of the study are in accordance with the results of studies previously conducted in the same subject field. A general problem regarding method in studies of risk perception, attitudes and accidents is skewed distributions in the

participants' answers due to the few accidents occurring and low levels of perceived risk. However, our results do not indicate that this was a problem in the study.

5. Conclusions

The results presented in this article show that cyclists' attitudes towards traffic safety and their risk perceptions are important predictors of their risk-taking behaviour. The present study has shown that attitudes, risk perception, and accident involvement influence cyclists' risk-taking behaviour. First, pragmatic attitudes toward traffic rule violations and safety priority were found to be important predictors of the frequency of rule violations when cycling. Second, attitudes towards the enforcement of traffic rules and dissatisfaction with the traffic rules for cyclists were found to be important predictors of the frequency of situations involving conflicts with other road users. Risk perception and accident involvement were found to be important for conflicts with other road users, but not for rule violations when cycling. Our findings show that risk perception and attitudes toward traffic safety are important for cyclists' risk-taking behaviour in traffic. As mentioned, the road infrastructure and the traffic regulations are primarily planned for car drivers and pedestrians. If cyclist's attitudes are to be changed, then also the cycling infrastructure and traffic rules for cyclists need to be changed and adjusted to cyclists as road users. When building new infrastructure and implementing new safety measures for cyclists, it is important to supplement them with attitude campaigns and communications to the public about safety and risks linked to cycling. Attitude campaigns could be used to strengthen communications from the authorities that cyclists are prioritized as road users. This might increase roader users' the respect for the traffic rules for cyclists. Furthermore, campaigns may motivate people who do not cycle today to use a cycle for their daily travels in a safe way in the future.

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Appendix

Questions included in the questionnaire about cyclists' attitudes towards traffic safety:

To what extent do you agree or disagree with the following statements? (1 = strongly disagree, 2 = disagree, 3 = neither agree/nor disagree, 4 = agree, 5 = strongly agree)

1 It is acceptable to break the rules as a cyclist when no others are involved
2 It is acceptable to cycle through a red traffic light when no others are present
3 It is acceptable to take chances as a cyclist when only you are exposed to risk
4 Breaking rules does not necessarily make you a less safe cyclist compared with those who always follow the rules
5 It is acceptable to cycle after drinking alcohol (< 0.2 ‰)
6 There should be more traffic surveillance for cyclists
7 There should be severe punishments for cyclists who break traffic rules
8 Many traffic rules for cyclists are impossible to comply with
9 The traffic rules for cyclists are too complicated to adhere to in practice
10 It is no wonder that many cyclists violate traffic rules
11 Many traffic rules for cyclists are unnecessary
12 Cyclists should always follow the rules
13 Sometimes it is necessary to bend the rules as a cyclist to make sure of arriving
14 It is more important to get ahead as a cyclist than always to follow the rules
15 It is important to have road safety campaigns directed towards cyclists

Questions included in the questionnaire about cyclists' risk-taking behaviour:

How often do you do the following when cycling? (1 = never, 2 = rarely, 3 = neither/nor, 4 = often, 5 = very often)

1 Cycle when using mobile phone
2 Cycle in the dark without cycle lights
3 Cross the road when a traffic light is red
4 Use a pedestrian crossing when the light is red for pedestrians
5 Cycle after drinking alcohol (< 0.2 ‰)
6 Cycle against traffic in one-way streets
7 Fail to notice a vehicle approaching from a side road

8 Brake hard because a vehicle is approaching faster than expected
9 Turn quickly away from a vehicle to avoid an accident
10 Brake hard down and/or turn quickly to avoid hitting a pedestrian

Appendix A: Questionnaire, Study 1

Spørreundersøkelse om risikopersepsjon, bekymring, holdninger og reiseatferd blant syklister

1. Har du syklet én eller flere ganger i løpet av det siste året? (ja; nei)

Du har svart at du har syklet én eller flere ganger i løpet av det siste året:

