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EDITED BY
Elisabeth Süßbauer,
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REVIEWED BY
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Aya Yoshida,
National Institute for Environmental Studies (NIES), Japan

*CORRESPONDENCE
Saga Sofia Santala
✉ saga.santala@aalto.fi

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Designing social behaviour change in households: sustainable mobility intervention and follow-up study

Saga Sofia Santala[1,2]*, Merja Honkanen[3], Michael Lettenmeier[2,4,5], Jari Kolehmainen[4] and Salla Lahtinen[4]

[1]Strategic Foresight, Strategy and Transformation, KONE Corporation, Espoo, Finland, [2]NODUS Sustainable Design Research Group, Department of Design, School of Arts, Design and Architecture, Aalto University, Espoo, Finland, [3]Strategic Design, Technology and Innovation, KONE Corporation, Espoo, Finland, [4]D-mat Ltd., Helsinki, Finland, [5]Division of Sustainable Consumption, Wuppertal Institute for Climate, Energy and Environment, Wuppertal, Germany

Limiting global warming to 1.5 degrees requires consistent action by people to change their lifestyles in order to limit annual household-related carbon emissions to 2.5 tonnes per person by 2030. As the required mobility reduction measures have already been identified, the challenge remains in scaling up the changes into a mainstream practice. Our study explored whether the involvement of close social communities, especially households, in the change process could be effective in achieving the required measures. Through a Climate Puzzle game intervention and a six-month follow-up study with 12 households in Espoo, Finland, we investigated the role of close social communities in implementing the planned sustainable mobility behaviour change. The findings are presented through 12 household narratives. These narratives show that the adoption of new sustainable mobility behaviours is influenced by both (infra)structural and social relationship factors and that close social communities can hinder or facilitate the shift of everyday mobility behaviours towards being more sustainable in diverse ways. The findings suggest that design interventions should target larger social communities rather than just individuals in order to achieve the 2.5 tonne target. The study also indicates that socially tailored interventions and low-carbon solutions should be developed and targeted at city districts to help households create and maintain lifestyle changes.

KEYWORDS

1.5 degree lifestyles, sustainable mobility transition, household travel behaviour, close social community, design for behaviour change, design game, intervention, follow-up study

1 Introduction

To respect planetary boundaries, an annual lifestyle carbon footprint (LCF) limit of 0.7 tonnes CO_2e per person must be achieved globally by 2050, with an interim target of 2.5 tonnes per person by 2030 (Akenji et al., 2021). In Finland, achieving the 0.7 tonnes target will require a 93% reduction in the current CO_2e footprint. Mobility—referring here to moving from A to B—accounts for 38% of the current LCF and therefore necessitates specific mitigation measures. As the required mobility emission reduction measures have already been identified, such as switching to electric vehicles, shared mobility and remote work, the remaining challenge is to scale up the adoption of these sustainable mobility practices.

Research on sustainable mobility behaviour change and related interventions have primarily focused on individual behaviours and approaches to change, which practice theorists

have critiqued for not addressing the complex dynamics of socially interconnected (mobility) practices and achieving the required change (Spurling et al., 2013; Shove et al., 2012). It has been suggested that identifying and engaging influential communities is a potential means of shifting mobility practices towards more sustainable (Nielsen et al., 2021; Brynjarsdottir et al., 2012). However, comprehensive knowledge and methods to understand the impact of social communities on promoting sustainable mobility practices are still needed.

This paper explores whether the involvement of close social communities could effectively achieve the required change. Close social communities are defined as groups that are in regular contact and that have a sense of belonging. Using a Climate Puzzle game intervention (Nielsen et al., 2021), 12 households from Leppävaara and Espoonlahti in Espoo, Finland, were engaged in discussions among household members about their daily mobility practices. Leppävaara, an established district with rail connections, and Espoonlahti, a developing district with a new metro extension, were chosen for their high car use rates as well as diverse socio-economic demographics and transport infrastructure. Followed by a six-month follow-up study, we examined the role of the close social community, especially the household community, in implementing the planned sustainable mobility behaviour changes and assessed the potential of the Climate Puzzle intervention to drive the required change.

The paper first reviews the discourse on sustainable mobility behaviour change, emphasising the influence of close social communities on achieving a 2.5 tonne lifestyle by 2030. It then describes the design for behaviour change approach using the Climate Puzzle intervention and a mixed-method follow-up study. This illustrates the impact of close social (household) communities in shaping people's daily mobility practices through narrative descriptions of 12 households in Espoo. Finally, implications are drawn for designing sustainable mobility behaviour by discussing the social factors that affect mobility behaviour at different levels, from the close social community to the broader district and city level.

2 Background

Here we describe the current discourse on 1.5 degree lifestyle targets in the context of sustainable mobility. We frame the problem space and highlight the need for understanding mobility behaviours, and what is required to change them, from a social perspective for achieving the required change towards a 2.5 tonne lifestyle by 2030.

2.1 Requirement for lifestyle changes

The international climate debate has increasingly recognised the role of lifestyle changes in meeting the goals of the Paris Agreement (UNEP–United Nations Environment Programme, 2020). Current lifestyle carbon footprints (LCFs) far exceed the levels needed to meet the 1.5 degree climate target, particularly in high-income countries (Akenji et al., 2021). In Finland, a 74% reduction in average LCFs is required by 2030, with similar reductions required in other high-income industrialised countries and significant reductions required in many middle-income countries. Mobility, a major contributor to LCFs, often exceeds one-third of the total LCF in high-income countries. This means that mobility alone could exceed the target level of 2.5 tonnes per person per year for total LCFs by 2030. The high share of private vehicle emissions is due to a significant overall demand for transportation with a high reliance on car use and carbon-intensive air travel. In Finland, the average reduction target for private transport is over 80%, with car use being a major contributor to the current unsustainable situation. Car use comprises the greatest share (55%) of the average personal transport carbon footprint in Finland, and car use alone accounts for 21% of the LCF of the average Finn (Akenji et al., 2021).

Sustainable mobility seeks to ensure that transport systems fulfil society's economic, social and environmental requirements while minimising negative impacts (Council of European Union, 2006). Traditional sustainability models, which distinguish between economic, environmental and social dimensions, have been critiqued for understating the environmental significance, the foundation of all human activity (Giddings et al., 2002; Kuhlman and Farrington, 2010). This has led to the concept of ecological sustainability, which emphasises that human activities should remain within nature's carrying capacity, thereby preserving vital ecosystems (e.g., Hirvilammi, 2015).

Finland's public transport infrastructure is well-developed. It includes a variety of modes such as buses, metro networks, light rails, city bikes and special mobility services for elderly people and people with severe disabilities. The country places a strong emphasis on sustainability and efficiency in its transport system, which is known for its punctuality and comfort. Depending on trip length, a single ticket for adults costs EUR 2.95–4.50 and a season ticket EUR 55–100 per month. In comparison, the total monthly costs of owning and using a car in Finland is estimated to be approximately EUR 500, including expenses such as fuel, insurance, maintenance and depreciation. Espoo, located in the capital area, is the second largest city in Finland. It has a long tradition of private car ownership which is strongly supported by its road infrastructure and rooted in local social norms. In 2023, the mode share for trips in Espoo was 40% by private cars, 20% by public transport, 30% by foot and 9% by bicycle. Annually, there are a total of 1.6 billion kilometres of car journeys in Espoo (City of Espoo, 2024).

Reducing car-based mobility and encouraging a shift to more sustainable travel modes is essential for lowering transport-related LCFs (IGES–Institute for Global Environmental Strategies, Aalto University, and D-mat Ltd, 2019). The transition to sustainable mobility patterns, especially in high-income countries, is long overdue, when considering the urgency of limiting global warming to 1.5°C. This transition involves understanding how individual mobility is a practice that is shaped by cultural influences rather than solely focusing on individual decision making (Barr, 2018). Examining how society affects mobility and promotes hypermobility reveals how provisioning systems have steadily increased the level of car dependency (Barr, 2018; Mattioli et al., 2020), of which Espoo is a good example. Brand-Correa et al. (2020) explain that the development of provisioning systems has made mobility a particularly challenging sector for climate change mitigation. In highly mobile, car-oriented OECD countries, changes in personal mobility are often restricted by real or perceived external constraints (Moriarty and Honnery, 2021). However, since most mobility-related emissions occur during the use phase (Sala and Castellani, 2019), considering mobility practices on a behavioural level is crucial in order to achieve a transition to sustainable mobility. Encouragingly, studies show that

many people experience improved quality of life when adopting a 1.5 degree lifestyle (Leiviskä, 2021; Vänttinen, 2021).

