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Original research article

Plugging in with neighbours: Defining the social dimension of electric vehicle charging in the Netherlands

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ABSTRACT

Residential public charging points are shared by multiple electric vehicle drivers, often neighbours. Therefore, charging behaviour is embedded in a social context. Behaviours that affect, or are influenced by, other public charging point users have been sparsely studied and lack an overarching and comprehensive definition. Consequently, very few measures are applied in practice to influence charging behaviour. We aim to classify and define the social dimension of charging behaviour from a social-psychological perspective and, using a behaviour change framework, identify and analyse the measures to influence this behaviour. We interviewed 15 experts on residential public charging infrastructure in the Netherlands. We identified 17 charging behaviours rooted in interpersonal interactions between individuals and interactions between individuals and technology. These behaviours can be categorised into prosocial and antisocial charging behaviours. Prosocial charging behaviour provides or enhances the opportunity for other users to charge their vehicle at the public charging point, for instance by charging only when necessary. Antisocial charging behaviour prevents or diminishes this opportunity, for instance by occupying the charging point after charging, intentionally or unintentionally. We then identified 23 measures to influence antisocial and prosocial charging behaviours. These measures can influence behaviour through human–technology interaction, such as providing charging etiquettes to new electric vehicle drivers or charging idle fees, and interpersonal interaction, such as social pressure from other charging point users or facilitating social interactions to exchange requests. Our approach advocates for more attention to the social dimension of charging behaviour.

1. Introduction

Electric vehicles (EVs) are essential to reduce greenhouse gas emissions [1]. The European Commission aims to ensure that all new cars registered in Europe will be zero-emission by 2035 [2]. Fully electric passenger vehicles comprise an important part of zero-emission transport and require (re)charging infrastructure, which must include private and workplace charging points [3].[2] However, as many Europeans cannot install an individual private charging point because they do not have an individual driveway, a considerable number of EVs (will have to) rely on public charging infrastructure in residential areas [4,5]. Residential public charging infrastructure is particularly important for inner-city neighbourhoods where residents rely on on-street parking [6,7]. Charging point availability is an important policy goal for public charging infrastructure [8]. Yet, public charging infrastructure expansion is falling behind to accommodate the growing EV fleet [9,10], and several European countries do not meet the charger availability recommended by the European Union [11].

Unlike private charging points, residential public charging points are a shared commodity. As one public charging point often accommodates more than one EV driver's charging needs, public charging point use has a social dimension: one user's behaviour (e.g., leaving the vehicle

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[2] We refer to charging points throughout this paper as the infrastructure that allows an EV driver to (re)charge their vehicle by using a cable to connect the EV to the charging point [53]. A charging station can contain multiple charging points, and each charging point requires a charging spot, a (dedicated) parking space close to the charging point to be used by the EV while charging.

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parked at the charging point long after charging [12]) can influence another user's behaviour (e.g., having to drive around to find another charging point). At public charging points, especially during weekdays, charging sessions start in the morning and early evening [8,13,14]. Particularly in residential areas, afternoon and evening charging sessions can last overnight [14]. One estimate on idle connection time, when an EV is connected to the charging point but not charging, finds EVs to be not charging for on average 73% of the total connection duration [8]. These charging sessions put pressure on the availability of charging points for EV drivers who need to charge their vehicles after work. Thus, specific behaviours can hamper charging point availability even with sufficient charging points. Behaviour that favours sharing the available public charging infrastructure adequately so that all users can charge will, therefore, become increasingly relevant for the success of the transition towards electric mobility. Failure to account for this social dimension means that opportunities to increase the effective and efficient use of charging points remain underutilised [15,16]. Hence, public charging infrastructure stakeholders, such as policymakers and charge point operators, need to understand the social dimension of charging behaviour and the measures available to influence this behaviour.

The term, social charging behaviour, has been used generally to describe an individual's action to move an EV from a public charging point, with the prompt for this action varying per description [15,17]. We suspect that moving an EV from a public charging point, regardless of the underlying prompt, is only one specific behaviour characteristic for the social context of public residential charging. Particularly in a residential context, where charging a vehicle might not be anonymous, and EV drivers can interact with one another as neighbours, other behaviours might play a role in assuring charging point availability. Therefore, we consider it essential to clearly classify and define the social dimension of charging behaviour to create a shared understanding of this behaviour. This leads to our first research question:

RQ1. How can we define the social dimension of charging behaviour at residential public charging infrastructure?

