Post COVID-19 teleworking and car use intentions. Evidence from large scale GPS-tracking and survey data in the Netherlands

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ABSTRACT

This study examines the changes in teleworking during the lockdown in April 2020 and the intention to change commuting behaviour after COVID-19 in the Netherlands. Survey data of 1,515 Dutch employees and large-scale smartphone-based GPS-data of the same participants before and during COVID-19 is used. The probability of increasing teleworking during COVID-19 is estimated using an ordinal logistic regression model, considering sociodemographic characteristics, the initial travel behaviour and the initial work situation as determining factors. Two binary logistic regression models are developed to analyse whether employees expect to continue teleworking after the COVID-19 pandemic and whether they will decrease car use for commuting. Both models consider teleworking and car use intentions in the context of behavioural changes during COVID-19. The main factors that influenced teleworking during the lockdown are job characteristics. Office workers and teaching staff were more likely to increase the amount of time spent working from home and showed a higher chance of changes in daily commuting routines. After COVID-19, office workers expect to increase teleworking. The results suggest that employees with a relatively large change in teleworking during the early lockdown expect to work from home more frequently after COVID-19. This effect is strengthened further by positive experiences with teleworking (i.e. more pleasure and higher productivity) and supporting policy measures by the employer, such as sufficient ICT facilities. The main conclusion related to intended changes in mode choice is that car use for commuting is expected to decrease after COVID-19, mostly because of an increase in teleworking.

Introduction

The COVID-19 virus outbreak at the beginning of 2020 had massive impacts on societies in Europe and elsewhere across the globe. In the Netherlands, the Dutch government announced in the early stage of the pandemic a lockdown. All schools, universities, libraries, pubs, barbershops and hairdressers, museums, cinemas, and restaurants had to be closed, and the government cancelled sports competitions, festivals, and major events. Everyone was advised to keep 1.5-meter distance from each other and not to travel to other countries unless strictly necessary. People were asked to stay at home as much as possible and, whenever possible, to work from home or to telework. Teleworking was seen as an essential measure to reduce daily travel and, consequently, to reduce the further spread of the virus. There was also a request to minimise the use of public transport. These measures strongly reduced travel options. The impact of COVID-19 on travel behaviour has been the subject of much research recently and mainly consists of analyses of observed changes during the pandemic (e.g., Abdullah et al. 2020; de Haas et al., 2020; Iranwan et al., 2021; Molloy et al., 2021; Rauws and van Lierop, 2020; Shamshiripour et al., 2020; Shakibaei et al., 2021). In the Netherlands, the number of trips, distance travelled, and mode choice changed considerably (van der Drift et al., 2021a). Teleworking contributed substantially to strongly reduced commuting flows by car and public transport in the first few weeks of the lockdown, reducing traffic congestion by more than 90% and resulting in empty trains during peak hours (e.g., van der Drift et al., 2021a; Taale and Turpijn, 2020).

In recent years, the impact of teleworking on travel behaviour or the factors that influence teleworking have received increasing attention. Teleworking is considered as an effective policy measure to reduce commuting trips and hence a positive contribution to reducing
congestion and the negative externalities of transportation (e.g., Helminen and Ristimäki, 2007; O’Keefe et al., 2016; Shabanpour et al., 2018). In most industrialised countries, including the Netherlands, teleworking strongly increased during the COVID-19 pandemic, also among employees which did not or hardly worked remotely before (de Haas et al., 2020). This inspired us to examine the impact of teleworking on commuting behaviour during and after the pandemic. This study aims to provide insight into the determinants that influenced teleworking during the pandemic and the impact of behavioural changes during the COVID-19 lockdown on stated intentions about teleworking and mode choice for commuting. The availability of tracking data at the individual level (i.e. travel and location data) for a more extended period, before and during the lockdown, and an online survey among the same individuals provided us with a unique dataset, with both changes in commuting behaviour during the pandemic and the intention to change behaviour afterwards. Some recent studies examined teleworking in the context of COVID-19. For example, Riggs (2020) examined the relationship between teleworking and changes in daily travel during the COVID-19 pandemic, while Nguyen (2021) investigated the determinants that affect working from home during the lockdown and employees’ attitudes towards teleworking in the post-COVID-19 era. Other studies focus on the safety of employees in relation to teleworking (e.g., Belzunegui and Erro-Garcés, 2020). No studies were found that examine simultaneously travel behaviour and teleworking before, during and after the lockdown.

The contribution to the literature of this paper is twofold. Firstly, this is the first study, to the authors’ knowledge, that investigates the relationship between observed changes in commuting behaviour during the lockdown and intended changes afterwards. Secondly, the paper contributes to the literature by examining the impact of moderating factors such as experiences with teleworking and the effect of policy measures, both by employers and the government, on teleworking intentions.

The rest of the paper is organised as follows. In Section “Teleworking and commuting behaviour”, an overview is provided of the literature on the determinants that influence teleworking, the impacts of teleworking on commuting behaviour, and the contribution of this study to existing literature. Section “Methods” explains the conceptual model and methods used for the analysis, and Section “Data collection and description” presents the data and variables used in the analysis. Section “Model results” describes the model results. Section “Discussion and conclusions” ends with a discussion and summary of the main conclusions.