2.2 Importance of social community-based research

Previous attempts and established policy approaches to decarbonise transport have targeted especially individuals as responsible for their actions. Here human action is framed as a matter of individual choices, and behaviours are seen to result from attitudes (Shove, 2010). The limited success of interventions following from this framing and failure to drive broader sustainable mobility transitions, calls for 'an alternative approach to human action to inform interventions' (Watson, 2012). We follow the suggestion to address the broader social structures and environments that shape actions (Hoolohan and Browne, 2020; Schwanen et al., 2012) by exploring a less researched close social community approach in the attempt to decarbonise mobility practices. Next, we build our argument by highlighting the potential of such an approach based on existing literature.

Previous research on changing travel behaviour has focused on predicting individuals' mobility behaviour based on diverse factors such as age, gender, income, reason for travel, travel time and cost, and transportation environments (Ding and Zhang, 2016; Le et al., 2018; Cools et al., 2010). Subsequent studies have included personal habits, emotions, inertia, perceptions, attitudes, preferences, the role of satisfaction and past behaviours in mobility mode choice, and other socio-psychological factors to better predict mobility behaviour (De Vos et al., 2016; Légal et al., 2016; Rieser-Schüssler and Axhausen, 2012; Şimşekoğlu et al., 2015; Wang et al., 2021). Finally, the requirement to understand how social relations shape travel behaviour has been emphasised (Wang et al., 2021, para. 1), and theories of social practice have been suggested as an alternative way of understanding human action and transitioning towards sustainable mobility practices (Watson, 2012).

Research indicates that mobility behaviours are strongly associated with close social communities, such as households and families (Berg and Henriksson, 2020; Rau and Sattlegger, 2018), in which various boundaries and interdependencies influence daily mobility practices (Santala et al., 2024). For instance, a study by Chakrabarti and Joh (2019) shows that couples in dual-earning heterosexual households with young children use cars more often and use active travel modes (walking and cycling) and public transport less compared to those couples without children. A specific decline has been identified when couples transition to parenthood, with a further decline when their children turn school age (Chakrabarti and Joh, 2019). This shows that the constant flux in community compositions expose community members for changes in practices. On the other hand, Lin et al. (2018) highlight that also residential relocation and changes in social surroundings (personal networks and neighbourhood environments) can also expose individuals to changes in mobility practices.

Also, travelling as a group exposes individuals to different mobility practices. Zhang et al. (2018, p. 42) have investigated group travel behaviour, defined as 'two or more persons intentionally travelling together from a single origin to a single destination'. They suggest that group travel behaviour differs from individual travel behaviour across time and space. They also identified that group travel typically occurs during weekends, afternoons and on public holidays. Lorenzo et al. (2012) demonstrate the advantages of incorporating group travel histories into individual travel predictions. Gardner (2014) investigated how neighbourhoods as social and physical environments influence community mobility—moving from one community to another (Highton, 2000)—and highlights identity and social engagement as important social factors and strong motivators in community mobility, especially among older adults.

Also, norms and practices are highlighted as social aspects that form people's mobility patterns. For example, materials, meanings and competences are introduced as relevant elements that shape human action in practice theory (Shove et al., 2012). From a social perspective, meanings in particular can be seen to result from social encounters, motivating spatio-temporal movement. Then again, many competences are transferred from generation to generation, such as ways of refuelling a car or repairing a bicycle. Also, materials, such as a shared family car, are made available by community members. Accordingly, people's mobility practices are interconnected and influenced by their life situations and close social communities, such as family, friends and colleagues (Rau and Sattlegger, 2018; Santala et al., 2024).

The examples above show that transitioning to sustainable mobility is not solely an individual choice but is influenced by socio-cultural processes and personal and social factors (Gifford and Nilsson, 2014). Hence, building on this existing literature and a practice theoretical approach to human action, we frame behaviour as a matter of a performance of a socially shaped practice bound to an individual's close social community context. We take the stance that individuals' practices cannot be changed as separate from their social context, including the interdependencies among close community members and their interlinked practices. However, new knowledge and methods are needed to understand how travel behaviour (change) unfolds within social communities to identify both social matters that tie people to unsustainable patterns of travel as well as potential points of intervention into these practices. Our paper advances this knowledge by showing how social dynamics, interdependencies and interaction among close social community members in the context of Espoo impact how they implement new collaboratively negotiated mobility patterns in their daily lives.

2.3 Design for behaviour change approach

Studying behaviour change in the highly dynamic mobility and close social community context is challenging and methods for this are lacking. Taking an interventionist approach and intervening into communities' practices allows identifying how interdependencies among close social community members support (un)sustainable ways of travelling and can thereby reveal 'foothold for change' (Kent, 2022). Therefore, we adopt a Design for Behaviour Change (also behavioural design) approach to explore how to facilitate the transition to sustainable mobility practices within close social communities. Unlike traditional design approaches that focus on creating products to satisfy needs, behavioural design aims to influence behaviour through targeted interventions (Cash et al., 2020; Khadilkar and Cash, 2020). These interventions can range from micro-scale interventions (e.g., apps targeting individual behaviour) to macro-scale interventions (e.g., taxation or changes to cultural norms).

For our study, meso-scale interventions, which target social communities, are particularly compelling. We have identified the community-targeted intervention called Climate Puzzle as a novel method for investigating how (un)sustainable mobility behaviours unfold through social interaction within close social communities such as households. This design game incorporates gamified elements (Vaajakallio, 2012) and serves as a tool for dialogue, negotiation and collaborative planning among community members. Members select actions and design pathways to implement sustainable lifestyle practices in their daily lives. As behaviour change fundamentally includes a transformation of practices on a time continuum, the game is especially useful for our (follow-up) study as the incorporation of pathways allows investigating the implementation of selected actions and thus communities' sustainable practice transitions over time.

Originally developed to support households achieve a 1.5 degree lifestyle (Nielsen, 2020), the puzzle format and negotiation-based community engagement allow us to also explore how transport practices connect to other practices such as shopping, parenting and caring in the selected communities. This approach identifies the complex interlinkages between practices that bind community members to unsustainable mobility patterns. As such it can reveal new opportunities for effective interventions that consider the broader social community, an aspect that is often missing in existing interventions (Brynjarsdottir et al., 2012; Niedderer et al., 2014). The game also represents a multifaceted practice-based 'sustainable mobility intervention' (Santala et al., 2024) aimed at reducing car use and promoting alternative sustainable mobility practices. It influences households' current mobility practices and provides strategies and alternative behaviours that align with a 2.5 tonne lifestyle.

Simultaneously, taking an interventionist approach allows us to investigate the efficiency of an existing community-level intervention (the Climate Puzzle game) to explore whether a close social community approach can be effective in promoting transitions towards sustainable mobility practices. In general, the efficiency of behaviour change interventions is measured by their ability to shift behaviours in the desired direction. This raises ethical questions about what constitutes desirable change and who should decide this (Niedderer et al., 2014). Ethical considerations are crucial, particularly regarding who determines desirable behaviours and whose interests and responsibilities are involved in designing such interventions. Critiques of behavioural interventions often highlight the lack of user involvement in defining desirable changes, and the focus on individuals rather than communities, which can achieve more effective behaviour changes using collective approaches (Brynjarsdottir et al., 2012). The Climate Puzzle game shifts the power dynamics from top-down to bottom-up, giving those communities that are affected by change an active role in planning and implementing desirable changes. Hence, we approach ethics from an individual and community perspective, using a normative target for an overall reduction in lifestyle carbon footprint (IGES–Institute for Global Environmental Strategies, Aalto University, and D-mat Ltd, 2019).

