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A longitudinal evaluation of satisfaction with e-cycling in daily commuting in the Netherlands

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ABSTRACT

This paper reports on the effects of an e-cycling stimulation program on travel satisfaction in the province of North-Brabant, the Netherlands. The program was designed to stimulate car-commuters to shift to e-bike in daily commuting, earning a monetary incentive for each kilometre e-cycled. With a longitudinal design, this study shows a significant increase in travel satisfaction when switching from car to e-bike. Starting from an average slightly positive satisfaction with car commuting, participants reported an extremely positive expected travel satisfaction by e-bike. Although a bit less than expected, the experienced travel satisfaction with e-cycling was high after a period of a month and even increased in the following period of half a year. Where the participants can be sub-divided into car-only and multi-modal car-commuters, this distinction does not show in the experienced travel satisfaction with e-cycling. Our study indicates that the hedonic treadmill mechanism does not automatically apply to the satisfaction with e-cycling. Multivariate analyses suggest that the increase in the travel satisfaction is affected by self-reported health, car ownership, urbanization degree, whether car use and e-cycling are experienced as strenuous, congestion on the route and the attractiveness of the cycle route.

1. Introduction

Cycling is widely regarded as a travel mode that is not only environmentally sustainable, but also contributing to a better health as a result of the physical activity involved (e.g. Morris and Hardman, 1997). An additional advantage of cycling is that is associated with better mood during travel (also termed travel satisfaction) as compared to motorized travel modes such as car and public transport. This effect is observed across cultures and geographical contexts (see Olsson et al., 2013; Mao et al., 2016; St-Louis et al, 2014; De Vos et al., 2015), suggesting that it is the intrinsic characteristics of cycling, such as the level of physical activity and exposure to outdoor environments, that are responsible for the higher levels of travel satisfaction (e.g. Ekkekakis et al., 2008). Various studies indicate that the positive effects on mood and well-being are not limited to the duration of cycling, but extend to other periods of the day and are even associated with higher satisfaction with life (e.g. Martin et al., 2014; Friman et al., 2017a). Despite its positive effects, cycling is not an option for many trips, due to (amongst others) its limited distance range (as a result of lower speed) and physical limitations that apply to part of the population (Popovich et al., 2014, MacArthur et al., 2014).

E-cycling has been introduced over the past decade in the Netherlands as a way to overcome limitations of distance and physical limitations, by providing additional peddling support. E-bikes used in the Netherlands require the cyclist to peddle, but lead to higher speeds with the same effort, or the same speed with less effort. This is in contrast to for instance Chinese e-bikes, that do not require peddling and therefore can be considered electric mopeds. The scope of this paper is on e-cycling with peddle support. Over the past decade, e-bikes with peddling support have obtained a non-trivial market share in various places in the world (e.g. Fishman and Cherry, 2016). This raises questions about the health and well-being effects of a shift from other travel modes to e-cycling. A key observation in this respect is that among the rapidly increasing pool of studies that have investigated satisfaction with travel for a variety of modes and in various contexts, travel satisfaction using e-bikes with peddling support has not yet been addressed. Hence, insight into this aspect is highly needed. A second important notion is that those taking up e-cycling use their e-bike for an important part to make trips they previously made by other modes. Hence, their shift in travel mode may be accompanied by a change in travel satisfaction (Abou-Zeid et al., 2012). Studying such a shift is important in order to learn about the well-being effects of a shift to e-bike beyond the mere health effects, but also since mood or satisfaction associated with new behaviours may be an important predictor of adherence to the new behaviour (Standage and Ryan, 2012). An additional relevant issue in this respect is how travel satisfaction will

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develop over a longer period, as this may have implications for adherence on the longer term.

To address the effects of a shift to e-cycling on travel satisfaction, this study uses unique longitudinal data of satisfaction with the commute trip among participants in a programme (B-riders) that stimulated car commuters to shift to e-bike use for their commute trip. Using travel satisfaction data of their commute trip by car before the programme and by e-bike on several points in the programme, conclusions are drawn regarding the direct and longer-term effects of the shift to e-bike on travel satisfaction, and on the personal and contextual factors influencing these effects. The paper is structured as follows. Section 2 outlines the literature. Section 3 describes the research and data collection methods. Section 4 analyses the changes in travel satisfaction and the potential underlying reasons for this change. Section 5 concludes on the results of the research.

2. Literature review

2.1. Travel satisfaction: concept

Travel satisfaction can be regarded as satisfaction with a specific life domain (next to domains such as family life, professional life, etc.) and as such is as a concept related to subjective well-being (SWB). SWB is an overall assessment made by individuals of their life, and is usually assumed to consist of three components: a cognitive assessment of one's life conditions, positive affect and negative affect (Diener and Suh, 1997). Cognitive life satisfaction is often measured using the Satisfaction with Life Scale (SWLS) (Diener et al., 1985; Pavot and Diener, 1993), which consists of five self-report items (e.g. "Overall I am satisfied with my life") which are rated on a scale ranging from "totally disagree" to "totally agree". Alternatively, Cantril's Self Anchoring Scale has been used, in which respondents rate their life on a ladder ranging from 0 ("worst possible life") to 10 ("best possible life"). The affective component refers to the frequency and intensity of positive and negative emotions, and is measured using scales such as PANAS (Positive and Negative Affect Scale) or the Swedish Core Affect Scale (SCAS) (Västfjäll and Gärling, 2007). In PANAS, respondents indicate for a number of distinct emotions to what extent they experience each emotion. SCAS is a dimensional scale, in which emotions are measured along two dimensions: valence and activation.