**Teleworking and commuting behaviour**

**Factors explaining teleworking**

Most of the literature on teleworking describes research conducted before the COVID-19 virus outbreak in 2020. The literature distinguishes three groups of determinants that affect teleworking: the work situation, sociodemographic characteristics and travel behaviour.

First, the individual work situation impacts the opportunities to telework, such as job function and job sector (e.g., He and Hu, 2015; Hjorthol and Nossom, 2007; Singh et al., 2013). In general, employees with office jobs were more likely to work from home. However, also in other job functions a growing trend in teleworking was observed (e.g., Thulin et al., 2019; Vilhelmson and Thulin, 2016), partly motivated by technological innovations (e.g., Frey and Osborne, 2017). Commuting distance might also be an influencing factor in the choice to telework or not. For instance, Helminen and Ristimäki (2007) found that larger commuting distances were positively associated with teleworking. Moreover, employees’ preferences towards teleworking (e.g., Haddad et al., 2009; Iscan and Naktiyok, 2005; Peters et al. 2004) and experiences with working from home (e.g., Mokhtarian and Salomon, 1994) may influence teleworking choices.

Several studies examined the influence of sociodemographic characteristics on teleworking. People with higher income (e.g., He and Hu, 2015; Loo and Wang, 2018; Sener and Reeder, 2012) and higher education levels (e.g., de Graaf and Rietveld, 2004; Hjorthol & Nossom, 2007; Singh et al. 2013) were found to be more likely to work from home. Peters et al. (2004) showed that the chance of teleworking was higher for people from households without children, while others concluded that young children might encourage individuals to work from home (e.g., Iscan and Naktiyok, 2005; Mokhtarian and Salomon, 1994). Singh et al. (2013) concluded that living in urbanised areas was positively associated with teleworking, because employers who allow teleworking are mostly concentrated in urban areas and the ICT network is of a higher quality in urbanised areas. Other sociodemographic characteristics that may affect the choice to telework are gender and age, although the results in this area were mixed. Some studies found a positive relationship between men and teleworking (e.g., Hjorthol and Nossom, 2007; Pouri and Bhat, 2003), while others found that women were more likely to work from home, mostly because of the combination of work and care tasks (e.g., Mokhtarian et al., 1998).

Finally, the teleworking choice may also be affected by people’s initial travel behaviour. For instance, previous research showed that car users were less likely to adopt teleworking than frequent public transport users (e.g., Nurul Habib et al., 2012; Yen, 2000). Yen (2000) also found that increased car ownership reduces teleworking adoption, controlling for other sociodemographic characteristics.

**Impact of teleworking on commuting behaviour**

The impact of teleworking on travel behaviour has been the subject of many studies. Most of these studies found a reduction in the number of trips by teleworkers (e.g., Choo et al., 2005; Ellder, 2003; Helminen and Ristimäki, 2007; Lachapelle et al., 2017; Pendyala et al. 1991; (Shabanpour et al., 2018)). Andreev et al. (2010) reviewed about 30 papers about the impact of telecommuting on travel behaviour and concluded that in the short-term teleworking reduces commuting trips. However, in the long term, the positive impact on congestion levels and transport-related emissions might disappear because of so-called rebound effects, such as induced travel demand for other purposes. For example, Abreu e Silva et al. (2018) found a positive relationship between higher teleworking frequencies and non-commuting car trips among single-worker households. Kim (2017) showed that telecommuting reduces commuting trips, but that at the household level there was an increase in non-commuting trips.

**The rationale of the study**

Existing research provides insight into teleworking adaption and the relationship with mode choice for commuting before the COVID-19 virus outbreak. However, these studies do not provide enough information about changes in teleworking during and after the pandemic. Therefore, this research was conducted. The context of the COVID-19 pandemic allowed to examine how employees changed teleworking due to a forced intervention aimed at this behaviour. Employees were strongly advised to stay and work from home for an extended period resulting in changes in the number of teleworking days. How these changes in behaviour influenced intended behaviour when the restrictions no longer applied was explored. Before the COVID-19 pandemic, stimulating teleworking had been considered a potential factor to reduce commuting traffic. However, it is difficult and complex to change behaviour: “habitual processes strongly determine the daily routine of commuting in particular” (e.g., Guell et al., 2012). It is assumed that people facing life events or interventions are more likely to start the process of re-evaluating daily routines and, therefore, are more likely to change behaviour (e.g., Verplanken et al., 2008). However, during the first lockdown in the Netherlands, there was no time for re-evaluating daily routines. The COVID-19 pandemic can be considered as a large-scale ‘live-experiment’, offering empirical data about changes in and
experiences with teleworking, and as a result, providing more insight into the potential impact of an increase in teleworking on commuting behaviour through changing behaviour. Moreover, a survey among employees in the Netherlands, whose travel behaviour was recorded before and during the lockdown by a smartphone app, allowed to study the relationship between observed travel behaviour, revealed experiences and stated intentions. To the authors’ knowledge, there is no research on the effects of changing behaviour on intentions when people had no choice but to change behaviour, as is the case in this study.