1. Hvor ofte sykler du når det er …
    a. Vinter (5 eller flere ganger i uka; 3–4 ganger i uka; 1–2 ganger i uka; Noen ganger i måneden; Sjeldnere; Aldri)
    b. Vår (5 eller flere ganger i uka; 3–4 ganger i uka; 1–2 ganger i uka; Noen ganger i måneden; Sjeldnere; Aldri)
    c. Sommer (5 eller flere ganger i uka; 3–4 ganger i uka; 1–2 ganger i uka; Noen ganger i måneden; Sjeldnere; Aldri)
    d. Høst (5 eller flere ganger i uka; 3–4 ganger i uka; 1–2 ganger i uka; Noen ganger i måneden; Sjeldnere; Aldri)
2. Hvor sannsynlig mener du det er at du selv kan bli utsatt for en ulykke med personskade om du sykler på …
    a. Vinterføre (1 = svært lite sannsynlig; 5 = svært sannsynlig)
    b. Sommerføre (1 = svært lite sannsynlig; 5 = svært sannsynlig)
3. Hvor alvorlige tror du konsekvensene vil være om du blir utsatt for en ulykke om du sykler på …
    a. Vinterføre (1 = svært lite alvorlige; 5 = svært alvorlige)
    b. Sommerføre (1 = svært lite alvorlige; 5 = svært alvorlige)
4. Hvor bekymret er du for å bli utsatt for en ulykke om du sykler på …
    a. Vinterføre (1 = svært lite bekymret; 5 = svært bekymret)
    b. Sommerføre (1 = svært lite bekymret; 5 = svært bekymret)
5. I hvilken grad tolererer du å bli utsatt for risiko om du sykler …
    a. Vinterføre (1 = tolererer absolutt risikoen; 5 = tolererer ingen risiko)
    b. Sommerføre (1 = tolererer absolutt risikoen; 5 = tolererer ingen risiko)
6. Hvor viktig mener du at det er at myndighetene prioriterer å iverksette tiltak for å bedre sikkerheten for syklister på …
    a. Vinterføre (1 = ikke viktig; 5 = svært viktig)
    b. Sommerføre (1 = ikke viktig; 5 = svært viktig)
7. Hvor enig eller uenig er du i følgende påstander? (1 = svært uenig; 5 = svært enig)

   a. Mange av trafikkreglene for syklister er umulig å overholde
   b. Noen ganger er det nødvendig å tøye reglene som syklist for å kunne komme seg fram
   c. Man bør alltid overholde trafikkreglene som syklist
   d. Syklister som aldri bryter trafikkreglene er ikke nødvendigvis mindre sikre enn de som gjør alt lovlig
   e. Det er ikke rart at mange bryter trafikkreglene som syklist
   f. Trafikkreglene for syklister er for kompliserte til at de kan følges i praksis
   g. Mange av trafikkreglene for syklister er unødvendige
   h. Det burde vært flere trafikkontroller av syklister
   i. Det burde vært strengere straffer for å bryte trafikkreglene som syklist
   j. Det er ikke viktig med holdningskampanjer rettet mot syklister
   k. Det er helt greit å bryte trafikkreglene som syklist når det ikke er noen andre tilstede
   l. Det er greit å sykle etter å ha drukket alkohol (promille over 0,2)
   m. Det er viktigere å komme seg fram som syklist enn alltid å følge reglene
8. Kjønn? (kvinne; mann)
9. Fødselsår? (årstall)
10. Høyeste fullførte utdanning? (1 = grunnskole; 2 = videregående skole; 3 = høyskole/universitet, inntil 3 år; 4 = høyskole/universitet, mer enn 3 år)
11. Hovedbeskjeftigelse? (1 = yrkesaktiv; 2 = student/skoleelev; 3 = alderspensjonist; 4 = annet)
12. Har du førerkort for personbil, MC/moped eller annet motorisert kjøretøy? (ja; nei)
13. Eier eller disponerer du personbil, MC/moped eller annet motorisert kjøretøy? (ja; nei)

Appendix B: Questionnaire, Study 2

Spørreundersøkelse om risikopersepsjon, bekymring og reiseatferd for gående

I de innledende spørsmålene er vi opptatt av om det er noe forskjell mellom om du går på ulike tider av døgnet. Vi skiller ikke mellom om du går på hele eller bare deler av en reise. All gåing er viktig å få fram her. Inkluder også korte gangturer du foretar deg uavhengig av lengde, varighet eller formål.