Measurement of cognitive life satisfaction refers to a longer term steady state, assuming that life satisfaction is reasonably constant, as long as one's basic life circumstances do not change. Measurement of affect typically refers to a momentary state, asking for emotions felt at a particular time. However, cognitive and affective components are also measured on shorter and longer time scales. For instance, it is common to ask for frequency of emotions, or average affective state over periods lasting for instance a day or a week (Friman et al., 2017b).

Travel satisfaction can be regarded as a subdomain of life satisfaction. In various studies, positive correlations between travel satisfaction and life satisfaction have been found, in the same way as satisfaction with other life domains contributes to life satisfaction. In this paper we assume that, similarly to subjective well-being, travel satisfaction includes both cognitive and affective components. Ettema et al. (2011) developed the Satisfaction with Travel Scale (STS), which includes 3 cognitive and 6 affective items. This scale has been tested in a variety of contexts, and it was consistently found that both the cognitive and affective dimensions were in logical ways related to travel circumstances. This implies that travellers develop an evaluation of their travel experience, which indicates how good or pleasant travel is, and how this experience can be improved through service and design factors. Apart from the STS-scale, travel satisfaction has also been measured with multiple items in a cognitive scale (Bergstad et al., 2011) and via single item measurements (see Mao et al., 2016). General findings about the factors influencing travel satisfaction are fairly consistent between these studies. In addition, travel satisfaction can be measured on different time scales. The concept and measurement scales have been applied to measure satisfaction with a concrete single trip (e.g. Mao et al., 2016), with a repeatedly made trip of a particular type (such as commuting, see St-Louis et al., 2014) or with one's general travel conditions (Friman et al., 2017b).

Travel satisfaction is reported by travellers directly, rather than derived from displayed behaviour, as is common practice in utility based discrete choice modelling (Ettema et al., 2010). On a conceptual level, this comes down to a distinction between decision utility (the expected outcome when a decision is made) and experienced utility. Various empirical studies indicated that experienced utility and decision utility are not the same. The underlying reason is that people are not necessarily very good at predicting their emotional responses to upcoming events. In addition, choices may be made under constraints, such as financial constraints, preventing individuals from choosing their preferred alternative. Given the difference between decision utility and experienced utility, experienced utility is a useful indicator of the effect that travel under particular circumstances has on a traveller's experience, which may have implications for his/her overall well-being (Friman et al., 2017b; De Vos et al., 2017). Relying on decision utility, as derived from observed choices, could potentially lead to biased results when determining the outcome of interventions in cost-benefit analysis.

2.2. Travel satisfaction: empirical findings

Studies of travel satisfaction have been carried out across a variety of geographic and cultural contexts, but certain outcomes have been found consistently. First, a major factor affecting travel satisfaction is travel mode. Consistently, active travel modes (walking, cycling) are evaluated as giving a higher satisfaction than car and especially public transport (see Olsson et al., 2013; Mao et al., 2016; St-Louis et al, 2014; De Vos et al., 2015). This higher satisfaction with active modes has been ascribed to the physical activity involved and resulting in the optimal level of arousal. Furthermore, factors influencing travel satisfaction differ between travel modes. For car travel, factors such as independence, freedom, prestige and mastery add to a positive travel satisfaction (Jakobsson Bergstad et al., 2011, 2012; Steg, 2005). However, factors such as congestion, leading to stress, and long travel times may make car use less attractive, leading to lower travel satisfaction. Other factors that may negatively affect travel satisfaction with the car include experienced unsafety, crowdedness and distraction by billboards (Ettema et al., 2011).

Public transport (PT) is usually evaluated as less attractive compared to active travel and car use. Factors affecting satisfaction with public transport include seat probability, frequency of service, cleanliness and safety (Redman et al., 2013; Stradling et al., 2007). In addition, the type of public transport influences travel satisfaction. Various studies found that rail transport is evaluated more positively than bus transport (St-Louis et al., 2014). Ettema et al. (2016) report that also quality, readability and design of stations and public transport stops may have a significant impact on travel satisfaction. With respect to active travel, few studies directly compare travel satisfaction with walking and cycling. Also, while many studies have investigated the factors influencing walking and cycling levels, research into the factors influencing satisfaction with walking and cycling has been limited. Factors that were found to affect travel satisfaction for active modes include climate and weather (temperature, precipitation) as well as darkness and shimmer (Böcker et al., 2015). Also, the cycling environment plays a role. More lively and aesthetic environments (Mambretti, 2011; Eliasson et al., 2007) are found to influence travel satisfaction positively, while experienced unsafety leads to a lower travel satisfaction (Ettema and Smajic, 2015). Next to the aesthetics, social aspects of place valuation (Cattel et al., 2008) influence the experience of cycling, such as the outdoor presence of people (Lin, 2009, Thorsson et al., 2007; Zacharias et al., 2001). Perceived safety, friendliness, liveliness and social interactions in outdoor public space might also positively affect emotions during cycling (Kööts et al., 2011). Notably, however, no studies to date have addressed travel satisfaction with e-bike, nor the personal or contextual factors influencing it.

2.3. Travel satisfaction and mode change

Given the differences in travel satisfaction between modes, the question arises how travel satisfaction changes in case of a shift in travel mode. This issue is of particular importance given policies and interventions aiming to bring about a mode shift, such as the e-bike stimulation program in this study. Cross sectional surveys as reviewed above are not necessarily a good base for estimating mode shift effects, as they ignore selection effects, leading travellers to choose the travel mode of their preference.

