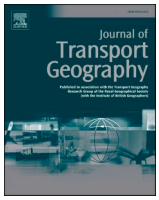
Journal of Transport Geography 101 (2022) 103351

Contents lists available at ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrangeo



Transport poverty meets car dependency: A GPS tracking study of socially disadvantaged groups in European rural peripheries

Christoph van Dülmen [a,*], Martin Šimon [b], Andreas Klärner [a]

[a] Thünen Institute of Rural Studies, Bundesallee 64, 38118 Braunschweig, Germany
[b] Institute of Sociology of the Czech Academy of Sciences, Jilská 1, 110 00 Praha 1, Czechia

ARTICLE INFO

Keywords:
Transport poverty
Social disadvantage
Social exclusion
Rural areas
Activity spaces
GPS tracking

ABSTRACT

This article explores the spatial mobility of disadvantaged populations in order to enhance our understanding of transport poverty. It is based on participatory GPS tracking data collected in peripheral rural regions in Czechia and Germany. The data provide information on the two-week mobility of 61 socially disadvantaged study participants belonging to the following groups: (a) the lone elderly, (b) the labor market disadvantaged, and (c) single parents. The quantitative analysis utilizes group comparisons of activity space metrics. The results show that the mobility of disadvantaged people varied little between countries and regions, which indicates that individual social disadvantage mattered more than regional spatial disadvantage. Daily mobility depended on individual mobility strategies, and on people's embeddedness in social networks. The mobility patterns of socially disadvantaged groups differed, and showed considerable within-group variability. Our analysis finds that the effects of car access depended on the respondents' levels of social disadvantage; and that a car was not a merely a transport variable, but a socially conditioned variable. Understanding how automobility in rural peripheries is mediated by social ties, and how it can both enable and constrain chances for social participation, is essential for developing measures aimed at reducing transport poverty.

1. Introduction

In our modern societies, mobility is a prerequisite for social participation in civic and economic life. An individual realizes their capabilities by actually being mobile (Vecchio and Martens, 2021). Mobility can generate possibilities for learning about new opportunities that can improve an individual's life situation. Insufficient mobility can lead to social exclusion (Lucas, 2011; Social Exclusion Unit, 2003), and involuntary mobility restrictions can even be considered a violation of fundamental human rights (Cresswell, 2006). Kenyon et al. (2002) defined mobility-related exclusion as the *process by which people are negatively affected in their social participation by reduced access to opportunities, services, and social networks due to insufficient mobility*. Hence, mobility has become an issue in social policy-making. Modern welfare states try to ensure that different means of transport are available and accessible to the public, and thus to reduce mobility barriers for their citizens (Donaghy et al., 2005; Lucas, 2006; Pyrialakou et al., 2016; Vitale Brovarone, 2021).

Social inclusion is ensured primarily through access to opportunity structures in physical space; i.e., in places that affect an individual's socioeconomic conditions (Galster and Sharkey, 2017). A mobility burden can occur if these places of opportunity are located far from each other (Cass et al., 2005). Rural areas are usually characterized by low population density and sparse public transport infrastructure (Milbourne and Kitchen, 2014; Osti, 2010). This is even more the case for rural peripheries, a subgroup of rural areas that are located far away from administrative centers and places where people can access the goods and services they require to meet their daily needs (Kühn, 2015). Thus, rural peripheries are spatially disadvantaged in multiple ways; not only in an urban-rural comparison, but also in a rural-rural comparison. This implies that all inhabitants of rural peripheries have an especially large mobility burden (Cass et al., 2005; ESPON, 2017; Pérez-Soba et al., 2012). Increased mobility demands within a society lead to mobility-related disadvantages among populations with lower mobility, as well among populations in areas with increased mobility requirements, such as rural peripheries.

Previous research has shown that socially disadvantaged groups often face challenges in meeting their daily mobility needs, as they do not have the same access to goods, services, and opportunities for social participation as the majority population (Maffii and Bosetti, 2021). The

* Corresponding author.
E-mail addresses: christoph.vanduelmen@thuenen.de (C. van Dülmen), martin.simon@soc.cas.cz (M. Šimon), andreas.klaerner@thuenen.de (A. Klärner).

https://doi.org/10.1016/j.jtrangeo.2022.103351
Received 3 December 2021; Received in revised form 14 March 2022; Accepted 16 April 2022

factors that contribute to social and spatial disadvantages are mutually dependent (Luz and Portugal, 2021; Schwanen et al., 2015), and can lead to multiple disadvantages for people living in rural peripheries (Binder and Matern, 2020). As has been demonstrated for peripheral urban areas, an individual's place of residence can contribute to a compounding effect of social exclusion for socially disadvantaged groups if public transport is sparse and/or expensive (Hernandez, 2018; Oviedo Hernandez and Titheridge, 2016). This interplay of social disadvantage and transport disadvantage (e.g., living in areas with high car dependency) has been conceptualized as *transport poverty* (Lucas, 2012; Lucas et al., 2016). Transport poverty can, in turn, contribute to the multidimensional phenomenon of social exclusion (Kenyon et al., 2002; Yigitcanlar et al., 2019).

The question of how the prevalence of transport poverty translates into actual mobility for different groups in different contexts is not well researched. Hence, detailed comparative descriptions of the mobility of socially disadvantaged groups in the same spatial setting are important, as they can provide an empirical basis for the development of public policy measures (Pyrialakou et al., 2016). On the one hand, it can be hypothesized that socially disadvantaged people in rural peripheries travel a lot because they must cover long distances to get to places where they can meet their daily needs. On the other hand, it can also be assumed that these people travel relatively little, since long-distance mobility is expensive in these areas, and public transport is sparse.

Against the background of these contrasting manifestations of *rural transport poverty*, the aim of this paper is to examine the effects of spatial and social disadvantages on people's realized daily mobility, with a focus on the car's role in it. We therefore compare the daily mobility of disadvantaged persons (the lone elderly, the labor market disadvantaged, single parents) (1) between countries and regions, and (2) between and within groups. This direct comparison is valuable, as conventional surveys have faced difficulties in reaching socially disadvantaged populations (Lucas et al., 2018). Furthermore, to better understand the role of the car in rural transport poverty, we ask whether (3) having a car increases people's daily mobility and (4) leads them to visit more places, and thus provides them with more opportunities for social participation. Thus, we explicitly address access to a car while living in a car-dependent area as one dimension of transport disadvantage (Lucas et al., 2016; Mattioli et al., 2019), and examine how it intersects with various forms of social disadvantage. Although the car plays a central role in rural life (Berg and Ihlström, 2019; ESPON et al., 2015; Kamruzzaman and Hine, 2011), its social conditionality is rarely considered.

2. A community of fate: Transport poverty, automobility, and social disadvantage

Transport poverty stems from the interplay of transport disadvantage and social disadvantage, which can lead to the social exclusion of transport-poor populations (Lucas, 2012). Both dimensions are shaped by structural and individual factors that have been identified by previous research (Yigitcanlar et al., 2019); the factors that are relevant to our study are outlined below.

2.1. Transport disadvantage in rural peripheries

The first dimension, transport disadvantage, contributes to the deterioration of living conditions in rural areas, and increases the risk of depopulation in these places (Camarero and Oliva, 2019; Osti, 2010). One approach that is often used for assessing rural transport disadvantage is spatial accessibility modeling. Research conducted from this perspective compares the macro-structural characteristics of different regions to assess the general provision of services and infrastructure (e.g., ESPON et al., 2015). Using this approach, Kaufman (1998) has shown that poor households in rural areas face difficulties in accessing larger retailers, and tend to rely on small and expensive local grocery stores. Hence, poor rural households have to deal with either higher food prices or higher transport costs (Neumeier, 2015). Thus, the ongoing thinning out of services is not only a fundamental characteristic of rural transformation, but a factor that influences the rural transport disadvantage more generally (Lang, 2012).

Accessibility analyses allow for a spatial differentiation on a macro level, and their outputs are commonly presented for aggregated spatial units. However, the general reachability of places that provide support and services does not necessarily reflect the extent to which individuals make use of them. Without an assessment of the actual use of the available mobility options and the potentially accessible places, such analyses can only shed light on one side of the phenomenon of rural transport poverty (Vecchio and Martens, 2021). By comparing conventional "objective" indicators of accessibility with an individual's own modal options as well as their "subjective" perceptions, Ryan and Pereira (2021) showed how these "objective" measures often overestimate accessibility levels, and underestimate accessibility inequalities. They pointed out the importance of considering heterogeneity in individual characteristics when evaluating accessibility levels. We argue that global ascriptions of accessibility values to certain regions only consider some of the factors that may influence daily mobility, especially of socially disadvantaged persons. A comprehensive analysis of rural transport poverty needs to address regional contextual factors, individual characteristics, and actual mobility in relation to each other.

