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Light electric vehicles: the views of users and non-users

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Abstract

Purpose Light electric vehicles (LEVs), such as e-bikes, e-scooters and electric two-wheelers, can potentially assist the transition to a sustainable transport system due to their low energy and spatial demands. This exploratory survey study investigated and compared the views of LEV users and interested non-users on the vehicles' advantages in Finland, Austria, Spain and Italy among urban residents (n = 4090) to understand factors influencing their adoption. Additionally, differences between personal and shared vehicles were investigated.

Method The survey queried respondents on the advantages of either the LEV they used most often, or the LEV they were most interested in using. Of respondents, 26% were LEV users, 37% were non-users interested in using an LEV and 37% were uninterested non-users. Factors concerning comfort, accessibility, safety, and practicality of travel were formed. The effects of respondent type (user vs. non-users), LEV type, whether the LEV was shared or personal, age, gender and country were examined with a full-factorial ANOVA for each factor and some additional variables.

Findings In general, LEVs were regarded well for travel comfort and supporting accessibility, but less positively for safety and assisting with practical aspects of travel. LEVs were also perceived environmentally friendly. Furthermore, users perceived LEVs more positively than non-users, while age and gender only mildly influenced views. The results suggest that increased familiarity with LEVs is associated with more favourable views concerning them. Existing positive views may have led to LEV use; however, experience could have changed these views as well. LEVs are novel vehicles with recognised benefits, but low familiarity may hinder adoption. Increasing familiarity with LEVs among non-users could encourage uptake, potentially supporting modal shifts from the car to LEVs and thus assist the transition to a more sustainable transport system.

Keywords e-mobility, Electric vehicles, Active travel, Transport mode choice, Electrification, Micromobility

1 Introduction

Improving the sustainability of urban transport while meeting the mobility needs of a growing urban population represents a significant challenge for transport systems globally. Cities characterized by high automobility and a dearth of viable low-carbon alternatives are often afflicted by externalities of car travel harmful to health and the environment, such as high congestion, poor air quality, noise pollution and substantial greenhouse gas contributions [5, 8, 18]. Attempts to mitigate these issues have involved policies encouraging modal shifting from private cars to less emissive, noisy and spatially demanding forms of travel such as cycling and walking [27]. However, the recent emergence of light electric vehicles (LEVs), such as electric kick scooters (e-scooters) and e-bikes, represent novel, potentially helpful travel modes to reduce car dependency in cities [66].

LEVs represent forms of micromobility powered either fully or partially by a battery-powered electric engine, and are characterised by low energy, weight and spatial demands. Typical currently used LEVs include

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e-scooters, e-bikes (limited to 25 km/h) and electric two-wheelers (limited to 45 km/h) [77]. As average daily trips distances in many of Europe's urban areas are approximately ten kilometres or less [26], LEVs represent a potentially economical, convenient and sustainable form of urban mobility [74]. Recently, the prevalence of LEVs has increased in urban areas [17, 48], supported by the emergence of shared services offering on-demand short-term access to the vehicles [48, 56, 61].

According to research explored in the literature review, people generally have less favourable attitudes toward a travel mode before gaining experience with it [51, 69]. If this applies to LEVs, promoting modal shifting from cars to LEVs may be challenging if people without prior experience hold less favourable views regarding them. Furthermore, shared and personally owned LEVs arguably provide a different experience, which could also influence views. For instance, shared e-scooters are typically available for short-term rental throughout urban areas and may be left wherever is convenient [61], popular for short trips and addressing the first/last mile problem within larger trip chains [12, 45]. Conversely, personal e-scooters need to be stored while not in use, but their use is not limited by time-based fees or operator-defined usage areas. Understanding whether views regarding LEVs differ between users and non-users, as well as between users of shared and personally owned LEVs, may provide insights into how the vehicles could best be promoted as an alternative to cars.

The focus of the present study was to explore views concerning LEV advantages to improve understanding on the factors influencing their adoption. The literature review identified that views on environmental sustainability, travel comfort, practicality, safety and the ability of the vehicles to improve mobility and accessibility could be the most relevant for the adoption of LEVs. We compared views related to these themes between LEV users and non-users with an interest in LEVs, as well as between personal and shared LEV variants across four European countries. Among non-users, those with an interest in an LEV are focused on, as they may be considered potential users of LEVs due to their interest in the vehicles. This study addresses the above with the following research questions:

- Do views concerning LEV advantages regarding comfort, practicality, safety and accessibility differ between LEV types, age groups, countries and genders?
- Do users of LEVs exhibit more positive views on the vehicles' advantages than non-users who were interested in at least some LEV?
- Do perceptions concerning the advantages of LEVs differ between users of their shared and personal variants?

Past studies on the advantages of LEVs have primarily focussed on individual LEV types and/or have been limited in scope to one country or region (e.g. [3, 24, 43, 54, 58, 74]). Furthermore, although views regarding the advantages of LEVs may differ between users and non-users as well as between users of the personal and shared variants of LEVs, comparisons between them are scarce, although Kopplin et al. [32] compared views concerning e-scooters between vehicle owners and non-owners. This shows that there is a research gap concerning the views of users and non-users of LEVs while considering possible differences between personal and shared LEVs. Understanding how such views differ could help inform efforts directing more sustainable travel behaviour by promoting modal shifting from cars to LEVs among non-users. Investigating the effect of LEV usership and ownership on views across LEV types together in an integrated approach provides a comprehensive image of views regarding the vehicles' advantages and constitutes the scientific novelty of this research. Additionally, a brief comparison between the countries included will help to understand what kind of differences can be expected across them.

2 Literature review

LEVs enable longer trip distances, faster speeds and reduced travel time for a lower effort than the vehicles' non-electric counterparts [3, 9, 25, 35, 43, 57, 59, 74]. Furthermore, LEVs can be parked more flexibly than cars on account of their typically small size [59], and are considered comfortable to drive [9, 24]. Some LEVs, especially e-bikes, may also increase physical activity for relatively little effort, representing a less sedentary but not entirely human-powered alternative to motorized modes [17]. The increasing availability of LEVs through various providers operating within the sharing economy enables access to the vehicles' advantages without paying a high upfront cost.