From a theoretical point of view, a change of travel mode will be at least partly driven by an expectation of the travel satisfaction derived from the new travel mode. Previous research revealed that individuals are reasonable capable of predicting the valence of their future experience, but much less capable of predicting the intensity and duration of their experience. This is due to various mechanisms. The forecasting mechanism (Wilson and Gilbert, 2003) holds that predictions of future experiences are based on the memory of previous experiences, and extreme experiences are more likely to be remembered. As a result, people will overestimate the intensity of positive and negative emotions of future events. The focusing illusion (Schkade and Kahneman, 1998) states that when anticipating an event, people tend to focus on a particularly good or bad aspect of it, and therefore expect the event to be either very good or very bad. In reality, this aspect is only one of many aspects influencing the experience, so that the experience will likely be more moderate.

With respect to the longer term stability of the experience, the hedonic treadmill mechanism is relevant (Diener et al., 2006). This implies that when circumstances improve (e.g. using a more attractive travel mode), this will initially result in improved well-being. However, gradually, the changed circumstance will be regarded as the standard, implying that aspiration levels will be raised, and well-being returns to its initial base level. This effect is strengthened as individuals will over time pay less attention to the improved factors in their circumstances. This diminishes the intensity of the emotional impact and the effect on well-being and mood.

Limited empirical work in longitudinal analysis of travel satisfaction confirms that travellers misestimate their travel satisfaction with a new travel mode. Studies in the US (Abou-Zeid and Ben-Akiva, 2012), Switzerland (Abou-Zeid et al., 2012) and Norway (Pedersen et al., 2011) all found that car users, when shifting to public transport as part of an intervention, experienced a higher travel satisfaction than they had expected. In the US and in Swiss studies, heterogeneity was observed in the responses with one group appreciating public transport much more than the other group, which had clear impact on their public transport use following the intervention.

2.4. Research gaps and hypotheses

The above overview suggests that empirical insight in travel satisfaction associated with e-cycling is lacking. This study will fill this gap, and will compare travel satisfaction with e-cycling with travel satisfaction by car for of a sample of car commuters. E-cycling bears similarities to conventional cycling in the sense that one is directly exposed to the environment and will experience weather, noise, pollution and other traffic directly. As conventional cycling, e-cycling requires physical effort, although this is significantly less than for conventional cycling with a similar speed. On the other hand, commuters may use the e-bike to travel faster with a similar input of physical activity, in order to cover larger distances. Based on these considerations and the widely reported high satisfaction with cycling, we expect that travel satisfaction with e-cycling will be higher than travel satisfaction with car use, and that a shift from car to e-cycling thus is associated with an increase in travel satisfaction. Regarding travellers' expectations, both the focusing illusion and the forecasting bias suggest that positive aspects of e-cycling will be overestimated, and thus that actual travel satisfaction with e-cycling will be lower than expected. With respect to travel satisfaction on the longer term, the hedonic treadmill effect suggests that following an expected increase in travel satisfaction as a result of the mode shift, travel satisfaction will decrease once travellers get used to the positive experience of e-cycling.

3. Materials and methods

3.1. Study design

With the e-cycling incentive program (B-Riders), the province of North-Brabant in the Netherlands aimed to stimulate a switch from car towards the use of the e-bike. From 2013 to date (2018) the program has been targeting car-commuters to participate. E-bike use was stimulated by giving participants financial compensation depending on their e-bike use. With the reduction of car-congestion as the main reason for the B-Riders program, the financial incentive in the peak hours was set at €0.15 per kilometre. In the off-peak period participants received €0.08 per kilometre with a maximum of €1000 per person overall. Incentives could be earned not only when using the e-bike for commuting, but also for other purposes. With an average of 10 km of cycling-commute distance, it would take up to a year to reach the maximum financial incentive. The program builds on previous projects in the Netherlands, in which travellers received incentives upon changing their behaviour in a desired direction, such as the Spitsmijden (peak avoidance) project (Ben-Elia and Ettema, 2009). E-bike use was monitored using a smartphone app that tracked participants' travel behaviour using GPS. From these GPS-tracks e-bike use was derived. Participants had to meet four recruitment conditions: (i) conducting at least 50% of their commuting trips a week by car before entering the program, (ii) the commute distance should be at least 3 km, and (iii) being between the age of 18 and 65 years old and (iv) working in the province of North-Brabant.

In order to measure behavioural change and satisfaction with travel, three questionnaires were conducted. The baseline questionnaire recorded the travel modes used in a regular week before starting to commute by e-bike. In addition, respondents reported their experienced satisfaction with current car-travel to work, their expected satisfaction with e-cycling to work and a set of personal and household characteristics. Personal and household characteristics included gender, age, educational level, income, car ownership, household composition and subjective health status. In addition, perceived characteristics of the commute by car and e-cycling were asked. The second questionnaire was held a month after the start of participation in the program. It included questions about frequency of travel modes used for commuting (including the e-bike), and experienced satisfaction with the e-bike commute. In addition, it included questions about the experienced characteristics of the e-bike commute and the landscape. The third questionnaire, held six months after entering the program, again recorded the frequency of travel modes used for commuting (including the e-bike) and experienced satisfaction with the e-bike commute and change in physical health since entering the program. In addition, it included questions about the experienced characteristics of the e-bike commute and the landscape. Cycling distance and level of urbanization of each participant were derived based on zip-codes of the home and work locations in combination with the existing cycling network in Open Street Map.