Our study aims to shed new light on how close social communities affect the implementation of planned sustainable mobility behaviours and how this influences the design of sustainable mobility behaviour change. Firstly, this paper aims to describe ways in which close social communities enable or prevent individuals from changing their mobility behaviours. Secondly, we reflect on ways in which the social context should be considered in designing effective interventions for sustainable mobility practices.

3 Materials and methods

In this study, we used the Climate Puzzle game intervention (Nielsen et al., 2021; Nielsen, 2020) together with a follow-up study to understand how sustainable mobility practices unfold through interaction within close social communities. We begin by detailing the Climate Puzzle method followed by the mixed method (George, 2021) data collection and analysis process.

3.1 Climate Puzzle design game intervention

The Climate Puzzle game consists of a two-sided game board, a marker for target CF for 2030 and 2050, a marker for the players' current CF level (based on a preliminary CF survey) and lifestyle action cards (Figure 1). At the time of this study, the game included 101 different lifestyle actions, such as 'I work remotely' and 'I use muscle power for short trips'. The actions extend across four domains of consumption: housing; mobility; food; and goods, services and leisure. A total of 33 mobility action were available.

Before the game, the participants complete a preliminary CF survey via a weblink. Then, based on the survey results, during the game, the participants first mark their current CF level and the per person societal target CF level for 2030 and 2050 on the game board. They then choose lifestyle action cards and place them on the game board (Figure 2, left). The cards are in four different size

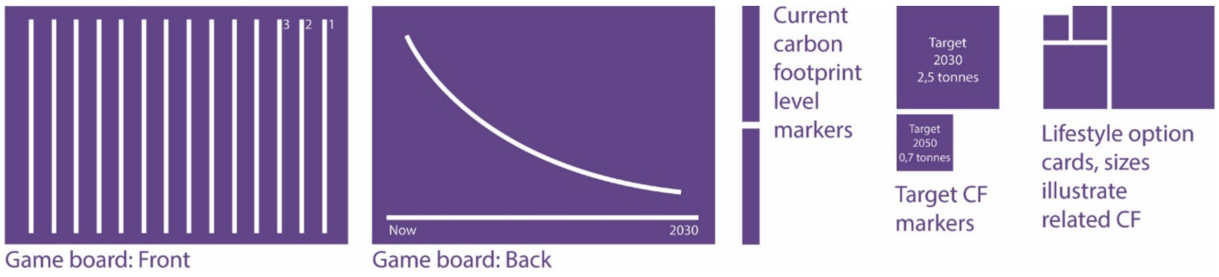

FIGURE 1
The Climate Puzzle game elements.

FIGURE 2
(Left) The household's baseline CF level is marked with two grey pieces on the left-hand side of one side of the game board. The per person societal target CF is represented by an orange card for 2030 (2.5 tonnes) and a black card on top of it for 2050 (0.7 tonnes). (Right) The collaboratively planned pathway of one of the households illustrates the order of implementation of the planned lifestyle actions from 2020 to 2030 on the other side of the game board. Mobility-related actions are represented by blue cards.

groups depending on their average CF impact. The aim is for the household to lay as many cards on the game board as necessary to reach the 2.5 tonne carbon footprint target by 2030 and 2050. Following this, the board is turned around, and the chosen cards are distributed on a timeline to create a pathway for the participants to implement these measures towards a sustainable lifestyle (Figure 2, right).

3.2 Data collection and analysis process

The data collection process comprised eight stages (Figure 3): (1) the recruitment of Leppävaara and Espoonlahti citizens, (2) a preliminary lifestyle CF survey with the selected participants ($n = 26$), (3) a separate Climate Puzzle workshop for Leppävaara ($n = 12$) and Espoonlahti ($n = 14$) participants with their household members, including a preliminary interview for a follow-up study with each household at the end of the workshop, (4) selecting households ($n = 12$) for the follow-up study, (5) a follow-up lifestyle CF survey and an implemented actions survey with the follow-up households, (6) a 30–60-min follow-up (group) interview with each follow-up household, (7) collaborative development of household narratives by seven researchers, and (8) a clustering activity to identify recurring themes.

First, 26 households from Leppävaara and Espoonlahti were recruited by a recruiting company through an invitation shared in selected Facebook groups including 31,400 members as well as with 600 panel members of the recruiting company. Purposive sampling was utilised to ensure diversity of demographics, household composition, and attitudes towards sustainable development.

Second, a carbon footprint survey was conducted with the 26 selected households to measure their current CF level. The survey consisted of 32 questions on five consumption domains—housing, mobility, leisure, food, and goods & other—plus background questions such as information on household members. The current CF was then calculated with the 'consumption x intensity' principle, where the survey responses provided the consumption behaviours and the (carbon footprint) intensities were based on national or city-level averages. Results were shared with participants, who were then invited to a workshop.

Third, two 2,5-h Climate Puzzle workshops were conducted in November 2021: one with Leppävaara households ($n = 12$) and one with Espoonlahti households ($n = 14$), involving 44 citizens. The workshops followed the Climate Puzzle design game structure described above. Each household sat among their own members and collaboratively selected actions and designed pathways for achieving carbon reductions in their daily lives. The game exercise focused on identifying actionable carbon reduction measures based on the societal per person target CF relative to their own levels. Short interviews were conducted at the end of the workshops with each household to discuss chosen actions and thoughts on the upcoming implementation phase.

Fourth, 12 households (six from Leppävaara and six from Espoonlahti) were selected for the follow-up study conducted in May 2022 (Table 1, participant demographics). These households were chosen because during the workshop they selected a high number of mobility-related lifestyle changes on their pathways for 2021 and 2022 (the follow-up phase) and demographic diversity (especially the type of household and family unit represented, age, and current level of sustainability). The sample, consisting of six families, four couples and two single households, reflects fairly well the household composition statistics of Leppävaara and Espoonlahti—Leppävaara with many single-person households and Espoonlahti with more families with children and elderly couples. This selection allowed us to examine how different types of social communities shape mobility practices and describe the mechanisms of change in diverse households in Espoo, including those of more isolated individuals. Rather than representing the average Finnish population, which increasingly consists of single-person households and smaller families, the study focused on the dynamics within these varied households.

Fifth, a follow-up lifestyle CF survey and implemented actions survey were conducted to identify the implemented lifestyle changes. In the implemented actions survey, households could estimate whether their actions were not implemented, partly implemented or wholly implemented. A comparison was performed between self-reported before and after CF values collected from November 2021

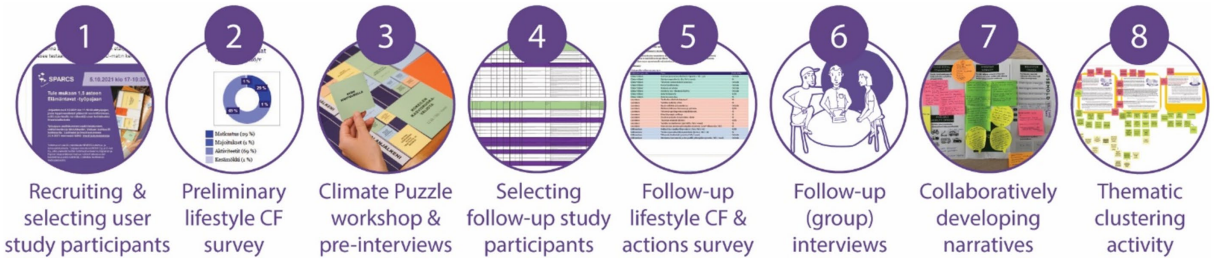

FIGURE 3
The eight stages of the data collection and analysis process.

and May 2022 from the households that played the Climate Puzzle game. The comparison provided an indicator that some changes occurred in the households' mobility patterns since they became aware of possible strategies to reduce their CF. The survey results and comparison provided a starting point to inform and guide the exploration of mobility behaviour during the qualitative interviews.

Sixth, at the end of the six-month follow-up period, semi-structured online thematic group interviews lasting from 30 to 60 min were conducted with each household. One to three household members participated in each interview. The purpose was to study the impact of the participants' social context on implementing their planned lifestyle changes. The thematic group interview method, suitable for gathering information on social environments (Hirsjärvi and Hurme, 2011), replicates real-life group interactions in which behaviours are formed. Both the design game and the interviews provided insights from the younger participants, supporting the inclusion of this often-marginalised group in studying social behaviour change.

