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A GENTLE PUSH TOWARDS SUSTAINABILITY?

THE EFFECT OF NUDGING TO PROMOTE CYCLING

MASTER THESIS

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A gentle push towards sustainability?

The effect of nudging to promote cycling

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Preface

Dear all,

I'm very proud to present to you the crowning glory of the master 'Spatial Planning' with special focus on Urban and Regional Mobility, that is my master's thesis. With this research, I shed a light on another side of the mobility issue by specifically focusing on travel mode choice and ICT. Writing this thesis opened my eyes on mobility. It also emphasized the many benefits related to increased cycling and revealed how app usage can play a role in this. It taught me that conducting an experiment in the real-life environment of participants brings some challenges, but ultimately exposes how individuals navigate their way around urban spaces and shows what really influences them.

Before you start reading my master's thesis, I'd like to take this opportunity to thank the people who have been of great importance during the research process. Firstly, I would like to express my sincere thanks to my supervisor Dr. Fariya Sharmeen for her critical eye and helpful recommendations. She motivated me to do the best I can to deliver a solid piece of work. Furthermore, I am very grateful to my on-site supervisor Koen Vrielink, who gave me constructive advice during and after finishing my internship at Lentekracht. Also, ambassador of Ring-Ring Jos Sluijsmans (Fietsdiensten.nl), who commissioned me to do this research. And, Janine Hoogendoorn, founder of Ring-Ring, who gave me the chance to use travel data and provided an e-bike to raffle among the participants. It would have been much more of a challenge without the support of my family and friends who always took time to help me and be there when mostly needed. Finally, I would like to thank all research participants who were willing to put time and effort in contributing to my research.

Enjoy reading!

Nikki Korzilius,

Nijmegen, July 2017

Abstract

As a result of the many negative consequences related to car use, modal shift towards cycling is a hot topic. It is however still inconclusive in which way to influence individuals so that more sustainable mobility patterns can be achieved. Previous research showed that nudging, as in making individuals more conscious about the choices they have, has great potential to promote environmental behaviour change. In addition, mobile apps can increase the effectiveness of nudging. However, the relationship between smart phone applications and travel mode choice has not been discussed to detail in academic literature. Within this thesis study, we try to close this knowledge gap. We focus on effectiveness of nudging, through a smart phone application, on transportation decisions. The central research question is: *Does nudging, through smart phone app usage, affect travel mode choice behaviour of commuters?* We concentrate on commuters, because transportation literature has shown that commuting makes up a substantial proportion of all daily trips. And these are the ones where congestion is most excessive and environmental issues most concentrated.

The theoretical framework in Chapter 2 explains the theory of planned behaviour and the technology acceptance model to discuss the relationship between ICT and travel mode choice. The theory of planned behaviour is introduced to approach the cognitive processes involved with transportation decisions in the journey to work. The constructs of attitude, subjective norm, and perceived behavioural control predict the intention to choose a certain travel mode choice. In turn, intention is a direct antecedent of the actual travel mode choice. We used the technology acceptance model to include an ICT element. The extent to which individuals are likely to adopt a particular ICT is measured in perceived usefulness, perceived ease of use, and perceived enjoyment. The theories are unified into an integral theoretical framework to explain the effect of ICT on travel mode choice.

A field experiment was conducted to test the relationship between ICT and travel mode choice behaviour. The experiment used a pretest-posttest control group design, meaning that an experimental and a control group were included to measure change after manipulation. The manipulative treatment is a mobile app called Ring-Ring. Ring-Ring was used by the experimental group during the 5 week experiment, while the control group did not use it. Before manipulation, all participants received a pre-test questionnaire containing questions on the research constructs. The experimental group received an additional question on their expectations of the use of Ring-Ring. After manipulation, all received a post-test questionnaire including similar questions as in the pre-test. In this way, we could test whether the research constructs changed because of the manipulative treatment. During the experiment, participants got a travel diary question every week to measure (the change of) travel mode choice.

An ANOVA analysis with a repeated-measures design shows that there are no differences between the experimental and the control group over time, meaning that the manipulative treatment is not able to cause any significant differences between both groups. For bicycle use, there is an effect of time. This implies that bicycle use changes during the experiment, however there are again no differences between both groups. For car use, there are also no differences between the experimental and the control group over time. A moderation analysis shows that the constructs of attitude, subjective norm, and perceived behavioural control do not moderate the relationship between ICT (use of app) and intention. Within the experimental group, we did not find significant evidence that intention mediates the relationship of ICT (user experience) on travel mode choice. The mediation analysis also shows that there is no significant direct effect of ICT on travel mode choice. Chapter 6 presents the results on travel mode choice. The hierarchical logistic regression analysis shows that attitude towards cars and attitude towards cycling are important predictors of travel mode choice. Also, educational level and perceived behavioural control when cycling were significant, however only in a single model. When adding more explanatory variables, these effects were suppressed by others.

Summarizing our findings, we have to conclude that this study did not establish an effect of app usage on travel mode choice behaviour of commuters. The nudging device, that is a smart phone application, did not change travel mode choice in terms of increased bicycle usage. It however emphasises the importance of further investigating the potential of mobile app usage to influence travel behaviour.

Keywords: Sustainable mobility, behavioural change, nudging, travel mode choice, Ring-Ring

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Chapter 1 – Introduction

In this Chapter, we will give a description of the studied topic embedded in scientific and societal relevance. Based on this, it presents research aim and questions.

1.1 Problem statement

Travelling is a derived demand (Kitamura, 2009). It is that people travel because they want to participate in activities (Kitamura, 2009). The private car is frequently used above other transportation means to travel to desired places. Individuals perceive it as the ultimate mode of transportation. Even though other options save time and money, people favour to travel by car (Innocenti, Lattarulo, & Pazienza, 2013). This is because travel mode is significantly influenced by heuristics and biases that leads to incoherent behaviour (Innocenti et al., 2013). This 'car-effect' has various negative societal consequences. Worldwide, cities suffer from carbon and noise pollution, congestion, and other assaults on the quality of life of its citizens (European Platform on Mobility Management, 2013; EuroTech Universities Alliance, 2016; Weiser, Scheider, Bucher, Kiefer, & Raubal, 2016). Additionally, these negative effects result in less accessibility for individuals to participate in desired activities. This makes mobility a dominant concern in debates about transition towards more sustainable patterns (Berger, Feindt, Holden, & Rubik, 2014).

From this environmental point of view, sustainable mobility patterns are best achievable when switching to other modes of transportation (Garvill, Marell, & Nordlund, 2003). Therefore, policy makers should investigate solutions that can compete with the convenience of the private car (Mont, Lehner, & Heiskanen, 2014). It is however challenging to find an alternative that has equal functionality as the car (Mont et al., 2014). Nevertheless, cycling could be our sustainable solution. It is clean, cheap, fast, easy, healthy and an effective form of mobility (Baird, 2010; Hendriksen & Van Gijlswijk, 2010). Infrastructure makes it possible for cyclists to move fast and flexible around the city, which enables them to engage in various activities (Te Brömmelstroet, 2012). Furthermore, it is a space efficient mobility, because in situations where cars must deal with congestion, cyclists are able to avoid congested routes (Schutte, 2015). This all, makes cycling a good alternative for the private car. It also explains policy makers' interest in encouraging cycling (Heinen, Van Wee, & Maat, 2010). But, to get people interested in cycling, governments need to create the optimal cycling conditions to make it convenient and easy for its users. Nevertheless, research of Heinen et al. (2010, p. 60) shows that: "Even in the Netherlands, which has a bicycle-friendly infrastructure and where cycling has a positive image, many people choose not to cycle in situations when cycling would be a highly appropriate transport mode". So, even with a good cycling infrastructure, a positive view on cycling and other advantages like health and environmental

sustainability, people do not automatically choose to take the bicycle. Thus, there appear to be other facets that affect travel behaviour.

It is evident that behavioural change is inevitable to achieve sustainable mobility patterns. This requires understanding of the nature of travel behaviour (Gaker, Zheng, & Walker, 2010). Or, as stated by Middleton (2011, p. 2857): "To understand decision making and the choices people make as they navigate their way around urban spaces". An approach that has its roots in behavioural science and has potential to change travel behaviour is 'nudging' (Metcalfe & Dolan, 2012). A nudge is an unconscious gentle push in a desired direction. Small interventions in a choice-making process aiming at changing behaviour (Avineri, 2011). The focus is not on changing knowledge, attitudes, or values, but on affecting individual decisions without restricting freedom of choice (Avineri, 2011; Mont et al., 2014). Seminal studies on nudging have been successfully conducted in other domains. Research by Delmas, Fischlein, and Asensio (2013) shows that individuals reduced their energy consumption by 7% due to early feedback by audits. Healthy food sales increased due to positively displaying these choices relative to less healthy food (Hanks, Just, Smith, & Wansink, 2012). Nudging seems a promising tool to promote sustainable behaviour. However, the potential of nudging in altering behaviour has not been systematically analysed in transportation studies (Metcalfe & Dolan, 2012). Its effectiveness remains an inconclusive matter (Mont et al., 2014).

ICT is strongly embedded in our everyday mobile lives (Line, Jain, & Lyons, 2011). Research of Mont et al. (2014) shows that ICT has the potential to increase the effectiveness of nudging. Baum (2011) reports that a smart phone is an important device for supporting individuals in changing behaviour. Thus ICT, and more specifically a smart phone application, may affect travel behaviour, such as travel demand, travel patterns, and travel modes (Baird, 2010; Cohen-Blankshtain & Rotem-Mindali, 2016; Mokhtarian, Salomon, & Handy, 2006). It offers a good platform for nudging because of its proficiency of providing real-time information, such as accurately measuring travel behaviour (i.e., it shows where and how a person travels) (Baum, 2011). Previous studies already illustrated the potential of mobile apps to promote environmental behaviour change (Coşkun & Ciğdem, 2014). Weiss, Mattern, Graml, Staake, and Fleische (2012) discovered that users have a positive mindset towards the use of mobile applications to stimulate energy conservation. Mobile apps are further used to retrieve real-time travel information, for instance about train arrival time. Line et al. (2011, p. 1498) claim that ICT has the potential to "compensate for the unreliability or unpredictability in both the transport system and people's schedules of activities". With real-time information, people can flexibly coordinate their activities and meetings with others. Therefore, it contributes to a more efficient travel pattern. However, the potential of smart phone applications to promote a change of travel mode choice behaviour has not been addressed in detail in academic literature. Scholars referred to this relationship

(Börjesson Rivera, 2015), but to the best of our knowledge, there is no systematic analysis of this. Thus, this thesis will concentrate on addressing this knowledge gap. The primary focus of this study is to analyse the effect of nudging on transportation decisions. Nudging appeared to have potential in other domains, so its effectiveness of changing behaviour, in specific travel mode choice, will also be investigated. Focus is on commuters, because commuting trips represent a substantial share of all daily trips and these trips are the ones where congestion is most excessive and environmental issues are most concentrated (Wardman, Tight, & Page, 2007).

1.2 Research aim

A modal shift from private car use to cycling is thus desirable to achieve more sustainable mobility patterns. This study is fundamentally theory-driven, yet may also have practical implications.

> *The aim of this thesis study is to test whether it is possible to affect travel mode choice behaviour of commuters by means of gentle manipulation, to encourage a sustainable shift from private car use to cycling.*

1.3 Research questions

The aim of this research is tried to achieve by the following main research question:

> *Does nudging, through smart phone app usage, affect travel mode choice behaviour of commuters?*

In order to give an answer to this research question, the main question is divided into sub-questions:

- What is the effect of app usage on travel mode choice behaviour of commuters?
- What factors, beyond app usage, explain travel mode choice of commuters?

This study will explore the potential of a nudging device, which is a smart phone app named Ring-Ring, to affect commuter's daily transportation decisions. Ring-Ring raises awareness of commuter's current travel behaviour and emphasizes the attractiveness and benefits of alternative transportation behaviour that is cycling (see Section 4.2.2). This research is bounded to the Heijendaal area in Nijmegen, because here automobile travel volume is high. Also, the national action program Beter Benutten Vervolg proposed this region as key area to apply measures to reduce car trips during peak hours and improve overall accessibility (Municipality of Nijmegen, 2016).

1.4 Research relevance

The importance of this study is divided into a scientific and societal relevance.

1.4.1 Scientific relevance

Research is needed to clarify the potential effect of ICT on travel mode choice behaviour of commuters. The effectiveness of nudging in other domains is already proved to be successful, however this approach is understudied in the transportation sector (Metcalfe & Dolan, 2012). To the best of our knowledge, this is the first attempt of exploring the effectiveness of a smartphone application as nudging device in influencing commuter's travel mode choice process. Academic studies on mobile applications are scarce since we are in an early stage of diffusion (Schmitz, Bartsch, & Meyer, 2016). There is though research on smartphone usage (Kim, Lin, & Sung, 2013; Verkasalo, López-Nicolás, Molina-Castillo, & Bouwman, 2010), however there remains a research gap on the use of smartphone apps used as a nudging device to change travel behaviour. Other studies investigated the effectiveness of smart phone persuasion without a control group or nudged both the experimental and the control group (Baird, 2010; Sunio & Schmocker, 2017). This study might therefore offer a better understanding of travel decision-making in everyday life. The study is a field experiment taking placing in the real-life environment of participants, hopefully gaining interesting new insights into how commuters make travel decisions in their everyday environment. It will show how individual travel behaviour is embedded in many systems of society. With as higher goal, encouraging a change from car to sustainable transportation that is cycling. Instead of making assumptions about what should work to influence people, this field experiment will expose what really works.

1.4.2 Societal relevance

This study, specifically focusing on the Heijendaal region in Nijmegen, may bring about solutions for accessibility problems during peak hours. Results can be translated into recommendations for governments on how to solve these problems by behavioural change. Involvement of citizens may even create a sense of awareness and hopefully activates individuals to actually alter their unsustainable travel behaviour. Furthermore, an increased cycling level can also have positive consequences in various policy domains. On the social level, cycling contributes to a healthier life. Research shows that cycling is healthy: it boosts your mental and physical fitness and leads to less absenteeism (Hendriksen & Van Gijlswijk, 2010). Plus, it increases people's happiness (Hendriksen & Van Gijlswijk, 2010). Cycling employees are also advantageous for employers, because healthy employees are more productive and creative. Moreover, climate as well benefits from fewer individuals travelling by car. If less kilometres are travelled by car, local CO_2 emissions decrease (Hendriksen & Van Gijlswijk, 2010). Public space is scarce, but cycling takes up less space than driving, both while cycling as during parking. And more space, means better accessibility. Attractive public space is also valuable for the local economy. Economies flourish where people thrive. Cyclists spend a lot of money locally, even more than drivers

(Badger, 2012). This is supported by a study of the European Cyclists' Federation (2016) that concluded that cyclists tend to shop more and spend more money when they do, in contrast to consumers coming by car. This means that increased cycling benefits local retailers. All these advantages related to cycling are beneficial for the whole society. Cycling may be a true sustainable solution that maintains accessible, clean, and connected cities.

1.5 Structure of thesis

This thesis consists of seven chapters. This introduction Chapter is followed by a Chapter including the theoretical framework. It starts with a review on the current debate about ICT and travel behaviour and follows with a discussion on important concepts and theories. In Chapter 3, the theoretical constructs are operationalised. Also, hypotheses and a conceptual model of the research constructs are developed. Chapter 4 introduces the research methodology of this thesis study. It outlines the philosophy, research strategy, data collection, research process, data analysis, ethical considerations, and research limitations regarding validity and reliability. The Chapter that follows focuses on the results of the experiment. It exposes the differences between the experimental and the control group and describes what happened within the experimental group. Chapter 6 presents the final composite analysis on travel mode choice behaviour. It deals with the explanatory variables that predict travel mode choice. Chapter 7 discusses the results and draws on conclusions. In addition, limitations of the study and (practical) recommendations for policy making and future research were drawn.

Chapter 2 – Theoretical framework

This Chapter deals with an elaboration of important concepts and theories related to this study. It starts with a review of the current debate about ICT and travel behaviour in research. Followed by a discussion of the theories and their interdependencies.

2.1 Literature review

Technological improvements have major effect on the way society has developed and they will continue to have a critical function in this (Cohen-Blankshtain & Rotem-Mindali, 2016). Information and Communication Technology (ICT) is "a collection of technologies and applications which enable electronic processing, storing and transfer of information to a wide variety of users or clients" (Cohen, Salomon, & Nijkamp, 2002, p. 34). These technologies diverge in complexity, varying from simple virtual communication to intelligent applications in travel management (Black & Van Geenhuizen, 2006). Its popularity has been growing in the last decades. For example, mobile phones are embraced by almost every individual and every household owns a computer. Because technology enables everyday practices and decisions, the widespread use of ICT innovations can change the way people undertake certain activities (Iveroth & Bengtsson, 2014; Pawlak, Le Vine, Polak, Sivakumar, & Kopp, 2015). ICT can substantially contribute to the transformation of our economies (Hippe & Demailly, 2015).

Travel behaviour is increasingly being influenced by ICTs (Line et al., 2011). To understand the implications of ICT for travel behaviour requires an understanding of how both are interrelated (Hippe & Demailly, 2015). The earliest research contribution on this topic was about the possible substitution effect of telecommunications on travel behaviour. It assumes that ICT can further raise space-time constraints and has the potential to reduce the importance of physical proximity (Cohen-Blankshtain & Rotem-Mindali, 2016). Due to ICT, individuals increasingly become decoupled from space (Schwanen, Dijst, & Kwan, 2008). Information technology can replace physical movements with electronic flows. Examples of these telecommunication developments that might replace the travel-based alternative are telecommuting or teleconferencing (Mokhtarian, 2002). Many believed that telecommuting as substitute for physical commuting might solve urban challenges, such as congestion, because less vehicle kilometres will be made. Early evidence came from Pendyala, Goulias, and Kitamura (1991), who evidenced that telecommuters substantially reduce their work-trip making. Nevertheless, the substitution effect also has its shortcomings. For example, teleworking can result into individuals or households moving farther away from their workplaces. Because housing is cheaper and individuals are able to work at home (Zijlstra, 2015). Substitution also assumes a dividing of the physical and digital world, but these two worlds are not that clearly separated in the daily lives of individuals (Schwanen et al., 2008). ICTs are thus far from being a flawless substitute for the private automobile (Cohen et al.,

2002). Regardless the promising power of ICTs to replace actual travel, people still travel physically because they prefer face-to-face communication (Line et al., 2011; Van Wee, Geurs, & Chorus, 2013).

The relationship between ICT and travel is thus not that indisputable as thought earlier. It is a diverse and complex connection that should be understood in the context of everyday practices and activities (Cohen-Blankshtain & Rotem-Mindali 2016). An in-depth analysis of effects within context is necessary to understand these complex connections (Zijlstra, 2015). This also shows travel generation effects (Nyblom, 2014). Working from home probably makes time available to drive children to other activities. It stimulates additional travel, rather than replacing transportation. Various research contributions only present effects of ICT with regard to substitution or generation (Schwanen et al., 2008). However, Vilhelmson and Thulin (2008) show that telecommunications fulfil various interconnecting roles of which substitution and generation are only two. Nyblom (2014, p. 18) agrees with this: "Rather than simply replacing travel, ICT *modifies* everyday practices, *enhances* the capacity, efficiency or attractiveness of physical networks and *remediates* pre-existing infrastructure and media". ICT services thus do not simply result in more or less physical mobility (Hippe & Demailly, 2015). Salomon (1986) has developed a framework for this. The framework considers four potential effects of ICT on travel: substitution, modification, enhancement/generation, and neutrality. Notwithstanding the drastic development of ICT technology and transportation over the past years, this classification of effects is still relevant (Oliver, 2013). While substitution declares a replacement of physical travel by ICT-related counterparts, does generation claim that ICT will results in new travel demand. In a situation of neutrality there will be no effect from ICT on travel. Recent research has started to explain that there is not only a direct effect of ICT on travel, but also a rather indirect effect, which is proposed as a modification of activities (Choo & Mokhtarian, 2007; Lenz & Nobis, 2008). ICTs are associated with the fragmentation of activities (Hubers, 2013; Lenz & Nobis, 2008; Schwanen et al., 2008). Activities are fragmented into smaller subtasks which are to be performed at different times, different locations, or both (Hubers, 2013). Fragmentation leads to that activities are not bound to places and/or times anymore, which increases flexibility and supports a growing travel demand (Lenz & Nobis, 2008). So, modification results in an adjustment in travel demand without the stimulation or elimination of travel (Zijlstra, 2015). It changes travel in a certain matter, without replacing or enhancing it (Mokhtarian, Salomon, & Handy, 2006). However, it should be emphasized that the extent and form of fragmentation is influenced by the type of ICT (Hubers, 2013). Hubers (2013) also proved that activity fragmentation is more significantly correlated with non-ICT factors than with ICT-factors. This shows that the context, such as cultural, social, institutional, and physical, does matter (Schwanen et al., 2008). However, these findings do not understate the importance of ICTs in everyday life, but even more show that ICTs

function as facilitators that do not always have direct causal effects (Schwanen et al., 2008). It might even indicate that ICT is becoming a take-for-granted innovation that supports everyday life. Overall, it must be concluded that ICT does affect urban travel patterns. ICT will probably not reduce the total amount of physical travel, but alters travel patterns, experiences, and perceptions (Cohen-Blankshtain & Rotem-Mindali, 2016).