3.2. Measuring satisfaction with travel

Key to the study is to investigate the relationship between behavioural change from car to e-cycling and the satisfaction with the commute trip. Participants' satisfaction with their commute trips was measured using the Satisfaction with Travel Scale (STS) (Ettema et al., 2011). The STS is based on methods developed to measure subjective well-being (SWB), which is defined in terms of an individual's cognitive and emotional well-being (Diener et al., 1985). Cognitive well-being refers to an individual's cognitive assessment of his or her life in general. Affective well-being refers to an individual's emotional state. As satisfaction with travel can be regarded as a form of domain specific SWB, it is measured in a way of analogous to SWB. The affective component of satisfaction with travel is based on the affect circumplex (Västfjäll and Gärling, 2007). In this conceptualization, each emotion can be defined according to two dimensions: valence (how good or pleasant is the experience) and activation. In the STS, endpoints of items used to measure affective well-being are defined as combinations of the valence/activation dimensions. Three items range between positive deactivation [−3] (e.g. relaxed) and negative activation [3] (e.g. time pressed). Another three range between positive activation [3] (e.g. alert) and negative deactivation [−3] (e.g. tired). Finally, three subscale items were designed to measure cognitive well-being derived from the commute trip. In the questionnaire the order between the subscales was counterbalanced. The items and endpoints included in the STS are summarized in Table 1. STS has been applied to measure travel satisfaction with car, various public transport options, walking and cycling (e.g. Olsson et al., 2013; De Vos et al., 2015) and recently also with e-bikes in China (Ye and Titheridge, 2017), which differ from the e-bikes in our study in that no peddling is required. As the STS has resulted in consistent results across travel modes in a variety of geographic settings, we believe it is a suitable approach to measure satisfaction with e-cycling in this study.

Satisfaction with travel scores were constructed for each respondent by averaging the ratings for each of three subscales. Next, one satisfaction with travel score for each respondent was constructed by averaging the ratings of all nine items.

3.3. Analyses

To explore the changes in satisfaction with travel along the study, we first carried out descriptive analyses of the STS averages sub-divided by all three STS sub-scales and a general satisfaction with travel score. The general satisfaction with travel was calculated by averaging across the three subscales. A test of the structure of the scale suggests that all three subscales contribute to a similar extent to an overarching construct of travel satisfaction (Friman et al., 2013). This was done for all participants before starting (Baseline), one month after starting to participate in the program and half a year after starting to participate. To investigate possible differences between car-only and multi-modal

Table 1
End points of the satisfaction with travel scale.

Negative activation – Positive deactivation (items 1–3)	
… I feel stressed	… I feel calm
… I feel hurried	… I feel Relaxed
… I feel Worried about arriving too late	… I feel Confident about arriving on time
Negative deactivation – Positive activation (items 4–6)	
… I'm Bored	… I'm Enthusiastic
… I'm Tired	… I'm Alert
… I'm Fed up	… I'm *engaged*
Cognitive evaluation (items 7–9)	
… *Travel was laborious*	… *Travel was easy*
… *Travel was uncomfortable*	… *Travel was comfortable*
… *I experience my trip as bad*	… *I experience my trip as optimal*

Table 2
sample composition of participants.

Variable	Category	Total	Car	Multi-mode
Age	25–39 years old	12%	15%	11%
	40–49 years old	37%	34%	38%
	50–65 years old	51%	51%	51%
Gender	Male	48%	45%	50%
	Female	52%	55%	50%
Education	Low	17%	17%	17%
	Medium	27%	26%	28%
	High	56%	58%	55%
Subjective health status	Bad	14%	17%	12%
	Neutral	18%	17%	19%
	Good	33%	33%	33%
	Excellent	35%	33%	36%
Car ownership	1 car	50%	45%	52%
	2+ cars	50%	55%	48%
Household income (in € per month)	< 3.000	35%	28%	38%
	3.000 to < 4.000	28%	23%	30%
	> 4.000	16%	18%	15%
Household composition	Single	7%	6%	7%
	Single parent	2%	2%	2%
	Couple without children	35%	40%	33%
	Couple with children	56%	52%	58%
Urbanization	(very) strong urbanized	15%	11%	17%
	Moderate urbanized	23%	26%	21%
	Less urbanized	32%	33%	31%
	Not urbanized	30%	30%	30%
Cycle distance	0–5 km	4%	1%	5%
	5 < 10 km	19%	13%	22%
	10 < 15 km	31%	30%	31%
	15 < 20 km	29%	30%	28%
	20+ km	18%	26%	14%
Flexibility working hours	Yes	60%	62%	59%
	No	40%	38%	41%
Number of commute days per week	1–3 days a week	14%	26%	9%
	4 days a week	33%	31%	33%
	5 days a week	53%	43%	58%
Frequency of cycling commute at baseline	0 days a week	37%	100%	7%
	1 day a week	20%	–	30%
	2 days a week	19%	–	28%
	3 + days a week	24%	–	35%
Frequency of car commute at baseline	1 day a week	25%	1%	18%
	2 days a week	18%	11%	12%
	3 days a week	25%	16%	13%
	4 days a week	18%	21%	6%
	5 days a week	14%	50%	50%
Reported change in health status	Δ Very bad–very good	0.12	0.26	0.05
Perceptions of commute trip when e-cycling				
Strenuous car commute	Not at all (1) – very much (7)	3.15	2.99	3.22
Strenuous E-cycling commute	Not at all (1) – very much (7)	2.89	3.18	2.75
Crowdedness during commute	Very quiet (1) – very busy (7)	3.27	3.19	3.31
Freedom of speed determination	Completely under control (1) – strongly determined by fellow road users (7)	2.59	2.58	2.60
Annoyed by road users	Not at all (1) – very much (7)	2.96	2.83	3.02
Threatened/Unsafe by road users	Not at all (1) – very much (7)	2.40	2.26	2.46
Route unsafety	Not at all (1) – very much (7)	2.83	2.77	2.86
Wayfinding	Very easy (1) – very difficult (7)	1.32	1.34	1.30
Distraction by billboards	Not at all (1) – very much (7)	1.85	1.84	1.86
Perceived characteristics of commute landscape when e-cycling				
Green	Very little green (1) – very green (7)	5.42	5.54	5.36
Openness	Sheltered (1) – open (7)	4.71	4.72	4.71
Aesthetics	Beautiful (1) – ugly (7)	2.93	2.81	2.98
Liveliness	Lively (1) – boring (7)	3.14	3.18	3.12