Methods

In this paper, insight is provided into the factors that influence teleworking during the lockdown and the impact of behavioural changes on intended commuting behaviour afterwards. This research is unique in that the behavioural changes resulting from ‘imposed’ changes to behaviour rather than reconsidering daily routines is investigated. The COVID-19 pandemic forced a large group of employees to work from home as much as possible. Daily routines were broken, such as cycling to work every morning. Ouellette and Wood (1998) found that when people face unstable conditions, they are more willing to reconsider their behavioural intentions. Moreover, experiences with new behaviour during the lockdown may increase the chance of structural changes in behaviour. Therefore, the question is whether these forced changes in teleworking and travel behaviour affect the intention to change behaviour after the COVID-19 pandemic.

The following two research questions were addressed:

1. Which factors determined changes in teleworking during the April 2020 lockdown?
2. Do changes in teleworking and travel behaviour during the lockdown influence the intention to increase teleworking or reduce car use for commuting after COVID-19, and how do experiences with teleworking and policy measures affect the stated intentions?

The conceptual model to answer the research questions is presented in Fig. 1. The framework shows the different factors that affect changes in teleworking during the lockdown and the intended changes in teleworking and car use after COVID-19. To answer the research questions, two analyses were performed. First, the factors that influenced the changes in the number of days working from home during the lockdown using sociodemographic characteristics, the initial work situation and the initial travel behaviour before the virus outbreak as explanatory variables were determined (RQ1). Second, the intended changes in teleworking and car use for commuting after COVID-19, considering different elements were examined (RQ2). It is suggested that changes in teleworking and travel behaviour during COVID-19 impact the intention to change behaviour after COVID-19. This process might be influenced by experiences with teleworking (i.e. change in pleasure or productivity) or by policy measures stimulating teleworking, both from the government and employer.

To answer the research questions, the following three models were estimated:

- Model 1, an ordinal logistic regression (OLR) model, was estimated to determine the degree to which sociodemographic characteristics, the initial work situation, and the initial travel behaviour (i.e. explanatory variables) predict the odds of the relative increase in teleworking during the lockdown (i.e. dependent variable). To distinguish the different degrees of increases in teleworking, an ordinal variable was created with the following four categories: 0–25%, 25–50% and 50–75% and 75–100% increase in teleworking. The response variable consists of three or more categories with a natural ordering to the levels. To make full use of all information in the ordinal response data and to predict multi-class ordered variables, an ordinal logistic regression technique was used. The ordinal logistic regression model is expressed as follows:

\[
\ln \left( \frac{P(Y \leq i)}{1 - P(Y \leq i)} \right) = \alpha_i + \beta_1 X_{1i} + \cdots + \beta_m X_{mi}
\]

- Two binary logistic regression (BLR) models were estimated to examine the factors that influence the intention to increase teleworking (model 2a) and the intention to decrease car use for commuting (model 2b) after COVID-19 compared to initial travel behaviour before the lockdown. This study explores the intention to change or not after COVID-19. Therefore, for both models, a dichotomous variable was created as dependent variable (0 = no intention to change, 1 = intention to change). Variables that measure changes in travel behaviour, changes in the number of days working from home, changes in experiences with teleworking and policy measures from both the government and employers to stimulate working from home during and after COVID-19 were added as explanatory variables, while controlling for the features of the situation before COVID-19. When the dependent variable is dichotomous or binary, simple linear regression cannot be used. Logistic

Fig. 1. Conceptual model of the factors that determine changes in teleworking during the lockdown and intended changes in teleworking and car use for commuting after COVID-19.
regression is the statistical technique to predict the relationship between the predictors and binary dependent variable. The binary logistic regression model is expressed as follows:

\[
\ln \left( \frac{P(Y)}{1 - P(Y)} \right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots
\]

in which,

- \( Y \) = dependent variable
- \( P(Y) \) = the probability of \( Y \) occurring
- \( X_1 \ldots X_n \) = set of predictors
- \( \beta_i \) = parameter of the predictor variables
- \( \alpha \) = intercept

Data collection and description

Data collection

In the analysis, data was used from the Dutch Travel Panel (in Dutch: Nederlands Verplaatsingspanel, NVP). The NVP, an initiative of DAT, Mobility, Kantar and Mobidot, started in 2019 and is a large-scale source of information to examine the dynamics in the travel behaviour of individuals (e.g. van der Drift et al., 2021a). GPS and survey data are collected with user consent and data collection procedures comply with EU’s privacy rules (GDPR). Travel information (for example, number of trips, distance, travel mode, origin and destination) was collected continuously through the smartphones of about 6,000 participants, along with their socio-demographic information. Modes are deduced from the enhanced trip data using probabilistic Bayesian mode use models. Thomas et al. (2018) provide more information about the automatic trip detection and registration process, as well as the mode deduction process. The members of the NVP are recruited from the online Kantar panel (TNS NIPObase), comprising over 200,000 respondents and form a representative selection of the Dutch population. In April 2020, during the first lockdown, the Ministry of Infrastructure and Water Management invited employed panel members of the NVP, whose GPS data were collected, to fill in an online survey. The respondents had to answer questions about the number of days they worked from home before and during the lockdown, their experiences with teleworking during the lockdown and their expectations about future behaviour. Experiences with teleworking during the lockdown included pleasure and productivity in work compared to the situation before COVID-19. Expectations about future behaviour comprised the number of days working from home and mode choice for travel days to work. This unique combination of information about observed changes in travel behaviour from the smartphone application of the NVP and revealed experiences and stated intentions from the online survey provided by the same participants enabled us to study the potential impact of behavioural changes on commuting behaviour.