Seventh, after the follow-up interviews, 12 household narratives were collaboratively developed in two co-analysis workshops held with seven researchers based on the collected research materials. These included images from the Climate Puzzle game activities, interview transcripts and the quantitative carbon footprint and implemented actions survey results. These researchers, who were familiar with the 1.5-degree lifestyle workshops and the follow-up interviews, analysed the materials using the Comparative Ethnographic Narrative Analysis Method (Saint Arnault and Sinko, 2021). Each researcher reviewed 1–2 interview transcripts, including the supportive material mentioned above, and marked the relevant content using a paper analysis template. The template included sections for identifying social communities, available mobility options, everyday mobility characteristics, CF measures, transitions related to the selected sustainable mobility actions and key quotes.

The dimensions that were identified and later compared included the participants' descriptions of their sociocultural context, i.e., the close social communities and everyday social interactions in which their mobility behaviours take place. To differentiate the behavioural changes between circumstances and active lifestyle changes, one researcher searched for similarities in the interview material for each observed carbon footprint change by placing the responses from the first and second questionnaires side by side in a table. Each change was reviewed using the interview data to determine the reason for the change and also validate and refine the CF data to increase its reliability. Only the changes that could not be attributed to circumstantial, seasonal or other similar factors were interpreted as changes resulting from the intervention. Based on the analysis, drafts for 12 household narratives were collaboratively developed and then finalised by two researchers (see Section 4, Results).

Eighth, a three-hour collaborative analysis using an online whiteboard platform was then held to identify recurring themes based on the narratives. Thematic clustering revealed factors that influenced changes in behaviour towards sustainable mobility at individual, household, community, district and city levels (see Section 5, Discussion).

4 Results

Here we provide narrative descriptions of the 12 households. The narratives illustrate the household members' close social community and ways in which their everyday mobility behaviours and related change unfold in relation to each other and their broader sociocultural environment. The narratives are built around the mobility actions chosen by each household in the Climate Puzzle workshops (see Appendix for list of selected actions). The households chose from 1 to 12 mobility actions for their pathway from 2021 to 2030. The paper focuses on the mobility actions in which the interaction among and the impact of the close social community were most present to highlight the social factors that maintain existing or shape new mobility practices, regardless of the original timeframe for implementation. These actions are presented in ***bold italics*** in the narratives, followed by households' follow-up survey answers about implementation of selected actions in ***(brackets)***.

4.1 Households in Leppävaara

First, we provide narrative descriptions of the six Leppävaara households. Leppävaara is an established urban area with good train connections. It is built around a large shopping centre, Sello, which includes a wide array of shops and services. The area is characterised by a high proportion of single households, including students and pensioners. With more public transportation options and less free parking space provision, Leppävaara has a relatively low mobility carbon footprint compared to Espoonlahti.

4.1.1 Household 1. Car-dependent trip-combiner

'Anni' (68) lives alone, and her close social community consists of her daughter, two granddaughters, and neighbours (Figure 4). She

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TABLE 1 Leppävaara and Espoonlahti household demographics and change in mobility CF.

Household ID	Household members*	Household type	Type of housing	Modes of mobility	Mobility CF: baseline to follow-up (tonnes)	Mobility CF difference (%)
Leppävaara households						
H1	**Woman, 67**	Single	Own apartment (terraced house)	Car (driver)	10.7–8.9	↓ 16.8%
H2	**Woman, 35** **Man, 36** **(Child, 6)** **Child, 1**	Family	Rental apartment (apartment building)	Car (driver), micro-mobility (walking, cycling, electric scooter, other)	4.8–6.7	↑ 39.6%
H3	**Man, 37**	Single	Rental apartment (apartment building)	Car (driver)	1.9–0.6	↓ 68.4%
H4	**Man, 41** (Woman, 37) (Child, 8)	Family	Rental apartment (apartment building)	Micro-mobility (walking, cycling, electric scooter, other)	1.8–2.7	↑ 50%
H5	**Woman, 57** **(Child, 15)**	Family	Right-of-occupancy apartment (terraced house)	Car (driver), micro-mobility (walking, cycling, electric scooter, other)	2.5–1.9	↓ 24%
H6	**Woman, 25** (Woman, 19)	Couple	Rental apartment (apartment building)	Car (passenger), bus, train	1.7–0.4	↓ 76.5%
Espoonlahti households						
H7	**Woman, 35** **Child, 13** **Child, 11**	Family	Own apartment (apartment building)	Car (driver), car (passenger), bus, metro	4.5–4.8	↑ 6.7%
H8	**Woman, 53** **Man, 56** (Child, 16) (Child, 12)	Family	Own apartment (detached house)	Car (driver), car (passenger), micro-mobility (walking, cycling, electric scooter, other)	–	–
H9	**Woman, 28** **Man, 30**	Couple	Own apartment (apartment building)	Car (passenger), bus, micro-mobility (walking, cycling, electric scooter, other)	2.8–0.9	↓ 67.9%
H10	**Man, 62** **Woman, 59** (Child, 17)	Family	Rental apartment (apartment building)	Car (driver)	2.2–2.7	↑ 22.7%
H11	**Man, 41** (Woman, 35)	Couple	Right-of-occupancy apartment (terraced house)	Car (driver)	13.4–13.9	↑ 3.7%
H12	**Woman, 56** (Man, 59)	Couple	Own apartment (apartment building)	Car (driver), car (passenger), bus, metro, micro-mobility (walking, cycling, electric scooter, other)	7.2–3.9	↓ 45.8%

*Household members who participated in the workshop are shown in bold. Household members who did not participate in the follow-up interview are shown in parentheses.

visits her family once a month by car, and her neighbours multiple times a week.

I switch to a plug-in hybrid (no). Anni currently has a part-time job, which includes meeting with customers throughout the capital region of Uusimaa. Her employer requires work journeys to be done by car, so switching to public transport is not an option. At the same time, due to financial constraints she is unable to buy a low-carbon car. Her upcoming retirement also influences her decisions:

> *I'd buy a plug-in hybrid as soon as I had the money. I've still got something like 25,000 on the clock. My car's only worth five or six thousand euros because it's so old, and plug-in hybrids are at least 30 thousand. I just don't have the money. That makes me think about what I'll do when I'm no longer working. Am I going to live out here [Leppävaara outskirts] in the middle of nowhere, or should I move to the city and use public transport? I don't know. I can't decide. ('Anni', 68)*

FIGURE 4
Illustration of Household 1.

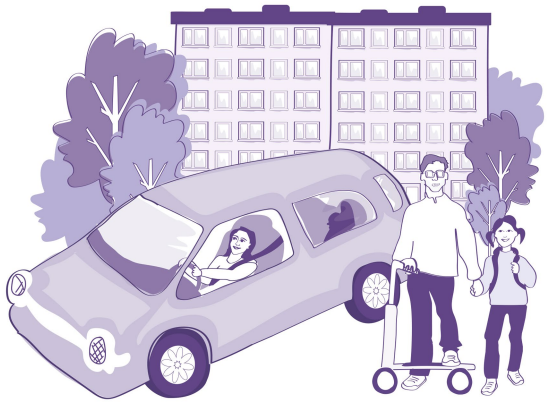

FIGURE 5
Illustration of Household 2.

I combine trips (yes). Anni combines her private long-distance journeys and work trips: she plans to visit her family according to wherever her working day will end, and she can also plan the last location. Similarly, her family combines trips when visiting her. She walks short distances, e.g., to the shops.

During the study, her household mobility carbon footprint decreased from 10.7 to 8.9 tonnes. As she did not report lifestyle changes during the study, the decrease is a result of seasonal or other changes in driving distance. Her travel distance and private driving practice are mostly affected by her employer, family and financial aspects.

4.1.2 Household 2. Disabled multi-located forerunner family

The family includes a mother (35), father (36), and two children (6 and 1) (Figure 5). The parents are private entrepreneurs who work at least partly remotely, and they have a wide close social community, including family in Northern Finland, kindergarten parents, neighbours, and the father's regular massage customers.