1. Hvor ofte går du utendørs på dagtid (kl 7-19) når det er …
    a. Vinter (desember, januar, februar) (5-7 ganger i uka; 3-4 ganger i uka; 1-2 ganger i uka; 1-3 måneden; Sjeldnere; Aldri)
    b. Vår (mars, april, mai) (5-7 ganger i uka; 3-4 ganger i uka; 1-2 ganger i uka; 1-3 måneden; Sjeldnere; Aldri)
    c. Sommer (juni, juli, august) (5-7 ganger i uka; 3-4 ganger i uka; 1-2 ganger i uka; 1-3 måneden; Sjeldnere; Aldri)
    d. Høst (september, oktober, november) (5-7 ganger i uka; 3-4 ganger i uka; 1-2 ganger i uka; 1-3 måneden; Sjeldnere; Aldri)
2. Hvor ofte går du utendørs på kvelds- eller nattestid (kl 19-7) når det er …
    a. Vinter (desember, januar, februar) (5-7 ganger i uka; 3-4 ganger i uka; 1-2 ganger i uka; 1-3 måneden; Sjeldnere; Aldri)
    b. Vår (mars, april, mai) (5-7 ganger i uka; 3-4 ganger i uka; 1-2 ganger i uka; 1-3 måneden; Sjeldnere; Aldri)
    c. Sommer (juni, juli, august) (5-7 ganger i uka; 3-4 ganger i uka; 1-2 ganger i uka; 1-3 måneden; Sjeldnere; Aldri)
    d. Høst (september, oktober, november) (5-7 ganger i uka; 3-4 ganger i uka; 1-2 ganger i uka; 1-3 måneden; Sjeldnere; Aldri)

Respondentene som oppgir at de går utendørs på kveldstid blir videre spurt om de noen ganger går alene.

20. Når du går utendørs på kvelds-/nattestid hender det at du går alene uten følge av noen du kjenner eller på tur med hund? (Ja, ofte; Ja, av og til; Nei, aldri)

Du vil nå få noen spørsmål om din opplevde risiko som fotgjenger på ulike tider av døgnet. Selv om du aldri går utendørs på dagtid eller kvelds-/nattestid ber vi deg om å gjøre en vurdering.

21. Som fotgjenger på dagtid, hvor sannsynlig mener du det er at du selv kan bli utsatt for følgende …
    a. Ulykke (1 = svært lite sannsynlig; 5 = svært sannsynlig)
    b. Tyveri (1 = svært lite sannsynlig; 5 = svært sannsynlig)
    c. Trakassering (1 = svært lite sannsynlig; 5 = svært sannsynlig)
    d. Terror (1 = svært lite sannsynlig; 5 = svært sannsynlig)
22. Som fotgjenger på kvelds- og nattestid, hvor sannsynlig mener du det er at du selv kan bli utsatt for følgende …
    a. Ulykke (1 = svært lite sannsynlig; 5 = svært sannsynlig)
    b. Tyveri (1 = svært lite sannsynlig; 5 = svært sannsynlig)
    c. Trakassering (1 = svært lite sannsynlig; 5 = svært sannsynlig)
    d. Terror (1 = svært lite sannsynlig; 5 = svært sannsynlig)
23. Som fotgjenger på dagtid, hvor alvorlige tror du konsekvensene vil være om du utsettes for følgende …
    a. Ulykke (1 = svært lite alvorlige; 5 = svært alvorlige)
    b. Tyveri (1 = svært lite alvorlige; 5 = svært alvorlige)
    c. Trakassering (1 = svært lite alvorlige; 5 = svært alvorlige)
    d. Terror (1 = svært lite alvorlige; 5 = svært alvorlige)
24. Som fotgjenger på kvelds- og nattestid, hvor alvorlige tror du konsekvensene vil være om du utsettes for følgende …
    a. Ulykke (1 = svært lite alvorlige; 5 = svært alvorlige)
    b. Tyveri (1 = svært lite alvorlige; 5 = svært alvorlige)
    c. Trakassering (1 = svært lite alvorlige; 5 = svært alvorlige)
    d. Terror (1 = svært lite alvorlige; 5 = svært alvorlige)
25. Som fotgjenger på dagtid, hvor bekymret er du for å utsettes for følgende …
    a. Ulykke (1 = svært lite bekymret; 5 = svært bekymret)
    b. Tyveri (1 = svært lite bekymret; 5 = svært bekymret)
    c. Trakassering (1 = svært lite bekymret; 5 = svært bekymret)
    d. Terror (1 = svært lite bekymret; 5 = svært bekymret)
26. Som fotgjenger på kvelds- og nattestid, hvor bekymret er du for å utsettes for følgende …
    a. Ulykke (1 = svært lite bekymret; 5 = svært bekymret)
    b. Tyveri (1 = svært lite bekymret; 5 = svært bekymret)
    c. Trakassering (1 = svært lite bekymret; 5 = svært bekymret)
    d. Terror (1 = svært lite bekymret; 5 = svært bekymret)

27. I hvilken grad tolererer at det er en risiko ved det å være fotgjenger? (1 = tolererer absolutt risikoen; 5 = tolererer ingen risiko)
28. Hvordan vurderer du muligheten til å beskytte deg selv mot risiko du er utsatt for som fotgjenger? (1 = stor mulighet; 5 = ingen mulighet)
29. Har du i løpet av de siste to årene vært utsatt for en eller flere ulykker som fotgjenger? (ja; nei)

Respondentene som oppgir at de har vært utsatt en ulykke blir videre spurt om andre var involvert i ulykken og om de oppsøkte lege etter hendelsen.