Modal shifts from internal combustion engine vehicles to LEVs can help reduce greenhouse gas emissions, transport energy consumption and air and noise pollution [17, 22, 23, 53, 59, 74]. Additionally, they make a smaller contribution to congestion than private cars due to their lower spatial demands [59]. However, Hollingsworth et al. [23] show that e-scooter sustainability is largely determined by the mode of travel it replaces. Recent evidence suggests that shared e-scooter and e-bike trips replace walking and public transport more than car use [13, 32, 67, 73], increasing emissions [23]. If LEVs replace car trips, they are likely to have a positive effect on the sustainability of the transport system, but the effect is expected to be negative if they replace walking, cycling or public transport trips. The role of mode substitution behaviour is critical regarding the sustainability of LEVs [32].

Disadvantages regarding LEVs include their negative implications for traffic safety. The greater speeds of LEVs relative to the vehicles' non-electric counterparts may increase accident risk and the severity of injuries [34, 42]. Additionally, the relative difficulty of optimising e-scooters' centre of mass and their typically small wheel radii can increase the risk of falling, especially when encountering a pothole [7, 55]. Due to their greater weight, electric two-wheelers and e-bikes require active steering at lower speeds to maintain stability [30], and are associated with more falls during mounting and dismounting than conventional bicycles, especially for older riders [60, 70]. Traffic safety concerns are compounded by the rarity of helmet use, especially among users of shared LEV services [34, 39, 49, 64, 76], and the frequent use of such services while inebriated [29, 34, 76].

E-bikes and electric two-wheelers are considered advantageous over conventional bicycles for transporting goods, a passenger, as well as not having to shower at the end of trips due to the lower physical exertion involved [19, 21, 35, 57]. The vehicles can also support the independent mobility of the elderly by providing a mobility option requiring relatively low effort, helping to overcome limitations of one's physical fitness [24, 37, 57]. Indeed, reduced labour requirements has been cited as an key reason for e-bike use [3]. On the other hand, Haustein and Møller, (2016b) identified user fears due to other road users not anticipating the speed of e-bikes, and e-bikes are under a greater risk of theft [54].

Shared e-bike use was less sensitive to hot and humid weather than shared conventional bikes in a survey study by Campbell et al. [10], suggesting benefits for coping with heat, but cold and rainy conditions were discovered to dissuade use in Hardt & Bogenberger [19]. Sanders et al. [58] show that e-scooters are also preferred over walking in hot weather.

Further results from Sanders et al. [58] show that e-scooters are perceived to be convenient, fun, relaxing to use and faster than walking. However, concerns include poor sense of safety, and unlike e-bikes and electric two-wheelers, difficulties transporting luggage [58, 63]. Furthermore, safety concerns are compounded by the riding tendencies of minors [33].

Differences may exist concerning the advantages between personal and shared variants of LEVs, as the vehicles may be used for somewhat different purposes. For instance, shared e-scooters and e-bikes are available throughout urban areas and may be left wherever is convenient [61], popular for supplementing larger trip chains [40, 72]. On the other hand, personal electric two-wheelers are considered suitable for full trips such as commutes [3, 24], potentially decreasing the utility of the shared version which must be found before it can be used.

Research has shown that people generally regard travel modes they do not use less positively than modes they use. For example, the relationship between familiarity and attitude toward travel modes was studied by Pedersen et al. [51], who found that users of public transport were generally more satisfied with the mode than non-users. Additionally, frequent car users became more satisfied with public transport after using it regularly for a month. In a study of the relationship between mobility patterns and attitudes towards modes, Ton et al. [69] also discovered that familiar modes are generally regarded more positively than unused modes. Peters et al. [52] found in their survey that a factor preventing potential users of electric vehicles from becoming familiar with the vehicles was a lack of testing opportunities. The authors speculate that the provision of such opportunities could encourage those interested in electric vehicles to become vehicle owners. It is possible that a relationship like the above, where the adoption of travel modes is constrained by a lack of familiarity with their advantages, could apply to LEVs as well.

The use of LEVs across the population groups is not equal. Some evidence suggests that young to middle-aged men form the current primary user group of several LEVs. Hyvönen et al. [24] found that men and the middle-aged were most interested in purchasing Segways and electric two-wheelers in Finland than other age groups and women. A number of studies suggest that most e-bike users are generally older and male (e.g., [24, 36, 75], although recent findings from The Netherlands show that younger people are increasingly becoming users of e-bikes [14]. E-scooter users consist mostly of young men. In Germany, 70% of shared e-scooter service users were male [15], similar to a rider survey in Portland, Oregon, where the figure was 60% [50]. Degele et al. [15] also report that most shared e-scooter users in their study were in their late twenties, with a smaller peak among those between 45–50 years old. Conversely, there were almost no users above the age of 65.

Views concerning LEVs appear to be largely influenced by issues related to environmental sustainability, travel comfort, practicality, safety concerns and the ability of the vehicles to improve mobility and accessibility. Furthermore, the literature suggests that experience with a travel mode is generally associated with more positive views on it, and that unfamiliarity can hinder the adoption of new modes. A similar effect could apply to LEVs as well. Finally, due to inherent differences in user experience between personal and shared LEVs, views concerning LEVs may differ between them.

3 Method

3.1 Survey

The data used in this study originates from an online survey initially collected as part of the Smart-Tailored L-category Electric Vehicle demonstration in heterogeneous urban use-cases (STEVE) project [65]. The original purpose of the survey was to identify the important drivers of daily mobility choices, the barriers to changing travel behaviour to favour electric micromobility vehicles and the user types most capable and willing to change their travel behaviour. As part of this, views concerning the advantages of LEVs were collected.

Views concerning the advantages of LEVs were collected in July 2020 with an online survey directed to four European countries: Austria, Spain, Italy and Finland. The survey was directed to these countries as they featured cities where pilots for the STEVE project were carried out [65]. The survey collected views from both LEV users and non-users.

The full survey included 26 questions, but only 12 resulted in data relevant for the present study. These relevant questions determined each respondent's most used or most preferred LEV and how much they agreed with a set of potential advantages concerning it. Additionally, the questions concerned background information of the respondents such as age and gender.