I use an e-scooter (partly). The father's visual impairment significantly affects the family's mobility. The mother is the 'designated driver' of their estate car, whereas available mobility options for the father are bicycle, personal e-scooter, and taxi due to the taxi vouchers he gets. These provide the father independence, for example, in taking the children to hobbies by himself:

> *We now go to parkour by taxi, as the kindergarten friend of [daughter, 6] also goes with us. (Father, 36)*

I order groceries home (partly). Ordering home delivered groceries was a new option the family adopted during the follow-up period. Instead of driving weekly to the supermarket, they successfully tested a robot grocery delivery:

> *Very funny and very chaotic—the robot came faster than it should have, I was in a video meeting. I had a little one yelling under one arm, a bigger child wanting to see, a robot playing me a serenade, and a meeting going on… (Mother, 35)*

The family is a group of forerunners interested in new sustainable innovations and practices and promoting them to others in practical, everyday ways with their close social community. They do not pressure others to change or get discouraged if their close social community criticises their progressiveness.

During the study, the household's mobility carbon footprint increased from 4.8 to 6.7 tonnes. The increase was due to flying to the north, where the family typically spends half of the year visiting extended family. However, the small carbon footprint of their everyday mobility continued to decrease, which can be seen as resulting from active change.

4.1.3 Household 3. Sparing public transport commuter

'Tomi' (37) lives by himself (Figure 6). His close social community consists of neighbours, colleagues (who also use public transport), and his relatives who live some distance away in the country (who use private cars).

I swap driving for public transport (yes). During the follow-up period, he switched to using public transport after his previous expensive rental car contract ended. For his IT support work, he now travels to customers by public transport when issues cannot be solved by phone. He finds this convenient. His employer affects his mobility choices significantly:

> *[Colleagues and friends] do not [affect my mobility choices]. I choose the cheapest option that works … But my employer has an influence, because they provide me with the public transport tickets. ('Tomi', 37)*

Giving up the car has made journeying to his hometown in the evenings slightly more challenging as local buses run infrequently, so a family member sometimes must get him from the station. He then prefers getting a lift instead of taking public transport. In general, his consumption choices are driven by his low salary and desire to live frugally. However, through the intervention, his attitude has changed, and, according to him, he has noticed that small things matter when aiming to live sustainably.

During the study, his household mobility carbon footprint decreased from 1.9 to 0.6 tonnes due to giving up private motoring. This was strongly affected by his employer and financial aspects.

10.3389/frsus.2024.1469285

FIGURE 6
Illustration of Household 3.

FIGURE 7
Illustration of Household 4.

4.1.4 Household 4. Family with relatives in two countries

The household includes a father (41), mother (37) and daughter (8) (Figure 7). The family's close social community is formed by the household members, the father's mother living in another city, and the mother's family living abroad. The household did not plan or pursue many, if any, mobility actions during the study period.

As a household with relatives in two countries, they intend, and have already started, to travel abroad more now the COVID-19 restrictions are removed. The father considers flying to be contradictory to his environmental aspirations, but finds justification for the trips in their lower daily commuting emissions:

> *But here I just had an idea that if… As we have now moved closer to basic services, as a result we can then make longer holiday trips with a good conscience. Let's put it this way. It sounds reasonable as a whole, I guess. If you think of an ideal life. Like, living locally, and then everyday life would include as short trips as possible, and then holidays are a separate thing. (Father, 41)*

I work remotely (partly). Both parents study, the father remotely and the mother—after a recent shift from remote to onsite studying—in contact teaching in the centre of Helsinki. The mother travels there by train. The household does not have a car, which the father describes as possible due to good public transport connections in the city of Espoo.

During the study, the household's mobility carbon footprint increased from 1.8 to 2.7 tonnes. The increase was due to flying more and shifting from remote studies to studying on campus, both due to the removal of COVID-19 restrictions. Extended family strongly impacts their desire to travel abroad.

4.1.5 Household 5. Everyday cyclists

Mother (57) and daughter (15) form a two-person household, whose close community consists of the mother's own mother living in the same city, and the daughter's friends from school and sports (Figure 8).

I use supervised bike parks (yes). As everyday cyclists, the family experimented with cycling-related actions, broadening the opportunities and infrastructure that cycling offers in a city. The mother had been familiar with the guarded bike parks but chose not to use them previously. She describes her new attitude as follows:

FIGURE 8
Illustration of Household 5.

> *Well, I don't constantly leave it in that exact bike park, but I don't remember using it before. It's not very attractive. I tend to prefer to leave my bike in a place where it can be locked and where people move around quite a lot, which is somehow visible. But it could be that it [using bike parks] has had a slight effect. (Mother, 57)*

I become a winter cyclist (partly). The family also experimented with winter cycling during the study. The mother and daughter considered the experiment problematic, mostly because the daughter's bike did not have winter tires. In addition, the mother fell and hurt herself while winter cycling, leaving her temporarily unable to cycle. The interview also revealed that the interest in winter cycling was not unanimous between the household members.

During the study, the household's mobility carbon footprint decreased from 2.5 to 1.9 tonnes. This was due to an overall reduction in everyday and leisure time mobility, such as less driving, less train use, and cycling and walking less. The results were due both to

seasonal and situational changes in mobility routines, such as the mother's cycling injury, and to implementing planned changes. The material aspects of the cycling infrastructure and cycling equipment in the mother-daughter dynamics restricted the adoption of winter cycling as a new practice in the household.

4.1.6 Household 6. Couple travelling together with city bikes

'Jenni' and 'Eeva' (25 and 19) are an active dog-owning couple (Figure 9). Their close community includes parents living nearby, Jenni's 35-member sports team, and other friends. Most frequently Jenni meets her team members. The team has training at least four times a week. The most common way for the whole team to commute to training is carpooling.

I use muscle power for short trips (yes). Despite their minimal everyday mobility footprint, the household is looking for opportunities to reduce car use. The couple is accustomed to using city bikes for shorts trips, especially in summer. They cycle together. Also, their friends are active city bike users. Thus, Jenni would also prefer to cycle to training if there was a city bike station next to the sports hall, or if she got her own bike.

> *Well, I moved to Espoo about a year ago, and before that I lived in Helsinki. So back then I used to… I had my own bike there, and then I used to cycle all the way to work and hobbies and so on. But now that I live here in Espoo, my trips are a bit longer, and I haven't even brought the bike here yet. So I'm just relying on city bikes. ('Jenni', 25)*

I travel less, but I stay for longer (partly). During the study period Jenni experimented with a new approach to holiday travel. Her sports hobby includes travelling to competitions. The team members cannot influence how trips abroad are made as the coaches have chosen flying and are not open to other options. Nevertheless, Jenni and some of her team members decided to stay at the location for longer to combine competition and holiday travelling.

During the study, the household's mobility carbon footprint decreased from 1.7 to 0.4 tonnes. As the couple's everyday mobility carbon footprint was close to zero already in the first carbon footprint survey, and did not increase during the study, the reduction is solely due to changes in free time mobility routines, i.e., favouring a small amount of flying (from 0 to 2 h/y) and train travel (from 20 to 600 km/y) over trips via cruise ships (previously around 10 back-and-forth cruises from Helsinki to Tallinn or Stockholm per year). Shared values and interests among the couple and their friends, as well as the shared decision among team members to stay for longer at their competition destination supported the household members' sustainable mobility behaviours. Also, infrastructure plays a role.

4.2 Households in Espoonlahti

Here, we provide narrative descriptions of the six Espoonlahti households. Espoonlahti is a developing area going through extensive changes, including a new subway extension. A large new shopping centre, Lippulaiva, was opened during the follow-up study in Espoonlahti in March 2022. Espoonlahti has a high proportion of family households and the mobility carbon footprint is higher compared to Leppävaara due to a high level of private motoring.

4.2.1 Household 7. In-between two households

The household of three includes a mother (35) and her daughters (13 and 11) (Figure 10). Their close community includes the daughter's father, his partner, and their children living at a different address. The two households have recently established an every-other-weekend visiting system at the father's place, instead of a week-for-week living arrangement. The kids travel between households by car.

