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School voor Mobiliteitswetenschappen

master in de mobiliteitswetenschappen

Masterthesis

Fatigue and behavioural assessment in truck drivers by means of a questionnaire

Kishan Vandael Schreurs

Scriptie ingediend tot het behalen van de graad van master in de mobiliteitswetenschappen, afstudeerrichting verkeersveiligheid

PROMOTOR :

Prof. dr. Tom BRIJS

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PREFACE

This thesis, called 'fatigue and behavioural assessment in truck drivers by means of a questionnaire', has been written as a part of the University of Hasselt master's degree 'Transportation Sciences', in the field of study 'Traffic Safety' for the academic year 2019-2020. The subject of this thesis concerns a questionnaire that tried to give a deeper insight into fatigue and the attitudes and behaviour of truck drivers regarding fatigue and fatigue detection technology. This subject has been undertaken as an alternative data acquisition method of an initial study in the context of the innovative European Horizon 2020 iDREAMS project.

I would like to thank my promoter dr. prof. Tom Brijs and co-promoter dr. Veerle Ross for the guidance throughout this thesis. Their confidence in my capabilities to contribute to the iDREAMS project has given me strength and self-confidence to perform this study. In extension would I also like to thank Ms. Hélène Dirix for the guidance throughout this thesis as the successor of dr. Veerle Ross during her maternity leave.

Next, do I want to thank Thomas Stieglitz, who gave me an introduction into the STISIM driving simulator program language, as well as the driving simulator itself. Also, do I want to thank my fellow students Glenn Godin, Jochen Huygen, and Karel Vandebergh for support throughout the year and honest work distribution for other university assignments, making it able for me to put as much work as possible in this thesis. Further, do I want to thank dr. prof. An Neven, which gave allowance to perform this study in the context of the master's degree thesis.

Second to last, do I want to thank all my friends and family for putting up with me during this extremely busy period. Especially for the support in both thesis subjects and the support during the COVID-19 outbreak, which made the future of this thesis very doubtful but also seriously affected the health of my family.

And last, but also of equal importance, would I like to express gratitude to the truck drivers that participated in this study. Their flexibility, persistence, and understanding made this thesis possible. There was not even the slightest hesitation when asked to fill in the alternative questionnaire (for them the second) as a favour, making it able to finish my thesis.

I hope you will enjoy reading.

Kishan Vandael Schreurs
Student of the Traffic Safety Master's Degree in Transportation Sciences

Hasselt June 2nd, 2020.

This master thesis was written during the COVID-19 crisis in 2020. This global health crisis has had an impact on the (writing) process, the research activities, and the research results that are at the basis of this thesis. This because the initial subject of this thesis, called 'Fatigue determination in long-haul truck drivers utilizing a steering wheel-based ECG: a simulator study', in the context of the innovative European Horizon 2020 iDREAMS project, was unable to be fully performed due to the COVID-19 outbreak at the most crucial part of the research. Data acquisition was made impossible with regards to the driving simulator near the end of the thesis deadline. Therefore, an alternative data acquisition method, via the use of a questionnaire, was necessary to achieve useable data for this thesis and the iDREAMS project. As a result, both subjects are discussed in this thesis.

ABSTRACT

Fatigue has been implicated as an important cause in many traffic accidents in the professional driving context. As fatigue is often misinterpreted with sleepiness and drowsiness, can it be described as a biological drive for recuperative rest which gets formed gradually and cumulatively, disappearing after a period of rest. Caused by personal characteristics, circadian factors, homeostatic factors, and task-related factors, resulting in sleep-related or task-related fatigue, do the effects include microsleep episodes, longer reaction times, vigilance reduction, deficits in information processing, and performance lapses which can directly result in crashes. This problem is prominently present in the truck driving profession, which is known for health-related issues, sleep-related problems, a high workload, conflicts with the circadian rhythm, and sleep restrictions. Although it can be measured via different methods, including direct observation through physical and physiological changes and self-reported levels of fatigue utilising a fatigue-related questionnaire, is an unreliable self-estimation by the driver the most common in detecting the level of fatigue. As a consequence, are countermeasures, which don't go beyond self-initiated solutions, used with little to no effects. As a result, this research was performed to get more insight into fatigue detection methods, attitudes about fatigued driving and facilitating factors for the performance of the target behaviour (i.e. not driving while feeling fatigued) in the professional driving context.

A small sample of 23 truck drivers participated in this study by filling in two fatigue-related questionnaires, gathering personal background information in cohesion with the Epworth Sleepiness Scale (ESS), Fatigue Assessment Scale (FAS), current behaviour regarding fatigued driving, openness to change to drive without fatigue, facilitating factors behind the execution of the target behaviour (based on the COM-B and Behaviour Change Wheel method), coping strategies, and attitudes towards fatigue detection technology. Results obtained from the validated FAS and ESS questionnaires show a presence of fatigue in 8 out of 23 drivers (i.e. 34,78%), but an absence of sleepiness. Subsequently, a significant correlation showed a higher age resulting in a lower FAS-score. A reliability and qualitative analysis performed on the current behaviour, openness to change, and attitude towards technology items showed positively oriented answers. Nevertheless, did drivers indicate being perfectly capable in estimating their level of fatigue, did they indicate having problems with performing the target behaviour, and were they afraid that fatigue detection technology would be used as a control device. Results from the COM-B item factor analysis matched with the behavioural change wheel framework, while mean scores from the reliability and qualitative analysis showed problems regarding these facilitating factors to perform the target behaviour.

Despite the small sample size, fatigue was detected in a substantial number of truck drivers. While drivers indicated taking a break and rest when feeling fatigued, did most drivers indicate being better in detecting their fatigue than technology would. This contradicts the trust drivers have in the development of fatigue detection technology, if it is not used to monitor their behaviour constantly. Drivers indicate a willingness to change their behaviour, in favour of the target behaviour but admit having problems to perform it. An important factor causing this problem concerns a lack of knowledge about fatigue, confirmed by the use of different coping strategies that are proven not to be able to trigger arousal, as well as having a lack of physical strength. Other obstacles in performing the target behaviour consist out of having a lack of social and physical opportunities together with problems in terms of automatic and reflective motivation.

This research suggests combatting fatigue behind the wheel, by using the intervention functions from the behaviour change wheel to influence the facilitating factors to perform the target behaviour. Special focus is needed to physical capability, psychological capability (more specific knowledge), physical and social opportunity, and automatic and reflective motivation through education, persuasion, incentivisation coercion, restriction, environmental restructuring, and enablement. Policy categories can support these interventions to facilitate target behaviour. Further, is the detection of fatigue a necessity since a large proportion of the drivers participating in this research suffered from fatigue, and is special attention needed to the development of technology with regards to communication to drivers. This leads to support from drivers to install these fatigue detection systems in their trucks, since an interest in these devices was present. Nevertheless, can full responsibility not be placed with the driver. Awareness needs to be raised among employers, companies, legislation, and the transport sector in general as well. Legislation, strict company rules, and busy work schedules need to be revised, so that drivers are able to perform safe behaviour without negative consequences.

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1 INTRODUCTION

1.1 General introduction

Traffic crashes have a numerous amount of causes in which certain factors play an important role. Many governments and vehicle manufacturers make an effort to compile policy measures to prevent crashes from happening. To illustrate, measures like speed rates, alcohol consumption limits, seat belt promotion, vehicle structure improvements, etc. can be used to lower the probability of a crash. However, the knowledge and technologies available today are still not enough to prevent crashes which resulted from a loss of alertness and lack of attention on drivers (Chin-Teng Lin et al., 2005), which can be seen as performance decrements that play a causal role in and injury and crashes (A. Williamson et al., 2011).

One of the factors that can cause this loss of alertness and lack of attention comprises driver fatigue, which can be seen as a constituent of impairment. This factor has been implicated as a causal factor in many accidents, with multiple outcomes, because of the marked decline in the drivers' abilities of perception, recognition, and vehicle control abilities while sleepy. As a result, people are less likely to produce safe performance and actions (Chin-Teng Lin et al., 2005; May & Baldwin, 2009; A. Williamson et al., 2011).

Estimations on the role of fatigue in crashes vary widely. Typical ranges in literature vary from 1% to 3% of all crashes, up to 20% of crashes occurring on major roads and motorways (A. Williamson et al., 2011). However, an underestimation of the involvement of sleep and fatigue-related crashes is likely. This due to the general agreement that percentages based on crash data underestimate the true magnitude of the problem, since police reports often misidentify the involvement of fatigue. (Sagberg, 1999; A. Williamson et al., 2011). On the other hand, is it safe to say that fatigue-related crashes most of the time result in more severe crashes due to higher speeds and a lack of action-taking. This because the driver fell asleep and was unable to counteract (Pack et al., 1995; Sagberg, 1999).

1.2 The problem of fatigue-related crashes in professional drivers

Apart from fatigue-related crashes within 'normal' drivers, are fatigue-related crashes within professional drivers posing a noteworthy more problematic issue. Important for this research concerns the fact that no distinction is made between short- and long-haul trucking because both types of drivers can suffer from fatigue. The difference between short- and long-haul trucking lies in the distance travelled, their start and ending point of the drive, and the driving task. Short-haul truck drivers typically engage in trips of 100 miles (160 kilometres) or less from their home base, they typically begin and end their day at their home base and have a day's driving schedule where they need to load the vehicle, get in and out of the vehicle numerous times, lift and carry packages, and perform many other tasks. Long-haul truck drivers have much longer day trips, are on the road for several days and their task primarily concerns operating the vehicle (Hanowski et al., 1998). In Belgium, both types of drivers can be found.

Fatigue has long been experienced as a problem in the professional driving context since truck drivers are at increased risk for sleepiness-related crashes (Arnold et al., 1997; McCartt et al., 2000; Stutts et al., 2003; A. Williamson et al., 2011). Percentages concerning the role of fatigue-related crashes vary greatly, from 1,7% to 25% (Temmerman et al., 2016).

Apart from the high levels of driving exposure, which imposes a higher crash risk, is truck driving a profession that leads to fatigued driving due to irregular hours (which conflicts with natural circadian rhythms), irregular work and sleep schedules, higher frequency of night-time driving, inadequate opportunities for sustained and restorative sleep and an unhealthy lifestyle (McCartt et al., 2000; Stutts et al., 2003). Arnold et al. (1997) found that professional truck drivers reported sleeping between 4 and 8 hours on average. However, of great concern was that about 12.5% of the unregulated drivers reported having had less than 4 hours of sleep on one or more of their working days. And 40% of the hazardous events were reported by 20% of drivers who reported having had less than 6 hours of sleep.

Apart from sleep-related factors are lonesome driving on long and monotonous roadways and extended driving times also reported as factors which can lead to fatigued driving (McCartt et al., 2000; Stutts et al., 2003). In the same study as mentioned before, Arnold et al. (1997) discovered that 38% of the drivers exceeded or would exceed 14 hours of driving in the 24 hour period. When other non-driving work was taken into account, the proportion exceeding 14 hours of work per 24-hour period increased by about 13%. The same applied for the 72-hours work limit in a week. When non-driving work is added, 30% worked over 72 hours.

Clearly, a big part of the problem is situated within the truck driver, because most drivers would exceed driving time limits and would give up sleep to achieve a certain benefit in terms of driving or an economic reward (Arnold et al., 1997; Philip, Sagaspe, Moore, et al., 2005). Furthermore is determined that drivers are unable to subjectively determine their level of fatigue (Liu et al., 2009). This problem led to the revision of legal driving time limits by the European Union in which the following rules apply nowadays (Temmerman et al., 2016):

- The daily driving limit amounts 9 hours. Twice a week, this limit can amount 10 hours.
- After a period of 4,5 hours, the driver must rest for 45 minutes.
- De daily resting time must contain 11 consecutive hours of rest per period of 24 hours after the previous resting time. This resting time can be divided into 3 hours of consecutive rest and 9 hours of consecutive rest.
- Weekly driving time limits (time within a calendar week), may not comprise more than 56 hours, while the biweekly driving time may not exceed 90 hours.

For Belgium, there is still a problem regarding resting times, despite the limits drafted by the European Union. Of the Belgian truck drivers, 24% worked more than 12 hours per week for one to three days per month in 2004. And 7,5% of the controlled drivers violated the legal limits in 2006 (Temmerman et al., 2016).

While research on truck drivers fatigue is becoming more and more present, much remains unknown about the extent, causes, and effects of sleepiness-related driving among commercial drivers (McCartt et al., 2000). On the other hand is it already clear that the consequences of crashes involving truck drivers are more severe for the fatigued driver, but also for other road users (A. M. Williamson et al., 1996). The weight of the truck and mass differences between a truck and a normal passenger car, increase the chance of a fatality compared to accidents not involving trucks (Häkkänen & Summala, 2001).

Due to the high crash severity, conflicts between physiological needs and social or professional activities, violations against resting times, etc. are understanding the human limits of fatigue/sleepiness and sleep deprivation becoming key issues in accident prevention (Philip, Sagaspe, Taillard, et al., 2005). In parallel, has the importance of developing driver sleepiness countermeasures been identified to prevent driving accidents and errors (Papadelis et al., 2007).

However, while research on countermeasures for traffic crashes focuses on the reinforcement of safety devices, improving roads, and regulations, little attention is given to the driver's human factors (Eoh et al., 2005). While being aware of the problems, drivers often consider themselves more able to cope with fatigue-related problems than others (Arnold et al., 1997).

1.3 Technology as a countermeasure

Many countermeasures for driver fatigue have been proposed (e.g. the use of bright light, caffeine, naps, etc.), but rely on drivers' self-monitoring of their level of fatigue, therefore making it unreliable. And even after correct recognition of danger signals, which indicates a risk of falling asleep, does it not guarantee that the driver will react appropriately to the signals (Sagberg, 1999; Ting et al., 2008).

As an alternative related approach, countermeasures based on objective driver-performance data have been developed, to detect driver high levels of fatigue (Liu et al., 2009). This leads to an ongoing need to develop tools for reliably detecting driver fatigue so that these crashes can be anticipated and avoided well in advance (Forsman et al., 2013). This can be done through the development of technological, in-car countermeasures (Häkkänen & Summala, 2001), which can be based on physiological measures (e.g., eye movements), vehicle dynamics, or a combination of these measures (Liu et al., 2009).

For this reason, carmakers are developing technologies to monitor car-based metrics of driving performance, so that the driver can be warned in advance. Such technologies typically rely on the detection of lane departures, large lateral deviations within the lane, and/or differences in steering corrections (Forsman et al., 2013).

Frankly, is this not the only way fatigue can be determined in a vehicle-based setting. As Chin-Teng Lin et al. (2005) discuss, is accurate and nonintrusive real-time monitoring of the driver highly desirable, particularly if this measure could be further used to predict changes in driver's performance capacity. This can also be done through the use of electrophysiological indicators. They are easily measured and logically related to physical effort and thereby perhaps to fatigue (Nilsson et al., 1997).

One of these electrophysiological indicators can be heart rate, which can be measured via an electrocardiographic (ECG) signal. In order to measure these physiological signals while driving, CardioWheel has been developed. It is described as "a state-of-the-art machine learning solution for driver biometrics based on electrocardiographic signals, which acquires heart signals from the user's hands through sensors embedded in the steering wheel. This to recognize the driver's identity via the combination of unsupervised and supervised machine learning algorithms" (Lourenço et al., 2015).

While the technology of CardioWheel is available and briefly tested, it is not completely clear if fatigue can be determined in the professional driving context. A controlled driving simulator study is needed to determine if CardioWheel can detect fatigue within professional drivers.

1.4 Research goals and questions

1.4.1 Driving simulator study (not been able to complete)

For this research, a pilot study was going to be conducted to test the functioning of CardioWheel in relation to the determination of fatigue in truck drivers. To accomplish this, two main research goals were defined. The first goal regarded the ability to determinate and provoke fatigue, to check when fatigue arose and how it could be reached in a driving simulator environment. Secondly, there would have been tested if CardioWheel, as an emerging technology, was able to reliably determine fatigue in the driving context of professional truck drivers, with a validation of the driving simulator parameters and Karolinska Sleepiness Scale (KSS).

This resulted in the main research question, that stated as followed: “Which fatigue effects, according to the assumption that CardioWheel can determine fatigue, can be found regarding driving behaviour, in correlation with the measurements of CardioWheel, so that the system can be seen as a valid fatigue detection system?”

This broad research question was subdivided into smaller and more concrete research questions, to have a clear vision on the matter. These research questions would have made it able to answer the main research question with substantiated evidence. The following list shows the specific research questions that were going to be used for this study.

- What is fatigue?
- What are the important causes and effects of fatigue?
- How does fatigue relate to the professional driving context?
- Which countermeasures are able to influence fatigue?
- Which measures can be used to determine fatigue?
- How does CardioWheel relate to fatigue in order to determine it?
- In which way can fatigue be influenced to study the effects that arise by it?
- In which way can the driving simulator be used to influence and study fatigue?
- Which relation can be derived between subjective feelings of sleepiness and objective measurements?
- How does CardioWheel, as a fatigue indicator, correlate with subjective feelings of fatigue?
- How does CardioWheel, as a fatigue indicator, correlate with objective driving simulator measurements of fatigue?
- What is the variance on the measurements of fatigue via CardioWheel?
- How can the measurements of CardioWheel be validated throughout the data acquisition phase?

1.4.2 Questionnaire study

As an alternative to the previously mentioned research, due to the COVID-19 outbreak, there is chosen to perform a questionnaire study. Of course, is it not possible to gather questionnaire data to study the validation of CardioWheel. Therefore, the focus is laid on getting other insights into fatigue and technology. This in relation to the same problem statement, namely, fatigue within truck drivers.

With this questionnaire study, the focus is laid on the detection of fatigue and sleepiness, together with a behavioural aspect. To accomplish this, three main research goals are defined. The first goal regards the detection of fatigue and sleepiness through a questionnaire. The second goal regards getting insights into the behavioural aspect, more concrete, the current behaviour, the explanation behind the current behaviour, and coping strategies regarding fatigue. The last goal regards the determination of attitudes and supportive surface for in-vehicle fatigue detection technology.

This results in the main research question, that can be stated as followed: “To what extent are fatigue and sleepiness present in truck drivers and how does this relate to the attitudes and behavioural aspects regarding fatigue and fatigue determination technology?”

This broad research question is subdivided into smaller and more concrete research questions, to have a clear vision on the matter. These research questions make it able to answer the main research question with substantiated evidence. The following list shows the specific research questions that are used for this study.

- What is fatigue?
- What are the important causes and effects of fatigue?
- How does fatigue relate to the professional driving context?
- Which aspects are able to influence fatigue?
- Which measures can be used to determine fatigue?
- How many drivers suffer from fatigue without possibly knowing?
- What are the attitudes regarding fatigued driving?
- How can we study the behavioural aspect of fatigued driving?
- Which underlying factors cause fatigued driving in truck drivers?
- How do truck drivers cope with fatigue during their driving task?
- What are the attitudes regarding in-vehicle fatigue detection technology?
- Which solutions can be given to combat fatigued driving?

2 LITERATURE REVIEW

2.1 The concept of 'fatigue'

2.1.1 Misinterpretation of the concept

Fatigue is a concept that is often misinterpreted, because of its multidimensional construct that has been difficult for researchers to define (May & Baldwin, 2009; A. Williamson et al., 2011). In literature, there is little agreement on the definition of fatigue (Smolensky et al., 2011; A. Williamson et al., 2011). Fatigue, sleepiness, and drowsiness are often confused and used synonymously (May & Baldwin, 2009; Philip, Sagaspe, Moore, et al., 2005). Even when the causes (heavy workload versus sleep deprivation) and counter-measures (rest versus sleep) are very different, people do not necessarily discriminate against the effects and remedies to the different conditions (Philip, Sagaspe, Moore, et al., 2005).

2.1.1.1 Fatigue – sleepiness – drowsiness

Many studies show the close relationship between drowsiness, sleepiness, and fatigue (Eoh et al., 2005; Philip, Sagaspe, Taillard, et al., 2005). But as mentioned before, the concepts are different from each other.

Fatigue is a general term that relates to both physiological and psychological processes and can be seen as a gradual and cumulative process due to sustained activity, work parameters, demographic variables, various medical conditions, and medication. It is associated with a disinclination towards effort and decreased capacity to perform, eventually resulting in performance decrements (Philip, Sagaspe, Moore, et al., 2005; Philip, Sagaspe, Taillard, et al., 2005; Smolensky et al., 2011; Thiffault & Bergeron, 2003). It has often been studied in driving episodes which require sustained attention for long periods of time and is characterized due to its elimination by a period of rest, therefore being a biological drive for recuperative rest (Philip, Sagaspe, Moore, et al., 2005; Philip, Sagaspe, Taillard, et al., 2005; Schmidt et al., 2009; A. Williamson et al., 2011). As a construct, it links a range of factors that potentially cause fatigue with several safety-related outcomes (i.e. the link between experiences like a long day at work and a crash while driving home, stand through the projected effect of fatigue). Because of this, fatigue is the mechanism by which the link exists, which produces phenomena that are, not always, directly observable or objectively measurable (A. Williamson et al., 2011).

Sleepiness can be seen as a construct in which it becomes difficult to stay awake, even when carrying out activities. It is a factor that is related to circadian and homeostatic influences. The difference with fatigue lies in the fact, that fatigue resolves after rest, while sleepiness only disappears after sleep. (Philip, Sagaspe, Moore, et al., 2005; Philip, Sagaspe, Taillard, et al., 2005; Schmidt et al., 2009).

Drowsiness can be used as a criterion for determining driver's fatigue and is more a symptom than a construct on itself (e.g. feeling drowsy due to fatigue, boredom, hunger, etc.) (Eoh et al., 2005). Fatigue can lead to drowsiness and sleepiness and is thus an important construct (Eoh et al., 2005).

Arnedt et al. (2001) compare fatigue with alcohol, making it a factor that impairs functioning at the level of the central nervous system, which can similarly jeopardize the safety of both the fatigued driver as well as others on the road.

2.1.1.2 Main types of fatigue

Fatigue can be broadly subcategorized based on the causal factors contributing to the fatigued state. This subcategorization regards sleep-related (SR) and task-related (TR) fatigue (May & Baldwin, 2009), but also endogenous and exogenous factors (Thiffault & Bergeron, 2003).

Sleep-related factors (e.g. sleep deprivation, extended duration of wakefulness, time of day, etc.) affect SR fatigue, while certain characteristics of a task (e.g. task demand, task duration, etc.) can induce TR fatigue in the absence of any sleep-related cause (May & Baldwin, 2009). Furthermore, task-related fatigue can be divided into active fatigue (i.e. performing a task that requires continuous and prolonged attention, which corresponds to mental overload) and passive fatigue (i.e. which develops in a monitoring task with only moderate levels of attention, which corresponds to mental underload) (May & Baldwin, 2009; Schmidt et al., 2009).

Regarding endogenous and exogenous factors, it can be stated that they interact continuously and that their joint influence determines fatigue. The main endogenous factors are related to factors within the organism (e.g. circadian variations associated with the time of day, fatigue generated with the duration of the task, sleep-related problems, etc.) and are associated with tonic variations of physiological activation. While exogenous factors are factors that define the task, resulting in an impact on performance by affecting arousal, alertness, and information processing. The latter, often being task-induced factors, stem from the interaction between the individual with the environment. (Thiffault & Bergeron, 2003).

2.1.2 Causes of fatigue

Multiple factors are causally associated with fatigue (Eoh et al., 2005; May & Baldwin, 2009; Smolensky et al., 2011; A. Williamson et al., 2011). As A. Williamson et al. (2011) determined by their research, do the causes that relate to fatigue comprise out of circadian factors, homeostatic factors (subdivided into sleep restriction/deprivation and sleep disorders), and-task related factors (subdivided into time-on-task factors and workload related factors). This has also been discussed in other studies (Chin-Teng Lin et al., 2005; May & Baldwin, 2009; Pack et al., 1995; Smolensky et al., 2011; Stutts et al., 2003; Thiffault & Bergeron, 2003; Ting et al., 2008). Further, are personal characteristics playing an important role as well (Otmani et al., 2005).

2.1.2.1 Circadian factors

The circadian factor can be seen as the circadian rhythm, which means the 24-hour physiological circadian rhythm, or time-of-day effect (May & Baldwin, 2009; Thiffault & Bergeron, 2003; A. Williamson et al., 2011). Sleep/wake patterns follow the body's natural internal clock, which drives humans to sleep during the night and be awake during the day, even in non-fatigued persons. Sleepiness and thus also fatigue is subjected to diurnal variation, which occurs at two particular periods of the day. This during the night (i.e. time of normal sleep), but also in the early afternoon (i.e. siesta time) roughly at respectively 2:00 - 6:00 a.m. and 1:00 - 4:00 p.m. throughout the day. It is thus controlled by a circadian pacemaker and by the process of sleep homeostasis. This can be shown by measuring the physiological tendency to sleep, as the latency to sleep in brief naps and performance decrements are evident during low activity levels in the circadian rhythm (May & Baldwin, 2009; Otmani et al., 2005; Pack et al., 1995; A. Williamson et al., 2011).

2.1.2.2 Homeostatic factors

Next to circadian factors, sleep is determined by homeostatic factors (i.e. factors that regulate physiological variables, to keep sleep nearly constant over time) (Deboer, 2018). Homeostatic factors can thus be seen as sleep-related factors, such as sleep deprivation, sleep restriction, extended time awake, sleep disorders, etc. (Pack et al., 1995; Thiffault & Bergeron, 2003).

Sleep deprivation can be described as the cumulation of inadequate sleep, resulting in sleep dept and thus also fatigue and sleepiness (Pack et al., 1995; Smolensky et al., 2011). Sleep restriction is typified by short-sleep duration and poor night sleep, in which the amount of sleep gets restricted for various reasons. Most of the time increasing sleep pressure, generating cumulative sleepiness and thus sleep deprivation (Philip, Sagaspe, Moore, et al., 2005). It is known to impair neurobehavioural functioning and increasing daytime fatigue (Philip, Sagaspe, Taillard, et al., 2005; Smolensky et al., 2011). Extend time awake, typified as a long time awake between two sleep episodes, has the same impact as sleep restriction and is often a result of sleep restriction or sleep deprivation (Philip, Sagaspe, Taillard, et al., 2005). However, Smolensky et al. (2011) mentioned that consistently sleeping more than 9 hours per night has been associated with the identical complaints, perhaps secondary to underlying sleep, organic, and/or psychiatric disorders.

Sleep disorders are medical conditions that directly or indirectly affect the quality and quantity of one’s sleep, which can cause excessive daytime fatigue (Smolensky et al., 2011). These sleep disorders can be diagnosed, undiagnosed, treated, or untreated (Stutts et al., 2003). The most common sleep disorders correlated with fatigue are insomnia, sleep apnea syndrome, narcolepsy, and periodic limb movement disorders (Pack et al., 1995; Smolensky et al., 2011).

Lastly, can chronic medical conditions directly or indirectly affect the quality of one’s sleep and cause excessive daytime fatigue. Those chronic medical conditions can be seen as non-primary sleep disorders, which are medical conditions that are not classified as sleep disorders, but can affect someone’s sleep (e.g. alcoholism, asthma, cancer, diabetes, head trauma, migraine, etc.) (Smolensky et al., 2011).

2.1.2.3 Task-related factors

An import task-related factor is time-on-task, which is known to produce fatigue and deterioration of performance (Thiffault & Bergeron, 2003). It can be defined in various ways, often referred to as time on duty, time into the work shift, driving time, etc. and is considered to induce fatigue. It is often examined as a surrogate exposure measure in evaluating the association with “accident” and injury risk in industrial and occupational settings. Injuries and accidents related to the time-on-task effect are most frequently reported to peak in the first half of the workday with a second peak occurring after prolonged work (A. Williamson et al., 2011).

Besides the time-on-task effect, workload related factors also play a role in fatigue, despite the limited evidence that it can affect safety (A. Williamson et al., 2011). Examples are shift duration, work hours per week, shift start time, mental/physical workload, job monotony, commute time, prolonged sitting, high work pressure, etc. (Garbarino et al., 2016, 2017; Guglielmi et al., 2018; Smolensky et al., 2011). Further does the nature of certain work tasks, such as monotony, boredom, and lack of stimulation, contribute to physical and mental fatigue as well (A. Williamson et al., 2011). It is often seen that these workload related factors play a role within night or rotating shift workers (Stutts et al., 2003).

