SCIENTIFIC SUMMARY:

DETERMINING THE CAUSAL BI-DIRECTIONAL RELATIONSHIP BETWEEN ACTIVE TRAVEL AND HEALTH

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Abstract

In the Netherlands, only 55% of the Dutch population meets the norm of 150 minutes of moderate physical activity per week. To increase overall physical activity, the Dutch government wants to stimulate active travel. Active travel has two important benefits: the accessibility effect and the health effect. Yet, the effect of active travel on the total net health benefits is not completely understood and "wrong" conclusions can be made if the complex causal relationships between active travel and health are overlooked. In this research, two hypotheses are tested that are a possible explanation for active travel to not have the same health benefits as physical activity: 1) active travel substitutes for other forms of physical activity, 2). there exists a causal bi-directional relationship between active travel and health. Leisure physical activity is used to examine other forms of physical activity. BMI and general mental health are used to examine health. To test the hypotheses, the Cross-Lagged Panel model is used and is estimated on the LISS Panel data. The findings indicate that there exists a positive effect between active travel and other forms of physical activity. Furthermore, this research indicates no relationship between active travel, BMI and mental health. Especially, the findings of the positive effect of active travel on other forms of physical activity are uplifting. This means that the current health benefits are underestimated. We recommend that these values will be changed in future reports regarding the health benefits of active travel.

Keywords: Active travel, (Random Intercepts) - Cross-Lagged Panel Model, Health and Physical activity

1. Introduction

Physical inactivity has been linked to various health problems such as several chronic diseases (e.g., cardiovascular disease, diabetes, cancer, obesity and depression) and premature death. Even though the benefits of physical activity are well-known, physical inactivity is still one of the most important health challenges of the 21st century. In the Netherlands, only 55% of the Dutch population meets the norm of 150 minutes of moderate physical activity per week (RIVM, n.d.).

To increase overall physical activity, the Dutch government wants to stimulate active travel. Active travel is travelling, for either leisure or transport, while using an active mode such as walking or cycling. Given the fact that people naturally have to travel around in everyday life, policymakers believe that active travel is an easy way to increase the overall levels of physical activity in the population and thereby increase the health of the population.

Active travel has two important benefits: the accessibility effect and the health effect. Yet, the effect of active travel on the total net health benefits is not completely understood and "wrong" conclusions can be made if the complex causal relationships between active travel and health are overlooked (Van Wee & Ettema, 2016). In this research, two hypotheses are tested that are a possible explanation for active travel to not have the same health benefits as physical activity. The two hypotheses that are examined in this research are:

1. Active travel substitutes for other forms of physical activity;
2. There exists a causal bi-directional relationship between active travel and health.

These two unknowns are also recognized in the current values that are used to estimate the benefits of cycling in the Cost-Benefit analyses (Decisio, 2017).

In the first hypothesis, it is assumed that active travel has a negative relationship with other forms of physical activity. If this is the case active travel does not increase the total amount of physical activity and therefore, stimulating active travel does not lead to extra health benefits. At the moment, limited research has been done regarding the effect of active travel on the total physical activity. By examining the relationship between active travel and leisure physical activity, this research tends to get a better understanding of the relationship between active travel and the total amount of physical activity. Currently, some of the estimations by Decisio are corrected for this possible substitution effect. If the substitution does not take place, the health benefits are currently underestimated.

The second hypothesis assumes that there exists a causal bi-directional relationship between active travel and health. This means that active travel leads to healthier people, but healthier people also tend to travel more actively. If only healthy people are stimulated to travel actively, the total net health benefit is lower compared to when unhealthy people start to travel actively. An increase in active travel for unhealthy people will lead to more health benefit than an increase of active travel for already healthy people. Currently, the estimations by Decisio are based on the health benefit of an average person. Depending on the individuals who increase their active travel, the current values for active travel are under- or overestimated. Because the majority of the researches is conducted with cross-sectional studies, the direction of influence cannot be established. This means that these researches make it not possible to establish whether active travel influences health or vice versa (Saunders, Green, Petticrew, Steinbach & Roberts, 2013).