Above analysis considered travel behaviour in general, but as travel demand and mode choice are interconnected, ICT also might have an effect on travel mode choice (Zijlstra, 2015). Such is the case if teleworking reduces trips made by private automobile, and results in making the remaining trips by another mode of transportation, e.g. bicycle of train. Fragmentation of activities because of ICTs can also lead to individuals choosing other modalities to participate in activities. Also, Cohen-Blankshtain and Rotem-Mindali (2016) assume that ICTs have the potential to change the use of various travel modes and therefore can alter mode choice. However, an extensive analysis of how ICT affects individuals to choose a certain travel mode choice is rather missing in current academic literature.

2.1.1 Public policy regarding travel behaviour and ICT

There is an increased focus on the use of ICT in society. Various policy makers even assume that ICT innovations are a valuable instrument in addressing societal challenges in policy fields like, health care, education, security, energy, and mobility (Poel, Kool, & Van der Giessen, 2009). Therefore, public policies have integrated ICT to support diverse urban goals. In the Netherlands, the Ministry of Economic Affairs is responsible for the government-wide coordination of ICT policy (Poel et al., 2009). These ICT policies can be categorised intro three main groups: direct, indirect, and 'by the way' policies. The aim of direct ICT policy is to stimulate the availability and adoption of ICT (Cohen et al., 2002). This includes the development of ICT, as well as creating equal access opportunities for individuals (Cohen et al., 2002). This type of policy is mostly formulated at the national level, because it contains rules and rights for everyone. On the contrary, indirect ICT policy attempts at achieving non-ICT objectives by the use of ICT, such as desirable behavioural changes (Cohen et al., 2002). Indirect policy is applied to accomplish goals in the social field, wherein ICT is considered as a treatment. 'By the way' ICT policies are products of other unrelated policies that have different goals.

Note Telematics (1989) is a policy document that first put the topic of ICT on the agenda within the transportation sector. In the note is formulated how ICT can be a valuable tool for management and control in traffic and transport, based on availability of information (Van Egeraat, 1998). ICT is especially applicable in the fields of: spatial distribution of traffic and traffic management (Heijer & Wouters, 1991). An example of ICT in transport, they mention, is routing and scheduling of trips: communication with drivers which allows planners to better manage the transportation process. However, this note does not have a clear vision on the specific use of ICT in the transportation sector. It merely considers

the strategic importance of ICT in this sector. In this respect, it rather can be regarded as an exploration of the possibilities of ICT in transportation (Heijer & Wouters, 1991).

Current ICT policy is more focused on elaboration of the ICT potential in the policy sectors of health care, education, security, energy, and mobility. For these sectors an action program called Social Sectors & ICT (Maatschappelijke sectoren & ICT) is developed (Ministry of Economic Affairs, 2009). This program is a joint initiative of diverse ministries. The program consists of action lines with detailed actions per sector. It differs with the Note Telematics which only considered the importance of ICT in addressing societal challenges. The three action lines of the mobility action program are: the use of ICT for improving accessibility in urban areas, strengthening logistics of ICT in main ports, and improving road safety with ICT (Ministry of Economic Affairs, 2009). A national program that focuses specifically on travel behaviour and mobility is called 'Beter Benutten'. Since 2011, twelve administrative regions have been working on over 350 measures to better utilize existing infrastructure and on innovative solutions to improve overall accessibility. Beter Benutten ITS supports traffic flow and aims at reducing travel times during peak periods, by using ICT solutions to create a more intelligent transport system (Ministry of Infrastructure and the Environment, 2016). Different projects work on encouraging behavioural change by ICT.

2.2 Theory & concepts

The theoretical background of this thesis study is inspired by several academic theories and concepts: theory of planned behaviour, technology acceptance theory, and nudging.

Individuals switching to other, more sustainable, modes of transportation means that individuals have to alter their patterns of behaviour. Therefore, knowledge of explanatory factors of modal choice is needed. We typically concentrate on the journey to work, because of excessive morning and evening congestion peaks due to work-related journeys (Commins & Nolan, 2011).

2.2.1 Theory of planned behaviour

Explaining human behaviour in all its complexity is challenging (Ajzen, 1991). Various theoretical frameworks have been introduced to approach the psychological processes involved when explaining individuals' decisions about how to travel to work, because they are assumed to be better predictors of travel mode choice than sociodemographic and infrastructure differences (Hunecke, Haustein, Böhler, & Grischkat 2010). The theory of Reasoned Action (TRA) from Fishbein and Ajzen (1975) is often used to interpret human behaviour. However, this theory is too narrow, since not all behaviours are voluntary (Nilsson & Küller, 2000). The TRA is not able to clarify uncontrollable behaviour (Van Acker, Van Wee, & Witlox, 2010). To overcome this issue, Ajzen (1991) developed the theory of Planned Behaviour (TPB),

which will be elaborated as a general theoretical framework in this thesis. This theory focuses on behaviour that is under volitional control, which means that an individual can decide whether he or she will perform the specific behaviour. This freedom of choice is an important rule prescribed by the theory of nudging, which will be discussed later on. Also, this theory is designed to interpret individuals' behaviour in specific contexts. It thus can be yielded in explaining travel mode choice behaviour of commuters. In Figure 1, the TPB is illustrated in its original design.

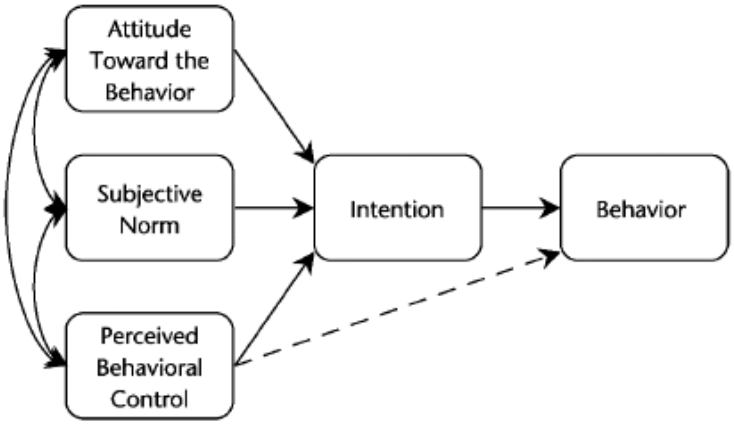

Figure 1. Theory of planned behaviour (Ajzen, 2005, p. 118).

Figure 1 shows that the TPB concentrates on cognitive processes that are involved with performance of a particular behaviour, in our study applied on travel mode choice. These are: *attitude towards the behaviour*, *subjective norm* (significance of others), and *perceived behavioural control* (ability to perform the behaviour) (Ajzen, 1991; Bamberg, Ajzen, & Schmidt, 2003; Gardner & Abraham, 2008; Schneider, 2013).

Attitude

Azjen (2005, p. 3) defines attitude as: "A disposition to respond favourably or unfavourably to an object, person, institution, or event". In this thesis it thus refers to the extent to which an individual has a favourable or unfavourable perspective of the considered behaviour, which is travel mode (Ajzen, 1991). Various studies show that attitudes toward travel modes are dominant for individuals when choosing a mode of transportation for journeys to work (Schwanen & Mokhtarian, 2005; Johansson, Heldt, & Johansson, 2006). An attitude is the sum of positive and/or negative beliefs towards the behaviour multiplied by the importance of each belief judged by the individual (Ajzen, 2005; Heinen & Handy, 2012). For instance, if people highly value the environment, they might have a positive attitude towards cycling as an alternative to the unsustainable automobile. The strength of an attitude depends on people's expectations about the outcome of the behaviour (expectancy) and the importance of these probable outcomes judged by the individual (value) (Domarchi, Tudela, & Gonzalez, 2008). Existing attitudes are sometimes rather persistent, e.g. diehard motorists think cycling is time-consuming, while

reality shows that going by bicycle is often much more faster, because a car must deal with traffic jams and diversions due to one way road (Ministry of Transport, Public Works, and Water Management, 2006). This demonstrates that individuals not always make rational choices. Attitudes related to travel behaviour can be categorised into: instrumental, affective, and symbolic attitudes (Gatersleben, 2004; Şimşekoğlu, Nordfjærn, & Rundmo, 2015; Steg, 2005). Instrumental factors are about benefits of using a certain travel mode (Tan, Choocharukul, & Fujii, 2014). This dimension can be further assorted into: short-term aspects, related to a single and specific trip/mode, such as the degree to which individual's consider a travel mode to be convenient or flexible (Busch-Geertsema & Lanzendorf, 2015). And long-term, which are more collectively related attitudes towards travelling, such as the degree to which individuals consider the environment and their health as important (Busch-Geertsema & Lanzendorf, 2015). Although these rational-instrumental motives are important determinants, modal choice is not entirely caused by a rational pros-cons analysis. Only instrumental motives fail to explain why individuals in the same situations and with similar socioeconomic features make different travel mode decisions (Heinen et al., 2011). More often also emotional perceptions and experiences play a role (Oosterhuis, 2015). For instance, if people rarely or never go by bicycle, they often see more barriers to do so compared to people who regularly cycle. These affective motives and subjective assessments of behaviour are in part embedded in habits and routines. Affective attitudes are emotional feelings related to travelling, i.e. particular behaviour might have effect on an individual's mood (Steg, 2005). For example, driving to work by car evokes feelings of pleasure. The symbolic attitudes are related to processes of social interaction, how individuals express their personal identity and their social position by using a specific mode of transportation, such as power and prestige (Steg, 2005; Tan et al., 2014). Fishbein and Ajzen (1975) defend the general outcomes of social psychological research arguing that attitudes better explain behaviour if they are explicitly designated to the behaviour. For each trip, individuals can choose between different travel modes, where each has typical features, pros and cons, and travel costs (Beirão & Cabral, 2007). The following section will therefore illustrate travel mode attitudes of car use, cycling, and public transport use as mentioned in transportation literature. These transportation modes are chosen, because these are usually enacted for work-related travels. A broad understanding of the attitude concept, and motives that underpin travel mode choice, is needed to give sound explanations for the individual choices that are made (Steg, 2005). Furthermore, travel mode values also depend on internal factors, such as personal preferences, standards and values (Gatersleben, 2013). It therefore can be concluded that motives for choosing a particular travel mode choice vary between individual and per situation (Westgeest, 2013).

Car travel is dominant and appealing (Beirão, & Cabral, 2007; Redman, Friman, Gärling, & Hartig, 2013). People are mostly positive about private car use (Steg, Vlek, & Slotegraaf, 2001). To discover which

(dis)advantages are significant in car use for commuting practices, there has been done a lot of research (see Abrahamse, Steg, Gifford, & Vlek, 2009; Gardner & Abraham, 2008; Steg et al., 2001; Steg, 2005). However, behavioural models focused on rational-instrumental aspects related to its use, such as travel costs, travel time, convenience, safety, comfort, privacy, and flexibility (Gatersleben & Uzzell, 2007; Steg, 2005). These instrumental motives are more or less objective consequences of car use (Steg & Kalfs, 2000). These utilitarian benefits often outweigh the disadvantages of car use, like gasoline costs, traffic congestion, and environmental pollution (Steg, Arnold, Ras, & Van Velzen, 1997). However, individuals who are more affected by environmental concerns are more likely to mould a negative attitude towards car use. Yet, these instrumental motives do not give sufficient clarification of car use (Steg, et al., 2001). It seems that the car is much more than simply a travel mode (Steg, 2005). Private cars also have affective and symbolic value which is coloured by feelings and emotions that determine the experience of using. The car appears to be a status symbol, individuals can express themselves by means of their car (Steg et al., 1997). It somehow shows someone's personality or identity, one often speaks of 'a typical BMW driver' (Harms, 2008). In a study of Hiscock, Macintyre, Kearns, and Ellaway (2002) some participants thought that owning a car could improve their social status. So, many people are emotionally attached to their car. People also appreciate driving as an adventurous and pleasurable activity which evokes feelings of excitement and power (Harms, 2008). Thus, the decision to drive depends not exclusively on its instrumental benefits, car use also has symbolic and affective importance, for instance excitement, driving thrill, feelings of power, and social status (Steg, 2005). A study of Nilsson and Küller (2000) shows that individuals who are more emotionally attached to their car, will drive more frequently and are less vulnerable to policy measures aiming at reducing private car use. Sandqvist and Kriström (2001) found that people simply drive cars because they like to, and not (only) as a result of the utilitarian need for driving a car. Lois and López-Sáez (2009) even argue that individual's affective link with their car explains a great proportion of the car use frequency. Instrumental and symbolic factors are then important as in that they predict the affective link with the car.

Environmentally conscious people are more likely to travel with sustainable transport, like public transit (e.g. train, tram, bus) (Nilsson & Küller, 2000). Hunecke, Blöbaum, Matthies, and Rainerhöger (2001) evidenced this by showing that people with genuine environmental beliefs make more often use of public transport services. This shows that ecological beliefs are important in attracting car users to public transport. However, environmental awareness is usually insufficient to alter travel behaviour (Anable, 2005). Furthermore, Redman et al. (2013) presented a comprehensive paper on the current knowledge about quality attributes that attract people to use public transport. They divided the attributes in physical (no inclusion of PT users, e.g. reliability, price, frequency, speed) or perceived (PT user responses that are directly or indirectly observed, e.g. safety, comfort, convenience). After analysis of

diverse PT studies they uncovered that reliability (of travel time) is a decisive attribute of public transport, followed by speed, frequency of service (flexibility) and prices of the ticket (Redman et al., 2013). However, the importance of these quality attributes largely depends on earlier experiences with a public transport service, socio-demographics, and personal situation (Redman et al., 2013). A study of Hensher, Stopher, and Bullock (2003) showed that travel time and fare level affect dissatisfaction of public transport services, while frequency and seat availability have the largest influence on satisfaction of the service. Also, Friman, Edvardsson, and Gärling (2001) concluded that there are four factors that form overall perceived quality of public transport: reliability of the transport service (departing and arriving on time), information provision (accessibility of travel information), design of service vehicle (like comfort and cleanliness), and treatment by service employee (competence and willingness to help clients). Likewise, Beirão and Cabral (2007) support that reliability (e.g. (un)certainty about when transport will arrive) is a crucial factor. Comfort and frequency may also have a positive impact on user satisfaction. People claim that lack of information discourages public transport use (Beirão, & Cabral, 2007) Overall, people prefer a relaxed trip with a nice atmosphere in uncrowded transport. All these studies showed the importance of notably instrumental attributes in the attractiveness of public transport. People tend to have a positive attitude towards public transport if it has positive benefits compared to other travel modes. For instance, going by bus is cheaper than owning a private car. On the contrary, symbolic attributes seems to have limited influence, because public transport is a service which cannot be individually possessed, and is thus not directly affected by feelings and emotions (Harms, 2008). Individuals probably do not choose public transport for reasons of personal expression or for enhancing social status.

Cycling is gaining in popularity due to its environmental and health benefits (Heinen, Maat, & Van Wee, 2011; Heinen, & Handy, 2012). However, Heinen et al. (2011) assumed that there is an attitudinal difference for short-distance and long-distance cyclists. For the short cycling distances more practical reasons, such as travel time, are decisive, whereas for longer distances the environment and physical health (exercise) advantages are prominent. Their results showed that people primarily ground their mode choice decision on direct advantages, such as flexibility, travel time, and comfort (Heinen et al., 2011). Followed by high scores on environmental and health benefit ('long-term awareness'), and social and traffic safety. Other stimulations are enjoyment (of doing so, or of the scenery), pleasure, and relaxation (Gatersleben & Uzzell, 2007). In a study of Heinen and Handy (2012) participants believed that cycling contributed to a sense of freedom; not only to being able to arrive at destination but also in the experience of cycling itself. Heinen et al. (2011) also mentioned that cycling has the potential to offer privacy. Also bicycle infrastructure (e.g., separated bicycle paths and marked sections on road lanes), and safe parking facilities at work (e.g., standard bike racks, bike lockers or other bicycle

enclosures), seem important factors that determine cycling percentages (Abraham, McMillan, Brownlee, & Hunt, 2002; Heinen et al., 2010; Hunt & Abraham, 2007). Bergström and Magnusson (2003) compared the views of different kind of cyclists and showed that attitude differs between frequent cyclists and non-cyclists. Also, Gatersleben and Appleton (2007) proved that individuals who never contemplated commuting by bicycle have the least positive attitude towards cycling, whereas people who do cycle to work have the most favourable attitude towards cycling. This showed that attitude is connected to actual cycling behaviour. Commonly cited restrictions to cycle are travel distance, bad weather, and traffic safety (heavy traffic and dangerous drivers) (Gatersleben, & Appleton, 2007; McClintoch, & Cleary, 1996; Nankervis, 1999). In the end, Heinen et al. (2011) indicated that people who also use the bicycle for other purposes, have a greater chance to go cycling to work.

Subjective norm

Traditional travel mode choice models turn to rational decision-making. However, travel decisions are all shaped by mobility decisions of close family members, the willingness to meet people a social network, and travel habits of their peers (Avineri, 2012). So, more and more studies consider the social processes that are involved with transportation decision-making, such as the mechanisms within social networks (Pike & Lubell, 2016). In this study, we focus on the social influence aspect of social networks, that are the behaviours, opinions, or knowledge of individuals that have effect on others to whom they are socially related (Pike & Lubell, 2016). In our study this means that social networks might influence the modal choice of individuals. One the one hand, social networks have a role as an information sharing chain to make decisions about travel mode choice (Wilton, Páez, & Scott, 2011). People share experiences about particular travel modes within their social networks. But, social relationships can also strengthen social norms for specific travel modes. Social norms can be injunctive when reflecting to rules and/or standards about what is morally accepted or unaccepted in a given situation (i.e., doing what is ought to be done). Here, it is about the expectations of socially connected people that might disapprove or approve performance of behaviour (Bamberg, Fujii, Friman, & Garling, 2011; Mattauch, Ridgway, & Creutzig, 2015). But, social norms can also be descriptive, meaning that it expresses how the majority acts in a given situation (i.e., doing what others do) (Heath & Gifford, 2002; Kormos, Gifford, & Brown, 2015). For example, students are inclined to travel by bicycle, if their neighbours bike too (Wang, Akar, & Guldmann, 2015). This is also found to be true with work-relations. Wilton et al. (2011) assumed that opinions and behaviour of co-workers are important in travel mode decisions. Also Hendriksen, Fekkes, Butter, and Hildebrandt (2010) argued that subjective norm, peer pressure, and exemplary behaviour are important in travel behaviour, especially when focusing on cycling the journeys to work. Workers are more likely to bike, when they feel that colleagues expect them to. De Geus, de Bourdeaudhuij, Jannes, and Meeusen (2008) confirmed this by saying that individuals commuting by

bicycle, often have people in their social networks that go by bike too. So, social relations can also serve as pathways for persuasion to change behaviour (Pike & Lubell, 2016). Thus, in many situations individuals act conform what others do. Meaning that modal choice often takes place without deliberating transportation alternatives. This shows that travel behaviour is not merely an issue of personal choice, but reflects a broad social context (Cairns, Harmer, Hopkin, & Skippon, 2014).

Perceived behavioural control

Perceived behavioural control refers to "the perceived ease or difficulty of performing the behaviour, and is assumed to reflect past experiences as well as anticipated impediments and obstacles" (Ajzen, 1991, p. 188). It is about how confident an individual is about its own ability to perform the given behaviour (Kraft, Rise, Sutton, & Røysamb, 2005). The performance of the actual behaviour is a product of the outcome and efficacy expectancies of an individual (Bandura, 1977). For example, if someone is convinced about its driving skills, they are more likely to travel by car. It is believed that perceived behavioural control is determined by certain control beliefs, considering the presence or absence of required resources and circumstances (Ajzen, 1991). These control beliefs may facilitate or hinder the performance of the behaviour in question. PCB thus reflects perceptions about internal and external elements (Garvill et al., 2003; Kraft et al., 2005). For example, external circumstance such as traffic regulation, but also access to alternative travel modes, have consequences for an individual's travel decision. However, weather conditions and the practicality of transporting luggage might as well be pivotal (Sabir, Koetse, & Rietveld, 2007; Steg & Kalfs, 2000). Except for these external resources and circumstances, do individual capabilities, such as skills and knowledge, also determine an individual's evaluation of how to perform the certain behaviour (Garvill et al., 2003). Thus, it can be assumed that PBC consists of two entangled concepts which are self-efficacy (i.e., ease or difficulty of performing and individuals' confidence that they can perform) and controllability (individuals' belief to have control over the behaviour) (Kraft et al., 2005). These are often labelled as perceived control and perceived difficulty (Kraft et al., 2005). On overall it can be said that the more requisite resources individuals perceive they have, and the fewer impediments they expect, the higher should be their perceived control over the behaviour in question (Ajzen, 1991).

Interrelations of constructs

Attitude, subjective norm, and perceived behavioural control are predictors of the intention to perform a given behaviour. These latent constructs together shape behavioural intention. Ajzen (1991, p. 188) presents a general rule for this: "the more favourable the attitude and subjective norm with respect to a behaviour, and the greater the perceived behavioural control, the stronger should be an individual's intention to perform the behaviour under consideration". Intentions are considered to reflect the motivational factors that have effect on the given behaviour (Ajzen, 1991). So, intention shows the

willingness of individuals to try to perform the behaviour. In general, it can be postulated that the higher the intention to perform a certain behaviour, the more likely an individual will carry out the intentions and translate it into action (Ajzen, 2005; Bamberg et al., 2003). Therefore, intention is seen as an immediate antecedent of the actual behaviour. For perceived behavioural control, researchers claim that it exerts both a mutual (via intention) and direct effect on behaviour (Armitage & Conner, 2001). This is argued because the translation of intention into action is at least partly affected by personal and contextual obstacles, that is perceived control circumstances (Ajzen, 1991). It is assumed that where behaviour is not under complete volitional control (i.e., where intention is not strongly associated with behaviour), PBC predicts behaviour. However, in an opposite situation with high volitional control, intention should alone predict behaviour (Armitage & Conner, 2001). Thus, the TPB proposes both an indirect and direct effect of perceived behavioural control.