Defining behaviour precedes identifying measures to influence behaviour and increase charging point availability. Thus far, measures to influence charging behaviour aim predominantly to discourage undesirable behaviours, such as leaving a vehicle parked at the charging point (long) after charging [12]. An example is a financial sanction, such as an idle fee, to discourage leaving vehicles at the charging point after their charging session is complete [18,19].[3] However, financial sanctions are only one of many methods to induce behaviour change [20]. In particular, there is potential for measures that include, or appeal to, the shared nature and social dimension that characterise residential public charging infrastructure. Therefore, it is essential to explore a broader range of measures to influence charging behaviour. This leads to our second research question:

RQ2. What measures to influence the social dimension of charging behaviour at residential public charging infrastructure can we identify?

To the best of our knowledge, the social dimension of charging behaviour has not been interpreted from a social-psychological perspective, despite its importance for charging point availability. Therefore, to answer our research questions, we have taken a social-psychological perspective. We used expert interviews to explore how behaviour and measures are perceived in practice. Expert interviews are a concentrated method of data gathering useful for the exploratory phase of a research project [21]. We focus on residential public charging infrastructure in the Netherlands because the Netherlands has an extensive public charging infrastructure [22] and a large and growing EV fleet [23]. As already mentioned, new EV drivers might lack the option to install and charge at a private charging point and will often rely on residential public charging infrastructure instead. Additionally, expanding public charging infrastructure can take months or even up to a year [13], for instance because the local power grid first requires expansion [24]. In some neighbourhoods, EV drivers might not be certain of being able to charge upon return from their daily commute because the number of charging points lags behind the number of vehicles [25]. For these reasons, we consider the social dimension of charging behaviour a relevant phenomenon for the Netherlands, along with all contexts where (potential) EV drivers (will) rely primarily on residential public charging points.

This paper is structured as follows: after a brief overview of the literature on charging behaviour and the measures that can influence this behaviour in section 2, we elaborate on the sample, design, procedure, and coding of the expert interviews in section 3. We present the analysis and results of the classifications and definitions of the social dimension of charging behaviours in section 4. We then explain how we analysed the measures using the Behaviour Change Wheel framework [20] and present the results on the range of measures to influence charging behaviour in section 5. In section 6, we discuss the results, provide recommendations for future research, and reflect on the methodology and generalizability. We close with the conclusion in section 7.

2. Theoretical framework

The term, social charging behaviour, has been described as moving an EV from a charging point (i) once the battery is fully charged [17] (ii) when another user indicates a desire to charge at that location or (iii) when the current user expects the location to be useful for another (not yet present) user [15]. The latter two descriptions have also been referred to as a form of cooperative behaviour [16]. Moving a vehicle from a charging point at the request of another EV driver is indicative of a prior interaction between charging point users and, hence, a relevant social context actively guiding behaviour. Moving a fully charged vehicle from a charging spot on the user's own initiative, on the other hand, might not involve a consideration of the social context. This behaviour might be motivated by the convenience of having the vehicle parked closer to the user's house if the charging point is far away. However, regardless of the motive, both behaviours can be considered desirable from the perspective of sharing a charging point with other users and affecting other users positively.

A prime example of undesirable behaviour for sharing the charging point is hogging the charging point, where an EV remains connected excessively long to a charging point without charging [12]. Behaviours closely related to hogging the charging point are parking but not charging an EV at a public charging point and non-EVs occupying the charging point parking space [13,26]. Other charging point users might attribute these behaviours to the individual's tendencies to be selfish and not care about other users, even though they might not have intended to frustrate other users with their actions and the behaviour is the result of contextual factors [27], such as a lack of available parking spaces [19].

All these desirable and undesirable behaviours have in common that they are social in nature because they can either obstruct or aid other users in charging their vehicles at the public charging point. Hence, charging at a shared charging point encompasses a form of social interdependence [28]: the outcome of whether or not an individual can charge at the charging point depends, in large part, on the actions of others.