2.2. The car's mediating role in transport poverty

In rural areas, car access is crucial for personal mobility, and for an individual's ability to participate in activities of daily life (Camarero and Oliva, 2019; Kamruzzaman et al., 2016). Macro-level studies on transport have highlighted the car's role in mobility in rural areas. According to large-scale transport surveys, the car is the main mode of transport (either as the driver or as the passenger) in rural areas. In Germany, the share of trips done by car is 62% in small cities and rural areas, but is only around 33% to 44% in metropolitan areas and big cities (MiT, 2017, own calculations). In Czechia, the share of trips done by car is 43% to 55% in rural areas and small towns, compared to 27% to 33% in larger cities (Česko v pohybu, 2019, own calculations).

Poor public transport provision is one of the main reasons for the large differences in modal splits between urban and rural areas (ESPON et al., 2015). The lack of coordination between mass transit and other basic services, as well as less frequent transit services, make traveling by public transport an arduous or even impossible task for many residents of rural areas, which leads to high levels of car dependency (Berg and Ihlström, 2019).

However, in rural peripheries, owning a car is not just a means of transport, as it also has strong social and economic interconnections that affect the practical accessibility of transport and its social costs. The economic link is indicated by the phenomenon of *forced car ownership,* whereby even households with limited financial resources need to own a car (Mattioli, 2017). In these cases, a car represents a major financial burden. Hence, car ownership is also a source of economic vulnerability and dependency due to factors such as rising fuel prices (Mattioli et al., 2019).

The social interconnections of car ownership become apparent when we consider the transport options of socially disadvantaged groups, such as the elderly, who depend heavily on drivers in their social networks (Ranković Plazinić and Jović, 2018). Hence, access to a car is often mediated by social ties (Cass et al., 2005). These findings suggest that car access should not be viewed solely as a transport variable (as was done in Lucas, 2012), but also as a socially conditioned variable. We therefore argue that understanding car access is pivotal when exploring the concept of transport poverty in rural areas, as it links the two dimensions of transport disadvantage and social disadvantage.

2.3. Relationships between social disadvantage and transport in rural peripheries

Research on social disadvantage in rural areas focuses on vulnerable population groups, such as the elderly; poor or single households; and people with health, economic, and/or social issues. These studies tend to identify the spatial imprints of social inequalities in limited or constrained spatial mobility among socially disadvantaged groups (Milbourne and Kitchen, 2014).

These studies often spotlight the elderly as a disadvantaged group (Graham et al., 2018; Nordbakke and Schwanen, 2013; Shergold and Parkhurst, 2012). Having poor access to health care services and higher transport costs can have detrimental effects on the health care practices of elderly people in rural areas (Goins et al., 2005). In a study on the mobility of elderly people in rural Serbia, Ranković Plazinić and Jović (2018) showed that in settlements with good access to basic facilities, the respondents' mobility is higher, their trip distances are shorter, and they make fewer car trips. The importance of the mode of transport was emphasized by Ahern and Hine (2012), who found that the availability of a car is central for older people in rural areas. Elderly people living alone face challenges in their everyday lives, especially when they reach higher ages, as the probability of becoming a non-driver increases with age (Ross et al., 2009). In particular, older women at risk of poverty tend to cover less distance and make fewer trips outside of their neighborhood (Giesel and Köhler, 2015).

Factors associated with economic disadvantage, such as unemployment and low income, play a prominent role in the phenomenon of transport poverty, and have been repeatedly identified as the most important indicators for transport-related social exclusion (Currie et al., 2010; Yigitcanlar et al., 2019). Hine et al. (2012) found that because lower-income individuals are less likely to own a car, they not only engage in fewer recreational activities, they are also unable to make longer-distance work trips. Thus, having financial constraints, especially when living in a remote area, reduces people's access to jobs, and, in turn, to opportunities to earn income.

Single parents have been repeatedly studied as a socially disadvantaged group (Gornick, 2018; Nieuwenhuis and Maldonado, 2018; Struffolino and Bernardi, 2017), but they are rarely the focus of transport poverty research. An exception is McQuoid and Dijst (2012), who demonstrated that the spatiotemporal day-to-day arrangements of single mothers depend to a large extent on the geographic location of social services. They also found that the resulting constraints affect how single mothers organize their lives, especially if they have limited financial resources; and that single parents must put considerable effort into planning their family's daily mobility to rationalize trip chains, as well as the number of trips and places visited (also Rogalsky, 2010). However, these studies focused on single parents in urban metropolitan regions, while the daily mobility of single parents in rural areas remains understudied.

3. Methods and data

3.1. Study design and sample characteristics

For this research, the 14-day activity spaces of 61 respondents were recorded via GPS tracking in 2019 and 2020 (see Table 1 for sample characteristics). Data were drawn from the larger international research project *Social Disadvantage in Rural Peripheries in Eastern Germany and the Czech Republic* Keim-Klärner et al., 2021. As spatial study contexts, we selected four regions in two neighboring countries to explore the possible effects of structural differences on the national level (such as demographic structure, gross national product, welfare state regimes) and the regional level (such as population density, transport provision) on daily mobility. All participants were living in rural peripheral regions (Bor and Jeseníky in Czechia, and Mansfeld-Südharz and Vorpommern-Greifswald in eastern Germany), which were selected due to their poor services and transport accessibility (ESPON, 2017; Küpper, 2016; Tagai et al., 2019).

Table 1
Sample characteristics.

	Lone elderly (N = 17)	Labor market disadvantaged (N = 22)	Single parents (N = 22)	Overall (N = 61)
Gender				
Female	14 (82%)	13 (59%)	20 (91%)	47 (77%)
Male	3 (18%)	9 (41%)	2 (9%)	14 (23%)
Age				
Mean (SD)	73.9 (7.22)	48.0 (11.3)	40.0 (9.16)	52.3 (16.8)
Median [Min, Max]	70.0 [63.0, 89.0]	49.5 [21.0, 63.0]	38.0 [19.0, 66.0]	49.0 [19.0, 89.0]
Country				
Czechia	9 (53%)	10 (45%)	11 (50%)	30 (49%)
Germany	8 (47%)	12 (55%)	11 (50%)	31 (51%)
Employment status				
Unemployed or parental leave	0 (0%)	10 (45%)	8 (36%)	18 (30%)
Retired or disability pension	17 (100%)	4 (18%)	2 (9%)	23 (38%)
Employed	0 (0%)	8 (36%)	12 (55%)	20 (33%)
Schooling				
Primary	7 (41%)	5 (23%)	5 (23%)	17 (28%)
Lower secondary	5 (29%)	15 (68%)	11 (50%)	31 (51%)
Secondary	5 (29%)	2 (9%)	6 (27%)	13 (21%)
Car access				
Yes	7 (41%)	10 (45%)	15 (68%)	32 (52%)
No	10 (59%)	12 (55%)	7 (32%)	29 (48%)
Car passenger during tracking				
Yes	8 (47%)	15 (68%)	13 (59%)	36 (59%)
No	9 (53%)	7 (32%)	9 (41%)	25 (41%)

Note: *Car access* means that the respondent had a valid driver's license as well as a car at their free disposal; *car passenger during tracking* means that the respondent was given a ride in a car by another person they know personally during the tracking period.

For this study, we selected three groups who were at high risk of experiencing social disadvantage and transport poverty. The first group consisted of elderly people who had been living alone for at least one year (lone elderly). The second group was made up of labor market disadvantaged people with primary or lower secondary education who faced a higher risk of unemployment, and were more likely to be unemployed, or employed in temporary and otherwise insecure work arrangements. The third group consisted of single parents who were co-residing with at least one child younger than age 14.

All respondents were recruited in person in the study regions; either by directly approaching them at potentially relevant places of daily life (e.g., coffee rounds in villages for the elderly, food banks, playgrounds), or through referrals by previously interviewed individuals or local gatekeepers, such as social workers. They were briefed about the research project, and signed informed consent forms prior to their participation. All three groups are regularly described as hard-to-reach in transport research (Lucas et al., 2018; Ranković Plazinić and Jović, 2018).

In the sample (Table 1), women were over-represented because they were more likely than men to be in a socially disadvantaged group (on average, women have higher life expectancy, are more likely to be the main child care provider, and are more likely to work part time than men). Two-thirds of the single parents had access to a car (meaning they had a car at their disposal and a valid driving license), compared to less than half of the lone elderly and the labor market disadvantaged. Almost half of the elderly had been given a ride during the tracking period, compared to two-thirds of the labor market disadvantaged, and just under 60% of the single parents.

3.2. Collection of movement data via GPS tracking

Movement data were collected using stand-alone GPS loggers (model: *Qstarz BT-Q1000XT*; weight: 65 g) with a recording interval of 10 s per data point. The advantage of using a stand-alone rather than a mobile phone app was that it enabled people without smartphones (in our case, some elderly and poor respondents) to participate in the study. Respondents were instructed to carry the device with them every time they left their home over 14 consecutive days. The process of participatory GPS tracking was labor-intensive. Recruitment and data collection required the intense involvement of the researchers (e.g., providing instructions on how to use the GPS loggers, offering assistance in resolving technical problems, reminding participants to return the loggers in time). Further information on participant compliance in GPS tracking studies on vulnerable populations is available in related literature (Duncan et al., 2016; Kerr et al., 2011; Šimon et al., 2019, 2020).