2.2.2 ICT for behavioural change

A serious limitation of the theory of planned behaviour for this specific thesis study is that it does not elaborate on ICT, while this is a crucial aspect because of its supposed effect on travel mode choice. Technology has great potential to influence individuals' travel behaviour. Therefore, this thesis also focuses on the technology acceptance model (Davis, 1989). Technology acceptance model (TAM) is an extended version of the theory of reasoned action (Di Pietro, Di Virgilio, & Pantano, 2012). Contrary to the TPB, it thus contains an information technology element. Since ICT is suggested as important, this study extends the knowledge on TPB by adding the construct of ICT, measured in perceived usefulness, perceived ease of use and perceived enjoyment. In addition, Lu et al. (2003) say that TAM has accepted a lot of empirical support through validations, applications, and replications. It therefore has great power to predict behavioural use of information systems.

TAM discusses the conditions under which technology (ICT) will be embraced by individuals (Venkatesh & Davis, 2000). Despite the fact that the TAM is generally applied in organizational ICT settings, the constructs of the model are favoured in other consumer acceptance technology situations, because of its robustness and simplicity (Chen & Mort, 2007; Doll, Hendrickson, & Deng, 1998; Nysveen, Pedersen, & Thorbjørnsen, 2005). It mainly focuses on extrinsic motivations that affect ICT acceptance, like usefulness and ease-of-use (Lee, Cheung, & Chen, 2005). Extrinsic motivation indicates that doing something leads to a valued (external) outcome, such as increased job performance (Deci, 1972; Yoo, Han, & Huang, 2012). However, more recent studies on TAM extended the model with intrinsic motivational drivers. In contrast to the more functional character of extrinsic motivation, does intrinsic motivation reflect the emotional motivation to do something because of inherent satisfaction or enjoyment (Yoo et al., 2012). Intrinsic motivation is a powerful motivator of behavioural drive, and thus could effectively influence the adoption of information technology. This is acknowledged by Lee and

colleagues (2005), they added perceived enjoyment to the original technology acceptance model to test whether these motivational constructs determined student intention to use internet-based learning medium (ILM). The results showed that enjoyment affects student attitude and intention to use ILM. Likewise, a study of Atkinson and Kidd (1997) shows that intrinsic motivation affects students' technology use significantly. However, Venkatesh and colleagues (2002) contradicted prior results. They showed that intrinsic motivation not directly influenced intention to use technology. However, intrinsic motivation is essential in a way that it serves as a catalyst for extrinsic motivators, such as perceived usefulness and perceived ease of use (Venkatesh, Speier, & Morris, 2002). The great volume of studies supported that both extrinsic and intrinsic drivers are influential on the acceptance of technology. Nonetheless, it remains controversial because of the uncertainty about which motivators most strongly predict behaviour (Yoo et al., 2012).

TAM includes five concepts, in which perceived usefulness and perceived ease of use determine an individual's attitude towards using a particular ICT (Venkatesh & Davis, 2000). This is in contrast with the TPB in which attitude, subjective norm, and perceived behavioural control are direct determinants of an individuals' intention. Figure 2 depicts the authentic TAM as described by Davis, Bagozzi, and Warshaw (1989).

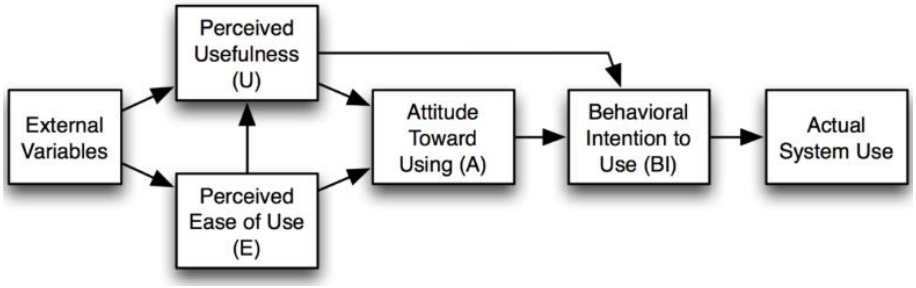

Figure 2. Original technology acceptance model, without enjoyment (Davis, Bagozzi, & Warshaw, 1989, p. 985).

Perceived usefulness (U) can be defined as user's perception of the extent to which using a technology will enhance the performance of some task (Kulviwat, Bruner, Kumar, Nasco, & Clark, 2007). These task performance expectancies reflect the willingness of an individual to use a technology because of its external rewards (Kim, Chan, & Gupta, 2007). Chen and Mort (2007) argued that if a mobile app is voluntary to use, perceived value has a positive effect on technology readiness. Thus, a consumer will only use the app if they believe that using it has personal value. Also, Dalcher and Shine (2003) explained that if user's think that a technology provides value to them, they are more likely to be satisfied with the technology. They add to this, that the more a person depends on a new technology to perform work tasks, the more salient are the judgements of technology usefulness. This means that if the technology works properly (i.e., can be operated without troubles), this enhances job performance and might produce a positive belief towards using the system.

Perceived ease of use (E) is described as the degree to which a user expects that using a technology will be free of effort (Kulviwat et al., 2007). Also, whether it requires an individual to show particular skills or have specific knowledge of the system in order to use the technology. Several researchers conclude that perceived ease of use is an important predictor in user's acceptance of mobile services, however be it unclear whether it has a direct effect on intention or influences via perceived usefulness (Davis et al., 1989; Gelderman, 1998; Lee et al., 2005).

These two constructs affect someone's attitude towards using the technology, which in turn has influence on the intention to actually use the technology. De facto, if a technology requires no effort (E) and enhances job/task performance (U), then individuals will make more use of the technology in terms of more frequency and time (Di Pietro et al., 2012). Just as in the theory of planned behaviour, is it usually true that if people have the intention to use the technology, this also results in actual system usage.

To complement the role of PU and PEOU, various research models added another element: perceived enjoyment (Nguyen, 2015; Van der Heijden, 2004; Verkasalo et al., 2010). Davis, Bagozzi, and Warshaw (1992) describe it as an intrinsic reward through the use of a specific technology, whereas perceived usefulness and perceived ease of use are examples of extrinsic motivation. Intrinsic motivation is simply an emotional consequence of performing the activity per se (Davis et al., 1992). It refers to whether using a technology derives feelings of enjoyment or pleasure in itself, apart from the actual performance outcome (Davis et al., 1992). Perceived enjoyment is the extent to which using a new system can produce fun. Some even claim that it is the most powerful predictor of the intention to use hedonic systems (Van der Heijden, 2004). However, research has shown that if people think that a technology is not useful, enjoyment of usage will not convince them to adopt the technology (Monno & Xiao, 2014). This supports the view that perceived usefulness is a significant predictor of technology usage/adoption, sometime at the expense of both perceived ease of use and perceived enjoyment (Davis et al., 1992; Liu & Li, 2011; Mahmood, Hall, & Swanberg, 2001; Van der Heijden, 2004). A study by Verkasalo et al. (2010) on app usage, showed that perceived enjoyment is more relevant for non-users than for users. This suggests that smart phone users are to a greater extent driven by instrumental or utilitarian value of an application (Verkasalo et al., 2010). Along similar lines, Nysveen et al. (2005) argued that perceived enjoyment has a positive effect on consumers' intention to use mobile data services, however be it primarily significant when using experiential services.

2.2.3 Extended theory of TPB and TAM

Above suggests a theoretical framework that is an extended version of Ajzen's (1991) theory of planned behaviour combined with elements from the technology acceptance model devised by Davis (1989). Taylor and Todd (1995) integrated TAM and TPB and proposed the C-TAM-TPB. This integrative model

has a high fitness in explaining people's behaviour when using new technology (Jen, Lu, & Liu, 2009). C-TAM-TPB holds that individuals' attitude toward using information technology is directly affected by perceived usefulness and perceived ease of use. In turn, behavioural intention is influenced by attitude, subjective norm, and perceived behavioural control. Furthermore, perceived usefulness is also a direct antecedent of behavioural intention, and perceived behavioural control of actual usage. These interrelations are exemplified in Figure 3. However, this extended model is specifically focused on predicting actual information system usage, whereas our study wants to include an ICT element (TAM) into a travel mode predictive model (TPB). So, we decided not to use the C-TAM-TPB as common theoretical framework. We will propose a new model in which technology predicts behavioural intention, which in turn directly affects the actual modal choice. This model, and its operationalisations, is presented in the next chapter.

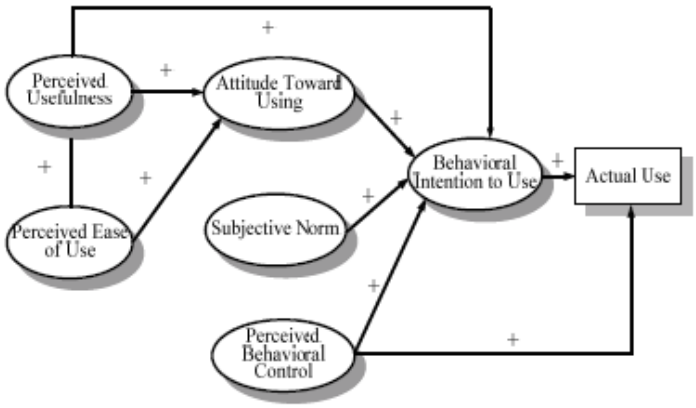

Figure 3. C-TAM-TPB model (From: Jen, Lu, & Liu, 2009, p. 97).

2.2.4 Nudging travel decisions

Neoclassical economics argue that human beings are *Homo Economics* that act on basis of perfect information. They make rational and efficient choices that maximize their economic utility (Avineri, 2012). However, behavioural economics disagree. They think that human beings are not that rationalist as have been defended by neoclassical economics. People are influenced by decision context, overwhelmed by decision making information and therefore may have difficulties in making choices (Mont et al., 2014). Our cognitive capacity for decision-making includes certain shortcuts, so called heuristics (Baird, 2010). These should produce the right utility calculations in order to make rational choices. However, heuristics are sensitive for errors that can result in wrong judgements and repeated cognitive mistakes (Baird, 2010). Individuals are thus highly biased and cannot act on perfect information. Because of this bounded rationality (first introduced by Herbert Simon in 1957), human beings usually choose an option that is rather satisfactory than perfectly optimal. Taking this into account, classic interventions, such as price-based measures or legislation, will not lead to desired

outcomes or behaviours (Avineri, 2011). Tørnblad, Kallbekken, Korneliussen, and Mideksa (2014) consider exploring more 'softer' interventions to motivate a pro-environmental behavioural change.

When keeping this in mind, nudging is introduced as a method to alter the travel mode decision process. Thaler and Sustein (2008) define a nudge as a gentle push in the desired direction. They are thus small interventions in complex choice-making situations that defeat cognitive errors, and highlight the best choices for individuals without forbidding any options (Avineri, 2011; Mont et al., 2014). In this way, it supports the libertarian paternalism philosophy (Jones, Pykett, & Whitehead, 2010). Changing the mental, social, and physical environment or altering the way choices are presented may increase the likelihood of an alternative to become the more attractive or preferred option (Mont et al., 2014). Nudges are exclusively effective if the nudged individual is motivated to change behaviour. Also, three conditions should be met to be qualified as a real nudge (Rachlin, 2015). It should manipulate means, not ends. Thus, the nudge must be transparent, to allow it to be recognized as an intervention (Goepel et al., 2015). There should be freedom of choice in the offered alternatives. This was already mentioned in the part on the theory of planned behaviour. And, the reward or cost must be little compared to the ultimate choice consequences (Rachlin, 2015). Furthermore, nudges are best suitable in situations that involve 'low-involvement' decisions or passive habitual behaviour (Mont et al., 2014). Human beings act on autopilot once they found a routine that works (Middleton, 2011). This is practical and allows individuals to think further than everyday activities. Nudging could be of help if the behaviour has unfavourable effects. In this study, a nudge is used as instrument to change habitual travel mode choice behaviour. It is also argued that people toe the line of behaviour and attitudes of their immediate peers. If nudges make use of this subjective norm, they are likely to be very successful (Webster, 2012).

Smartphone apps as behaviour change persuaders

Using mobile technology to change attitudes and behaviour is gaining in interest. The most straightforward way of changing travel behaviour is by presenting characteristics of travel choices to make people conscious about their behaviour and the possible alternative choices they have (Baird, 2010). So, the way choices are presented (i.e., the choice architecture), is altered. Smartphone applications have great potential to be used as a behavioural change intervention. The app is used as a nudging device. Apps have diverse competences able to give a detailed measurement of active travel behaviour of its users (Baird, 2010). Baird (2010, p. 42) defines their promising skills as: "These apps can track individual travel via a combination of GPS location and accelerometer readings, accurately determine when and where a person is travelling, and distinguish between walking, cycling, and motorized modes". So, because of their smartness we can investigate ones travel behaviour with an

app. Also, apps can give personal feedback on particular mobility patterns, such as an overview of the trip (origin, destination, route, et cetera), money saved (by avoiding certain modal choices), emitted or avoided CO_2 emissions, and calories burned (Westgeest, 2013). Some apps even adapted to social norm, by giving the possibility of comparing your own behaviour with others whom you are socially connected to, such as colleagues, neighbours, or friends. Many studies expose the benefits of using mobile applications as promoters of pro-environmental behaviour. A study of Froehlich et al. (2009) shows that a smartphone application that sends feedback to its users, encourages green travel choices. Another research of Rahman, O'Brien, Manning, Cowdy, and Ahamed (2012) provides app users with feedback about their carbon footprint related to travel mode choices, and proposes an eco-friendly alternative. Travel mode choices are thus heavily embedded in our daily routine meaning that people often make decisions founded on merely convenience. This implies that interventions delivered by an app, that make particular travel decisions more salient or emphasizes the cons of a commuting routine (e.g., auto-dependent), could be very effective in changing travel behaviour where only financial stimulus will not succeed, or is politically not feasible (Baird, 2010).

Habit

Many day-to-day travel mode choices are habitual, and often not guided by deliberation of other options (De Bruijn, Kremers, Singh, Van den Putte, & Van Mechelen, 2009; Hannes, Janssens, & Wets 2008). Therefore, including habit might improve the predictive power of travel behaviour models (Bamberg et al., 2003; Verplanken, Aarts, Van Knippenberg, & Van Knippenberg, 1994). Especially in the case of commuting behaviour: because of its repetitive character, habit may be a predictor of actual travel behaviour (Anable, 2005; Westgeest, 2013). Habit can cause other travel modes to be less attractive (Berger et al., 2014). It is often positioned as a barrier for realizing sustainable travel behaviour, because it is simply complicated to change an embedded auto-dependent routine (Middleton, 2011). However, habit is not permanent element of the travel behavioural models. Moreover, including habit in our theoretical framework will make interpretation difficult. As transportation literature shows its importance, it will be included as a control variable.

Chapter 3 – Operationalisation and conceptual model

In this Chapter, theoretical constructs are operationalised, meaning that is formulated how the constructs are empirically measured within this study. Further, the hypotheses and their illustration in a conceptual model are described.

3.1 Operationalisation of concepts

ICT is the independent variable from which is tested if it affects travel mode choice behaviour of commuters. The tested ICT is a mobile app called Ring-Ring. The indicators that are measured in this research are perceived ease of use, perceived usefulness, and perceived enjoyment of ICT (Davis, 1989; Kulviwat et al., 2007; Lee et al., 2005).

- *Perceived ease of use*: the degree to which a research participant expects that Ring-Ring will be easy to use (e.g., how much effort it costs using the app; if the app works properly).
- *Perceived usefulness*: the extent to which a research participant believes that using Ring-Ring will enhance the performance of commuting to work.
- *Perceived enjoyment*: the extent to which a research participant believes that using Ring-Ring derives feelings of enjoyment and pleasure in itself (i.e., apart from the actual performance outcome). In other words, whether using Ring-Ring can produce fun.

Actual behaviour is the dependent variable (Ajzen, 1991). In this study, it is investigated whether ICT affects travel mode choice behaviour. The actual behaviour is thus the definite choice for a transportation mode to travel to work. In this study, the actual usage of a travel mode is measured in terms of frequency. Frequency is determined by the number of times a travel mode is used during the experiment.

Behavioural intention is a mediator variable. It is tested whether there is a relationship between ICT and actual travel mode choice behaviour, explained by their relationship on a third variable that is intention. In this study, intention to choose a particular travel mode reflects the motivational factors that may have effect on the actual choice of a travel mode (Ajzen, 1991). Or as Ajzen (1991, p. 181) says; "… they are indicators of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour." Because the overall goal of this study is to encourage the participants to switch from car to bicycle as their mode of transportation for commuting, intention focuses on this specific type of travel mode.

Attitude acts as a moderator variable that nuances the relationship between ICT (use of app) and intention. Attitude reflects the extent to which a research participant has a favourable or unfavourable perspective of a travel mode (Ajzen, 1991). Is it the sum of positive and/or negative beliefs towards a

travel mode, multiplied by the importance of each belief judged by the research participant (Ajzen, 2005). Attitudes related to each travel mode as categorised into instrumental, affective, and symbolic attitudes:

- *Instrumental*: Benefits related to using a certain travel mode, this can be short-term related to a specific travel mode (e.g., convenience or flexibility), and long-term that are more collectively related to travelling (e.g., importance of environment and health).
- *Affective*: emotional feelings related to using a certain travel mode (i.e., using a particular travel mode may affect an individual's mood). For instance, it can evoke feelings of pleasure.
- *Symbolic*: attitudes that are related to processes of social interaction. Individuals can express their personal identity and/or social position by using a certain travel mode. For instance, power and prestige.

Subjective norm also acts as a moderator variable that nuances the relationship between ICT (use of app) and intention. In this study, it focuses on the social influence aspects of social networks, that is the behaviours, opinions, or knowledge of individuals that have effect on others to whom they are socially related to (Pike & Lubell, 2016). It focuses on injunctive and descriptive social norms:

- *Injunctive*: Research participants act in a way that is in line with expectations of people from their social networks. For instance, if important people approve a decision for a certain travel mode, they are more likely to actually choose this one.
- *Descriptive*: Research participants act conform how the majority would act in a given situation. For instance, participants will choose a certain travel mode if they know others will do too.

Perceived behavioural control (PCB) is also a moderator variable that nuances the relationship between ICT (use of app) and intention. Ajzen (1991, p. 188) refers to PBC as "the perceived ease or difficulty of performing the behaviour, and is assumed to reflect past experiences as well as anticipated impediments and obstacles". In this study, PBC considers the presence or absence of required resources and circumstances to perform the actual behaviour, which is using a certain travel mode. These can be external resources and circumstances, such as infrastructure or traffic safety, and individual capabilities, such as skills and knowledge. Concluding, PBC consists of two entangled concepts:

- *Self-efficacy*: how confident a research participant is that they can use a certain travel mode. This is related to specific situations in which challenges or impediments affect successful performance.
- *Controllability*: a research participants' belief that they do or do not have control over the chosen travel mode.

This study also includes various control variables. These variables may influence the results, but are not main interest of this study.

Socio-demographic characteristics are included because research shows that commuting behaviour is related to personal and household characteristics (Heinen, 2011; Olde Kalter ,Geurs, & Hoogendoorn-Lanser, 2015):

- *Gender*: male or female.
- *Age:* actual number.
- *Educational level*: no education/elementary education, lower secondary vocational (LBO), general secondary school (MAVO), Intermediate vocational (MBO), Senior General Secondary Education/Pre-University Education (HAVO/VWO), Higher Vocational/ University (BA), Higher Vocational/ University (MA & PhD).
- *Income:* monthly gross income (less than 999,99; 1000,00 – 1499,99; 1500,00 – 1999,99; 2000,00 – 2999,99; 3000;00 – 4999,99; more than 5000,00)
- *Living situation:* alone, together with/without partner with/without children, with parents, student residence.

Habit strength. Measured based on the self-report habit index of Verplanken and Orbell (2003). In this study, we used two items from this index to measure habit strength:

- *Automaticity*: the degree to which a research participant automatically choses a certain travel mode for a commuting trip.
- *Consciously remember*: the degree to which a research participant choses a travel mode for a commuting trip without consciously having to remember.

3.2 Conceptual model and hypotheses

Based on the TPB and TAM, this study assumes that ICT influences travel mode choice behaviour of commuters. Therefore, we propose five hypotheses that are related to differences between the experimental and control group, within the experimental group, and explanatory variables of travel mode choice. Hypotheses are summarized in Table 1.

First, in H_1 it is assumed that there are differences between the experimental and the control group before (t1) and after (t2) manipulative treatment. H_2 expects that because of the manipulative treatment, there is a linear increase in bicycle use from t1 to t2 that is larger for the experimental group. In the third hypothesis, it is assumed that attitude, subjective norm, and perceived behavioural control moderate the relationship between ICT (use of app) and intention towards cycling. Next, intention

towards cycling mediates the relationship of ICT (user experience) on travel mode choice behaviour (H_4). The last hypothesis H_5 assumes that socio-demographic variables, attitude, subjective norm, perceived behavioural control, use of app (ICT), and distance to work predict travel mode choice behaviour.

Table 1. Summary of hypotheses.