(*continued on next page*)

Table 2 (*continued*)

Variable	Category	Total	Car	Multi-mode
Atmosphere	Comfortable (1) – distant atmosphere	2.91	2.94	2.90
Height difference	A lot of (1) – little (7)	5.49	5.62	5.43
Landscape	Varied (1) – monotonous (7)	3.25	3.18	3.29
Urbanization	Not (1) – very strong (7)	2.97	2.81	3.05

car-commuters, analyses are carried out for each group separately. Next, we carried out regression analyses of the change in the nine-item overall satisfaction with travel when shifting from car use to e-cycling for the expected change as well as the change after one and six months. Based on the factors reported to influence travel satisfaction, explanatory variables include personal, household and commute characteristics, as well as route and spatial context characteristics as explanatory variables. Following Ettema et al. (2013), we include aspects resulting from the interaction with other road users in the analyses (see Table 2). Similarly, we include aspects related to landscape characteristics, based on literature review (see Table 2). This allows us to draw conclusions about the factors that influence the satisfaction with e-cycling within the e-bike stimulation program relative to the satisfaction with the car commute at baseline, and how the importance of these factors might change over time.

3.4. Sample descriptives

The study is based on responses from 547 participants. One group of participants only commuted by car during the baseline measurement (n = 172), another group combined commuting by car with other modes (n = 375) in the baseline measurement. Sample characteristics are shown in Table 2, including characteristics of the commute and perceived landscape characteristics.

Table 2 shows that more than half of the participants is between 50 and 65 years old and highly educated. This is in line with the literature reporting that e-bike is especially popular among older age cohorts (Fishman and Cherry, 2016). 70% reported a good or excellent health. More than 50% of the participants belongs to the category ‘couple with children’. Half of the sample owns at least two cars, and the majority of participants (54%) falls in the higher income categories (> 3.000 EURO/month). 78% of the participants has a cycle-commute distance longer than 10 km, suggesting that the e-bike may be an important alternative to car-commuting, which offers acceptable travel times also for longer distances. Finally, about 60% of the sample has flexible working hours.

Car-only commuters and multimodal car-commuters do not differ substantially on most characteristics. However, the percentage of longer distance commuters (20+ kilometres) for car-only commuters is higher, and this group more often has two or more cars in the household and more often has a higher income.

4. Results

4.1. Descriptive analyses

Table 3 shows the average STS scores at baseline, after one and after six months per STS sub-scale and the overall STS score per participant. Significance (p-values of an independent samples *T*-test) of the differences is shown in Table 4. Although the experienced satisfaction with car commuting at baseline is positive, indicating a positive experience of the car commute, both the expected satisfaction with e-cycling (baseline) as well as the experienced satisfaction with e-cycling (after one and six months) are significantly higher for all participants. This holds for the aggregate nine-item STS score as well as the three subscales. Hence, both affective experience and cognitive assessment of e-cycling is better than of the original car commute. In addition, it is important to note that the large increase in travel satisfaction is found both for commuters only using the car at baseline and those occasionally cycling. Apparently, the e-bike is an attractive alternative for the car commute, irrespective of cycling experience in commuting. The size of the increase (1.4 units for the overall STS for all participants) is markedly larger than the differences between satisfaction with cycling and car use in previous cross-sectional studies using the STS (e.g. 0.3 in Sweden (Olsson et al., 2013). This may be due to the difference between e-cycling and conventional cycling, but also to the effect of a behaviour change having a positive effect in itself.

Comparison between the experienced STS after one and six months and the expected satisfaction with e-cycling at baseline shows that experienced STS of e-cycling after one month is somewhat lower than at baseline. This difference occurs in the aggregated STS and the subscales, and turns out to be statistically significant for only-car as well as multimodal commuters. Hence, participants seem to overestimate their travel satisfaction. Nevertheless, the increase in experienced STS as compared to commuting by car is much larger than the small difference with the expectation. Experienced STS after six months shows an increase in multimodal commuters compared to after one month, bringing the experienced STS back to the initial expectations on most STS subscales, although experienced positive activation levels remain somewhat lower than the initially expected level. Apparently, over a 5-month period, multimodal commuters learn to appreciate e-cycling more. This trend shows up to a somewhat lesser extent for car commuters, but does not turn out to be statistically significant.