The GPS loggers were collected after the tracking period, and the raw data downloaded via USB. In the resulting CSV files, each row constituted a unique data point containing a timestamp and the spatial coordinates. Subsequently, the movement data were processed using R 3.6.0 (R Core Team, 2019) and the *dbscan* (v1.1–5; Hahsler et al., 2019) and *sf* (v0.9–4; Pebesma, 2018) packages. Density Based Clustering of Applications with Noise (DBSCAN) was used to remove most of the noise that can occur when GPS loggers have poor satellite reception (for example, indoors) by grouping data points that were spatially and temporally close. The resulting geometries were then used to perform the geo-computations needed to calculate the activity space measurements.

3.3. Activity space measurements

Activity spaces are defined as the areas that people cover within a given period in their daily lives. Thus, they are measures of individual mobility, and allow for the analysis of the social or spatial factors that may influence mobility (Rai et al., 2007). The core function of the activity space method is to reduce complex mobilities to simple metrics that capture essential aspects of the measured movements (Kamruzzaman et al., 2016). While this method has been applied in many disciplines, ranging from gerontology (Hirsch et al., 2014) to movement ecology (Demšar et al., 2015), it has so far been applied to a limited extent only in research on rural areas (Kamruzzaman and Hine, 2012).

The analysis is based on two activity space metrics that describe key characteristics of the extent of daily mobility in an aggregated way. First, *daily path area* (DPA) is defined as the mean value of a 50-m buffer around all daily path trajectories over two weeks (in km^2). Accordingly, DPA measures mobility that occurs within transport infrastructures, and thus provides insight into the extent of daily mobility within the activity space's reach (Miller, 1991). It assumes that the greater the extent of an individual's daily activity space, the greater the person's choice of accessible places, and, thus, the more chances they have to use services or engage in social activities. Correspondingly, it may be assumed that when the extent of an individual's DPA is low, their choices and access to opportunities and services are also reduced (Kwan, 1999).

Second, *average places visited* (APV) is defined as the average number of unique places a person visited (including their home) during each 24-h period over two weeks. Places are defined as geographic positions where the individuals stayed for more than three consecutive minutes. For the detection of places, we used a DBSCAN algorithm. Accordingly, APV provides information about the intensity of use of the activity space reached in daily mobility. It may be assumed that if a person visited a larger number of places, they were also utilizing more opportunities in different places, and thus had more opportunities for social participation. Accordingly, a low number of places visited per day indicates a low utilization of opportunities and services in the individual's activity space (Hine et al., 2012).

The robustness of the data analysis steps was tested, and outliers were excluded from the computation of activity space metrics using the Hampel criterion (Leys et al., 2013). DPA and APV have been calculated as averages. Thus, outliers in these metrics could be better compensated for than if, for example, one-day measurements had been used. As the correlation between the DPA and APV scores was generally positive, but was not strong, it appears that these two metrics represented different components of daily mobility.

4. Results

4.1. Regional mobility of socially disadvantaged groups

The daily mobility of the socially disadvantaged groups varied little between the Czech and the German regions under study (Table 2), as the daily path area (DPA) and average places visited (APV) scores were similar in the two countries. For example, the mean DPA for respondents was 1.1 km^2 in Czechia and 1.2 km^2 in Germany. Additionally, respondents visited, on average, 3.8 places in Czechia and 3.5 places in Germany (APV). The results of both the two-sample *t*-test for country differences and pairwise comparisons using the Wilcoxon rank sum test for regional differences were not significant at the $p < 0.05$ level; with the only exception being a difference in APV between the Mansfeld-Südharz (MSH) region and the Vorpommern-Greifswald (VG) region. The results were consistent when controlling for settlement size, as there were no significant differences between the two activity space metrics. Thus, the individual mobility of the socially disadvantaged groups was structurally similar across regions.

4.2. Group differences in mobility

Mobility differed between and within the three study groups. The lone elderly and the labor market disadvantaged had smaller activity spaces than the single parents, as measured by DPA (Fig. 1A). Similarly, the lone elderly visited fewer places in their daily life than the labor market disadvantaged and the single parents, as measured by APV (Fig. 1B).

On average, the single parents had a DPA that was almost 50% larger than that of the other two groups; with a mean of 1.51 km^2, their DPA differed from that of the lone elderly (mean = 0.94 km^2) and the labor market disadvantaged (mean = 1.05 km^2). Of the groups, the single parents visited the most places per day (mean = 4.02), followed by the labor market disadvantaged (mean = 3.65) and the lone elderly (mean = 3.29). Due to the small sample size, these results should be treated with caution.

4.3. Automobility and rural social disadvantage

Social exclusion and transport exclusion are interlinked, with the car being the dominant means of independent transport in rural areas. In our study, 59% of the elderly, 55% of the labor market disadvantaged, and 32% of the single parents did not have access to a car (Table 1). People with lower secondary or secondary education were three times more likely to have access to a car than people with primary education (Table 3). The differences in net equivalent income between car users and non-car users were not significant.

In the three groups, having access to a car significantly increased daily mobility to similar degrees, roughly doubling the median values of DPA (Fig. 2A). It therefore appears that the residential context, the infrastructure, and the services available within the neighborhood played a pivotal role for these less mobile groups. But did this transport disadvantage also constrain their opportunities for social participation? One way to evaluate this question is to look at whether not owning a car limited the number of places people visited in their everyday lives.

Unlike DPA, APV was not uniformly linked to car access in the three groups (Fig. 2B). Different types of social disadvantage affected realized mobility differently, and were shaped by car access. Thus, the

Table 2
Activity space metrics for countries and regions.

	Czechia		Germany		Countries		Overall
	Bor Region ($N = 14$)	Jeseniky Region (N = 16)	MSH Region ($N = 16$)	VG Region ($N = 15$)	CZ ($N = 30$)	GER ($N = 31$)	($N = 61$)
Daily path area (km^2)							
Mean (SD)	1.3 (0.74)	0.98 (0.75)	1.2 (0.81)	1.3 (0.76)	1.1 (0.76)	1.2 (0.77)	1.2 (0.76)
Median	1.1	0.96	1.2	1.1	1.0	1.1	1.1
Average places visited							
Mean (SD)	3.4 (1.1)	4.2 (2.1)	4.2 (0.87)	2.9 (0.82)	3.8 (1.7)	3.5 (1.1)	3.7 (1.4)
Median	3.5	4.4	3.9	2.7	3.7	3.6	3.6

Note: *Daily path area*: mean of the daily area covered per respondent, calculated by buffering 50 m around daily trips, without overlap (in km^2); *average places visited*: mean of the daily places visited per respondent with a minimum stay of three minutes, automatically detected using a DBSCAN algorithm.

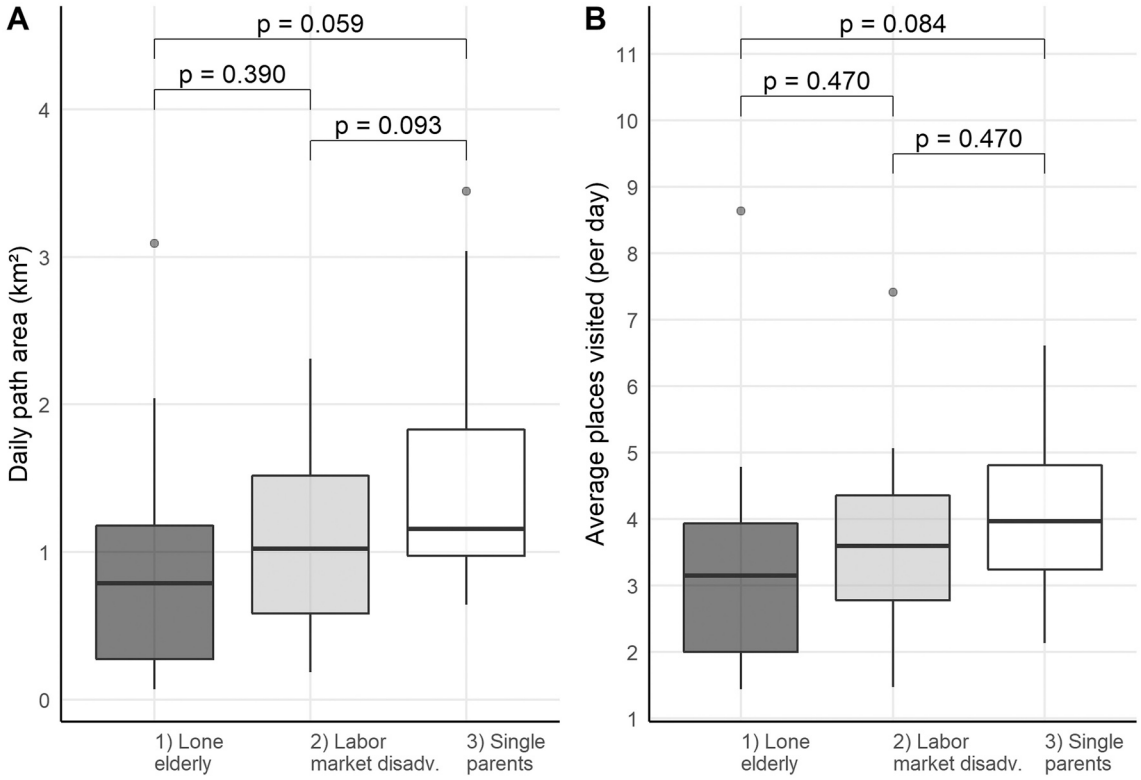


Fig. 1. Activity spaces and places visited of socially disadvantaged groups (A: DPA by group; B: APV by group).
Note: The *p*-values are derived from a pairwise Wilcoxon test between groups, adjusted with the Holm method.