	***Between** experimental and control group*
1	The mean scores from *t*1 to *t*2 of the research constructs differ between the experimental and the control group
2	The linear increase in bicycle use from *t*1 to *t*2 in the experimental group is larger than in the control group
3	Attitude towards cycling, subjective norm of cycling, and perceived behavioural control when cycling, moderate the relationship between app usage and intention towards cycling
	***Within** experimental group*
4	Intention towards cycling mediates the relationship of ICT user experience on travel mode choice behaviour
	Travel mode choice
5	Socio-demographic variables, attitude, subjective norm, and perceived behavioural control, use of app, and distance to work predict travel mode choice behaviour

Together, the research variables are presented in our conceptual model that is showed in Figure 4. The conceptual model shows that ICT is assumed to have effect on travel mode choice behaviour of commuters.

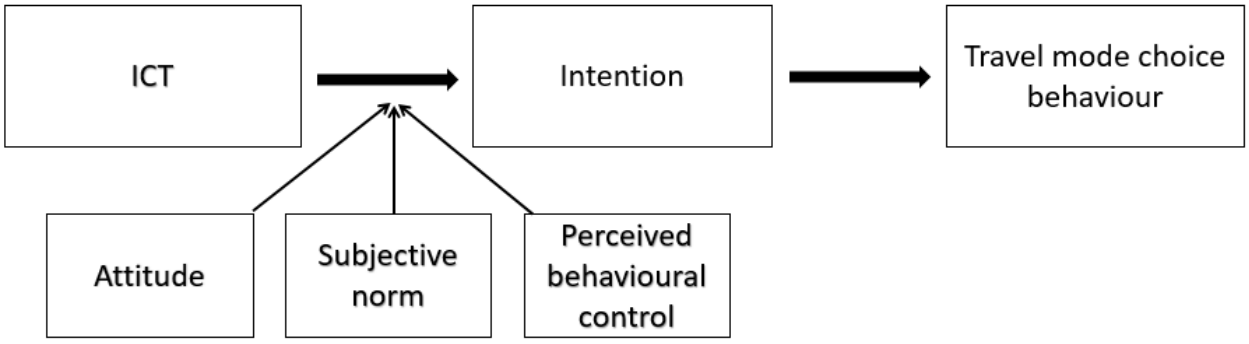

Figure 4. Conceptual model on ICT and travel mode choice behaviour.

Chapter 4 – Research methodology

As is indicated in the title, this Chapter includes the research methodology of this thesis study. In more detail, this part outlines the research philosophy, research strategy, data collection methods, research process, data analysis, ethical considerations, and research limitations regarding validity and reliability.

4.1 Research philosophy

The methodology of this study is associated with a positivist understanding of society. Positivism suggests that reality is objectively observable (Saunders, Lewis, & Thornhill, 2012). This study follows that strategy in that it will test if theoretical considerations are true. That is, it examines if use of ICT affects travel mode choice. The positivist ontology assumes that there is simply a single objective reality to any research phenomenon. The researcher distances oneself from its research object to make sure the phenomenon can objectively be investigated. In this way, the researcher is independent of its data and makes the study relatively value-free (Saunders et al., 2012). When staying emotionally distant, the researcher can make clear distinctions between objective reasoning and subjective experience and feelings. Positivists therefore use consistently rational and logical research approaches. We used a deductive reasoning approach to guide our research, meaning that behavioural theories and related hypotheses are tested.

4.2 Research strategy

In positivist studies the research findings are generally observable and quantifiable (Saunders et al., 2012). Therefore, a quantitative research design best fits our objective search for causal behaviour relationships. This ICT-behaviour research is not searching for an in-depth understanding of individuals' feelings and meaning, but deducts behavioural theory and hypotheses. This is supported by our research aim and questions that revealed that this study seeks to confirm theoretical hypotheses. Goal of this study is thus not to generalize results. This might be a threat to external validity. The key approach of the scientific, positivist method is the experiment. In our study a model of travel mode choice was tested by means of a field experiment. We chose to perform a field experiment because research in the natural setting is likely to be associated with the everyday conditions under which participants live and work (Wilson & Maclean, 2011). In fact, a field experiment is expected to better reflect real life. Also, Metcalfe and Dolan (2012) suggest that the field experiment is a relevant method to test causality in transportation research. Experiments are characterised by a high internal validity. Meaning that experiments can show that the differences in the independent variable caused the observed difference in the dependent variable (Wilson & Maclean, 2011). However, because a field experiment takes place in a natural setting, participants cannot be isolated as in a laboratory experiment (Wilson & Maclean,

2011). This might jeopardize the results, because the researcher has no total control of the external conditions. In general, reliability is strong. Because there are standard procedures for selecting participants and developing measurements of concepts that make the research replicable (Bryman & Bell, 2015). We used a pretest-posttest design, because they are widely used in behavioural research (Dimitrov & Rumrill, 2003). Within this design we compared an experimental group with a control group to measure the change that can be resulted from the manipulative treatment. The use of pre-test data can produce a more robust design than if only post-test data was used (Dimitrov & Rumrill, 2003). The independent variable was manipulated to test the effect on travel mode choice (Wilson & Maclean, 2011). In our study, the manipulative treatment was an application called Ring-Ring (see Section 4.2.2).

4.2.1 Experimental design

The research objects investigated within the experiment were people who work at an (academic) institution or company situated on campus Heijendaal in Nijmegen. Participants were selected on a criterion that required regularly commuting to and from their work by car. Participants were invited to voluntarily participate in the experiment. To fully inform participants about purpose of the research, expected duration and procedures, they received an information consent. This contained information on inter alia, participants' rights when engaging in the experiment, such as limits of confidentiality (data analysis, data sharing and archiving), contact information, lottery of reward (e-bike), and data privacy. Participants of the experimental group were specifically informed on the privacy procedure of Ring-Ring. Because Ring-Ring meets all requirements of data-protection laws, it was required to explicitly ask them if they agreed with using their travel data in our research. It was also guaranteed that all data (e.g., questionnaires) were used anonymously. Voluntary participation can be a threat to validity, because acquisition of participants depends on people's willingness to engage in the experiment. People that participate might be more motivated because they are interested in the studied topic, this may influence the results. Participants were randomly assigned to either the experimental group or the control group. Sample size was based on a power analysis (Cohen, 1992). This analysis revealed that using a power of .80, establishing a medium effect size, using a t-test for mean differences for two groups at an alpha of .05, each group had to consists of 64 participants (Cohen, 1992, p. 158). However, during the execution of the experiment group sizes were 18 and 19, meaning that mean differences of the two groups need to be very large in order to be statistically significant.

The experiment has a between-subjects design. This means that the experimental group experienced a manipulative treatment, while the control group did not (Wilson & Maclean, 2011). Moreover, participants were not able to engage in both groups. The experiment was designed by a pretest-posttest control group design. So, travel mode choice behaviour (dependent variable) was measured before and after manipulation of the independent variable (Wilson & Maclean, 2011). During the experiment both

groups experienced the same conditions except for the manipulative treatment. The experimental group experienced the Ring-Ring app (see Section 4.2.2) during five weeks to check whether the app influenced them to change travel mode decisions. The greater goal of this study was to change participants' auto-dependent commuting routine into a more cycle-friendly routine. Travel data was gathered with a weekly travel diary. Participant's travel mode motivations were collected by a pre-test and a post-test questionnaire. In this way, the differences between pre- and post-test could be determined to seek an overall understanding of the travel decision-process.

4.2.2 Experimental treatment

As was mentioned earlier, a smart phone application is a promising tool to nudge people in a certain direction, in other words: making people conscious about their travel behaviour and the possible alternative choices they have. Ring-Ring is such a nudging device. Ring-Ring is an mobile application designed by the idea that cycling can serve as a solution for various societal problems (e.g., accessibility, air quality, and health). It is an easy-to-join community for cyclists. Ring-Ring has the potential to raise awareness of individuals' current auto-dependent travel behaviour by emphasizing the attractiveness and benefits of alternative, cycling behaviour. Users are provided with feedback about their travel behaviour, like stats of cycling kilometres, routes, avoided CO_2 emissions, and burned calories. Also, gamification elements push intrinsic motivation to stimulate users to travel by bicycle more often. Kilometres travelled by bike are automatically measured and converted into a value for each user. Cycle miles can be exchanged for discounts at various companies or local initiatives. Furthermore, cycle miles are shared in an open platform. In this way, individuals are able to compare their own behaviour with that of others in the cycle community. Ring-Ring thus makes a healthy, green mode choice visible without prohibiting alternative travel modes.

4.3 Sample

This section summarizes the sample characteristics of our data sample (see Table 2). The sample consists of 37 people who work at an (educational) institution or company situated on campus Heijendaal in Nijmegen, of which the experimental and control group have 18 and 19 participants respectively. In both groups, the number of female participants is larger than the number of male participants. In the control group approximately 74% is female, towards 67% in the experimental group. The mean age for the sample was 43 years (SD = 10,83), ranging from 24 to 63 years. An even share of the participants lived together with a partner or together with a partner and children (both 14 people; 37,8%). The majority of the people (n = 30) is highly educated (BA, MA or PhD). About 70% of the participants had a monthly income of 2000,00 or more. All participants live within 22 kilometres (single trip) from their

work, however the majority of the participants live between 11 and 15 kilometres from their work (44.4%; 47.4%).

With independent sample t-tests (*p*) and Chi-square tests (df) we checked for differences between the two groups. For the categorical variables we used a Chi-square test for independences. The other (not categorical) variables were tested by means of an independent samples t-test. Table 2 presents an overview of the sample broken down by experimental group and control group. The p-value, that is above the significance criterion of .05, shows that there are no differences in the distribution of gender, age, education, living situation, and income between the experimental group and control group.

Table 2. Sample overview broken down by experimental and control group for the pre-test.

Variable	Experimental group (%)	Control group (%)	X^2 (df)	Sig. (*p*)
Gender			.641	
Male	6 (33.3)	5 (26.6)		
Female	12 (66.7)	14 (73.7)		
Age				.110
< 25	1 (5.6)	1 (5.3)		
26 – 35	5 (27.8)	4 (21.1)		
36 – 45	7 (38.9)	4 (21.1)		
46 – 55	4 (22.2)	4 (21.1)		
56 – 65	1 (5.6)	6 (31.6)		
Educational level				.503
Lower secondary vocational (LBO)	1 (5.6)	1 (5.3)		
General secondary school (MAVO)	0 (0.0)	1 (5.3)		
Intermediate vocational (MBO)	2 (11.1)	2 (10.5)		
Higher vocational/university (BA)	5 (27.8)	8 (42.1)		
Higher vocational/university (MA/PhD)	10 (55.6)	7 (36.7)		
Income				.716
< 999.99	2 (11.1)	0 (0.0)		
1500.00 – 1999.99	2 (11.1)	3 (15.8)		
2000.00 – 2999.99	5 (27.8)	8 (42.1)		
3000.00 – 4999.99	6 (33.3)	6 (31.6)		
> 5000.00	1 (5.6)	0 (0.0)		
I don't know	1 (5.6)	0 (0.0)		
I don't want to say	1 (5.6)	2 (10.5)		
Living situation			.447	
Living alone	2 (11.1)	3 (15.8)		
Living with partner	6 (33.3)	8 (42.1)		
Living with partner and children	6 (33.3)	8 (42.1)		
Living with children (without partner)	2 (11.1)	0 (0.0)		

Living with parents (without children)	1 (5.6)	0 (0.0)	
Different: housing association	1 (5.6)	0 (0.0)	
Distance to work			.345
< 5	2 (11.1)	2 (10.5)	
6 – 10	5 (27.8)	5 (26.6)	
11 – 15	8 (44.4)	9 (47.4)	
16 – 20	3 (16.7)	2 (10.5)	
> 20	0 (0.0)	1 (5.3)	

Notes. This table contains Chi Square statistics (x^2) and independent T-test significance probabilities (*p*). *$p < 0.05$. ** $p < .01$. *** $p < .001$.

4.4 Procedure

To reach as many people working at campus Heijendaal, research flyers with information about research purposes, duration of the experiment, and procedures were spread at various locations (e.g., different parking lots at Radboud university, Radboud UMC, and HAN Higher Education) to invite people to participate in this study. Also, this flyer was spread online via social media (e.g., University and HAN Facebook pages). However, this did not provide enough response. Therefore, potential participants were also approached personally. Several academic and research institutions were visited to get people to participate in the study. A personal approach proved to be an effective way of sampling.

After sampling, the participants were randomly assigned to the experimental and the control group. Participants of both groups received their pre-test questionnaire at t1 (before officially launching the experiment). The pre-test questionnaires differed between the experimental and the control group. The experiment started on March 21 with a first travel diary (a week after distribution of the pre-test questionnaires). The experiment endured five weeks, from March 21 until March 20. Each week, the participants received a travel diary either on Tuesday of Thursday. The travel diaries were similar for both groups. The experimental group was exposed to an experimental treatment during the five weeks of the experiment, meaning that they were asked to download and use the Ring-Ring app. After five weeks, the experiment came to an end. Participants of both groups were asked to fill in the post-test questionnaires at t2. Also here, the questionnaires were distinctive for both groups. The questionnaires were designed and distributed (via personal respondent IDs) using Qualtrics.

4.5 Data collection

This section discusses the triangulation of data collection methods. In detail, it describes content of the pre- and post-test questionnaires and the travel diary surveys.

4.5.1 Questionnaires

This study consisted of two questionnaires, one before the treatment phase and one distributed afterwards. The pre-test questionnaire is about participants' travel decisions and motivations (see Appendix 1). This questionnaire consists of nine parts. Most scores were rated on a 5-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree). The questionnaire items were subtracted from or inspired by earlier research. Next, each part of the questionnaire, including various items, are briefly introduced.

The first part addresses participants' present travel behaviour. Questions are about used travel mode for commuting practices and average working week (e.g., which days are travelled with which travel modes). Part two to four focused on the latent variables of the TPB, which are attitude, subjective norm, and perceived behavioural control. While probably not everyone always commutes by same travel mode these parts focused on the three most widely used travel modes: car, bicycle, and public transport. Section two were statements about motives that can play a role in choosing to commute by car, bicycle, and public transport to campus Heijendaal (attitude). The third part was about social influences that can affect travel mode choice for the three modes of transportation (subjective norm). The fourth part dealt with self-efficacy and controllability when choosing a travel mode (perceived behavioural control). Section five was comprised of statements concerned with aspects related to taxed and prices that can play a role in choosing a mode of transportation to travel to work. While section six was about intention, was part seven about the degree to which participants automatically and without consideration choose a travel mode for commuting practices. Part eight focused on sociodemographic questions (e.g., gender, age, educational level, income, and living situation). The only distinction between the experimental and control group was section nine. This question was solely assigned to the experimental group, because it was about their expectations about the effect of Ring-Ring on their future commuting behaviour. At the end of the questionnaire, participants could leave their email address if wanted to be informed about the research results.

The post-test questionnaire was presented to the participants after the treatment period (see Appendix 2). This questionnaire is quite similar to the pre-test questionnaire. Part two, three, and four were again comprised of questions regarding attitude, subjective norm, and perceived behavioural control. This was an important requirement to compare both datasets to check if participants altered their travel mode motivations. Also, part five and seven stayed the same. The other sections have (partially) changed. The first and eighth part have been shortened because information is not expected to have essentially changed. In the first part, participants were only asked how their average working week looked like (i.e., on which days they travelled by which modes of transportation, to their work on campus Heijendaal). This question was to check whether participants actually changed their travel patterns. The

sociodemographic information gathered in part eight remained the same in essential. Therefore, we did not have to repeat these questions. Part six was also partly modified because of its retrospect character. For intention we asked the participants whether they actually travelled by bicycle during the experimental period. The last part was again only assigned to the experimental group. In this part, we asked the participants about their experiences with the Ring-Ring app and to what extent they altered their commuting behaviour because of the app usage. Statements were about: usefulness, easy to use, enjoyment, effectiveness, general user experience (e.g., particular benefits associated with the app), and the effect of Ring-Ring on travel mode choice (stimulation to change travel mode and to commute by bicycle more often).

4.5.2 Travel diary

During the experiment, the participants received a travel diary question every week (see Appendix 3). The majority of the participants received the question on Tuesday. This was decided because from the pre-test it was discovered that a majority of the people worked at campus Heijendaal on that day. However, a total of five participants weekly received the travel diary question on Thursdays, because they practically never worked on Tuesday. The question they had to answer was about which travel mode they had used on that specific day to travel to and from their work on campus Heijendaal. It was explicitly requested that in case participants used multiple travel modes during a trip, they had to mark the mode of transportation that they used for most part of the trip. In addition, participants had the opportunity to choose a response category if they had not worked, had worked somewhere else, or had worked at home on that day.

4.6 Measures

Cronbach's α coefficient was used to test internal consistency of various scales. Cronbach's α has to exceed 0.7 to indicate stability of the questionnaire items (Field, 2009, p. 675). This iterative analysis tests which items did not contribute to a scale. These were deleted if their corrected item-total correlation was smaller than zero, that is had a negative value. The remaining items constitute an internally consistent scale (see Table 3). This scale construction was done based on the pre-test data. Identical items were deleted for the post-test data. We chose this procedure instead of factor analysis, because the common rule is that you need at least 10-15 participants per variable for conducting factor analysis (Field, 2009). This means that our sample size is too small to warrant stable and thus reliable factor scores.

In general, the reliabilities were adequate (> .69) or in some cases even superior (> .90). In a few cases, reliability was moderate (between .60 and .67) or insufficient (between .45 and .59). The Cronbach's α

of habit is also moderate for both pre-test as well as post-test data, however deleting an item will induce too few component variables in the scale. For the moderate or insufficient cases it was tested whether deleting items caused a higher Cronbach's α. The new reliabilities of the pre-test and post-test are showed in Table 3. Original reliabilities of pre-test and post-test can be found in Appendix 4.

For attitude towards cars, we deleted one item that caused a higher, and in all cases at least a sufficient Cronbach's α. In the post-test dataset this also resulted in increased values, however the α of the control group remaining moderate. Also for subjective norm (car) removing an item resulted in an increased Cronbach's α in all cases. Again, this was also true for the post-test dataset. For perceived behavioural control (car) we deleted one item which had a positive effect on the Cronbach's αs. This also applied for the post-test data, but only the reliability of the control group stayed moderate. For perceived behavioural control (bicycle), it was necessary to delete three items from the scale to achieve adequate Cronbach's α. These were principally items that were added to every scale to enact consistency. However, 'household responsibility' and 'practical reasons' and 'weather' did not contribute to an internally consistent scale. After removing these items at least the reliability of the groups combined became adequate. The reliability of the experimental group stayed moderate, yet deleting more items decreased all Cronbach's αs. Unfortunately, because we want to create equal pre- and post-test scales, the coefficients of the post-test data did stay unchanged, and moderate. Two items were deleted for perceived behavioural control (public transport), causing all Cronbach αs to increase, except for the reliability of the post-test experimental group stayed moderate. No items were deleted from intention, this however had consequence that the post-test reliability of the experimental group was not adequate. The original reliability of ICT was already superior that it was not needed to remove any items from the scale.

This shows that there are a few exceptions of scales that did not increase after deleting the items. However, because of consistency we will deal with this in further thesis. In general, the reliabilities of all scales in the two groups combined were adequate.

Table 3. Reliabilities in terms of Cronbach's αs of the experimental group (EG), the control group (CG), and the groups combined for pre-test (t1) and post-test (t2).

Construct	*Both groups*$_{t1}$	*Both groups*$_{t2}$	*EG*$_{t1}$	*EG*$_{t2}$	*CG*$_{t1}$	*CG*$_{t2}$
Attitude						
Car	.88[c]	.88[c]	.94[c]	.93[c]	.69[b]	.68[b]
Bicycle	.80	.79	.75	.69	.83	.84
Public transport	.91	.91	.89	.87	.93	.93
Subjective norm						

Car	.90[b]	.84[c]	.95[c]	.71[b]	.86[b]	.92[c]
Bicycle	.77	.88	.77	.72	.75	.91
Public transport	.86	.91	.84	.82	.86	.93
PBC						
Car	.84[c]	.77[c]	.90[c]	.88[c]	.73[b]	.41[b]
Bicycle	.70[b]	.58[b]	.66[b]	.67[b]	.76[b]	.45[b]
Public transport	.74[c]	.71[b]	.71[b]	.67[b]	.80	.75[b]
Habit	.69	.67	.72	.55	.61	.72
Intention	.84	.73	.81	.59	.88	.80
ICT		.90		.90		

Notes. This table contains Cronbach's α's for the various scales measured. [b]α if deleting the causing items. [c]α also changed because of items deleted.

After the reliability analyses, composite mean scores were calculated for all scales. These were used in further statistical analyses.

4.7 Exploring assumptions

Prior to running any type of statistical analyses, we first completed the basic data screening activities to guarantee the accuracy and legibility of data entry and assess the normality of the continuous variables. Descriptive and inferential analyses were conducted with the cleaned data set to describe the data sample and to address the research hypotheses.

Detecting missing data and outliers

In our data set, there were no missing data. The data were also checked for outliers, characterized as values that are greater than 3 standard deviation units from the sample mean for a given variable. For the continuous items that were measured with a Likert scale, we decided to not remove the extreme values. This because the subjects responded with the 'outlier' for a reason. Simply because they had the possibility to answer the question between the floor and ceiling of the scale (i.e., between 1 and 5). A model including all values better reflects reality. In the end, no extreme values were removed.