Of the STS subscales, the subscale ranging between negative activation and positive deactivation has the highest average. This suggests that across modes and times, the commute is relatively calm and relaxed. An interesting finding is that the positive activation score is lower than the cognitive evaluation for the car commute, but higher for the e-bike commute. Likely, the physical activity involved in e-cycling makes commuters more alert, engaged and enthusiastic. Logically, the group of car-only car-commuters show higher satisfaction with car-commuting.

4.2. Regression models of change in travel satisfaction

In order to investigate how travel satisfaction changes with a shift from car commuting to commuting by e-bike, regression analyses were carried out on the difference in travel satisfaction between:

1. The expected travel satisfaction by e-bike at baseline and the travel satisfaction by car at baseline;
2. The travel satisfaction by e-bike after one month and the travel satisfaction by car at baseline;
3. The travel satisfaction by e-bike after six months at baseline and the travel satisfaction by car at baseline;

Explanatory variables included household characteristics (gender, age, health status, household income, education, household composition, urbanization level and car ownership) and work place related circumstances (flexibility of start and end time, travel days to work, cycling distance). In addition, we included commute related characteristics such as the level of effort, crowdedness on the route, freedom of speed determination, annoyance by other road users, perceived route unsafety, wayfinding and distraction by billboards, as well as the share of habitual commute cycling at baseline. Because we might expect a difference between car-only commuters and multi-modal car-commuters a dummy variable was included denoting whether someone is a car-only commuter. Finally, to investigate the impact of the spatial context on satisfaction with travel during e-cycling, the perceived degree of green, openness and liveliness together with the aesthetical value, atmosphere, height differences and perceived urbanization were added.

Table 3
Satisfaction with car-commuting (baseline), expected e-cycling (baseline) and experienced e-cycling after one and six months.

Variable	Car experience baseline	Expected E-bike baseline	E-bike experience after one month	E-bike experience after six months
All participants (N = 547)				
Positive deactivation–negative activation	0.87	2.18	2.05	2.15
Positive activation–negative deactivation	0.27	2.06	1.85	1.92
Cognitive evaluation	0.55	1.83	1.66	1.78
Satisfaction with travel	0.56	2.02	1.85	1.95
Only car-commuters (N = 172)				
Positive deactivation–negative activation	1.05	2.15	2.02	2.09
Positive activation–negative deactivation	0.35	2.02	1.84	1.88
Cognitive evaluation	0.69	1.81	1.65	1.77
Satisfaction with travel	0.70	1.99	1.83	1.91
Multi-modal car-commuters (N = 375)				
Positive deactivation–negative activation	0.79	2.19	2.06	2.17
Positive activation–negative deactivation	0.23	2.07	1.85	1.94
Cognitive evaluation	0.48	1.84	1.67	1.78
Satisfaction with travel	0.50	2.03	1.86	1.96

As we hypothesize that health status may influence satisfaction with e-cycling, the change in physical health after six months of participation was added as a variable in the model after six months. This variable is a dummy variable indicating whether a participant has a higher self-reported health status after six months as compared to the baseline situation. Table 5 shows the results of the three models.

All models have a very acceptable goodness-of-fit. Overall, the models indicate that the amount of increase in travel satisfaction, which was reported before, is not systematically related to personal characteristics such as age, gender, income or household composition. Notably, whether the respondent occasionally commuted by bicycle before the program does not affect the change in travel satisfaction resulting from the mode shift either. However, individuals' mobility and residential context appears to have an impact. Commuters with one car in the household (as opposed to two or more) experience a larger increase in travel satisfaction one month after entering the program. This may be due to a less car oriented lifestyle, making it easier to appreciate e-cycling. After six months the differences between different levels of car ownership are not significant. In addition urban density has an impact on the change in travel satisfaction. Compared to participants in non-urbanised areas, those in strongly urbanised areas and less urban areas have a lower expectation of satisfaction with e-cycling, and a marginally significant lower satisfaction after six months. Participants in less urban areas also have a lower travel satisfaction after one month. Probably, the higher speed of e-bikes, which is one of their main merits, is less experienced in denser urban areas due to more interaction with other road users.

The change in travel satisfaction is also influenced by current commuting behaviour and the commute experience. In particular, those using the e-bike more frequently for commuting have a larger increase in travel satisfaction after one and six months. This points at an clear self-selection effect, in that those with a higher satisfaction also use their e-bike more frequently. In addition, the extent to which car use and e-cycling is experienced as strenuous has strong effects on the increase in travel satisfaction. Logically, those who find car commuting more strenuous start from a lower commute satisfaction, and likely profit more from a shift to e-cycling. This holds for the expected travel satisfaction as well as for the travel satisfaction after one and six months. Likewise, the extent to which e-cycling is expected or experienced to be strenuous, has a negative effect on expected and experienced satisfaction with commuting by e-bike. If one can determine the speed of cycling more autonomously, this will lead to a larger increase in travel satisfaction resulting from the mode shift, both in terms of expected satisfaction and satisfaction after six months. Apparently, as

Table 4
Significance of differences between STS for car-commuting (baseline), expected e-cycling (baseline) and experienced e-cycling after one and six months.