2.1.2.4 Personal characteristics

Individual or personal characteristics can play an important role as well in fatigue (Otmani et al., 2005). Factors like obesity, a high blood pressure, smoking, drinking, insufficient exercise, etc. are factors that can lead to sleep disorders or fatigue (Catarino et al., 2014; Chen et al., 2016; Garbarino et al., 2017; Guglielmi et al., 2018). Also, does the usage of medications result in fatigue (Stutts et al., 2003).

2.1.3 Subdivision of the types and causes

As described before, numerous types of fatigue are possible (i.e. SR-fatigue, TR-fatigue active, TR-fatigue passive) that can have multiple endogenous and exogenous factors. It is therefore important to make a distinction, to make clear where different factors can be situated. The own interpretation of the concepts is displayed in table 1.

TABLE 1: Own interpretation of the possible subdivision per type and cause of fatigue

SR-fatigue		**TR-fatigue**	
Endogenous	Exogenous	Endogenous	Exogenous
Circadian rhythm Sleep deprivation Sleep restriction Extended time awake Sleep disorders Medical conditions Personal characteristics	Sleep deprivation Sleep restriction Extended time awake Personal characteristics	Time on task	Task workload

Sleep deprivation, sleep restriction, extended time awake, and personal characteristics can be classified within both SR-fatigue categories, because these are factors associated within the individual (e.g. sleep deprivation due to insomnia resulting from fear, sleep restriction due to the fact a person doesn't want to drive at dusk and therefore shortens afternoon rest, extended time awake because a person does not feel fatigued, or a personal characteristic like low blood pressure resulting in fatigue) as well as outside the individual (e.g. sleep deprivation due to insomnia resulting from the stress of high demanding tasks, sleep restriction because a person wants to get the job done within the foreseen time, extended time awake due to a long important phone call, or a personal characteristic like insufficient exercise due to the lack of training facilities at disposal of the person). In contrast with the circadian rhythm, sleep disorders and medical conditions which drive sleep and fatigue without the influence of factors outside the individual, therefore relating to only endogenous factors

Time on task is situated within endogenous TR-fatigue because it is associated with tonic variations of physiological activation related to the task. While task workload influences arousal, alertness, and information processing due to the creation of mental under or overload resulted from the task, leading to categorization within exogenous TR-fatigue.

2.1.4 The effects of fatigue

Fatigue has different negative effects, including one that can, on its own, directly result in a dangerous situation due to the strong propensity to rest or sleep. Namely the occurrence of sleepiness and microsleep episodes (Otmani et al., 2005; Pack et al., 1995).

On the other hand, does it also result in less severe effects. Where, in combination with other factors, dangerous situations can arise. Those effects are a longer reaction time, vigilance reduction (including nonresponses or responding with a delay where performance on attention-demanding tasks declines with fatigue), deficits in information processing (which may reduce the accuracy and correctness in decision-making) and performance lapses (Chin-Teng Lin et al., 2005; Pack et al., 1995; Schmidt et al., 2009; Thiffault & Bergeron, 2003; A. Williamson et al., 2011).

Further, fatigue produces symptoms like 'sore feet', 'tired eyes', and 'feeling drowsy', which can be seen as subjective factors to recognize if someone gets fatigued (Nilsson et al., 1997).

2.1.5 Arousal versus activation

Other concepts that tend to be misinterpreted are the concepts of activation and arousal, which can both influence fatigue. Activation can be described as the tonic maintenance of alertness over long periods of time, while arousal rather refers to short-acting, task-induced changes (Thiffault & Bergeron, 2003).

2.2 Translating the concept into traffic safety for professional drivers

Apart from the more abstract description of fatigue and its effects, is it also useful to review the concept in the context of traffic safety, and more important in the context of professional truck drivers.

2.2.1 The causes

Arnold et al. (1997) mentioned different contributors to fatigue, through questioning professional drivers. Contributors that were often mentioned comprised out of long driving hours, a lack of sleep, inexperience, loading the truck, and delays in loading.

Clearly, this is a concise and highly specific listing of causes, given the aspects that were discussed in the previous section. Because of this, the different contributing factors from 2.1.2, are discussed hereafter, applied to the concept of traffic safety for professional drivers.

2.2.1.1 Circadian rhythm

Circadian factors play a role in drowsy driving crashes once exposure is controlled or corrected for. The human body is programmed for sleep during the night-time sleep period and again 12 hours later. This cyclic pattern of wakefulness has been discovered in time of day plots for drowsy driving crashes as well as in other fields of interest. Crashes attributable to the driver falling asleep follows this natural circadian variation in sleepiness, which results in a substantial increase in the risk of having a crash at times when a person would normally be asleep (McCartt et al., 2000; Stutts et al., 2003; A. Williamson et al., 2011).

The large proportion of fatigue-related crashes occur predominantly at night, between 11 p.m. and 7 a.m., which can be seen as the time that most people are asleep (Arnedt et al., 2001; Chin-Teng Lin et al., 2005; Smolensky et al., 2011). Another large portion of fatigue-related crashes occurs in the mid-afternoon, between 1 p.m. and 5 p.m., often seen as the post-lunch dip (Arnedt et al., 2001; Chin-Teng Lin et al., 2005; Pack et al., 1995; Smolensky et al., 2011). This in contrast with alcohol-related crashes, where an increase in the hourly frequency of crashes from noon until midnight is seen, with no mid-afternoon peak (Pack et al., 1995).

2.2.1.2 Homeostatic factors

Regarding the homeostatic factor sleep deprivation, it is known that sleep deprivation plays an important role in fatigue and car crashes, because it increases levels of fatigue and the risk of errors (Eoh et al., 2005; Pack et al., 1995; Philip, Sagaspe, Moore, et al., 2005; Ting et al., 2008; A. Williamson et al., 2011). Sleep deprivation is closely related to the quantity and quality of sleep because this determines if a person develops a sleep deficit. More specific are factors like averaging less than 6 hours sleep per night, poorer overall quality of sleep and driving after sleeping less than 5 hours the night before important factors related to sleep deprivation, which increase a driver’s risk for involvement in a sleep-related motor vehicle crash (Stutts et al., 2003) and fatigue in truck drivers (McCartt et al., 2000). The underlying cause of why a person can be sleep deprived is, from own interpretation, likely various (e.g. stress leading to short night sleep, sleep restriction, sleep disorders, etc.).

As mentioned before is sleep restriction related to sleep deprivation, as multiple short sleep episodes can result in a sleep deficit. This homeostatic factor has also been reviewed as an important risk factor for fatigue-related crashes with cars and trucks. Sleep restriction can be seen as a shorter sleep period than a person normally would have had, but can also occur due to split sleep patterns (A. Williamson et al., 2011). As Arnold et al. (1997) found in a large survey of Australian truck drivers, reported 20% of drivers who had less than 6 hours of sleep before their journey, 40% of hazardous events. Furthermore, Hanowski et al. (2007), cited in (A. Williamson et al., 2011), confirmed the importance of sleep restriction in commercial vehicle drivers, through a reduction in sleep hours compared with usual sleep in the period preceding safety-relevant critical incidents under normal driving conditions. Further, is it important to note that drivers with regular sleep/work patterns can develop fatigue while on the job, while drivers with irregular sleep patterns arrive at work already fatigued (A. Williamson et al., 2011).

Regarding extend time awake, which can be seen as the time that has passed since waking (A. Williamson et al., 2011), Arnedt et al. (2001) found that after 19 hours of sustained wakefulness, driving performance deteriorated. This to a level that corresponds to a BAC (blood alcohol content) of 0.05%. After 24 hours of being awake, performance deterioration was similar to a BAC of 0.10%. This shows that the extended time awake plays an important role as well in fatigue-related crashes, due to the homeostatic drive to sleep (A. Williamson et al., 2011). Especially when the legal alcohol limit for professional truck drivers, where fatigue can be compared to in terms of performance deterioration, is more strictly set in Belgium on a BAC-limit of 0.2 per mil.

Moreover, the influence of sleep disorders on fatigue and safety outcomes, in terms of traffic safety, has also been studied. Sleep disorders can disrupt the quantity and quality of sleep, leading to chronic or acute sleep loss (A. Williamson et al., 2011). Smolensky et al. (2011) found that respondents who reported sleeping poorly at night were likely to feel tired, perform inefficiently, and drive drowsy during the daytime, which can be caused by a sleep disorder. Examples of sleep disorders that are associated with car crashes are narcolepsy, obstructive sleep apnea syndrome (OSAS), insomnia, hypersomnia, etc. (McCartt et al., 2000; Pack et al., 1995; Smolensky et al., 2011). These disorders are caused by different factors, such as prolonged and irregular hours typical for road transport, living style, health condition, etc. (Häkkänen & Summala, 2001; A. M. Williamson et al., 1996).

Lastly, the influence of medical conditions (not classified as sleep disorders) plays a role in traffic safety as well. Acute and chronic medical conditions have the potential to directly or indirectly affect the quality and quantity of night-time sleep, daytime alertness, or the energy level, therefore increasing the risk of fatigue-related crashes. These medical conditions include asthma, chronic fatigue syndrome, obesity, diabetes, respiratory failure, etc. (Häkkänen & Summala, 2001; Smolensky et al., 2011).

2.2.1.3 Task-related factors

Among the task-related factors is time-on-task a well-known fatigue factor that under typical driving conditions can affect driver safety. It occurs when driving requires sustained attention over long periods of time, impacting the psychophysiology of the driver (Ting et al., 2008). Time-on-task differs from the task that is being performed but refers to the duration of the task, often leading to fatigue in truck drivers and falling asleep at the wheel (McCartt et al., 2000). Examples are the duration of continuous driving, long driving hours, the number and pattern of hours worked, hours that a task was performed off-duty, trip length, etc. (Chin-Teng Lin et al., 2005; Eoh et al., 2005; McCartt et al., 2000; Sagberg, 1999; Stutts et al., 2003).

Workload related factors revolve around the task itself and can be diverse. Monotony, in terms of the task itself or the driving environment, plays here a big factor that results in fatigue, due to the lack of stimulation, therefore resulting in fatigue and possibly a crash. A situation is monotonous when the stimuli remain unchanged or when those stimuli change in a predictable manner, where driving in monotonous situations can be viewed as a vigilance task (i.e. "the ability to sustain attention to a task for a period of time" (Schmidt et al., 2009)). Psychological reactions to monotony consist of feelings off drowsiness and boredom, a loss of interest in performing the task, stress, etc. which can result into highway hypnosis (i.e. the loss of conscious awareness that can result from the monotony of a long stretch of roadway) and fatigue (Chin-Teng Lin et al., 2005; Sagberg, 1999; Thiffault & Bergeron, 2003; Ting et al., 2008; A. M. Williamson et al., 1996). Other workload related factors are tasks which require sustained attention, work quotas that need to be met, a busy driving environment, holding multiple jobs, working night shifts, etc. (Eoh et al., 2005; McCartt et al., 2000; Stutts et al., 2003; Thiffault & Bergeron, 2003; A. M. Williamson et al., 1996).

2.2.1.4 Personal characteristics

Another important cause of driver's fatigue concerns personal characteristics (Eoh et al., 2005). This is a broad concept that refers to the lifestyle and life choices of the driver, because it relates to the use of medication, consumption of alcohol, smoking, being overweight, being unaware of high blood pressure, insufficient exercise, gender, age, etc. These factors can induce fatigue and cause fatigue-related crashes but have the potential to result in the development of potential sleep disorders and medical conditions, which were already proven to affect drivers fatigue (Catarino et al., 2014; Chen et al., 2016; Chin-Teng Lin et al., 2005; Garbarino et al., 2017; Guglielmi et al., 2018; Häkkänen & Summala, 2001).

2.2.2 The effects of fatigue

There is a link between the causes of fatigue and performance outcomes, which can be seen as different changes within the individual (A. Williamson et al., 2011). These different changes that occur within fatigued individuals can have different effects, which potentially lead to dangerous consequences. These consequences will depend on the environment that a person is in, of which driving is perhaps the most dangerous environment (Pack et al., 1995).

An aspect that is associated with fatigue, which can be seen as an effect of accumulating fatigue, is daytime sleepiness. This relates to sleepiness because it is a state wherein staying awake throughout the day becomes difficult, even when a person is not driving (e.g. still being fatigued or sleepy after a weekend) (McCartt et al., 2000; Stutts et al., 2003). This excessive daytime fatigue/sleepiness is an important factor for road crashes, of which nodding of crashes is the most common (Smolensky et al., 2011; Stutts et al., 2003).

As discussed before, driving under influence does cause effects, such as a longer reaction time, vigilance reduction, deficits in information processing and performance lapses (Chin-Teng Lin et al., 2005; Pack et al., 1995; Schmidt et al., 2009; Thiffault & Bergeron, 2003; A. Williamson et al., 2011).

Longer reaction time can potentially lead to a higher crash risk, particularly at high speeds (e.g. being able to brake quickly if a pedestrian steps out on the road) (Chin-Teng Lin et al., 2005; Jackson et al., 2013). Furthermore, vigilance decrement is a problem (Chin-Teng Lin et al., 2005), because vigilance will designate the ability to maintain sustained attention within the road environment. It is a robust effect of fatigue and sleepiness that has a part in road crashes, due to this loss of attention (e.g. not noticing lane drifting on a monotonous road when driving fatigued) (Jackson et al., 2013; Thiffault & Bergeron, 2003). Another effect of fatigue lies in information processing, which may reduce the accuracy and correctness in decision-making (Chin-Teng Lin et al., 2005). This can lead to performance lapses or a loss in alertness, which potentially results in a crash. (e.g. due to fatigue, forgetting to take an exit on a highway and making a brisk last-minute manoeuvre to the exit) (Pack et al., 1995; Thiffault & Bergeron, 2003). Lastly, do fatigued drivers have difficulties focusing on driving, and do they tend to commit manipulation errors. This is a consequence of the decrease in information processing speed and memory capacity, which leads to a drastic change in task performance (Wylie et al., as cited in Eoh et al., 2005). These performance lapses can potentially result in a crash (e.g. crashing into the back of a traffic jam, due to a loss of focus) (Pack et al., 1995).

Häkkänen & Summala (2001) investigated the type of accident that was most common in truck drivers. It was found that head-on collisions were the most usual accident type, followed by crashes on the same driving course. Not all of these crashes are related to fatigue, but it can play a role in these crashes. It has been shown that impaired daytime alertness, due to fatigue, causes an increase in lateral deviations during real driving, possibly leading to the head-on collisions (Philip, Sagaspe, Taillard, et al., 2005; A. M. Williamson et al., 1996). Further is the ability to keep speed constant also a fatigue-related impairment, which can explain the crashes in the same driving course (A. M. Williamson et al., 1996). Pack et al. (1995) also found that drive-off-the-road crashes are more common in fatigue-related crashes, since drivers fall asleep, making them unable to correct the driving course.

Important to note is the fact that fatigue or sleepiness, even in the absence of frankly being asleep, degrades the previously explained factors. Thus, there may be many more crashes in which sleepiness plays a role than described. This because fatigue, as a contributor, remains hard to determine in crashes (Pack et al., 1995). As found by Häkkänen & Summala (2001), big crash causations in truck drivers were errors in attention, anticipation or estimation, and errors in operating the vehicle, while crashes with drivers who had fallen asleep were less common. Given the knowledge of the impairments that are likely caused by fatigue, it becomes clear that the crashes due to errors could also have been a result of fatigue, but that these were not classified by it. This corresponds to the finding of (Pack et al., 1995) regarding the underestimation of fatigue-related crashes.

2.2.3 Measuring fatigue

Multiple methods to measure fatigue have been studied throughout the years. According to Chin-Teng Lin et al. (2005) these methods can be categorised into two major categories. One category focuses on the detection of physical changes during drowsiness in drivers by image processing techniques (e.g. average of eye-closure speed, percentage of eye-closure over time, eye tracking as quantization of drowsiness level, driver’s head movements, etc.). The other category consists out of other methods, which focus on measuring physiological changes of drivers as a means of detecting the human cognitive state (e.g. heart-rate variability (HRV), electrooculographic (EOG), electroencephalogram (EEG)).

In contrast with Chin-Teng Lin et al. (2005), A. Williamson et al. (2011) discuss multiple methods to measure fatigue. These measures are (1) model-based indices of fatigue or sleepiness, (2) direct observation, (3) self-reported fatigue or sleepiness, and (4) in-depth crash investigations. These methods can be used individually to measure the level of fatigue but can also be combined to improve the validity and reliability of the measurement. It is possible for certain methods, to place them in the two categories as discussed in the previous paragraph, but not for all four methods which will be discussed hereafter.

2.2.3.1 Model-based indices

Another measure that can be used to determine fatigue are model-based predictors. The inputs for the model are data on both homeostatic and circadian factors. These include the "Sleep-Wake Predictor", which is associated with a significantly increased risk of serious injury car crashes. This models the level of sleepiness based on hours of sleep, time since waking, and time-of-day (A. Williamson et al., 2011). The level of sleepiness will thus be modelled and not measured, making it difficult to bring this measure back to the two major categories of Chin-Teng Lin et al. (2005).

2.2.3.2 Direct observation

Direct observation can also be used to determine fatigue. These observational studies have many different parameters to measure fatigue, within naturalistic driving studies and simulator studies. These can be combined or used alone (Eoh et al., 2005; Philip, Sagaspe, Taillard, et al., 2005; Sagberg, 1999; A. Williamson et al., 2011; A. M. Williamson et al., 1996). Depending on the measure that is being used, they can be classified under the two main categories of Chin-Teng Lin et al. (2005).

Physical changes that can be directly observed, can be detected via simulator studies and field studies. For field studies, video and other in-vehicle technologies have made it possible to conduct naturalistic driving data. For driving simulator studies, measures like video, driving simulator parameters, and impairment parameters can be used. Both allow for a more direct assessment of the relative risk associated with various levels of driving behaviour and performance (A. Williamson et al., 2011).

Within these physical changes, eye-related measures are very reliable in detecting fatigue (X. Wang & Xu, 2016). Measures like increases in eye blink rates, increasing eye blink durations, decreases in blink amplitude, pupil diameter and percentage of eyelid closure (PERCLOS) have already been able to indicate fatigue (Chin-Teng Lin et al., 2005; Howard et al., 2014; Nilsson et al., 1997; X. Wang & Xu, 2016). On the other hand is nodding also off a physical measure that can be used to determine fatigue (Arnold et al., 1997; May & Baldwin, 2009; A. Williamson et al., 2011).

Driving simulator parameters can also be seen as measures for physical changes. This because higher SDLP (Standard Deviation of the Lateral Position), steering wheel movement (SWM) related measures (e.g. mean amplitude of steering wheel movements, frequency of larger steering wheel movements, mean steering wheel angle, etc.), reaction time, average headway, and speed-related measures (e.g. mean speed, deviations of speed, etc.) are able to indicate fatigue (Arnedt et al., 2001; Forsman et al., 2013; Howard et al., 2014; Ingre et al., 2006; Liu et al., 2009; May & Baldwin, 2009; Otmani et al., 2005; Philip, Sagaspe, Taillard, et al., 2005; Thiffault & Bergeron, 2003; Ting et al., 2008; X. Wang & Xu, 2016). The same can be said for impairment measures like running off the road and the number of road line crossings (Liu et al., 2009; Otmani et al., 2005; Philip, Sagaspe, Taillard, et al., 2005; Ting et al., 2008). Most of these measures can hereby also be detected in real-driving scenario's (Philip, Sagaspe, Taillard, et al., 2005).

On the other hand, measures of physiological arousal, such as heart rate, brain activity, retinal activity, etc. are able to provide evidence for the development of fatigue (Eoh et al., 2005; A. M. Williamson et al., 1996). These measures can be captured by electroencephalogram (EEG), electrooculogram (EOG), electrocardiogram (ECG), blood pressure, etc. to get insight in the relation between fatigue and physiological arousal (Eoh et al., 2005). Typically, heart rate has been found by A. M. Williamson et al. (1996) to slow with fatigue and prolonged driving, with increasingly variable time between heartbeats.

Although driving simulator studies are widely used for studying fatigue, there are a couple of disadvantages. These rely on the fact that laboratory and simulator studies are more vulnerable to fatigue effects since real-life circumstances involve more stimulation. Further, are the consequences of performance decrements not the same as in the real world, leading to certain thoughts that the implications of performing poorly are not as great as in the real world. This could explain why performance decrements are found more often in simulator studies than in the field (A. Williamson et al., 2011), which can also be related to the relative validity of driving simulators (Kaptein et al., 1996).

2.2.3.3 Self-reported fatigue or sleepiness

Self-reported measures of fatigue or sleepiness are based on the person's perception of fatigue. This self-reported approach cannot be placed between the two categories from Chin-Teng Lin et al. (2005), because it relies on self-recognition and not on objective measures. Measuring self-reported fatigue can be done through questioning. However, there is a possibility that individuals have different abilities to recognize fatigue and that a bias occurs if a person over or underestimates the level of fatigue. To deal with this, questionnaires are developed to decrease the chance of a bias, while still questioning fatigue in a self-reported manner (A. Williamson et al., 2011). Three questionnaires will be discussed in this section and comprise out of the Karolinska Sleepiness Scale (KSS), Epworth Sleepiness Scale (ESS), and Fatigue Assessment Scale (FAS).

The KSS is frequently used for the evaluation of subjective sleepiness and was originally developed to constitute a one-dimensional scale of sleepiness (Kaida et al., 2006). It was validated against alpha and theta EEG activity as well as slow eye movement, longer blink durations, EOG activity, and driving performance measures. It has been widely used and provides reasonable results in studies of shift work, driving abilities, jet lag, attention, performance and clinical settings, including driving simulator sessions and field study experiments (Ingre et al., 2006; Kaida et al., 2006; Philip, Sagaspe, Taillard, et al., 2005).

The KSS is an answering scale for the determination of sleepiness. The scale ranges from 1 to 9 on which the respondent can rate the level of sleepiness at the moment of questioning (Ingre et al., 2006). The scale is hereby displayed in table 2. Studies show, that serious behavioural and physiological changes do not occur until a relatively high level of sleepiness is reached (i.e. KSS-score 7) (Ingre et al., 2006). These higher sleepiness scores are often seen in driving simulator studies and sleep-restricted conditions since the experiment is safer to perform in a simulator (Philip, Sagaspe, Taillard, et al., 2005).

TABLE 2: KSS answering scale (Åkerstedt et al., 2014)

Score	Corresponding feelings
1	Extremely alert
2	Very alert
3	Alert
4	Rather alert
5	Neither alert nor sleepy
6	Some signs of sleepiness
7	Sleepy, but no effort to keep awake
8	Sleepy, some effort to keep awake
9	Very sleepy, great effort to keep awake, fighting sleep

Secondly, the ESS is a questionnaire that measures the daytime sleepiness of the respondent. It asks the respondent to rate on a 4-point scale, ranging from 0-3, what the usual chance of dozing off or falling asleep is. This with the help of eight predetermined different activities such as “the chance of dozing while watching tv”, or “the chance of dozing while sitting in a car, when traffic stopped for a few minutes” (Johns, 1991). The ESS has a high reliability and internal consistency. This because the scores didn’t change when the same respondents were tested twice, within a couple of months period difference. But for people who went on therapy for sleep disorders, the scores did change in a positive manner, which can be explained due to the fact that they went on therapy (Johns, 1992).

The ESS item-scores provide an estimate of the eight different SSPs (Situation Sleep Propensities) for that person. The total score (i.e. summation of the 8 item-scores) gives an estimate of a more general characteristic, which is being considered as the person’s ‘average sleep propensity’ (ASP), across a wide range of activities in their daily lives. The ESS scores have the following total subdivision: (0-5) lower normal daytime sleepiness, (6-10) higher normal daytime sleepiness, (11-12) mild excessive daytime sleepiness, (13-15) moderate excessive daytime sleepiness and (16-24) severe excessive daytime sleepiness. These subdivisions can be merged into the two categories ‘normal’ (i.e. ESS-score 0-10) and ‘sleepiness too high’ (i.e. ESS-score 11-24) (Johns, 1991). The questionnaire is displayed in figure 1.

THE EPWORTH SLEEPINESS SCALE

Name: ______________________________

Today's date: ______________ Your age (years): ________

Your sex (male = M; female = F): ______________

How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently try to work out how they would have affected you. Use the following scale to choose the *most appropriate number* for each situation:

0 = would *never* doze
1 = *slight* chance of dozing
2 = *moderate* change of dozing
3 = *high* chance of dozing

Situation	**Chance of dozing**
Sitting and reading	________
Watching TV	________
Sitting, inactive in a public place (e.g. a theater or a meeting)	________
As a passenger in a car for an hour without a break	________
Lying down to rest in the afternoon when circumstances permit	________
Sitting and talking to someone	________
Sitting quietly after a lunch without alcohol	________
In a car, while stopped for a few minutes in the traffic	________

Thank you for your cooperation

FIGURE 1: Original ESS-questionnaire (Johns, 1991)

Lastly, the FAS is a 10-item fatigue scale that determines fatigue within respondents, based on semantic and empirical considerations. The FAS, which is a measure of chronic fatigue, was developed with the use of 4 commonly used fatigue questionnaires, including the Fatigue Scale (FS), the Checklist Individual Strength (CIS), the Emotional Exhaustion (EE) subscale of the Dutch version of the Maslach Burnout Inventory (MBI-NL) and the Energy and Fatigue subscale of the World Health Organization Quality of Life assessment instrument (WHOQOL-EF). Off these questionnaires has the FAS shown a high internal consistency and strong correlation with the other fatigue scales, with the highest factor loading on the single factor fatigue. Thus being a good measure of fatigue (Michielsen et al., 2003). Moreover, the factor analyses of follow-up research has revealed that depression and emotional stability are separate constructs, which are not being measured by the questionnaire. Also, did it show that 8 out of the 10 FAS-items were unbiased concerning gender (Michielsen et al., 2004).

The unidimensional FAS consists out of 10 items and 5 answering categories, ranging from (1) never to (2) sometimes, (3) regularly, (4) often and (5) always, of which the scores on question 4 and 10 should be recoded (i.e. 1=5, 2=4, 3=3, 4=2, 5=1) (Michielsen et al., 2003). The total FAS score can be calculated by summing the scores on all questions, including the recoded scores for questions 4 and 10, which can indicate fatigue. A total score ranging from 10 to 21 states that there is no fatigue (normal). A score ranging from 22 to 50 states that there is substantial fatigue with a subdivision in scores leading to two subgroups. Scores ranging from 22 to 34 give an indication of fatigue, while scores ranging from 35 to 50 give an indication of extreme fatigue (Vries et al., 2004). The questionnaire is displayed in figure 2.

	Never	Sometimes	Regularly	Often	Always
1. I am bothered by fatigue (WHOQOL)	1	2	3	4	5
2. I get tired very quickly (CIS)	1	2	3	4	5
3. I don't do much during the day (CIS)	1	2	3	4	5
4. I have enough energy for everyday life (WHOQOL)	1	2	3	4	5
5. Physically, I feel exhausted (CIS)	1	2	3	4	5
6. I have problems starting things (FS)	1	2	3	4	5
7. I have problems thinking clearly (FS)	1	2	3	4	5
8. I feel no desire to do anything (CIS)	1	2	3	4	5
9. Mentally, I feel exhausted	1	2	3	4	5
10. When I am doing something, I can concentrate quite well (CIS)	1	2	3	4	5

Note. Between brackets, the questionnaire is given from which the item is taken.
WHOQOL = World Health Organization Quality of Life assessment instrument; CIS = Checklist Individual Strength; FS = Fatigue Scale.
Items 4 and 10 require reversed scoring. The scale score is calculated by summing all items.

FIGURE 2: The Fatigue Assessment Scale (Michielsen et al., 2003)

The difference between the questionnaires mentioned above lays in the type of fatigue that it is measuring. The KSS is a questionnaire that measures acute sleepiness, while the ESS and FAS both measure chronic (daytime) sleepiness. In driver studies, the KSS and ESS have often been used, in contrast with the FAS. But the association of the ESS with crash risk has been inconsistent. Although descriptive studies have found a positive association between the ESS and the risk of a crash in car drivers and truck drivers (A. Williamson et al., 2011).