I switch to a smaller car (yes). The household downsized to a smaller car between the interviews, reducing its footprint. The mother had considered buying an electric car, but the tax reliefs offered were not sufficient. When asked if they have an electric car:

> *No, no. But if we could get some support for that, then maybe. Charging and so on. I was considering an electric car, but it seems a bit difficult. (Mother, 35)*

I travel by land (yes). The mother and daughters decided to spend their winter holiday in Lapland instead of travelling abroad. As a result, the family flew less and travelled more by coach. The family was

FIGURE 9
Illustration of Household 6.

FIGURE 10
Illustration of Household 7.

also still planning how they would spend the summer, and the mother estimates that they will, again, most likely stay in Finland.

During the study, the household's mobility carbon footprint increased from 4.5 to 4.8 tonnes. Holiday travel and travelling between two homes strongly impact this household's mobility carbon footprint.

4.2.2 Household 8. Espoo-typical car-driving family with children

The family consists of a mother (53), father (56), two sons (16, 12) and two dogs (Figure 11). Their close social community consists of both parents' mothers, living in the same greater district, and the children's friends.

I use muscle power for short trips (no answer). The parents visit their mothers several times per week, the father by car, the mother by car or walking. The walking ability of the mother's mother is restricted, so the car enables driving to beautiful locations for short walks. The mother also often does shopping for her mother when visiting her. Sometimes she also takes their two dogs with her. As the distance is too long for the dogs to walk or run, she has been considering buying a cargo bike. Both the dogs and her mother influence the mother's mobility choices when visiting her mother:

> *My mother and the dogs affect the choice of mode of mobility fifty-fifty when visiting my mother, as the dogs are very important to my mother. (Mother, 53)*

I switch to a smaller car (no answer). The family downsized one of their three cars during the follow-up period. They still plan to buy a more modern new car, but they will first purchase a temporary manual car for the older son to practice for his driver's licence with the father. Before their sons were born, the parents used to live without a car for some time. Since moving to Espoo they have had several cars, one bought by the mother's father.

I combine trips (–). The father drives to work three days a week and works remotely two days a week, saving him 65 km of driving per day. He uses a car to minimise his commuting time. The father often combines visiting his mother and food shopping with commuting.

No mobility carbon footprint data comparison was available as the family did not fill in the second survey. The family is an Espoo-typical car-driving family who uses the car as default because it makes life easy. There is little opportunity to question their car use, as the family is strongly tied to the existing system. However, the problems of car use are known and sometimes raised by the household, yet facilitating daily life overrules those concerns, including trips with dogs to the mother's physically restricted mother.

4.2.3 Household 9. Modern-day cottage nomads

'Tilda' (28) and 'Arto' (30) are an active couple, whose close social community consists of parents, siblings, and friends (Figure 12). Both sets of parents live close by, and the couple visits them at least once a month, often by car.

I travel less, but I stay for longer (no). The couple has access to five holiday cottages, each a 2–3 h drive away and owned and maintained by their parents and grandmother. The couple visits one of the cottages almost every weekend by themselves by car or with friends (usually carpooling) but not with their relatives. During a typical summer week, the couple drives to one of the cottages, stays there for the weekend, and then drives back for the working week. Otherwise, they could imagine staying longer at each cottage and visiting only one cottage a month. The cottage trips are the biggest reason for owning a car, along with Arto's work. Their social relationships also hinder changing this routine:

> *… we have a car, and it is not so ecological, but for our lifestyle, we couldn't get to the summer cottages [without the car]. So, we kinda have to have it. ('Tilda', 28)*

I use muscle power for short trips (no). The couple often travels together. Within the household, Arto normally drives and Tilda, who also tends to avoid driving alone, gets a lift. Car sharing is also a way of saving compared to buying public transport tickets for both. However, the couple has significantly reduced their everyday driving, and the opening of a new shopping centre close to home is mentioned as one reason. Car use for everyday trips has halved from 10,200 km to 5,100 km per year. The couple has increased walking and cycling by 13 km per week and decreased motoring by 100 km per week. The couple also started to cycle more after Tilda received her parents' old bicycle, enabling them to cycle together. Their parents who gave the bike are also described by the couple as inspirational.

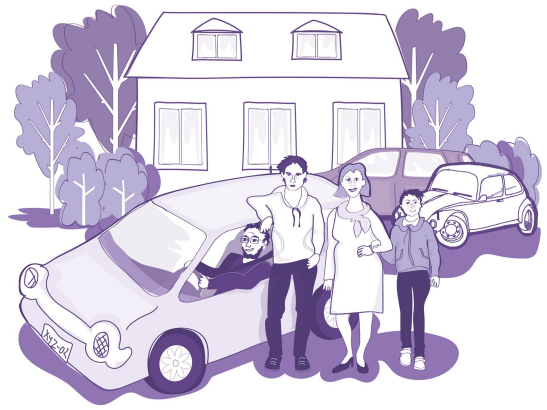

FIGURE 11
Illustration of Household 8.

FIGURE 12
Illustration of Household 9.

During the study, the couple's mobility carbon footprint decreased from 2.8 to 0.9 tonnes. This was mainly due to halving everyday mobility from 200 to 100 km per week. These changes can be linked to extended family, financial aspects, the opening of the new shopping centre in the district, and societal work rhythm and practices.

4.2.4 Household 10. Disability pensioned driver family

The father (62) and mother (59) are on disability pension, and with them lives a son (17) who does not have a driver's licence (Figure 13). Their close social community consists mainly of the parents' three children from previous marriages and two grandchildren, who they visit regularly by car.

I use muscle power for short trips (partly). The couples' typical mobility revolves around running errands and visiting family members. However, a recently opened large shopping centre has changed their mobility routines towards a 'what you cannot get from there, you do not need' ethos. Also, online shopping has reduced their supermarket visits. However, they find visiting the supermarket by car easier due to the father's restricted walking ability:

> *Osteophyte, one and a half years ago. It limits my walking. But the distances we walk are short, so those I manage. (Father, 61)*

I combine trips (yes). The couple always travels together. Household mobility is strongly affected by the father, who is the main driver of their 10-year-old combustion engine car and has an osteophyte that limits his ability to walk. Before the study, the father temporarily lost his driver's licence due to a seizure, but has since got it back. At that time, the couple travelled by bus, with masks, to laboratory tests and the pharmacy. The mother has a driver's licence, but is anxious about driving. With strong sustainability values, the couple negotiates ways to combine supermarket visits and several buying needs at one time, which they have been doing already prior to the study.

The mobility carbon footprint of the household increased from 2.2 to 2.7 tonnes during the study. The household's leisure mobility increased from 400 to 6,000 km and everyday mobility decreased from 6,120 km to 2,040 km. The decrease in everyday mobility resulted from seasonal and situational changes in mobility routines, such as the opening of the new shopping centre in the district, and to implementing planned changes. Extended family and interdependencies among household members strongly shape their mobility practices.

4.2.5 Household 11. Motorized husband and public transport wife

'Leo' (41) and 'Ella' (35) are a married couple (Figure 14). Ella's two sisters live with them temporarily. They have two cars, one from Leo's work and one of their own.

I travel closer to home and by land (yes). Before COVID-19, the couple used to fly a couple of times a year somewhere remote for holidays. Since the pandemic, they have been flying less. However, they are unsure whether this might change back to 'normal' in the future. During COVID-19 they also flew to Lapland, a journey they would have normally done by car. Their choice of domestic flights instead of car journeys is strongly influenced by elevated fuel prices:

> *Maybe during the summer holiday [some domestic car trips] are possibly an idea. But of course, the price of fuel has a bit of an effect, because it has risen so significantly. So if you get cheap flights to Lapland, it's cheaper than going by car. ('Leo', 41)*

I use muscle power for short trips (partly). Leo drives 70 km to work daily, and often goes food shopping after his workday with the work car. Sometimes he uses their own car in the evenings. He only uses public transport when he goes to Helsinki city centre, drinks alcohol, or when car parking is difficult at the destination. Ella mainly uses the subway and bus. She often phones for a lift, and Leo picks her up even when he feels tired after a workday. Leo is willing to combine walking and light shopping, but only in good weather.

The mobility carbon footprint of their household increased from 13.4 to 13.9 tonnes. The increase was mainly the result of increased driving to work. No changes were implemented and, based on the responses, motivation for change appears low. Each of the spouses have their own mobility practices, which sometimes overlap through the practice of caring. Financial aspects and existing routines seem to drive this couple's mobility behaviours more than their interdependencies.