In this research, before COVID-19 covers the period from January to (mid) March 2020, when there were no travel restrictions. During COVID-19 is the first period of the lockdown, from 16 March till the end of April 2020. After COVID-19 considers the period without any restrictions and when people can behave like ‘normal’. A total of 3,562 individuals aged 20 years and older completed the online survey between 20 and 26th April 2020. Respondents who participated in the NVP for at least one entire week before and during the lockdown in the Netherlands were selected (N = 1,675). For each respondent, one week before and during the lockdown was picked. The focus of this study is on employees who did not work full-time from home before COVID-19 and to highlight the differences between employees who did not change and employees who started or increased teleworking with at least one day teleworking. Respondents were classified as “not teleworking”, “started teleworking” or “increased teleworking”. Consequently, respondents who during the lockdown worked fewer hours from home than before (n = 36) were excluded. Also, employees who already worked full-time from home before the lockdown and did not change their behaviour (n = 124) were excluded from further analyses.

The final sample contained 1,515 individuals with observed data about their travel behaviour before and during the lockdown from the NVP. From the online survey, the number of days they worked from home and their mode choice for commuting before and during the lockdown, and their expectations about teleworking and mode choice for commuting after COVID-19 is known. Based on changes in the number of teleworking days of respondents who were not fulltime teleworking before COVID-19, the following three subgroups were distinguished:

1. Not teleworking (no change): Respondents who were not teleworking before the COVID-19 outbreak and did not change their working pattern during the first lockdown (n = 496)
2. Started teleworking (change): Respondents who were not teleworking before the COVID-19 outbreak and worked at least one day from home during the first lockdown (n = 675)
3. Increased teleworking (change): Respondents who were teleworking at least one day before the COVID-19 outbreak and increased the number of days teleworking during the first lockdown (n = 344)

Data description

To analyse the relationships in our conceptual model, the following variables were used:

| Period     | Category                     | Variables                              | Source    |
|------------|------------------------------|----------------------------------------|-----------|
| Before COVID-19 | Sociodemographic characteristics | Age, gender, educational level, urbanisation of the residential location, household composition | Survey data |
| Initial work situation | Job function, job sector | | Survey data |
| Initial travel behaviour | Frequency of mode use for all trips, intrapersonal mode use variation | | NVP data |
| During COVID-19 | Changes in teleworking | Change in number of days working from home | Survey data |
| | Changes in travel behaviour | Frequency of mode use for all trips, intrapersonal mode use variation | NVP data |
| | Changes in experiences with teleworking | Pleasure, productivity | Survey data |
| | Policy measures stimulating teleworking | Policy measures to facilitate teleworking such as offering sufficient teleconferencing tools | Survey data |
| After COVID-19 | Intention to change teleworking | Intention to increase the number of days working from home | Survey data |
| | Intention to change car use for commuting | Intention to decrease car use for commuting | Survey data |

Variables describing the situation before COVID-19

Sociodemographic characteristics and initial work situation

In the analyses, the following sociodemographic characteristics of the respondents were included: age, gender, educational level, urbanisation of the residential location and household composition. As it is
known from previous research, these factors might influence teleworking and commuting behaviour (see Section “Factors explaining teleworking”). Dichotomous variables were created for gender (male = 0, 1 = female), educational level (0 = no or low educated, 1 = high educated), urbanisation (0 = rural, 1 = urban) and household composition (0 = without children < 12 yr, 1 = with children < 12 yr).

To describe the initial work situation, the job function and job sector of each employee from the survey data were used. Job functions were categorised as follows: office worker, working in health care, teaching staff, and production or sales personnel. For the job sector, three main categories were distinguished, conforming to the standard business classification in the Netherlands: building and construction, professional services, and non-commercial services. Also, the commuting distance based on the zip code of the residential and job location from the NVP data was calculated. Previous research has shown that the accessibility of the work environment affects mode choice for commuting (e.g., Maat and Timmermans, 2009). Therefore, the dataset was enriched with the distance from the job location to the nearest highway exit and public transport facilities. Following Hilbers et al. (2005), a variable representing the job location’s accessibility was derived. A-locations represent good access by both public transport and car (i.e. areas in the immediate area around intercity stations and close to the highway), while R-locations represent poor access (i.e. not easily accessible by public transport and not close to the highway).

Table 1 gives an overview of the sociodemographic and initial work situation of the selected sample and the Dutch employed population. Higher educated people and teaching staff are underrepresented in the sample, and production/sales employees and families without children are overrepresented. Other sociodemographic characteristics are comparable with the total employed population in the Netherlands, such as age, gender and urbanity level of the residential location. Overall, the selected sample fairly represents the composition of the Dutch employed population.

Respondents who did not work from home before and during the lockdown were more likely to be women, to live in rural areas, to be lower educated, and to live in households without children. Also, members of this group had a greater tendency to work in the building/construction sector or to have a care or production/sales function. Respondents who started to telework during the lockdown were more likely to be office workers or teachers. Because universities and schools were closed, teachers and students were forced to distance learning. Finally, respondents who already worked from home and increased the number of teleworking days during the lockdown were more likely to be male, to be higher educated and to live in households with children under 12 years old. These findings were confirmed by earlier research (see Section “Factors explaining teleworking”). Also, these employees had a higher chance of being employed in the non-commercial service sector, and to be an office worker or teacher. Because universities and schools were closed, teachers and students were forced to distance learning.
Variables describing intended changes in behaviour after COVID-19

Stated intentions about teleworking were derived from the survey data. Respondents were asked to imagine a post-COVID-19 situation without any travel restrictions and to assume their personal situation was the same as the situation before COVID-19 (e.g., no income or job loss).