Another point of interest for this research is the different aspects of health. Currently, research regarding health is mainly focussed on all-cause mortality and cardiovascular outcome (Saunders et al., 2013). However, physical activity has a different health effect on physical health or mental health (Centers for Disease Control, 2001). Therefore, this research includes physical health, as well as mental health to examine the relationship with active travel. Weight is used as the indicator of physical health and general mental health is used as the indicator for mental health. The relationship between activity and mental health is not well-established, with only weak evidence for the relationship on the population level. The relationship between active travel and overweight is well-established.

The aim of this research is two-folded. The first objective is to contribute to the Dutch transport policy aimed at stimulating active travel for health benefits. The second aim is to contribute to the current knowledge about active travel and health. This is done by answering the main question: *"What is the relationship between active travel and health?"*. This main question is answered by examining the direction of causation between physical activity and active travel, and the direction of causation between active travel, overweight and mental health.

This summary is organized as follows: the next section provides an overview of the current literature. In the third section, the data collection is described and the key variables. This is followed by a description of the modelling approach in section four. The results are discussed in section five. In the last section, the discussions, limitation, contribution and conclusion are discussed.

2. Literature review and conceptual model

To find the current literature regarding the relationship between active travel and health, two methods are used: keyword search and snowballing. The keywords that are used in this research are: *physical activity, active travel, health, overweight, BMI, mental health, cross-lagged panel model and causal relationship*. In the snowballing method, the articles found with the keyword search method are used as a stepping stone to find more articles. By looking through related articles, the less popular articles are found. For the literature search, the following databases were used: Web of Science, Scopus, ScienceDirect and Google Scholar.

In the first hypothesis, it is assumed that people substitute cycling to work for other physical activities. Researches examining the relationship between total physical activity and travel-related physical activity are scarce and show contradicting results (Van Wee et al., 2016). Xu, Wen & Rissel (2013) found increasing evidence that active transport increases physical activity. This would mean that active travel would not substitute for physical activity and would add up to the normal health benefits of physical activity. However, Van Wee et al. (2016) found that spatial setting can impact the amount of transportation, but does not affect the overall physical activity. This would suggest that active travel does indeed substitute for other forms of physical activity.

In the second hypothesis, it is assumed that there exists a bi-directional relationship between active travel and health. The influence of physical activity on overweight is almost common knowledge. Nonetheless, the scientific evidence is not as straightforward and conclusive. Most studies regarding this topic are conducted cross-sectional (Saunders et al., 2013). Currently, the longitudinal researches are mainly focussed on children and have found contradicting results. Ranging from active travel does lower BMI to no significant relationship between active travel and overweight. The knowledge about the relationship between active travel and mental health is quite limited. The researches that do examine the relationship, are conducted by cross-sectional research. In general, a positive relationship between active travel and mental health has been found, but the evidence for the relationship are reviewed as weak (Xu et al, 2013).

Socio-demographic variables are known to influence active travel and are often used as control variables. Therefore, the most important control variables are included in the model. Given the limited resources and time of this research, only age, gender, income, civil status, urban character and level of education are included in the model when possible.

To overcome these knowledge gaps and examine the direction of causation between physical activity and active travel, and the direction of causation between active travel, overweight and mental health, longitudinal data is necessary. This is an effective way to address the time order. In figure 1 the conceptual model that is examined in this research is depicted.

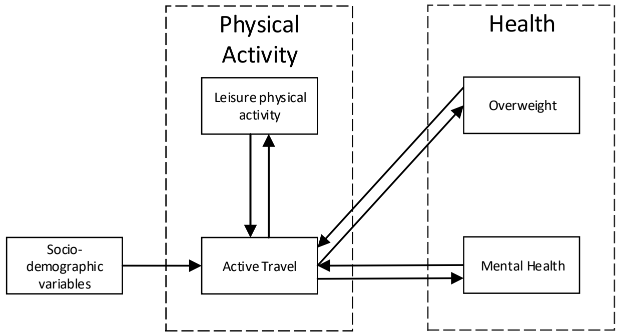

Figure 1 - Conceptual model as examined in this research

3. Data and operationalization

3.1 LISS Data

This research is conducted with Longitudinal Internet Studies for the Social sciences (LISS) Panel data. These surveys for this panel data are conducted by the CentERdata research institute and consists of 4500 households. The data is based on a true probability sample of households drawn from the population register by Statistics Netherlands (CBS). Households complete online questionnaires and are paid for each completed questionnaire. In case a household cannot participate otherwise, CentERdata provides a computer and an internet connection (LISS panel, n.d.).