Given the literature about the questionnaires discussed above, it can thus be concluded that the KSS can be used to measure fatigue at the very moment, whether or not performing a task, while the ESS and FAS, on the other hand, can be used to determine if a person suffers from fatigue or sleepiness. The latter will make it able to determine if a person has a basic level of fatigue due to potential sleep-related disorders, while the KSS helps to determine baseline fatigue and fatigue levels at certain predetermined moments.

2.2.3.4 In-depth crash investigations

In-depth crash investigations represent another research possibility to determine driver fatigue. It is based on a consensus of factors and circumstances that resulted in a particular crash. Standard police reports give little information about the crash, which makes it difficult to determine the role of fatigue in the accident. In-depth crash investigations gather a bigger amount of reliable data to analyse, making it more plausible to determine the effect of fatigue in the crash (A. Williamson et al., 2011). Although it is still possible to oversee the effect of fatigue due to similar-looking factors, leading to underestimation of fatigue-related crashes (Pack et al., 1995). This measure cannot be brought back to the two main categories of Chin-Teng Lin et al. (2005), because the role of fatigue gets determined post-crash.

2.2.4 Countermeasures for fatigue

Different countermeasures to combat fatigue or make drivers aware of their fatigued state are studied over time. This leads to effective countermeasures and the disproval of made up countermeasures.

2.2.4.1 Man-made solutions

Made up strategies that were often used by drivers to combat fatigue were drinking caffeine beverages, smoking, eating candy, taking pills or drugs, drinking alcohol, putting on the air-conditioning, etc. (Arnold et al., 1997). Out of these made up countermeasures, only caffeine was proven to produce a reduction in driver fatigue (May & Baldwin, 2009). Slow-release caffeine can have an important role in combating driver fatigue over long trips, especially if circumstances do not allow taking a nap (Liu et al., 2009). Although this countermeasure is not assessing the problem.

Obviously, it is better to take countermeasures, which lie in the cause of fatigue. Long hours, time of day, sleep-related problems, etc. are thus not only seen as major contributors to fatigue, but also as potential countermeasures to prevent fatigue-related crashes (Thiffault & Bergeron, 2003). Pulling over when tired, having a good night's sleep, staying fit and healthy, sleeping regular hours, etc. is thus a better option to counter for and get rid of fatigue (Arnold et al., 1997). However, the problem lies in the fact that this relies on the unreliable self-assessment of fatigue and that most of these factors (e.g. pulling over, good night's sleep, staying fit, etc.) are unable for the drivers (Arnold et al., 1997; A. Williamson et al., 2011).

2.2.4.2 Technology

To combat this, technological aids for detecting driver fatigue are being developed. These technological devices try to measure fatigue objectively, to prevent crashes from happening (May & Baldwin, 2009). Well-known examples are displayed in table 3.

TABLE 3: Examples of technology to detect and combat fatigue (May & Baldwin, 2009)

Detection and warning technology	
Eye closure technology	Technology where PERCLOS is determined to detect fatigue.
Head nodding technology	Technology to determine fatigue, based on the head-nodding behaviour of the driver. This can be seen as a late alert system because the driver potentially already fell asleep.
Deadman switch technology	Technology where a button constantly needs to be pressed, but when released due to falling asleep, it determines that something happened with the driver. This can also be seen as a late alert system because the driver already fell asleep.
Crash prevention technology	
Roadway designs	Adaptation to the roadway design (e.g. Transversal Rumble Strips).
Lane departure warning systems	Warning system which alerts the driver if he/she is leaving the lane unintentionally.
Collision avoidance system warnings	System that warns the driver when a crash is imminent.

According to (May & Baldwin, 2009), no attention has been given to differentiating technology by subcategorizing driver fatigue based on the causal factors of the fatigue as discussed before (i.e. TR and SR fatigue). They state that certain detection technologies may be helpful in determining both types of fatigue, but that technologies aimed at increasing alertness may only be suitable for countering TR fatigue. In addition, they state that it is critical to also distinguish between active and passive fatigue. Because adding a task for the driver (e.g. reaction time task), could improve performance during passive fatigue. They further state that classifying driver fatigue into SR and TR (active and passive) categories, will lead to improved development and implementation of fatigue countermeasures.

TR active fatigue resulting from a high task load driving condition, which requires sustained attention and prolonged driving, can benefit from increased automation and in-vehicle technologies to lower the workload on the driver. On the other hand, is further automation of the driving task going to aggravate TR passive fatigue caused by monotonous conditions and highly familiar roadways. Thus, a driver suffering from TR passive fatigue can benefit from a driving task that is more demanding, through interactive technologies, although it is important not to get distracted by the second task (May & Baldwin, 2009). However, comes SR fatigue from homeostatic related factors, which are more difficult to counter with TR-measures. Only naps or sleep will produce a reduction in driver fatigue in this context (May & Baldwin, 2009).

CardioWheel, which is the main focus of this research, can be seen as a detection system that will set the base for a warning system. It will try to determine fatigue, like the technologies described by (May & Baldwin, 2009) in table 3, but in a pre-crash setting through the acquisition of ECG signals. This is a steering wheel cover that acquires the ECG signal from the driver by the use of conductive fabric electrodes. Compared to traditional approaches, the signals have a lower Signal to Noise Ratio (SNR). CardioWheel uses the heart signal to enable driver recognition, comparable to a fingerprint recognition. The ECG signal is acquired from the driver's hands with sensors embedded in the steering wheel. This makes it possible to perform a measurement continuously and unobtrusively while driving (Lourenço et al., 2015).

2.2.4.3 Creating arousal and activation

Activation is also a possibility to counteract fatigue. This applied to the theory of arousal and activation from Thiffault & Bergeron (2003), makes it possible to determine a countermeasure that can potentially create arousal, that on its turn could lead to a longer period of arousal, also known as activation.

Multiple methods have been used in order to create arousal, which are based on warning the driver. Signals can be sent to the driver in multiple ways, of which auditory, visual, tactile, or mixed signals are the most common (Chun et al., 2012; Lin et al., 2013; Meng & Spence, 2015; Z. Wang et al., 2017). These arousing warning signals can considerably improve task performance and may effectively reduce the number of lapses of attention (Lin et al., 2013). Nevertheless, there is a difference in performance regarding these different arousing signals.

Auditory signals can increase arousal but have shortcomings. Lin et al. (2013) found that auditory feedback sometimes failed to arouse drowsy subjects with a lack of EEG activity, showing no neural response to the feedback. Further, arises the problem that auditory signals can easily be masked. This due to ambient noise in the vehicle or listening to music. This way, it becomes difficult for auditory signals to grab the attention of drivers. Also, can inattentional deafness result in missing the auditory signal (Lin et al., 2013; Z. Wang et al., 2017).

In order to have an alternative, visual signals can be used to create arousal. However, does this also have certain limitations. Meng & Spence (2015) state that visual signals are likely to be missed when driving or when the driver is distracted by a secondary visual task (e.g. operating the entertainment system, driving in a lot of traffic, dealing with navigation messages, etc.). Further, can it increase the workload which is already high during the driving task (Lin et al., 2013). Especially for fatigue, the biggest problem with visual signals concerns the fact that they can be missed when drivers close their eyes.

To combat this, much attention has been given to vibration and tactile signals. Although tactile signals can be overlooked due to engine vibrations, uneven roadways, thick clothing, or a simultaneous movement of the body (Meng & Spence, 2015; Z. Wang et al., 2017), does it have several advantages over visual and auditory feedback. Haptic feedback uses a different sensory channel, which does not increase the workload of the visual or auditory modalities which are already busy when driving. Further, has it additional benefits associated with cognitive processes. This because haptic feedback is transferred through direct contact and delivered directly from the haptic feedback generator to the driver, which enables information to be delivered only to the driver, who actually needs the warnings (Chun et al., 2012). Another benefit concerns the fact that it can elicit faster reactions from drivers than comparable visual or auditory warning signals (Meng & Spence, 2015).

Some automobile manufacturers have developed haptic warning systems on the steering wheel, seats, and pedals. In order to evaluate the best location, the efficacy has been tested. Haptic warning signals on pedals (brake and accelerator) were rated as ‘Poor’ to ‘Fair’ because the driver’s foot may not always be on the pedals. Steering wheel torque and vibration were rated as ‘poor’, while a seat shaker was rated as ‘Fair’ to ‘Good’ (Chun et al., 2012). This efficacy, on the other hand, relies on the situation, because tactile signals can also be used as a directional cue (Petermeijer et al., 2017). While a warning signal on the accelerator could be poor for a fatigue warning, its efficacy could be higher for an emergency brake warning.

Important for fatigue, however, concerns the spatial information that can be given to tactile signals (i.e. a vibration at the left part of the seat, when the car crosses a driving lane on the left side). Directional cues can be presented using static (i.e. non-directional stimuli at one location on the human body) or dynamic patterns (i.e. a sequence of stimuli at different locations on the body, to simulate a directional movement) (Meng & Spence, 2015; Petermeijer et al., 2017; Spence & Ho, 2008). As fatigue doesn’t require a certain movement or action, it is better to use a static pattern for a tactile warning system. Also has been revealed that tactile cues delivering a higher intensity vibration give rise to a higher level of perceived urgency as well and are usually associated with faster response times (Meng & Spence, 2015).

However, eliminating habituation is important. When warning signals are designed, it must be considered that habituation, or the decreasing likelihood that the driver will notice the warning, can increase as the number of subsequent encounters increases. This could lead, for simple audio and vibration signals, to a gradual loss of their effect as they are repeated.

2.3 Human behaviour and fatigue

Fatigue, as discussed before, is a broad concept with multiple causes for which multiple countermeasures can apply. Frankly, is it important to understand human behaviour to make sure that certain countermeasures can have their effects. In order to get more insight into human behaviour, and more specific behavioural change, have multiple strategies and models been developed over time (e.g. theory of planned behaviour, health belief model, protection motivation theory, etc.). This to understand why a certain behaviour occurs and how it can be influenced. The same applies to fatigue because it is a public health issue for which it is unclear why drivers still perform a driving task whilst feeling fatigued.

Behaviour change interventions (i.e. coordinated sets of activities designed to change specified behaviour patterns) are important for public health, due to the many pressing issues in society. They are used to promote healthy lifestyles and adequate behaviour. But in order to identify a type of intervention that is likely to be effective, a full range of options needs to be available together with a rational system for selecting the right options among them. This should be supported by a model of behaviour and the factors that influence it, without overlooking certain important influences (e.g. the Theory of Planned Behaviour and Health Belief Model are good in explaining certain behaviours, but they do not address certain important roles, such as impulsivity, habit, self-control, etc.). On the other hand, broad distinctions are often widely used, of which the population-level and individual-level interventions are one. Here, it is often impossible to readily classify this distinction to arrive at a satisfactory definition of the distinction that does not contain inconsistencies (Michie et al., 2011).

In order to tackle this problem, and to fully get a covering behaviour intervention model, Michie et al. (2011) developed the behaviour change wheel. To achieve this new model, a literature review was performed to identify the most important components that can explain current behaviour, in which three factors were identified that were necessary and sufficient prerequisites for the performance of a specified volitional behaviour. Namely, the skills necessary to perform the behaviour, environmental constraints that make it impossible to perform the behaviour, and a strong intention to perform the behaviour. This led to three items, respectively ‘capability’, ‘opportunity’, and ‘motivation’. In this behaviour system, capability, opportunity, and motivation interact to generate behaviour that, in its turn, influences these components as shown in figure 3 (the ‘COM-B’ system).

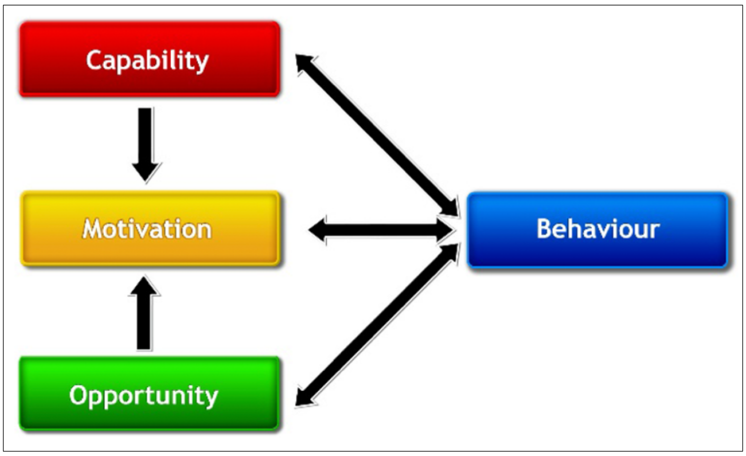


FIGURE 3: The COM-B framework for understanding behaviour (Michie et al., 2011)

Michie et al. (2011) define ‘capability’ as “the individual’s psychological and physical capacity to engage in the activity concerned, including having the necessary knowledge and skills.” Further, do they define ‘Opportunity’ as “all the factors that lie outside the individual that make the behaviour possible or prompt it.” Lastly, they define ‘motivation’ as “all those brain processes that energize and direct behaviour, not just goals and conscious decision-making. It includes habitual processes, emotional responding, as well as analytical decision-making.” The arrows in the model represent a potential influence between components in the system. They further state that a given intervention might change one or more components in the behaviour system. “The causal links within the system can work to reduce or amplify the effect of particular interventions by leading to changes elsewhere. While this is a model of behaviour, it also provides a basis for designing interventions aimed at behaviour change.”

With the COM-B model as a basis, a new framework was developed that tried to incorporate the sources of behaviour, together with interventions and policy measures. This led to the creation of the behaviour change wheel (BCW), that discusses all the possible interactions. Around the hub, nine intervention functions were placed aimed at addressing deficits in one or more of these conditions. Around this, seven categories of policy were placed that could enable those interventions to occur (Michie et al., 2011). The model can be seen in figure 4, with definitions of the terms displayed in table 4.

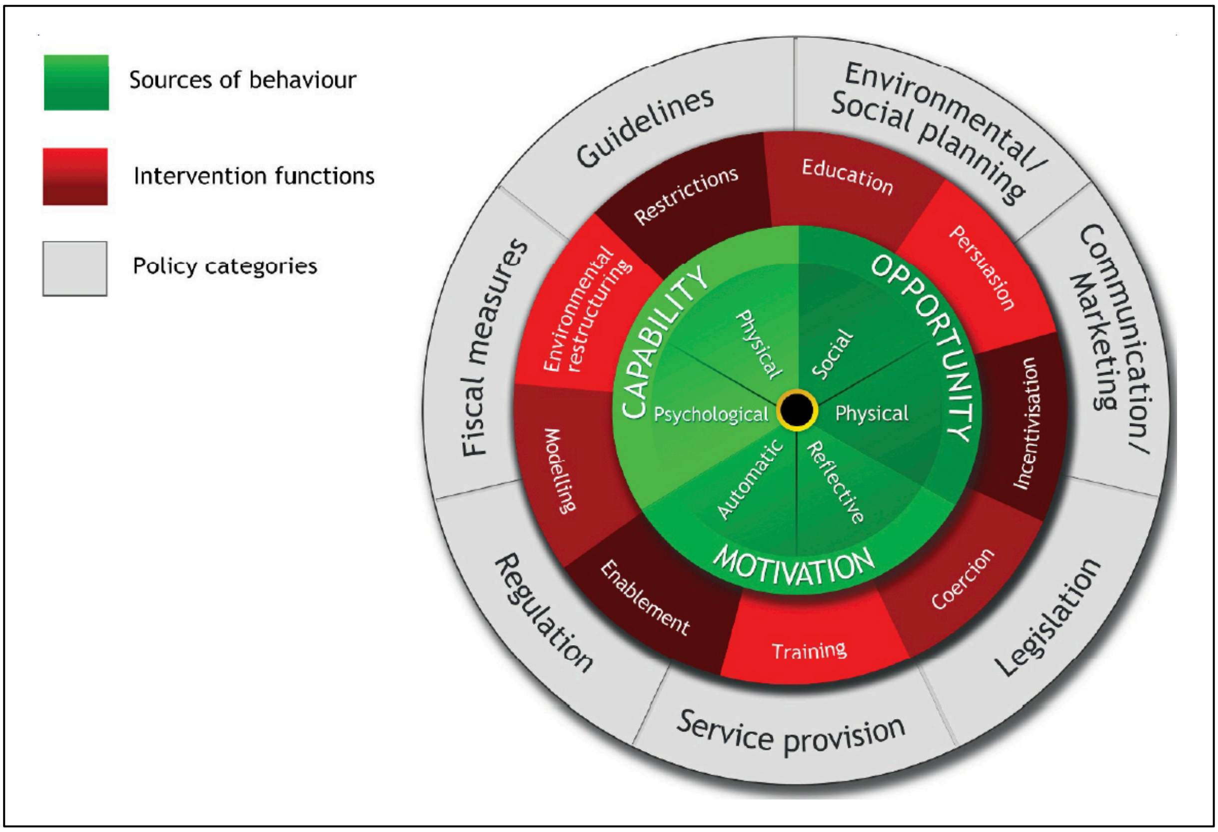


FIGURE 4: The behaviour change wheel system (Michie et al., 2011)

TABLE 4: Definitions of interventions and policies with examples of fatigue and truck driving (Michie et al., 2011)

Interventions	Definition	Examples
Education	Increasing knowledge or understanding.	Providing information on how to drive without fatigue.
Persuasion	Using communication to induce positive or negative feelings or to stimulate action.	Using campaigns to show the possible negative outcomes for fatigued driving.
Incentivisation	Creating an expectation of a reward.	Using bonusses to induce attempts for taking rest brakes.
Coercion	Creating an expectation of punishment or cost.	Raising the fines (for driver or company) if the driver didn't take rest brakes.
Training	Imparting skills.	Advanced training to recognise fatigue signals.
Restriction	Using rules to increase the target behaviour by reducing the opportunity to engage in competing behaviours.	Obliging resting breaks by law based on a track and trace system that keeps track of the driving time.
Environmental restructuring	Changing the physical or social context.	Providing more slack in the driving schedule for rest.
Modelling	Providing an example for people to aspire to or imitate.	Using TV drama scenes with a fatigue-related accident to decrease fatigued driving.
Enablement	Increasing means/reducing barriers to increase capability or opportunity[1].	Behavioural support for non-fatigued driving, medication for sleep disorders, installing in-vehicle fatigue detection technologies.
Policies	**Definition**	**Examples**
Communication/ marketing	Using print, electronic, telephonic, or broadcast media.	Conducting mass media campaigns.
Guidelines	Creating documents that recommend or mandate practice. This includes all changes to service provision.	Have a company newsletter that regularly recommends taking a rest whilst feeling fatigued.
Fiscal	Using the tax system to reduce or increase the financial cost.	Giving fiscal benefits to companies that make resting brakes accessible for drivers without drivers having to bear with a salary loss.
Regulation	Establishing rules or principles of behaviour or practice.	Establishing voluntary agreements between drivers and companies regarding fatigued driving.
Legislation	Making or changing laws.	Prohibiting driving whilst being fatigued by law.
Environmental/ social planning	Designing and/or controlling the physical or social environment.	As a company only hiring truck drivers that obey the rules.
Service provision	Delivering a service.	Establishing support services for drivers with sleep disorders.

[1] Capability beyond education and training, opportunity beyond environmental restructuring

This behavioural change wheel makes it possible to determine interventions and policy categories, which relate to certain current behaviour and the reason why this behaviour occurs. As an example, it is not beneficial to focus on knowledge about fatigued driving (i.e. psychological capability) through education, if the driver knows the consequences but doesn't take a break due to habitual behaviour and attitudes (i.e. automatic motivation). Michie et al. (2011) state that just by identifying all the potential intervention functions and policy categories, this framework could prevent policymakers and intervention designers from neglecting important options.

In order to see which intervention functions (i.e. layer one around the hub) can be linked to the sources of behaviour (i.e. the hub of the wheel), table 5 can be used. It shows which interventions link best to a certain explanation behind the current behaviour. To see which policy categories (i.e. layer two around the hub) can be further linked to the intervention functions, table 6 can be used. By showing it this way, it becomes clear that not every intervention and policy measure can work for everyone. This because a person performs or doesn't perform a certain (target) behaviour due to underlying factors recapitulated by the wheel's hub.

TABLE 5: Links between the components of the COM-B model of behaviour and the intervention functions (Michie et al., 2011)

		Sources of behaviour					
		C-Ph	C-Ps	M-Re	M-Au	O-Ph	O-So
Intervention functions	Education		X	X			
	Persuasion			X	X		
	Incentivisation			X	X		
	Coercion			X	X		
	Training	X	X				
	Restriction					X	X
	Environmental restructuring				X	X	X
	Modelling				X		
	Enablement	X	X		X	X	X

TABLE 6: Links between policy categories and intervention functions (Michie et al., 2011)

		Policy categories						
		Com./ Mark.	Guid.	Fisc.	Regu.	Legis.	Env./ soc. pla.	Serv. Prov.
Intervention functions	Education	X	X		X	X		X
	Persuasion	X	X		X	X		X
	Incentivisation	X	X	X	X	X		X
	Coercion	X	X	X	X	X		X
	Training		X	X	X	X		X
	Restriction		X		X	X		
	Environmental restructuring		X	X	X	X	X	
	Modelling	X						X
	Enablement		X	X	X	X	X	X

3 METHODS

3.1 Driving simulator study (not been able to complete)

3.1.1 Participants

As truck drivers were seen as the target population for this research, it was beneficial to establish a focus on truck drivers from the beginning. This means that no subdivision between drivers was made based on distance travelled (i.e. no distinction between long-haul, short-haul, delivery, etc.). In order to reach this specific sample, a collaboration with interest groups and contacts within the field of occupation was used, together with social media campaigns, to gather as many participants as possible. For this, a flyer was constructed which included all the necessary information for the participant to get in touch with the researcher.

Regarding the driving simulator study, a limited amount of exclusions were performed at the start of this research. Variables such as medical conditions, age, the basic level of fatigue, experience, etc. were taken into account from the start but were not used to exclude respondents before participating because further exclusion could be done in a later stadium when necessary. Experience with the driving simulator was not essential. Furthermore, did participants need to hold a valid driving license and did they recently had to have driven a truck (i.e. at least have driven the previous month). A sample size of 30 participants was minimally required to perform reliable statistical analyses. Due to possible exclusions, simulator sickness, technical problems, or other unforeseen events, there was chosen to endeavour for a sample size of at least 40 participants.

3.1.2 Apparatus

A medium fidelity fixed base STISIM simulator would have been used, consisting out of 3 screens and vehicle controls. The simulator was adapted, to get a realistic truck seating position and vision. Laboratory temperature would have been controlled at 21°C, to minimise external effects that can influence fatigue. The system was fitted with realistic vehicle control instrumentation to make braking, accelerating, and driving in general possible. A small screen was used, on which the KSS-scoring items would have been displayed. Further, a butt-kicker was installed at the seat, that could give a haptic feedback warning signal.

To assess fatigue in this pilot study, CardioWheel would have been used. This technology acquires the ECG from the driver's hands to continuously detect fatigue. The system has a driver change alert time window of 20 seconds (i.e. the time the system needs to adapt to the driver to make reliable measurements). It detects fatigue via R-Peak detection, accurate for 98%, but also makes use of heart rate variability for which the system needs a 2 to 5 minutes analysis time window. The outputs being generated are heart rate parameters and a fatigue indication, which is based on the Karolinska Sleepiness Scale, which will be collected and saved in a dataset through a Bluetooth module. The system makes use of a relative (i.e. determine fatigue based on the first ECG-measurement when a person grabs the steering wheel) and absolute (i.e. determine fatigue based on a predetermined system base condition) detection technique (CardioID Technologies, n.d.).

Before the participant got detailed information about the simulator session, a questionnaire had to be filled in via the online questionnaire tool Qualtrics. This questionnaire was based on demographic information and personal information, including their name, to make a connection possible between both datasets. Retrospectively, the name would have been replaced by an ID to make identification impossible in the dataset. Further, did the questionnaire consist out of questions regarding their health (i.e. possible sleeping disorders, potential smoking, medication, etc.) and the ESS and FAS questionnaires. Both fatigue-related questionnaires were implemented to have an insight into possible fatigue and sleepiness levels. The results from the questionnaires would have been used to counterbalance participants based on their fatigue levels, to schedule a simulator session. At the testing facility, the KSS would have been used to enquire the subjective level of fatigue from the driver. Although this answering scale is not intuitive, because the scale is not equally divided in terms of fatigue accumulation, there was still chosen to use the KSS. This because its validity and reliability have often been proven in previous research.

To retrieve data from the simulator, MATLAB would have been used. The CardioWheel output would have been directly imported and synchronised with the simulator data. The data preparation for the driving and CardioWheel data would have been done via MATLAB to perform analyses. The analyses would have been conducted in SPSS 25.0.

3.1.3 Inducing fatigue

In order to induce fatigue, a manipulative strategy would have been used that is based on the causes of fatigue. As discussed before, do these consist out of the circadian rhythm, homeostatic factors, task-related factors, and personal characteristics, which can be divided into SR and TR-fatigue. As May & Baldwin (2009) describe in their research regarding SR and TR-fatigue, are most driver fatigue studies focusing on sleep deprivation or circadian rhythm effects. On the other hand, do they require that drivers perform driving tasks during monotonous, highway conditions, which confounds the effects of SR and TR-fatigue. Nevertheless, it is clear that driver fatigue does produce performance decrements in driver simulation and on-road driving tasks, even when SR and TR-fatigue are not separately used. Frankly, due to budgetary and time limitations, was it impossible to use all the factors as described before to induce fatigue. This led to certain choices that had to be made.

Regarding the circadian rhythm, there was chosen to make use of the post-lunch dip to induce fatigue. This natural decrease in wakefulness can contribute to the generation of fatigue, which is also a factor that is used in other driving simulator studies (e.g. (May & Baldwin, 2009; Otmani et al., 2005; Thiffault & Bergeron, 2003; Ting et al., 2008)). SR-fatigue would thus have been incorporated in this research in terms of the circadian rhythm, although it would have been possible to control for this variable if necessary.

As for the homeostatic factors (i.e. sleep deprivation, sleep restriction, extended time awake, and sleep disorders), these were not chosen to incorporate in the study to manipulate fatigue. Although many different studies have used homeostatic factors to influence fatigue (e.g. (Arnedt et al., 2001; Eoh et al., 2005; Howard et al., 2014; Ingre et al., 2006; May & Baldwin, 2009; Otmani et al., 2005; Philip, Sagaspe, Moore, et al., 2005; Philip, Sagaspe, Taillard, et al., 2005; X. Wang & Xu, 2016)), do these also induce practical issues. Influencing sleep deprivation, extended time awake or sleep restriction would have imposed responsibility for the participant that could not be controlled for in this research. Due to the limited resources and time, it would have been difficult to supervise if the respondents had implemented what was asked from them. Controlling another person's amount of sleep or time awake would have been difficult without constant supervision over the behaviour of the participant. While relying on the honesty of the participant to execute what was asked for in advance, without being able to control this, would this have imposed a great risk on a bias (e.g. asking the respondent not to sleep the night prior of the research, without the possibility to verify this, could have resulted in a bias if this person would have slept while being in a test group of sleep-deprived participants). Due to the inability to supervise, there was chosen not to manipulate fatigue in this manner, because it would become unclear who would be fatigued beforehand. Regarding sleep disorders, it was possible to ask if a participant had a sleep disorder in advance of the study via the questionnaire. For this reason, there would have only been controlled for sleep deprivation prior to the study, as an exclusion criterion or control variable for further analyses, and not as a fatigue-inducing method. SR-fatigue would thus not have been used in this research regarding the homeostatic factors.

This research, on the other hand, mainly focussed on task-related factors to induce fatigue. The task-related factor time-on-task would have been applied by the use of a long driving scenario. This in order to find variance in the sample, regarding the objective and subjective measures of fatigue. For this, multiple options were possible, mainly driving for a long-pre-set time or driving until the respondent would indicate to stop. Both had their limitations, in which driving for a pre-set time had the best potential. Driving until the respondent would indicate to stop meant that the driver knew in advance that this would have been possible. It was suspected that this could have resulted in early quitting, even when no signs of fatigue would be present. Further, would it become difficult to determine if a person could be objectively more fatigued, since a participant would likely have stopped when subjective fatigue/sleepiness reached a high level. But this did not mean that the participant would be objectively fatigued. Further, would it also result in various scenario lengths, which could be difficult to analyse. For this reason, there was chosen to construct a 135-min lasting driving scenario. In this method, it was still possible that objective fatigue effects did not arise, although this chance would have become small because fatigue effects were already present in a 105-min driving scenario in the study of (Philip, Sagaspe, Taillard, et al., 2005). In addition, would a fixed length of the driving scenario have led to better scheduling of the different sessions and would it have made manipulations possible at a fixed time in the scenario (e.g. short stimulation at the end of the session via tactile feedback). The focus would thus have lied on TR-fatigue and not SR-fatigue in this research.