Normality check

For various interval and ratio variables we tested whether the data were normally distributed. For all variables we ran a Shapiro-Wilk test because these are more adequate of assessing normality for small sample sizes (< 50) of which we are dealing with (Field, 2009). A Shapiro-Wilk significance level p >.05 shows that the data is normal. If the corresponding Q-Q plot graphically shows a pattern with data values that are clustered around the diagonal line, this also may indicate normality. This is furthermore supported if the skewness and kurtosis dived by their standard errors show a value that is

less than 2. We checked for normality in both the pre-test and post-test datasets. In both datasets nearly all of the tested variables are normally distributed (see Appendix 5). However, a few require additional explanation. The test of normality of the pre-test data showed that intention was not normally distributed, according to its p-value that presents a value that is greater than the declared level of .05. However, the skewness and kurtosis had a value that is below 2. Also the normal Q-Q plot showed a slight deviation, but the data values were still considerably clustered around the diagonal line. In contrast, the test of normality of the post-test data showed that intention is rather normal. Attitude towards public transport showed a pattern that is quite left-skewed. And perceived behavioural control of car and bicycle was a bit right-skewed. The histogram and normal Q-Q plot of subjective norm showed for all travel modes a distinctive pattern that is skewed to the left, and with only a few observed values. This makes this variable not proficient for further analyses. Therefore, we decided to transform subjective norm into a dichotomous variable. In short, even though there are some variables that deviated from normality, we decided that this is not a decisive reason to not conduct any statistical analyses including these variables.

Checking for homogeneity of variance

To check for homogeneity of variance for the groups of data we used the Levene's test. It tests the null hypothesis that the variances in different groups are equal (Field, 2009). To meet the assumption of equality the outcome should not be significant. In both data sets that are a few variables with a violated homogeneity of variance (see Appendix 6). However, this is no crucial burden for conducting further statistical analyses.

4.8 Data analyses

Data was analysed using statistics software SPSS.

Descriptive statistics

Basic features of relevant constructs were described in the descriptive statistics in Section 5.1. It provided a summary of mean scores and standard deviations of the pre- and post-test sample. We also checked if there were differences between the means of the experimental and the control group for the pre-test. This was done using an independent samples T-test. In case of non-normality, a Mann-Whitney U-test was used. The analyses showed that there were no statistically significant differences in the pre-test (see Appendix 7). This means that the two population means are equal.

Correlation

For the analyses of correlation in Section 5.2, a Pearson product-moment correlation coefficient was used to measure strength and direction of correlation. In case of a nonparametric variable, correlation was measured with a Kendall's Tau rank correlation coefficient. We tested whether the independent

variables (attitude, subjective norm, and perceived behavioural control) and dependent variable (intention) were related with a one-tailed correlation test. This was chosen because the research hypotheses already determined the direction of the potential correlation.

ANOVA analyses

The measurement of change comparing the experimental and control group over time was tested with an ANOVA analysis of variances using a repeated-measures design (see Section 5.3). This was chosen because the same group samples participated in all conditions of the experiment. The ANOVA analysis examined whether the mean scores differed between both groups before (t1) and after (t2) manipulative treatment. The statistical value showed if there was a statistically significant difference between the samples (Wilson & Maclean, 2011). Also, an ANOVA analysis was also used to test for differences in travel mode use between both groups over time (see Section 5.3.1). In this study, differences for car use and bicycle use were of main interest, meaning that dummy variables were created of the travel diary data (which also included other travel modes).

Moderation

In Section 5.3.2, moderation effects were tested. We conducted moderation analyses using model 1 of Hayes' PROCESS Macro for SPSS. A model in which attitude towards cycling, subjective norm of cycling, and perceived behavioural control when cycling acted as moderators on the relationship between ICT (i.e., use of app) and intention was tested. The p-values, with a criterion level of .05, showed whether the effect was significant.

Mediation

In Section 5.4, we conducted a mediation test by use of model 4 of Hayes' PROCESS Macro for SPSS. It was tested whether the relationship between ICT (user experience) and actual travel mode choice behaviour was explained by their relationship on intention (i.e., the mediator variable). Also here, criterion level for significance was .05.

Hierarchical logistic regression analysis

A hierarchical logistic regression analysis was performed by incrementally entering the explanatory variables into the model (See Chapter 6). In all analyses in which travel mode choice was the dependent variable, car was used as reference category. Because repeated measures were considered as separate case (five per participant) it may occur that observations are not independent (also known as serial correlation between errors). In order to check for this, Field (2009, p. 220-221) suggests to calculate Durbin-Watson statistic. Durban-Watson values close to 2 indicating absence of serial correlation between errors and thus that observations may be considered as independent.

In the first model, the sociodemographic variables were entered (gender, age, educational level, and income). Second, attitude, subjective norm, and perceived behavioural control were added. In the final model, use of app (i.e., EG/CG) and distance to work were included. With the -2 Log Likelihood and the Chi-square it was tested whether adding more explanatory variables could increase an accurate prediction of the dependent variable. R^2, measured by Cox and Snell and Nagelkerke, showed the explained variance by the predictors. Hosmer and Lemeshow tests were used to indicate goodness of fit of the regression model. Next, variables that significantly (*p*s < .05) predicted travel mode choice were discussed in more detail. The regression coefficient B determined the direction of the effect (negative or positive effect; strong or weak effect). The odds ratio is the exponentiation of the B coefficient.

Chapter 5 – Results of experiment

In this Chapter the quantitative results are discussed, showing outcomes of the experiment and what happened within the experimental group.

5.1 Descriptive statistics

Table 4 summarizes the descriptive statistics of relevant variables. Attitude towards bicycle use shows the highest mean (M = 3.72) compared to car (M = 3.01) and public transport (M = 2.42) use at t1. However, the mean score for attitude towards bicycle marginally decreased (M = 3.70) at t2, while mean scores for car and public transport use increased (M = 3.32 and M = 2.47 respectively). Subjective norm is highest for cycling (M = 0.43) at t1. Subjective norm for car and public transport show similar mean scores (M = 0.32) at t1. Mean scores of subjective norm increased for all travel modes (M = 0.47, M = 0.58, and M = 0.50). Perceived behavioural control when using a car (M = 4.05) and riding a bicycle (M = 4.22) demonstrate very high mean scores at t1. In contrast, the mean score for using public transport is lower (M = 2.58). At t2, all mean scores for perceived behavioural control declined (M = 3.98, M = 4.08, and M = 2.31). Intention to commute by bicycle shows a high mean score (M = 3.42) at t1. This mean score (M = 3.06) remained moderate, however slightly decreased at t2. The mean score for habit increased when comparing t1 (M = 2.91) and t2 (M = 2.93). ICT was only measured at t1, but shows a moderate mean score (M = 2.01).

Table 4. Descriptive statistics regarding the research constructs before (t1) and after (t2) manipulation.

Construct	M_{t1}	SD_{t1}	M_{t2}	SD_{t2}
Attitude				
Car	3.01	0.67	3.32	0.74
Bicycle	3.72	0.43	3.70	0.41
Public transport	2.42	0.74	2.47	0.72
Subjective norm				
Car	0.32	0.47	0.47	0.51
Bicycle	0.43	0.50	0.58	0.50
Public transport	0.32	0.47	0.50	0.51
PBC				
Car	4.05	0.80	3.98	0.73
Bicycle	4.22	0.65	4.08	0.57
Public transport	2.58	0.75	2.31	0.69
Intention	3.42	1.04	3.06	1.02
Habit	2.91	1.02	2.93	1.03

ICT	2.01	0.68

Note. N_{t1} = 37. N_{t2} = 36. N_{ICT} = 17.

5.2 Correlations

In this paragraph correlation between the independent variables (attitude, subjective norm, and perceived behavioural control) and the outcome variable of intention was tested. The correlation ranges between -1 (perfect negative correlation) and 1 (perfect positive correlation). For the normally distributed variables (see Appendix 5) we used the Pearson product-moment correlation coefficient to measure the strength and direction of the correlation. For the non-parametric variables (see Appendix 5) we used a Kendall's Tau rank correlation coefficient to measure the strength and direction of the correlation. Criterion is a significance level of less than .05 to indicate correlation. Correlations were tested for both the pre-test as well as the post-test data.

Table 5 shows that there was a strong, positive correlation between attitude towards cycling and intention to commute by bicycle for the pre-test data. This relationship was statistically significant (r = .63, p = < .01). Meaning that attitude was related to intention. Also, the R^2 indicates that 63% of the variability in intention is shared by attitude, indicating a strong relationship. Furthermore, the table shows that there was a positive, statistically significant, relationship between perceived behavioural control of bicycle use and intention to commute by bicycle (r = .37, p < .01). The R^2 of .37 determines that the relationship is moderate. It says that perceived behavioural control shares 37% of the variability in intention.

Table 5. Correlations between independent variables and outcome variable 'intention' (pre-test).

Variable	*Pearson r*	*Kendall's Tau*
Attitude		
Car	-.09	
Bicycle	.63**	
Public transport		.02
Subjective norm		
Car	.05	
Bicycle	.01	
Public transport	.05	
PBC		
Car		.02
Bicycle		.37**
Public transport	.23	

Note. One-sided testing (N = 37). * p < .05. ** p < .01.

Table 6 presents that attitude towards using a bicycle has a positive relationship with intention to use a bicycle when commuting to work (r = .38, p < .05). This relationship was statistically significant. However, the R^2 of attitude decreased compared to the pre-test. In contrast to the pre-test does subjective norm have a relationship with intention, with the R^2 of bicycle showing the strongest relationship with intention (r = .53, p < .01). This correlation coefficient shows that subjective norm accounts for 53% of the variability in intention. Furthermore, there was a positive relationship between perceived behavioural control of bicycle use and intention (r = .57, p < .01). It implies that perceived behavioural control shares 57% of the variability in intention. It is somehow remarkable that there was no statistically significant relationship between ICT and intention, while this was hypothesized.

Table 6. Correlations between independent variables and outcome variable 'intention' (post-test).

Variable	*Pearson r*	*Kendall's Tau*
Attitude		
Car	-.07	
Bicycle	.38*	
Public transport		.00
Subjective norm		
Car	.28*	
Bicycle	.53***	
Public transport	.37*	
PBC		
Car		.14
Bicycle	.57**	
Public transport	.27	
ICT	-.27	

Note. One-sided testing (N = 36). * p < .05. ** p < .01.

5.3 Outcome of experiment: between experimental and control group

We now turn to the central aspect of our study, the measurement of change comparing the experimental and control group between the pre-test and the post-test data. With special attention to whether the intervention had effect on intention towards commuting by bicycle. Because we are dealing with the same participant groups engaging in all conditions of the experiment (Field, 2009), we conducted an ANOVA analysis of variance using a repeated-measures design. This test investigates changes in the mean scores over time, and differences in mean scores under different conditions (i.e.,

treatments). The null hypothesis asserts that the population means are equal, whereas the alternative hypothesis states the opposite.

Table 7 presents the results of the ANOVA analysis. The output of the multivariate test highlights that there were no significant differences found between the two groups in the experimental conditions (pre-test and post-test). Initially, there seems to be small differences between mean scores of the control and experimental group over time. However, Wilk's Lambda values were not significant (*p*s < .05). These results reveal that there are no differences between both groups over time. Therefore, there is not enough evidence to support the alternative hypothesis.

Table 7. Means of experimental (EG) and control (CG) group before (t1) and after (t2) manipulation.

Variable	M_{EGt1}	M_{CGt1}	M_{EGt2}	M_{CGt2}	Wilk's Lambda
Attitude					
Car	3.00	3.03	3.25	3.39	.53
Bicycle	3.60	3.81	3.65	3.75	.29
Public transport	2.40	2.44	2.44	2.50	.97
Subjective norm					
Car	0.24	0.42	0.35	0.58	.81
Bicycle	0.35	0.53	0.41	0.74	.41
Public transport	0.24	0.42	0.35	0.63	.63
PBC					
Car	3.98	4.10	4.00	3.96	.41
Bicycle	4.15	4.29	4.15	4.01	.15
Public transport	2.56	2.20	2.54	2.41	.26
Intention	3.29	3.58	2.92	3.18	.92
Habit	2.62	3.16	2.62	3.21	.88

Notes. *p < .05. ** p < .01. *** p < .001.

5.3.1 Differences of travel mode use over time

However, we will also test if there were differences in travel mode use over time between the experimental and control group. Therefore, we again conducted an ANOVA analysis of variance using a repeated-measures design. We are notably interested if the experimental participants showed a significant increase in bicycle use when commuting to work, in contrast to the control group.

Before conducting the ANOVA analysis we first had to restructure the data set by creating dummy variables of the travel diary data. We built variables that represent the travel mode groups using only values of 0 or 1. Because we want to see what happened for car and bicycle use over time, we created

dummies for these two groups. Subsequently, we produced a frequency table of these dummy variables to detect the means of the variables over time. With this information we created a graph that showed the differences between car and bicycle use (see Figure 5). This figure shows the travel mode differences between the experimental (EG) and control group (CG) over time (week 1-5).

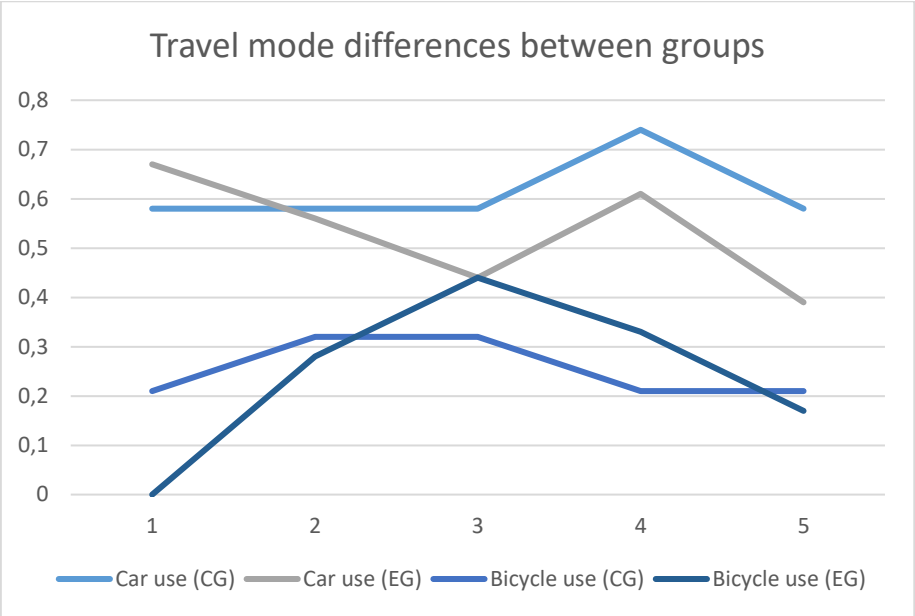

Figure 5. Travel mode differences between the experimental and the control group.

Car use practically shows a similar pattern for both groups. However, in the beginning the control group presents a flat line whereas the experimental group decreases. From week three on they follow an equivalent pattern. Bicycle use is comparable, however has a reverse-shaped pattern with a temporary increase in the first weeks. It reaches its climax in week three, from which it gradually levelled off.

To test if these differences of travel mode choice between the experimental and control group were statistically significant, we conducted two ANOVA analyses of variance: one for bicycle use, another for car use.

Cycling to work

Mauchly's test of Sphericity has a significance value of $p > .05$. This means that we can conclude that the variances of differences were not significantly different. Because sphericity is assumed, we can use the test of within-subjects effects. The results show if there was an overall significant difference between the means at the different time points (see Table 8). It exposes that repeated measures is significant (because $p = .02$, which is less than the criterion value of .05), meaning that there was a significant effect over time. This is a quadratic effect for the experimental group, with a line that first goes up and then goes down (see Figure 5). However, the test also presents evidence that there was no significant interaction effect, in other words time did not interact with groups ($F(4, 140) = 1.33$, $p > .05$).

Therefore, we cannot assume that there were differences of bicycle use between the experimental and control group over time.

Table 8. ANOVA analysis using a repeated-measures design for bicycle use.

Variable	*Df*	*Error*	F	*p*
Time	4	140	2.97	.02*
Interaction (Time*Group)	4	140	1.33	.26

Notes. * $p < .05$. ** $p < .01$. *** $p < .001$.

Driving to work

Mauchly's test of Sphericity shows that the variances of the differences between levels were equal ($p > .05$). The tests of within-subjects effects reveals that there was no statistically significant effect of time ($p > .05$). This assumes that there we no differences over time. The within-subjects test also shows that there was no significant interaction effect, or in other words: time did not interact with groups ($F(4, 140) = 0.76$, $p > .05$). We thus cannot conclude that there were differences of car use between both groups. All is summarized in Table 9.

Table 9. ANOVA analysis using a repeated-measures design for car use.

Variable	*Df*	*Error*	F	*p*
Time	4	140	1.53	.20
Interaction (Time*Group)	4	140	0.76	.55

Notes. * $p < .05$. ** $p < .01$. *** $p < .001$.

5.3.2 Testing moderation effects

We now will test a model that incorporates a combined effect of two or more independent variables on an outcome variable. The moderator variable affects the strength, direction, or both, of the relationship between an independent variable and the outcome (Field, 2013). In our case, we conducted moderation tests using Hayes' PROCESS Macro for SPSS. With moderation model 1 we tested a model in which attitude towards bicycle use, subjective norm of cycling, and perceived behavioural control when cycling act as moderators on the relationship between ICT (use of app) and intention. We followed two steps to test if there was a moderation effect: in step one we introduced the independent variable (ICT) and the moderator (Field, 2013). Both the effects and the explained variance (R^2) should be significant. In step two, we introduced the interaction effect (independent*moderator). Here too, the interaction effect ought to be significant. In case the p-values of the effects and the explained variance (R^2) are significant there is a statistically evidenced effect of a moderator. The tested models are illustrated in Figure 6, Figure 7, and Figure 8.

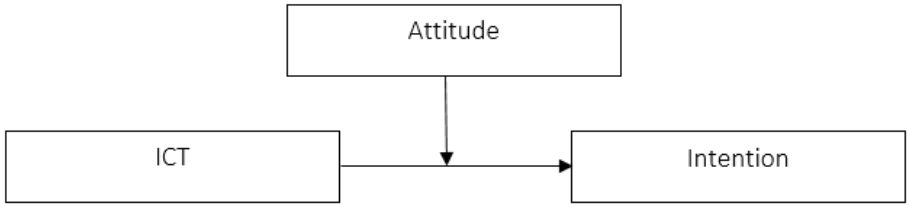

Figure 6. Diagram of moderating effect of attitude.

The results of testing the moderating effect of attitude on the relationship between ICT and intention in showed in Table 10. It demonstrates that the interaction was not statistically significant. This means that there is no evidence to assume that there is a moderation effect of attitude. However, it shows that there is an effect of attitude ($p < .01$).

Table 10. Results testing the moderating effect of attitude towards cycling ($N = 36$).

Variable	*B*	*SE b*	z	*p*
Constant	-0.40	0.13	-3.12	.00**
Attitude	1.67	0.55	3.04	.00**
ICT	-0.16	0.25	-0.63	.53
Interaction (Attitude*ICT)	0.31	1.06	0.29	.77

Notes. $R^2 = .31$. * $p < .05$. ** $p < .01$. *** $p < .001$.

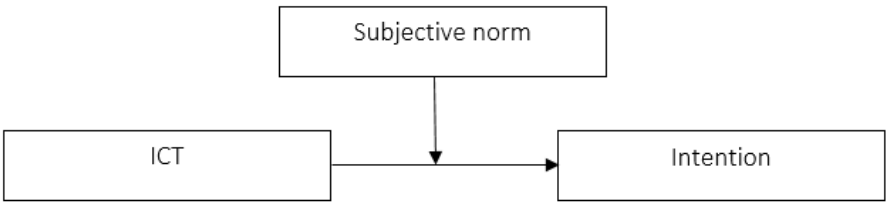

Figure 7. Diagram of moderating effect of subjective norm.

In Table 11 the results of the moderation analysis of subjective norm are presented. There was no significant moderation effect of subjective norm on the relationship between ICT (use of app) and intention ($p > .05$).

Table 11. Results testing the moderating effect of subjective norm of cycling ($N = 36$).

Variable	*B*	*SE b*	z	*p*
Constant	-0.44	0.17	-2.54	.02*
Subjective norm	0.18	0.41	0.45	.66
ICT	0.05	0.34	0.14	.89
Interaction (SN*ICT)	-1.23	0.81	-1.51	.14

Notes. R^2 = .14. * *p* < .05. ** *p* < .01. *** *p* < .001.

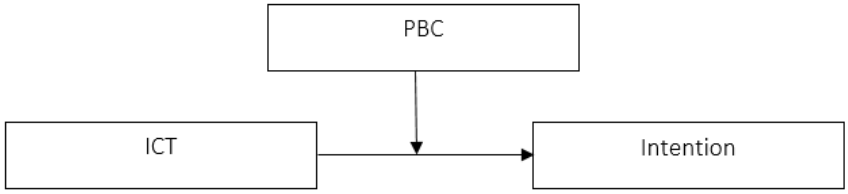

Figure 8. Diagram of moderating effect of perceived behavioural control.

Finally, the outcomes of the moderation analysis of perceived behavioural control are showed in Table 12. Also here, it shows that there was no statistically significant moderation effect of perceived behavioural control (*p* > .05). Therefore, it cannot be statistically proven that perceived behavioural control moderates the relationship between ICT (use of app) and intention.

Table 12. Results testing the moderating effect of perceived behavioural control when cycling (*N* = 36).

Variable	*B*	*SE b*	z	*P*
Constant	-0.38	0.15	-2.59	.01*
PBC	0.61	0.38	1.62	0.11
ICT	-0.14	0.30	-0.46	.65
Interaction (PBC*ICT)	-0.08	0.73	-0.11	.91

Notes. R^2 = .13. * *p* < .05. ** *p* < .01. *** *p* < .001.