The LISS Core Study is a longitudinal study and the aim is to be repeated yearly. Included in the Core Study are questions about the background, health and sports habits of the panel members (LISS panel, n.d.). Additional to the core study, two other studies are used for this research. The first is: "Travel behavior, well-being and transport-related attitudes". This additional survey includes questions about active travel behavior of the respondents. The second is: "The weighing project". This project aims to measure the weight of the respondents objectively, by providing the respondents weighing scale that sends the data directly to the researchers.

In this research, almost all the respondents of the travel behavior survey are included. However, 18 respondents are taken out of the dataset for implausible answers. For active travel, the threshold is set at 700 km travelled per week. For BMI, the respondents with a BMI higher than 150 are taken out of the dataset. This resulted in a dataset of 2,214 respondents. In table 1, the socio-demographic variables of the sample are presented. The socio-demographic variables change in the expected direction.

3.2 Variables

Leisure physical activity is any muscular movement that increases energy expenditure, performed during leisure time. To assess the extent to which responders were physically active during their leisure time, the respondents answered the question: "How many hours do you spend on sports per week, on average?". Table 2 depicts the key activity variables.

Table 1 - Key activity variables

Travel variables	Description	2013 (N=2214)	2014 (N= 1285)
		Mean (s.d.)	Mean (s.d.)
Active travel	Total active travel	38.42 (44.11)	39.53 (44.46)
Physical Activity	Amount of hours someone spends on sport	2.08 (3.10)	2.07 (2.98)

Active travel is defined as travelling, either for leisure or transport, while using an active mode such as walking or cycling. Active travel has been assessed by two questions: "How many kilometres do you travel (approximately) in a regular week, using the following modes of transport? – By bicycle" and "How many kilometres do you travel (approximately) in a regular week, using the following modes of transport? – On foot". Combined the answers of the two questions make up for the total amount of active travel a respondent has travelled per week.

Table 2 - Socio-demographic variables

Variable	Description	2012	2013	2014	2015
		Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)
N	Respondents	2196	2214	2151	2051
Age	Average age	49.54 (17.19)	50.41 (17.22)	51.32 (17.11)	52.36 (16.98)
Income	Personal net income per month	1728 (7510)	1792 (8873)	1577 (4459)	1623 (4580)
Gender	Female	53.3 %	53.5 %	53.3 %	53.3 %
	Male	46.7 %	46.5 %	46.7 %	46.7 %
Civil status	Couple	59.7 %	59.2 %	59.7 %	61.0 %
	Single	40.3 %	40.8%	40.3 %	39.0 %
Urban character of place of residence	Extremely urban	11.5 %	11.6 %	11.7 %	11.8 %
	Very urban	25.3 %	25.4 %	25.5 %	25.6 %
	Moderate urban	24.5 %	24.4 %	24.4 %	24.3 %
	Slightly urban	23.0 %	22.9 %	22.6 %	22.2 %
	Not urban	15.8 %	15.6 %	15.8 %	16.0 %
Level of education	Primary school	10.0 %	8.6 %	7.7 %	6.7 %
	Vmbo	23.1 %	23.3 %	23.1 %	22.4 %
	Havo/Vwo	10.9 %	11.3 %	10.8 %	11.2 %
	Mbo	24.4 %	24.6 %	25.2 %	25.9 %
	Hbo	23.4 %	23.6 %	24.2 %	24.4 %
	Wo	8.3 %	8.6 %	9.0 %	9.5 %

Overweight is defined as weighing more than is optimally healthy and is calculated by using the Quetelet's index with the formula: weight/height (kg/m^2). The LISS Core Study includes the questions: "How tall are you in cm?" and "How much do you weigh, without clothes and shoes in kilogram?". Both answers are used to calculate the BMI score. A BMI score below 25 is seen as optimally healthy.

