Who commutes by bicycle all year round? Analysis of influencing factors based on a survey incorporating weather sensitivity

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SHORT SUMMARY

Using survey data from Germany, we investigate how people incorporate weather into their mobility decisions and combine this with questions towards weather sensitivity. We compare people who primarily use bicycles to commute to work in summer but another mode of transportation in winter, and people who report bicycles as their primary mode of transportation in both seasons. We find that the respondents' self-assessment matches the reported behavior. People who describe themselves as cold-sensitive change their mode of transportation in winter, whereas insensitive people do not. Furthermore, a longer commuting trip correlates with not using the bicycle for commuting in winter. Finally, having a car contributes to being in this group as well. People who switch to another mode in winter mainly switch to a motorized mode (public transport or car). These findings contribute to understanding usage patterns of the bicycle, which is a key element in many current transport policies.

Keywords: travel behavior, survey, weather, mode choice

1. INTRODUCTION

Many studies have already investigated the influence of weather and the seasons on travel behavior, especially mode choice. Data and methods used in these studies mostly analyze travel diaries, traffic or passenger count data, or revealed preference data. Building on that, we conducted a survey in Germany to investigate explicitly how people incorporate weather in their mobility decisions, especially for commuting trips. This paper analyses commuting trips by bicycle in different seasons and how peoples' assessment of their individual sensitivity to weather conditions influences their mode choice throughout the year.

It is well known that weather influences individuals' mode choice, especially regarding the use of the bicycle, which is the most weather-sensitive mode as found by various studies (Liu et al., 2015; Miranda-Moreno and Nosal, 2011; Rudloff et al., 2015). Böcker et al. describe warm and dry weather as the optimal weather condition for cycling, resulting in variations throughout the year (Böcker et al., 2016). Cyclists exhibit distinct patterns in response to varying weather conditions, often leading to the use of motorized means of transportation under adverse weather conditions like low temperatures or precipitation (Sabir, 2011). This is underlined by qualitative research, indicating that cyclists, who state that weather is often or always influential to them, are more likely to switch to a motorized means of transport (Barr et al., 2022). Faber et al. identified the alternating use of car and bicycle as a typical "modality style", switching between these modes depending on the weather (Faber et al., 2022).

Apart from the weather conditions, individual sensitivity and personal attitudes towards cycling strongly impact the reaction towards the weather. On the one hand, the individual's environment plays a role. When the weather conditions are typical for the place of residence, people show the smallest changes in travel behavior (Liu et al., 2015). Furthermore, weather is less influential when the bicycle is an established means of transportation in the personal environment (Böcker et al., 2019). On the other hand, the identification as being a "cyclist" reduces the sensitivity to weather as well, as shown by Nordbakke and Olsen (2019). Also, the regular use of the bicycle for a certain trip purpose can reduce sensitivity. While people who cycle frequently do not change their behavior under adverse weather, people who use it on a less frequent base are more likely to do so (Heinen et al., 2011). In general, commuting trips, like investigated in this study, are less influenced by weather than leisure trips (Cools et al., 2010; Helbich et al., 2014). However, this trip purpose can be easiest to compare between respondents and allows to examine changes in routines.

While most of the studies use travel diaries or counting data, which deliver implicit relations between weather and behavior, in the survey of the present study the respondents were asked explicitly how they incorporate weather in their mobility and mode choice. After a short overview of how the survey was conducted, results for weather sensitivity, consumption of weather information and sociodemographic factors will be analyzed, regarding if someone commutes by bicycle in winter and if this is done in summer.

2. DATA & METHODOLOGY

This study uses data from a survey conducted in Germany in 2023. The survey content was based on findings from the literature concerning mode choice, seasonality of travel behavior, as well as own analyses from German national household travel surveys.

A sample of about 2,000 persons was recruited through an online access panel and additional 500 people were recruited through social media and newsletters, leading to an overall sample of about 2,500 people.