Intention to change teleworking

- Each respondent was asked how many days they were expecting to work from home. As expected, employees who did not telework before or during the lockdown do not have the intention to start teleworking after COVID-19. Almost two-thirds of the employees who started or increased teleworking during the lockdown expect to return to the situation as it was before COVID-19. Nearly a third of the employees who did not telework before COVID-19, and started teleworking during the lockdown, expect to continue teleworking after COVID-19. Most of them intend to switch from one to two days teleworking (24%).

- A dichotomous variable based on the difference between the number of teleworking days before and after COVID-19 (0 = no increase, 1 = increase) was derived, which represents the intention to change teleworking after COVID-19 and was used as a dependent variable in model 2a and an explanatory variable in model 2b.

Table 1

| Sociodemographic characteristics and initial work situation of the selected sample, bold numbers indicate the highest share (%) of each category (source: Survey data). |
|--------------------------------------------------------------------------------------------------|
| Before and during not teleworking (n = 496) | Before not teleworking, during started teleworking (n = 675) | Before teleworking, during increased teleworking (n = 344) | Total sample (n = 1,515) | Dutch employed population |
|---------------------------------------------|--------------------------------------------------|--------------------------------------------------|-------------------------|-------------------------|
| **Gender** | | | | |
| % male | 47.0 | 48.0 | 54.9 | 49.2 | 53.3 |
| **Age** | | | | |
| mean | 46.6 | 44.4 | 44.7 | 45.2 | 43.0 |
| **Residential location (%)** | | | | |
| urban | 48.4 | 59.0 | 58.4 | 55.4 | 55.5 |
| non-urban | 51.6 | 41.0 | 41.6 | 44.6 | 44.5 |
| **Education level** | | | | |
| % high educated | 29.4 | 67.3 | 80.5 | 57.9 | 48.5 |
| **Household composition (%)** | | | | |
| single | 20.0 | 18.2 | 18.3 | 18.8 | 18.9 |
| without children | 46.6 | 37.6 | 36.0 | 40.2 | 44.3 |
| with children < 12 years | 24.8 | 34.7 | 34.3 | 31.4 | 26.2 |
| with children 12-17 years | 8.7 | 9.5 | 11.3 | 9.6 | 11.4 |
| **Job sector (%)** | | | | |
| building and construction | 18.5 | 12.6 | 8.4 | 13.6 | 12.2 |
| professional services | 34.1 | 34.1 | 54.4 | 38.7 | 54.1 |
| non-commercial services | 47.4 | 53.3 | 37.2 | 47.7 | 33.8 |
| **Job function type (%)** | | | | |
| office worker | 34.7 | 70.2 | 77.9 | 60.3 | 63.0 |
| health care | 29.4 | 8.7 | 5.2 | 14.7 | 11.5 |
| education | 2.6 | 15.3 | 8.4 | 9.6 | 3.8 |
| production/sales | 33.3 | 5.8 | 8.4 | 15.4 | 21.6 |
| **Distance to job location** | | | | |
| average distance (km) | 14.7 | 17.9 | 26.9 | 18.9 | 19.8 |
| **Accessibility of job location** | | | | |
| A-location | 8.1 | 13.2 | 11.7 | 11.0 | n/a |
| R-location | 29.6 | 19.6 | 15.9 | 21.8 | n/a |

Table 2

| Travel behaviour before COVID-19 of the selected sample, bold numbers indicate the highest share (%) of each category (source: NVP data). |
|--------------------------------------------------------------------------------------------------|
| Mode choice, all trips (%) | Before and during not teleworking (n = 496) | Before not teleworking, during started teleworking (n = 675) | Before teleworking, during increased teleworking (n = 344) | Total sample (n = 1,515) |
| Car | 62.1 | 56.1 | 57.9 | 58.4 |
| Public transport | 2.9 | 4.5 | 5.8 | 4.3 |
| Bicycle | 20.6 | 22.6 | 19.0 | 21.1 |
| Walk | 14.4 | 16.8 | 17.4 | 16.1 |
| **Intrapersonal mode use variation (%)** | | | | |
| Trips | 28.6 | 33.4 | 35.1 | 32.2 |
Model results

Changes in teleworking during the lockdown

The model results for Model 1 are reported in Table 3. The proposed model presents a good model fit regarding the final loglikelihood statistic ($\chi^2 = 566.243, p < 0.000$). Ordinal logistic regression models are performed under the assumption of proportional odds (i.e. the effects of the explanatory variables are the same across the different thresholds). The 'test of parallel lines' showed that this assumption was upheld in our model ($p = 0.192$).