Self-reported measures of height and weight show trends of over-reporting height and under-reporting weight (Xu et al., 2013). This results in a lower estimated BMI. To adjust for this effect, the measurement error is taken into account in the estimated model. The correlation between the self-reported weight from the LISS Core Study and the objectively measured weight of the Weighing Project acts as the reliability measure. Similar to the test-retest method as described by Bollen (1989). The Weighing Project stopped after 2014. No information is available about the reliability of BMI for 2015, therefore, this is set at 0.9. This value is lower than the correlation of the other years. In table 3, the key health variables of 2012, 2013 and 2015 are depicted.

Mental health is used to indicate people with mental health problems or a mental disorder. To assess the general mental health of the respondents, the MHI-5 test is used. This test is the standardized method to measure general mental health in population-based studies. This test does not diagnose specific psychological disorders but tests if someone suffers from any psychological disorder (Driessen, 2011). The test consists of the following questions: 1)"This past month I felt very anxious", 2) "This past month I felt so down that nothing could cheer me up", 3) "This past month I felt calm and peaceful" 4) "This past month I felt depressed and gloomy" and 5) "This past month I felt happy".

For the test, the number in front of the answer indicates the score. The scores range from 0 to 5. For questions 1, 2 and 4 the respondents can choose from: 0 = never, 1 = seldom, 2 = sometimes, 3 = often, 4 = mostly and 5 = continuously. For question 3 and 5 the respondents can choose from: 5 = never, 4 = seldom, 3 = sometimes, 2 = often, 1 = mostly and 0 = continuously. By summing the scores of the questions, a total score between 0 and 25 is calculated. A low total score indicates a low mental health and mental health problems. A score above 15 indicates a good general mental health. To address the measurement error in mental health, the reliability is estimated using Cronbach's Alpha (α) of the 5 MHI questions as described by Bollen (1989).

Table 3 - Key heath variables

Health Variables	Description	2012 (N=2074)	2013 (N=2067)	2015 (N=1841)
		Mean (s.d.)	Mean (s.d.)	Mean (s.d.)
MHI	MHI score (0-25)	18.65 (17.50)	18.87 (16.83)	19.10 (16.17)
MHI reliability	Cronbach's Alpha score	0.859	0.839	0.868
BMI	Body Mass Index	25.76 (8.57)	25.47 (5.12)	25.74 (5.26)
BMI Reliability		0.945	0.913	0.9

4. Modelling approach

To model the relationships, the Cross-Lagged Panel Model (CLPM) and the Random Intercepts – Cross-Lagged Panel Model (RI-CLPM) are used. In general, the CLPM is used to investigate a hypothesis regarding the causal directionality of two or more variables. An example of the CLPM is depicted in figure 2. X1 represents variable X measured at time point 1 and X2 represents the same variable measured at time point 2. The same applies for Y1 and Y2. β2 and β4 are autoregressive paths and represent the stability of a variable over time. A value closer to 1 indicates relative stability within the variable over time. Assuming that the model is corrected for measurement errors in the measured variables, the remaining unexplained variation in endogenous variables X2 and Y2 is regarded as variance from individual changes which have occurred in the period between the two measurements. P1 controls for the initial overlap between X1 and Y1 correcting for the effects of third variables and previous causal influences between both variables. U1 and U2 represent the error terms. These indicate the covariation between variables X2 and Y2 and are associated with variables that are not included in the model. The correlation Pu1u2, therefore, accounts for possible third variables that influenced variables X and Y between the two measurements and possible synchronous effects between X and Y (Kroesen, Molin, & van Wee, 2010).

The most important parameters in this model are the cross-lagged paths: β1 and β3. The standardized parameters represent the causal effect from one variable to the other and try to explain the variance in X2 and Y2, that is not already explained by the stability coefficient (β2 and β4) while controlling for initial overlap (P1), third variables and synchronous causal influences (Pu1u2).

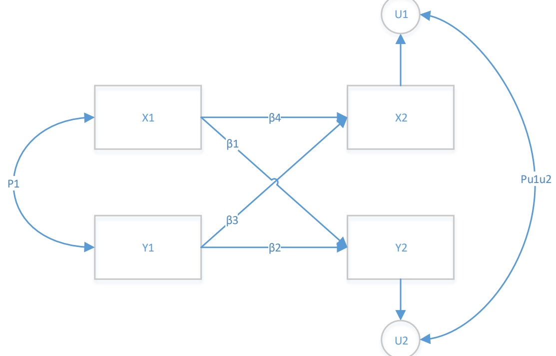

Figure 2 - Example of a Cross-lagged panel model (CLPM).