The survey first asked which LEVs each respondent typically uses and how often they are used. Vehicle options included the "e-scooter" (electric kick scooter), "e-bike (limited to 25 km/h)", "electric two-wheeler motorcycle, moped or speed pedelec with electric assistance over 25 km/h" (henceforth referred to as electric two-wheeler and abbreviated E-2W) and "none". Those who responded "none" were given the option to report which LEV they were most interested in using. Personal and shared options were available for each LEV. Based on responses to this question, the most used (in the case of users) and most preferred (in the case of non-users) LEV was identified. For each respondent, the following survey questions probing views on the advantages of LEVs related to this most used or most preferred vehicle only. Respondents only evaluated their most used or most preferred LEV and did not evaluate the merits of LEVs relative to each other. Additionally, respondents who did not use an LEV nor were interested in using an LEV skipped the questions concerning LEV advantages entirely and were thus not analysed. As the non-users analysed here all chose a preferred LEV, they may be considered potential users of LEVs due to their interest in the vehicles.

The survey queried respondents concerning their most used (users) or most preferred (non-users) vehicle by asking them how much they agreed or disagreed with 14 statements regarding the advantages of LEVs on a five-point Likert scale ranging from strongly disagree to strongly agree. The statements (Table 1) were primarily based on the main advantages concerning LEVs uncovered in previous literature referenced in the introduction. However, the advantages concerning avoiding others who may have a transmittable disease and avoiding harassment were anticipated advantages not based on past studies.

Table 1 Assignment of statements to factors, standardised factor loadings and Cronbach's alpha statistics

Factor	Statements (The vehicle…)	Std. factor loading	Cronbach's α
COMFORT	Is physically comfortable	0.60	0.66
	Helps me avoid congestion	0.57	
	Helps me cope with poor infrastructure	0.72	
PRACTICALITY	Eases travel with others	0.75	0.78
	Eases transporting goods	0.77	
	Eases coping with poor weather	0.70	
ACCESSIBILITY	Can travel long distances	0.74	0.70
	Has sufficient range	0.66	
	Saves my time	0.61	
SAFE	Helps me travel more safely	0.80	0.71
	Helps me better avoid harassment	0.69	
Unassigned	Helps me cope with my physical fitness. (CopeFit)	NA	
	Helps avoid others who may have a transmittable disease. (AvoidContact)		
	Is environmentally friendly. (EnvFriendliness)		

Respondents were accessed through online survey panels provided by market research company Taloustutkimus Oy. The target population of the survey was residents living in urban areas with populations over 50,000 aged 18–70. Sampling aimed for comparable proportions of respondents aged 18–30, 31–50 and 51–70 with at least 20% of each, as well as a roughly even gender split.

3.2 Advantage factors and indicators

Factors were formed from responses to survey questions concerning advantages. The assignment of statements to factors was based on the results of an exploratory factor analysis using oblimin rotation, which assigned the variables to four factors using ordinary least squares to obtain a minimum residual solution allowing for correlated factors [20]. The total number of factors was set to four based on a sharp break in a scree plot of the eigenvalues for principal factors. The fit of the final constructs was confirmed with a confirmatory factor analysis resulting in a comparative fit index (CFI) of 0.95 and an RMSEA index of 0.06 indicating good fit [28]. Factor score estimates were calculated for each respondent by taking the mean of responses to statements constituting each factor. Before the analysis, the responses were converted into numeric scale (Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5). Table 1 presents the factors, their meaning and the individual survey questions constituting them.

The resulting factors are COMFORT, PRACTICALITY, ACCESSIBILITY and SAFE. COMFORT depicts the ability of LEVs to improve physical comfort and alleviate discomfort caused by congestion and poor infrastructure. PRACTICALITY depicts the vehicles' ability to overcome practical issues with everyday travel, specifically regarding travel with others, transporting goods and travel in poor weather. ACCESSIBILITY depicts the ability of LEVs to improve mobility and access, such as travelling farther and faster. SAFE depicts the ability of LEVs to improve personal safety during travel, referring to both traffic safety and harassment from others. Although traffic safety and security are usually considered separately, both influence travel decisions [4]. In this study, views on both varied similarly.

Table 1 shows Cronbach's alpha statistics for each factor, which measures the internal consistency of the individual items constituting them. Ursachi et al. [71] suggest that Cronbach's alpha statistics between 0.6–0.7 indicate acceptable factor reliability, with higher values indicating good or very good reliability. The statistic is 0.7 or above for all factors except COMFORT (0.66). The table also shows standardised factor loadings, most of which are above Kline's [28] recommended value of 0.7. For indicators assigned to a single factor, standardised factor loadings can be interpreted as regression coefficients, with lower values suggesting weaker association with the factor it is assigned to [28]. Although several loadings are below 0.7, the Cronbach's alpha, CFI and RMSEA statistics altogether suggest that the factors perform reasonably with minor weaknesses concerning convergent validity. These weaknesses were not considered critical, as this research aims to consider findings on a general level. All correlations between factors are below Kline's [28] recommended value of 0.9.

In addition, three single variable indicators were used. They were EnvFriendliness, CopeFit, and AvoidContact. Although CopeFit and AvoidContact are arguably related to accessibility and safety issues respectively, they reflect slightly different aspects regarding them and do not fit well with the constructs.

3.3 Data analysis

This study investigates the research questions by testing a set of factors and indicators depicting LEV advantages for differences between respondent groups. Differences between respondent groups are explored by testing factor score estimates and indicator means for differences with full-factorial ANOVAs.

To answer the research questions, full-factorial ANOVAs were run for the factors and indicators to investigate the effect of age group (15–34, 35–55 and 56–70), gender (male and female), vehicle type, whether the vehicle was personal or shared and whether the respondent was an LEV user or not. Type III sums of squares with sum-to-zero contrasts were used, because the data were unbalanced. Significant ($p < 0.05$) effects were interpreted with estimated marginal means (EMMs) and their 95% confidence intervals.

The group representing non-users were given the opportunity to provide views on both their preferred personal and shared vehicles. To ensure that samples analysed by the ANOVAs were independent, respondents indicating a preferred vehicle in the non-user group ($n = 1500$) were randomly split into two groups to represent respondents preferring either personal ($n = 918$) or shared ($n = 582$) vehicles. The proportions of respondents in the personal and shared groups are equal to their proportion in the full non-user group prior to splitting. Of all values in the raw data, 9.1% were missing due to "don't know" and "not relevant" answers. These values were imputed with predictive mean matching. Imputation was considered necessary so that factor score estimates would not be computed by a subset of their variables, thereby giving them unequal weight. An average of 1.27 responses to original survey questions were imputed per respondent. Running the analyses on cases without missing values suggests that the results were affected by value imputation. However, given the exploratory nature of the study, where focus was on exploring the data and gaining insights, the impact was not considered major (see Additional file 1: Supplementary material A and chapter 5.4).