On the other hand, did this research also use the workload related factor 'monotony' as a fatigue-inducing factor. But to lower the impact of monotony on a loss of non-fatigue alertness, distraction, and boredom was there chosen to have a well-balanced level of monotony in the scenario. Also, was a following task included in the scenario to reduce monotony and impose a task workload.

Lastly, regarding the personal characteristics, there was chosen to control for certain personal characteristics such as smoking, drinking caffeine, being overweight, risky driving, etc., but these personal characteristics were not used to induce fatigue. There would have been asked to eliminate caffeine beverages, energy drinks, and smoking prior to the test.

3.1.4 Dependent variables

The dependent variables that would have been used to assess fatigue were based on the measures that can be used to measure fatigue. Driving simulator parameters, as well as heart rate parameters (acquired by CardioWheel), and questionnaire variables would, in this case, have been used.

For the driving simulator, many parameters would have been gathered. SDLP, frequency of larger SWM (i.e. SWM >6°, SWM >8° and SWM >10°), mean steering wheel angle, mean amplitude of steering wheel movements, average headway during the following task, mean speed, mean deviation of speed and the number of right lane crossings would have been used to assess fatigue. This in order to have more objective variables for the detection of fatigue effects. Further, was there chosen to calculate certain averaged parameters per 10-minute driving blocks, to have multiple mean measurements throughout the whole scenario. This way, variations could have been detected more easily between the mean scores itself.

For CardioWheel, the predetermined signals necessary for functioning would have been collected (e.g. heart rate variability, mean heart rate, the determined KSS-score by the system, etc.). Regarding the subjective measures, the KSS would have been used to assess the subjective level of sleepiness as a parameter for fatigue, that could directly be compared with the CardioWheel KSS output. The ESS and FAS scores would have helped to determine if daytime fatigue was present, which could indicate the presence of a sleep disorder and basic levels of fatigue. Lastly, the demographic and personal background questionnaire was conducted to retrieve the necessary information from the respondent.

3.1.5 Study design

Driving simulator studies have dominated fatigue studies in the traffic safety context. This because they are safe, have a low cost, and ensure easy data collection (Philip, Sagaspe, Taillard, et al., 2005). Moreover, literature was not consistent in terms of studying fatigue, because many different protocols were used together (e.g. partial or total sleep deprivation, short- or long-term sleep restriction, long driving scenarios, monotony, etc.) with a wide range of subjective and objective performance measures (Otmani et al., 2005). Although this is true, the same findings often did come forward in the different driving simulator studies. This research tried to incorporate as many theoretical constructs as possible, given the practical limitations, without deviating too much from previous fatigue related research. That is why most of the study design choices were made, based on the earlier discussed theoretical constructs, together with new proposals to investigate the fatigue-related problem.

While other driving simulator studies often used a within-subjects study design (e.g. (Ingre et al., 2006; Otmani et al., 2005; Philip, Sagaspe, Taillard, et al., 2005; Thiffault & Bergeron, 2003; Ting et al., 2008), this study would have made use of a cross-sectional design. Within-subjects study designs are possible if fatigue can be manipulated in advance, through the use of SR-fatigue related factors. These can, as discussed before, make it able to pre-set fatigue from the start. This way participants can be divided into fatigued and non-fatigued participants while performing the study. Frankly, due to the recruiting and verification problems that arose from these SR-fatigue related factors (e.g. higher budget necessary for higher rewards, bringing the respondent to the study, verifying that the respondent is not sleeping, etc.), was it not possible to influence base level fatigue. This made it unable to predetermine fatigued and non-fatigued drivers, which caused the urge of a cross-sectional design. Participants would thus have been studied from start to end, to determine the development of fatigue and its effects without baseline fatigue manipulation. Further, would a within-subjects study design need more participants to reliably perform a within-subjects study design, which was not possible within the timeframe, hence the cross-sectional design.

Further, are (partial) sleep deprivation and the circadian rhythm often used in driving simulator studies, as seen in the literature review of Liu et al. (2009). But, due to the same limitations as mentioned before, were task-related measures (i.e. monotony and following task) used to replace sleep deprivation. A 135-min lasting driving session would have been performed in order to constitute fatigue and find variance in the sample. This because having a shorter driving episode could have implicated that few fatigue-related effects would have been found.

The circadian rhythm would also have been incorporated into the research because the driving sessions were going to be performed in the afternoon. Important, however, concerned the fact that only 2 testing sessions could be scheduled in the afternoon (i.e. from 2 p.m. to 4.30 p.m. and from 5 p.m. to 7.30 p.m.). This meant that the circadian rhythm played an influence on the first session, but not on the second, because the post-lunch dip takes place from 1 p.m. to 5 p.m., as described before. Therefore, it was necessary to keep this variable in mind while conducting the test, making it able to control for the circadian rhythm as necessary. Otherwise, differences between both tests could have occurred, due to the circadian effect, separate from the other influences that would have been implemented, leading to a potential bias. Ideally, one session would have been scheduled in the afternoon to keep all factors constant throughout the data acquisition phase. However, due to time limitations of data collection, it was necessary to plan 2 tests in the afternoon. Counterbalancing became essential to counter for this option, which on its turn depended on the availability of participants and their willingness to come to the testing facility at a certain time.

To achieve the fatigued state earlier, there would have been asked from the respondent to abstain from caffeine, energy drinks, sports, stimulating medication, alcohol, and sugar-rich foods. This was necessary because these items could influence fatigue in a certain measure that cannot be controlled for. Asking the participant to abstain from these items, would have made sure that every participant started the test equally without any fatigue-related influences (apart from the individual differences in terms of fatigue within the participant). This would have lowered the chance on a potential bias between the different participants and would have been consistent with previous research (e.g. (Otmani et al., 2005; Ting et al., 2008; X. Wang & Xu, 2016)). Other factors that had to be kept constant for the test, to minimise potential manipulation of fatigue, were the time of testing, the scenario, the room temperature, and study setup. (Ting et al., 2008).

In order to find out if a participant had any sleep-related problems, which can influence daytime fatigue to a higher level, questionnaires were used. The ESS and FAS were sent to the participant beforehand to fill in. By doing this, the participants could fill in the questionnaire in their natural home environment, also shortening the total time at the testing facility when the driving test would have had to be performed. These questionnaires would have made able to determine if potential sleep disorders or problems were present within the participant, which could later be used as an exclusion criterion when necessary. Furthermore, did it allow to counterbalance participants for the driving sessions in the afternoon (e.g. if one participant was planned for a session at 2 p.m. with a high ESS-score, then another participant with a high

ESS-score would have been planned at 5 p.m.). There was chosen not to exclude beforehand based on the ESS and FAS-scores because differences of interest could potentially be found in the gathered simulator and CardioWheel data. Further, a demographic and personal questionnaire was used which helped to retrieve basic information about the respondent, which could contain variables that possibly relate to fatigue. This questionnaire was incorporated in the ESS and FAS-questionnaire. A version of the questionnaire can be found in the annex.

The subjective level of fatigue would have been gathered utilizing the KSS. It would have been used to have a subjective indication of baseline fatigue at the start of the driving session but could also indicate subjective levels of fatigue throughout the whole experiment. Because of this, differences between subjective and objective fatigue could be studied. The KSS would have been conducted at the start of the driving session, up and concluding to the end of the session with 10-minute intervals. The KSS answering scale would have been distributed to the participant prior to the test to get acquainted with it, but it would have also been displayed on a small screen in front of the driver as a reminder. This in order to minimalize distraction during the driving task. A version of the KSS, which was going to be used can be found in the annex.

The main focus of this research would have lied in the fatigue detection by CardioWheel. This steering wheel cover would have been applied around the driving simulator steering wheel to retrieve ECG data. This CardioWheel output would have been used in cohesion with objective driving simulator parameters, to validate the measurements of fatigue. If CardioWheel would have detected fatigue within the participant, would this have had to be validated by the objective driving simulator parameters and correlated to the subjective levels of fatigue. This way it could be tested if CardioWheel was a valid technology for detecting fatigue within the professional driving context. Further, there could have been evaluated how the subjective level of fatigue, gathered by the KSS, related to the CardioWheel KSS output. Multiple driving simulator parameters would have been used, discussed in 3.1.4, in order to have more validating measures for CardioWheel.

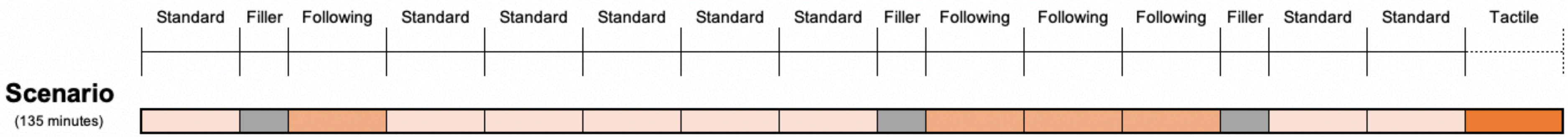
Regarding the driving simulator scenario, multiple considerations had to be taken into account. Other driving simulator studies often used different scenario's ranging from highway driving (e.g. ((Otmani et al., 2005; Thiffault & Bergeron, 2003; Ting et al., 2008)) to rural driving (e.g. (Howard et al., 2014; Ingre et al., 2006; X. Wang & Xu, 2016)). However, for this study, there was only focussed on a highway driving scenario. Highway driving can be seen as a monotonous task (Thiffault & Bergeron, 2003), which is related to task-related fatigue. Although it remained important not to create a too monotonous environment, due to the length of the driving session that would have been used in this research as discussed before. A too monotonous task could potentially create boredom, a loss of non-fatigue related attention, and even distraction (e.g. when a person starts reflecting about their day during the driving task). In order to tackle this, reality was pursued in the driving scenario as close as possible. This to have a truthfully driving task, lowering the amount of monotony, which lowered the chance of boredom, attention loss, or distraction. It was on the other hand necessary to keep a certain amount of monotony in the task, to lower the chance on higher amounts of stimulation, which could result in a reduction of fatigue. Having a well-balanced level of monotony was thus necessary. Further, did a monotonous task reduce the programming time for the scenario drastically. The highway driving environment consisted out of a 2 by 2 road profile with a central reservation, bridges, hedges, curves, crash barriers, a breakdown lane, and a small amount of traffic on the highway. Single overheads were used at fixed distances, which told the driver to rate their subjective level of fatigue with the KSS every 10 minutes.

Next to the driving environment, was a certain driving task added to the scenario. Often used driving tasks are keeping the car within the lane as best as possible (e.g. ((Arnedt et al., 2001; Howard et al., 2014; Otmani et al., 2005; Thiffault & Bergeron, 2003), driving like the respondent is used to (e.g. (Eoh et al., 2005; Ingre et al., 2006)) or a car following task (e.g. (Ting et al., 2008)). All driving studies have monotonous situations in common, where the number of stimuli is limited. For this research, a following task was added to the scenario at certain predetermined points. Drivers would have been asked to drive as they normally would, but when a car appeared in front they were prohibited to pass. This following task made the scenario less monotonous, raising the chance of completing the full driving session. The scenario would have remained constant for every respondent.

By the use of the realistic driving environment and the differentiating driving task it would have been possible to obtain multiple different driving simulator parameters. The car following task would have been more suitable for the collection of headway distance and speed deviations, while the normal driving situation on the highway without a following task, would have made it possible to collect the other parameters as described in 3.1.4.

The last 10 minutes of the driving scenario were added, without the respondent knowing. During this 10-minute drive, tactile feedback would have been given to study if this tactile feedback had any effects on driver's fatigue. Communicating about this part of the drive beforehand could have resulted in a bias because the respondent could have known what to expect. For that reason, there was chosen not to communicate about this part of the driving scenario. Differences between the 10-minute tactile feedback driving part could then have been compared to the last 10-minute standard driving part, to find any differences in fatigue due to this countermeasure. There was chosen to have a standard highway driving scenario for the last part of the driving task to eliminate possible interaction effects. The tactile feedback would have been transmitted to the driver via the driver seat at pre-determined moments (i.e. 4 times in the 10-minute tactile feedback part at equal intervals).

Lastly, regarding the full driving session, there was determined how long each driving task would have to be driven and when the following task had to be added. The 135-minute scenario was divided into 13 blocks of 10-minute driving tasks, to correspond with the KSS answering every 10 minutes. Small filler pieces (i.e. leading to the other 5 minutes) were used when driving tasks changed, to let the participant get acquainted with the new driving task, to lower the impact of this change on the driving data. This way, equal driving parts were created that could be compared with each other. Constantly differentiating between the tasks every 10 minutes, could have led to less fatigue in each situation and less measurable effects with extra unnecessary filler pieces. Due to this, were the driving blocks put together in such a way, that each driving task lasted for a notable time, resulting in better comparable data. The first 20 minutes of the driving scenario were reserved for both driving tasks, to let the driver get used to both driving situations. The outline of the scenario is displayed in figure 5.



(light)	Standard highway situation where the respondent can drive free on it's own.
(medium)	Highway following task situation where the respondent is obliged to follow the car in front.
(dark)	Extra tactile session in standard highway environment. The respondent will be given a tactile signal at predetermined moments.
(grey)	Filler piece to let the participant get used to the new driving task situation, at transition of the following task.

General properties	- Daytime driving. - Total driving time of approximately 2h and 15min divided in 10-min blocks with filler pieces. - 10-min driving environments (filler pieces excluded) with curves and realistic properties. - Filler pieces have a fixed length of 500m. - Monotonous situations created throughout the environments. - Recognisable highway scenario (based on real world). - 90 km/h speed limit.

Highway design	
Road	2 by 2 + central reservation + breakdown lane
Road material	Default asphalt
Lane width	4m
Breakdown lane	4m
Fore slope	20m wide with 32% slope
Edge marking	0.30m or default
Stripe with	0.20m or default
Stripe length	2.5m or default
Length between	10m or default
Central reserv.	15m (grass)
Crash barrier	Default at bridge pillars
Street lights	Default in central strip
Scenery	Grass, hedge (only at filler pieces) and bridges
KSS-scoring	Displayed on single overhead

FIGURE 5: Driving scenario outline

3.1.6 Testing procedure

Participants were recruited via interest groups, contacts within the field of occupation, and social media, by the use of a summary of the study. Those indicating a willingness to cooperate in the study were sent the questionnaire in advance, to determine sleep-related problems and to gather background data. These questionnaires were not used to exclude participants (except for age and non-recent driving). After filling in the questionnaires, the driving simulator session would have been scheduled in consultation with the participant. Further, there would have been asked to respect sleeping hours only between 11 p.m. (the day before the test) and 7 a.m. (day of the test). While this could not be strictly supervised, its purpose lied in thwarting sleeping for a long time. Participants were also informed in advance about the testing facility location.[1]

As the participant would arrive at the testing facility, a short welcome would have been given before the start of a first 5-minute practice session. After the practice session, a short 5-minute break would have been given before starting the 135-minute driving session. At the beginning of the driving session, a first KSS-score would have been asked from the respondent to determine the baseline subjective level of fatigue. During the 135-minute driving session, every 10 minutes another KSS-score would have been asked from the respondent, up to and concluding the end of the driving session, including the tactile feedback part. After this, another KSS-scoring, representing the subjective level of fatigue after creating arousal, would have been asked. Finally, ending the complete driving session.

Before sending the participant home, a beverage and snack would have been offered to let the respondent feel comfortable. Further, would this have served as a period of rest before driving home. A reward for participating would also have been given at the end of the study.

The participant had to fill in a form of consent in the questionnaire, before taking part in the study, that the gathered data could be used for research. The data would have been analysed anonymously and no data would have been gathered that could lead back to the direct identification of the participant. Data would only be used for this research and potentially for follow up research but would not have been sold or distributed for other fields of interest.

3.1.7 Analyses

For the analyses of the main driving scenario, linear regression analyses would have been performed to look for the accumulative effect of fatigue in relation to the driving time. This way a trend analysis could have been performed to find an underlying pattern in a time series. For this, the driving simulator parameters would have been assessed in relation to the driving time, to map fatigue. The same could then be done for the CardioWheel measurements that were also gathered continuously over the total driving scenario. This could have been carried out for the whole scenario where data was logged continuously but could also have been done in terms of driving blocks with averaged parameters. Multiple driving simulator parameters could also have been correlated to the CardioWheel data via the use of Pearson product-moment correlations.

[1] At this point, the research was called to an end, due to the COVID-19 outbreak.

In order to assess if the following task could have had any significant impact on the cumulative effect of fatigue, an ANOVA analysis would have been performed. Here, the 13 driving blocks would be compared with regards to the different driving simulator parameters, CardioWheel data, and KSS scoring.

Further, would the impact of the time of day effect (i.e. post-lunch dip) have been assessed by the use of a t-test. This t-test would have made it able to look for differences between both samples (i.e. the group of participants that drove from 2 p.m. to 4.30 p.m. in comparison with those who drove from 5 p.m. until 7.30 p.m). This for multiple parameters that were gathered during the driving task.

The subjective KSS-scoring, gathered during the driving task every driving block, could have been compared to the average KSS scoring by CardioWheel per driving block to look for inconsistencies between the measurements. For this, ANOVA analyses could have been used. This way comparisons could have been made between the subjective assessment of fatigue by the driver and objective measurements. Of course, this comparison makes more sense if CardioWheel would have been found to be a validated fatigue detection method, via the previously performed regression analyses.

3.2 Questionnaire study

3.2.1 Participants

As truck drivers were seen as the target population for this research, it was beneficial to establish a focus on truck drivers from the beginning. This means that no subdivision between drivers was made based on distance travelled (i.e. no distinction between long-haul, short-haul, delivery, etc.). In order to reach this specific sample, a collaboration with interest groups and contacts within the field of occupation was used, together with social media platforms, to gather as many participants as possible.

Due to unforeseen events, an alternative approach became necessary, leading to an online data collection via a questionnaire. For this approach, the same exclusion criteria were used. This also led to a fewer number of drivers in the study, due to the late shift in terms of data collection methods. For this research, participants were used which already gave consent to perform the driving simulator study, leading to a sample size of 23 participants. Additional participants were not sought due to the limited time available at hand.

3.2.2 Apparatus

In order to assess fatigue, attitudes, and behaviour in this study, a questionnaire was constructed. This questionnaire was split up into two parts, conducted at two different moments in time. To gather this data, the online questionnaire tool Qualtrics was used. The first questionnaire, which can be found in the annex, had already been conducted in the context of the driving simulator research.

In a later phase, the second questionnaire, which can also be found in the annex, was used as an alternative for the driving simulator research. The main part of the questionnaire focussed on behaviour and the background explanations why truck drivers potentially chose to drive fatigued. Also were coping strategies incorporated in this questionnaire, together with attitudes about technology and fatigued driving.

Data was retrieved from Qualtrics and screened in Microsoft Excel. Both datasets were imported into one Excel database and recoded as necessary. The finished dataset was then imported into SPSS 25.0 for further data analyses.

3.2.3 Study design

Due to the fact that multiple stages from the driving simulator research had already been performed, it was possible to reuse the first questionnaire. This questionnaire was based on demographic information and personal information, together with questions regarding their health (i.e. possible sleeping disorders, potential smoking, medication, etc.). Furthermore, the ESS and FAS questionnaires were also used, which made it possible to have a subjective indication of fatigue and sleepiness. This data was ready to use but would have been to concise to discuss fatigue and behaviour. For this reason, there was chosen for an alternative to replace the driving simulator task, which consisted out of a follow-up questionnaire. The questionnaire focussed on human behaviour, coping, and attitudes.

Because the name of the respondent was asked to make linking possible between the questionnaire data and driving simulator data, it was possible to link both questionnaires to each other by asking the respondent's name again in the follow-up questionnaire. This questionnaire was conducted, approximately, one month after the previous questionnaire by contacting the same respondents from the first questionnaire. Retrospectively, the name would be replaced by an ID after combining the datasets, to make identification in the dataset impossible.

In the second questionnaire, multiple behaviour related questions were constructed that tried to unravel current behaviour. These questions were constructed as such, that it was possible to find out if participants already performed the target behaviour (i.e. taking a break when feeling fatigued) or to capture their thoughts on being completely capable to cope with fatigue during a driving task. On the other hand, questions were also developed to discover attitudes and proneness to change with regards to fatigue and driving. These questions can be related to the transtheoretical model of change, because multiple stages wherein a person could identify itself, can be derived from these questions. The answers had to be given on a 5-point Likert scale, ranging from 'Fully disagree', 'Disagree', 'Neutral', 'Agree', to 'Fully disagree'.

To have more insight into current behaviour and possible underlying causes, which can undermine the target behaviour, questions were constructed based on the behaviour change wheel in the second part of the questionnaire. Here, questions were developed in relation to the COM-B sources of behaviour (i.e. physical and psychological capability, physical and social opportunity, and reflective and automatic motivation), together with attention for the intervention functions in the questions. This way it became possible to find an underlying cause for certain behaviours, for which a certain intervention can be more at its place. The answers had to be given on the same 5-point Likert scale, as previously described.

Furthermore, there was chosen to construct questions regarding coping strategies that drivers use to combat fatigue. Literature already has proven that only rest (or sleep) and coffee can have an impact on fatigue. Nevertheless, was it interesting to create questions by which it became possible to find out if drivers performed the target behaviour or if they chose to cope with fatigue with other strategies, that are very likely to fail.

Lastly, questions were developed regarding attitudes about in-vehicle technology. This way, attitudes could be gathered to see if drivers would support in-vehicle fatigue detection technologies. This last part was added to the questionnaire because CardioWheel would have been tested in the driving simulator research, but no insight was available about a supportive surface around these types of technologies by the drivers.

3.2.4 Testing procedure

In terms of gathering participants, the questionnaire study relied on the recruiting methods of the previously mentioned driving simulator research. Participants were recruited via interest groups, contacts within the field of occupation, and social media, by the use of a summary of the study. Those indicating a willingness to cooperate in the simulator study were sent questionnaire 1 in advance, to determine sleep-related problems and to gather background data. These questionnaires were not used to exclude participants (except for age and non-recent driving).

A month after filling in the first questionnaire, the same participants that normally would have done the simulator drive were contacted again to fill in the second questionnaire due to time limitations. While having successfully constructed the second questionnaire with, the research relied on the willingness to cooperate from the respondents that had already filled in the first questionnaire. Luckily, all the respondents that were contacted agreed to fill the second questionnaire. Hereafter the questionnaire was closed, and no additional participants were sought due to time limitations.

The participants had to sign an informed consent in every questionnaire, before taking part in the study, that the gathered data could be used for research. The data was analysed anonymously, so that no data could lead back to the direct identification of the participant. Data would only be used for this research and potentially for follow up research but would not be sold or distributed for other fields of interest.

3.2.5 Analyses

Due to the small sample size, analyses were more oriented to descriptive qualitative analysis methods. A sample size of 23 participants was simply not enough to perform reliable inferential statistics. Because of this, there was mainly focussed on graphs, simple statistics, and interpretation of the sample. This way, it was still possible to gather some insights about the sample and the problem at hand.

Nevertheless, does this not mean that extrapolation to the population could be made because it wouldn't be reliable due to the small sample size. Furthermore, do multiple statistical analyses (e.g. linear regression, correlation, factor analysis, etc.) also require a large sample size to be reliable, which is not the case with this data. On the other hand, this does not mean that certain statistical analyses couldn't be performed.

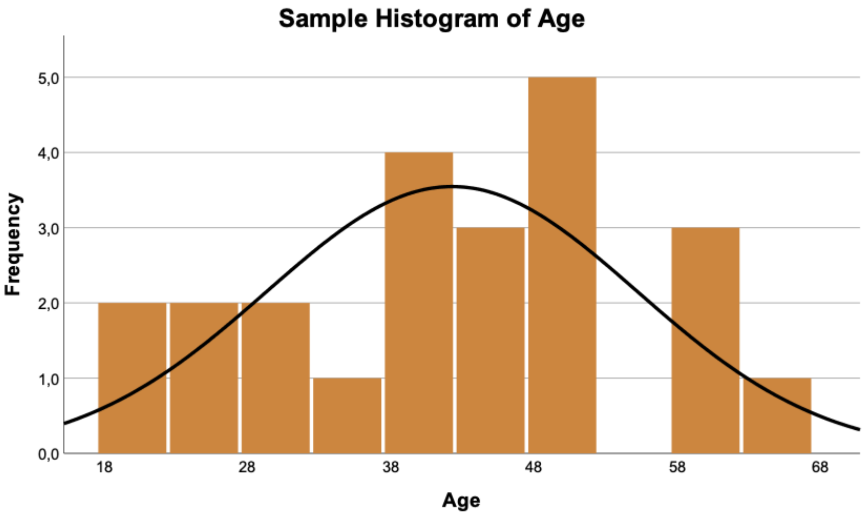
Due to this, there was chosen to perform a factor analysis, together with an internal consistency analysis via Cronbach's Alpha, together with correlation analyses. These analyses were not used to make a closing statement about the population but were used to add information and insight from the sample. Also, could this give added information for the questionnaire. Nevertheless, caution is still needed in this case.

4 RESULTS

4.1 Sample statistics

Before going deeper into the results of the questionnaire regarding fatigue, the sample is discussed, in order to have a clear image of the small sample.

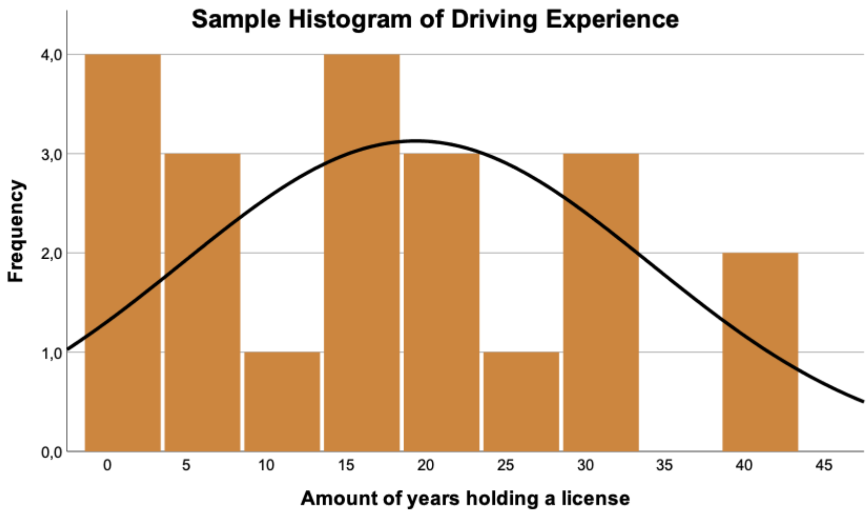
Regarding the age of the respondents, the histogram in figure 6 shows the age distribution of the participants. For this analysis, there was chosen to look at the active population, for which the maximum age was set at 65. The normal curve indicates a normal distribution between the ages within the active population, although the sample is particularly small. Nevertheless, are multiple ages present in this sample. The small sample was more or less able to cover the active population.