30. Var andre trafikanter involvert i ulykken(e) du var utsatt for? (e.g. syklist, fotgjenger, motorkjøretøy) (ja; nei)
31. Oppsøkte du lege (legesenter, legevakt, sykehus etc.) som følge av denne/disse hendelsene(e)? (ja; nei)
32. Har du i løpet av de siste to årene vært utsatt for trusler, fysiske angrep eller tyveri som fotgjenger? (ja; nei)

Respondentene som oppgir at de har vært utsatt trusler, fysiske angrep eller tyveri blir videre spurt om de oppsøkte lege etter hendelsen.

33. Oppsøkte du lege (legesenter, legevakt, sykehus etc.) som følge av denne/disse hendelsene(e)? (ja; nei)
34. Kjønn? (kvinne; mann)
35. Fødselsår? (årstall)
36. Høyeste fullførte utdanning? (1 = grunnskole; 2 = videregående skole; 3 = høyskole/universitet, inntil 3 år; 4 = høyskole/universitet, mer enn 3 år)
37. Hovedbeskjeftigelse? (1 = yrkesaktiv; 2 = student/skoleelev; 3 = alderspensjonist; 4 = annet)
38. Har du førerkort for personbil, MC/moped eller annet motorisert kjøretøy? (ja; nei)
39. Eier eller disponerer du personbil, MC/moped eller annet motorisert kjøretøy? (ja; nei)

Appendix C: Questionnaire, Study 3

Spørreundersøkelse om risikopersepsjon, bekymring, holdninger til trafikksikkerhet og risikotaking blant syklister

1. Har du syklet én eller flere ganger i løpet av det siste året? (ja; nei)

Du har svart at du har syklet én eller flere ganger i løpet av det siste året:

2. Hvor ofte sykler du når det er …
    a. Vinter (5 eller flere ganger i uka; 3–4 ganger i uka; 1–2 ganger i uka; Noen ganger i måneden; Sjeldnere; Aldri)
    b. Vår (5 eller flere ganger i uka; 3–4 ganger i uka; 1–2 ganger i uka; Noen ganger i måneden; Sjeldnere; Aldri)
    c. Sommer (5 eller flere ganger i uka; 3–4 ganger i uka; 1–2 ganger i uka; Noen ganger i måneden; Sjeldnere; Aldri)
    d. Høst (5 eller flere ganger i uka; 3–4 ganger i uka; 1–2 ganger i uka; Noen ganger i måneden; Sjeldnere; Aldri)
3. Som syklist, hvor sannsynlig mener du det er at du selv kan bli utsatt for følgende …
    a. Fallulykke? (1 = svært lite sannsynlig; 5 = svært sannsynlig)
    b. Påkjørsel eller kollisjon med fotgjenger? (1 = svært lite sannsynlig; 5 = svært sannsynlig)
    c. Påkjørsel eller kollisjon med annen syklist? (1 = svært lite sannsynlig; 5 = svært sannsynlig)
    d. Påkjørsel eller kollisjon med motorkjøretøy? (1 = svært lite sannsynlig; 5 = svært sannsynlig)
4. Som syklist, hvor alvorlige tror du konsekvensene vil være om du blir utsatt for følgende …
    a. Fallulykke? (1 = svært lite alvorlige; 5 = svært alvorlige)
    b. Påkjørsel eller kollisjon med fotgjenger? (1 = svært lite alvorlige; 5 = svært alvorlige)
    c. Påkjørsel eller kollisjon med annen syklist? (1 = svært lite alvorlige; 5 = svært alvorlige)
    d. Påkjørsel eller kollisjon med motorkjøretøy? (1 = svært lite alvorlige; 5 = svært alvorlige)
5. Som syklist, hvor bekymret er du for å bli utsatt for følgende …