Table 3
Car access by respondents' characteristics.

	Car access		Overall ($N = 61$)
	No ($N = 29$)	Yes ($N = 32$)	
Age			
Mean (SD)	53 (19)	52 (14)	52 (17)
Median	55	48	49
Schooling			
Primary	12 (41.4%)	5 (15.6%)	17 (27.9%)
Lower secondary	13 (44.8%)	18 (56.2%)	31 (50.8%)
Secondary	4 (13.8%)	9 (28.1%)	13 (21.3%)
Employment status			
Unemployed/parental leave	11 (37.9%)	7 (21.9%)	18 (29.5%)
Retired/disability pension	13 (44.8%)	10 (31.2%)	23 (37.7%)
Employed	5 (17.2%)	15 (46.9%)	20 (32.8%)
Net equivalent income (in euros)			
Mean (SD)	650 (630)	810 (530)	730 (580)
Median	500	590	540
Missing	0 (0%)	1 (3.1%)	1 (1.6%)

discrepancies between the extent of mobility (DPA) and the number of places visited (APV) among the three groups remind us that the role of car access must be assessed carefully when measuring and evaluating transport poverty.

First, among the lone elderly group, having access to a car led to significant increases in activity spaces, as measured by DPA, from a median of 0.37 to 1.16 km^2. At the same time, it also increased the number of places visited per day (APV), from a median of 2.39 for elderly people without car access to 3.93 for those with car access. Age was identified as an interacting variable, as the older the respondents were, the less likely they were to have access to a car.

Second, among the labor market disadvantaged group, those with access to a car had significantly larger activity spaces, as measured by DPA (median = 1.51 km^2), than those without access to a car (median = 0.78 km^2). However, this difference did not translate into a discrepancy in the number of places visited per day, as measured by APV. Thus, the labor market disadvantaged visited almost the same number of places per day, regardless of whether they had access to a car.

Third, among the single parents group, car access significantly increased the area covered per day; i.e., median DPA was almost twice as

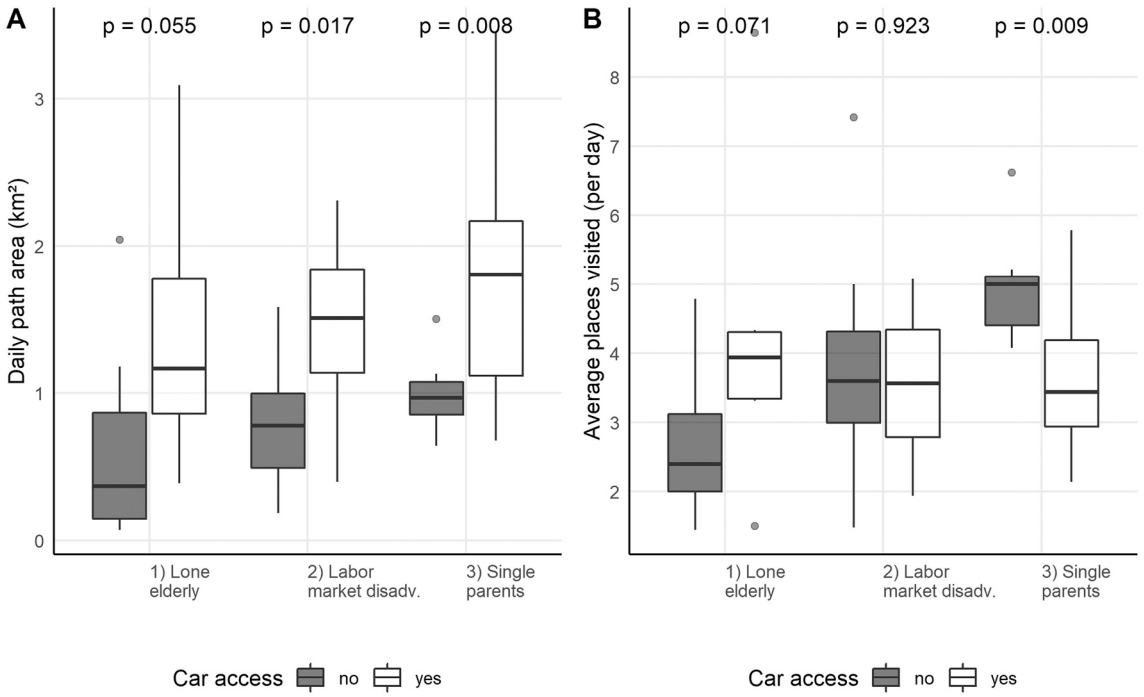


Fig. 2. Rural automobilities - activity spaces and places visited of socially disadvantaged groups (A: DPA by group by car access; B: APV by group by car access).
Note: The p-values are derived from the Wilcoxon rank sum test within groups between car users and non-car users.

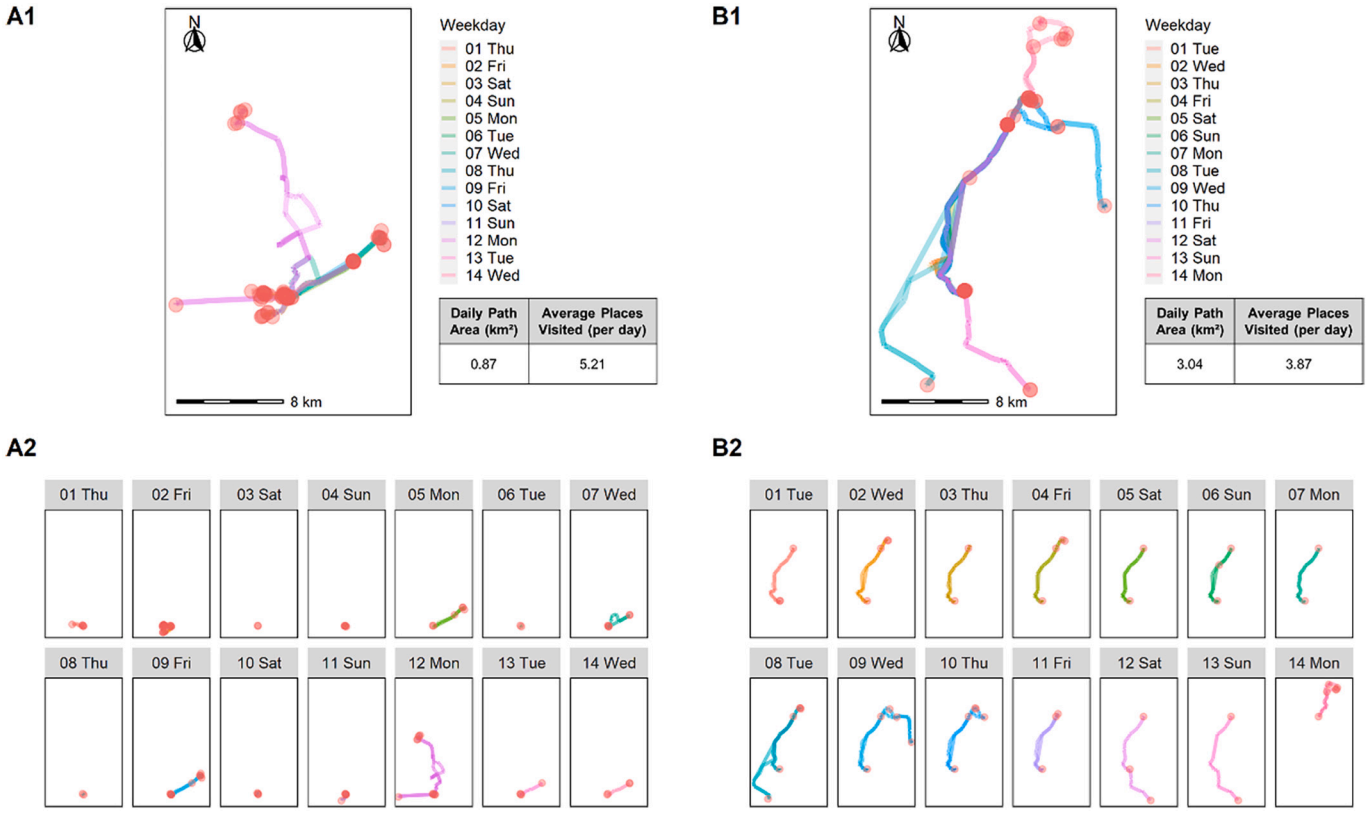


Fig. 3. Activity spaces and mobility of single parents (A1: two-week mobility of a single parent without a car, A2: single-day mobility of a single parent without a car; B1: two-week mobility of a single parent with car access, B2: single-day mobility of a single parent with car access).
Note: Each day is represented with a separate color; automatically identified places are represented by red dots; spatial overlaps in daily mobility paths and places visited illustrate the repetition of mobility patterns.

high for those who had car access (1.80 km^2) than for those who lacked car access (0.97 km^2). Thus, the effect of car access was more pronounced for this group than for the other two groups. At the same time, however, APV among the single parents was significantly lower for those who had car access (3.44 places visited per day) than for those who lacked car access (5.0 places visited per day). Thus, in contrast to the patterns observed for the other two groups, the single parents with car access traveled more extensively but visited fewer places, on average, than their non-car-owning counterparts. Fig. 3 illustrates the differences in daily mobility and places visited between two single parents, one with car access and one without.