5.4 Within experimental group

Previous section showed the outcome of the experiment. It made conclusions about the differences between the experimental and control group after several analyses.

Here, we will examine what happened within the experimental group. Meaning that we want to know if ICT (user experience) had an effect on the actual travel mode choice behaviour of the experimental participants (*N* = 17). It is tested whether there is a relationship between ICT and actual behaviour that is explained by their relationship on a third variable (the mediator). A common rule in mediation is that there is a relationship between the mediating variable (intention) and the dependent variable, that is behaviour (path b) (Field, 2013). Another required condition is that the independent variable (ICT) has an effect on the mediating variable that is intention (path a). We expect that the relationship between the independent and dependent variable is less strongly because of the mediator (path c). Figure 9 illustrates the mediation model. We conducted a mediation test with the PROCESS Macro for SPSS. The mediation analysis is represented by model 4.

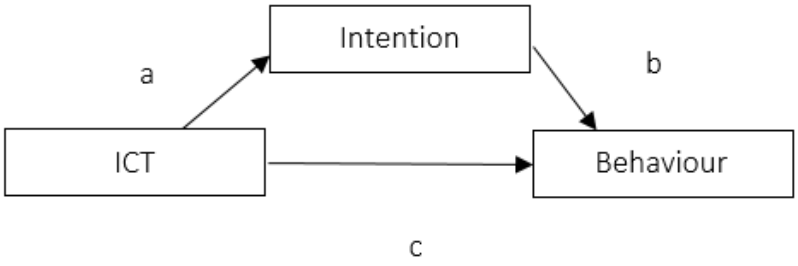

Figure 9. Diagram of the mediation model.

Table 13 shows the results of the simple regression of intention predicted from ICT (i.e., path a). It shows that there was no statistically significant relationship between ICT and intention (*b* = 0.19, *t* = 1.21, *p* = 0.23).

Table 13. Simple regression of the effect of ICT on intention (path a).

Variable	*B*	*SE b*	t	*p*
Constant	-0.64	0.33	-1.96	.05
ICT	0.19	0.16	1.21	.23

Notes. R^2 = .02. * *p* < .05. ** *p* < .01. *** *p* < .001.

Table 14 shows the output of the regression model between the independent variable (ICT) and the dependent variable (behaviour) (i.e., path c). It shows that there was no statistically significant effect of ICT on behaviour (*b* = 0.18, z = -0.48, *p* = 0.63). Furthermore, the table also shows the effect of intention on behaviour (i.e., path b). Here too, there was no statistically significant effect (*b* = 0.16, z = 0.52, *p* = 0.60).

Table 14. Logistic regression of behaviour predicted from ICT (path c) and intention (path b).

Variable	*B*	*SE b*	Z	*p*
Constant	-0.27	0.80	-0.34	.73
Intention	0.16	0.31	0.52	.60
ICT	-0.18	0.38	-0.48	.63

Notes. * *p* < .05. ** *p* < .01. *** *p* < .001.

Table 15 demonstrates the most important part of the analysis, it presents the results of the indirect effect of ICT on behaviour, via intention (the mediator). It shows that the b-value for the indirect effect falls between -0.07 and 0.36. This range includes zero, meaning that there was no evidence to assume an indirect effect. This indicates that intention does not mediate the relationship between ICT and intention.

Table 15. Indirect effect of ICT on behaviour, via intention (path ab).

Variable	*Effect*	*Boot SE*	BootLLCI	*BootULCI*
Intention	0.03	0.09	-0.07	0.36

Notes. * $p < .05$. ** $p < .01$. *** $p < .001$.

Chapter 6 – Results on travel mode choice

Previous Chapter showed that there were no differences between both groups over time. There were also no striking results within the experimental group. This Chapter presents the final composite analysis that will test the original model of the Theory of Planned Behaviour (see Figure 10). We will test whether the latent constructs of attitude, subjective norm, and perceived behavioural control are statistically significant predictors of travel mode choice.

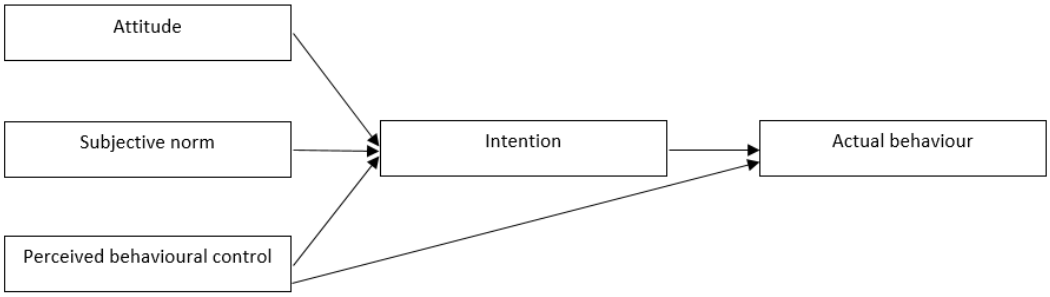

Figure 10. Theory of planned behaviour model [Graph].

6.1 Data restructuring

Before the analysis, we had to restructure the data in SPSS from wide (repeated measures) to long (travel mode choice as case) format to predict travel mode choice. Each row in the dataset is one time point per subject. So, each respondent has five rows, one for each week. We also decided that the outcome variable of travel mode choice had to be modified, because some response categories did not reflect a possible travel choice (e.g., 'working somewhere else', 'working at home', and 'not working'), or categories that had too few response in the dataset (e.g., 'walking' and 'carpooling'). These categories were addressed as missing value. This also applied for the variable of income, from which two response categories did not reflect a possible income category (e.g., 'I don't know' and 'I don't want to say'). For the variable of living situation we decided to report three categories as missing value, because they had too few response (e.g., 'Living with parents without children', 'Living in a student residence', and 'Different'). After reshaping the dataset we were able to conduct the analysis.

6.2 Descriptive statistics

The sample consists of a total of 185 travel episodes, of which are 95 (51.4%) from the control group and 85 (48.6%) who are engaging in the experimental group. There is a larger number of female (*N* = 130 cases) than male (*N* = 55) participants. The mean age in the sample was 43 years (SD = 10.71), ranging from 24 to 63 years. A majority of the people (*N* = 150 cases) is highly educated, referring to BA,

MA or PhD (81%). Majority of the participants lived together with their partner or with their partner and children (*N* = 140; 80%). Approximately 76% of the participants had a monthly income of more than 2000.00 euros per month (*N* = 130). The mean distance participants had to travel from their home address to their working address was 11.57 kilometres (SD = 4.60), ranging from 2 to 22 kilometres. Sample overview is summarized in Table 16.

Table 16. Sample overview of post-test descriptives.

Variable	*Number of travel episodes (%)*	*N*
Gender		185
Female	130 (70.3%)	
Male	55 (29.7%)	
Age		185
< 25	10 (5.4%)	
26 – 35	45 (24.3%)	
36 – 45	55 (29.7%)	
46 – 55	40 (21.6%)	
56 – 65	35 (18.9%)	
Educational level		185
Lower secondary vocational (LBO)	10 (5.4%)	
General secondary school (MAVO)	5 (2.7%)	
Intermediate vocational (MBO)	20 (10.8%)	
Higher Vocational/University (BA)	65 (35.1%)	
Higher Vocational/University (MA and PhD)	85 (45.9%)	
Living situation		175
Living alone	25 (14.3%)	
Living with partner	70 (40.0%)	
Living with partner and children	70 (40.0%)	
Living with children without partner	10 (5.7%)	
Income		165
< 999.99	10 (6.1%)	
1500.00 – 1999.99	25 (15.2%)	
2000.00 – 2999.99	65 (39.4%)	
3000.00 – 4999.99	60 (36.4%)	
> 5000.00	5 (3.0%)	
Distance to work		185

< 5	20 (10.8%)
6 – 10	50 (27.0%)
11 – 15	85 (45.9%)
16 – 20	25 (13.5%)
21 – 25	5 (2.7%)

Note. *N* = number of cases included.

6.3 Preliminary analysis

In Section 5.3, an ANOVA using repeated measures was reported using time (within subjects) and groups (between subjects). In order to incorporate additional explanatory variables, a mixed logistic regression model would have been appropriate. This because repeated observations were from the same sample (Field, 2009). This may have resulted in non-independent observations. However, analysis of the travel patterns of car and bicycle (in Section 5.3.2) showed a quadratic curve for bike use and no effect for car use. In addition, there was no interaction effect of time and group for both travel modes. In particular, it was difficult to give meaning to the quadratic curve pattern as the expectation of the experiment was a linear increase of bicycle use, and not a temporary increase which levelled off later on. Second, the number of additional model variables for the explanation of travel mode choice would have been limited because the number events per variable was small in a sample of 37. Therefore, it was decided to focus on the explanation of travel mode choice as registered in the travel mode diaries of participants. This was done using a multinomial logistic regression analysis predicting travel mode choice: car, bicycle, and public transport.

However, we encountered two problems in the analysis. First, errors regarding zero frequencies in cells were reported (called “unexpected singularities in the Hessian matrix”), likely to be caused by too few participants (*N* = 10) choosing public transportation (also known as the necessary number of events per variables which is preferably greater than 10). This is in line with Peduzzi, Concato, Kemper, Holford, and Feinstein (1996) who stated that logistic regression analyses might produce disputable results when there are too few available outcome variables. Major concerns are accuracy and precision of the regression coefficients. This makes the validity of the model fit uncertain. Therefore, we chose to remove the public transportation category and conducted a binary logistic regression with two travel mode categories: car versus bicycle. Second, the socio-demographic variable of living situation led to unstable results. It caused extraordinary high odds ratios of above 40. A plausible explanation for this to happen is that some categories of living situation had too few response values which had a disturbing effect on other explanatory variables. Therefore, we were not able to fully explain the reported effects. We could not say with certainty that all significant effects we found were truly predictors of travel mode

choice. This made us decide to not include this variable living situation in the final logistic regression analysis.

The final hierarchical logistic regression analysis included three models. In model 1 we entered sociodemographic variables (gender, age, education, and income). In model 2 we entered the latent constructs (attitude, subjective norm, and perceived behavioural control). In model 3 we entered the variable use of app (i.e., EG/CG) and a remaining control variable that tests the effect of distance to work.

6.4 Model estimates

Final findings are reported by means of incrementally hierarchical model specifications (see Table 17). In line with the recommendations of Field (2013, p. 322) car, being the category with the largest numbers of subjects, was used as the reference category in the model. The -2 Log Likelihood statistic showed a decreasing value compared to the baseline model. This means that the new models, in which more independent variables are added, more accurately predicts the dependent variable than in the intercept-only model. Confirmed by the chi-square that is statistically significant in model 2 ($\chi^2(10) = 39.84$, $p < .001$) and model 3 ($\chi^2(12) = 42.27$, $p < .001$). R^2 of model 1, measured by Cox and Snell and Nagelkerke, 4.6% and 6.5% respectively, indicates the explained variance by the predictors. The R^2 increases when more predictors are entered into the model. Model 2 shows a Cox and Snell R^2 of 26.2% and a Nagelkerke R^2 of 37.2%. The final model has the greatest explained variance: R^2, measured by Cox and Snell and Nagelkerke, 27.6% and 39.2% respectively. This implies a quite high explained variance. The Hosmer and Lemeshow test shows in all three models a p-value that is not significant ($p > .05$) meaning a good fit of the regression model. In Table 17, the results of the hierarchical logistic regression analysis are presented. The table contains unstandardized regressions coefficients with standard error in brackets.

In model 1 alone the socio-demographics were entered. It shows that educational level is a statistically significant predictor of travel mode choice ($p < .05$). The regression coefficient B determines the direction of the effect. The value of 0.34 means that an increase in educational level results in an increase in bicycle versus car use. The odds ratio shows that when educational level increases by one point, the change in odds of choosing to commute by bicycle instead of going by car, would be expected to increase with 1.40 units. This means that participants are more likely to go by bicycle than by car.

However, model 2 shows that when adding more variables, educational level is no significant predictor anymore. Model 2 entered the latent constructs of attitude, subjective norm, and perceived behavioural control. It demonstrates that attitude towards car ($p < .001$), attitude towards cycling ($p < .05$), and

perceived behavioural control when cycling ($p < .05$) were statistically significant. The B-value of -2.02 means that an increase in attitude towards car use results in a decrease in bicycle versus car use. Also the odd ratio shows that when attitude towards cars increases by one point, the change in odds of choosing to commute by bicycle compared to going by car, would be expected to increase with 0.13 units. This means that participants are more likely to go by car instead of going by bicycle. For attitude towards bicycle use it shows a B-value of 1.62, meaning that an increase in attitude towards bicycle use results in an increase in bicycle versus car use. The odds ratio shows that if attitude towards bicycle increases by one point, the change in odds of choosing to commute by bicycle compared to going by car, would be expected to increase by 5.06 units. This indicates that participants with a high attitude towards cycling are more likely to commute by bicycle than by car. Perceived behavioural control when cycling presents a B-value of 1.35. This suggests that if perceived behavioural control increases this causes an increase in bicycle versus car use. Confirmed by the odds ratio that shows that if perceived behavioural control when cycling increases by one point, the change in odds of choosing to commute by bicycle in comparison to going by car increases by 3.85 units. Meaning that if people feel controlled when cycling they are more likely to commute by bicycle instead of going by car.

Model 3 entered use of app and distance to work. Both of the new included variables are not statistically significant predictors of travel mode choice. Also, perceived behavioural control when cycling is not a significant predictor of travel mode choice anymore. However, Table 17 shows attitude towards cars and attitude towards cycling continue to be statistically significant. The value of -2.01 means that an increase in attitude towards car use results in a decrease in bicycle versus car use. Participants will probably go by car instead of going by bicycle. This is a similar effect as in model 2. Attitude towards bicycle use shows a value of 1.75, meaning that an increase in attitude towards bicycle use results in an increase in bicycle versus car use. This indicates that participants are more likely to commute by bicycle compared to going by car.

Table 17. Results of hierarchical logistic regression analysis regressing the binary outcome of travel mode choice (car vs bicycle).

Variable	*Model 1*	*Model 2*	*Model 3*
Constant	-1.56 (1.55)	-8.84 (3.83)*	-9.53 (4.07)*
Socio-demographics			
Gender	0.23 (0.45)	0.88 (0.64)	0.87 (0.66)
Age	0.02 (0.02)	-0.02 (0.03)	-0.01 (0.03)
Educational level	0.34 (0.17)*	-0.05 (0.21)	-0.16 (0.23)
Income	-0.59 (0.30)	-0.21 (0.41)	-0.06 (0.43)
Latent constructs			

Attitude			
Car		-2.02 (0.48)***	-2.01 (0.52)***
Bicycle		1.62 (0.81)*	1.75 (0.84)*
Subjective norm			
Car		-0.07 (0.89)	-0.36 (0.92)
Bicycle		0.78 (0.97)	1.61 (1.14)
PBC			
Car		0.94 (0.52)	0.94 (0.58)
Bicycle		1.35 (0.65)*	1.21 (0.68)
Use of app (control vs. experimental)			0.91 (0.62)
Distance to work			-0.02 (0.06)
Model fitting information			
-2 Log likelihood function	153.41	119.70	117.26
Chi-square	6.13	39.84***	42.27***
R^2 Cox & Snell (df)	4.6 (4)	26.2 (10)	27.6 (12)
R^2 Nagelkerke (df)	6.5 (4)	37.2 (10)	39.2 (12)

Notes. This table contains the unstandardized regression coefficients *B(SE)*. * $p < .05$, ** $p < .01$, *** $p < .001$.

Chapter 7 – Conclusion and discussion

7.1 Conclusions

The aim of this research was to test whether it is possible to affect travel mode choice behaviour of commuters by means of gentle manipulation, to encourage a sustainable shift from private car use to cycling. The main research question was: *Does nudging, through smartphone app usage, affect travel mode choice behaviour of commuters?*

A theoretical framework (see Chapter 2) was developed to explain the potential relationship between ICT and travel mode choice behaviour. A model combining features of TPB (explaining travel behaviour) and TAM (describing use of ICT) was introduced. From this, hypotheses about the constructs and their interrelations were formulated (see Table 18). The model was tested in an experiment using a pretest-posttest control group design. In this way, results could be validated. Using this design also produced high methodological quality in contrast to other studies that only tested effectiveness of smart phone persuasion without a control group (Sunio & Schmocker, 2017).

Table 18. Summary of hypotheses.

	***Between** experimental and control group*
1	The mean scores from *t*1 to *t*2 of the research constructs differ between the experimental and the control group
2	The linear increase in bicycle use from *t*1 to *t*2 in the experimental group is larger than in the control group
3	Attitude towards cycling, subjective norm of cycling, and perceived behavioural control when cycling, moderate the relationship between app usage and intention towards cycling
	***Within** experimental group*
4	Intention towards cycling mediates the relationship of ICT user experience on travel mode choice behaviour
	Travel mode choice
5	Socio-demographic variables, attitude, subjective norm, and perceived behavioural control, use of app, and distance to work predict travel mode choice behaviour

The central findings of this study are as follows. The results showed that there were no differences between the mean scores of the experimental and the control group before and after manipulative treatment. Meaning that this study was not able to establish significant differences between both groups by means of a manipulative treatment. Therefore, H_1 cannot be confirmed.

However, when focusing on differences between travel mode choice, it demonstrates an effect of time for bicycle use. This indicated that bicycle use changed during the five weeks of the experiment, showing a quadratic curve. This is in contrast with what was hypothesized in H_2 that bicycle use of the

experimental group would increase linearly. Furthermore, for bicycle use as well as car use the analysis showed that there was no interaction effect (group*time), implying that for both travel mode categories there were no differences between the experimental and control group over time. This means that we were not able to confirm H_2 within this study.

The conceptual model assumed that attitude, subjective norm, and perceived behavioural control acted as moderators affecting the relationship between ICT (use of app) and intention. However, there was not enough evidence to support H_3. It therefore cannot be concluded that attitude, subjective norm, and perceived behavioural control moderate the relationship between ICT and intention.

H_4 tested whether ICT (user experience) had an effect on travel mode choice behaviour, explained by their relationship on intention (mediation variable). The mediation analysis showed no indirect effect, meaning that within this study we could not conclude intention mediated the relationship between ICT and travel mode choice behaviour. This implies that H_4 is not confirmed. In addition, there was also no significant effect of ICT on travel mode choice behaviour found.

The results showed which explanatory variables were significant predictors of travel mode choice (car vs. bicycle). The first model revealed that the higher the educational level of the research participants, the more likely they are to go by bicycle instead of going by car. In model 2, the effect of educational level was not found any longer. It however showed that participants with a high attitude towards cars are more likely to choose to go by car. Also, people with a high attitude towards cycling are more likely to travel by bicycle. Both attitude effects remain significant in the final model. Model 2 also presents that perceived behavioural control when cycling is significant, meaning that people are more likely to go by bicycle compared to going by car. Yet, this effect was not found in the last model. Concluding there was only partial evidence for H_5 that assumed that socio-demographic variables, attitude, subjective norm, and perceived behavioural control, use of app, and distance to work predict travel mode choice behaviour.

7.2 Discussion

To the best of our knowledge, this study was the first attempt of exploring how to nudge travel mode choice behaviour of commuters by use of a smartphone application as nudging device. It makes a contribution to transportation literature by gaining new insights in ICT and travel behaviour. However, summarizing above findings, we have to conclude that this study did not prove the effect of app usage on travel mode choice behaviour of commuters. The nudging device, that is a smart phone application, did not change travel mode choice in terms of increased bicycle usage. Because the smart phone application was the nudging device, we cannot make definite conclusions about the possibility of

participants to truly being nudged, in terms of becoming more conscious about the choice-making context (Mont et al., 2014). However, a comment given to the open question in the post-test questionnaire suggested that participants' awareness would have increased under the influence of nudging. As such, app usage may have made participants more conscious about alternative travel mode options for future commuting. This effect however may be visible in the long term.