FIGURE 13
Illustration of Household 10.

FIGURE 14
Illustration of Household 11.

FIGURE 15
Illustration of Household 12.

4.2.6 Household 12. Compelled car users and caretakers of the nearest and dearest

The household consists of a wife (56) and husband (59) (Figure 15). The wife's close social community includes her ageing mother and a network of colleagues she is in contact with daily or weekly. The husband's work requires travelling around the country by car to meet clients. Aside from work, the couple travels by car to their holiday cottage and to visit relatives in central Finland.

I work remotely (yes)/I swap driving for public transport (partly). The wife is in a high risk group for coronavirus and works partly from home. When she must travel to her workplace 2 days a week she therefore travels by car. A subway stop is close by, and she hopes to switch to using the subway and bus for commuting in the future. Her everyday mobility is also determined by her ageing mother's reduced mobility, which prohibits her from using public transport. She views transporting her mother to the doctor and to laboratory testing as her 'everyday responsibility' and justifies her car use:

> *No matter what you think about the environment, the climate, our actions, people must be able to care for their loved ones and use exactly the type of transport needed [for that]. (Wife, 56)*

I combine trips (yes)/I use muscle power for short trips (yes). The couple's car is now often unused. During the follow-up period, the wife switched to combining supermarket and pharmacy trips with her work journey and walking to pick up small groceries. She describes wearing a backpack and jogging clothes, so fetching groceries involves not only shopping but also maintaining fitness. The ease and speed of the car are now less prioritised.

During the study, the couple's mobility carbon footprint decreased from 7.2 to 3.9 tonnes. The reduction is due to executing planned actions as well as seasonal and situational variation, such as the improved COVID-19 situation. Social community strongly shapes the couple's travel needs and ways of travelling, whereas mobility practice changes seem to be more linked to personal aspects.

5 Discussion and conclusions

Here we discuss the role of the household and extended close social community in influencing the planned sustainable mobility behaviour change. Based on the narratives, several themes were identified that highlight the varying potential for change in the respective households. We discuss different spheres of measures and suggest that real-life behaviour change requires individual actions, shared actions within the household, as well as other kinds of action, for example, changes in local infrastructure or mobility options. We acknowledge that individual-level transformation to sustainable mobility is not an individual choice but, more importantly, is part of a sociocultural process and is facilitated by personal and social influences, as stated by Gifford and Nilsson (2014). Finally, we discuss the challenges of studying behaviour change and of designing interventions targeted at the community level in order to create mobility-related behaviour change within close social communities.

5.1 Aspects of district and infrastructure level impact on mobility behaviour

Based on the interviews, infrastructure and infrastructural changes emerge as key factors that affect mobility behaviour. People are limited by the options offered by the existing infrastructure and these limitations generally determine the options people perceive as viable. The newly opened shopping centre in Espoonlahti significantly reduced the need to drive to another shopping centre in another district. In turn, the dense urban structure of Leppävaara helps households to keep their daily trips short and provides better opportunities for using public transport. However, the road network in Espoo allows people to commute up to 35 km within an acceptable timeframe (by car). Similar observations can be made for other parts of the infrastructure or provisioning system in Leppävaara. At the time of the study, existing e-scooter or city bike schemes were available in Leppävaara, but not in Espoonlahti. Similarly, if city bike stations are not located close to leisure facilities, or if bus services are discontinued during public transport restructuring, for example, building a metro line extension, people have to choose other modes of transport, and the participants stated that the private car was often the easiest and most reliable option.

Anticipating new infrastructure and its effects appears challenging when planning personal and household transitions towards more sustainable modes and patterns of mobility. In the Espoonlahti workshop, the participants talked about the upcoming metro line extension (set to open 18 months after the workshop), yet were unsure about how it would change or ease their mobility patterns. As the previous metro line extension had not made mobility any easier but had actually reduced the number of existing bus connections, people were also rather cautious regarding the new extension. However, it was considered a potential game changer. In connection with the metro station, a new shopping centre was also established and opened 6 months after the workshop. Interestingly, although the interviews revealed that the new shopping centre had greatly reduced daily mobility, the shopping centre was barely mentioned during the workshop, even though the participants were aware that it would soon open.

5.2 Close social community members influencing each other's mobility behaviour

Within the framework of by the existing infrastructure, people's close social community influences the way they relate to their surroundings. Personal mobility within households was organised

based on the needs of the close social community. Grandparents were helped by giving them lifts and combining trips, young people were driven to leisure activities using carpooling, relatives offered a lift or lent their cars to family members, divorced parents arranged their children's transfers between households, people commuted in various ways to work, daily shopping was done with other family members, and so on.

In some households a parent had a disability that impacted the mobility of the family as a whole. For example, in one household, shopping was done using a private car to avoid walking, and in another family the father had the option to use taxi vouchers because he was disabled. The ways in which mobility was organised around the needs of one household member had a marked effect on the mobility of other family members. Also, some of the participants had elderly parents who were unable to drive and were given lifts or visited by car by their adult children on a daily basis. These interdependencies based on physical condition and the provision of assistance are perhaps the most common social aspects to impact individuals' mobility behaviour.

Among couple households, mobility patterns were described as being either very similar or very varied in terms of daily choices based on whether people travelled together or separately. Adult couples typically had quite traditional roles regarding car use—the man drove and the woman was a passenger. If travelling alone, however, women tended to prefer public transport or cycling. Thus, the mobility behaviour of couples seemed to differ considerably when travelling either separately or together. The mobility carbon footprint of couple households was therefore unbalanced due to the higher amount of private driving by men compared to the use of public transport by women. The social interdependencies and roles that people naturally take influence their mobility behaviour, as also identified in Santala et al. (2024). Thus, social practices can stop people from giving up using their cars, as the practice of driving together has been shaped and stabilised over the years. In many households the know-how and motivation, for example, to use public transport when commuting alone already exists, at least partially. However, to bring about the required change, all household members would need to adopt similar CF reduction measures or at least be prepared to make meaningful changes to their personal preferences. This is in line with practice theory, which highlights how practices are motivated by comfort and convenience (Shove et al., 2012). The examples above show that changing behaviours is an extremely complex and time-consuming process, motivated by both social and individual factors.

5.3 Other social contexts and social interdependencies that influence mobility behaviour

For several of the participants, work or study was a major factor in the increasing amount of car use or daily commuting. The main reason for driving was not necessarily commuting, but the mobile nature of work, such as visiting customers, as well as returning to the office or place of study after the COVID-19 restrictions were lifted. In such cases, the work or study community can be perceived as a close social community that influences mobility behaviour. Business meetings could arguably be arranged remotely, but the company had made a decision and the line manager expected that physical meetings were preferable, if at all possible. Similarly, social reasoning could be seen to be at play when students were expected to attend studies in person after the end of the remote study period.

These social negotiations and ways of organising work and studies affect people's daily mobility needs. In some cases, mobility behaviour was defined by work more than an individual would have preferred. Also, owning a car had become the norm because work required an individual to have a car. However, there was one exception. One participant sold their car during the six-month period—despite their work requiring a considerable amount of travel—and used public transport to commute to work instead, funded by their employer, as well as to visit relatives in another city. While visiting his relatives, he was also more dependent on getting a lift from family members to/from the train station. Thus, living without a car is likely to increase dependency on family members and friends.

Social context can also impact people in other ways. For example, if parents drive their children to school and leisure activities, their children may inherit certain behavioural models from their parents that they take into their adulthood. As another example, friends who have mopeds create social pressure on their peers to get a moped in order to be included in the group. However, this also works the other way around. One participant received a bicycle from her parents, which created the desire to cycle more. She also viewed her parents as role models as far as cycling was concerned.