Although car access increased the extent of mobility for all groups, some of the non-car-owning respondents also had high DPA scores that require explanation. Automobility again played a role, but was mediated by being a passenger. Fig. 4A and Fig. 4B show the mobility metrics by car ownership during the tracking period further split into active transport as a car driver and passive transport as a car passenger. Both active and passive car transport increased the distances traveled and the number of places visited. Respondents who were neither a car driver nor a car passenger had a median DPA of 0.28 km^2, and thus had the smallest activity spaces in absolute terms across the entire sample (overall median DPA = 1.08 km^2). The composition of this least mobile group was comparatively homogeneous, as it was made up exclusively of the elderly and people receiving disability pensions. However, the share of this subgroup within the sample was small ($N = 5$), which highlights the important role car access played in the mobility of most respondents.

5. Discussion and conclusion

This study examined the effects of spatial and social disadvantages on people's daily mobility, with a focus on automobility. Based on detailed GPS tracking data and applying multiple comparisons, we analyzed and compared the daily mobility of three socially disadvantaged groups (lone elderly, labor market disadvantaged, single parents) in Czech and German rural peripheries. These groups face different challenges, have diverse mobility needs, and are difficult to reach in conventional transport surveys (Lucas et al., 2018). Thus, our analysis represents an empirical contribution illustrating how the GPS tracking method can be used to examine transport poverty and social exclusion from a relational perspective.

Our findings indicated that the daily mobility of socially disadvantaged groups varied little between the Czech and the German regions under study. This observation suggests that individual-level factors matter more than the structural differences between countries and rural regions, such as differences in demographic structure, gross national product, or welfare state regime (Marsden et al., 2012). The similarities we detected in the daily mobility patterns at the national and the regional level support the use of an analytical perspective that does not define space as a deterministic contextual variable, but instead views mobility as a complex phenomenon influenced by various social and spatial processes (Sheller and Urry, 2006). Thus, these findings support the argument by Ryan and Pereira (2021) that the phenomenon of rural transport poverty should be assessed using measures beyond those of simple spatial accessibility. In many policy documents, accessibility values are attributed to large spatial units, based on the assumption that all inhabitants of these areas are affected to a similar extent. However, the large variances we found both between and within the groups suggest that other factors beyond the mere spatial distribution of different services and infrastructures drove the major differences in everyday mobility we observed.

5.1. Group-dependent car effects

The range of effects car access has on different socially

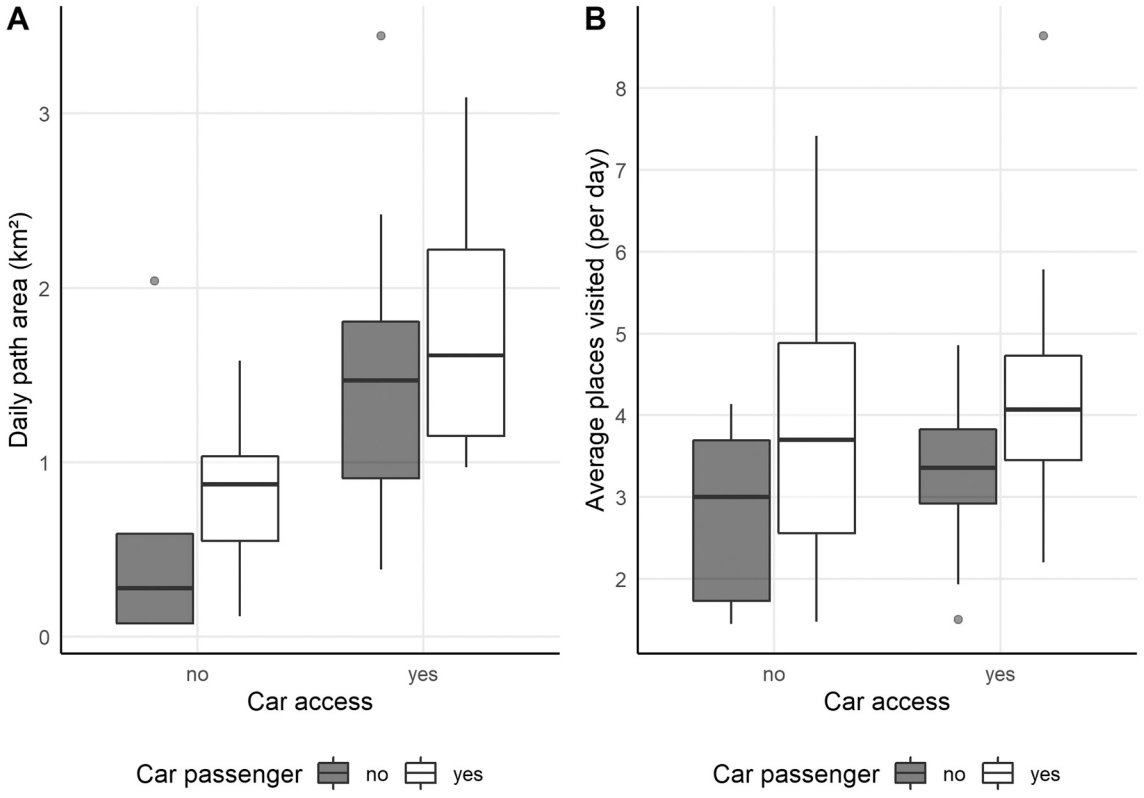


Fig. 4. Rural car passenger mobility – activity spaces and number of places visited of car and non-car users (A: DPA by car access through being a car passenger; B: APV by car access through being a car passenger).
Note: Car passenger is a binary variable indicating the use of carpooling within the GPS tracking period.

disadvantaged groups has not been exhaustively addressed in existing studies (Farber and Páez, 2009), even though across disciplines, the car is widely acknowledged as being the primary mode of transport in rural areas, with a profound impact on transport poverty (Binder and Matern, 2020; Delbosc and Currie, 2011; Osti, 2010; Ward et al., 2013). Our exploration of the role of car access in the extent of mobility and the number of places visited for socially disadvantaged groups uncovered group-specific car mobility effects. While car access enabled people to use different mobility strategies, and provided them with more options and greater flexibility, it did not automatically mean that they visited more places.

In our study, the lone elderly people without car access had, on average, the smallest activity spaces out of all groups. In line with previous studies, we found that having access to a car increased both the distances traveled and the number of places visited for the lone elderly. Thus, our findings support previous studies, which showed that high levels of car dependency in rural areas increase the risk of social exclusion for the non-car-driving elderly (Ranković Plazinić and Jović, 2018; Shergold and Parkhurst, 2012), and that the risk of negative health impacts increases when medical services cannot be reached in time (Fields et al., 2021).

The labor market disadvantaged frequently lack access to cars or the financial means to use them for non-essential purposes. Thus, by limiting people to a smaller set of potential places to visit (e.g., being tied to a limited local labor market or expensive local shopping opportunities; Kaufman, 1998), transport disadvantage can exacerbate existing economic disadvantage. The present study showed that the labor market disadvantaged who had cars traveled longer distances and sought out more distant destinations. However, we found that the daily mobility of the labor market disadvantaged was not structured differently in a quantitative sense depending on whether they had access to a car, as they visited the same number of places per day, on average, regardless of whether they had car access. This similarity in the numbers of places visited suggests that for this group, the services they used and the social activities they participated in were similar regardless of whether they had a car. While for this group, having a car led to more choices of destinations to visit, it did not change the economic constraints associated with being labor market disadvantaged. Moreover, as Farber and Páez (2009) noted, it is conceivable that the additional time spent traveling to more distant places reduces the time people have available for other social activities.

Previous research has shown that single parents adapt their mobility to their specific life circumstances; i.e., they typically need to visit a wide variety of places each day while experiencing a constant time crunch (Gilow, 2020; Rogalsky, 2010). Moreover, the potential incompatibility of work and care duties often leads to single parents becoming unemployed and experiencing further disadvantages (Treanor, 2018). While our results are in line with these earlier findings, they also showed that for this group, the impact of car access is more nuanced. The non-car-owning lone parents in our sample visited an average of 4.96 places per day (sample mean = 3.67). However, the pattern for the car-owning single parents was fundamentally different, as they traveled longer distances, but visited fewer places (mean = 3.56) than their non-car-owning counterparts. This may be because having a car enabled these single parents to visit places where several errands could be done at once, even if this meant that they had to travel greater distances. As the single parents without a car did not have this choice, they likely had to visit more individual places in closer proximity to obtain the goods and services they needed. It therefore appears that the single parents organized their daily lives in significantly different ways depending on whether they had a car.