4 Results

A total of 4,090 respondents answered the survey: approximately 1,000 per country with a similar age distribution. For all countries, approximately 37%–41% of respondents were aged 18–34, 36%–41% were aged 35–55 and 20%–26% were aged 56–70. The oldest age group accounted for the smallest proportion in all. The gender distribution in the data was equal between men (50%) and women (50%). The distribution was similar for individual countries, with men and women accounting for approximately 49%–51% each.

Most respondents (74%) reported that they do not use an LEV at all, followed by respondents whose most used LEV was personal (16%) and respondents whose most used LEV was shared (10%). Figure 1 presents these shares by country. Italy accounts for the largest proportion of personal users and lowest proportion of non-users. Finland features the lowest proportion of personal users and highest proportion of non-users, while Spain had the greatest proportion of shared vehicle users.

Of respondents, 1,068 (26%) represented LEV users and 1,500 (37%) represented non-users. A total of 1,522 (37%) respondents did not use an LEV nor were interested in using one, and therefore did not provide views. Table 2 presents distributions for age group, gender and country according to respondents' most used LEV (users) or most preferred LEV (non-users). Personal LEVs were most popular among users, and the most used LEV type was the personal e-bike. Respondents aged 15–34 and males were most represented for all LEVs among users. Among non-users, personal vehicles were preferred over shared vehicles, with most interest directed toward the personal e-bike. Interest in LEVs among non-users was also mainly from younger respondents, but there was greater interest from older age groups as well as women in comparison to users.

Most personal e-scooter users were from Austria and Spain and most e-bike and electric two-wheeler users were from Italy. Most shared e-scooter users were from Finland, and most shared e-bike users were from Italy. Spain had the largest proportion of shared electric two-wheeler users by a considerable margin. The personal e-scooter was preferred most in Spain, and the personal e-bike and electric two-wheeler were preferred most in Finland. Shared e-scooters were most preferred in Italy and shared e-bikes were most preferred in Finland. Shared electric two-wheelers were preferred most in Spain.

Figure 2 presents overall factor score estimates and indicator means. In general, the most positively ranked factors were COMFORT and ACCESSIBILITY, while PRACTICALITY and SAFE were ranked least positively. EnvFriendliness was the most positively ranked indicator, with AvoidContact and CopeFitness ranked slightly less positively. Two-sided one-sample t-tests computed for SAFE [$t(2567) = 4.56$, $p < 0.01$] and PRACTICALITY [$t(2567) = -3.42$, $p < 0.01$] confirm that they are significantly different from indifference (a mean of 3) with a 95% level of confidence.

Table 3 presents the results of the ANOVAs. The results suggest that in general, views regarding LEVs were affected by LEV type, whether the LEV was personal or shared, whether the respondent was an LEV user or not as well as country and gender (full table available in Additional file 2: Supplementary material B). Moreover, significant interactions suggest that responses sometimes depended on interactions between country, LEV type,

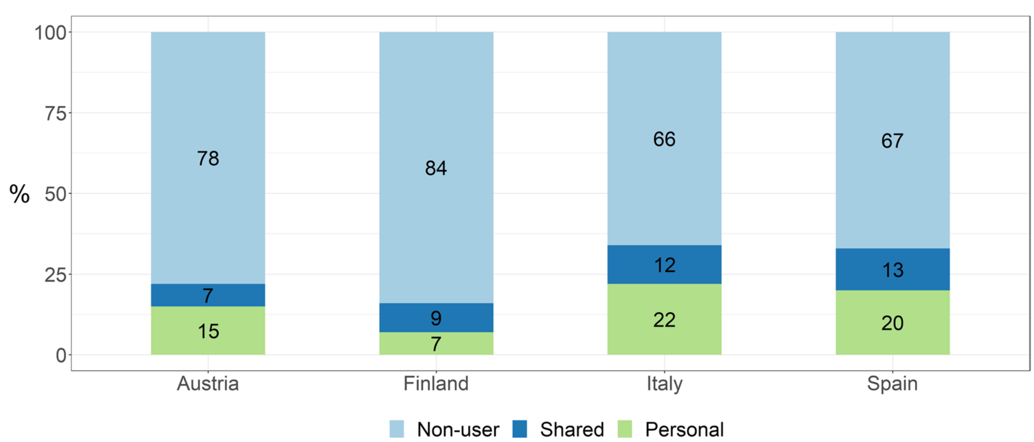

Fig. 1 Access to most used LEV by country

Table 2 Age, gender and country distributions by LEV for users and non-users

	Users						Non-users					
	Personal (n = 646) (%)			Shared (n = 422) (%)			Personal (n = 918) (%)			Shared (n = 582) (%)		
	e-scooter	e-bike	E-2W	e-scooter	e-bike	E-2W	e-scooter	e-bike	E-2W	e-scooter	e-bike	E-2W
15–34	52.9	49.5	56.8	75.4	58.0	62.4	50.6	35.8	32.3	52.2	45.1	42.8
35–55	40.8	38.0	34.9	18.3	37.0	34.1	34.4	42.0	47.5	35.7	35.5	41.8
56–70	6.4	12.5	8.3	6.3	4.9	3.5	15.0	22.2	20.1	12.2	19.4	15.5
χ^2	χ^2(6.4), df = 4, p = 0.17			χ^2(5.6), df = 4, p = 0.24			χ^2(17.2), df = 4, p < 0.01*			χ^2(5.55), df = 4, p = 0.24		
Male	66.2	54.2	58.9	54.3	54.3	58.8	43.8	42.2	59.1	47.8	42.1	58.2
Female	33.1	45.1	40.6	45.7	45.7	41.2	54.4	57.8	40.9	51.3	57.5	40.7
χ^2	χ^2(6.2), df = 2, p = 0.05			χ^2(0.56), df = 2, p = 0.76			χ^2(21.7), df = 2, p < 0.01*			χ^2(12.40), df = 2, p < 0.01*		
AU	33.8	22.6	14.6	17.1	17.9	11.8	27.5	23.1	23.4	27.0	23.4	26.8
ES	35.0	23.2	39.1	24.0	32.1	48.2	28.1	13.0	24.4	23.5	17.9	32.5
IT	18.5	39.1	41.7	16.0	37.0	36.5	25.0	27.9	18.5	28.7	21.2	18.6
FIN	12.7	15.2	4.7	42.8	13.0	3.5	19.4	36.0	33.7	20.9	37.4	22.2
χ^2	χ^2(52.2), df = 6, p = 0.01*			χ^2(77.8), df = 6, p < 0.01*			χ^2(38.1), df = 6, p < 0.01*			χ^2(26.5), df = 6, p < 0.01*		
N	157	297	192	175	162	85	160	455	303	115	273	194