Mean	42.30
SE of Mean	2.697
SD	12.935
Median	43.00
Mode	48
Variance	167.312
Minimum	20
Maximum	65

FIGURE 6: Age distribution of the sample

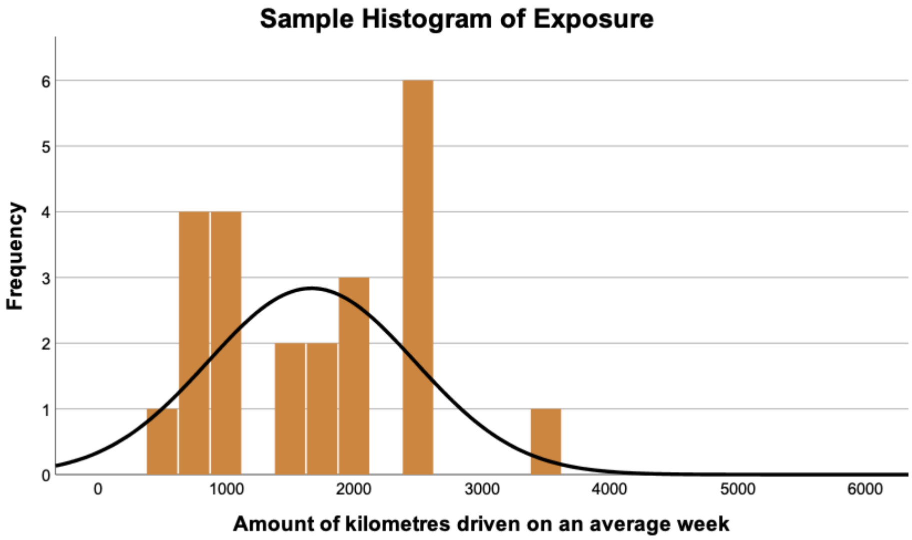
Regarding driving experience, the distribution differs. A right-skewed distribution regarding the normal curve can be seen in figure 7, with more respondents having lower experience. Nevertheless, multiple levels of experience are present within this small sample.



Mean	19.39
SE of Mean	3.059
SD	14.668
Median	18.00
Mode	2
Variance	215.158
Minimum	1
Maximum	45

FIGURE 7: Distribution of driving experience

Regarding driving exposure, figures differ much between respondents. The normal curve in figure 8 shows a right-skewed distribution in the results, although caution is needed due to the high standard deviation. Nevertheless, can be said that two types of drivers are present in the sample. Namely, drivers that drive short distances, as well as long-haul truck drivers.



Mean	1667.39
SE of Mean	168.685
SD	808.985
Median	1700.00
Mode	2500
Variance	654456.522
Minimum	500
Maximum	3500

FIGURE 8: Distribution of exposure

Other sample statistics are shown in table 7, where frequencies regarding health-related factors from participants are also shown.

TABLE 7: Other important sample statistics

Variable	Description	N	Frequency (%)
Gender	1 = Male	23	19 (92.6%)
	2 = Female		4 (17.4%)
Sleeping disorder	1 = Yes	23	0 (0.0%)
	2 = No		23 (100%)
Medication usage	1 = Yes	23	9 (39.1%)
	2 = No		14 (60.9%)
Smoking	1 = Yes	23	10 (43.5%)
	2 = No		13 (56.5%)
Caffeine intake via coffee	1 = I don’t drink coffee	23	4 (17.4%)
	2 = Less than 1 coffee per week		0 (0.0%)
	3 = Multiple coffees per week		3 (13.0%)
	4 = 1 coffee per day		4 (17.4%)
	5 = Multiple coffees per day		12 (52.2%)
Working out	1 = I don’t work out	23	16 (69.6%)
	2 = I work out 1 time per week		3 (13.0%)
	3 = I work out 2 times per week		3 (0.0%)
	4 = I work out 3 times per week		0 (0.0%)
	5 = I work out 4 times per week		0 (0.0%)
	6 = I work out 5 times per week		0 (0.0%)
	7 = I work out 6 times per week		0 (0.0%)
	8 = I work out every day of the week		1 (4.3%)

The sample statistics show that male respondents are overrepresented in the sample. Further, can an absence of sleep disorders among the participants be noted, that otherwise could have resulted in a bias in the results. Some participants use specific medication for which, after further investigation, the effects on fatigue are likely small. Also, do most participants use caffeine, and do they tend to workout rarely.

4.2 Subjective fatigue and sleepiness

The ESS and FAS were used, in order to search for sleepiness and fatigue within the driver. These subjective questionnaires led to the scores displayed in figure 9 and figure 10 together with descriptive statistics in table 8.

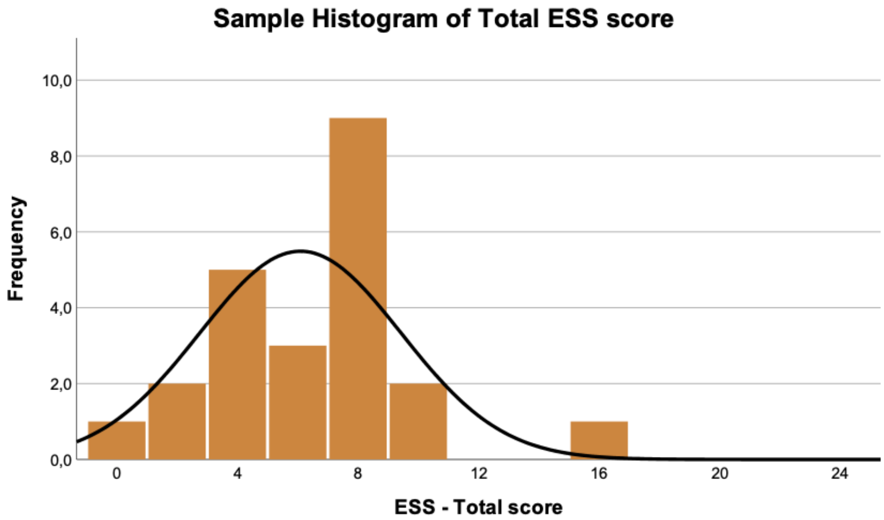


FIGURE 9: Distribution of the ESS scores

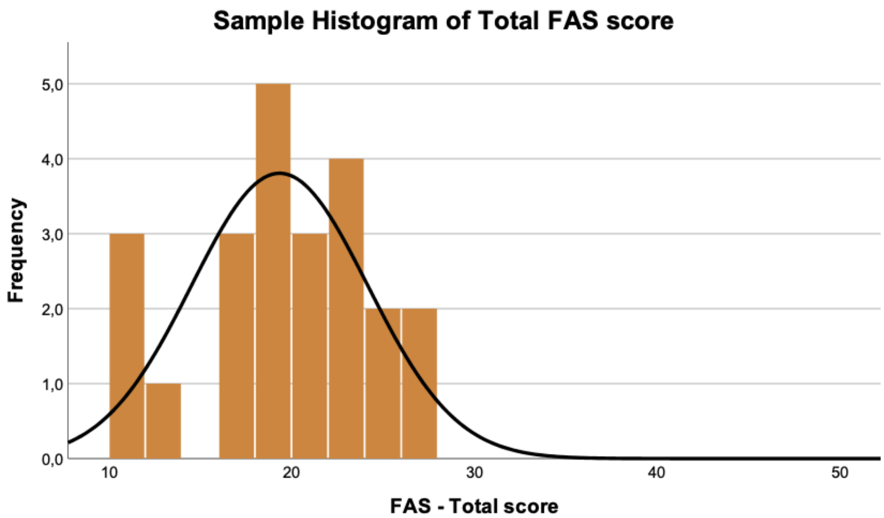


FIGURE 10: Distribution of the FAS scores

TABLE 8: Descriptive statistics of the ESS and FAS scores

Descriptive statistics							
	N	Min	Max	Mean		S.D.	Variance
				Statistic	S.E.		
ESS – Total score	23	0	15	6.09	0.697	3.343	11.174
FAS – Total score	23	11	27	19.35	1.005	1.005	23.237

Low ESS and FAS scores can be seen, with a right-skewed distribution focussing around the low and middle scores. Furthermore, low variances are present, because the scores are clustered in the low and middle end, with the absence of very high scores and outliers. This finding is supported by figure 11 and figure 12. For the ESS, the graph shows that only one respondent had high sleepiness (i.e. 'sleepiness too high' ranging from 11-24). For the FAS, fatigued respondents were found (i.e. scores ranging from 22 to 50), while no respondents suffered from extreme fatigue (i.e. scores ranging from 35 to 50).

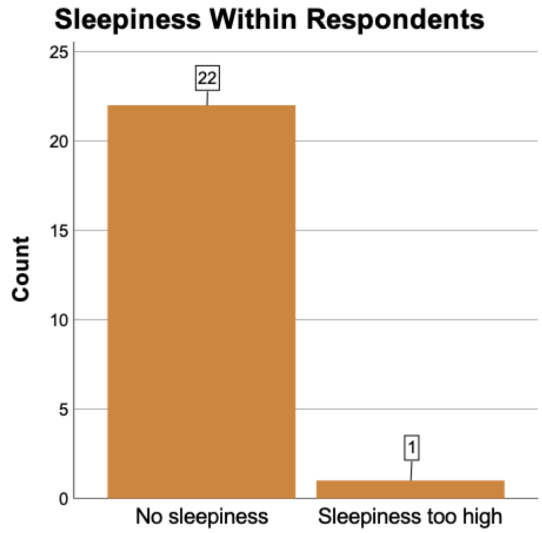


FIGURE 11: ESS verdict regarding sleepiness

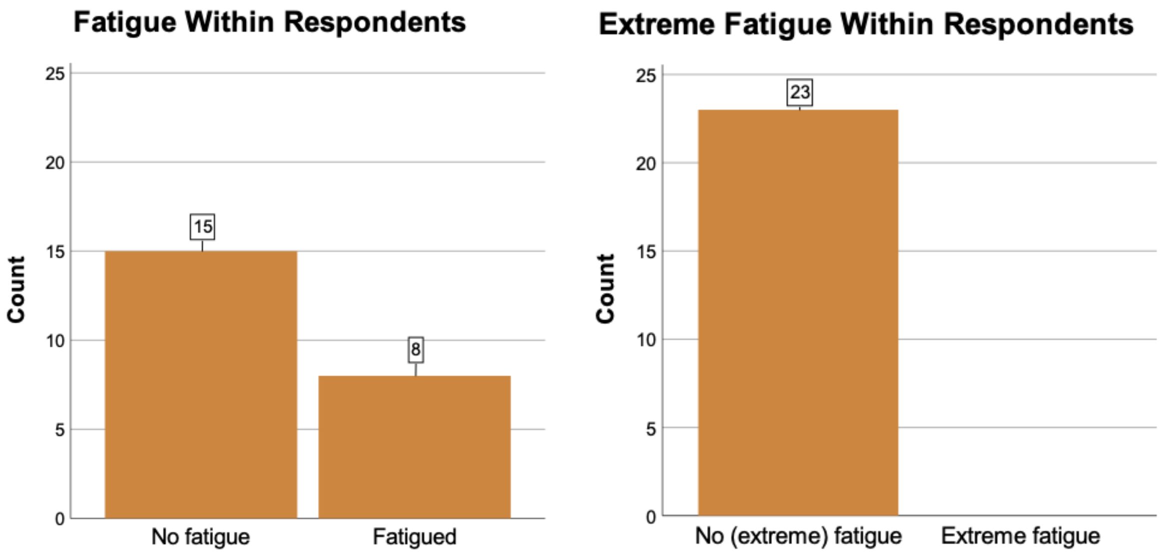


FIGURE 12: FAS verdicts regarding fatigue and extreme fatigue

4.3 Factor analysis COM-B questionnaire

In order to find out if the questions, that were compiled in the questionnaire regarding the COM-B model, were able to capture the 3 main sources of behaviour, a factor analysis was performed. For this, a factor analysis with varimax rotation was applied to the 22 questions which tried to capture the COM-B model. The minimal eigenvalue was set on 1 with 25 iterations.

For this factor analysis, seven factors could be identified. But looking at the scree plot in figure 13, it shows that the differences in eigenvalue between six and seven factors was not high. This could also indicate that six factors can be extracted, which corresponds to the Behavioural Change Wheel model. This model has three main sources of behaviour, for which every main source can be subdivided, resulting in six items in total. In that case, the factor analysis was able to determine the six factors from the Behavioural Change Wheel, but only if the marginal added eigenvalue of factor 7 is disregarded.

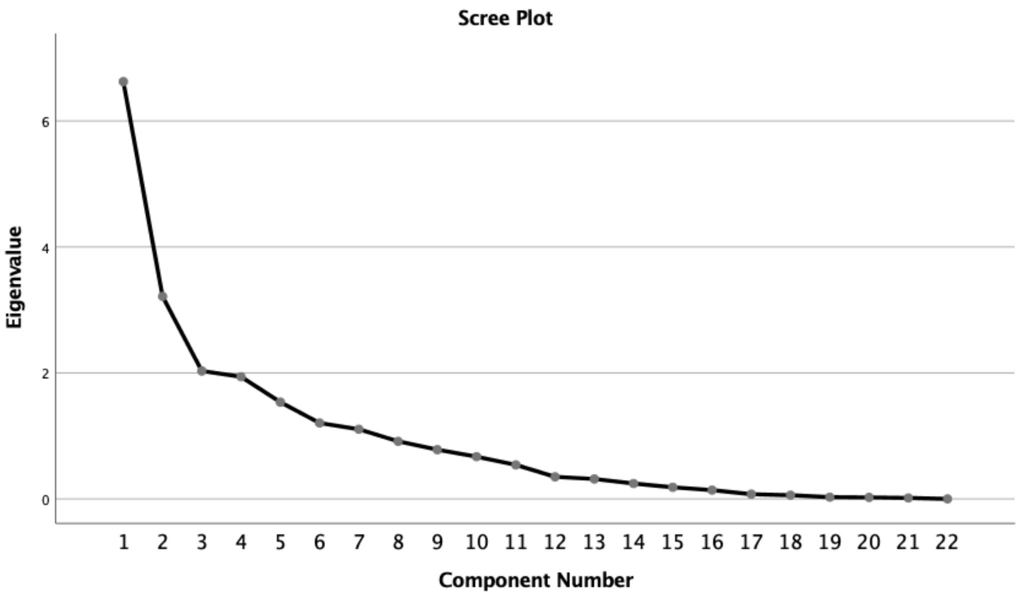


FIGURE 13: Scree plot factor analysis COM-B model questions

However, there was chosen to perform a second factor analysis where the number of factors that could be extracted was set at a fixed level of 3. With this, the 3 main sources of behaviour from the COM-B model were represented, for which corresponding items could be determined. To do so, a factor analysis with varimax rotation was used with 25 iterations and a cut-off value of 0,3. The results from this analysis are shown in table 9, together with the results of a reliability analysis. It shows the individual factor scores, as well as the mean score and standard deviation per factor, together with the total Cronbach's Alpha score. The reliability analysis was performed on all the items that corresponded to a certain factor, in order to determine the reliability of these items with regards to that factor. Due to this reliability analysis, some items were excluded from the factor, when a Cronbach's Alpha score could be improved.

TABLE 9: Principal component analysis with varimax rotation of the COM-B items

Items	Factors		
To drive without fatigue, …	Capability	Opportunity	Motivation
1. I would have to know more about the fact why it would be dangerous to drive with fatigue. (e.g. knowing more about the possible consequences)	**<u>0,761</u>**	-0,019	-0,043
2. I would have to know more about measures that can counter fatigue. (e.g. Needing to know if coffee helps to combat fatigue)	**<u>0,706</u>**	0,128	-0,278
3. I would need to be in a better physical shape. (e.g. not getting fatigued very fast while unloading the truck)	**<u>0,669</u>**	-0,032	0,261
4. I would need to have better mental skills. (e.g. being better in estimating my level of fatigue)	**<u>0,739</u>**	-0,285	0,006
5. I would need to have more physical strength and force. (e.g. being able to lift more weight with the same effort)	0,171	-0,029	**<u>0,681</u>**
6. I would need to have more mental strength and resistance. (e.g. developing more resistance against busy traffic)	**0,398**	0,001	0,003
7. I would need to overcome physical shortcomings. (e.g. trying different seating positions when a position stimulates fatigue)	**<u>0,714</u>**	0,008	-0,052
8. I would need to overcome more mental barriers. (e.g. don't care about others' opinions while doing exercises against fatigue)	**<u>0,626</u>**	0,053	**<u>0,521</u>**
9. I would need to have more physical endurance and perseverance. (e.g. more persistence to perform physical exercises before a trip)	**<u>0,476</u>**	**<u>0,467</u>**	0,266
10. I would need to have more mental endurance. (e.g. developing a bigger capacity to feel fatigues less easily)	0,076	0,166	**<u>0,317</u>**
11. I would need to have more time and flexibility so that I can perform actions to combat fatigue. (e.g. more time to be able to work out)	0,136	0,274	**-0,526**
12. I would need to have more financial resources. (e.g. receiving a small bonus when I take a necessary break due to fatigue)	**0,376**	**<u>0,625</u>**	-0,112
13. I would need to have material resources at my disposal. (e.g. having a reliable system that detects fatigue and warns me)	0,014	**<u>0,592</u>**	**<u>0,550</u>**
14. The employer needs to provide instruments that can measure fatigue. (e.g. the employer installs a fatigue detection system if he doesn't want me to drive fatigued)	0,060	**<u>0,753</u>**	0,262
15. I would need to have people around me that also refuse to drive when they feel fatigued. (e.g. colleagues that only drive if they are allowed to rest while feeling fatigued)	-0,049	**<u>0,732</u>**	0,003
16. I would need to have more triggers that stimulate me. (e.g. having a system that sends personal messages when I feel fatigued)	-0,003	**<u>0,480</u>**	**<u>0,467</u>**
17. I would need to be encouraged and supported by others. (e.g. the employer states that driving is only allowed without fatigue)	-0,002	**<u>0,788</u>**	-0,027
18. I would need to feel more like I genuinely want to do something about it. (e.g. feeling guilty when I drive with fatigue)	-0,101	0,140	**<u>0,585</u>**
19. I would need to feel more like it is necessary to drive non-fatigued. (e.g. reflecting more about the consequences of fatigued driving)	**<u>0,694</u>**	**<u>0,369</u>**	-0,122
20. I would need to be more convinced that it is beneficial to drive without fatigue. (e.g. having a stronger agreement about the fact that fatigued driving doesn't work in terms of traffic safety)	**<u>0,845</u>**	0,270	0,172
21. I would not only need to have resolutions but also a specific plan to drive without fatigue. (e.g. think about a routine that I can develop)	**<u>0,865</u>**	0,072	0,271
22. I would need to develop a habit not to get behind the wheel whilst feeling fatigued. (e.g. developing a habit to rest when a system informs me that I am fatigued)	**<u>0,690</u>**	**<u>0,358</u>**	-0,064
Mean	3,565	3,720	3,587
Std. Deviation	0,766	0,657	0,539
Chronbach's Alpha	0,911	0,823	0,665
Bold, underlined items are part of the factor and were taken to calculate a mean score and standard deviation for the factor. Items displayed in bold loaded onto the factor but were left out, because it would have resulted in a lower alpha value.			

Regarding factor 1 'Capability', thirteen items loaded on this factor accounting for 30,12% of the variance. Although item 6 and item 12 loaded high on this factor, it was not possible to bring these items back to this factor, due to an increase in the Cronbach's Alpha value with the removal of these items. Because of this, only 11 items were taken into account for the factor 'Capability'. All the items can be easily explained through capability, except for the items 19 until 22. This because the last 5 questions (i.e. item 18 until 22) were compiled with the factor 'Motivation' in mind. The factor analysis shows that the last 5 questions relate more to capability than motivation according to the sample in this study, while the items tried to measure motivation. All 11 items resulted in a high Cronbach's alpha value, assuring a high cohesion between the items and high internal reliability. Several cross-loadings could be found with the different factors, which indicates that some questions are too broad and not specific enough to load onto a single factor.

Factor 2 'Opportunity' included 9 of the COM-B items, resulting in an explained variance of 14,61%. All items showed high internal reliability, which could not be improved with the removal of an item. Because of this, all the 9 items were taken into account for the factor 'Opportunity'. Most of the items relate to the factor for which the questions were designed for, although a higher factor score for item 9 (an item design to measure capability) and the items 19 and 22 (items designed to measure motivation) could be found. All 10 items led to a high Cronbach's alpha value. Here, several cross-loadings were also found, indicating that the specificity could be improved.

Seven items loaded on factor 3 'Motivation', accounting for 9,23% of the variance. Important however concerns the fact that six out of seven items cannot be explained through 'Motivation' because these items were not designed for this factor. Only item 18, which was designed around the factor motivation, loaded on the appropriate factor. Nevertheless, was high internal reliability found between the items, which improved after the removal of item 11. Again, multiple cross-loadings were found, indicating that the questions were not specific enough.

Although cross-loadings were found between the items were all the items relating per factor still incorporated in the factor mean score for further analyses. In general, high alpha values ranging from 0.665 to 0.911 are seen, explaining good cohesion between the different items per factor, as well as higher reliability.

4.4 Reliability analysis of attitudes and current behaviour items

Alongside the COM-B related questions, attitude related questions and questions regarding current behaviour were asked in the questionnaire. There was chosen not to perform a factor analysis because underlying factors were not sought in this case. Here, the reliability analysis was used to determine which attitude related or behaviour related questions were able to capture the attitude of interest or the current behaviour of interest with good reliability. For this analysis, the answering scale of the items 3, 4, 10, 11, 12, 13, 19, 20, and 21 were recoded (i.e. 5 =1, 4 = 2, 3 = 3, 2 = 4, and 1 = 5) to measure the answer in the same direction (e.g. tendency towards a positive attitude). The reliability results are displayed in table 10.

TABLE 10: Reliability analysis results of the attitude and behaviour related questions

Items		Item-total correlation	α if item deleted	Mean
Current behaviour (Cronbach's Alpha = 0,484 / Mean = 3,217 / SD = 0,845)				
1.	I already take a break (e.g. to rest or take a coffee break) when I feel fatigued during driving.	,242	,479	3,91
2.	I don't start my trip (or don't continue driving) when I notice feeling fatigued.	,425	,137	2,70
3.	I'm perfectly capable to estimate my own level of fatigue during driving.	/	/	1,78
4.	Even when I feel fatigued, I find myself perfectly capable to complete my trip, because I know how capable I am at driving with fatigue.	,258	,461	3,04
Openness to change (Cronbach's Alpha = 0,710 / Mean = 3,752 / SD = 0,554)				
5.	I have already thought about trying to drive without fatigue (or taking a break) when I feel fatigued.	,201	,724	4,22
6.	Sometimes I reflect on the fact that driving and fatigue don't go together, and I consider doing something about it.	,577	,638	4,04
7.	I am really trying to change my choice regarding driving with fatigue.	,568	,634	3,22
8.	I hope that someone can give me good advice about driving without fatigue.	,474	,663	3,70
9.	It is easy to say that I will not drive when I feel fatigued, but I will actually try to do something about it.	,739	,599	3,52
10.	It doesn't make sense for me to pay attention to driving without fatigue.	,235	,724	3,78
11.	Trying to drive without fatigue is a waste of time.	,194	,726	3,78
12.	I understand that it is better for me to drive without fatigue, but there is actually nothing I would like to change about the choice to continue driving.	/	/	3,48
13.	After all I have done to change my choice, I notice that the choice to drive whilst feeling fatigued does come forward again.	/	/	2,35
Attitude regarding technology (Cronbach's Alpha = 0,813 / Mean = 3,424 / SD = 0,724)				
14.	The development of technology to reliably detect fatigue in a truck is important.	,358	,813	4,35
15.	Fatigue detection technology in a truck is essential because I am bad at estimating my level of fatigue.	,427	,805	2,74
16.	I am convinced that in-truck technology to detect fatigue can improve traffic safety.	,742	,760	4,09
17.	I would like to have technology in my truck that can detect fatigue, even when it would implicate taking an additional break.	,450	,803	3,22
18.	I trust technology in general in my truck (e.g. GPS, lane-keeping assist, etc.)	,534	,792	3,57
19.	I'd rather have no technology in my truck, because it only restricts myself	,671	,770	3,70
20.	I am more capable to estimate my level of fatigue than technology.	,539	,790	2,78
21.	I'd rather have no technology in my truck, because I have a feeling that it will be used to monitor or penalise me.	,528	,795	2,96
Items which don't give an alpha score in the table were not used to calculate the mean scores, because these items contributed to a significant reduction in the alpha value.				

The reliability analysis shows high and moderately high scores. 3 items were reliable in measuring current behaviour, 7 in measuring the openness to change, and 8 in measuring the attitude regarding technology. In some cases, there was chosen to incorporate an item even when the Cronbach's Alpha value could increase upon removal of that item. This was only done when the marginal added value to the alpha score was small while a contribution by that item was still relevant. This way, as many items as possible could be kept. In general, most items were able to reliably contribute to the measurement of attitudes, current behaviour, or openness to change.

Overall, a positive attitude towards (fatigue-related) technology could be seen. As the mean score of 3,424 is closer to the max score of 5. The same can be said about the openness to change and the performance of the target behaviour (i.e. not driving with fatigue). The mean scores on these 3 main items were used for further analyses, but the individual items were not disregarded either.

4.5 Explorative analyses

After performing the descriptive analyses, factor analysis, and the reliability analyses regarding to the items in the questionnaire, explorative analyses were performed. For this, multiple correlation analyses and differences sought regarding the ESS and FAS scores. This to determine if certain factors had a direct influence on fatigue. But on the other hand, it also gives an insight into the current behaviour and attitudes in relation to the current fatigue level. These analyses are not conclusive, due to the small sample size.

First, an explorative correlation analysis was performed on the personal information gathered in the questionnaire, in relation to the ESS and FAS scores. The results in table 11 show that a small number of significant correlations are found. Age and driving experience correlate high at the 0,01-significance level, which can be explained through the fact that experience was asked in terms of the number of years a person held a license (i.e. a person with a higher age can have more years of experience in driving). On the other hand, does the FAS score correlate with age and the ESS score at the 0,05-significance level. A higher FAS score gets achieved when a person gets younger, for which an explanation has to be found, and a higher FAS score is also achieved with a higher ESS score, which is in line with a higher level of fatigue when sleepiness is present.

TABLE 11: Correlation analysis between the ESS/FAS scores and personal information

Correlations						
		Age	Driving experience	Exposure	ESS Total score	FAS Total score
Age	Pearson Corr.	1				
	Sig. (2-tailed)					
Driving experience	Pearson Corr.	**,913**	1			
	Sig. (2-tailed)	,000				
Exposure	Pearson Corr.	,185	,216	1		
	Sig. (2-tailed)	,399	,322			
ESS Total score	Pearson Corr.	-,287	-,160	,083	1	
	Sig. (2-tailed)	,185	,465	,705		
FAS Total score	Pearson Corr.	**-,422**	-,319	-,188	**,506**	1
	Sig. (2-tailed)	,045	,138	,390	,014	

Furthermore, table 12 shows multiple independent sample t-tests between the ESS and FAS scores in relation to gender, whether or not the participant smokes, and medication usage. The results from these analyses show no significant differences between both sample means. It is important to mention that the sample size for each variable category is strongly differing.

TABLE 12: t-test between the ESS/FAS scores and the personal information

Independent Samples T-Test Gender								
		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	S.E. Diff.
ESS Total score	Equal variances assumed	,002	,964	1,404	21	,175	2,526	1,800
	Equal variances not assumed			1,442	4,483	,215	2,526	1,752
FAS Total score	Equal variances assumed	3,850	,063	-,747	21	,464	-2,000	2,679
	Equal variances not assumed			-1,436	18,951	,167	-2,000	1,392

Independent Samples Test Smoking								
		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	S.E. Diff.
ESS Total score	Equal variances assumed	1,731	,202	-,354	21	,727	-,508	1,435
	Equal variances not assumed			-,332	13,836	,745	-,508	1,531
FAS Total score	Equal variances assumed	2,190	,154	-1,094	21	,286	-2,208	2,019
	Equal variances not assumed			-1,044	15,498	,312	-2,208	2,114

Independent Samples Test Medication								
		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	S.E. Diff.
ESS Total score	Equal variances assumed	,859	,365	-,994	21	,331	-1,421	1,429
	Equal variances not assumed			-,978	16,278	,342	-1,421	1,452
FAS Total score	Equal variances assumed	,193	,665	-,713	21	,484	-1,484	2,083
	Equal variances not assumed			-,699	16,130	,494	-1,484	2,123

Next, two ANOVA analyses were performed, displayed in table 13. Both analyses show that no significant differences were found between the FAS and ESS scores and whether or not a driver works out or drinks coffee.