However, most of the current measures deployed or proposed by research to influence charging behaviour tend to focus on the individual users and their behaviour rather than the social context. Examples of such measures are loyalty point reward systems where users receive points for specific behaviours that they can use for discounts at charging stations [29] and fees charged when the vehicle occupies a charging station after charging [19]. These measures aim to motivate users to

[3] An idle fee is a fee charged when an EV is connected to a charging point but not charging [18].

move their vehicles away from the charging point by providing individual financial incentives. Charging point reservation systems [26,30] would aim to secure a charging spot for an individual EV driver, with the potential for efficient allocation of charging spots to local EV drivers. Yet such reservation systems could also create more competition amongst EV drivers for reserving the ideal time slot, which will likely overlap for multiple users. Unplugging another user's charging cables, if technically possible, could allow users to charge regardless of whether other vehicles were connected to the charging point, but this requires insight into the charging session of the currently connected vehicle and the vehicle owner's permission to avoid uncharged batteries and possible social conflict [12]. Accordingly, not all measures that allow one user to charge are automatically beneficial for other users or the relation between users.

Instead of focusing on individual advantages, measures targeting the social context and mutual interaction between users might reduce (feelings of) competition and stimulate cooperation. Creating and strengthening connections between users so that they can interact with one another could be a first step in leveraging the social context for behaviour change [12,31,32]. In these interactions, EV drivers sharing charging points have been shown to develop charging etiquettes that indicate the desirable use of a charger from a social perspective [33,34]. Conveying charging etiquettes to users through messages [35], emphasising the benefit of specific behaviour for neighbours [29], or providing normative feedback on the behaviour of others [31] might prove effective measures for leveraging the social context for behaviour change, but they have not been tested empirically on a large scale. Hence, focusing on the social context, such as the interactions between users, provides new and possibly more effective opportunities for behaviour change measures rather than focusing solely on an individual's behaviour. Therefore, it is essential to explore what these measures could be and how they could change behaviour.

Thus, there are differences between behaviours that influence charging point availability and the various types of measures that can influence those behaviours. Therefore, we have set out to explore and define the social dimension of charging behaviour and identify the range of measures that can influence this behaviour.

3. Methods

3.1. Sample and participants

An exploratory approach is required to define the social dimension of charging behaviour as a concept that has received little attention in research and policy. The expert interview is the exploratory research method [36] that we chose to gather insights about this behaviour from a broad perspective. We used maximum variation sampling as a purposeful sampling approach before data collection [37,38] by selecting experts from a broad variety of organisations working on, or having knowledge of, residential public charging infrastructure in the Netherlands, such as a municipality, a charge point operator, and a distribution systems operator. Table 1 provides an overview of organisation type per interview. Experts were approached via email, either directly by the first author or via gatekeepers [38] from the first author's network. During data collection, we used snowball sampling to further increase both sample size and diversity [37] to strive for a broad variety of perspectives on the social dimension of charging behaviour at residential public charging points. The first author asked several interviewees for contact details of relevant experts who either were not included in the initial sample or had not responded (yet) to an interview invitation.

The first author conducted 14 interviews with 15 experts representing 13 organisations.[4] Interviewees worked as directors, managers, or advisors. To avoid the identification of individuals, we have not specified the type of organisation or specific role in Table 1.

As Table 1 shows, we included multiple municipalities in the sample (interviews 3, 7, and 11) because municipalities, as the commissioning party for public charging points, are central actors in public charging infrastructure placement processes [39]. The municipalities differed in terms of number of inhabitants and, therefore, number of EV drivers, as well as the size of their charging infrastructure. Additionally, two interviewees worked at the same organisation (interviews 4 and 9) and had different and relevant expertise.

Table 1
Organisation type per interview in chronological order.

	Organisation type		Organisation type
1	Mobility association	8	Commercial consultancy
2	Charging optimisation platform	9	Non-academic knowledge institute
3	Municipality (100,000–200,000 inhabitants)	10	Distribution systems operator
4	Non-academic knowledge institute	11	Municipality (200,000–300,000 inhabitants)
5	Non-academic knowledge institute	12	Charge point operator and energy supplier
6	Provincial government	13	Ministerial agency
7	Municipality (more than 500,000 inhabitants)	14	Mobility association

3.2. Interview design

Interviews were semi-structured and included 14 open-ended questions to allow elaborate answers from the interviewees based on their expertise and knowledge. The interview format consisted of three sections, each with a distinct aim. Table 2 presents an overview of the interview format's aims, questions, and topics.