Further, our research has underlined the importance of explaining travel behaviour. It showed that there are other explanatory variables, beyond app usage, that predict travel mode choice. For education, it was suggested that the higher the educational level, the more likely participants are to go cycling. This finding appears to be well substantiated by previous studies that found that higher educated individuals had greater active travel activity levels (e.g., walking and cycling). Commins and Nolan (2011) assume that higher educated people will potentially cycle to work. Likewise, De Geus et al. (2008) associate higher educational levels with more possible commuting trips by bicycle. On the other hand, Heinen (2011) observed a negative effect of education on cycling (i.e., more highly educated individuals that cycle less). This highlights its unambiguous character. It seems that contrasting research outcomes vary by country, for instance countries like the United States and the United Kingdom have a low cycling shares in general, while cycling is very common in the Netherlands (Oosterhuis, 2015). This implies that research findings are very context dependent. In the current study, perceived behavioural control regarding cycling was found to affect travel mode choice, in that people are more likely to travel to work by bicycle. De Geus et al. (2008) reported a similar effect. They claimed that when people are highly confident about their ability to go cycling, and this is not influenced by external barriers (e.g., bad weather), they are more likely to go cycling. Also, Heinen et al. (2011) argued that if people have a positive perception of their ability to commute by bicycle, this will have a positive effect on their actual choice to cycle the journey to work. A study of Gatersleben and Appleton (2007) however, pointed out that people who never go cycling are more likely to perceive personal or physical barriers. Thus, there is a difference of perception between non-cyclists and people who already cycle on a regular basis. However, both the effects of educational level and perceived behavioural control where only found in a single model, meaning that there might be stronger predictors of travel mode choice that suppressed these effects (Field, 2009, p. 213). When the model is expanded with extra explanatory variables, the effect of both variables ceases while the attitude constructs (for car and bicycle) continue to predict travel mode choice. Attitude towards cars predicted travel mode choice, in that a higher attitude resulted in participants being more likely to go by car. This is consistent with research of Hoffmann et al. (2017) that indicated that there is a positive relationship between attitudes related to car use and actual car use. For attitude towards cycling we found a similar effect: the higher the attitude, the more likely participants were to commute by bicycle. Heinen et al. (2011) also concluded that attitudes may

have a strong effect on the decision to commute by bicycle. It showed that the attitude constructs do not necessarily exclude one another: participants can score high on car attitude as well as on attitude towards cycling simultaneously. Moreover, the strength of both attitude constructs, that remained significant irrespective of including other explanatory variables, seems to indicate that attitude is the strongest construct predicting travel mode choice in this study. Also earlier studies already supported the important role assigned to attitudes (Ben-Elia & Ettema, 2011; Fujii & Gärling, 2003; Hofmann et al., 2017; Johansson et al., 2006). Research of Ben-Elia and Ettema (2011) showed that individuals with a positive attitude towards cycling, were more likely to change behaviour by switching away from the car. So, attitudes discourage particular travel modes and encourage alternative ones. It indicates that attitudes affect transportation decisions. Our findings corroborate this. This study confirms the importance of attitudes in explaining travel mode choice and reveals its potential as a stimulation mechanism for behavioural change. We can interpret this as that travel mode choice behaviour can be altered by changing attitudes towards a specific travel mode. It demonstrates the relevance of the theory of planned behaviour as a conceptual framework for explaining travel mode choice. However, attitude as strongest predictor is not entirely consistent with past studies on TPB (e.g. Donald, Cooper, & Conchie, 2014; Haustein & Hunecke, 2007). These often present perceived behavioural control as the dominant variable. Researchers (Haustein & Hunecke, 2007) also showed that inclusion of extra variables enhances the TPB constructs, while within this study we found evidence for the opposite arguing that including more variables suppresses the effect of other variables. Thus, the findings of our study are not completely consistent with earlier research. It would, however, be premature to conclude that besides attitude, there is no role for other TPB constructs in travel decision-making. It shows that human behaviour is complex and measurement of these latent constructs is very complicated. This encourages to search for greater methodological and conceptual accuracy in order to better predict travel mode choice behaviour in future research.

This study also has some practical or policy implications. The field experiment illustrated the relevance of explaining travel mode choice behaviour in its real-life context with its ever changing character. It showed that individuals do not live and work in isolation. This may have affected the separate impact of the app. Governments should be aware of this. The context in which our experiment took place is very bike-minded, meaning that there are already many other cycling-stimulation projects. An example is the Bike to Work Week that was organised by Radboud University and Radboud UMC. Furthermore, the city of Nijmegen was starting location for the Giro D'Italia in 2016 and was host of the international cycling congress Velo-City in May 2017. Moreover, cycling promotion is an important part of mobility policy. Many investments are already done to upgrade the bike network, for instance several fast-track cycling routes (e.g., RijnWaalpad). In addition, the city of Nijmegen uses social media and diverse smart phone

applications to develop an active cycling community whereas people can be encouraged to go cycling (Municipality of Nijmegen, 2015). Nevertheless their attempt to more solidly integrate cycling into society, we did not find many robust effects. All these cycling-stimulation apps, projects, and policies might even disturbed the effect of the app in this study. Therefore, we would recommend to conduct a similar study in another (less cycling friendly) context to observe whether a cycling-stimulation app could have profound effects. Another recommendation is to focus more intensely on attitude as an important catalyst of change. Attitude has proved to be a strong predictor of travel mode choice. Governments, more in particular transportation planners, should bear this in mind when designing and developing future sustainable mobility policies. Communication campaigns should focus on promoting sustainable transportation alternatives by increasing related attitudes (e.g., regarding cycling) and discouraging unsustainable travel modes by decreasing car attitudes.

7.3 Limitations and recommendations

This research has several limitations. The first is the sample size. While much time and effort was committed, it proved to be difficult to encourage people to participate in the experiment. Therefore, group sizes were small in contrast to what was required by power analysis. This meant that mean differences of the two groups needed to be very large in order to be statistically significant. The results showed that there was basically no difference between the experimental and the control group, which could have been the result of the small sample size in the model tests. Due to the small sample size, the results also showed a small number of events per variable. Therefore, probably not all effects could have been manifested. Although there was no effect of the app in this study, it is too soon to conclude that the app does not affect travel mode choice at all. Therefore, future research should use larger samples to better test the impact of app usage on travel mode choice behaviour. If possible, cooperation of authorities, like local governments or employers of intended organisations, could further promote participation in future research. Reaching the necessary amount of participants to produce solid research, will be less difficult if these powerful organisations give their support and assist in the sampling process (e.g., approaching its citizens or employees to participate in the experiment).

A second limitation was the duration of the experiment. The field experiment lasted for five weeks, however from this relatively short period it is difficult to make conclusions about the effect in the long run. It often varies between people how long it takes to change new behaviour into automatically performed habits. Time is needed to make behavioural change more likely to be sustained. Future research should therefore conduct an experiment with a longer time span, to increase the chance that change of behaviour sticks.

A third limitation was that the sample may have been biased and thus not have been representative for the whole population. Although an effect of education was found, we have to keep in mind that the majority of the participants in the sample was highly educated. This is probably a result of the various higher education institutions situated on campus Heijendaal. Another drawback is that the research context could have biased the results. Many cycling-stimulation projects in the region could have suppressed the impact of the app on travel mode choice. Moreover, an e-bike as reward may have affected the sample composition. Instead of being motivated to change travel behaviour, people could have been stimulated to participate because they could win an e-bike. Therefore, future research should perform a similar study to test the effect of a cycling-stimulation app. However, in a different research context in which is tried to reach a sample with more variation in participants (socio-demographic characteristics). This may positively affect external validity, because the sample would better present the total population.

A fourth limitation was related to the measurement of constructs and variables. It was chosen to compose scales of the constructs based on reliability outcomes of pre-test measurements. Some items had to be deleted of the scales in the pre-test in order to achieve reliable scales. In the post-test we used the same scales and retained the same items to have comparable and consistent measures. However, this may have resulted in less optimal post-test reliability scores. We nevertheless used pre-test measures as point of departure, because at that moment participants had probably less reflected on the measured constructs and therefore results in a more objective measure. Furthermore, because subjective norm was not normally distributed, dummy variables had to be created which has led to a reduction of the variation in the construct and thus of its predictive power. In contrast to earlier studies, the effect of this scale could not have been proved within our research. Therefore, item formulation should be reconsidered in future research. Furthermore, the category of public transportation had too few available outcome variables. Because of concerns regarding accuracy and precision of the regression coefficients we had to delete this category from analysis, resulting in better internal validity. However, at the expense of external validity because less responses were included in analysis. The socio-demographic variable of living situation had categories with too few response values that had a disturbing effect on other variables. After removing this variable from the final analysis, the effects of other variables could be better explained. Because this variable has proved to have effect on travel behaviour, future research with a bigger sample size could show the power of this variable.

A final limitation is the calibration and the operating of the Ring-Ring app. Several participants commented in the post-test that the app did not function optimally. As is common for GPS-based devices, the app needs adjustment time to adequately register the movements of its user. However, feedback about this is not reported or visually displayed. This may have confused participants because

they were unsure whether the app was registering their travel behaviour or not, which could have led to less active Ring-Ring usage, or even worse, to participant dropout. As such, the app malfunctioning may have negatively biased the results because travel behaviour might have been underreported. Its stimulation functions, such as social gamification elements and reinforcing feedback about travel behaviour, were then possibly less powerful in influencing users to go cycling more often. We therefore recommend to add a training phase of app usage in addition to the extensive written information provided in this study. We expect that this will produce a more robust registration of travel behaviour and as a result more valid research findings. We must seize this opportunity to increase the possibilities of nudging travel behaviour.

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Appendices

Appendix 1 Pre-test questionnaire

Before the experiment at t1, all participants received a pre-test questionnaire, containing questions on: general travel behaviour (part 1), attitude (part 2), subjective norm (part 3), perceived behavioural control (part 4), related to taxed and prices (part 5), intention (part 6), habit (part 7), and socio-demographics (part 8). Part 9 was exclusively for the experimental group, because it comprises a question on their expectations about the effect of Ring-Ring on their future commuting behaviour.

Beste deelnemer,

Hartelijk dank voor uw deelname aan mijn afstudeeronderzoek naar het reisgedrag van forenzen richting campus Heijendaal! Het doel van dit onderzoek is om in beeld te brengen welke factoren van invloed zijn op de keuze voor een bepaald vervoermiddel. Daarom wil ik u vragen om de volgende vragenlijst in te vullen. Uw mening is zeer waardevol!

Het invullen van de vragen zal ongeveer 15 minuten van uw tijd in beslag nemen. De door u verstrekte gegevens zullen uitsluitend voor dit onderzoek worden gebruikt en worden vertrouwelijk behandeld. Mocht u interesse hebben in de bevindingen van het onderzoek, dan kunt u aan het eind van de vragenlijst uw e-mailadres achterlaten. Uw e-mailadres wordt uitsluitend voor dit doel gebruikt.

Neem rustig de tijd om de vragen en stellingen door te lezen en te beantwoorden.

Bij voorbaat dank,

Nikki Korzilius

Master student Planologie

Radboud Universiteit Nijmegen

Deel 1. De volgende vragen gaan over uw reisgedrag richting uw werk op campus Heijendaal.

V1. Hoe ziet uw gemiddelde werkweek eruit? Geef hieronder per dag aan waar uw werkzaamheden plaatsvinden.

	Werken (op campus Heijendaal)	Werken vanuit huis	Niet werken
Maandag (1)	❍	❍	❍
Dinsdag (2)	❍	❍	❍
Woensdag (3)	❍	❍	❍
Donderdag (4)	❍	❍	❍
Vrijdag (5)	❍	❍	❍
Zaterdag (6)	❍	❍	❍
Zondag (7)	❍	❍	❍

V2. Wat zijn uw werkpatronen?

- ❍ Vaste diensten/vaste werktijden (1)
- ❍ Ploegendiensten/wisselende werktijden (2)
- ❍ Flexwerken (4)
- ❍ Anders (3) _____

V3. Hoe reist u over het algemeen naar uw werk op campus Heijendaal? Bijvoorbeeld: 4 keer per week met de auto en 1 keer per week met de fiets.(Beantwoord de vragen over afstand en reistijd van uw woonadres naar uw werkadres op campus Heijendaal)

	Aantal dagen per week (1)	Afstand in km (enkele reis) (2)	Reistijd in min. (enkele reis) (3)
Auto (1)			
Fiets (ook elektrisch) (2)			
Lopend (3)			
Openbaar vervoer (4)			
Carpoolen (5)			
Multimodaal (voorbeeld: trein + fiets) (6)			

De volgende twee vragen gaan specifiek over uw reisgedrag met de fiets.

V4. In welke perioden van het jaar gaat u met de fiets naar het werk?

- ❍ Ik reis nooit met de fiets naar mijn werk (1)
- ❍ Een enkel seizoen (3 maanden) of minder (2)
- ❍ 2 seizoenen (6 maanden) (3)
- ❍ 3 seizoenen (9 maanden) (4)
- ❍ Het hele jaar (5)

V5. Voor welke andere activiteiten gebruikt u de fiets?

	Nooit (1)	Soms (2)	Regelmatig (3)	Vaak (4)	Altijd (5)
Dagelijkse boodschappen (1)	❍	❍	❍	❍	❍
Winkelen voor niet dagelijkse boodschappen (2)	❍	❍	❍	❍	❍
Recreatie in het groen (park, natuur) (3)	❍	❍	❍	❍	❍
Eten of drinken buitenshuis (café, restaurant, bar) (4)	❍	❍	❍	❍	❍
Culturele activiteit (theater, bioscoop, museum, concert, schouwburg) (5)	❍	❍	❍	❍	❍
Bezoek aan bibliotheek, apotheek, postkantoor, etc. (6)	❍	❍	❍	❍	❍
Sporten, zwemmen, fitness, sauna, etc. (7)	❍	❍	❍	❍	❍
Club- of verenigingsactiviteit (geen sport) (8)	❍	❍	❍	❍	❍
Bezoeken van nabije familie/vrienden (9)	❍	❍	❍	❍	❍

Deel 2. De volgende stellingen gaan over motieven die een rol kunnen spelen bij het kiezen voor de auto, de fiets en het openbaar vervoer naar campus Heijendaal. Beantwoord deze ook als u nooit met een van de vervoermiddelen naar uw werk reist.

V6. Ik zou met de auto naar mijn werk op de campus reizen, omdat ...

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Autorijden comfortabel is (1)	❍	❍	❍	❍	❍
Autorijden leuk is (2)	❍	❍	❍	❍	❍
Ik mij veilig voel in de auto (3)	❍	❍	❍	❍	❍
Autorijden mij privacy biedt (4)	❍	❍	❍	❍	❍
Autorijden goedkoper is dan andere vervoermiddelen (5)	❍	❍	❍	❍	❍
De auto voor mij de snelste reismethode is (6)	❍	❍	❍	❍	❍
Autorijden flexibel is (7)	❍	❍	❍	❍	❍
Autorijden ontspannend is (8)	❍	❍	❍	❍	❍
Mijn werk goed te bereiken is met de auto (9)	❍	❍	❍	❍	❍
Er op mijn werk goede parkeerfaciliteiten zijn voor de auto (10)	❍	❍	❍	❍	❍
Autorijden beter is voor mijn gezondheid (11)	❍	❍	❍	❍	❍
Autorijden mij een gevoel van vrijheid geeft (12)	❍	❍	❍	❍	❍
Autorijden past bij mijn levensstijl (13)	❍	❍	❍	❍	❍
Autorijden voor mij de enige mogelijkheid is om naar mijn werk te reizen (14)	❍	❍	❍	❍	❍

V7. Ik zou met de fiets naar mijn werk op de campus reizen, omdat ...

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Fietsen comfortabel is (1)	❍	❍	❍	❍	❍
Fietsen leuk is (2)	❍	❍	❍	❍	❍
Ik mij veilig voel tijdens het fietsen (3)	❍	❍	❍	❍	❍
Fietsen mij privacy biedt (4)	❍	❍	❍	❍	❍
Fietsen goedkoper is dan andere vervoermiddelen (5)	❍	❍	❍	❍	❍
Fietsen voor mij de snelste reismethode is (6)	❍	❍	❍	❍	❍
Fietsen flexibel is (goed te combineren met andere activiteiten) (7)	❍	❍	❍	❍	❍
Fietsen ontspannend is (8)	❍	❍	❍	❍	❍
Mijn werk goed te bereiken is met de fiets (9)	❍	❍	❍	❍	❍
Er op mijn werk goede parkeerfaciliteiten zijn voor de fiets (10)	❍	❍	❍	❍	❍
Fietsen goed is voor mijn dagelijkse lichaamsbeweging (11)	❍	❍	❍	❍	❍
Fietsen goed is voor mijn gezondheid (12)	❍	❍	❍	❍	❍
Fietsen mijn impact op het milieu vermindert (13)	❍	❍	❍	❍	❍
Fietsen mij een gevoel van vrijheid geeft (14)	❍	❍	❍	❍	❍
Fietsen past bij mijn levensstijl (15)	❍	❍	❍	❍	❍
Fietsen voor mij de enige mogelijkheid is om te reizen naar mijn werk (16)	❍	❍	❍	❍	❍

V8. Ik zou met het openbaar vervoer naar mijn werk op de campus reizen, omdat ...

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Het openbaar vervoer comfortabel is (1)	❍	❍	❍	❍	❍
Reizen met het openbaar vervoer leuk is (2)	❍	❍	❍	❍	❍
Ik mij veilig voel in het openbaar vervoer (3)	❍	❍	❍	❍	❍
Het openbaar vervoer goedkoper is dan andere vervoermiddelen (4)	❍	❍	❍	❍	❍
Het openbaar vervoer voor mij de snelste reismethode is (5)	❍	❍	❍	❍	❍
Het openbaar vervoer flexibel is (bijvoorbeeld: rijdt regelmatig en rijdt op tijd) (6)	❍	❍	❍	❍	❍
De reisinformatie voor het openbaar vervoer duidelijk is (7)	❍	❍	❍	❍	❍
Ik dan kan multitasken (reizen en werken tegelijkertijd) (8)	❍	❍	❍	❍	❍
Er gratis internet (WiFi) is (9)	❍	❍	❍	❍	❍
Er over het algemeen genoeg plek is in het openbaar vervoer (10)	❍	❍	❍	❍	❍
Reizen met het openbaar vervoer ontspannend is (11)	❍	❍	❍	❍	❍
Mijn werk goed te bereiken is met het openbaar vervoer (12)	❍	❍	❍	❍	❍
Reizen met het openbaar vervoer goed is voor mijn gezondheid (13)	❍	❍	❍	❍	❍
Reizen met het openbaar vervoer mijn impact op het milieu vermindert (14)	❍	❍	❍	❍	❍
Reizen met het openbaar vervoer past bij mijn levensstijl (15)	❍	❍	❍	❍	❍
Het openbaar vervoer voor mij de enige mogelijkheid is om te reizen naar mijn werk (16)	❍	❍	❍	❍	❍

Deel 3. De volgende stellingen gaan over invloeden vanuit uw omgeving die een rol kunnen spelen bij het kiezen voor steeds drie vervoermiddelen (aangeduid als ...) naar campus Heijendaal. Beantwoord deze ook als u nooit met een van de vervoermiddelen naar uw werk reist.

V9. Ik reis met ... naar mijn werk omdat mijn nabije familieleden en vrienden dit ook doen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V10. Ik reis met ... naar mijn werk omdat mijn collega's dit ook doen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V11. Ik ga met ... naar mijn werk, omdat ik dan samen kan reizen met anderen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

Deel 4. De volgende stellingen gaan over aspecten waar u zelf in meer of mindere mate controle over kunt uitoefenen bij het kiezen voor steeds drie vervoermiddelen (aangeduid als ...) naar campus Heijendaal. Beantwoord deze ook als u nooit met een van de vervoermiddelen naar uw werk reist.

V12. In verband met huishoudelijke taken (bijv.: kinderen afzetten en ophalen, boodschappen doen) kies ik ervoor om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V13. Uit praktische overwegingen (bijv.: bagage, meerdere afspraken op verschillende locaties) kies ik ervoor om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V14. De goede infrastructuur van de weg/het fietspad/het spoor maakt het voor mij mogelijk om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V15. Het verkeer is veilig waardoor ik in staat ben om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V16. Het weer belet mij niet om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V17. Ik ben fysiek in staat om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V18. Wanneer ik met ... naar mijn werk reis dan heb ik zelf controle over mijn reisschema

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

Deel 5. V19. De volgende aspecten (gerelateerd aan belasting en prijzen) spelen een rol bij de keuze voor een vervoermiddel om te reizen naar mijn werk op campus Heijendaal.

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Fietsplan (aangeboden vanuit uw werk) (1)	❍	❍	❍	❍	❍
(stijgende) Motorrijtuigenbelasting (2)	❍	❍	❍	❍	❍
Benzinekosten (3)	❍	❍	❍	❍	❍
Parkeerkosten (4)	❍	❍	❍	❍	❍

Deel 6. Hieronder volgt een aantal stellingen. Gelieve uw mening te geven door te klikken op een van de antwoorden die lopen van helemaal mee oneens tot helemaal mee eens.

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Ik wens dat ik aankomende maand het merendeel van de reizen naar mijn werk met de fiets kan doen (1)	❍	❍	❍	❍	❍
Ik ben van plan om aankomende maand het merendeel van de reizen naar mijn werk met de fiets te doen (2)	❍	❍	❍	❍	❍
Ik doe mijn best om aankomende maand het merendeel van de reizen naar mijn werk met de fiets te doen (3)	❍	❍	❍	❍	❍

Deel 7. Hieronder volgt een aantal stellingen. Gelieve uw mening te geven door te klikken op een van de antwoorden die lopen van helemaal mee oneens tot helemaal mee eens.

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch me eens (3)	Mee eens (4)	Helemaal mee eens (5)
Ik kies voor een vervoermiddel om naar mijn werk op campus Heijendaal te reizen zonder dat ik hier bewust over nadenk (2)	❍	❍	❍	❍	❍
Ik kies automatisch voor een vervoermiddel om naar mijn werk op campus Heijendaal te reizen (1)	❍	❍	❍	❍	❍

Deel 8. Hieronder volgt een aantal vragen over uw persoonlijke situatie.

V20. Wat is uw 4-cijferige postcode?

V21. Wat is uw geslacht?

❍ Vrouw (1)
❍ Man (2)

V22. Wat is uw leeftijd?

V23. Welke woonsituatie is op u van toepassing?

❍ Alleenwonend (1)
❍ Samenwonend met partner/echtgeno(o)t(e) (2)
❍ Samenwonend met partner/echtgeno(o)t(e) en kind(eren) (3)

- ❍ Samenwonend met kind(eren) zonder partner/echtgeno(o)t(e) (4)
- ❍ Wonend bij ouders/verzorgers zonder kind(eren) (5)
- ❍ Wonend in studentenhuis zonder kind(eren) (6)
- ❍ Anders, namelijk: (7) _____

V24. Wat is uw hoogst genoten opleiding?