In arranging daily mobility, it appears that comfort and ease of life are the most important factors. Also, financial aspects were highlighted as relevant factors limiting the adoption of more sustainable options such as switching to an electric car or travelling by public transport. However, contrasted to the estimated monthly costs of owning a car in Finland (~EUR 500), people's perceptions of the actual expenses of specific modalities were not always realistic. A private car was often considered as a cheaper option compared to public transport (~EUR 100 per month). Then again, from a community aspect, the costs of public transport increase in relation to the amount of community members requiring a public transport ticket, whereas the expenses of a car stay the same. This highlights that specific mobility options and actions are more potential from a community perspective than others. In most cases, environmental concerns are of less importance but are readily adopted where appropriate. In some specific cases, environmental concerns have been a major driver of change, for example, in changing to a car-free lifestyle. Environmental considerations can also facilitate changes that are already under consideration, such as changing to a smaller car or an electric car, or giving up a remote holiday cabin.

5.4 The difficulty of describing and studying social behaviour change

Measuring the actual environmental effect of mobility changes proved more complex than we had anticipated. Carbon footprint calculations based on the same online survey before the workshop and 6 months later provided different results. While several changes in the carbon footprint calculations of the households were clearly due to the actions selected, other households seemed to have carbon footprint changes because of other factors, such as bigger life changes (e.g., moving house), seasonal variations, or post-Covid changes to their daily lives.

Implementation of the game-based interventions the participants had planned during the workshop had only partially started—which was to be expected as the Climate Puzzle game includes changes that must be implemented by 2030. However, for many households the workshop and the Climate Puzzle game provided an opportunity to re-evaluate their daily mobility needs, in either major or minor terms.

This also shows that the active provision of new infrastructure and mobility options combined with questioning existing patterns can incentivize people towards focusing on low-carbon mobility.

Previous research shows the potential of the Climate Puzzle game to contribute to 'low-carbon lifestyles through learning, knowledge sharing, and empowerment' (Vaajakallio, 2012). Yet, the results of this study indicated less behaviour change than anticipated. This could be due to mobility being a challenging context in which to achieve behaviour change. The differences in how people related to the metro line extension and the new shopping centre, both under construction in Espoonlahti at the time of the study, point to the unpredictability of the anticipated change. The impact of the metro line on mobility behaviour was more anticipated by the participants than the impact of the nearby shopping centre. This raises questions about the overall predictability of people's behaviour. While the ability to prediction has been one of the main approaches to sustainable mobility behaviour change (e.g., Ding and Zhang, 2016; Le et al., 2018; Wang et al., 2021), we question whether people can predict, plan and make personal changes in the long term if they are not even able to predict short-term (six-month) changes.

The difficulty in anticipating and reducing the amount of mobility has been highlighted by Moriarty and Honnery (2021). They describe several studies that show the difficulty of changing behaviours and the improbability of voluntary reductions in mobility. According to their study, the travel needs of residents who live closer to inner city services are less than the needs of those residents who travel from the suburbs. This might also explain the differences between Leppävaara and Espoonlahti, and especially reflect the high level of car use in the Espoonlahti area which, at the time of the study, was still lacking efficient rail transport to Helsinki city centre.

When examining the data, it became apparent that the observed differences were not necessarily evident of lifestyle changes, but a consequence of seasonal changes or reporting differently between surveys. In controlled circumstances, the effectiveness of an intervention can be determined by comparing changes between the original and follow-up measurements. However, a more-in-depth understanding of the reasons behind the observed changes by means of statistical methods in a real-life study would have required a much larger sample size, including control groups, random assignment to treatment and control in experimental settings, potentially combined with the automatic collection of mobility data. As this kind of setting was not feasible in our study, we also conducted follow-up interviews with the households and combined their results with the calculated survey results. On this basis, we found that a self-completed, technically oriented questionnaire can be challenging to answer consistently over time, and that in many cases, 6 months is enough time to lead to changes in household circumstances, such as friends moving further away, thereby increasing the demand for mobility. To improve accuracy in future projects, a larger sample size with a control group, a longer period between studies, preferably during the same season in each study, and a 'no change' checkbox alongside each follow-up question is recommended.

The identified factors could also have varied to some extent if different households (especially from different, maybe even less or more car-dependent, geographical areas) had participated in the study. As such, the results provide input to further research on the social factors that drive mobility behaviours. Immigrants in particular represent a highly relevant and, in the context of this study, underrepresented target group for such a study. So does people who are socially isolated or have not been able to build good relationships with their local communities. This highlights a relevant aspect to be considered in a close social community approach to sustainable mobility interventions. There is a risk that community-level interventions might not serve all people. On the other hand, there is also a possibility to provide socially more isolated people opportunities for interacting with people and feeling a sense of belongingness with their local communities.

Using only a workshop and a qualitative interview, it is also quite challenging to study and understand how the members of households influence each other's behaviour. The household members had difficulties identifying and describing the different phases of their change process and related interaction among community members along implementing planned actions. Therefore, the narratives are not either straightforward. In order to collect insights as changes unfold, ethnographic research methods such as field observations and self-documentation of social practices would support such a study. This could potentially lead to a greater clarity also in descriptions of practice change processes in communities.

The initial objective of the study was to understand the change process from the perspectives of different household members, which proved more challenging than expected. Some household members did not attend the workshop or participate in the interview for unspecified reasons. Therefore, in some households, we only heard the story and perspective of one person. For the study, it would have been worthwhile understanding and investigating how different household members related to, for example, the new metro line under construction or the shopping centre that was opened, and how the household members discussed these changes with each other. Studying and engaging multiple members from each household and from their extended close social communities would have required a different study setup and field trips over a longer period. A longer study period could also include prompts reminding the participants of their chosen mobility actions.

5.5 Practical proposals for interventions targeting larger social communities

The Climate Puzzle game offered a unique practice-focused intervention for studying and involving community members in the planning and implementation of sustainable mobility practices. The intervention raised awareness about the communities' own CF, as well as better alternative practices. The alternative practices made use of three strategies for changing mobility patterns, ranging from 'recrafting practices' to 'substituting practices' and 'changing how practices interlock' (Spurling et al., 2013), making the Climate Puzzle an especially interesting intervention for the complex domain of mobility. It also enabled a qualitatively interesting setting for studying behaviour change processes over time through dialogue among the community members facilitated by the chosen actions. However, the intervention and research process could also be developed by including the implementation of the planned change. This could mean sending reminders or motivating and encouraging community members to implement their planned actions.

Based on our research, we cannot say that the Climate Puzzle intervention in one workshop would be sufficient to achieve the 2.5 tonnes CF target by 2030. As the findings of this paper show, and which support the findings of Santala et al. (2024), each close social community has its own needs and characteristics. The Climate Puzzle intervention educated the participants about alternative options and their climate impact in an easily understandable and tangible way, tying the information to the communities' own context, thereby supporting actionable change.

Specific measures to be included in interventions targeting larger social communities could involve a facilitated change process that reminds, motivates and supports behaviour change. Similarly, policymaking should address job-related travel by making it easier to avoid private driving. For example, employers could organise shared rides for employees or offer benefits that promote more sustainable modes of mobility. Additionally, it is important to avoid the supply–demand gap, where people are expected to adopt more sustainable practices but lack the necessary options.

Based on our findings and supporting the findings of Ryöppy et al. (2022), we argue that community members should be involved in the planning, development and implementation of sustainable mobility interventions. This could enhance the success of an intervention through input and buy-in. Based on our findings, understanding and addressing the specific characteristics and interdependencies of close social communities in intervention design could help to scale up change in the domain of mobility. These kinds of actions also have the potential to contribute to more inclusive and flourishing urban environments.

Data availability statement

The datasets presented in this article are not readily available because of possibly recognisable and sensitive participant data. Requests to access the datasets should be directed to the main author.

Ethics statement

The studies involving humans were approved by the KONE data privacy counsel prior to conducting the research. Participants have been fully informed about the purposes of the research, the participants' rights regarding their participation, and how the research material is used, stored and published. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent was obtained from the individuals, and minors' legal guardian, for the publication of any potentially identifiable images or data included in this article.

Author contributions

SS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. MH: Formal analysis, Writing – original draft, Writing – review & editing. ML: Formal analysis, Methodology, Writing – original draft, Writing – review & editing. JK: Formal analysis, Methodology, Writing – original draft. SL: Formal analysis, Methodology, Writing – original draft.

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Conflict of interest

S-SS and MH were employed by KONE Corporation. ML, JK and SL were employed by D-mat Ltd.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsus.2024.1469285/full#supplementary-material

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