The first section aimed to identify the experts' descriptions of the social dimension of charging behaviour; the perceived effects of the social dimension of charging behaviour; the perceived opportunities for, and barriers to, promoting desirable or discouraging undesirable charging behaviour; and the perceived relevance of the social dimension of charging behaviour considering technological developments in charging infrastructure. Because of this study's explorative nature and the richness of data on behaviour and measures to influence behaviour, the result section is based on the analysis of data resulting from questions 1, 2, and 3 (behaviour, RQ1) and 6 to 9 (measures, RQ2).

To keep this paper focused, data from questions 4, 5, and 10 were not included. Results from these questions covered various actors other than EV drivers, such as municipalities, charge point operators, and distribution system operators. Additionally, results from these questions

Table 2
The aims and topics per question of the interview format.

Aim	Question	Topic
I	1–3	Descriptions of the social dimension of charging behaviour
	4–5	Effects of the social dimension of charging behaviour
	6–9	Opportunities for, and barriers to, promoting or discouraging desirable and undesirable charging behaviour
	10	Relevance of the social dimension of charging behaviour considering technological developments
II	11	Research topics of interest to expert
III	12	Case studies
	13	Distribution of survey
	14	Closing remarks

[4] One paired interview was held at the request of the initial interviewee contacted (interview 7). This provided rich information because the interviewees interacted with each other by complementing each other's answers. Time constrains however, prevented the posing of all interview questions.

covered effects of charging behaviour unrelated to charging point availability, such as the effect of charging behaviour on the image non-EV drivers could have of driving an EV. Since we focus on the effects of the social dimension of charging behaviour on charging point availability, and thus the effects of behaviour on EV drivers, discussing the results from questions 4, 5, and 10 would dilute the core analysis presented in this paper.

The questions addressing Aims II and III served a practical rather than a scientific purpose and are reported here only for full transparency. Aim II aspired to explore the research questions and topics of interest to the interviewee related to the social dimension of charging behaviour. Aim III aspired to identify case study opportunities to be used as entry points for the next stage of research, the possibility of distributing a survey amongst EV drivers, and to discuss any closing remarks that the interviewee might have.

3.3. Procedure

Emails to prospective interviewees included a description of the topics of interest (e.g., the social dimension of charging behaviour and measures to influence this behaviour), but no interview formats were shared with interviewees beforehand, for two reasons. First, and in line with this study's exploratory nature, we wanted interviewees to think about and conceptualise the social dimension of charging behaviour *during the interview*, to gather their initial ideas about the phenomenon without them studying the topic beforehand and basing their ideas of the behaviour on existing literature. Our approach aimed at increasing the diversity of answers. We considered asking interviewees to think about the social dimension of charging behaviour before the interview, as this could lead to more elaborate and diverse answers. However, because only a few papers refer to this social dimension, we wanted to avoid interviewees basing their ideas on these papers. Second, given the study's explorative nature, some interview questions required an introductory explanation to explain the meaning of certain concepts and for interview questions to logically follow up on one another. Hence, sharing an interview format beforehand would have diminished both of these efforts.

At the start of each interview, the first author explained the goal of the interview and the overall study and stressed the relevant knowledge that the interviewee could bring to the interview based on their work experience in their current position at their organisation. The first author emphasised that all interview questions were about residential public charging points and then first asked how the interviewee would describe the social dimension of charging behaviour at residential public charging points. After the interviewee answered these questions, the first author shared two descriptions of behaviour fitting within the social dimension of charging behaviour from the literature and subsequently asked the interviewee to reflect on this description. These descriptions were based on the work of Helmus and colleagues [15] and Van der Kam and colleagues [17]: moving an EV from a charging point either when the vehicle is sufficiently charged or at a fellow EV driver's request.

Interviews were held between 27 February 2023 and 14 March 2023. Before the interview, each interviewee signed a digital informed consent form following the ethical standards for research with human participants. Interviews, lasting 45 min on average and conducted in Dutch, were held in an online video meeting environment to allow for flexibility in their scheduling and still allow for rapport between the first author and interviewee by viewing each other's facial expressions. Probing was used to elicit clarification and elaboration during the interviews. Audio and video were recorded with the interviewees' permission. A transcription service created clean verbatim transcripts that the first author reviewed.