Statistically significant (p < 0.05) chi-square tests for independence are denoted with *

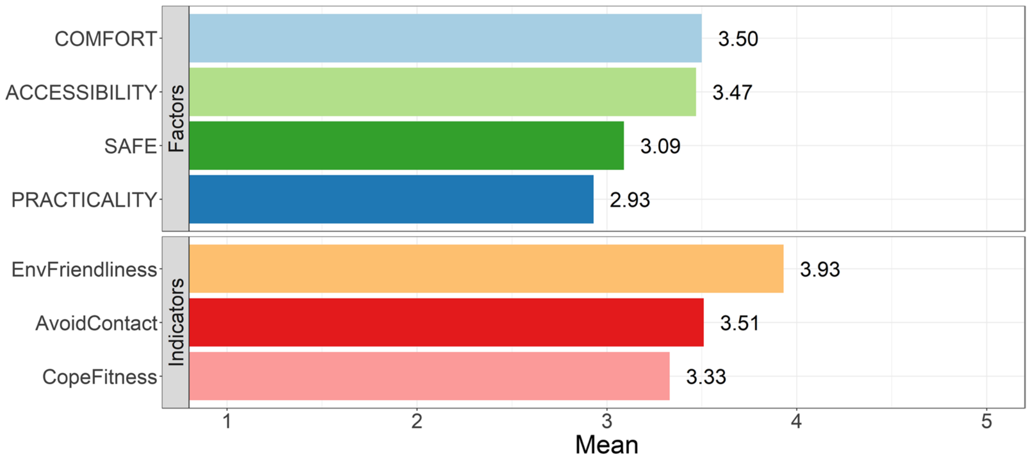

Fig. 2 Overall factor score estimates and indicator means

Table 3 Results of the full-factorial ANOVAs

Independent variables	Factors				Indicators		
	Comfort	**Practic-ality**	**Accessibilty**	**Safe**	**CopeFitness**	**AvoidContact**	**EnvFriend-liness**
LEV	$F_{2,2550}=4.4$ $p=0.01$*	$F_{2,2550}=9.0$ $p<0.01$*	$F_{2,2550}=6.2$ $p<0.01$*		$F_{2,2550}=22.4$ $p=0.01$*		
Personal or shared	$F_{1,2550}=5.5$ $p=0.02$*		$F_{1,2550}=6.3$ $p=0.01$*	$F_{1,2550}=4.0$ $p<0.05$*	$F_{1,2550}=7.6$ $p<0.01$*	$F_{1,2550}=19.3$ $p<0.01$*	
User or non-user	$F_{1,2550}=16.8$ $p<0.01$*	$F_{1,2550}=29.8$ $p<0.01$*	$F_{1,2550}=10.1$ $p<0.01$*	$F_{1,2550}=31.0$ $p<0.01$*	$F_{1,2550}=61.2$ $p<0.01$*		
Age group							$F_{2,2550}=4.2$ $p=0.02$*
Gender			$F_{1,2550}=15.5$ $p<0.01$*			$F_{1,2550}=15.7$ $p<0.01$*	$F_{1,2550}=6.7$ $p<0.01$*
Country	$F_{3,2550}=17.8$ $p<0.01$*	$F_{3,2550}=39.3$ $p<0.01$*	$F_{3,2550}=9.0$ $p<0.01$*	$F_{3,2550}=46.2$ $p<0.01$*	$F_{3,2550}=15.2$ $p<0.01$*	$F_{3,2550}=2.8$ $p=0.04$*	$F_{3,2550}=7.4$ $p<0.01$*
[Country]* [LEV]							
[Country]* [Per-sonal or shared]				$F_{3,2550}=3.4$ $p=0.02$*			
[Country]* [User or non-user]	$F_{3,2550}=3.0$ $p=0.02$*	$F_{3,2550}=4.3$ $p<0.01$*			$F_{3,2550}=4.1$ $p<0.01$*		
[LEV]* [Personal or shared]							$F_{2,2550}=5.8$ $p<0.01$*
[LEV]* [User or non-user]							
[Personal or shared]* [User or non-user]							
[LEV]* [Personal or shared]* [User or non-user]				$F_{2,2550}=3.5$ $p=0.03$*			$F_{2,2550}=3.1$ $p<0.05$*

Significant effects ($p<0.05$) marked with *

whether the LEV was personal or shared and whether the respondent was an LEV user or not. No significant interactions were found for gender or age group.

The results of the ANOVAs are first interpreted in Fig. 3, which compares factor score estimates and indicator means by LEV type. Statistically significant pairwise comparisons based on EMMs and their 95% confidence