   a. Fallulykke? (1 = svært lite bekymret; 5 = svært bekymret)
   b. Påkjørsel eller kollisjon med fotgjenger? (1 = svært lite bekymret; 5 = svært bekymret)
   c. Påkjørsel eller kollisjon med annen syklist? (1 = svært lite bekymret; 5 = svært bekymret)
   d. Påkjørsel eller kollisjon med motorkjøretøy? (1 = svært lite bekymret; 5 = svært bekymret)
6. I hvilken grad tolererer du å bli utsatt for risiko når du sykler? (1 = tolererer absolutt risikoen; 5 = tolererer ingen risiko)
7. Hvor høyt prioriterer du sikkerhet når du sykler? Vinterføre (1 = svært lavt; 5 = svært høyt)
8. Når du sykler, hvor ofte gjør du følgende? 1 = aldri, 2 = sjelden, 3 = av og til, 4 = ofte, 5 = svært ofte)
   a. Bruker mobiltelefon mens du sykler
   b. Sykler i mørket uten å benytte sykkellys (eller annet lys som hodelykt, lys festet på ryggsekk etc.)
   c. Sykler over veibanen på rødt lyssignal
   d. Sykler på rød mann over gangfelt
   e. Sykler etter å ha drukket alkohol (< 0.2 ‰)
   f. Sykler mot kjøreretningen i en enveiskjørt gate (hvor dette ikke var skiltet som lovlig)
   g. Ikke legger merke til bil som kommer fra sidegate
   h. Bremser hardt fordi en bil nærmer seg fortere enn du har beregnet
   i. Må vike for et kjøretøy for ikke å bli påkjørt
   j. Må bremse og/eller svinge brått for å unngå nestenkollisjon med fotgjenger
9. Hvor enig eller uenig er du i følgende påstander? (1 = svært uenig; 2 = uenig, 3 = verken enig eller uenig, 4 = enig 5 = svært enig)
   a. Mange av trafikkreglene for syklister er umulig å overholde
   b. Noen ganger er det nødvendig å tøye reglene som syklist for å kunne komme seg fram
   c. Man bør alltid overholde trafikkreglene som syklist
   d. Syklister som aldri bryter trafikkreglene er ikke nødvendigvis mer sikre enn de som gjør alt lovlig
   e. Det er ikke rart at mange bryter trafikkreglene som syklist

f. Trafikkreglene for syklister er for kompliserte til at de kan følges i praksis
g. Mange av trafikkreglene for syklister er unødvendige
h. Det burde vært flere trafikkontroller av syklister
i. Det burde vært strengere straffer for å bryte trafikkreglene som syklist
j. Det er viktig med holdningskampanjer rettet mot syklister
k. Det er helt greit å bryte trafikkreglene som syklist når det ikke er noen andre tilstede
l. Det er greit å sykle etter å ha drukket alkohol (promille over 0,2)
m. Det er viktigere å komme seg fram som syklist enn alltid å følge reglene
n. Det er greit å sykle på rødt lys når det ikke er andre i nærheten
o. Det er greit å ta sjanser som syklist når det kun er du selv som utsettes for risiko

10. Har du i løpet av de siste to årene vært utsatt for en eller flere ulykker da du syklet? (ja; nei)

Respondentene som oppgir at de har vært utsatt en ulykke blir videre spurt om de oppsøkte lege etter hendelsen.

11. Oppsøkte du lege (legesenter, legevakt, sykehus etc.) som følge av ulykken(e)? (ja; nei)
12. Har du i løpet av de siste to årene vært utsatt for en eller flere nestenulykker da du syklet? (ja; nei)
13. Kjønn? (kvinne; mann)
14. Fødselsår? (årstall)
15. Høyeste fullførte utdanning? (1 = grunnskole; 2 = videregående skole; 3 = høyskole/universitet, inntil 3 år; 4 = høyskole/universitet, mer enn 3 år)
16. Hovedbeskjeftigelse? (1 = yrkesaktiv; 2 = student/skoleelev; 3 = alderspensjonist; 4 = annet)
17. Bor du i et tettsted eller by med … (1 = under 2 000 mennesker; 2 = mellom 2 000 og 20 000 mennesker; 3 = mellom 20 000 og 100 000 mennesker; 4 = 100 000 mennesker eller mer)
18. Har du førerkort for personbil, MC/moped eller annet motorisert kjøretøy? (ja; nei)
19. Eier eller disponerer du personbil, MC/moped eller annet motorisert kjøretøy? (ja; nei)

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