Variable	Car baseline vs. E-bike baseline	Car baseline vs. E-bike after 1 month	Car baseline vs. E-bike after 6 months	E-bike baseline vs. E-bike after 1 month	E-bike baseline vs. E-bike after 6 months	E-bike after 1 month vs. E-bike after 6 months2
All participants (N = 547)						
Positive deactivation–negative activation	0.000	0.000	0.000	0.000	0.414	0.013
Positive activation–negative deactivation	0.000	0.000	0.000	0.000	0.001	0.056
Cognitive evaluation	0.000	0.000	0.000	0.000	0.290	0.010
Satisfaction with travel	0.000	0.000	0.000	0.000	0.046	0.006
Only car-commuters (N = 172)						
Positive deactivation–negative activation	0.000	0.000	0.000	0.033	0.470	0.262
Positive activation–negative deactivation	0.000	0.000	0.000	0.003	0.042	0.483
Cognitive evaluation	0.000	0.000	0.000	0.047	0.662	0.131
Satisfaction with travel	0.000	0.000	0.000	0.005	0.233	0.177
Multi-modal car-commuters (N = 375)						
Positive deactivation–negative activation	0.000	0.000	0.000	0.005	0.617	0.025
Positive activation–negative deactivation	0.000	0.000	0.000	0.000	0.009	0.071
Cognitive evaluation	0.000	0.000	0.000	0.002	0.325	0.038
Satisfaction with travel	0.000	0.000	0.000	0.000	0.110	0.016

Table 5
Regression analysis of expected and experienced change in STS when shifting from car to e-bike.

	Car baseline > E-bike baseline		Car baseline > E-bike after one month		Car baseline > E-bike after six months	
	B	sig.	B	sig.	B	sig.
(Constant)	0.644	0.173	−0.254	0.659	−0.676	0.197
25–39 years	0.007	0.963	−0.074	0.639	0.085	0.578
40–49 years	0.110	0.302	0.127	0.272	0.020	0.858
50–65 years	–	–	–	–	–	–
Male	−0.034	0.750	−0.147	0.202	−0.087	0.428
Female	–	–	–	–	–	–
Phys. cond. bad	−0.276	0.080	−0.339	0.053	−0.160	0.349
Phys. cond. neutral	-0.200	0.127	−0.035	0.806	−0.067	0.629
Phys. cond. good	−0.150	0.166	−0.086	0.470	0.003	0.982
Phys. Cond. excellent	–	–	–	–	–	–
1 car per household	0.132	0.158	0.210	0.038	0.145	0.134
2+ cars per household	–	–	–	–	–	–
< 3.000	−0.045	0.691	−0.083	0.494	−0.123	0.294
3.000 to < 4.000	0.075	0.500	−0.056	0.644	−0.049	0.673
> 4.000	–	–	–	–	–	–
Single	0.266	0.216	−0.289	0.227	0.017	0.938
Single parents	−0.102	0.745	−0.099	0.773	−0.109	0.739
Couples without children	−0.316	0.145	0.189	0.426	−0.227	0.315
Couples with children	–	–	–	–	–	–
(very) Strong Urbanized	−0.298	0.040	−0.177	0.261	−0.262	0.082
Moderate urbanized	−0.071	0.572	−0.146	0.293	−0.102	0.443
Less urban urbanized	−0.258	0.023	−0.265	0.032	−0.202	0.089
Not Urbanized	–	–	–	–	–	–
0–5 km	−0.127	0.633	−0.538	0.065	−0.343	0.228
5 < 10 km	−0.169	0.286	−0.281	0.113	−0.121	0.471
10 < 15 km	−0.095	0.482	−0.172	0.250	−0.003	0.983
15 < 20 km	−0.196	0.144	−0.248	0.091	−0.099	0.485
20+ km	–	–	–	–	–	–
1–3 days a week	0.142	0.349	−0.005	0.978	0.066	0.677
4 days a week	0.077	0.458	0.232	0.040	0.167	0.125
5 days a week	–	–	–	–	–	–
Conventional cycle share at baseline	0.292	0.136	0.213	0.335	0.269	0.195
E-cycle share	–	–	0.872	0.000	0.874	0.000
Strenuous car commute	0.432	0.000	0.439	0.000	0.379	0.000
Strenuous E-cycling commute	−0.159	0.000	−0.120	0.001	−0.129	0.000
Crowdedness during commute	−0.042	0.251	−0.042	0.347	−0.038	0.404
Freedom of speed determination	0.141	0.000	0.083	0.068	0.103	0.022
Annoyed by road users	−0.056	0.184	−0.011	0.789	−0.022	0.616
Threatened/Unsafe by road users	0.012	0.775	0.019	0.683	0.013	0.794
Route unsafety	−0.022	0.616	−0.029	0.580	−0.037	0.493
Wayfinding	−0.043	0.458	−0.124	0.092	−0.115	0.104
Distraction by billboards	−0.029	0.501	−0.028	0.608	0.019	0.729
Green	−0.010	0.811	0.069	0.209	0.154	0.002
Openness	0.061	0.069	0.041	0.298	−0.018	0.629
Aesthetics	−0.056	0.278	−0.005	0.924	0.082	0.172
Liveliness	−0.052	0.317	−0.001	0.988	−0.040	0.464
Atmosphere	−0.075	0.208	−0.157	0.012	−0.054	0.381
Height difference	0.018	0.508	0.019	0.562	0.028	0.375
Landscape	0.007	0.862	0.003	0.952	−0.077	0.066
Urbanization	0.111	0.006	0.059	0.184	0.053	0.238
Reported change in health status	0.144	0.003	0.140	0.008	0.191	0.000
Share of car-commuting at baseline	0.000	0.999	0.063	0.670	0.019	0.895
Adjusted R-square	0.407		0.408		0.398	

noted in the context of urbanization level, if one can take full profit of the higher speed of e-cycling, this leads to a higher appreciation of e-cycling.