TABLE 13: ANOVA between the ESS/FAS scores and the personal information

ANOVA Working Out					
FAS - Total score					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	33,947	3	11,316	,450	,720
Within Groups	477,271	19	25,120		
Total	511,217	22			
ESS - Total score					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	44,743	3	14,914	1,409	,271
Within Groups	201,083	19	10,583		
Total	245,826	22			

ANOVA Caffeine intake via coffee					
FAS - Total score					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	90,551	3	30,184	1,363	,284
Within Groups	420,667	19	22,140		
Total	511,217	22			
ESS - Total score					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	49,409	3	16,470	1,593	,224
Within Groups	196,417	19	10,338		
Total	245,826	22			

Lastly, a correlation analysis was performed between the ESS and FAS scores in relation to the current behaviour, openness to change, and attitude towards technology. The results in table 14 only show one additive correlation, next to the correlation between the ESS and FAS scores, that already had been found. A correlation between the current behaviour and attitude towards technology could be found at the 0,01-significance level. It states that a positive feeling towards technology in a truck positively relates to the current behaviour in line with the target behaviour (i.e. taking a break when feeling fatigued). Thus, stating that drivers with a positive feeling towards technology are more likely to perform the target behaviour and vice versa.

TABLE 14: Correlation analysis between the ESS/FAS scores and attitudes/current behaviour

Correlations						
		ESS Total score	FAS Total score	Current Behaviour	Openness to change	Attitude technology
ESS Total score	Pearson Corr.	1				
	Sig. (2-tailed)					
FAS Total score	Pearson Corr.	**,506**	1			
	Sig. (2-tailed)	,014				
Current Behaviour	Pearson Corr.	,079	,111	1		
	Sig. (2-tailed)	,721	,615			
Openness to change	Pearson Corr.	,086	,165	,070	1	
	Sig. (2-tailed)	,697	,451	,752		
Attitude technology	Pearson Corr.	,092	-,126	**,536****	,163	1
	Sig. (2-tailed)	,676	,568	,008	,456	

With regards to other explorative correlation analyses, no correlations were found between the age and gender of the participant in relation to the COM-B factors, current behaviour, openness to change, and attitude towards technology. Also, no significant correlations were found between the ESS and FAS scores in relation to the COM-B factors.

4.6 Qualitative results

Given the small sample size, it is not sufficient enough to only look at the factor and reliability analysis together with the correlation analyses. The sample mean in this case deviates too much to have a perfect reliable mean, which is very common in small sample sizes. Therefore, the results from the questionnaire are briefly qualitatively discussed. A summary of the frequencies of the chosen answers regarding the COM-B items, current behaviour items, openness to change items, and attitude towards technology items, is added in the annex.

4.6.1 COM-B items

For the factor 'Capability', items 1 and 2, both relate to knowledge as a psychological aspect of capability. For these two items, a tendency of higher scores can be seen regarding a lack of knowledge to facilitate the behaviour. Drivers indicate that they would like to have more knowledge about the problem and how it can be foreseen, in order to perform the target behaviour. On the other hand, items 3, 5, 7, and 9 relate to physical strength and endurance as a part of the physical factor of capability. Here, a tendency of more neutral to higher scores is present, also indicating that drivers would like to have more physical strength and endurance to be able to perform the target behaviour. Lastly, regarding the factor capability, items 4, 6, 8, and 10 have a tendency of neutral responses for mental skills and endurance regarding the psychological factor of capability. Although higher scores are also seen, a more neutral tendency can be made up of the answers. Indicating that drivers do not necessarily need to have better mental skills to facilitate non-fatigued driving.

Regarding the factor 'Opportunity', small differences can be detected between social (i.e. items 15, 16, and 17) and physical opportunity (i.e. items 11, 12, 13, and 14). While both subdivisions of the factor opportunity tend to be higher, indicating that social and physical opportunities need to improve to perform the target behaviour, do the scores of social opportunity tend to be even higher with less neutral opinions. Drivers thus indicate that both types of opportunity would need to be better to perform the target behaviour, where the social aspect is even more important. This in terms of encouragement, support, and lead by example of others.

For the factor 'Motivation', differences between automatic (i.e. items 18 and 22) and reflective motivation (i.e. items 19, 20, and 21) are absent. The answers tend to be very high with less neutral opinions. Drivers indicate that they would need to develop a stronger motivation to perform the target behaviour, with no differences between automatic motivations and reflective motivations.

4.6.2 Current behaviour - openness to change - attitude towards technology

Similar to the previous section, the items regarding current behaviour, openness to change, and attitude towards technology are assessed qualitatively. However, an important difference between scores in the annex and the reliability analysis mean scores has to be mentioned. While the annex shows the results from the questionnaire, the reliability analysis tried to measure the reliability of the items with regards to the subject together with a calculation of the mean score. This mean score represents a score concerning the positive orientation of the questioned item, for which multiple item scales had to be inverted (e.g. for current behaviour some items were inverted, so that all items described a positive current behaviour when a score would be closer to 5). This was done to make sure that all question items could be measured in the same direction in favour of the positive outcome. (e.g. items 1 and 4 of current behaviour had an answering scale that is oriented opposite of the other items regarding positive current behaviour. For this reason, the item scale was reversed for these items to measure positive current behaviour in the same direction, to perform the reliability analysis). The results from both tables, can thus not be compared directly.

Regarding current behaviour, the reliability analysis showed that positive behaviour could already be seen within the participant. However, looking at the questionnaire results, caution is needed. Drivers indicate that they already take a break when they feel fatigued. While this lays in line with the positive mean score of the target behaviour, do the subsequent items contradict this. Nearly all drivers find themselves perfectly capable in detecting their own level of fatigue. Furthermore, do the majority of the drivers think that they are perfectly capable to complete their trip, even when feeling fatigued. They also do indicate to still start their trip even when they already feel fatigued before they get behind the wheel. This shows that the mean score from the reliability analysis is not conclusive.

With regards to the openness to change, the results are more in line with the reliability mean score. Drivers indicate that they are open to change and know that driving without fatigue is important, although they indicate not knowing how they could do it. This is complementary with the findings regarding the COM-B model, where they indicated having a lack of knowledge. Nevertheless, is it noticeable that a lot of drivers indicate already haven taken actions to change their choice about driving with fatigue, while still tending to relapse.

Lastly, the attitude towards technology was assessed. While the mean score of the reliability analysis showed a positive attitude for fatigue detection technology, are the answers from the questionnaire less clear. It stands out that opinions differ greatly and that opinions regarding different items, nearly questioning the same aspect, differ as well. While there is a tendency of a positive attitude regarding the necessity of current in-vehicle technology and the development of in-vehicle fatigue detection technology, do a lot of participants indicate that they would be better in estimating their level of fatigue than technology. Also, do they indicate that they are afraid of getting penalised.

4.6.3 Coping strategies

Finally, are the coping strategies to combat fatigue briefly discussed that drivers indicate to use. For this, figure 14 can be used. Most drivers (i.e. 73,9%) indicate that they take a break and rest to combat their fatigue. On the other hand, other strategies are also used to specifically combat fatigue, such as drinking coffee, smoking, drinking energy drinks, performing physical exercises, and working out. Taking drugs, drinking alcohol, or taking medication is not being done by the participants. Also, do nearly all drivers indicate to perform self-initiated strategies to combat fatigue (e.g. opening a window, putting the air-conditioning on, putting the radio on, etc.), and did thirteen drivers indicate performing other made-up strategies than indicated by the questionnaire.

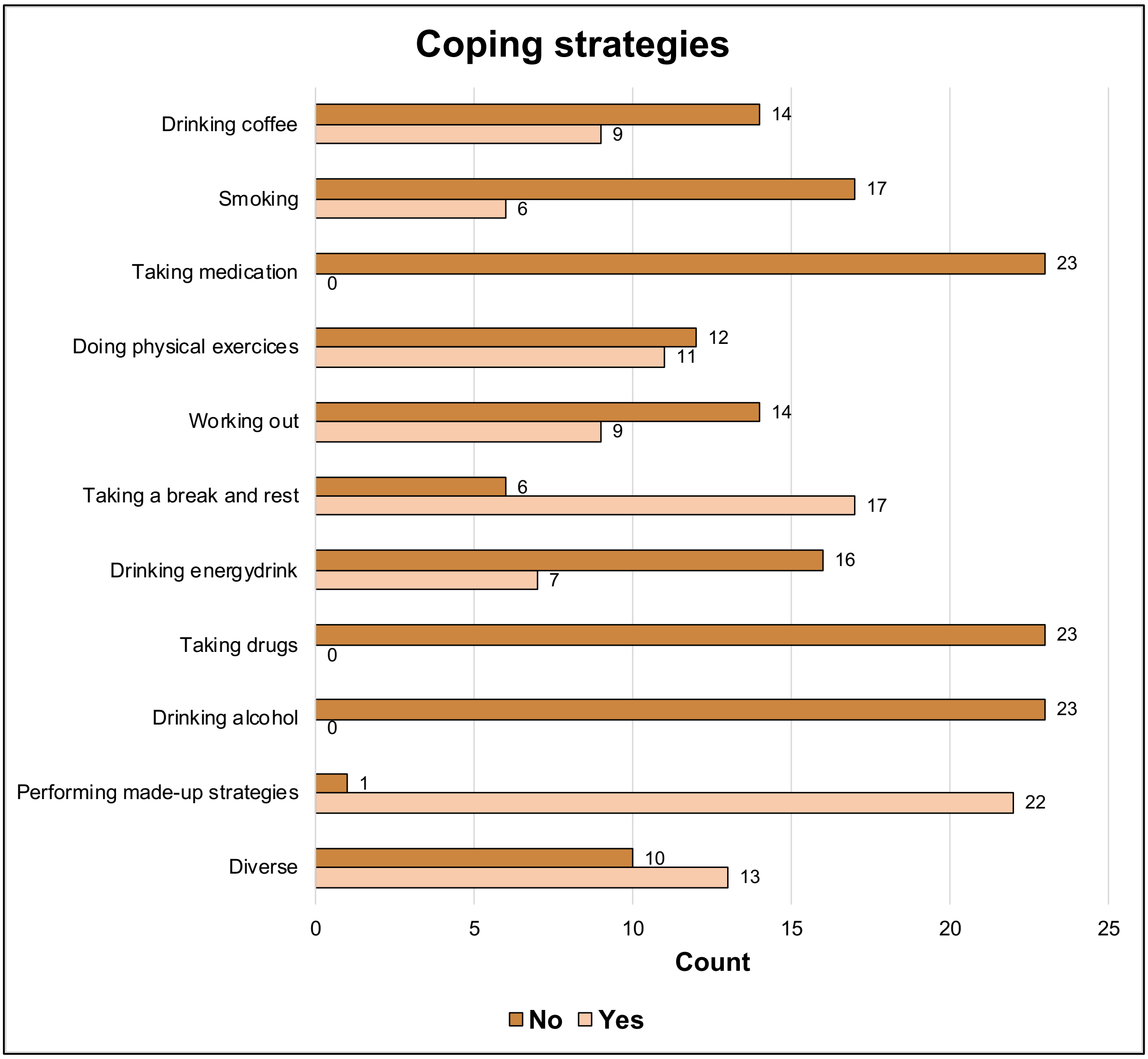


FIGURE 14: Coping strategies to combat fatigue according to truck drivers

5 DISCUSSION

5.1 Fatigue in truck drivers

In this study, the misinterpretation about fatigue was addressed in order to discuss the aspects as precisely as possible. This because other studies often discuss the concepts without a proper distinction. However, this is especially important for truck drivers, where fatigue is often treated in general to discuss truck-related accidents. This led to the use of fatigue (i.e. a biological drive for recuperative rest which is a gradual and cumulative process) and sleepiness (i.e. a drive for sleep where it is difficult to stay awake, even when carrying out activities) as separate constructs in this research.

The literature review revealed that fatigue, in this manner, is influenced through circadian factors, homeostatic factors, task-related factors, and personal characteristics, which can be divided into SR and TR-fatigue inducing factors. The circadian rhythm aligns with sleep periods throughout the 24-hour day (i.e. at night and in the early afternoon), which is a variable factor in truck driving. This because the profession results in driving at various times throughout the day. On the other hand, homeostatic factors are also largely present in truck drivers. Factors, such as sleep deprivation, sleep restriction, extended time awake, sleep disorders, and medical conditions lead to an improper rest or sleep, resulting in fatigue even after a break. Due to the stress of the job, lack of healthy behaviour, pressing deadlines, etc. can these homeostatic factors have an important share in the reason of developing fatigue (Häkkänen & Summala, 2001; McCartt et al., 2000; Stutts et al., 2003; A. Williamson et al., 2011). Also, do task-related factors, such as time-on-task and workload, play an important role in fatigue, as truck driving can be seen as a profession with long working hours and a high workload. This finding is supported by the violation of the legal daily driving hour limits as discussed by Temmerman et al. (2016), which is a result of long and heavy working days, facilitating fatigue. Lastly, personal characteristics often consolidate fatigue. As demographic characteristics, lifestyle, and life choices of the driver can lead to the development of potential sleep disorders and medical conditions, and eventually fatigue.

Obviously, this fatigue can lead to different changes that occur within fatigued individuals. It has different effects, potentially leading to dangerous consequences due to performance decrements. As Pack et al. (1995) state, effects such as longer reaction time, vigilance reduction, deficits in information processing and performance lapses are common, and do the consequences depend on the environment that a person is in. It becomes clear that driving, in this case, is perhaps the most dangerous environment wherein a person can be situated, which can be disastrous for truck drivers, because they tend to drive most of the day. This accentuates the importance of the determination of fatigue via either direct observations or self-reported fatigue, in order to lower the chance of performance decrements due to fatigue. For direct observations, multiple detection methods can be used to detect fatigue. However, a reliable and simple system still has to be developed. Questionnaires, on the other hand, can be used to have a self-reported indication of fatigue. For this are the ESS and FAS questionnaires very reliable measures, therefore used in this research.

As literature widely varied in terms of the contribution of fatigue in truck crashes, typical ranges were seen between 3% up to 20% (A. Williamson et al., 2011). Although this figure tells something about the role of fatigue in truck crashes, is it still unclear how many drivers feel fatigued during driving with and without having a crash. It is convincing that the number of drivers that drive fatigued is substantially higher than the percentual contribution of fatigue in crashes. This percentage can thus underestimate the problem of fatigue in drivers, which has also been found by Sagberg (1999), who reported an underestimation of fatigue in police reports. The underestimation of fatigue can be underpinned by the results of this research. The results showed that sleepiness was not an imminent problem within the sample. The ESS scores were rather low with only one participant having a higher sleepiness level than normal. For fatigue, on the other hand, the situation was different. Although FAS-scores were not very high, was fatigue present within truck drivers by means of this subjective fatigue detection method. Fatigue was measured in 8 out of 23 participants (i.e. 34,78%) indicating that fatigue is indeed present within truck drivers. Extreme fatigue was completely absent in the sample. This indicates that the percentage of fatigued truck drivers is higher than the percentual contribution determined by fatigue-related crashes. Therefore, indicating that the problem is more than substantial. This finding can be supported by McCartt et al. (2000), where was found that almost one-half of long-distance truck drivers (47.1%) traveling New York's roadways reported having fallen asleep at the wheel of their truck, and 25.4% reported falling asleep at the wheel on at least one occasion during the year. While this figure does not make it able to make any statements about the fact if many drivers drive with fatigue without noticing it, there can be supposed that a possibility arises where drivers get behind the wheel without even noticing their fatigue.

With regards to the fatigue-inducing factors, the circadian factor as well as homeostatic factors and task-related factors could not be easily implemented in this research. This because the questionnaire did not lend itself to capture these factors. Task-related factors weren't questioned either, because the profession itself is already intensive for every driver, with small mutual differences between drivers. However, the homeostatic factors, sleep disorders, and medical conditions were questioned. The results showed that these factors were not present within the drivers.

In terms of personal characteristics, further analyses were not able to find any important influence on fatigue, except for the age of the participant. A correlation analysis showed that age correlated significantly with the FAS-score, indicating that a lower age contributed to higher fatigue. This contradictory effect was also found by (Dolan & Kudrna, 2015) and (Engberg et al., 2017). In a general fatigue study in Sweden by Engberg et al. (2017), an explanation was sought via the relatively economically stable, healthy and unstressful life of elderly people. However, the effect was seen across ages without any threshold effect after retirement, therefore stating that other unmeasured causal factors were present, other than retirement. The same applies to this sample, due to the fact that only drivers from the working population participated in the study, making it impossible to have an influence of retirement on the reduction of fatigue. Dolan & Kudrna (2015), on the other hand, suggested that fatigue is not an inevitable aspect of ageing regardless of health status, where symptoms of tiredness are indicative of an underlying physical or mental condition. They stated that the presence of a disease or lifestyle choices surrounding time or activity management could be responsible for the relationship between age and tiredness. This finding clarifies the fact that other possible causal factors can be various in terms of time and activity management for truck drivers, because diseases were not present in the sample of this study. Possible assumptions for this can be sought in busier workdays due to the lack of financial stability at a younger age, or the decline in a busy social life at increasing age.

5.2 Attitudes and current behaviour

Attitudes and current behaviour questions gave more insight into the current rationale of respondents concerning fatigue. The reliability analysis of the attitude items showed that most items were reliable in measuring the openness to change from the drivers. The same applied to the current behaviour of drivers in terms of non-fatigued driving. This reliability analysis showed that a positive attitude regarding the openness to change was present as well as current behaviour corresponding with the target behaviour (i.e. taking a break when feeling fatigued, to drive without fatigue). Nevertheless, were correlations between openness to change, current behaviour, ESS-scores, and FAS-scores absent in relation to the calculated mean scores from the reliability analysis. The qualitative analysis, inevitable due to the small sample size, covered further insights where the reliability analysis was too general.

Regarding the openness to change, the results of the qualitative analysis were congruent with the reliability mean score. In accordance with Häkkänen & Summala (2001), which indicated that truck drivers themselves generally believe that driver fatigue is a problem for the industry, did drivers indicate in this study to acknowledge the importance of driving without fatigue, while being open for change regarding their behaviour. However, they did indicate having insufficient knowledge about the way they can drive without fatigue, indicating that the willingness is high but knowledge about implementing the behaviour is absent. This is supported by the finding that drivers indicated having already taken actions to change their choice about driving with fatigue, while indicating having relapses in unwanted behaviour. This can be brought back to the transtheoretical model of change regarding health behaviour by Prochaska & Velicer (1997). The participating truck drivers can, in this case, be situated in the action taking phase of the transtheoretical model of change, because drivers have made specific actions in modifying their problem behaviour to new healthy behaviour. However, do they fail into moving to the maintenance phase since drivers indicated having relapses in their behaviour. A lack of insufficient knowledge about the way the healthy behaviour (i.e. driving without fatigue) can be achieved, leads to wrong coping intentions, and therefore relapses, since fatigue couldn't be reduced.

Concerning current behaviour, the reliability analysis showed that drivers already implement the positive target behaviour (i.e. taking a break when feeling fatigued, to drive without fatigue). The qualitative analysis on the other hand showed that, while drivers indicate taking a break whilst feeling fatigued, nearly all drivers found themselves perfectly capable of detecting their own level of fatigue. Furthermore, the majority of the drivers was convinced that they were perfectly capable to complete their trip with fatigue and did they indicate still starting their trip even when they already felt fatigued before they got behind the wheel. This is supported by Häkkänen & Summala (2001), which stated that drivers develop a strong subjective control in terms of fatigue, feeling they can manage the task despite some 'lapses' now and then. However, the literature review in this study already proved that this subjective estimation is inaccurate since performance lapses and accidents still occur frequently. This indicates that drivers only tend to take a break when fatigue levels get dangerously high.

The importance of this finding lies in the relation between the current behaviour and openness to change. While drivers indicated having a strong willingness to change in terms of driving fatigued, the current behaviour showed that they still find themselves perfectly capable in estimating their level of fatigue and being able to cope with fatigue. Revealing that the mindset of drivers contradicts itself, without them realising this, of which the lack of knowledge can be an important factor. However, the constructed questionnaire also benefits from this contradiction, since it was able to capture the contradicting behaviour and attitude without creating cognitive dissonance within the participant, which according to Festinger (1957), can ultimately lead to an attitude change.

5.3 Facilitating target behaviour

While the items regarding current behaviour and openness to change gave an insight in the current performed behaviour and attitude towards changing the behaviour, these items lacked the ability to unravel the reason behind the non-performance of the target behaviour. Therefore, the COM-B model was used as a base for identifying underlying factors that facilitate the target behaviour. So that the behavioural aspect of fatigued driving could be studied in more detail.

The factor analysis was able to extract the six underlying factors from the behaviour change wheel model (i.e. the three main sources of behaviour with their subdivision), indicating that the questions were able to capture the underlying factors from the BCW in terms of fatigue. Further, did a second factor analysis performed with three fixed factors, representing the COM-B model components (i.e. ‘capability’, ‘opportunity’, and ‘motivation’), make a classification of the items possible. This together with high factor loadings and high internal reliability of the items in relation to each factor. However, did this factor analysis also show multiple cross-loadings per factor, and were the items constructed for the factor ‘Motivation’ not able to capture this factor, due to irrelevant factor loadings (i.e. the items, except for one, constructed for the factor motivation loaded onto the different factors). While these cross-loadings and wrong factor loading were present in the analysis, the analysis shows that the items were constructed with the right mindset, since the items regarding capability and opportunity were validated by the factor analysis. However, problems with these cross-loadings and wrong factor loadings could not be disregarded. A possible explanation can be sought through several aspects such as a problem in terms of the specificity of the items, the understandability of the questions, the given examples for every item (i.e. interviewer bias), or the small sample size.

The factor analysis and accompanying reliability analysis regarding the COM-B questionnaire showed that the underlying factors for facilitating the target behaviour were overall more negatively oriented. The mean scores were high per factor, indicating that drivers had some problems regarding the facilitating factors (e.g. a mean score of 3,565 on the factor capability, with a max score of 5, indicates that drivers would like to have better capabilities to be able to drive without fatigue). However, this mean score cannot be seen as conclusive due to the small sample size, wrong factor loadings, and cross-loadings, imposing the need for the qualitative assessment of the items and accompanying answers.

The qualitative analysis regarding the factor ‘capability’, showed that physical strength and endurance, as a part of the physical factor of capability, contributed to a problem in facilitating the target behaviour. Drivers would like to have more physical strength and endurance to be able to perform the target behaviour. However, concerns the fact that most of the drivers (i.e. 69,6%) indicated not to workout, which in contrast has been proven to enhance strength, endurance, and health in general (Haskell et al., 2007). Drivers could thus easily improve their physical strength and endurance, to facilitate the target behaviour by starting to exercise regularly. Further, a lack of knowledge to facilitate the target behaviour was noted. Drivers indicated wanting to have more knowledge about the problem of driving fatigued and how it can be eliminated in order to perform the target behaviour. This complies with the earlier finding within the openness of change, where a lack of knowledge led to wrong decision making and relapses in the target behaviour. For mental skills and endurance, regarding the psychological factor of capability, drivers indicated not necessarily needing to have better mental skills to facilitate non-fatigued driving.

As for the factor ‘opportunity’, small differences between social, and physical opportunity were present. Drivers indicated that both types of opportunity needed to be better in order to perform the target behaviour. A bigger importance to the social aspect was indicated in terms of encouragement, support and example behaviour of others. In terms of ‘motivation’, differences between automatic and reflective motivation were absent. Drivers indicated the need to develop a stronger motivation to perform the target behaviour, with no differences between automatic motivations and reflective motivations.

Although, in general, the mean scores of the factor analysis of the COM-B questionnaire gave a good image of the potential factors that influence the performance of the target behaviour. Showed the qualitative analysis the importance and influences discussed by the behaviour change wheel. The qualitative interpretation of the results from the COM-B model questionnaire showed that it would not be beneficial in terms of interpretation, when only an assessment of the factor mean scores would have been conducted. This becomes even more clear for the factor ‘Capability’, where knowledge and physical capability play a more important role than the psychological capability with regards to mental skills. Noteworthy however, concerns the fact that this qualitative analysis was necessary to correct for the small sample size, which made the factor analysis less reliable.

While this qualitative analysis showed that knowledge and physical strength with regards to capability, physical and social opportunity, and both types of motivation were key factors in the non-performance of the target behaviour, does it have to be unravelled why this occurs in further research. The lack of knowledge can for example be explained through a lower level of education, low interest in the topic, absent communication between employers and their drivers, etc. While the lack of physical strength can result from barely working out, which on its turn, can be influenced through the workload of the job, shortage of time, physical problems, etc. It is of course also necessary to take into account the feasibility of these aspects.

The behaviour change wheel defined interventions that can be performed in order to tackle the non-performance of the target behaviour in terms of the facilitating factors. Since a lack of knowledge has been indicated as a factor that hinders the target behaviour, the BCW shows that education and training are able to resolve this problem (enablement in this case not, because this regards to mental skills in terms of physical capability). For physical strength, on the other hand, enablement and training are interventions that can be used. With regards to physical and social opportunity are restriction, environmental restructuring, and enablement appropriate for both types of opportunity. For motivation, differences between reflective and automatic motivation were absent, meaning that interventions are best used when they are able to influence both types of motivation simultaneously, which is the case for persuasion, incentivisation, and coercion. In order to define strategies to work the interventions in hand, are the policy categories form the behaviour change wheel important, so that eventually the intervention will be effective and target behaviour will be provoked and made possible to continue. This way, a new level in the transtheoretical model of change can be achieved (i.e. the maintenance or termination phase), making sure that fatigued driving will be eliminated.

5.4 Coping against fatigue

Coping against fatigue can be done in different ways of which man-made solutions, increasing arousal or activation, exercising, and technology are often used. As the literature already covered, it is important to cope with fatigue with regards to the causes of fatigue (i.e. reducing workload, reducing time-on-task, take into account the circadian rhythm, have a healthy lifestyle, etc.). Nevertheless, different strategies are used by drivers to cope with this fatigue.

The questionnaire revealed that drivers often take a break and rest, or drink coffee to cope with their fatigue. Still, do a lot of drivers indicate that they performed self-initiated strategies, such as smoking, drinking energy drinks, putting the AC on, blasting the radio, rolling down the window, talking on the phone, singing, etc. As May & Baldwin (2009) indicated in their research, only naps and caffeine are effective in producing a reduction in driver fatigue. It can thus be seen detrimental that most drivers indicate performing self-initiated strategies to combat fatigue, while these are not effective in reducing it. Exercising is done by a small number of drivers to combat fatigue, but as discussed earlier do most drivers not perform any form of physical exercise. Further, divers indicate not to use alcohol, medication, or drugs to combat their fatigue behind the wheel. While this can be seen as a positive evolution, is it important to take socially desirable answering into account. As Arnold et al. (1997) found in their study that some drivers took alcohol, medication, or drugs to combat their fatigue, which can still be possibly done by drivers nowadays.

As legal resting and driving times are already used for several years, it can be overlooked if problems from measures taken in the past still arise. The qualitative analysis showed that, while the legal driving limits were set to combat fatigue, most drivers indicate that the legal driving limit is one of the many factors that can induce fatigue. They indicated that these legal driving limits often conflict with the job, leading to longer working days, fewer revenues, and higher work pressure. Because of this, sleep is lost which works fatigue and sleepiness in hand. They admitted sometimes surpassing the legal daily driving limit or conflicting with the daily driving limits if they would need to take a break. This corresponds with Braver et al. (1992), as cited in (Häkkänen & Summala, 2001), who found that nearly three-quarters of the surveyed truck drivers violated the regulation, for which the primary reason for violation was economic. Of course, most of these problems can be resolved if employers and big transport companies refrain from taking small marginal revenues per trip to keep the costs low.

5.5 Technology

As countermeasures can be based on objective driver-performance, is an ongoing need to develop tools for reliably detecting driver fatigue initiated (Forsman et al., 2013). This is done through the development of technological, in-car countermeasures (Häkkänen & Summala, 2001), based on physiological measures (e.g., eye movements), vehicle dynamics, or a combination of both of these measures (Liu et al., 2009). Carmakers are developing technologies to monitor car-based metrics of driving performance so that the driver can be warned in advance. Technology can be used in terms of technological aids in order to measure and warn for fatigue. While this is not a direct form of coping, it can still help drivers to cope with fatigue, as drivers can perform one of the proven coping strategies to combat fatigue when a warning had been given by the technological aid. The technology can create arousal and possibly activation but is not used to keep driving with a fatigued feeling. The foundation for this technology rests in creating awareness to cope with fatigue.