The survey's main objective was to gather deeper insights into how people include weather conditions and information into their mode choice of everyday mobility. We focused on commuting trips, which we defined as trips to the workplace, university, or school. At the beginning, the respondents were asked about their personal sensitivity to certain weather conditions, followed by questions about their mobility tools and their typical mobility behavior. After that, questions about the commuting trip were posed, such as distance, the regular mode of transportation used in each season and the possibility and experiences to arrive at the workplace with other modes. People with a regular route to a workplace were furthermore asked about their flexibility concerning arriving late or early and other characteristics. The people who stated to have used more than one transport mode on their commuting trip in the past then had to complete a stated choice experiment. Finally, respondents were asked for general sociodemographic information. Due to different filter criteria, the survey had paths of different lengths. For the longest path, the survey took between 15 and 20 minutes.

The final sample contains 2,430 completes, divided into:

- 1,415 people having used at least two different modes on their commuting trip
- 289 people that have never used another mode on their commuting trip
- 228 people without a fixed commuting trip
- 498 people without a job (retired, unemployed, etc.)

In this paper, we focus on two specific groups: people who use the bicycle as their main means of transport for commuting in summer and winter (n=147, named "*non-changers*") and people who use it in summer as their main mode for commuting, but use a different means of transport as main mode in winter (n=271, named "*changers*"). While e-bikes and regular bicycles were

asked for separately in the survey, we do not differentiate between these in this analysis – e-bikes are always included in the group of bicycles in the rest of this paper. All respondents in these groups stated that they used a different mode for the same trip in the past, therefore they would have an alternative to commuting by bicycle. It needs to be mentioned that the respondents who participated in the survey without profit (i.e., those who do not originate from the online access panel) have a much higher affinity towards bicycle and use it more often in adverse conditions.
In addition to descriptive analyses, statistical tests were performed to show whether the results are significant. All analyses refer to categorical or nominal variables, so the chi-square independence test was used. The test results show if the characteristics of both variables are dependent on each other and present the p-value, which is commonly used to verify significance. Based on this, Cramers V was tested to depict the effect strength of an observed significance. The value lies between 0 and 1. Values above 0.1 suggest a slight effect, above 0.3 a moderate effect and values above 0.5 a strong effect (McHugh, 2013).

3. RESULTS AND DISCUSSION

In the survey, the respondents were asked about their main means of transport for their commuting trip in each season, leading to the results depicted in Figure 1. A strong impact of the seasons can be seen. While the share of the bicycle as main means of transport is 28.1% in summer, it drops to 19.2% in fall and 11.9% in winter. At the same time, car as driver and public transport show opposite trends, having their lowest shares in summer and highest in winter. This does not only confirm the expectation of motorized, more protected modes being preferred in adverse weather conditions but also shows that people are aware of their preferred mode choice in different seasons. Due to the clear shift from bicycle to motorized means of transport from summer to other seasons, this aspect will be examined in more detail in the following analyses.

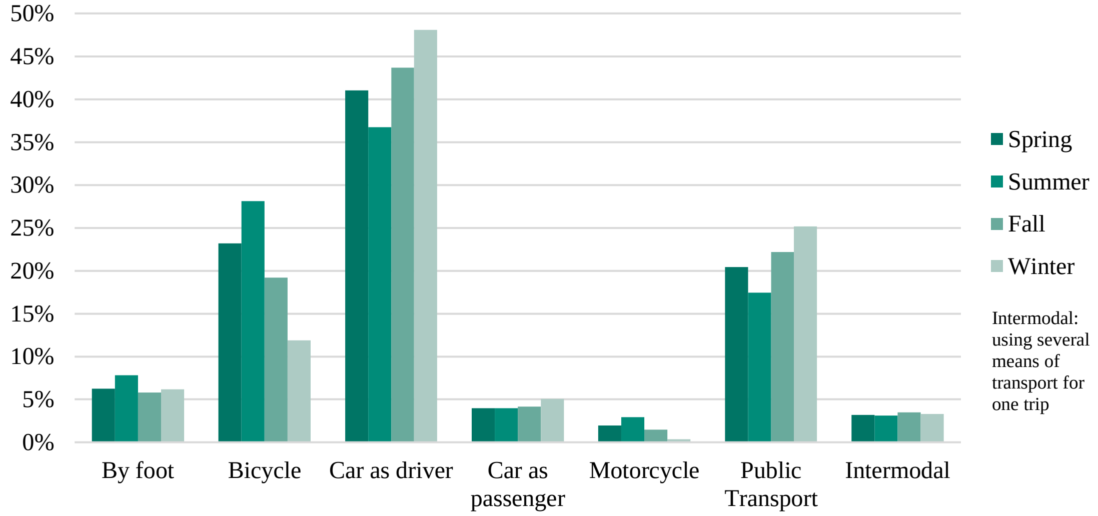

Figure 1 Main means of transport for commuting trip by season, n=1,704 respondents