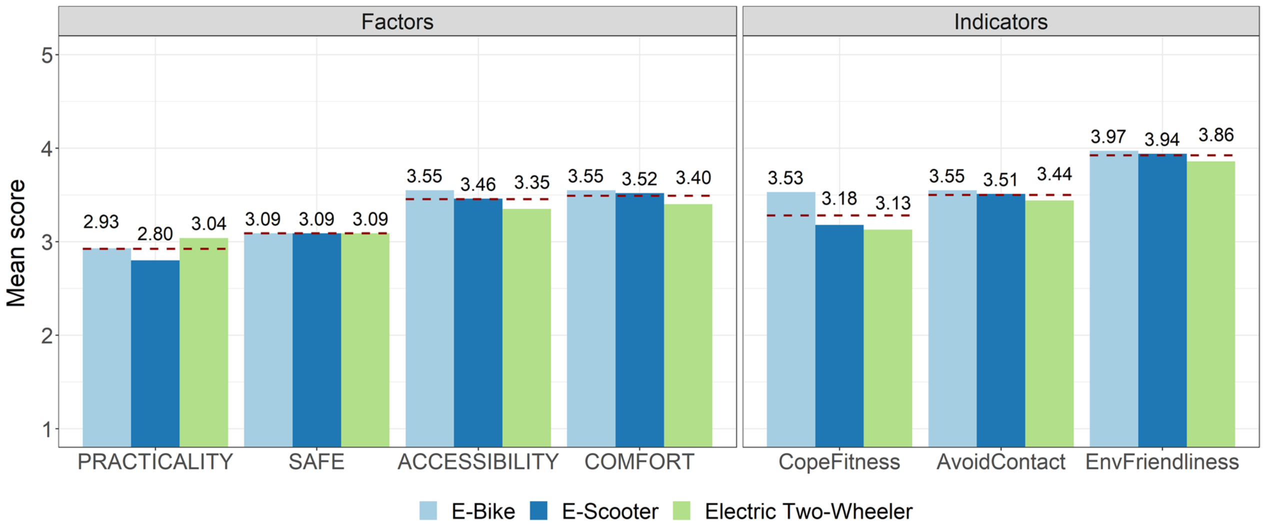

Fig. 3 Factor score estimates and indicator means by LEV. Dotted lines indicate overall means

intervals were used to identify significant differences. In general, mean factor score estimates across LEV types are relatively similar. However, e-bikes were regarded significantly more positively than the electric two-wheeler for COMFORT, ACCESSIBILITY and CopeFitness, and respondents regarded the electric two-wheeler and e-bike significantly more positively than e-scooters for PRACTICALITY. No significant differences were detected for SAFE, AvoidContact or EnvFriendliness.

Figure 4 presents factor score estimates and indicator means by country, all of which differed significantly. Italian and Spanish respondents had significantly more positive views than Austrian and Finnish respondents for all factors and EnvFriendliness. Furthermore, Finnish respondents had a significantly more positive score for CopeFitness compared to the other countries, while Austrian respondents had a significantly less positive score. The ANOVAs also detected statistically significant effects for gender with three variables. This resulted from female respondents generally contributing more positive responses to ACCESSIBILITY, AvoidContact and EnvFriendliness. However, these differences were negligible despite statistical significance.

The ANOVAs are further interpreted in Fig. 5, which shows significant differences for factor score estimates and indicator means by LEV type between users and

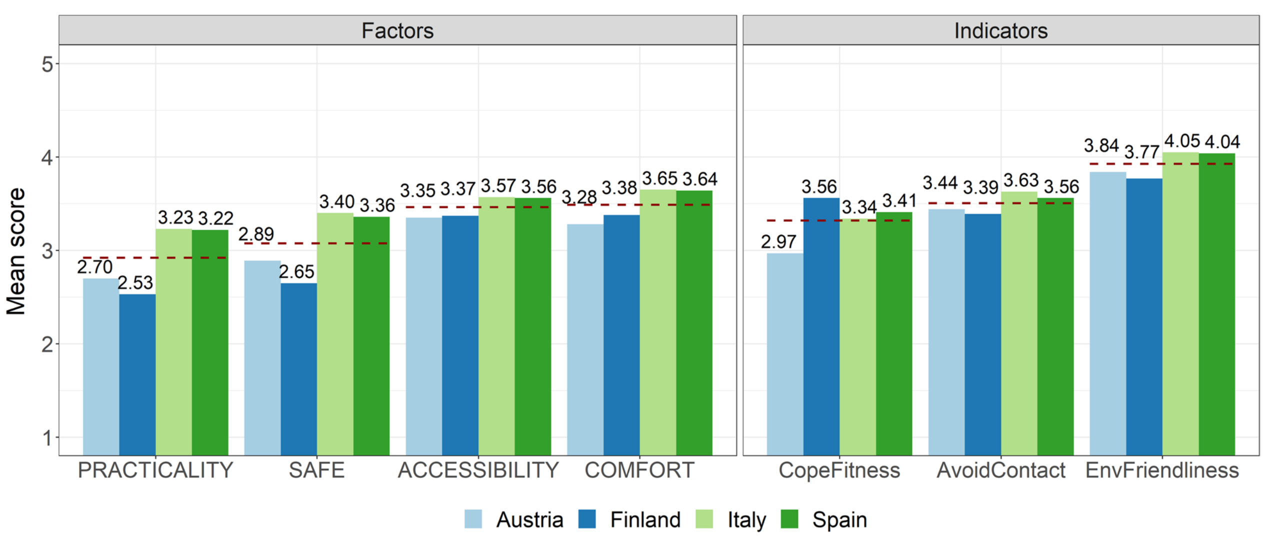

Fig. 4 Factor score estimates and indicator means by country. Dotted lines indicate overall means