Finally, the landscape through which one cycles has impact on the increase in travel satisfaction. A greener landscape leads to a larger increase in travel satisfaction after six months. A less cosy landscape leads a smaller increase after one month, and a more urbanised landscape leads to a higher expected increase in travel satisfaction. The latter is in contrast with the effect of urbanization level noted before, but it should be noted that this variable concerns the perceived urbanization of the commute route, which may differ from the urbanization level of the residence. Finally, although health status itself does not impact on the increase in travel satisfaction, improvement of health status does have an effect. Apparently, the experience of improved health as a result of e-cycling has a positive effect on travel satisfaction.

5. Discussion

This paper reported on the effects of an e-cycling stimulation program on travel satisfaction in the province of North-Brabant, the Netherlands. The program was designed to stimulate car-commuters to use their e-bike in daily commuting, earning monetary incentives for each kilometre participants e-cycled. With a longitudinal design this study allowed to observe changes in behavioural and travel satisfaction.

Our study did find support for the hypothesis that the travel satisfaction with e-cycling is higher than for car-commuting. With an increase of about 1.4. on a 7-point scale, this suggests that a shift from car to e-bike generates a considerable increase in commute satisfaction, and therefore possibly in overall well-being. Notably, a similar increase was observed for commuters who only used the car before the programme and those who occasionally used the bicycle. This implies a high and intrinsic travel satisfaction with e-cycling among participants, that is not dependent on cycling experience. Motivational theories of behaviour change, such as Self Determination Theory (SDT) (Standage and Ryan, 2012) posit that changes in behaviour are more likely to be sustained if individuals find the new behaviour more pleasant and therefore develop an intrinsic motivation to perform it. In that sense, our results suggest that e-cycling might be sustained on the longer run. Of course, this requires that travel satisfaction remains at the similar high level as at the one-month and six-month measurement, which should be investigated in follow up studies.

We find that the initially experienced satisfaction with e-cycling is slightly lower than the expected satisfaction. This suggests that both the focussing illusion and a forecasting bias might be present: participants slightly overestimate the positive aspects of e-cycling. However, initial satisfaction with e-cycling is still high. Where some well-being literature indicates a hedonic treadmill effect, our study finds that travel satisfaction remains high for a period up to six months, and actually slightly increases. Apparently, the habituation to e-cycling causes an increase of travel satisfaction over time. Interestingly, the negative impact of physical condition diminishes over time, suggesting that improved health as a result of e-cycling might be a reason for the slightly increased satisfaction. Again, this adds to the attractiveness of e-cycling in the long term. With respect to the health effects, we note that although the e-bike has technical advantages over the conventional bicycle regarding speed and action radius, e-cyclists still have to deliver substantial physical effort (Simons et al., 2009) which enhances health and reduces the chance of sedentary lifestyle diseases (De Geus et al., 2013). In addition, our study finds that the attractiveness of the route influences travel satisfaction. Factors like greenness and liveliness of the environment contribute to a positive travel satisfaction. In this respect, e-cycling resembles conventional cycling. However, there are also indications that factors that are specific for e-cycling such as autonomy in choosing one's speed influence travel satisfaction, leading to preferences for less urbanized areas to e-cycle.

Of course, this study is subject to limitations. One limitation concerns the setting of the e-cycling stimulation program, mainly focussing on commute travel. It remains uncertain to what extent trips for different travel purposes made by e-bike would have similar travel satisfaction. The use of e-bikes for recreation purposes may imply different requirements to infrastructure and cycling environment, resulting in different levels of satisfaction. In addition, although the results are promising in terms of the increase in travel satisfaction, it remains questionable to what extent satisfaction with e-cycling will remain high in the longer term, and whether the modal shift from car to e-bike will last after the program ended. Another limitation concerns the way in which commuters were persuaded to start the use of the e-bike in this study, based on monetary incentives. It is unclear if commuters who take up e-cycling independently (i.e. without a stimulation programme) will experience a similar increase in travel satisfaction, as their characteristics and the social context may be different, as well as their motivations to e-cycle. In addition, the fact that a monetary incentive is earned for e-cycling may affect the satisfaction with e-cycling. In the current study we could not disentangle these effects, as satisfaction was only measured during the program, when the incentive was received. It is therefore recommended that future studies address satisfaction with e-cycling in other contexts.

This study is a first step to investigate the potential of e-cycling in commute travel. More research is needed to fully understand the shift to e-cycling and its implications. Firstly, the shift towards the e-bike in daily commuting was induced by monetary incentives as part of a regional mobility program. It cannot be concluded that similar effects in size can be expected in other contexts (e.g., in different geographical contexts or without providing incentives) nor that responses are subject to the same influential factors. More studies of e-bike adoption with a longitudinal character in a variety of contexts are required to answer these questions. Secondly, the quality of cycling infrastructure was not taken into account explicitly, where the Dutch context generally caters for high quality cycle infrastructure. These characteristics may differ strongly between for instance the Netherlands, with an extensive cycling infrastructure, and North-American settings where such infrastructure is often lacking. Next to questionnaires, route characteristics could be based on available GPS-data from the participants commute trips, augmented with detailed information about spatial and natural context. Thirdly, it makes sense to study behavioural change and travel satisfaction over a longer period, than in the current study, to find out if a sustained high level of travel satisfaction indeed leads to sustain e-cycling behaviour, as discussed before. Adherence to e-cycling as healthy behaviour is a crucial factor for sustained positive health effects. Studies in other domains (Ettema et al., 2010) have shown behavioural change brought about by incentive programs not to be necessarily sustained when the incentive ends.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.tbs.2018.04.003.

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