5.2. Social ties of car access

Car access is a profoundly social variable that contributes to the expression of transport poverty; thus, it is not merely an individual transport option that a person "freely" chooses. The social conditionality of the car is addressed in research on *forced car ownership* (Mattioli, 2017), which implies that even poor people whose budgets barely cover car-related expenditures are forced to own a car. In our study, the incomes of the car owners and the non-car owners did not differ significantly. Hence, it may be assumed that the phenomenon of *forced car ownership* applied to some of the individuals in our sample. This suggests that for many people living in rural peripheries, a car is not a luxury item, but a necessary expense. The social conditionality of the car is further reflected in its availability, which is dependent on a person's age and education.

This observation draws our attention to the social networks of the respondents (family, friends, neighbors), i.e. the individuals with whom they are in contact, and who can provide social support, but who may also represent a source of stress or a burden (Perry et al., 2018). We argue that the respondents' social networks influenced the effects that car access had on their daily mobility. First, these social networks helped to explain how even people who did not own a car were able to travel long distances in rural peripheries. Empirical support for this concept has, for example, been provided by Ranković Plazinić and Jović (2018), who observed that elderly people living in rural areas who were integrated into multi-generational households had a higher transport potential than their counterparts who were living alone (also Ahern and Hine, 2012). The analysis also revealed, however, that even people who were living alone and without a car could travel long distances because they had access to mobility capital (motility) in the form of car drivers within their social networks. Only a few of the participants in our study were not mobile during the tracking period, either actively as a car driver or passively as a car passenger. Accordingly, when evaluating people's transport potential, their social networks, and not just their household members, should be considered (Cass et al., 2005; Schwanen et al., 2015). Kaufmann et al. (2004) described this point theoretically using the concept of *motility* on the *meso* level, noting that people's access to means of transport strongly depends on their social network constellations, which, in turn, create different social participation opportunities or limitations. However, if a large proportion of the non-car-owning respondents nevertheless traveled longer distances by car, the question of who had to compensate for this dependence on others arises (Siren and Haustein, 2015).

Second, for drivers, the role of the car can change from a capability to a constraint if they are enabling the mobility of others by driving them. The time drivers devote to mobility provision can limit their own possibilities for social participation (Kamruzzaman and Hine, 2012; Schwanen et al., 2015). The results of our comparisons indicated that the social networks of car drivers affected them to differing degrees depending on their care obligations. This was most evident among the single parents, who had substantial daily care obligations. For these individuals, having access to a car almost doubled the extent of their mobility, but led to a surprising decrease in the number of places they visited. Thus, car access fundamentally changed the mobility strategies of single parents by enabling them to visit more distant places with bundled opportunities. In contrast, for the lone elderly group who had the fewest regular care obligations, having a car increased both the extent of their mobility and the number of places they visited. Thus, the role a car can play in providing people in rural peripheries with access to opportunities for social participation depends largely on their care obligations; i.e., on the drivers' social networks. Hence, high levels of car dependency in an area can have social exclusion effects, not only on non-car-owning residents, but also on residents who supposedly have the optimal means of transport.

5.3. Study limitations

This research has four limitations. First, the present study examined the mobility of socially disadvantaged groups based on GPS movement data. Therefore, the respondents' subjective perceptions of their

individual access to mobility have not been considered. Ryan and Pereira (2021) emphasized that only a person's subjective assessment of the accessibility of a place is relevant, regardless of what the objective accessibility indicators show. However, we argue, in line with Vecchio and Martens (2021), that examining realized mobility is crucial as well, since it can change or reinforce subjective perceptions of accessibility. Second, people can achieve a high degree of social participation without being spatially mobile themselves; e.g., through the mobility of others or through information and communication technologies. Addressing these issues would require an exploration of the dimensions of immobility, about which this study cannot make claims. Third, since the data collection process took place over a longer period, participants were tracked in different seasons. Although the influence of the weather on mobility cannot be ruled out, we assume that most relevant places of daily life are visited regardless of the season (e.g., shops, schools, workplaces, health care facilities). Fourth, our small case numbers ($N = 61$) limited our ability to perform advanced statistical analyses. However, for this study, the composition of the sample was more crucial than its size, since it consisted of hard-to-reach groups, especially in rural peripheries (cf. also the experiences of Ranković Plazinić and Jović, 2018).

5.4. Outlook

The present study demonstrated the utility of GPS tracking as a method to capture the extent and the variability of the spatial mobility of socially disadvantaged groups. The collection of precise movement data over a two-week period allowed us to capture the majority of the respondents' daily routinized mobility (Stanley et al., 2018). GPS tracking makes it possible to compare hard-to-reach groups in different regional and national contexts, without encountering the language barriers that often arise when collecting mobility data through surveys or travel diaries. Moreover, Klous et al. (2017) found that in surveys, respondents tend to strongly overestimate their mobility by walking and biking. Tracking movement data circumvents this recall bias.

In conclusion, the wide range of mobility forms that exist among socially disadvantaged groups needs to be emphasized. This observation illustrates that making a deterministic attribution of mobility as either "socially disadvantaged" or "spatially disadvantaged" does not add to our understanding of transport poverty. In future studies, the social conditionality of automobilities should be explored in detail. The effects of car access on daily mobility are not uniform, but instead differ significantly depending on an individual's life situation, life phase, and social network connections. We therefore argue that the role of the car in enabling mobility (for passengers) and demanding mobility (from drivers) is relevant for understanding transport-related social exclusion. Consequently, and in line with Farrington and Farrington (2005) or Manderscheid (2014), we encourage future research on mobility to shift the unit of analysis away from isolated individuals or single trips, and toward social relationships and social networks. Gaining a better understanding of the interplay of the factors that contribute to spatial or social disadvantage is a prerequisite for providing appropriate recommendations for their mitigation.

Funding Acknowledgement

This work was supported by the German Research Foundation [DFG; Project Number: 391073923]; and the Czech Science Foundation [GAČR; Contract ID: 18-05704J].

Declaration of Competing Interest

none.