Job function seems to have the strongest influence on changes in teleworking, given the large and significant coefficients for office workers and teaching staff. Office workers were 4.9 and teachers 6.6 times more likely to have higher values for the relative change in the number of days working from home. This suggests that office workers and teachers had a considerable chance of changing daily routines regarding commuting behaviour during the lockdown. This is not surprising considering that all schools and universities were closed during the lockdown. Being an employee in the non-commercial or professional sector increases the probability of being in the second (25–50% change), third (50–75% change) or fourth (75–100% change) category compared to employees in the building and construction sector. However, office workers in the building and construction sector were more likely to have a larger change in teleworking. Considering sociodemographic characteristics, higher educated people were more likely to increase working from home during the lockdown, while increasing age showed a negative association with changes in teleworking. For employees with a commuting distance of more than 50 km, the probability of being more likely to change is multiplied by 1.4. Intrapersonal mode use variation showed a small but positive effect on changes in teleworking. Employees

| Model 1                | \( \beta \) | \( \exp(\beta) \) |
|------------------------|-------------|-------------------|
| **Threshold dependent variable**                                      |             |                  |
| 0–25% | 25–50% change in teleworking                                      | 0.877**     |                  |
| 25–50% | 50–75% change in teleworking                                      | 1.346***    |                  |
| 50–75% | 75–100% change in teleworking                                     | 2.051***    |                  |

| Explanatory variables                      | \( \beta \) | \( \exp(\beta) \) |
|-------------------------------------------|-------------|-------------------|
| **Sociodemographic characteristics**       |             |                  |
| gender (ref = female)                      | 0.070       | 1.073             |
| age                                        | -0.009*     | 0.991             |
| residential location (ref = rural)         | 0.113       | 1.119             |
| education (ref = no or low education)      | 1.066***    | 1.902             |
| household with children < 12 yr (ref = no) | 0.206*      | 1.228             |
| **Initial work situation**                 |             |                  |
| distance to the job location (ref < 50 km) | 0.325*      | 1.384             |
| A-location (ref = no)                      | 0.184       | 1.202             |
| R-location (ref = no)                      | -0.359**    | 0.698             |
| job function: office worker (ref = no)     | 1.585***    | 4.881             |
| job function: health care (ref = no)       | -0.449**    | 0.638             |
| sector: building and construction (ref = no) | 1.885***    | 6.585             |

| Initial travel behaviour                  |             |                  |
| intrapersonal mode use variation (%)      | 0.009**     | 1.009             |
| share of PT use (%)                       | 0.781       | 2.184             |

| Number of observations                    | 1,515       |                  |
| Pseudo R$^2$ of Nagelkerke                | 0.344       |                  |
| Loglikelihood with zero coefficients      | 3607.246    |                  |
| Final Loglikelihood                      | 3041.002    |                  |
| \( \chi^2 \)                             | 566.243***  |                  |

Notes: *p < 0.10, **p < 0.05, ***p < 0.00.
who use more different modes, were more likely to increase the number of days working from home.

**Intention to increase teleworking and reduce car use for commuting after COVID-19**

The model results of model 2 are reported in Table 4. For this analysis, respondents who increased teleworking during the lockdown were selected (N = 1,019) because changes in teleworking are only known for these respondents. The proposed models present a good model fit (good of days working from home).

Model 1 showed that higher educated employees were almost two times more likely to switch from not working from home to (almost) full-time working from home during the first lockdown. In addition, the results of model 2a reveal that higher educated employees are also more likely to increase teleworking after COVID-19. No significant relationships were found between other sociodemographic characteristics and the intended increase in teleworking. The initial work situation seems to have a greater influence. A positive and significant association was found with the intention to increase teleworking and to reduce car use for employees with longer commuting distances and office workers. This is not surprising, as reducing travel time is considered as one of the main advantages of teleworking. Teaching and health care personnel showed a positive association with the intention to reduce car use for commuting after COVID-19. This indicates that teaching staff and health care personnel are more likely to switch from the car to other modes of transport. However, they do not show a higher chance of increasing the amount of teleworking. Although teachers were forced to work from home and provide online education, most of them prefer teaching in the classroom.

In model 2, the relationship between the observed changes during the lockdown and intended behaviour after COVID-19 was examined. No significant associations between changes in travel behaviour (i.e. change in use of public transport or intrapersonal mode use variation) and the intention to increase teleworking were found. However, changes in travel behaviour show some small but significant associations with the intention to reduce car use after COVID-19. Frequent public transport users are less likely to reduce car use for commuting after COVID-19. This is not surprising, as they did not use the car frequently before the pandemic. Also, a higher share of mode use variation during the lockdown increases the chance of reducing car use. This suggests that experiences with other transport modes might cause a re-consideration of mode choice behaviour.

Regarding changes in teleworking during the lockdown, employees with relatively high changes in teleworking are more likely to increase the amount of time working from home and reduce car use after COVID-19. Also, there is a very strong association between the intention to increase teleworking and reducing car use. This is in line with prior expectations that experiences with new behaviour weakens daily routines and increases the likelihood of behavioural changes. This is further emphasised by the positive impact of positive experiences with teleworking during the lockdown. Employees who experienced more pleasure and a higher level of productivity during the lockdown have a higher chance of increasing the extent to which they work from home after COVID-19. However, additional policy measures are required to sustain a higher share of teleworking after the pandemic. Employees expressed the need to make agreements about teleworking at the individual level. Continued encouragement to work from home and offering a helpdesk for teleworking-related questions both positively impact the intention to increase the amount of time spent working from home. This suggests that if policy measures regarding teleworking match these expectations, intended changes might result in structural behavioural changes.