3.4. Interview coding

The transcripts were analysed, using ATLAS.ti software, after all interviews were conducted. As the interviews were exploratory, we used an inductive approach for data analysis. Transcripts were coded in multiple rounds. In the first round, the first author read the transcripts and assigned emerging codes to excerpts in the transcripts. Emerging codes were then assigned to categories [38]. Several categories corresponded with the interview questions from Aims I and II in Table 2. For example, the category, opportunity to promote desirable charging behaviour, corresponds with interview question 7 on the same topic. The categories were linked to four main themes. Two themes are relevant for this study: the social dimension of charging behaviour and measures to influence this behaviour.

In the second round, the first author coded the transcripts again with the set of codes from the first round, merging and specifying codes to create a comprehensive set of codes in each category. After this second round, the first, second, and third authors discussed the codes for each category to increase code reliability. In the third round of coding, the first author merged, split, and specified several codes based on the discussion with the second and third authors. The transcripts were then reread to check whether all codes were assigned to relevant excerpts.

4. The social dimension of charging behaviour: analysis and results

4.1. Analysis of behaviours: grid-conscious charging behaviour

We coded descriptions of behaviours and divided these codes into two categories: behaviours that are beneficial for sharing the charging point and those that are not. We also separately coded the specific examples of behaviour that interviewees provided as an illustration of the descriptions of behaviour.

After coding, the code, grid-conscious charging, was not included in the analysis of the social dimension of charging behaviour. Interviewees explained grid-conscious charging behaviour as charging behaviour that avoids peaks in energy demand, primarily because the charging point user chooses to charge before or after (evening) peak hours. Grid-conscious charging behaviour was considered social behaviour by some interviewees because it takes other local electricity users into account, not only users of the same charging point. However, answers referred to the benefits of the behaviour from a grid perspective, such as countering grid congestion, rather than benefits for charging point availability on a neighbourhood scale. We view this behaviour as a distinct form of charging behaviour, similar to load shifting behaviour in households, whereby energy is used at a specific time of day in response to grid conditions [40], aimed primarily at optimising local grid conditions for all electricity users in the neighbourhood [39] rather than improving charging point availability for EV drivers. Therefore, grid-conscious charging behaviour does not align with our focus on the social dimension of charging behaviour for sharing charging points.

4.2. Defining the social dimension of charging behaviour

In relation to RQ1 about defining the social dimension of charging behaviour, we identified 17 behaviours, listed in Table 3. Behaviours are categorised as prosocial or antisocial and rooted in human–technology interaction or interpersonal interaction. This categorisation results in four subsets of behaviour.

Before elaborating on the categorisation listed in Table 3, we want to highlight that each of these behaviours refers directly or indirectly to the social context of other charging point users, in line with the idea that a residential public charging point is a shared commodity with multiple returning users. Therefore, each behaviour fits within the concept of social behaviour: each behaviour could either be influenced by the presence of other charging point users, whether actually present or otherwise [41], or have consequences for other charging point users. Hence, the identification of the behaviours confirmed that sharing the charging point is inherently a social matter. Therefore, all behaviours

Table 3
Behaviours per type of behaviour and type of interaction.

	Prosocial charging behaviour	Antisocial charging behaviour
Interpersonal interaction	1. Contacting other EV drivers about the charging point, for example: a) Sending a message to, or ringing the doorbell of, a neighbour to request the use of the charging point b) Organising a WhatsApp group with other charging point users c) Leaving your telephone number on a note behind the windshield or posting it via a QR code on the charging point d) Notifying someone when the charging point becomes available	7. Not participating in joint agreements with other EV drivers 8. Not responding to messages from other EV drivers 9. Not granting requests from other EV drivers
Human–technology inter	2. Charging only when necessary or only charging the necessary energy 3. Moving a vehicle from the charging spot after charging or within a specific time after charging 4. Treating the charging point properly by avoiding damage or misuse 5. Reporting damage to, or malfunctioning of, the charging point 6. Requesting a new public charging point	10. Using a charging spot only as a parking spot, including: a) Using a charging spot for parking when parking pressure is high b) Non-electric vehicles parking at a charging spot 11. Occupying the charging point longer unintentionally, such as: a) Forgetting to move the vehicle b) Not being able to move the vehicle 12. Blocking the charging point for specific EV drivers 13. Not reporting damage to, or malfunctioning of, the charging point 14. Parking too spaciously, obstructing a second vehicle from parking close to the charging point 15. Reserving a charging spot unauthorised 16. Charging without any need to charge 17. Charging slowly or at a later time purposefully so that the vehicle can be parked at and connected to the charging point longer[a]