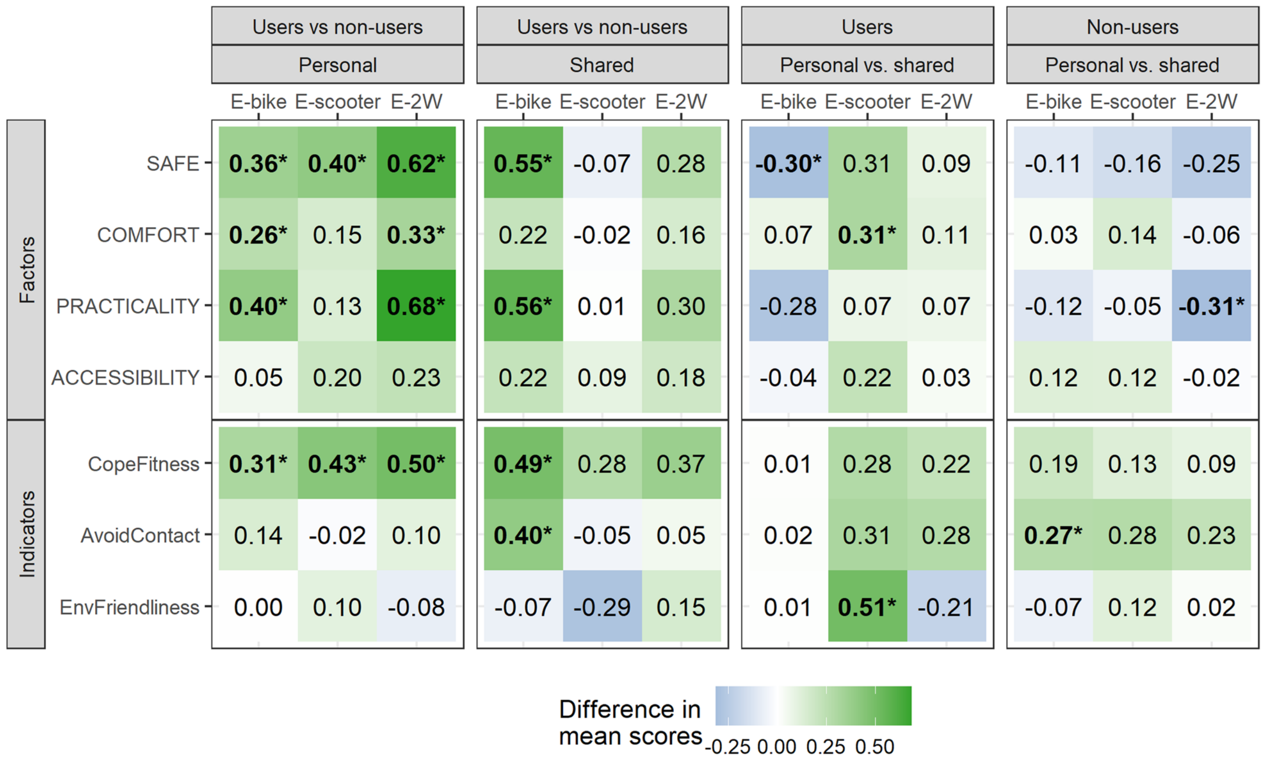

Fig. 5 Differences in factor score estimates and indicator means by LEV type, users and non-users and personal and shared vehicles. * Denotes a statistically significant difference based on EMMs with non-overlapping 95% confidence intervals. In the two left columns, positive values indicate that users contributed more positive views. In the two right columns, positive values indicate that personal LEVs were associated with more positive views

non-users and between shared and personal LEVs. The two left columns compare values between users and non-users (positive values indicate that users contributed more positive views), and the two right columns compare values between personal and shared LEVs (positive values indicate that personal LEVs were associated with more positive views).

Users contributed to higher factor score estimates and indicator means for all statistically significant comparisons between users and non-users, most of which concern personal vehicles. Most significant differences between users and non-users were detected for the personal e-bike and electric two-wheeler. Users of personal vehicles had more positive views regarding COMFORT, PRACTICALITY, SAFE and CopeFitness compared to non-users preferring personal vehicles. Several significant differences were detected between users and non-users of shared vehicles but only for the e-bike. Specifically, users regarded the shared e-bike more positively than its personal variant for PRACTICALITY, SAFE, CopeFitness and AvoidContact. Although significant interactions between the terms “user and non-user” and “country” were detected for COMFORT, PRACTICALITY and CopeFitness, the general trend of users contributing more positive responses remained. For these items, the differences between users and non-users were larger in Austria than in the other countries.

Significant differences between the personal and shared variants of the vehicles mainly concern the personal e-scooter, with its users regarding the vehicle more positively for COMFORT and EnvFriendliness compared to users of its shared variant. Only two significant differences were detected among non-users between shared and personal vehicles, and no significant differences were detected for ACCESSIBILITY.

5 Discussion

More sustainable travel options are needed in cities to mitigate the harmful environmental and social issues caused by urban car dependence while meeting the mobility needs of growing urban populations [18]. Inspired by the potential of LEVs to mitigate some of these issues, the present study aimed to investigate how their advantages are perceived by users and non-users, between LEV types and between personal and shared LEV variants to inform efforts seeking to influence their adoption. Previous literature suggests that views concerning environmental sustainability, travel comfort, practicality, safety concerns and the ability of the vehicles to improve mobility and accessibility are the most relevant for LEV adoption.

5.1 Differences in views concerning LEV advantages

The results suggest that LEVs were generally considered environmentally friendly and regarded well for travel comfort and accessibility. On the other hand, the vehicles were considered less positively for travel safety and their ability to overcome practical issues with everyday travel.

Although some differences in views concerning the advantages of LEVs are statistically significant, they remain small, suggesting that the vehicles are generally viewed relatively similarly across the studied dimensions. Among the main differences, the e-scooter received a lower factor score estimate for PRACTICALITY than the electric two-wheeler and e-bike, which is unsurprising, as the LEV does not offer space for cargo and is always single-occupancy. Difficulty transporting goods with e-scooters was also found to be a disadvantage in Sanders et al. [58] and Sikka et al. [63]. Furthermore, the e-bike had a significantly greater indicator mean for CopeFitness than the other LEVs, supporting previous research suggesting that the e-bike is useful for coping with reduced physical capabilities and improving accessibility by assisting the independent mobility of the elderly [24, 37, 57]. No significant differences were detected by LEV type for SAFE, AvoidContact and EnvFriendliness.

Differences in views between male and female respondents were minor, despite the gender division between users and non-users. It is possible that the difference in use may not relate to the vehicles' advantages. Regardless, females demonstrated a clear interest in LEVs based on their majority among non-users.

No differences were detected between age groups, although evidence suggests that interest in LEVs differs across age groups, for example with older persons typically less interested in e-scooters [15, 24]. However, as older persons have recognised benefits of LEVs, for example helping with their independent mobility [24, 37, 57], it is reasonable that there are not, for instance, notably negative views among the elderly. This is particularly understandable when considering that all views analysed here are from either users or interested non-users.

Views differed significantly by country. Furthermore, the countries differed from each other in a systematic pattern, with Austrian and Finnish respondents generally contributing less positive views than Spanish and Italian respondents. LEVs may be appealing in the countries due to their ability to help travel in hot weather, as found by Sanders et al. [58] for e-scooters. The results may also reflect the overall familiarity with and suitability of small-sized motorised two-wheelers in the countries. For example, Barcelona in Spain features widespread use of motorcycles and mopeds, which are well suited for travel in dense and congested urban environments typical for the Mediterranean [31, 44]. Furthermore, Italy has the largest motorcycle fleet in Europe [2]. No significant interactions between respondents' country of origin and LEV type were detected in the ANOVA, suggesting that country did not explain the variance in views between different LEVs across the dimensions studied.

All LEV types were generally considered very environmentally friendly by respondents, a result similar to Hyvönen et al. [24] and Calefato et al. [9]. Environmental concern was also found by Kopplin et al. [32] as a main motivating factor for e-scooter use. The consensus among respondents is strong despite the uncertain sustainability of LEVs [13, 23].