Questions related to in-vehicle technology were incorporated into the questionnaire to gain more insight into the current rationale of respondents. The reliability analysis of the technology items showed that all items were reliable in measuring attitude towards in-vehicle technology, also indicating that a positive attitude regarding in-vehicle technology was present. Further, a strong correlation was found between the mean score from the reliability analysis regarding the attitude towards technology and the mean score regarding current behaviour. This correlation analysis showed that a positive attitude towards technology is achieved when current behaviour is more in line with the target behaviour (i.e. not driving while feeling fatigued), and vice versa, stating that drivers who tend to perform healthy behaviour, also have a more favourable opinion about in-truck technology. The positive mindset and openness due to healthy behaviour can thus influence the support for in-vehicle technology. On the other hand, this indicates that people tend to despise in-vehicle technology when their behaviour is not in line with model behaviour. This can be supported by the aggregation principle of (Eagly & Chaiken, 1993), which states that while a general attitude (e.g. fatigued driving is dangerous) is typically only a weak predictor of a single behaviour (e.g. taking a break), such an attitude can be a relatively good predictor of the general tendency to engage in behaviours relevant to the attitude object (e.g. to engage in various behaviours to help diminish fatigue behind the wheel, such as supporting in-vehicle fatigue detection technology). Furthermore, it can be possible that this correlation was found due to the fact that drivers already had a fatigue-related incident, making it personally relevant, which can influence attitudes as well according to (Liberman & Chaiken, 2016). Nevertheless, here a qualitative analysis was also performed, which covered further insights where the reliability analysis was too general.

The qualitative analysis showed varying results in contrast with the mean score of the reliability analysis. Opinions differed greatly between multiple questions, even when certain items nearly questioned the same aspect. While there was a tendency of a positive attitude regarding the necessity of current in-vehicle technology and the development of in-vehicle fatigue detection technology, did a lot of participants indicate being better of estimating their level of fatigue than technology. This corresponds with the findings of current behaviour, where drivers indicated being perfectly capable in estimating their own level of fatigue. Also did this match with the findings of Häkkänen & Summala (2001), which stated that drivers believe they develop a strong subjective control, by which they think that the task can still be handled despite some ‘lapses’ now and then. Further, drivers indicated that they are afraid that the system will register everything they do, resulting in a fear of getting penalised.

While drivers are positively oriented towards fatigue, many misconceptions are still present. The fear of getting penalised can only disappear if the driver knows exactly what the capabilities of the system are, and when transparent communication is performed. Furthermore, the drivers need to get acquainted with the fact that this technology will be better in estimating the level of fatigue than their own judgmental skills. An important finding however concerns the contradiction from Häkkänen & Summala (2001). Their research claimed that nearly half of the drivers questioned expressed a negative view towards the development of possible technological countermeasures to cope with driver fatigue. The qualitative analysis in this research shows the opposite, which can be explained through the trust that has been gained in terms of technology since the latest years and exposure to technology in trucks nowadays.

Nevertheless, is attention for risk compensation necessary, as people tend to increase their perceived level of risk when a safer situation is created (Fuller, 2005). This effect has been found in terms of multiple in-vehicle technology systems such as airbags and anti-lock braking (Hertz et al., 1995; Peterson et al., 1995; Sagberg et al., 1997).

5.6 Limitations

While this study was able to give insights into the aspect of fatigue within truck drivers, the validity and reliability of this study are two important limitations. The questionnaire was able to capture attitudes and current behaviour as foreseen, but due to the small sample size was an impact on the reliability of the statistical analyses present. This led to different choices in analyses methods and problems in reliably strengthening the validity of this research. These analyses are therefore not conclusive, leading to the fact that extrapolation to the population cannot be done easily. Caution in the interpretation of the results is needed. However, was this research a first step in studying the reason behind fatigued driving.

Further is the time interval between the conduction of both questionnaires another limitation. Both questionnaires were conducted a month separate from each other, in which the situation from the near past could be changed. ESS and FAS scores were questioned a month in advance relative to the attitudes, current behaviour, and facilitating factors. The possibility arises that drivers' attitudes, current behaviour and facilitating factors had a change within that same time period.

Relative to the ESS and FAS scores is an objective measurement of fatigue a missing factor. While the ESS and FAS scores are valid subjective fatigue measuring tools, can an objective measurement of fatigue be used as a control measure. Answers on the ESS and FAS scores could thus easily be filled in socially desirable for which a validation couldn't be performed in this study, due to the lack of an objective fatigue detection method. Furthermore, it is possible that coping strategies specified by the drivers, where answered socially desirable.

Lastly, a lot of positively oriented drivers were present in the sample. This because motivated truck drivers applied for the original research, already showing a positive mindset concerning traffic safety. This led to a decrease in capturing certain behaviours by drivers who do not care about traffic safety (e.g. taking medication or drugs to stay awake behind the wheel). Further, could this positive mindset have also resulted in positive attitudes about in-vehicle technology, while the general population was known in the past as being hesitant about technology in the vehicle as discussed by Häkkänen & Summala (2001). This effect can be seen as a self-selection bias. However, this does not implicate that certain barriers are absent with regards to performing the target behaviour.

5.7 Recommendations

A new study, which deals with limitations of this research and further studies the facilitating factors to perform healthy behaviour, is recommended. The usage of a bigger sample can hereby be seen as most important. This will make sure that more reliable analyses can be performed, so that extrapolation to the truck driving population can be made. In that case, is a sample necessary that fully represents the truck driving population. This means attracting drivers with different opinions and behaviours to lower the chance of a self-selection bias with regards to positively or negatively oriented drivers.

Furthermore, it is recommended to perform studies with a focus on fatigue detection technologies, to make further development of reliable and objective fatigue measuring systems possible. For this, the other study defined in this research can be used as a base. Solutions, such as creating arousal and activation through technological devices, can be studied to help drivers detect their level of fatigue, in order to combat fatigued driving.

A re-evaluation of the legal driving limits and resting times is also recommended. The transport sector evolves in a rapid tempo, leading to legislation that is running behind. In addition, many drivers indicate that the legal resting times make the time-on-task and workload even higher during a workday. Because these factors are prone to facilitate fatigue, is a re-evaluation necessary.

Lastly, it might be beneficial to study the possibilities of integrating human health in the development of fatigue detection systems (and other systems that are being developed for driver safety). Monitoring the human body for certain diseases and problems (e.g. impending heart failure, epileptic seizures, high amounts of stress, etc.) could be integrated into these systems, to support healthcare in general.

5.8 Implications

While this study implicates that drivers have problems in regard to the performance of healthy behaviour (i.e. taking a break when feeling fatigued, to drive without fatigue) is it important that drivers are not held solely accountable. Employers need to get involved and committed as well in this situation. If the driver wants to take measures to drive without fatigue, without the support of the employer and a decent driving schedule, will it become nearly impossible for drivers to perform this healthy behaviour. Most truck drivers indicate that taking an additional rest break, due to feelings of fatigue, is nearly impossible due to the high work pressure. This responsibility lies with the employer and the transport sector as a whole. The shift needs to be made from a mere economic and profit motive to a well-balanced motive between traffic safety and economics. Truck drivers must be rewarded for the performance of healthy behaviour in terms of traffic safety, not punished.

6 CONCLUSION

As fatigue is often wrongly interpreted, it can be described as a biological drive for recuperative rest. It relates to both physiological and psychological processes and can be seen as a gradual and cumulative process that disappears after a period of rest. Causes of fatigue relate to personal characteristics (i.e. age, usage of medication, being overweight, insufficient exercise, etc.), the circadian rhythm (i.e. the time of day effect), homeostatic factors (i.e. sleep deprivation, sleep restriction, extended time awake, sleep disorders, and medical conditions), and task-related factors (i.e. time-on-task and workload), making it able to subdivide fatigue into sleep-related and task-related fatigue (active or passive fatigue). It is associated with a disinclination towards effort and decreased capacity to perform, eventually resulting in performance decrements. The difference between sleepiness lies in the fact that fatigue disappears after rest, while that is not the case for sleepiness, as sleepiness only disappears after a period of sleep.

The relation with the professional driving context lies in the different causes of fatigue, as truck drivers often suffer from sleep-related problems (i.e. sleep disorders, sleep deprivation, sleep restriction, medical conditions, and extend time awake) and task-related pressure (i.e. a high workload and a long time-on-task). Furthermore, their living style does not contribute to a healthy situation, resulting in sleep-related problems, and excessive fatigue. This all leads to daytime sleepiness, vigilance reduction, longer reaction times, deficits in information processing, and performance lapses. Resulting in fatigue-related crashes, of which head-on collisions, crashes in the same driving course and drive-off-the-road crashes are most often seen. The consequences of these crashes are also more severe due to the higher vehicle mass and lack of action taking due to falling asleep.

Fatigue can be influenced through, on one hand, the factors that are associated causing fatigue (i.e. personal characteristics, circadian rhythm, homeostatic factors, and task-related factors), as well as three different aspects which increase arousal in an effort to create a state of activation. These three aspects are technological fatigue detection and warning systems, a resting break, and caffeine. Other self-initiated strategies are unable to combat fatigue. The detection of fatigue is done in a couple of ways, of which direct observation and self-reported fatigue (or sleepiness) scales are the most common during driving. Fatigue detection via direct observation mostly relies on technology, that monitors the driver's state during the driving task. Self-reported fatigue (or sleepiness) scales are able to detect a certain level of fatigue within the driver by the use of standardised questionnaires (ESS, FAS, KSS, etc.)

Since the ESS shows that only one driver out of the sample had a higher level of sleepiness, can it be stated that sleepiness in this sample can be disregarded. However, does this not implicate that sleepiness is absent in the population, due to the implication of the smaller sample size. The FAS, on the other hand, was able to determine fatigue in 8 out of 23 drivers in the sample (i.e. 34,78%), indicating that fatigue can be a problem in the professional context. Since literature agrees on fatigue in the professional driving context, is it possible that this estimation is indeed correct. Furthermore, it is plausible that a lot of drivers suffer from fatigue without knowing it, since this figure is quite high.

While a third of the drivers were feeling fatigued at the time of questioning, participants indicated that fatigue and driving don't go hand in hand. Taking a break and resting is something that drivers indicate doing when they feel fatigued. However, most of the drivers indicated being able to cope with fatigue and being able to correctly estimate their level of fatigue. It is actually unclear how dangerously high this feeling of fatigue needs to be in order to take a break and rest. Nevertheless, the drivers in the sample agreed upon the fact that the willingness to drive without fatigue was there, although they indicated not having an idea on how this could be put to practice.

The COM-B related questionnaire, which made it able to study the behavioural aspect of fatigued driving, was able to give more insight into the reasons behind the malperformance of the target behaviour. Drivers indicated that more knowledge and physical strength were necessary to perform the target behaviour. This corresponded to the willingness to drive without fatigue, where they indicated not knowing how the behaviour could be implemented. The lack of physical strength can be explained through the inadequate amount of physical exercise that drivers specified. Furthermore, a lack of physical and social opportunity were other factors that contributed to the malperformance of the target behaviour. Physical barriers such as an absent fatigue detecting system, a busy work schedule, and a lack of financial resources are the reason behind this malperformance, as well as social barriers such as poor support from the employer and colleagues that do not encourage safe behaviour. In terms of reflective and automatic motivation is, in general, a more positive motivation needed to perform the target behaviour. Even when the willingness to drive without fatigue is high, do drivers genuinely need to feel like they want to do something about it, do they need to be more convinced that it is beneficial to drive without fatigue, and is a new habit necessary to refrain from getting behind the wheel when they feel fatigued. While these factors need to get attention to perform the driver behaviour, can they also be treated as extra underlying factors that cause fatigue or keep fatigue constant, next to the circadian rhythm, task-related factors, homeostatic factors, and personal factors.

Coping with fatigue is done by truck drivers in different ways. While napping, drinking coffee, and performing healthy behaviour in line with the causes of fatigue are only able to reduce fatigue, do a lot of drivers use self-initiated methods to cope with their fatigue (e.g. putting the AC on, blasting the radio, putting the window down, calling someone, etc.). Technology can in this case help to cope with fatigue, but only as a reminder. It is not intended that technology gets rid of fatigue, but it will help to remind the driver that fatigue levels are rising for which the performance of effective coping strategies is necessary. Drivers indicated being positive towards fatigue detection technology in their truck, as long as it will not be used to penalise or control. Nevertheless, they still think that their own judgemental capabilities will be better in the estimation of fatigue than technology.

Solutions to combat fatigue lie in the intervention functions from the COM-B model to facilitate the target behaviour. It is necessary to only respond to the factors that come short in terms of performing the target behaviour (i.e. in this case knowledge, physical strength, physical opportunity, social opportunity, reflective motivation, and automatic motivation). This way, the target behaviour can be facilitated through these factors. Nevertheless, it does remain important not to put full responsibility at the driver. Awareness needs to be raised for employers, companies, legislation, and the transport sector in general as well so that this safe behaviour gets promoted and not punished. Legislation, strict company rules, and busy work schedules need to be revised so that drivers are able to perform safe behaviour without negative consequences.

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ANNEX

FREQUENCIES COM-B ITEMS

Items	Count				
To drive without fatigue, …	**FD**	**U**	**N**	**A**	**FA**
1. I would have to know more about the fact why it would be dangerous to drive with fatigue. (e.g. knowing more about the possible consequences)	1	6	4	9	3
2. I would have to know more about measures that can counter fatigue. (e.g. Needing to know if coffee helps to combat fatigue)	1	3	0	13	6
3. I would need to be in a better physical shape. (e.g. not getting fatigued very fast while unloading the truck)	2	1	4	12	4
4. I would need to have better mental skills. (e.g. being better in estimating my level of fatigue)	2	6	7	7	1
5. I would need to have more physical strength and force. (e.g. being able to lift more weight with the same effort)	1	6	4	11	1
6. I would need to have more mental strength and resistance. (e.g. developing more resistance against busy traffic)	2	4	2	14	1
7. I would need to overcome physical shortcomings. (e.g. trying different seating positions when a position stimulates fatigue)	1	2	3	14	3
8. I would need to overcome more mental barriers. (e.g. don't care about others' opinions while doing exercises against fatigue)	0	2	7	11	3
9. I would need to have more physical endurance and perseverance. (e.g. more persistence to perform physical exercises before a trip)	0	4	4	13	2
10. I would need to have more mental endurance. (e.g. developing a bigger capacity to feel fatigues less easily)	1	3	11	8	0
11. I would need to have more time and flexibility so that I can perform actions to combat fatigue. (e.g. more time to be able to work out)	1	2	8	10	2
12. I would need to have more financial resources. (e.g. receiving a small bonus when I take a necessary break due to fatigue)	1	5	4	7	6
13. I would need to have material resources at my disposal. (e.g. having a reliable system that detects fatigue and warns me)	0	1	4	10	8
14. The employer needs to provide instruments that can measure fatigue. (e.g. the employer installs a fatigue detection system if he doesn't want me to drive fatigued)	1	2	5	11	4
15. I would need to have people around me that also refuse to drive when they feel fatigued. (e.g. colleagues that only drive if they are allowed to rest while feeling fatigued)	0	4	4	7	8
16. I would need to have more triggers that stimulate me. (e.g. having a system that sends personal messages when I feel fatigued)	0	2	3	15	3
17. I would need to be encouraged and supported by others. (e.g. the employer states that driving is only allowed without fatigue)	0	3	3	11	6
18. I would need to feel more like I genuinely want to do something about it. (e.g. feeling guilty when I drive with fatigue)	0	4	4	12	3
19. I would need to feel more like it is necessary to drive non-fatigued. (e.g. reflecting more about the consequences of fatigued driving)	1	3	6	9	4
20. I would need to be more convinced that it is beneficial to drive without fatigue. (e.g. having a stronger agreement about the fact that fatigued driving doesn't work in terms of traffic safety)	1	1	6	9	6
21. I would not only need to have resolutions but also a specific plan to drive without fatigue. (e.g. think about a routine that I can develop)	1	3	5	9	5
22. I would need to develop a habit not to get behind the wheel whilst feeling fatigued. (e.g. developing a habit to rest when a system informs me that I am fatigued)	1	4	3	10	5

FD: Fully disagree D: Disagree N: Neutral A: Agree FA: Fully agree

FREQUENCIES CURRENT BEHAVIOUR – OPENNESS TO CHANGE – ATTITUDE TOWARDS TECHNOLOGY

Items	Count				
Current behaviour	**FD**	**D**	**N**	**A**	**FA**
1. I'm perfectly capable to estimate my own level of fatigue during driving.	0	2	0	12	9
2. I already take a break (e.g. to rest or take a coffee break) when I feel fatigued during driving.	0	3	4	8	8
3. I don't start my trip (or don't continue driving) when I notice feeling fatigued.	4	9	3	4	3
4. Even when I feel fatigued, I find myself perfectly capable to complete my trip, because I know how capable I am at driving with fatigue.	4	4	5	9	1
Openness to change	**FD**	**D**	**N**	**A**	**FA**
5. It doesn't make sense for me to pay attention to driving without fatigue.	6	8	7	2	0
6. I have already thought about trying to drive without fatigue (or taking a break) when I feel fatigued.	0	1	2	11	9
7. Sometimes I reflect on the fact that driving and fatigue don't go together, and I consider doing something about it.	0	2	2	12	7
8. Trying to drive without fatigue is a waste of time.	3	14	4	2	0
9. I understand that it is better for me to drive without fatigue, but there is actually nothing I would like to change about the choice to continue driving.	4	10	4	3	2
10. I am really trying to change my choice regarding driving with fatigue.	1	6	5	9	2
11. I hope that someone can give me good advice about driving without fatigue.	1	1	7	9	5
12. It is easy to say that I will not drive when I feel fatigued, but I will actually try to do something about it.	0	4	4	14	1
13. After all I have done to change my choice, I notice that the choice to drive whilst feeling fatigued does come forward again.	1	3	2	14	3
Attitude towards technology	**FD**	**D**	**N**	**A**	**FA**
14. The development of technology to reliably detect fatigue in a truck is important.	0	1	2	8	12
15. Fatigue detection technology in a truck is essential because I am bad at estimating my level of fatigue.	1	10	6	6	0
16. I'd rather have no technology in my truck, because it only restricts myself	7	7	4	5	0
17. I am convinced that in-truck technology to detect fatigue can improve traffic safety.	1	2	0	11	9
18. I am more capable to estimate my level of fatigue than technology.	1	6	5	9	2
19. I'd rather have no technology in my truck, because I have a feeling that it will be used to monitor or penalise me.	5	3	3	10	2
20. I would like to have technology in my truck that can detect fatigue, even when it would implicate taking an additional break.	2	4	5	11	1
21. I trust technology in general in my truck (e.g. GPS, lane-keeping assist, etc.)	1	5	2	10	5

FD: Fully disagree D: Disagree N: Neutral A: Agree FA: Fully agree

FLYER

INSTITUUT VOOR MOBILITEIT

UHASSELT

Oproep tot deelname aan wetenschappelijke studie voor

VRACHTWAGENCHAUFFEURS

- Ben je tussen 18 en 75 jaar?
- Heb je enige rijervaring met een vrachtwagen?
- Heb je de afgelopen maand nog met een vrachtwagen gereden?
- Heb je interesse om de verkeersveiligheid te verbeteren voor jouw collega bestuurders?
- Wil je meewerken aan een toonaangevend wetenschappelijk onderzoek om vermoeidheid achter het stuur te meten aan de hand van hartmonitoring via het stuur?
- Wil je hiervoor een geschenk ter waarde van 20 euro voor ontvangen?
- Wil je een rit maken in de vrachtwagen simulator en een korte vragenlijst afleggen? (Totale duur ca. 2,5 - 3 uur)
- Wil je hiervoor in de periode maart-april-mei 2020 naar de onderzoekscampus in Diepenbeek komen?
- Wil je helpen om mij als masterstudent aan UHasselt het diploma te behalen?

GEEF DAN EEN SEINTJE AAN:

Kishan Vandael Schreurs

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Met de vermelding van **UW NAAM** en **EEN HART VOOR VRACHT**

KAROLINSKA SLEEPINESS SCALE

Op een score van 1 tot en met 9, hoe beoordeel je jouw alertheid op dit moment?

1	Extreem alert
2	Zeer alert
3	Alert
4	Enigszins alert
5	Noch alert, noch slaperig
6	Ik merk enige tekenen van slaperigheid op
7	Slaperig, maar moet geen moeite doen om wakker te blijven
8	Slaperig en ik moet wel wat moeite doen om wakker te blijven
9	Zeer slaperig, ik moet moeite doen om wakker te blijven, ik vecht tegen de slaap

QUESTIONNAIRE 1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814761.

Block 1: Inleiding

Introductie in het onderzoek

Bedankt voor uw interesse in het rijsimulator onderzoek naar de detectie van vermoeidheid bij vrachtwagenchauffeurs. Dit onderzoek wordt uitgevoerd in het kader van een masterproef aan de Universiteit van Hasselt, binnen de opleiding verkeersveiligheid. Deze studie kadert binnen het Europese Comissie Horizon 2020 project i-DREAMS[**], dat instrumenten wenst te ontwikkelen en testen om de veiligheid van de bestuurder te verbeteren.

Voor we u verder contacteren om een afspraak te maken voor de rijsimulator vragen we om eerst drie korte vragenlijsten in te vullen. Hieronder wordt eveneens meer informatie gegeven over het doel van het onderzoek en de aard van de dataverzameling en behandeling. Gelieve beneden aan de tekst te klikken op ‘akkoord voor deelname’ indien u wenst verder te gaan naar de vragenlijsten.

Ik dank u alvast!

Informatie voor de participant

DOEL VAN DE STUDIE

Dit wetenschappelijk onderzoek tracht te achterhalen in welke mate een nieuwe rijtechnologie in staat is om vermoeidheid te detecteren bij vrachtwagenchauffeurs tijdens de rit.

PROCEDURE

Indien u wenst deel te nemen aan deze studie, dient u de volgende aspecten uit te voeren:

- Het invullen van **een vragenlijst** welke bestaat uit een socio-demografische achtergrond, enkele persoonlijke gegevens en een vragenlijst over vermoeidheid. Deze vragenlijst zal **niet meer dan 5-10 minuten** in beslag nemen.
- Het **rijden in een rijsimulator,** met de volgende specifieke aspecten:
    - U rijdt in de simulator op een dusdanige manier zoals u dat ook zou doen in uw eigen voertuig. Indien er een wagen voor u rijdt, dient u deze echter verplicht te volgen.
    - **Een stuurwielhoes (CardioWheel)** zit rond het stuur verwerkt, dat u ten allen tijde met beide handen dient vast te nemen tijdens de rit, waardoor hartgegevens verzameld kunnen worden. Op deze manier kan vermoeidheid, stress en afleiding gemeten worden.
    - Het doorlopen van de **totale test** (met inbegrip van een oefensessie, de rijsimulatorsessie, een korte bespreking) **van ongeveer 2,5 uur**.
    - Een persoonlijke inschatting maken van het huidige vermoeidheidsniveau op het ogenblik dat de onderzoeker er naar vraagt, volgens een antwoordschaal welke u verder wordt meegedeeld bij akkoord van deelname.

[**] Dit project verkreeg financiering van het Horizon 2020 onderzoeks- en innovatieprogramma van de Europese Unie, Beurs Overeenkomst Nr. 814761

POTENTIEEL RISICO EN ONGEMAK

Met betrekking tot de deelname aan deze studie zijn er geen risico's verbonden. Ongemakken (vb. moeilijkheden met het bekend geraken van bepaalde technologieën) of onvoorzienigheden (vb. het falen van de apparatuur of praktische implicaties) worden verwacht laag te blijven. Het is bijvoorbeeld mogelijk dat u, in zeldzame gevallen, een soort simulatorziekte (vb. draaierigheid, hoofdpijn, …) kan ervaren. Als dit ongemak voorkomt heeft u altijd de keuze om uw deelname te beëindigen. Gelieve dit altijd tijdig aan te geven als u een bepaald ongemakt opmerkt. In dat geval wordt het experiment vroegtijdig stopgezet.

In het geval dat er toch enige vorm van lichamelijke of materiële schade zou voortkomen uit dit onderzoek, wordt dit gedekt door een verzekering die afgesloten werd door de UHasselt.

VOORDELEN VOOR DE PARTICIPANT EN VOOR DE SAMENLEVING

U zal er toe bijdragen dat we als onderzoekers met dit onderzoek beter inzicht krijgen in vermoeidheid achter het stuur, alsook de detectie hiervan. Deze bijdrage kan van enorme waarde zijn voor de samenleving aangezien een groot aantal van de ongevallen (variërend van 1,7% - 25%) aan vermoeidheid gerelateerd kunnen worden.

GEHEIMHOUDING, PRIVACY EN DATAGEBRUIK

Er zal geen gevoelige data verzameld of verwerkt worden in het kader van dit onderzoek. Elke vorm van informatie die verzameld wordt in relatie met deze studie, zal confidentieel blijven en wordt enkel openbaar gemaakt met uw toestemming of zoals vooropgesteld door de wet. Dit onderzoek volgt de **GDPR (General Data Protection Regulation)** strikt op, zoals verplicht door de Europese wetgeving.

Confidentialiteit/vertrouwelijkheid zal behouden blijven bij dit onderzoek. Uw naam wordt enkel gebruikt om de resultaten tijdens de gegevensverzameling samen te houden. Zonder enige koppeling van naam aan de data zou het immers niet mogelijk zijn om na het onderzoek uw data nog in te kunnen zien of te vragen om te verwijderen. Uw naam zal echter tijdens het verzamelen van alle data een ID krijgen, waardoor analyses en resultaten anoniem verwerkt kunnen worden. Aan het eind van dit onderzoek, zal de lijst welke de naam met het ID koppelt, enkel worden toevertrouwd aan de UHasselt.

Dataverzameling: CardioWheel zal gebruikt worden om met behulp van de positie van de handen aan het stuur hartgegevens te verzamelen. Er wordt hierbij niet gekeken of u bepaalde hartproblemen heeft. Deze, alsook de andere verzamelde gegevens zullen opgeslagen worden op dataservers van de UHasselt, waartoe enkel personen verbonden aan het IMOB toegang hebben. Enkel de de gecodeerde gegevens worden door onderzoekers verbonden aan de UHasselt gebruikt voor data analyse. Verder zal enkel geaggregeerde data gebruikt worden voor rapporteringsdoeleinden (bijv. onderzoeksrapporten, artikels, en presentaties). De gecodeerde gegevens kunnen verzonden worden naar andere teamleden in andere Europese landen betrokken bij het *i*-DREAMS project. In geen enkel geval zal de codelijst doorgegeven worden die toelaat uw naam aan uw data te koppelen. De informatie die bij deze studie verzameld wordt kan gebruikt worden voor verdere analyses, wetenschappelijke publicaties of educatie, tijdens en na het onderzoek. Enkel de leden van het onderzoeksteam verbonden aan het *i*-DREAMS project zullen de data gebruiken na afloop van de studie. Elke informatie die gebruikt wordt voor publicatie of educatie zal het niet mogelijk maken om u individueel te identificeren. **Aan het einde van de studie, volgens het EU open data beleid, zal een gepast en volledig anoniem deel van de data vrijgemaakt kunnen worden**.

U hebt het **recht op toegang** tot uw persoonlijk data, u kan een **elektronische kopie verkrijgen**, u kan **rechtzetting** vragen of vragen om data te **verwijderen** welke verzameld werd tijdens de studie. In dit geval dient u contact op te nemen met prof. dr. Tom Brijs.

Uw gecodeerde data zal opgeslagen worden op een data server, gelokaliseerd aan UHasselt. **De data zal maximaal voor een periode van 5 jaar opgeslagen worden**. Deze server is gelokaliseerd op een beveiligde locatie en **voldoet aan de regels voor gegevensbeveiliging**. De anonieme versie van de data kan gedeeld worden met andere leden van het onderzoeksteam, waarvoor dezelfde regels voor gegevensbeveiliging gelden.

Een gegevensberschermingsfunctionaris (Data Protection Officier, DPO) verbonden aan de UHasselt zal toezien op de correcte toepassing van de wettelijke procedures gerelateerd aan GDPR binnen dit project.

PARTICIPATIE, COMPENSATIE EN TERUGTREKKING

U kan kiezen om al dan niet deel te nemen aan deze studie. Als u vrijwillig aangeeft om deel te nemen aan deze studie, kan u zich op elk ogenblik terugtrekken, zonder dat u hiervoor een verantwoording dient te geven. Verder mag u weigeren om op bepaalde vragen te antwoorden.