[a] Charging speed or time of charging can be adjusted via settings in the vehicle.

presented in Table 3 can be considered *social* behaviour, as they are inseparable from the social context that they affect or are influenced by.

4.2.1. Interpersonal and human–technology interactions

Not every behaviour identified concerns the actual *usage* of the charging points. Rather, every behaviour affects the *opportunity* for (other) EV drivers to charge their vehicle at the charging point. Opportunity here refers to external factors, both social (e.g., through direct interaction with other EV drivers) and physical (e.g., through interaction with technology such as the charging point or an EV), that increase or decrease the likelihood of behaviour occurring [20], in this case, charging an EV at a residential public charging point. These external factors can influence behaviour positively, aiding the use of the charging point, or influence behaviour negatively, obstructing the use of the charging point. Therefore, we distinguished between two types of *interactions* through which the opportunity to charge can be provided or enhanced, or prevented or diminished. The first type is interpersonal interactions, encompassing the interactions between individuals, such as communicating via face-to-face contact or digital communication technology. These behaviours are displayed in the top row of Table 3. The second type is human–technology interactions, encompassing the interactions between individuals and technology, such as a charging point or EV. These behaviours are displayed in the bottom row of Table 3.

4.2.2. Prosocial and antisocial behaviour

The 17 behaviours presented in Table 3 can be classified into two distinctive categories. In the first category, presented in the left column of Table 3, six out of the 17 behaviours benefit other charging point users by making the public charging point accessible to these users. From a social-psychological perspective, behaviours that benefit others can be considered *prosocial behaviour* [42,43]. Examples of prosocial charging behaviour include notifying a neighbour when the charging point becomes available or promptly moving a vehicle from the charging spot after charging. In the second category, presented in the right column of Table 3, 11 out of the 17 behaviours are disadvantageous for other charging point users, as these behaviours make it increasingly difficult for other users to charge their vehicles. These behaviours can be classified as *antisocial behaviour*, behaviours that infringe on other users' rights [44] to use the public charging point as a shared commodity accessible for all. Examples of antisocial charging behaviour include occupying a charging spot long after charging or not reporting a malfunctioning charging point.

Differentiating between prosocial and antisocial behaviour leads us to two definitions of the social dimension of charging behaviour. Answering RQ1, How can we define the social dimension of charging behaviour at residential public charging infrastructure?, we define prosocial charging behaviour as *behaviour that provides or enhances the opportunity for other users to charge their vehicle at a public charging point.* In contrast, we define antisocial charging behaviour as *behaviour that prevents or diminishes the opportunity for other users to charge their vehicle at a public charging point.*

As not all behaviours concern charging of the vehicle, a distinction can be made between direct and indirect prosocial and antisocial charging behaviours. Direct prosocial and antisocial charging behaviours influence the opportunity to charge for other users because of the connection between the EV and the charging point. Examples are charging a vehicle only when necessary (*behaviour 2*) or timely moving a vehicle from a charging spot once charged (*behaviour 3*). Indirect prosocial and antisocial charging behaviours influence the opportunity to charge for other users for reasons not related to the connection between the EV and the charging point, such as parking. Hence, non-EV drivers can exhibit antisocial charging behaviour by parking at a charging point and consequently blocking this charging point for an EV driver (*behaviour 10b*).