### Table 4

| Explanatory variable | Model 2a | Model 2b |
|----------------------|----------|----------|
| **Dependent variable** | Intended increase in teleworking | Intended reduce in car use for commuting after COVID-19 |
| Sociodemographic characteristics | | |
| gender (ref = female) | −0.221 0.802 | −0.285 0.752 |
| age | −0.005 0.995 | −0.006 0.994 |
| residential location (ref = rural) | 0.050 1.052 | −0.273 0.761 |
| education (ref = no or low education) | 0.410** 1.0507 | −0.242 0.785 |
| household with children < 12 yr (ref = no) | −0.217 0.805 | −0.132 0.876 |
| Initial work situation | | |
| distance to the job location (ref < 50 km) | 0.455** 1.577 | 0.622** 1.862 |
| A-location (ref = no) | −0.114 0.892 | −0.086 0.918 |
| R-location (ref = no) | 0.135 1.144 | 0.133 1.143 |
| job function: office worker (ref = no) | 0.664** 1.942 | 0.943** 2.567 |
| job function: health care (ref = no) | 0.441 1.555 | 3.383 3.987 |
| job function: teaching staff (ref = no) | −0.268 0.765 | 0.968* 2.633 |
| sector: building and construction (ref = no) | 0.432 1.540 | 0.642 1.901 |
| office worker * building and construction (ref = no) | −0.361 0.697 | −0.614 0.541 |
| Initial travel behaviour | | |
| intrapersonal mode use variation (%) | 0.000 1.000 | −0.008 0.992 |
| share of PT trips (%) | −0.773 0.462 | −5.878** 0.003 |
| Changes in teleworking | | |
| change in teleworking (%) | 0.727** 2.068 | −0.640 0.527 |
| Changes in travel behaviour | | |
| change in mode use variation (%) | −0.002 0.998 | 0.014*** 1.014 |
| change in use of public transport (%) | −0.747 0.474 | 1.337 3.809 |
| Changes in attitudes towards teleworking | | |
| pleasure: less (ref = much less) | 0.116 1.123 | 0.273 1.314 |
| pleasure: about the same (ref = much less) | 0.504* 1.655 | 0.566 1.761 |
| pleasure: more (ref = much less) | 0.558* 1.748 | 0.731* 2.076 |
| pleasure: much more (ref = much less) | 0.837** 2.308 | 0.313 1.367 |
| productivity: less (ref = much less) | 0.296 1.345 | −1.268*** 0.281 |
| productivity: about the same (ref = much less) | 0.089 1.093 | −0.786* 0.456 |
| productivity: more (ref = much less) | 0.683* 1.979 | −1.074** 0.342 |
| productivity: much more (ref = much less) | 0.748* 2.112 | −0.770 0.463 |
| Measures during lockdown | | |
| flexible working hours (ref = no) | 0.330** 1.392 | 0.189 1.208 |
| facilitating tools for teleconferencing (ref = no) | 0.261 1.298 | 0.314 1.369 |
| facilitating computer supplies (ref = no) | −0.101 0.904 | 0.076 1.078 |
| obliged by government (ref = no) | 0.123 1.131 | 0.136 1.145 |
| obliged by employer (ref = no) | 0.078 1.081 | 0.140 1.150 |
| Future measures employer after COVID-19 | 0.493*** 1.638 | −0.342 0.710 |

(continued on next page)
Table 4 (continued)

| Dependent variable | Model 2a | Model 2b |
|--------------------|----------|----------|
|                     | Intended increase in teleworking | Intended reduce in car use for commuting |
| Explanatory variables | \( \beta \) | \( \exp(\beta) \) | \( \beta \) | \( \exp(\beta) \) |
| making agreements about teleworking at individual level (ref = no) | | | | |
| active stimulating teleworking by employer (ref = no) | 0.359** | 1.432 | 0.189 | 1.209 |
| appointing a contact person for questions about teleworking (ref = no) | 0.509*** | 1.664 | 0.044 | 1.045 |
| Intention to increase teleworking after COVID-19 | | | | |
| intention to increase teleworking (ref = no) | - | - | 3.336*** | 28.119 |
| Constant | -3.297*** | 0.037 | -2.026** | 0.132 |
| Number of observations | 1,019 | 1,019 |
| \( R^2 \) of Nagelkerke | 0.201 | 0.517 |
| \( \chi^2 \) | 160.813*** | 439.415*** |

Notes: *p < 0.10, **p < 0.05, ***p < 0.01.