Voor het doorlopen van de studie verkrijgt u als compensatie een waardebon t.w.v. 20 euro, uit dankbaarheid voor uw vrijwillige deelname. Er zijn geen kosten betrokken bij deze studie met betrekking tot uw deelname, met uitzondering van de verplaatsing naar de test-locatie.

CONTACTGEGEVENS VAN DE ONDERZOEKER

Indien u vragen heeft met betrekking tot dit onderzoek kan u altijd contact opnemen:

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DEELNAME

- ☐ Akkoord voor deelname
- ☐ Ik wens niet deel te nemen aan dit onderzoek

Ik geef aan dat ik gelezen en begrepen heb wat beschreven werd in dit informatieluik, met betrekking tot de deelname aan de studie “Vermoeidheidsdetectie bij vrachtwagenchauffeurs aan de hand van het gebruik van een stuurwiel gebaseerd elektrocardiogram: een rijsimulatorstudie”. Tevens werd er mij een kopie gegeven van dit formulier.

Naam van de deelnemer

……………………………………………………………………………

Handtekening van de deelnemer

Vragenlijst

Block 2: Personenvragenlijst

In het eerste deel van de vragenlijst worden enkele gegevens gevraagd die betrekking hebben tot u als persoon. Deze gegevens dienen louter als achtergrond en kunnen in het onderzoek gebruikt worden om verdere inzichten te verkrijgen in het onderwerp.

Er zal gevraagd worden om uw naam in te vullen. Deze wordt enkel gebruikt om achteraf de rijsimulator gegevens bij de vragenlijst te koppelen, aangezien deze afzonderlijk worden afgenomen. Verder zal hier niets mee gebeuren en zal deze ook niet gedeeld worden met externe partijen.

Wat is uw geslacht?	☐ Man ☐ Vrouw ☐ Anders
Wat is uw leeftijd?	…………………………………… jaar
Hoeveel jaar bent u reeds in het bezit van uw vrachtwagen rijbewijs?	…………………………………… jaar
Heeft u de afgelopen maand met een vrachtwagen gereden?	☐ Ja ☐ Nee
Hoeveel kilometer legt u ongeveer per week af?	……………………………..…………km
Hoe vaak drinkt u koffie?	☐ Ik drink geen koffie ☐ Minder dan 1 koffie per week ☐ Meerdere koffies per week ☐ 1 koffie per dag ☐ Meerdere koffies per dag
Rookt u? (indien nee, sla de volgende vraag dan over)	☐ Ja ☐ Nee
Hoeveel sigaretten/sigaren rookt u per dag?	……………………………… per dag
Neemt u bepaalde medicatie? (indien nee, sla de volgende vraag dan over)	☐ Ja ☐ Nee
Welke medicatie neemt u?	…………………………………………… …………………………………………… …………………………………………… …………………………………………… ……………………………………………
Hebt u een gediagnosticeerd slaapprobleem? (indien nee, sla de volgende vraag dan over)	☐ Ja ☐ Nee

Welk slaapprobleem werd er bij u gediagnosticeerd?	…………………………………………… …………………………………………… …………………………………………… …………………………………………… ……………………………………………
Hoeveel fysieke beweging heeft u gedurende een gemiddelde week?	☐ Ik sport niet ☐ Ik sport 1 dag per week ☐ Ik sport 2 dagen per week ☐ Ik sport 3 dagen per week ☐ Ik sport 4 dagen per week ☐ Ik sport 5 dagen per week ☐ Ik sport 6 dagen per week ☐ Ik sport elke dag van de week
Gebruikt u wel eens iets om uzelf op te peppen net voor of tijdens het rijden? (meerdere antwoordopties zijn mogelijk)	☐ Neen ☐ Energiedrank ☐ Tabak ☐ Drugs ☐ Medicatie ☐ Alcohol ☐ Andere: ……………………………………………

Block 3: Epworth Sleepiness Scale

In dit deel van de vragenlijst dient u aan te geven in welke mate u geneigd bent om in slaap te vallen bij bepaalde situaties. Dit in tegenstelling tot een gewoon vermoeidheidsgevoel. Voor deze stellingen dient u terug te kijken naar de meest recente situaties in uw leven, waarbij deze zich hebben voorgedaan. Als u recent geen van deze activiteiten ondernomen hebt, wordt het sterk aangeraden om u zich in te leven in de situatie, waarbij u een schatting geeft.

Deze schaal omvat 8 situaties waarmee de ernst van uw slaapneiging kan worden ingeschat. Omcirkel hierbij het getal dat het best past bij uw toestand in die situatie.

0 = ik word niet doezelig/slaperig
1 = lichte kans dat ik doezelig/slaperig word
2 = matige kans dat ik doezelig/slaperig word
3 = hoge kans dat ik doezelig/slaperig word

Situatie	Niet slaperig	Lichte kans	Matige kans	Hoge kans
Tijdens zitten en lezen.	0	1	2	3
Tijdens televisie kijken.	0	1	2	3
Zittend in een openbare instelling. (vb. bioscoop, theater, enz.)	0	1	2	3
Langer dan 1 uur zittend als passagier in de auto.	0	1	2	3
Tijdens rust in de namiddag.	0	1	2	3
Zitten en pratend met iemand.	0	1	2	3
Na de lunch.	0	1	2	3
In de auto in een stilstaande file.	0	1	2	3

Block 4: Fatigue Assessment Scale

In het laatste deel van de vragenlijst dient u aan te geven in welke mate u zich kan relateren aan bepaalde stellingen. Al deze stellingen hebben hierbij te maken met vermoeidheid. U kan per uitspraak kiezen uit 5 antwoordmogelijkheden variërend van 'nooit' tot 'altijd'.

1 = nooit
2 = soms (denk hierbij aan maandelijks of minder)
3 = regelmatig (denk hierbij aan een paar keer per maand
4 = vaak (denk hierbij aan wekelijks)
5 = altijd (denk hierbij aan dagelijks)

Stelling	Nooit	Soms	Regelmatig	Vaak	Altijd
Ik heb last van vermoeidheid.	1	2	3	4	5
Ik ben snel moe.	1	2	3	4	5
Ik vind dat ik weinig doe op een dag.	1	2	3	4	5
Ik heb genoeg energie voor het dagdagelijkse leven.	1	2	3	4	5
Lichamelijk voel ik me uitgeput.	1	2	3	4	5
Ik heb problemen om met dingen te beginnen.	1	2	3	4	5
Ik heb problemen om helder na te denken.	1	2	3	4	5
Ik heb geen zin om iets te ondernemen.	1	2	3	4	5
Mentaal/geestelijk voel ik me uitgeput.	1	2	3	4	5
Als ik ergens mee bezig ben, kan ik mijn gedachten er goed bijhouden.	1	2	3	4	5

Dit was het einde van de vragenlijst. Enorm bedankt voor het invullen. U hebt hiermee deel 1 van het onderzoek voltooid. U wordt binnenkort gecontacteerd om een afspraak te maken voor het rijsimulatoronderzoek.

Door op de knop te drukken valideert u uw antwoorden. Tot snel!

QUESTIONNAIRE 2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814761.

Block 1: Inleiding

Onderzoek naar vermoeidheid bij vrachtwagenchauffeurs

Bedankt voor uw interesse in de vragenlijst met betrekking tot het onderzoek naar vermoeidheid bij vrachtwagenchauffeurs. Dit onderzoek wordt uitgevoerd in het kader van een masterproef aan de Universiteit van Hasselt, binnen de opleiding verkeersveiligheid. Deze studie kadert binnen het Europese Comissie Horizon 2020 project i-DREAMS[**], dat instrumenten wenst te ontwikkelen en testen om de veiligheid van de bestuurder te verbeteren.

Hieronder wordt eveneens meer informatie gegeven over het doel van het onderzoek en de aard van de dataverzameling en behandeling. Gelieve beneden aan de tekst te klikken op ‘akkoord voor deelname’ indien u wenst verder te gaan naar de vragenlijsten.

Ik dank u alvast!

DOEL VAN DE STUDIE

Deze vragenlijststudie tracht meer inzicht te verschaffen in het aspect vermoeidheid bij vrachtwagenchauffeurs met het oog op vervolgonderzoek.

PROCEDURE

Indien u wenst deel te nemen aan deze studie, dient u een vragenlijst in te vullen welke bestaat uit: een socio-demografische achtergrond, enkele persoonlijke gegevens, een vragenlijst over vermoeidheid en een vragenlijst over uw mening omtrent technologie en vermoeidheid. Deze vragenlijst zal maximaal 15 minuten in beslag nemen.

POTENTIEEL RISICO EN VOORDELEN VOOR DE PARTICIPANT EN SAMANLEVING

Met betrekking tot de deelname aan deze studie zijn er geen risico’s verbonden. Wel zal u er toe bijdragen dat we als onderzoekers met dit onderzoek beter inzicht krijgen in vermoeidheid achter het stuur. Deze bijdrage kan van enorme waarde zijn voor de samenleving aangezien een groot aantal ongevallen (1,7% - 25%) aan vermoeidheid gerelateerd kan worden.

GEHEIMHOUDING, PRIVACY EN DATAGEBRUIK

Er zal geen gevoelige data verzameld of verwerkt worden in het kader van dit onderzoek. Elke vorm van informatie die verzameld wordt in relatie met deze studie, zal confidentieel blijven en wordt enkel openbaar gemaakt met uw toestemming of zoals vooropgesteld door de wet. Dit onderzoek volgt de **GDPR (General Data Protection Regulation)** strikt op, zoals verplicht door de Europese wetgeving.

Confidentialiteit/vertrouwelijkheid zal behouden blijven bij dit onderzoek. Uw naam wordt enkel gebruikt om de resultaten tijdens de gegevensverzameling samen te houden. Zonder enige koppeling van naam aan de data zou het immers niet mogelijk zijn om na het onderzoek uw data nog in te kunnen zien of te vragen om te verwijderen. Uw naam zal echter tijdens het verzamelen van alle data een ID

[**] Dit project verkreeg financiering van het Horizon 2020 onderzoeks- en innovatieprogramma van de Europese Unie, Beurs Overeenkomst Nr. 814761

krijgen, waardoor analyses en resultaten anoniem verwerkt kunnen worden. Aan het eind van dit onderzoek, zal de lijst welke de naam met het ID koppelt, enkel worden toevertrouwd aan de UHasselt.

Dataverzameling: De verzamelde gegevens zullen opgeslagen worden op dataservers van de UHasselt, waartoe enkel personen verbonden aan het IMOB toegang hebben. Enkel de gecodeerde gegevens worden door onderzoekers verbonden aan de UHasselt gebruikt voor data analyse. Verder zal enkel geaggregeerde data gebruikt worden voor rapporteringsdoeleinden (bijv. onderzoeksrapporten, artikels, en presentaties). De gecodeerde gegevens kunnen verzonden worden naar andere teamleden in andere Europese landen betrokken bij het i-DREAMS project. In geen enkel geval zal de codelijst doorgegeven worden die toelaat uw naam aan uw data te koppelen. De informatie die bij deze studie verzameld wordt kan gebruikt worden voor verdere analyses, wetenschappelijke publicaties of educatie, tijdens en na het onderzoek. Enkel de leden van het onderzoeksteam verbonden aan het *i*-DREAMS project zullen de data gebruiken na afloop van de studie. Elke informatie die gebruikt wordt voor publicatie of educatie zal het niet mogelijk maken om u individueel te identificeren. **Aan het einde van de studie, volgens het EU open data beleid, zal een gepast en volledig anoniem deel van de data vrijgemaakt kunnen worden**.

U hebt het **recht op toegang** tot uw persoonlijk data, u kan een **elektronische kopie verkrijgen**, u kan **rechtzetting** vragen of vragen om data te **verwijderen** welke verzameld werd tijdens de studie. In dit geval dient u contact op te nemen met prof. dr. Tom Brijs.

Uw gecodeerde data zal opgeslagen worden op een data server, gelokaliseerd aan UHasselt. **De data zal maximaal voor een periode van 5 jaar opgeslagen worden**. Deze server is gelokaliseerd op een beveiligde locatie en **voldoet aan de regels voor gegevensbeveiliging**. De anonieme versie van de data kan gedeeld worden met andere leden van het onderzoeksteam, waarvoor dezelfde regels voor gegevensbeveiliging gelden.

Een gegevensberschermingsfunctionaris (Data Protection Officier, DPO) verbonden aan de UHasselt zal toezien op de correcte toepassing van de wettelijke procedures gerelateerd aan GDPR binnen dit project.

PARTICIPATIE, COMPENSATIE EN TERUGTREKKING

U kan kiezen om al dan niet deel te nemen aan deze studie. Als u vrijwillig aangeeft om deel te nemen aan deze studie, kan u zich op elk ogenblik terugtrekken, zonder dat u hiervoor een verantwoording dient te geven. Verder mag u weigeren om op bepaalde vragen te antwoorden.

CONTACTGEGEVENS VAN DE ONDERZOEKER

Indien u vragen heeft met betrekking tot dit onderzoek kan u altijd contact opnemen:

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DEELNAME

Ik geef aan dat ik gelezen en begrepen heb wat beschreven werd in dit informatieluik, met betrekking tot de deelname aan de studie.

- ☐ Akkoord voor deelname
- ☐ Ik wens niet deel te nemen aan dit onderzoek

Block 2: Naam respondent

Aangezien u de eerste vragenlijst reeds had ingevuld kunnen we al een deel van de vragenlijst overslaan.

Aangezien deze vragenlijst daarentegen nog nieuwe onderdelen bevraagd, is het wel noodzakelijk dat u even uw naam invult. Deze wordt enkel gebruikt om achteraf de gegevens van deze vragenlijst te kunnen koppelen aan de vorige vragenlijst, aangezien ze afzonderlijk werden afgenomen. Verder zal hier niets mee gebeuren en zal deze ook niet gedeeld worden met externe partijen.

Wat is uw naam? (voor- en achternaam)

………………………………………………………..

Block 3: Attitude vermoeid rijden - huidig gedrag – openheid tot verandering

In dit onderdeel van de vragenlijst wordt uw mening gevraagd omtrent het al dan niet rijden wanneer u vermoeid bent. Elk van onderstaande uitspraken geven een reeks meningen weer die u zou kunnen hebben bij de evaluatie van de keuze die u maakt om al dan niet zonder vermoeidheid te rijden.

Bij iedere uitspraak zijn er 5 antwoordmogelijkheden:

1 = Helemaal niet akkoord
2 = Niet akkoord
3 = Neutraal
4 = Akkoord
5 = Helemaal akkoord

Duid hieronder voor iedere uitspraak de antwoordmogelijkheid aan die het beste weergeeft in welke mate u akkoord of niet akkoord bent.

Huidig gedrag

		Helemaal niet akkoord	Niet akkoord	Neutraal	Akkoord	Helemaal akkoord
1.	Ik ben perfect in staat om mijn vermoeidheidsgevoel zelf in te schatten wanneer ik rij.	1	2	3	4	5
2.	Ik neem nu al een pauze (vb. om te rusten of een koffie te drinken) als ik me vermoeid voel tijdens het rijden.	1	2	3	4	5
3.	Ik begin mijn rit niet (of ik rijd niet verder) wanneer ik zelf merk dat ik me vermoeid voel.	1	2	3	4	5
4.	Ook al voel ik me vermoeid, toch vind ik dat ik perfect in staat ben om mijn rit uit te voeren, omdat ik weet hoe rijvaardig ik ben zelfs als ik vermoeid ben.	1	2	3	4	5

Attitude / Openheid tot verandering

		Helemaal niet akkoord	Niet akkoord	Neutraal	Akkoord	Helemaal akkoord
1.	Het heeft voor mezelf niet veel zin om aandacht te schenken aan rijden zonder vermoeidheid.	1	2	3	4	5
2.	Ik heb wel eens gedacht dat ik moet proberen om niet te rijden (of een pauze te nemen) wanneer ik vermoeid ben.	1	2	3	4	5
3.	Soms sta ik er wel bij stil dat vermoeidheid en rijden niet samen gaan en ik overweeg er iets aan te doen.	1	2	3	4	5
4.	Een poging ondernemen om te rijden zonder vermoeidheid is zonde van de tijd.	1	2	3	4	5
5.	Ik neem best aan dat ik beter niet rij als ik me vermoeid voel, maar er is eigenlijk niets dat ik echt zou willen veranderen aan de keuze om dan toch verder te rijden.	1	2	3	4	5
6.	Ik ben er echt hard mee bezig om mijn keuze te veranderen met betrekking tot het rijden met vermoeidheid.	1	2	3	4	5
7.	Ik hoop dat iemand me goede raad zou kunnen geven over rijden zonder vermoeidheid.	1	2	3	4	5
8.	Het is wel gemakkelijk om te zeggen dat ik niet vermoeid ga rijden, maar ik ga ook echt proberen er iets aan te doen.	1	2	3	4	5
9.	Na alles wat ik al gedaan heb om mijn keuze te veranderen om zonder vermoeidheid te rijden, komt de keuze om toch te rijden wanneer ik me vermoeid voel af en toe toch terug opzetten.	1	2	3	4	5

Block 4: COM – B model vragenlijst

In dit onderdeel van de vragenlijst willen we wat meer te weten komen over mogelijke redenen die kunnen verklaren waarom jij al dan niet zonder vermoeidheid zou rijden. Bij iedere uitspraak zijn er 5 antwoordmogelijkheden:

1 = Helemaal niet akkoord
2 = Niet akkoord
3 = Neutraal
4 = Akkoord
5 = Helemaal akkoord

Duid hieronder voor iedere uitspraak de antwoordmogelijkheid aan die het beste weergeeft in welke mate u akkoord of niet akkoord bent.

Capability – Bekwaamheid (fysiek & mentaal)

Als het erop aankomt dat u niet vermoeid op een veilige manier moet rijden, wat denkt u dan dat er voor nodig is om dit te doen?

Om zonder vermoeidheid te rijden zou ik…		Helemaal niet akkoord	Niet akkoord	Neutraal	Akkoord	Helemaal akkoord
1.	… meer moeten weten over het feit waarom rijden gevaarlijk is als ik vermoeid ben. (vb. Ik zou meer te weten moeten komen over de gevolgen van rijden met vermoeidheid.)	1	2	3	4	5
2.	… meer moeten weten over welke middelen vermoeidheid tegen kunnen gaan. (vb. Ik zou moeten weten of koffie helpt of dat ik best een pauze neem.)	1	2	3	4	5
3.	… een betere algemene fysiek moeten hebben. (vb. Ik zou in een betere lichamelijke conditie moeten zijn.)	1	2	3	4	5
4.	… betere mentale vaardigheden moeten hebben. (vb. Ik zou beter in staat moeten zijn om te bepalen of ik vermoeid ben of niet.)	1	2	3	4	5
5.	… meer fysieke sterkte en kracht moeten hebben. (vb. Ik zou minder moeite moeten hebben na het lossen van een zware lading.)	1	2	3	4	5
6.	… meer mentale sterkte en weerbaarheid moeten hebben. (vb. Ik zou een sterkere weerbaarheid moeten ontwikkelen tegen drukte op de weg.)	1	2	3	4	5

7.	… bepaalde fysieke tekortkomingen moeten overwinnen. (vb. Ik probeer op te lossen of een bepaalde zithouding vermoeidheid in de hand werkt.)	1	2	3	4	5
8.	… bepaalde mentale obstakels moeten overwinnen. (vb. Ik zou moeten leren om mij niets aan te trekken van wat anderen denken als ik enkele actieve oefeningen doe voor een rit, zoals het tikken van de tenen.)	1	2	3	4	5
9.	… meer fysieke uithouding en doorzettingsvermogen moeten hebben. (vb. Ik zou meer volharding moeten hebben om voor de rit enkele oefeningen te doen die me helpen om me actiever te voelen, zoals eens rond de vrachtwagen wandelen.)	1	2	3	4	5
10.	… meer mentale uithouding moeten hebben. (vb. Ik zou een grotere capaciteit moeten kunnen ontwikkelen om minder snel vermoeid te worden.)	1	2	3	4	5

Opportunity – Gelegenheid (fysiek & sociaal)

Als het erop aankomt dat u niet vermoeid op een veilige manier moet rijden, wat denkt u dan dat er voor nodig is om dit te doen?

Om zonder vermoeidheid te rijden zou…		Helemaal niet akkoord	Niet akkoord	Neutraal	Akkoord	Helemaal akkoord
1.	… ik meer tijd of flexibiliteit moeten hebben zodat ik dingen kan doen die vermoeidheid tegen gaan. (vb. Meer tijd om te kunnen sporten.)	1	2	3	4	5
2.	… ik meer financiële middelen moeten kunnen hebben. (vb. Een bonus krijgen wanneer ik op tijd pauzeer zodat ik niet vermoeid hoef te rijden bij een strak schema.)	1	2	3	4	5
3.	… ik over materiële middelen moeten kunnen beschikken. (vb. Een betrouwbaar systeem dat vermoeidheid kan detecteren en mij daarvoor waarschuwt.)	1	2	3	4	5

4.	… de werkgever instrumenten ter beschikking moeten stellen zodat vermoeidheid gemeten kan worden. (vb. Een vermoeidheids-detectiesysteem in de wagen plaatsen door de werkgever.)	1	2	3	4	5
5.	… ik mensen uit mijn omgeving moeten hebben die het ook weigeren om te rijden wanneer ze vermoeid zijn. (vb. collega's die duidelijk aangeven aan de werkgever dat ze de rit enkel kunnen doen als ze nog mogen rusten omdat ze zich vermoeid voelen.)	1	2	3	4	5
6.	… ik meer 'triggers' nodig moeten hebben om me te stimuleren. (vb. een systeem dat persoonlijk relevante boodschappen stuurt wanneer ik daadwerkelijk vermoeid ben.)	1	2	3	4	5
7.	… ik meer aanmoediging en ondersteuning nodig moeten hebben van anderen (vb. Mijn werkgever geeft duidelijk aan dat het noodzakelijk is dat de rit pas uitgevoerd wordt als ik niet vermoeid ben.)	1	2	3	4	5

Motivation – Motivatie (reflectief & geautomatiseerd)

Als het erop aankomt dat u niet vermoeid op een veilige manier moet rijden, wat denkt u dan dat er voor nodig is om dit te doen?

Om zonder vermoeidheid te rijden zou ik…		Helemaal niet akkoord	Niet akkoord	Neutraal	Akkoord	Helemaal akkoord
1.	… meer het gevoel moeten hebben dat ik er werkelijk iets aan wil doen. (vb. Ik sta positief tegenover rijden zonder vermoeidheid, maar ik heb niet het gevoel dat ik mezelf ontevreden of schuldig ga voelen als ik eens vermoeid zou blijven rijden.)	1	2	3	4	5
2.	… nog meer het gevoel moeten hebben dat het wel degelijk nodig is om te rijden zonder vermoeidheid. (vb. Ik moet meer stilstaan bij de gevolgen van rijden bij vermoeidheid.)	1	2	3	4	5

3.	… zelf nog meer overtuigd moeten zijn dat het goed is om zonder vermoeidheid te rijden. (vb. Sterker instemmen met de idee dat rijden zonder vermoeidheid echt bijdraagt tot veiligheid in het verkeer.)	1	2	3	4	5
4.	… niet enkel voornemens moeten maken, maar vooral een concreter plan moeten hebben om zonder vermoeidheid te kunnen rijden. (vb. Eens nadenken over een routine die ik kan ontwikkelen om vermoeidheid tegen gaan.)	1	2	3	4	5
5.	… een gewoonte moeten ontwikkelen om niet vermoeid achter het stuur te kruipen. (vb. Er een gewoonte van maken om even te rusten als een systeem in de vrachtwagen aangeeft dat ik vermoeid ben.)	1	2	3	4	5

Block 5: Coping vragenlijst

In het voorlaatste deel van de vragenlijst wordt er bevraagd op welke manieren u vermoeidheid probeert te verminderen en hoe u hiermee omgaat.

1.	Ik drink koffie om mijn vermoeidheid tegen te gaan voor of tijdens de rit.	☐ Ja ☐ Neen
2.	Ik rook om vermoeidheid tegen te gaan voor of tijdens de rit.	☐ Ja ☐ Neen
3.	Ik neem medicatie, speicifiek om vermoeidheid tegen te gaan, voor of tijdens de rit.	☐ Ja ☐ Neen
3.b	Welke medicatie neemt u dan?	……………………………………………… ……………………………………………… ………………………………………………
4.	Ik doe enkele fysieke oefeningen vlak voor de rit om vermoeidheid tegen te gaan (vb. rond mijn vrachtwagen wandelen, eens op en neer springen, …)	☐ Ja ☐ Neen
5.	Ik sport, al dan niet om vermoeidheid tegen te gaan. (In de vrije tijd, niet voor het begin van een rit)	☐ Ja ☐ Neen
5.b	Hoeveel fysieke beweging heeft u gedurende een gemiddelde week?	☐ Ik sport 1 dag per week ☐ Ik sport 2 dagen per week ☐ Ik sport 3 dagen per week ☐ Ik sport 4 dagen per week ☐ Ik sport 5 dagen per week ☐ Ik sport 6 dagen per week ☐ Ik sport elke dag van de week
6.	Ik stop onderweg om te rusten wanneer ik me vermoeid voel tijdens de rit.	☐ Ja ☐ Neen
7.	Ik gebruik wel eens energiedrank om mezelf op te peppen voor of tijdens de rit.	☐ Ja ☐ Neen
8.	Ik gebruik wel eens drugs om mezelf op te peppen voor of tijdens de rit.	☐ Ja ☐ Neen
9.	Ik gebruik wel eens alcohol om mezelf op te peppen voor of tijdens de rit.	☐ Ja ☐ Neen
10.	Ik gebruik wel eens een van de volgende manieren om vermoeidheid tegen te gaan. (vb. radio opzetten, tegen passagier praten, raampje open zetten, …)	☐ Ja ☐ Neen
11.	Ik doe iets anders om mezelf wakker te houden voor of tijdens een rit.	☐ Ja ☐ Neen
11b.	Wat doet u dan om uzelf voor of tijdens een rit wakker te houden?	…………………………………………..

Block 6: Attitude t.o.v. technologie in het voertuig

Dit betreft het laatste onderdeel van de vragenlijst. Hier wordt gevraagd om uw mening te geven met betrekking tot technologie in de vrachtwagen (om al dan niet vermoeidheid te kunnen detecteren in het voertuig).

Gelieve aan te geven in welke mate u akkoord gaat met deze stellingen.

		Helemaal niet akkoord	Niet akkoord	Neutraal	Akkoord	Helemaal akkoord
1.	Het ontwikkelen van technologie om op een betrouwbaar manier vermoeidheid te detecteren in de vrachtwagen is belangrijk.	1	2	3	4	5
2.	Technologie om vermoeidheid te meten in de vrachtwagen is noodzakelijk omdat ik slecht in staat ben mijn vermoeidheid in te schatten.	1	2	3	4	5
3.	Ik heb liefst dat er geen enkele technologie in mijn vrachtwagen zit, omdat het me toch enkel beperkt.	1	2	3	4	5
4	Ik geloof dat technologie in de vrachtwagen om vermoeidheid te detecteren, de verkeersveiligheid kan verbeteren.	1	2	3	4	5
5.	Ik ben zelf beter in staat om te bepalen of ik vermoeid ben dan technologie.	1	2	3	4	5
6.	Ik heb liefst dat er geen technologie in mijn vrachtwagen zit, omdat ik het gevoel heb dat het gebruikt zal worden om me te controleren en beboeten.	1	2	3	4	5
7.	Ik zou graag technologie in mijn vrachtwagen hebben om vermoeidheid te detecteren, ook al zou dat betekenen dat ik dan een extra rustpauze zou moeten inlassen.	1	2	3	4	5
8.	Ik vertrouw in het algemeen technologie in mijn vrachtwagen. (vb. gps, lane keeping assist, …) Deze vraag heeft geen betrekking op technologie voor de detectie van vermoeidheid, maar eerder technologie in het algemeen.	1	2	3	4	5

Antwoordbox voor aanmerkingen of bedenkingen.

Dit was het einde van de vragenlijst. Enorm bedankt voor het invullen.