Comparing the effects of the parameters β1 and β3 can be used to examine the causal predominance and can be interpreted in terms of predicting change. If the cross-lagged effect is significant in one direction but is not significant in the other direction, the results indicate that the causal effect works in one direction but not in the other direction. If none of the cross-lagged effects are significant, then the results indicate no causation in either direction, given the time lag and the sample size of the study. If both cross-lagged effects are significant, the results suggest that the causal effects work in both ways (Newsom, 2015).

The RI-CLPM is a new adaptation of the CLPM, introduced in the article of Hamaker, Kuiper and Grasman (2015). Limited researches have used the RI-CLPM and to the best of the knowledge of the author, this will be the first research using the RI-CLPM to examine the relationship between BMI and MHI.

Increasing concerns are expressed regarding the use and interpretation of the CLPM. Their criticism is mainly aimed at the fact that CLPM does not allow to examine the within-person change, but only examines the between-person difference. In the CLPM, the differences are only examined at the population level. However, it is possible that these differences are not necessarily true at the individual level (Hamaker et al., 2015). To address this problem, Hamaker et al. (2015) introduced the RI-CLPM. In the RI-CLPM, the variance at the within-level is distinguished from the variance at the between-level. By including a random intercept, this model can control for time-invariant trait-like individual differences (between-person effect). The random intercept takes out the between-person variance such that the lagged relationship in the RI-CLPM applies to the within-person effect (Hamaker et al., 2015).

To estimate the CLPM the method of Maximum Likelihood is used. This is the default method in most Structural Equation Modeling (SEM) computer programs. In Maximum

Likelihood, the estimates are the ones that maximize the likelihood that the data is drawn from the population (Kline, 2010). The CLPM is estimated using AMOS version 25. In AMOS Graphics, the user can specify the model by drawing the model on the screen. SPSS version 25 is used to conduct the descriptive and correlational analysis.

5. Results

The first hypothesis suggests that active travel has a negative influence on physical activity over time. Contrary to the hypothesized effect, the correlations indicate a positive relationship between active travel and leisure physical activity. In the estimated model, the model fit of the CLPM could not be established. The CLPM estimations indicate significant autoregressive parameters and positive cross-lagged parameter between active travel and physical activity. Similar results are found in the model with the control variables. This indicates that people who travel with an active mode conduct more leisure physical activities over time. Additionally, the findings indicate a bi-directional influence between active travel and physical activity. People who practice more sports also travel more with an active mode.

Table 4 - Standardized estimates of the CLPM

	Active travel 2014	Physical activity 2014
Active travel 2013	0.613***	0.067***
Leisure physical activity 2013	0.077**	0.737***

*** Effect is significant at the 0.001 level.
** Effect is significant at the 0.01 level.

The second hypothesis suggests that there exists a bi-directional relationship between active travel and health. The correlational analysis revealed a highly significant correlation between the same variables over the years, indicating a high stability of the variables over the years for active travel, BMI and MHI. The correlation between active travel 2013 and MHI 2012 and MHI 2013 is also significant. Indicating a possible positive relation between active travel and MHI. The other correlations are not significant, indicating no relationship between active travel and BMI. The CLPM and the RI-CLPM both fit the data, the model fit indicators are depicted in table 5. In the CLPM, the autoregressive parameters are significant, indicating stability within the variables. However, no effect was found between active travel and BMI or MHI. The same results were found in the RI-CLPM, when taking into account the within-level variance from the between-level variance for the health indicators.

6. Discussions and conclusion

6.1 Discussions

The relationship between active travel and BMI is well-established. Therefore, the findings can give an important indication that a fundamental problem is encountered in this research. In this case, we expect that an important reason for these findings is the short time lag of only 1 and 2 years. This idea is supported by the high stability of BMI that is found in this research.