References

Ahern, A., Hine, J., 2012. Rural transport – valuing the mobility of older people. Res. Transp. Econ. 34 (1), 27–34. https://doi.org/10.1016/j.retrec.2011.12.004.
Berg, J., Ihlström, J., 2019. The importance of public transport for mobility and everyday activities among rural residents. Soc. Sci. 8 (2), 58. https://doi.org/10.3390/socsci8020058.
Binder, J., Matern, A., 2020. Mobility and social exclusion in peripheral regions. Eur. Plan. Stud. 28 (6), 1049–1067. https://doi.org/10.1080/09654313.2019.1689926.
Camarero, L., Oliva, J., 2019. Thinking in rural gap: mobility and social inequalities. Palgrave Commun. 5 (95), 1–7. https://doi.org/10.1057/s41599-019-0306-x.
Cass, N., Shove, E., Urry, J., 2005. Social exclusion, mobility and access. Sociol. Rev. 53 (3), 539–555.
Česko v pohybu, 2019. Česko v pohybu - První celostátní průzkum dopravního chování: Czechia in motion - The first nationwide survey of traffic behavior. Centrum dopravního výzkumu, v. v. i; agenturou SC&C. https://www.ceskovpohybu.cz/#tl. Accessed 21 September 2021.
Cresswell, T., 2006. The right to mobility: the production of mobility in the courtroom. Antipode 38 (4), 735–754. https://doi.org/10.1111/j.1467-8330.2006.00474.x.
Currie, G., Richardson, T., Smyth, P., Vella-Brodrick, D., Hine, J., Lucas, K., Stanley, J., Morris, J., Kinnear, R., Stanley, J., 2010. Investigating links between transport disadvantage, social exclusion and well-being in Melbourne – updated results. Res. Transp. Econ. 29 (1), 287–295. https://doi.org/10.1016/j.retrec.2010.07.036.
Delbosc, A., Currie, G., 2011. The spatial context of transport disadvantage, social exclusion and well-being. J. Transp. Geogr. 19 (6), 1130–1137. https://doi.org/10.1016/j.jtrangeo.2011.04.005.
Demšar, U., Buchin, K., Cagnacci, F., Safi, K., Speckmann, B., van de Weghe, N., Weiskopf, D., Weibel, R., 2015. Analysis and visualisation of movement: an interdisciplinary review. Movement Ecol. 3 (1), 5. https://doi.org/10.1186/s40462-015-0032-y.
Donaghy, K., Poppelreuter, S., Rudinger, G. (Eds.), 2005. Social Dimensions of Sustainable Transport: Transatlantic Perspectives. Routledge, London, New York.
Duncan, D.T., Kapadia, F., Regan, S.D., Goedel, W.C., Levy, M.D., Barton, S.C., Friedman, S.R., Halkitis, P.N., 2016. Feasibility and acceptability of global positioning system (GPS) methods to study the spatial contexts of substance use and sexual risk behaviors among young men who have sex with men in New York City: a P18 cohort sub-study. PLoS One 11 (2), e0147520. https://doi.org/10.1371/journal.pone.0147520.
ESPON, 2017. PROFECY – processes, features and cycles of inner peripheries in Europe: inner peripheries: national territories facing challenges of access to basic services of general interest. In: Final Report. https://www.espon.eu/inner-peripheries (Accessed 23 September 2021).
ESPON, Spiekermann, Wegener, 2015. TRACC - transport accessibility at regional/local scale and patterns in Europe. In: Volume 1 - TRACC Executive Summary and Main Report.
Farber, S., Páez, A., 2009. My car, my friends, and me: a preliminary analysis of automobility and social activity participation. J. Transp. Geogr. 17 (3), 216–225. https://doi.org/10.1016/j.jtrangeo.2008.07.008.
Farrington, J., Farrington, C., 2005. Rural accessibility, social inclusion and social justice: towards conceptualisation. J. Transp. Geogr. 13 (1), 1–12. https://doi.org/10.1016/j.jtrangeo.2004.10.002.
Fields, N.L., Cronley, C., Mattingly, S.P., Roark, E.M., Leat, S.R., Miller, V.J., 2021. Transportation mobility and health among older adults: examining missed trips and latent demand. J. Transp. Health 21 (2), 101069. https://doi.org/10.1016/j.jth.2021.101069.
Galster, G., Sharkey, P., 2017. Spatial foundations of inequality: a conceptual model and empirical overview. RSF: The Russell Sage Foundation J. Soc. Sci. 3 (2), 1–33. https://doi.org/10.7758/rsf.2017.3.2.01.
Giesel, F., Köhler, K., 2015. How poverty restricts elderly Germans' everyday travel. Eur. Transp. Res. Rev. 7 (2) https://doi.org/10.1007/s12544-015-0164-6.
Gilow, M., 2020. "It's work, physically and logistically": analyzing the daily mobility of employed mothers as domestic mobility work. J. Transp. Geogr. 85 (4) https://doi.org/10.1016/j.jtrangeo.2020.102693.
Goins, R.T., Williams, K.A., Carter, M.W., Spencer, M., Solovieva, T., 2005. Perceived barriers to health care access among rural older adults: a qualitative study. J. Rural Health Off. J. Am. Rural Health Assoc. Natl. Rural Health Care Assoc. 21 (3), 206–213. https://doi.org/10.1111/j.1748-0361.2005.tb00084.x.
Gornick, J.C., 2018. The socioeconomics of single parenthood: Reflections on the triple bind. In: Nieuwenhuis, R., Maldonado, L.C. (Eds.), The Triple Bind of Single-Parent Families. Resources, Employment and Policies to Improve Well-Being. Policy Press, Bristol, Chicago, pp. 437–448.
Graham, H., de Bell, S., Flemming, K., Sowden, A., White, P., Wright, K., 2018. The experiences of everyday travel for older people in rural areas: a systematic review of UK qualitative studies. J. Transp. Health 11, 141–152. https://doi.org/10.1016/j.jth.2018.10.007.
Hahsler, M., Doran, D., Piekenbrock, M., 2019. dbscan: fast density-based clustering with R. J. Stat. Soft. 91 (1), 1–30. https://doi.org/10.18637/jss.v091.i01.
Hernandez, D., 2018. Uneven mobilities, uneven opportunities: social distribution of public transport accessibility to jobs and education in Montevideo. J. Transp. Geogr. 67, 119–125. https://doi.org/10.1016/j.jtrangeo.2017.08.017.
Hine, J., Kamruzzaman, M., Blair, N., 2012. Weekly activity-travel behaviour in rural Northern Ireland: differences by context and socio-demographic. Transportation 39 (1), 175–195. https://doi.org/10.1007/s11116-011-9322-4.
Hirsch, J.A., Winters, M., Clarke, P., McKay, H., 2014. Generating GPS activity spaces that shed light upon the mobility habits of older adults: a descriptive analysis. Int. J. Health Geogr. 13 (1), 1–14. https://doi.org/10.1186/1476-072X-13-51.