Discussion and conclusions

In this paper, the factors that influence changes in teleworking and explored the impact of behavioural changes during the COVID-19 lockdown on stated intentions about teleworking and mode choice for commuting were examined. Large-scale smartphone-based GPS-data and survey data from 1,515 Dutch employees were used. First, the changes in teleworking and travel behaviour during the lockdown and the intention to change commuting behaviour after COVID-19 were described. Secondly, logit models were developed to investigate the odds to increase teleworking and reduce car use. Our research findings contribute to the literature about teleworking and travel behaviour before the pandemic. The main factors that influenced teleworking during the lockdown were job characteristics. Office workers and teaching staff were more likely to increase working from home and showed a higher chance of changes in daily commuting routines. Also, office workers were more likely to increase working from home after COVID-19, although this does not apply to teaching staff. In particular, employees with relatively large changes in teleworking during the lockdown expect to work from home more often after COVID-19. This effect is strengthened further by positive experiences with teleworking (i.e., more pleasure and higher productivity) and supporting policy measures by the employer, such as sufficient ICT facilities. Furthermore, evidence is provided that an increase in teleworking leads to a substantial reduction in car use for commuting. In this way, there is an excellent potential for the contribution of teleworking in meeting climate targets, such as the reduction of transport-related emissions and congestion. It must be noted, however, that most employees in the Netherlands have access to high internet quality. Therefore, the results of this study are not necessarily applicable to countries where internet is of much lower quality.

Habits strongly influence our daily behaviour (e.g., Lally and Gardner, 2013; Verplanken and Wood, 2006). Most of our travel behaviour, including commuting, is habitual behaviour. Research outside the transport domain has shown that it takes about two months to adopt new habits (e.g., Lally and Gardner, 2013). In this respect, the first lockdown in the Netherlands, a period of two and a half months, was a perfect chance to build new habits. There was no time for re-considering existing habits, and people were directly ‘forced’ into new behaviour. The model results show that these experiences with behaviour changes for a more extended period contribute to an expected increase in teleworking and changes in mode choice for commuting after COVID-19. However, intentions do not always lead to actual changes in behaviour. Intention to change travel behaviour is, to a large extent, determined by preferences and attitudes (e.g., Clark et al., 2016; Klocker and Friedrichsmeijer, 2011; Paulssen et al., 2014). The findings of this study confirm this relationship: employees who experienced more pleasure and higher productivity during the lockdown, mostly white-collar jobs, are more likely to increase working from home after COVID-19. However, as the pandemic continued, the question is whether this group of employees remained this positive and what possible effect there might be on the intention to change behaviour. Our survey was carried out six weeks after the start of the COVID pandemic, and at that time respondents might have anticipated that the situation would soon return to normal. The longer duration of the pandemic might have influenced the intention to work from home after COVID-19 (e.g., MarketResponse, 2020). Meanwhile, some large employers in the Netherlands, for instance, KPMG and ABN Amro, have already changed their policy to retain teleworking. The future will show whether and to what extent the intention to change commuting behaviour remains and whether it eventually lead to changes in actual behaviour.

This paper clearly shows the added value of using GPS tracking data in combination with an online survey to examine changes in travel and activity patterns. GPS tracking data with detailed information about the travel behaviour of the same persons over time allowed us to analyse differences in weekly travel patterns at the individual level. This is not possible with traditional cross-sectional surveys and 1- or 3-day travel diaries. With information about expected behaviour after COVID-19 of the same respondents from the online survey it was, in this study, possible to examine the relationship between changes in actual behaviour and stated intentions. This possibility of submitting a survey with in-depth questions to the panel members offers many opportunities for future research. For example, conducting the same survey will reveal if and to what extent intentions to change behaviour have changed over time, or an online survey among employees who do not intend to increase teleworking might provide more insight into the barriers.

The results of this study are in line with previous research on the impact of teleworking on commuting behaviour on the short term (e.g., Clark et al., 2016; Elder, 2020). A reduction in car use and an increase in cycling and walking were found. However, re-bound effects on teleworking are debatable. It would be an interesting topic to examine the relationship between the impact of teleworking on, for example, travel behaviour for non-commuting activities. Another direction for future research is to investigate whether changes in travel behaviour and teleworking during the lockdown affect gender differences in mobility. Furthermore, the impact of an increase in teleworking on residential relocation could also be explored. Employees with longer commuting distances are more likely to expect an increase in teleworking after COVID-19. In the long term, an increase in working from home could, therefore, result in residential relocations (e.g., Toger et al., 2021).

This study provides policymakers with new insights when it comes to achieving structural changes in commuting behaviour. A contextual change in someone’s life is an essential pre-condition for increasing the effectiveness of policy measures. The government’s appeal to work from home as much as possible caused a major change in the work situation, although there is still a large group of employees for whom working from home is not possible. Our results show that the changes in teleworking have had a large impact on the intention to telework after COVID-19 and reduces in particular car use for commuting. The impact of changes in travel behaviour during the lockdown on mode choice for commuting after COVID-19 is much less. The key determinants of mode choice, for example, commuting distance, do not change in the short term. To that end, the COVID-19 pandemic is a ‘best practice’ of how interventions can stimulate future changes in behaviour. Therefore, policy makers who want to utilize this situation in order to
influence behaviour after COVID-19 should primarily focus on stimulating teleworking, possibly in combination with stimulating the use of more sustainable modes of transport.

This study shows that the first signs of intended changes in teleworking are positive, however, there are also some remarks. First, there is still a substantial part of the workforce in the Netherlands that have no or low digital skills, which makes teleworking more complicated (e.g., Non et al., 2021). Investments in skills development are key to improving teleworking, possibly in combination with stimulating the use of ICT. This study shows that the first signs of intended changes in teleworking, possibly in combination with stimulating the use of ICT, is an important strategy to reduce travel demand, which is particularly relevant in the context of the COVID-19 pandemic.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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