Avoiding others who may have a transmittable disease was also a very positively rated advantage of all LEVs, an issue likely relevant to most respondents due to the COVID-19 pandemic. The positive view is unsurprising, as most LEVs are single-occupancy and shared services represent an alternative to crowded public transport. The finding is also in line with Campisi et al. [11], who discovered that use of public transport became more stressful after COVID-19 cases began to rise in Sicily, Italy. Furthermore, Bergantino et al. [6] noted a growth in interest in shared micromobility services in Italian cities during the pandemic, and Li et al. [38] found similar results in Zürich.

5.2 Users vs. non-users and personal vs. shared vehicles

According to the results, users regarded the advantages of LEVs more favourably than non-users. Users contributed higher factor score estimates and indicator means than non-users in all significant comparisons of EMMs. Pre-existing positive views could have led the group to become users initially, but given their experience, they should also be most aware of the vehicles' limitations. Therefore, it could be plausible that users would have less positive views than non-users for some of the evaluated advantages. Additionally, non-users may also have contributed less positive views due to a lack of first-hand experience, as they must rely on external information from third parties and/or their preconceptions, for example based on seeing the vehicles used in traffic. Kopplin et al. [32] also found that non-owners of e-scooters have a less optimistic view of the vehicles than owners.

The finding suggests that LEV advantages may remain less clear to non-users, only becoming evident after experience with the vehicles has been gained. Therefore, gaining experience and increasing familiarity with LEVs could potentially enable non-users to become more aware of the vehicles' advantages and help identify how they could improve their daily travel. Peters et al. [52] also noted that a lack of opportunities to test and become familiar with EVs may constitute a barrier to their adoption. A similar relationship could also apply to LEVs. In general, the finding supports previous research linking experience and familiarity with a travel mode with more favourable views [51, 69].

The results show few significant differences in views between shared and personal vehicles, suggesting modest differences between them based on the advantages examined in this study. Furthermore, views were even less divided when comparing personal and shared LEVs among non-users. The finding is unsurprising, as non-users arguably have the weakest understanding of the vehicles' strengths and weaknesses.

5.3 Policy implications

To facilitate the further adoption of LEVs, decision makers should increase the familiarity of LEVs among non-users. Public LEV trials could provide a low-threshold opportunity for non-users to familiarise themselves with the vehicles. For example, the Helsinki regional transit operator (HSL) piloted a docked e-scooter scheme in 2019, after which 66% of surveyed users agreed that the transit operator should promote novel mobility solutions [25]. Furthermore, to maximise sustainability benefits, modal shifts should be directed from private cars to LEVs, as the replacement of walking, cycling and public transport trips can increase emissions and critically affect the sustainability of LEVs [23]. To help achieve this, LEVs could be integrated with public transport services and promoted as a sustainable solution for first and last-mile trips, especially in cities where short car trips represent a large proportion of all travel [1]. Such integration also has the potential to improve accessibility to public transport services and improve its competitiveness with private cars, further encouraging modal shifts to sustainable transport [41, 46].

Efforts should also be made to promote safe LEV riding practices, for instance with appropriate regulation. A recent Finnish study recommends that speed, age and drunk riding regulations for LEVs should be considered [47]. Other policies, such as designated parking areas, service area limitations and increased enforcement of traffic rules among LEV users could also help to manage and minimise potential disadvantages of increased LEV use [62].

The demographic differences between the user and non-user groups suggests that potential LEV users may represent a more diverse group. To help activate these potential users, suitable merits of the vehicles should be promoted to the right groups to help non-users find a suitable LEV for them. This could help overcome perceived incompatibility with one's mobility needs, which can prevent LEV adoption [16]. For instance, e-bikes could be promoted to the elderly as a solution enhancing their independent mobility (as also noted by e.g. [24, 37, 57]) as it was considered most useful for coping with physical fitness.

5.4 Limitations

The following limitations apply to the present study: First, although the sample represented different age groups and genders, it was not a representative sample of the urban population. Therefore, the results cannot be generalized to concern the whole population. Secondly, as the data used was collected for the purposes of another research project [65], it were not specifically collected to be analysed as factors. This potentially contributed to several standardized factor loadings remaining below 0.7. The third limitation concerns the missing data in the original survey responses and their imputation, which may have affected groupwise comparisons. Running the analyses on cases without missing values returned fewer statistically significant comparisons and a slightly better fit for the factor solution compared to the full data with imputed values. However, given the exploratory nature of this study, the effect was not considered to so major as to have a significant impact on the validity of the conclusions drawn (see Additional file 1: Supplementary material A). The larger p-values in the analysis without missing values may also have been influenced by a lower sample size [68]. The practical result of these limitations is that results must be considered on a general level only. As the aim of this study was to remain exploratory and provide a general overview of LEV perceptions between respondent groups, these issues were not considered to compromise the conclusions made.

6 Conclusion

The findings indicate that LEVs have recognisable advantages. Views differed by LEV type and country, but not by age group and only slightly by gender. Furthermore, users regarded the advantages more positively than non-users. Conversely, there were almost no differences between personal and shared vehicles. As the non-users included in this study had selected an LEV they were interested in using, the results also demonstrate considerable interest in LEVs from a group of people more diverse than young males who represent the current main users, further supporting them as alternatives to combustion engine traffic in cities. Decision makers aiming to increase LEV use should increase non-user's familiarity with the vehicles to help them identify how the advantages might help them with their daily travel, while directing LEV use to replace car travel instead of cycling, walking and public transport. Future research is recommended to investigate the views of those who do not use LEVs nor are interested in them. As uninterested non-users account for a large proportion of the surveyed sample (37%), understanding their views on LEV advantages and reasons for disinterest in the vehicles could provide valuable insights for efforts promoting modal shifts from the car to LEVs.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12544-023-00611-3.

Additional file 1. Supplementary material A. Supplementray tables and figures.

Additional file 2. Supplementary material B. Results of the full-factorial ANOVAs. Significant effects (p<0.05) market with *.

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Author contributions
Mesimäki and Lehtonen conceptualized the study. Mesimäki conducted the data analysis and wrote the first version of the manuscript. Lehtonen gave guidance on the data analysis and reviewed the manuscript. Both authors have approved the manuscript for publication.

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Availability of data and material
Data used for this study is not available to protect the privacy of survey respondents.

Competing interests
None.

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