Table 5 – Standardized estimates of the CLPM

	AT 2014	BMI 2013	BMI 2015	MHI 2013	MHI 2015
AT 2013	0.631 ***	0.003	0.017	0.014	0.012
BMI 2012		0.986 ***		0.006	
BMI 2013	-0.012		0.993 ***		-0.013
MHI 2012		-0.008		0.776 ***	
MHI 2013	-0.003		0.014		0.778 ***
	Chi-square: 71.676, df:6, P:0.000, RMSEA: 0.070, CFI: 0.993				

The relationship between active travel and mental health is less well-established. Therefore, we can say with less certainty that the relationship between active travel and mental health does exist. A possible explanation for these findings can be found in the time-lag. However, for mental health, the time lag is expected to be too long. Another possibility is that a possible ceiling effect has been found, i.e. that active travel only influences people with a low mental health. In the dataset used, the mental health on average was quite high.

6.2 Limitations and future directions

The limitations of this research can be divided into two categories. The first limitations are linked to the method used. It is possible that third unobserved variables influence both variables. A biological factor, such as genes could explain the increase in active travel and physical activity. Another limitation is the usage of the CLPM over the RI-CLPM, even though this research has proven that the RI-CLPM can be fruitful and can find different results than the CLPM. Therefore, we recommend in the future to include other third variables and estimate the relationships using the RI-CLPM. To conduct the RI-CLPM three waves of data are necessary.

The other category of limitations is based on the LISS data. There is no clear distinction between active travel and leisure physical activity. This results in a possible overlap in the dataset. In future research, we recommend making the distinction between active travel and physical activity as clear as possible. Furthermore, LISS data relies on self-reported data. For BMI this could lead to overestimations because people tend to describe themselves as healthier than they actually are. Therefore, we suggest the use of objectively measured weight and height. Mental health is difficult to measure objectively, therefore, we suggest to measure individual mental health disorders. For active travel, automatic tracking systems, such as GPS and accelerometers, could help increase the reliability of the measures.

For physical activity, it is important to include how many hours a respondent spends per sport. This way the Metabolic

Equivalent Task (MET) score can be calculated. MET score has the benefit of taking into account the intensity of a specific sport. As the health outcome is depending on intensity, the usage of MET-hours per week could be a feasible option to examine the effect of intensity on active travel.

The last recommendation is to study the impact of more socio-economic and demographic variables on travel behaviour and health. In this research, only a small amount of socio-demographic variables is examined. Health-related attitudes and self-selection processes related to travel behaviour can be an important topic to examine in future research.

6.3 Contribution

Despite the mentioned limitations, we believe that this study provides a significant contribution to the field for active travel and health. As the majority of the literature investigates the relationship cross-sectional, this research adds stronger evidence for causality, because of the longitudinal nature of this study. Therefore, we now know that the time-lag of 4 months and 16 months, is not long enough to examine overweight and not short enough to examine mental health. Within the knowledge of the writer, this is one of the first researches that examines the substitution effect between active travel and another form of physical activity with longitudinal data. The additional effect from active travel on other forms of physical activity and even the bi-directional effect are promising for policy to stimulate active travel. The last contribution of this research is regarding the RI-CLPM. The RI-CLPM is applied between health variables and the results have shown that the results of the RI-CLPM can differ from the CLPM.

These new insights also have practical implications. These implications are mainly focussed on changes in the current Cost-Benefit values by Decisio. Currently, the estimations that are used in a Cost-Benefit analysis are based on the current knowledge about active travel. This research provides new insights into the relationship between active travel and health. In general, we can state that the health benefits in the report of Decisio are underestimated. Mainly because the stimulating effect between active travel and physical activity is not taken into account and because some values are corrected for a substitution effect. This research found evidence to believe that not only the substitution effect does not take place, but the effect is even found to be additional. Therefore, we would argue that the health benefits should be changed in a second version of the Decisio report or a similar report used to estimate the cost and benefits of active travel related policy. On the other hand, an increase in active travel will lead to some negative effects on health. However, overall the health benefits of active travel outweigh the negative effects on health (De Hartog, Boogaard, Nijland & Hoek, 2010).

6.4 Conclusion

Overall, the findings of this study provide support for stimulating active travel policy that is aimed at increasing the health of the population. The positive influence of active travel on other forms of physical activity is encouraging. It implies that the stimulation of active travel will lead to more total physical activity and that physical activity will lead to more active travel. Taken into account that physical inactivity, in itself, is linked to various health outcomes, this is an important argument to stimulate active travel policy. Combined with other non-health related benefits, active travel can be seen as an important transport policy goal.

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