Commuting in winter – to cycle or not to cycle

The following analysis focuses on the two groups defined in Section 2: "*changers*", i.e., people that use a bicycle as main mode for commuting in summer but not in winter, and "*non-changers*", i.e., people that use a bicycle in both summer and winter.
Table 1 shows how the respondents in these groups assess their personal sensitivity to low temperatures, high temperatures and rain. It is apparent that the *non-changers* are far less sensitive to low temperatures than the *changers*. While the effect strength is not strong (value of 0.17), the sensitivity to cold is significantly connected to the preferred mode of transportation in winter. In contrast, the sensitivity to high temperatures is not significantly different between these groups. For rain, significance is given, but the effect size is smaller than for low temperatures. This indicates that people who do not use their bicycle for commuting in winter experience stronger discomfort under adverse weather conditions, which occur more frequently in this season.

Table 1 Self-assessment of sensitivity to weather conditions

	Non-changers n=146	***Changers*** n=271	***Significance***
Sensitivity to cold			
insensitive	9.6 %	5.5 %	X^2: 13,396
rather insensitive	50.7 %	36.6 %	df: 3
rather sensitive	26.0 %	39.7 %	p-value: < 0,05
sensitive	13.7 %	18.2 %	Cramer's V: 0,174
Sensitivity to heat			
insensitive	9.6 %	10.3 %	X^2: 2,49
rather insensitive	37.7 %	44.9 %	df: 3
rather sensitive	43.2 %	36.0 %	p-value: 0,47
sensitive	9.6 %	8.9 %	Cramer's V: 0,07
Sensitivity to rain			
insensitive	18.5 %	18.5 %	X^2: 8,79
rather insensitive	54.8 %	42.1 %	df: 3
rather sensitive	21.9 %	34.2 %	p-value: < 0.05
sensitive	4.8 %	5.4 %	Cramer's V: 0,14

The factors that show the largest effect sizes are, how much weather influences the respondent's mobility in general and how strongly low temperatures affect it. The results of that analysis are displayed in Table 2.
The relation between being in the groups *changers* or *non-changers* and the overall influence of the weather is significant and show an effect size of 0.5. This, again, implies that people who change from bicycle to another means of transport in winter are aware of the fact that weather plays an important role in their everyday mobility. About 70 % of the *non-changers* state that weather does not or only slightly influence their mobility, while it is only about 22 % for the *changers*. For low temperatures, the same tendencies can be observed in the data. With a value of 0.46, the effect size is again close to a strong effect. While the shares of people who are not at all or only rarely influenced by low temperatures are similar in both groups, they show opposite trends for moderate and strong influence. Only 19 % of the *non-changers* describe themselves as strongly influenced by low temperatures, whereas, for the *changers*, it is 32 %.
As weather and seasonality seem to influence mode choice on the commuting trips, respondents were also asked how often they inform themselves about weather regarding their mobility. Again, a significant dependence on group affiliation can be observed. While the effect size is 0.23, indicating a slight effect, the shares show substantial differences between both groups. About 52.3 % of the *changers* say they use information on weather often, while it is only 37.7 % of the *non-changers*. This leads to the assumption that people who do not regularly change their means of transport care less about weather conditions, maybe because they are less relevant to their choices.

It is questionable if the sensitivity to cold leads to switching from bicycle to another means of transport or if the permanent use of the bicycle makes people less sensitive to weather; i.e., the causal relation is not clear. Still, we observe that these aspects are interrelated.