- ❍ Geen onderwijs/basisonderwijs/lagere school (1)
- ❍ LBO/VBO/VMBO (lager beroepsonderwijs) (2)
- ❍ MAVO (middelbaar algemeen voorbereidend onderwijs) (3)
- ❍ MBO (middelbaar beroepsonderwijs) (4)
- ❍ HAVO/VWO (hoger algemeen voortgezet onderwijs/voorbereidend wetenschappelijk onderwijs) (5)
- ❍ HBO/WO-bachelor of kandidaats (hoger beroepsonderwijs/wetenschappelijk onderwijs) (6)
- ❍ WO-doctoraal of master (7)

V25. Hoeveel bedraagt u maandelijkse brutoloon?

- ❍ Minder dan 999,99 euro per maand (1)
- ❍ 1000,00 euro - 1499,99 euro per maand (2)
- ❍ 1500,00 euro - 1999,99 euro per maand (3)
- ❍ 2000,00 euro - 2999,99 euro per maand (4)
- ❍ 3000,00 euro - 4999,99 euro per maand (5)
- ❍ 5000,00 euro per maand of meer (6)
- ❍ Ik weet het niet (7)
- ❍ Ik wil het niet zeggen (8)

Als u nog opmerkingen en/of suggesties heeft dan kunt u ze hier invullen.

……..

Deel 9. Tot slot een laatste vraag aan u over uw verwachting over het gebruik van de app.

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Ik verwacht dat de Ring-Ring app mij kan stimuleren om vaker met de fiets naar mijn werk te gaan (1)	❍	❍	❍	❍	❍

Notitie. Deze vraag is uitsluitend aan de experiment groep gesteld.

Hartelijk dank voor het invullen van de vragenlijst, uw ervaringen zijn zeer waardevol voor mijn onderzoek! Na afloop van het onderzoek zult u nog een vragenlijst ontvangen die vraagt naar uw ervaringen.

Als u op de hoogte wilt worden gehouden van de bevindingen van dit onderzoek, laat dan hieronder uw e-mailadres achter.

……

Appendix 2 Post-test questionnaire

After the experiment at t2, all participants receive a post-test questionnaire. This questionnaire is comprised of, in essential, comparable questions as the pre-test questionnaire. Part 8 is exclusively for the experimental group, because it asks about their experiences with using the Ring-Ring app and to what extent they believe that their app usage promoted behavioural change.

Beste deelnemer,

Hartelijk dank voor uw deelname aan mijn afstudeeronderzoek naar het reisgedrag van forenzen richting campus Heijendaal! Bij aanvang van dit onderzoek heb ik uitgelegd dat het onderzoek uit twee meetmomenten zal bestaan. Aangezien het onderzoek vandaag ten einde loopt, wil ik u vriendelijk verzoeken om nogmaals een soortgelijke vragenlijst over uw reisgedrag in te vullen. Uw mening is zeer waardevol!

Het invullen van de vragen zal ongeveer 15 minuten van uw tijd in beslag nemen. De door u verstrekte gegevens zullen uitsluitend voor dit onderzoek worden gebruikt. De resultaten worden dus vertrouwelijk behandeld.

Neem rustig de tijd om de vragen en stellingen door te lezen en te beantwoorden.

Bij voorbaat dank,

Nikki Korzilius

Master student Planologie

Radboud Universiteit Nijmegen

Deel 1. De volgende vraag gaat over uw reisgedrag richting uw werk op campus Heijendaal.

V1. Hoe reist u over het algemeen naar uw werk op campus Heijendaal? Bijvoorbeeld: 4 keer per week met de auto en 1 keer per week met de fiets.(Beantwoord de vragen over afstand en reistijd van uw woonadres naar uw werkadres op campus Heijendaal)

	Aantal dagen per week
Auto (1)	
Fiets (ook elektrisch) (2)	
Lopend (3)	
Openbaar vervoer (4)	
Carpoolen (5)	
Multimodaal (voorbeeld: trein + fiets) (6)	

Deel 2. De volgende stellingen gaan over motieven die een rol kunnen spelen bij het kiezen voor de auto, de fiets en het openbaar vervoer naar campus Heijendaal. Beantwoord deze ook als u nooit met een van de vervoermiddelen naar uw werk reist.

V2. Ik zou met de auto naar mijn werk op de campus reizen, omdat ...

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Autorijden comfortabel is (1)	❍	❍	❍	❍	❍
Autorijden leuk is (2)	❍	❍	❍	❍	❍
Ik mij veilig voel in de auto (3)	❍	❍	❍	❍	❍
Autorijden mij privacy biedt (4)	❍	❍	❍	❍	❍
Autorijden goedkoper is dan andere vervoermiddelen (5)	❍	❍	❍	❍	❍
De auto voor mij de snelste reismethode is (6)	❍	❍	❍	❍	❍
Autorijden flexibel is (7)	❍	❍	❍	❍	❍
Autorijden ontspannend is (8)	❍	❍	❍	❍	❍
Mijn werk goed te bereiken is met de auto (9)	❍	❍	❍	❍	❍
Er op mijn werk goede parkeerfaciliteiten zijn voor de auto (10)	❍	❍	❍	❍	❍
Autorijden beter is voor mijn gezondheid (11)	❍	❍	❍	❍	❍
Autorijden mij een gevoel van vrijheid geeft (12)	❍	❍	❍	❍	❍
Autorijden past bij mijn levensstijl (13)	❍	❍	❍	❍	❍
Autorijden voor mij de enige mogelijkheid is om naar mijn werk te reizen (14)	❍	❍	❍	❍	❍

V3. Ik zou met de fiets naar mijn werk op de campus reizen, omdat ...

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Fietsen comfortabel is (1)	❍	❍	❍	❍	❍
Fietsen leuk is (2)	❍	❍	❍	❍	❍
Ik mij veilig voel tijdens het fietsen (3)	❍	❍	❍	❍	❍
Fietsen mij privacy biedt (4)	❍	❍	❍	❍	❍
Fietsen goedkoper is dan andere vervoermiddelen (5)	❍	❍	❍	❍	❍
Fietsen voor mij de snelste reismethode is (6)	❍	❍	❍	❍	❍
Fietsen flexibel is (goed te combineren met andere activiteiten) (7)	❍	❍	❍	❍	❍
Fietsen ontspannend is (8)	❍	❍	❍	❍	❍
Mijn werk goed te bereiken is met de fiets (9)	❍	❍	❍	❍	❍
Er op mijn werk goede parkeerfaciliteiten zijn voor de fiets (10)	❍	❍	❍	❍	❍
Fietsen goed is voor mijn dagelijkse lichaamsbeweging (11)	❍	❍	❍	❍	❍
Fietsen goed is voor mijn gezondheid (12)	❍	❍	❍	❍	❍
Fietsen mijn impact op het milieu vermindert (13)	❍	❍	❍	❍	❍
Fietsen mij een gevoel van vrijheid geeft (14)	❍	❍	❍	❍	❍
Fietsen past bij mijn levensstijl (15)	❍	❍	❍	❍	❍
Fietsen voor mij de enige mogelijkheid is om te reizen naar mijn werk (16)	❍	❍	❍	❍	❍

V4. Ik zou met het openbaar vervoer naar mijn werk op de campus reizen, omdat ...

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Het openbaar vervoer comfortabel is (1)	❍	❍	❍	❍	❍
Reizen met het openbaar vervoer leuk is (2)	❍	❍	❍	❍	❍
Ik mij veilig voel in het openbaar vervoer (3)	❍	❍	❍	❍	❍
Het openbaar vervoer goedkoper is dan andere vervoermiddelen (4)	❍	❍	❍	❍	❍
Het openbaar vervoer voor mij de snelste reismethode is (5)	❍	❍	❍	❍	❍
Het openbaar vervoer flexibel is (bijvoorbeeld: rijdt regelmatig en rijdt op tijd) (6)	❍	❍	❍	❍	❍
De reisinformatie voor het openbaar vervoer duidelijk is (7)	❍	❍	❍	❍	❍
Ik dan kan multitasken (reizen en werken tegelijkertijd) (8)	❍	❍	❍	❍	❍
Er gratis internet (WiFi) is (9)	❍	❍	❍	❍	❍
Er over het algemeen genoeg plek is in het openbaar vervoer (10)	❍	❍	❍	❍	❍
Reizen met het openbaar vervoer ontspannend is (11)	❍	❍	❍	❍	❍
Mijn werk goed te bereiken is met het openbaar vervoer (12)	❍	❍	❍	❍	❍
Reizen met het openbaar vervoer goed is voor mijn gezondheid (13)	❍	❍	❍	❍	❍
Reizen met het openbaar vervoer mijn impact op het milieu vermindert (14)	❍	❍	❍	❍	❍
Reizen met het openbaar vervoer past bij mijn levensstijl (15)	❍	❍	❍	❍	❍
Het openbaar vervoer voor mij de enige mogelijkheid is om te reizen naar mijn werk (16)	❍	❍	❍	❍	❍

Deel 3. De volgende stellingen gaan over invloeden vanuit uw omgeving die een rol kunnen spelen bij het kiezen voor steeds drie vervoermiddelen (aangeduid als ...) naar campus Heijendaal. Beantwoord deze ook als u nooit met een van de vervoermiddelen naar uw werk reist.

V5. Ik reis met ... naar mijn werk omdat mijn nabije familieleden en vrienden dit ook doen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V6. Ik reis met ... naar mijn werk omdat mijn collega's dit ook doen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V7. Ik ga met ... naar mijn werk, omdat ik dan samen kan reizen met anderen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

Deel 4. De volgende stellingen gaan over aspecten waar u zelf in meer of mindere mate controle over kunt uitoefenen bij het kiezen voor steeds drie vervoermiddelen (aangeduid als ...) naar campus Heijendaal. Beantwoord deze ook als u nooit met een van de vervoermiddelen naar uw werk reist.

V8. In verband met huishoudelijke taken (bijv.: kinderen afzetten en ophalen, boodschappen doen) kies ik ervoor om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V9. Uit praktische overwegingen (bijv.: bagage, meerdere afspraken op verschillende locaties) kies ik ervoor om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V10. De goede infrastructuur van de weg/het fietspad/het spoor maakt het voor mij mogelijk om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V11. Het verkeer is veilig waardoor ik in staat ben om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V12. Het weer belet mij niet om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V13. Ik ben fysiek in staat om met ... naar mijn werk te reizen

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

V14. Wanneer ik met ... naar mijn werk reis dan heb ik zelf controle over mijn reisschema

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Auto (1)	❍	❍	❍	❍	❍
Fiets (2)	❍	❍	❍	❍	❍
Openbaar vervoer (3)	❍	❍	❍	❍	❍

Deel 5. V15. De volgende aspecten (gerelateerd aan belasting en prijzen) spelen een rol bij de keuze voor een vervoermiddel om te reizen naar mijn werk op campus Heijendaal.

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Fietsplan (aangeboden vanuit uw werk) (1)	❍	❍	❍	❍	❍
(stijgende) Motorrijtuigenbelasting (2)	❍	❍	❍	❍	❍
Benzinekosten (3)	❍	❍	❍	❍	❍
Parkeerkosten (4)	❍	❍	❍	❍	❍

Deel 6. Hieronder volgt een aantal stellingen. Gelieve uw mening te geven door te klikken op een van de antwoorden die lopen van helemaal mee oneens tot helemaal mee eens.

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Ik heb de afgelopen maand het merendeel van de reizen naar mijn werk met de fiets afgelegd (1)	❍	❍	❍	❍	❍
Ik ben van plan om vanaf nu vaker met de fiets naar mijn werk te reizen (2)	❍	❍	❍	❍	❍
Ik doe mijn best om vanaf nu vaker met de fiets naar mijn werk te reizen (3)	❍	❍	❍	❍	❍

Deel 7. Hieronder volgt een aantal stellingen. Gelieve uw mening te geven door te klikken op een van de antwoorden die lopen van helemaal mee oneens tot helemaal mee eens.

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch me eens (3)	Mee eens (4)	Helemaal mee eens (5)
Ik kies voor een vervoermiddel om naar mijn werk op campus Heijendaal te reizen zonder dat ik hier bewust over nadenk (2)	❍	❍	❍	❍	❍
Ik kies automatisch voor een vervoermiddel om naar mijn werk op campus Heijendaal te reizen (1)	❍	❍	❍	❍	❍

Deel 8. Hieronder volgt een aantal stellingen over uw ervaring met de Ring-Ring app. Gelieve uw mening te geven door te klikken op een van de antwoorden die lopen van helemaal mee oneens tot helemaal mee eens.

	Helemaal mee oneens (1)	Mee oneens (2)	Noch mee oneens/noch mee eens (3)	Mee eens (4)	Helemaal mee eens (5)
Ik vind de Ring-Ring app gemakkelijk te gebruiken (1)	❍	❍	❍	❍	❍
Het gebruik van de Ring-Ring app vereist weinig inspanning (2)	❍	❍	❍	❍	❍
De Ring-Ring app werkt naar behoren (3)	❍	❍	❍	❍	❍
De Ring-Ring app heeft nut voor mij (4)	❍	❍	❍	❍	❍
Ik gebruik de Ring-Ring app omdat het financiële voordelen biedt (bijvoorbeeld: het inwisselen van mijn fietskilometers voor kortingen) (5)	❍	❍	❍	❍	❍
Ik vind het leuk om de Ring-Ring app te gebruiken (6)	❍	❍	❍	❍	❍
De informatie over mijn gefietste afstanden en routes die ik via de Ring-Ring app ontvang motiveren mij om vaker naar mijn werk te fietsen (7)	❍	❍	❍	❍	❍
Het inzicht in hoeveel kilometers anderen fietsen stimuleert mij om vaker naar mijn werk te fietsen (8)	❍	❍	❍	❍	❍
De Ring-Ring app maakt het aantrekkelijker om naar mijn werk te fietsen (9)	❍	❍	❍	❍	❍
De Ring-Ring app beïnvloedt welk vervoermiddel ik kies om naar mijn werk te reizen (10)	❍	❍	❍	❍	❍
De Ring-Ring app stimuleert mij om vaker op de fiets naar mijn werk te gaan (11)	❍	❍	❍	❍	❍
Ik ben van plan om de Ring-Ring app te blijven gebruiken (12)	❍	❍	❍	❍	❍

Deel 9. Hieronder volgt een laatste vraag over uw persoonlijke situatie. Deze informatie is nodig voor een juiste registratie van de gegevens.

V16. Wat is uw 6-cijferige postcode?

Indien u nog opmerkingen heeft over uw ervaring met de Ring-Ring app of opmerkingen en/of suggesties in het algemeen, dan kunt u deze hier noteren.

Nogmaals hartelijk dank voor het invullen van de vragenlijst en het deelnemen aan mijn onderzoek!

Appendix 3 Travel diary

During the experiment, all participants received a travel diary question every week. Most travel diaries were sent on Tuesday, however for a few participants who hardly never worked on Tuesday, the diaries were sent on Thursday. The question was about which travel mode a participant had used, on that specific day, to travel to and from their work on campus Heijendaal.

Beste deelnemer,

Dit is het […] moment tijdens de onderzoeksperiode dat u een vraag ontvangt over welk vervoermiddel u vandaag heeft gebruikt om van en naar uw werk op campus Heijendaal te reizen. Alvast hartelijk dank!

Met vriendelijke groet,

Nikki Korzilius

V1. Met welk vervoermiddel bent u vandaag (dinsdag/donderdag; datum] van en naar uw werk op campus Heijendaal gereisd? Bij gebruik van meerdere voertuigen noteert u het vervoermiddel dat u voor het grootste gedeelte van uw reis hebt aangewend. Kies uit:

- ❍ Auto (1)
- ❍ Carpoolen (2)
- ❍ Fiets (ook elektrisch) (3)
- ❍ Openbaar vervoer (4)
- ❍ Lopend (5)
- ❍ Ik heb vandaag thuis gewerkt (6)
- ❍ Ik heb vandaag ergens anders gewerkt (niet op campus Heijendaal) (7)
- ❍ Ik heb vandaag niet gewerkt (8)

Appendix 4 Original reliabilities

To test internal consistency of various scales we used Cronbach's α coefficient. Before deleting items that did not contribute to the scale, we reported the original reliabilities for the pre-test as well as the post-test data (see Table 19).

Table 19. Original reliabilities in terms of Cronbach's αs of the experimental group (EG), the control group (CG), and the groups combined for the pre-test (t1) and post-test (t2).

Construct	*Both groups$_{t1}$*	*Both groups$_{t2}$*	*EG$_{t1}$*	*EG$_{t2}$*	*CG$_{t1}$*	*CG$_{t2}$*
Attitude						
Car	.86	.87	.93	.92	.59[a]	.62[a]
Bicycle	.80	.79	.75	.69	.83	.84
Public transport	.91	.91	.89	.87	.93	.93
Subjective norm						
Car	.65[a]	.80	.83	.62[a]	.50[a]	.86
Bicycle	.77	.88	.77	.72	.75	.91
Public transport	.86	.91	.84	.82	.86	.93
PBC						
Car	.81	.78	.89	.86	.66[a]	.61[a]
Bicycle	.55[a]	.53[a]	.53[a]	.47[a]	.58[a]	.60[a]
Public transport	.69	.57[a]	.52[a]	.53[a]	.80	.60[a]
Habit	.84	.73	.81	.59[a]	.88	.80
Intention	.69	.67[a]	.72	.55[a]	.61[a]	.72
ICT		.90		.90		

Notes. This table contains Cronbach's αs for the various scales measured. [a]α < .69.

Appendix 5 Tests of normality

We used a Shapiro-Wilk test to measure whether various interval and ratio variables assessed normality. The significance levels show whether the variable is distributed normally. Table 20 shows the outcomes for the pre-test data. Whereas Table 21 is the test of normality for the post-test data.

Table 20. Shapiro-Wilk test of normality for the pre-test.

Variable	*Z*	*Skewness*	*Kurtosis*
Socio-demographics			
Age	0.96	0.08	1.45
Income	0.89**	0.14	1.34
Educational level	0.72***	-1.58	1.71
Attitude			
Car	0.97	0.44	1.26
Bicycle	0.72	0.80	0.92
Public transport	0.91**	2.88	4.71
Subjective norm			
Car	0.65**	3.72	1.67
Bicycle	0.75**	3.53	2.06
Public transport	0.67**	3.56	1.55
PBC			
Car	0.86**	3.20	1.73
Bicycle	0.92*	2.31	1.26
Public transport	0.97	0.41	0.13
Habit	0.96	0.22	0.75
Intention	0.93*	0.03	1.59

Notes. * p = < .05. ** p = < .01. *** p < .001. Df = 37.

Table 21. Shapiro-Wilk test of normality for the post-test.

Variable	*Z*	*Df*	*Skewness*	*Kurtosis*
Attitude				
Car	0.96	36	0.00	2.27
Bicycle	0.95	36	1.20	2.51
Public transport	0.92*	36	2.06	4.82
Subjective norm				
Car	0.64**	36	0.30	2.74
Bicycle	0.63**	36	0.90	2.59
Public transport	0.64**	36	0.00	2.76
PBC				
Car	0.89**	36	2.91	4.66
Bicycle	0.95	36	1.51	0.78
Public transport	0.97	36	0.50	0.86
Habit	0.96	36	0.50	0.86
Intention	0.96	36	0.55	0.45
ICT	0.94	17	1.52	0.79

Notes. * p = < .05. ** p = < .01. *** p < .001.

Appendix 6 Tests of homogeneity of variance

To check for homogeneity of variance we used a Levene's test. Table 22 shows the outcome for the pre-test, while Table 23 presents the results for the post-test.

Table 22. Homogeneity of variance between the experimental and the control group for the pre-test.

Variable	*F*
Socio-demographics	
Age	1.53
Gender	0.82
Income	0.71
Living situation	2.52
Educational level	0.06
Attitude	
Car	8.31*
Bicycle	0.81
Public transport	0.00
Subjective norm	
Car	2.41
Bicycle	6.28*
Public transport	3.38
PBC	
Car	1.00
Bicycle	0.30
Public transport	0.07
Habit	0.53
Intention	1.55

Notes. *F* = Levene statistic. *$p < .05$. ** $p < .01$. *** $p < .001$.

Table 23. Homogeneity of variance between the experimental and the control group for the post-test.

Variable	*F*
Attitude	
Car	6.14*
Bicycle	1.58
Public transport	0.67
Subjective norm	
Car	0.64
Bicycle	2.98
Public transport	0.04
PBC	
Car	3.41
Bicycle	1.93
Public transport	0.17
Habit	0.01
Intention	0.89

Notes. *F* = Levene statistic. * $p < .05$. ** $p < .01$. *** $p < .001$.

Appendix 7 Differences in means between both groups

To check whether there are differences between the means of the experimental and the control group we used an independent samples T-test. However, in case of non-normality, a Mann-Whitney U-test was practiced. This is summarized in Table 24.

Table 24. T-test (t) and Mann-Whitney test (U) for equality of means for the pre-test.

Scale	M_{eg}	M_{cg}	*t*	*U*
Attitude				
Car	2.99	3.03	0.17	
Bicycle	3.63	3.81	1.33	
Public transport	19.17	18.84		168.00
Subjective norm				
Car	17.11	20.79		137.00
Bicycle	17.17	20.74		138.00
Public transport	17.11	20.79		137.00
PBC				
Car	19.58	18.45		160.50
Bicycle	18.25	19.71		157.50
Public transport	2.63	2.54	-0.38	
Habit	2.64	3.16	1.58	
Intention	17.39	20.53		142.00

Notes. * $p < .05$. ** $p < .01$. *** $p < .001$.