Kamruzzaman, M., Hine, J., 2011. Participation index: a measure to identify rural transport disadvantage? J. Transp. Geogr. 19 (4), 882–899. https://doi.org/10.1016/j.jtrangeo.2010.11.004.
Kamruzzaman, M., Hine, J., 2012. Analysis of rural activity spaces and transport disadvantage using a multi-method approach. Transp. Policy 19 (1), 105–120. https://doi.org/10.1016/j.tranpol.2011.09.007.
Kamruzzaman, M., Yigitcanlar, T., Yang, J., Mohamed, M., 2016. Measures of transport-related social exclusion: a critical review of the literature. Sustainability 8 (7), 696. https://doi.org/10.3390/su8070696.
Kaufman, P.R., 1998. Rural poor have less access to supermarkets, large grocery stores. Rural Dev. Perspect. 13 (3), 19–26. https://doi.org/10.22004/AG.ECON.289786.
Kaufmann, V., Bergmann, M.M., Joye, D., 2004. Motility: mobility as capital. Int. J. Urban Reg. Res. 28 (4), 745–756. https://doi.org/10.1111/j.0309-1317.2004.00549.x.
Keim-Klärner, S., Bernard, J., Bischof, S., van Dülmen, C., Klärner, A., Steinführer, A., 2021. Analyzing Social Disadvantage in Rural Peripheries in Czechia and Eastern Germany: Conceptual Model and Study Design. Thünen Working Paper 170. Thünen-Institut für Ländliche Räume, Braunschweig. https://literatur.thuenen.de/digbib_extern/dn063367.pdf. (Accessed 25 April 2022).
Kenyon, S., Lyons, G., Rafferty, J., 2002. Transport and social exclusion: investigating the possibility of promoting inclusion through virtual mobility. J. Transp. Geogr. 10 (3), 207–219. https://doi.org/10.1016/s0966-6923(02)00012-1.
Kerr, J., Duncan, S., Schipperijn, J., Schipperjin, J., 2011. Using global positioning systems in health research: a practical approach to data collection and processing. Am. J. Prev. Med. 41 (5), 532–540. https://doi.org/10.1016/j.amepre.2011.07.017.
Klous, G., Smit, L.A.M., Borlée, F., Coutinho, R.A., Kretzschmar, M.E.E., Heederik, D.J.J., Huss, A., 2017. Mobility assessment of a rural population in the Netherlands using GPS measurements. Int. J. Health Geogr. 16 (30) https://doi.org/10.1186/s12942-017-0103-y.
Kühn, M., 2015. Peripheralization: theoretical concepts explaining socio-spatial inequalities. Eur. Plan. Stud. 23 (2), 367–378. https://doi.org/10.1080/09654313.2013.862518.
Küpper, P., 2016. Abgrenzung und Typisierung ländlicher Räume. Thünen Working Paper 68. Thünen-Institut für Ländliche Räume, Braunschweig. https://literatur.thuenen.de/digbib_extern/dn057783.pdf. (Accessed 26 April 2022).
Kwan, M.-P., 1999. Gender and individual access to urban opportunities: a study using space–time measures. Prof. Geogr. 51 (2), 210–227. https://doi.org/10.1111/0033-0124.00158.
Lang, T., 2012. Shrinkage, metropolization and peripheralization in East Germany. Eur. Plan. Stud. 20 (10), 1747–1754. https://doi.org/10.1080/09654313.2012.713336.
Leys, C., Ley, C., Klein, O., Bernard, P., Licata, L., 2013. Detecting outliers: do not use standard deviation around the mean, use absolute deviation around the median. J. Exp. Soc. Psychol. 49 (4), 764–766. https://doi.org/10.1016/j.jesp.2013.03.013.
Lucas, K., 2006. Providing transport for social inclusion within a framework for environmental justice in the UK. Transp. Res. A Policy Pract. 40 (10), 801–809. https://doi.org/10.1016/j.tra.2005.12.005.
Lucas, K., 2011. Making the connections between transport disadvantage and the social exclusion of low income populations in the Tshwane Region of South Africa. J. Transp. Geogr. 19 (6), 1320–1334. https://doi.org/10.1016/j.jtrangeo.2011.02.007.
Lucas, K., 2012. Transport and social exclusion: where are we now? Transp. Policy 20, 105–113. https://doi.org/10.1016/j.tranpol.2012.01.013.
Lucas, K., Mattioli, G., Verlinghieri, E., Guzman, A., 2016. Transport poverty and its adverse social consequences. Proc. Inst. Civil Eng. Transp. 169 (6), 353–365. https://doi.org/10.1680/jtran.15.00073.
Lucas, K., Philips, I., Mulley, C., Ma, L., 2018. Is transport poverty socially or environmentally driven? Comparing the travel behaviours of two low-income populations living in central and peripheral locations in the same city. Transp. Res. A Policy Pract. 116 (4), 622–634. https://doi.org/10.1016/j.tra.2018.07.007.
Luz, G., Portugal, L., 2021. Understanding transport-related social exclusion through the lens of capabilities approach. Transp. Rev. 1–23 https://doi.org/10.1080/01441647.2021.2005183.
Maffii, S., Bosetti, S., 2021. Preface. In: Kuttler, T., Moraglio, M. (Eds.), Re-Thinking Mobility Poverty. Understanding Users' Geographies, Backgrounds and Aptitudes. Routledge, Abingdon, New York, pp. xxiii–xxvii.
Manderscheid, K., 2014. Criticising the solitary mobile subject: researching relational mobilities and reflecting on mobile methods. Mobilities 9 (2), 188–219. https://doi.org/10.1080/17450101.2013.830406.
Marsden, T.K., Murdoch, J., Lowe, P., Ward, N., 2012. The Differentiated Countryside. Routledge, Abingdon.
Mattioli, G., 2017. 'Forced car ownership' in the UK and Germany: socio-spatial patterns and potential economic stress impacts. Soc. Inclusion 5 (4), 147–160. https://doi.org/10.17645/si.v5i4.1081.
Mattioli, G., Philips, I., Anable, J., Chatterton, T., 2019. Vulnerability to motor fuel price increases: socio-spatial patterns in England. J. Transp. Geogr. 78, 98–114. https://doi.org/10.1016/j.jtrangeo.2019.05.009.
McQuoid, J., Dijst, M., 2012. Bringing emotions to time geography: the case of mobilities of poverty. J. Transp. Geogr. 23, 26–34. https://doi.org/10.1016/j.jtrangeo.2012.03.019.
Milbourne, P., Kitchen, L., 2014. Rural mobilities: connecting movement and fixity in rural places. J. Rural. Stud. 34, 326–336. https://doi.org/10.1016/j.jrurstud.2014.01.004.
Miller, H.J., 1991. Modelling accessibility using space-time prism concepts within geographical information systems. Int. J. Geogr. Inf. Sci. 5 (3), 287–301. https://doi.org/10.1080/02693799108927856.
MiT, 2017. Mobilität in Tabellen der Erhebung "Mobilität in Deutschland". im Auftrag des Bundesministeriums für Verkehr und digitale Infrastruktur (BMVI). infas Institut für angewandte Sozialwissenschaft GmbH. https://mobilitaet-in-tabellen.dlr.de/mit/. Accessed 21 September 2021.
Neumeier, S., 2015. Street petrol station shops as an alternative to missing local food suppliers – contribution to the German discourse on 'Daseinsvorsorge': a German view. Appl. Geogr. 60, 150–164. https://doi.org/10.1016/j.apgeog.2015.03.003.
Nieuwenhuis, R., Maldonado, L.C. (Eds.), 2018. The Triple Bind of Single-Parent Families: Resources, Employment and Policies to Improve Well-Being. Policy Press, Bristol, Chicago.
Nordbakke, S., Schwanen, T., 2013. Well-being and mobility: a theoretical framework and literature review focusing on older people. Mobilities 9 (1), 104–129. https://doi.org/10.1080/17450101.2013.784542.
Osti, G., 2010. Mobility demands and participation in remote rural areas. Sociol. Rural. 50 (3), 296–310. https://doi.org/10.1111/j.1467-9523.2010.00517.x.
Oviedo Hernandez, D., Titheridge, H., 2016. Mobilities of the periphery: informality, access and social exclusion in the urban fringe in Colombia. J. Transp. Geogr. 55, 152–164. https://doi.org/10.1016/j.jtrangeo.2015.12.004.
Pebesma, E., 2018. Simple features for R: standardized support for spatial vector data. R J. 10 (1), 439–446. https://doi.org/10.32614/RJ-2018-009.
Pérez-Soba, M., ESPON coordination unit, et al., 2012. GEOSPECS: Inner Peripheries: A Socio-Economic Territorial Specificity. ESPON coordination unit, Luxemburg. http://archive-ouverte.unige.ch/unige:79976. Accessed 8 September 2021.
Perry, B.L., Pescosolido, B.A., Borgatti, S.P., 2018. Egocentric Network Analysis: Foundations, Methods, and Models. Cambridge University Press, Cambridge.
Pyrialakou, V.D., Gkritza, K., Fricker, J.D., 2016. Accessibility, mobility, and realized travel behavior: assessing transport disadvantage from a policy perspective. J. Transp. Geogr. 51, 252–269. https://doi.org/10.1016/j.jtrangeo.2016.02.001.
R Core Team, 2019. R: A Language and Environment for Statistical Computing: Vienna, Austria. https://www.R-project.org/.
Rai, R.K., Balmer, M., Rieser, M., Vaze, V.S., Schönfelder, S., Axhausen, K.W., 2007. Capturing human activity spaces. Transp. Res. Rec. 2021 (1), 70–80. https://doi.org/10.3141/2021-09.
Ranković Plazinić, B., Jović, J., 2018. Mobility and transport potential of elderly in differently accessible rural areas. J. Transp. Geogr. 68, 169–180. https://doi.org/10.1016/j.jtrangeo.2018.03.016.
Rogalsky, J., 2010. The working poor and what GIS reveals about the possibilities of public transit. J. Transp. Geogr. 18 (2), 226–237. https://doi.org/10.1016/j.jtrangeo.2009.06.008.
Ross, L.A., Anstey, K.J., Kiely, K.M., Windsor, T.D., Byles, J.E., Luszcz, M.A., Mitchell, P., 2009. Older drivers in Australia: trends in driving status and cognitive and visual impairment. J. Am. Geriatr. Soc. 57 (10), 1868–1873. https://doi.org/10.1111/j.1532-5415.2009.02439.x.
Ryan, J., Pereira, R.H., 2021. What are we missing when we measure accessibility? Comparing calculated and self-reported accounts among older people. J. Transp. Geogr. 93 (4), 103086 https://doi.org/10.1016/j.jtrangeo.2021.103086.
Schwanen, T., Lucas, K., Akyelken, N., Cisternas Solsona, D., Carrasco, J.-A., Neutens, T., 2015. Rethinking the links between social exclusion and transport disadvantage through the lens of social capital. Transp. Res. A Policy Pract. 74 (1), 123–135. https://doi.org/10.1016/j.tra.2015.02.012.
Sheller, M., Urry, J., 2006. The new mobilities paradigm. Environ. Plan. A 38 (2), 207–226. https://doi.org/10.1068/a37268.
Shergold, I., Parkhurst, G., 2012. Transport-related social exclusion amongst older people in rural Southwest England and Wales. J. Rural. Stud. 28 (4), 412–421. https://doi.org/10.1016/j.jrurstud.2012.01.010.
Šimon, M., Vašát, P., Daňková, H., Gibas, P., Poláková, M., 2020. Mobilities and commons unseen: spatial mobility in homeless people explored through the analysis of GPS tracking data. GeoJournal 85, 1411–1427. https://doi.org/10.1007/s10708-019-10030-4.
Šimon, M., Vašát, P., Poláková, M., Gibas, P., Daňková, H., 2019. Activity spaces of homeless men and women measured by GPS tracking data: a comparative analysis of Prague and Pilsen. Cities 86, 145–153. https://doi.org/10.1016/j.cities.2018.09.011.
Siren, A., Haustein, S., 2015. What are the impacts of giving up the driving licence? Br. J. Soc. Work. 35 (9), 1821–1838. https://doi.org/10.1017/S0144686X14000610.
Social Exclusion Unit, 2003. Making the Connections: Final Report on Transport and Social Exclusion. Office of the Deputy Prime Minister.
Stanley, K., Yoo, E.-H., Paul, T., Bell, S., 2018. How many days are enough?: capturing routine human mobility. Int. J. Geogr. Inf. Sci. 32 (7), 1485–1504. https://doi.org/10.1080/13658816.2018.1434888.
Struffolino, E., Bernardi, L., 2017. Vulnerability of Lone Mothers over the Life Course in Switzerland. In: Project: Lone parenthood in the XXI century. Lives Working paper 2017/60. https://www.centre-lives.ch/fr/bibcite/reference/83. Accessed 27 September 2021.
Tagai, G., Bernard, J., Šimon, M., Koós, B., 2019. Two faces of peripherality: labour markets, poverty, and population dynamics in Hungary and Czechia. Reg. Stat. 8 (2), 19–45. https://doi.org/10.15196/RS080204.
Treanor, M.C., 2018. Income poverty, material deprivation and lone parenthood. In: Nieuwenhuis, R., Maldonado, L.C. (Eds.), The Triple Bind of Single-Parent Families. Resources, Employment and Policies to Improve Well-Being. Policy Press, Bristol, Chicago, pp. 81–100.
Vecchio, G., Martens, K., 2021. Accessibility and the capabilities approach: a review of the literature and proposal for conceptual advancements. Transp. Rev. 1–22. https://doi.org/10.1080/01441647.2021.1931551.

Vitale Brovarone, E., 2021. Accessibility and mobility in peripheral areas: a national place-based policy. Eur. Plan. Stud. 1–20. https://doi.org/10.1080/09654313.2021.1894098.

Ward, M.R.M., Somerville, P., Bosworth, G., 2013. 'Now without my car I don't know what I'd do': the transportation needs of older people in rural Lincolnshire. Local Econ. 28 (6), 553–566. https://doi.org/10.1177/0269094213495232.

Yigitcanlar, T., Mohamed, A., Kamruzzaman, M., Piracha, A., 2019. Understanding transport-related social exclusion: a multidimensional approach. Urban Policy Res. 37 (1), 97–110. https://doi.org/10.1080/08111146.2018.1533461.