Table 2 Influence of weather, low temperatures and information on respondent's mobility and group affiliation

	Non-changers n=146	***Changers*** n=271	***Significance***
Influence of weather on mobility in general			
strong	4.1 %	28.4 %	X²: 108,8
moderate	26.7 %	50.0 %	df: 3
little	54.8 %	20.2 %	p-value: < 0,05
not at all	14.4 %	1.4 %	Cramer's V: 0,5
Influence of cold on mobility in general			
strong	18.5 %	31.5 %	X²: 90.941
moderate	54.8 %	43.5 %	df: 4
little	22.0 %	18.8 %	p-value: < 0.05
not at all	4.8 %	4.8 %	Cramer's V: 0.46
Information on weather			
strong	37.7 %	52.3 %	X²: 22.773
moderate	37.7 %	39.2 %	df: 2
little	20.5 %	5.8 %	p-value: < 0.05
not at all	4.1 %	2.8 %	Cramer's V: 0.23

Trip length to work

As another influencing factor, the trip length to the workplace was identified. Since all respondents used their bicycle in summer, it can be assumed that they generally assess their commuting trip as feasible by bike. Nevertheless, the trip length shows moderate effect sizes regarding group affiliation and length. Table 3 shows the shares and statistical parameters. While about 67 % of the non-changers have a trip to work that is less than 5 km long, it is only 33 % of the *changers*. At the same time, most of the *changers* (31 %) have a work trip longer than 15 km. This adds another dimension to the topic, indicating that the duration of the trip has influence on whether people use their bicycle or not. It may therefore not only be important how sensitive someone is to temperatures or adverse weather, but also how long they are exposed to it.

Table 3 Distribution of trip lengths for the commuting trip

	Non-changers n=146	***Changers*** n=271	***Significance***
Trip length to work [km]			
< 2	17.1 %	9.9 %	X²: 34,432
2 - 5	40.4 %	22.9 %	df: 4
5 - 10	24.0 %	24.0 %	p-value: < 0,05
10 - 15	8.2 %	12.3 %	Cramer's V: 0,281
> 15	10.3 %	30.8 %	

Sociodemographic factors

In addition to the length of the commuting trip and the respondents' sensitivities, sociodemographic factors and mobility tools were considered. For gender, transit pass and the type of employment, no significant results were found. Table 4 shows the results for the statistically significant factors age and car availability. For age, the effect is 0.20, and for car availability, it is 0.26. It is striking that the *changers* have a share of 50 % under 29 years old, while for *non-changers*, it is only 32 %. This indicates that younger people tend to change their means of transport throughout the seasons, whereas people over 29 years have a higher consistency in their mode choice. This could be caused by younger people being more flexible or having less routine on their commuting trip, while older people do so.
For car availability, a binary variable was used, indicating "yes" if the respondent always has a car available and "no" when it is only available through agreements in his household or with friends or not at all. It is noticeable that respondents who have a car available, are more likely to switch their main means of transport from bicycle to another one in winter, potentially the car. This aligns with the literature identifying the typical pattern of the switch between car and bicycle under different weather conditions.

Table 4 Car availability and age

	Non-changers n=146	***Changers*** n=271	***Significance***
Car availability			X^2: 29.147
yes	32.5 %	58.2 %	df: 2
no	67.5 %	14.7 %	p-value: < 0.05
			Cramer's V: 0.26
Age			
< 29 years	32.2 %	49.7 %	X^2: 17.15
30 - 39 years	22.0 %	20.2 %	df: 4
40 - 49 years	22.6 %	11.0 %	p-value: < 0.05
50 - 59 years	17.1 %	14.0 %	Cramer's V: 0.20
> 60 years	6.2 %	5.1 %	

4. CONCLUSIONS

This paper has shown that significant relations exist between whether someone commutes by bicycle in winter and their general sensitivity to weather, low temperatures, and the consumption of information on weather. In addition, aspects like the trip length to work, age and car availability play a role. It becomes clear that people change their main means of transportation for commuting throughout the year, mainly from bicycle to motorized means like car and public transport. These findings therefore contribute to understanding usage patterns of the bicycle, which is a key element in many current transport policies in the face of climate change.
Even though statistical significance could be demonstrated, deeper analysis could help to understand the correlations between these aspects, e.g., by using multinominal models and considering more factors than presented in this paper. It would be useful to incorporate weather in future surveys, not only because the climate is changing, but also to improve knowledge about people's decision-making process concerning ambient factors.

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