4.2.3. Behaviour intention

When describing specific behaviours, some interviewees referred to a user's *intentions*. The analysis indeed shows that several behaviours seem to signal an intention to provide or enhance, or prevent or diminish, the opportunity for other users to charge their vehicle. Intention here refers to the commitment to the outcome of the behaviour [45] and thus

whether the outcome of the behaviour is also the motivation for the behaviour [46]. In contrast, unintentional behaviour could have the same outcome but as a consequence rather than an aim. Examples of intentional behaviours include blocking the charging point for a specific EV driver out of frustration with the antisocial behaviour of that specific EV driver (*behaviour 12*), knowing that neighbours make joint agreements but choosing to ignore, and not participate in, those agreements (*behaviour 7*), and starting a WhatsApp group to allow for contact between EV drivers about the use of the charging point (*behaviour 1*). An example of unintentional antisocial charging behaviour includes not responding to messages from other EV drivers because one does not have one's phone to hand (*behaviour 8*). A benefit of interpersonal interaction includes the opportunity to explain intention: not granting someone's request to charge (*behaviour 9*) might be because the owner of the vehicle currently charging cannot make time to move the vehicle. As interviewees referred to the hypothetical behaviours of others, we highlight intentionality as an essential aspect of understanding prosocial and antisocial charging behaviour but also emphasise that intentionality is only assumed in the examples given here. Therefore, we decided not to include intentionality as a distinguishing category of behaviour.

5. Influential measures: analysis and results

5.1. Analysis of measures: the Behaviour Change Wheel framework

We labelled the opportunities to promote desirable or discourage undesirable charging behaviour (interview questions 6 to 9) as *measures* for influencing the social dimension of charging behaviour. We then categorised these measures using the Behaviour Change Wheel framework [20], which stipulates that measures to influence behaviour use one or more *intervention functions*: "broad categories of means by which an intervention [measure] can change behaviour" (p. 109) [20]. The Behaviour Change Wheel contains nine intervention functions: *education*, *persuasion*, *incentivisation*, *coercion*, *training*, *restriction*, *environmental restructuring*, *modelling*, and *enablement* [20]. We assigned each measure to the most prominent intervention function. We did not ascribe any measures to the intervention function *training*, because interviewees did not mention any opportunities that fit this intervention function. *Restriction* was not considered a relevant intervention function for the analysis given the lack of ascribed behaviour change techniques (see next paragraph) [20]. As *environmental restructuring* can refer to a social or a physical context [20], we specified this intervention function as *social environmental restructuring* and *physical environmental restructuring* to clearly indicate the environment that a measure restructures.

Within each intervention function, each measure was then linked to a behaviour change technique: "an active component of an intervention [measure] designed to change behaviour" (p. 145) [20]. We used behaviour change techniques to specify how each measure aims to change behaviour within a specified intervention function, allowing us to further characterise each measure's content and identify similarities between measures [47]. Per measure, we selected the most fitting technique from the Behaviour Change Technique Taxonomy (v1) [20]. If no suitable technique was found in this taxonomy, we selected a technique from the Intervention Mapping Approach Taxonomy [48]. We considered techniques most fitting when they matched the measure's content as described by interviewees. We did not use techniques, which do not change behaviour by themselves but need to be used in combination with other techniques [47] such as tailoring [48] or credible source [20]. For two measures, no suitable technique was found in either taxonomy. Therefore, we formulated two new techniques, covering the influence of technological aspects that we consider lacking in the two existing taxonomies. The selection of techniques was discussed between the first, second, and third authors. This analysis resulted in 23 measures covering seven of nine intervention functions and 16 behaviour change techniques. The analysis showed that interviewees mentioned several opportunities that could both discourage undesirable charging behaviour and promote desirable charging behaviour for sharing the charging point and improving charging point availability. Hence, we combined all measures that have the potential to influence the social dimension of charging behaviour in one overview.

5.2. Identifying and analysing measures for influencing the social dimension of charging behaviour

RQ2 enquires about measures to influence the social dimension of charging behaviour. Table 4 shows the 23 measures, an example of each measure from the interviews, the type of interaction that each measure targets to influence, and how these measures relate to the behaviour change techniques and the intervention functions. We have divided the measures into two distinctive categories based on the type of interaction that each measure aims predominantly to influence: human–technology interaction and interpersonal interaction. This distinction between these two interactions continues the same distinction identified for the behaviours displayed in Table 3. The type of interaction is displayed in the second column of Table 4 and is based on the assigned intervention function and behaviour change technique for each measure.

5.2.1. Human–technology interaction

In the first category, 16 measures aim to influence the interactions between individuals and technology. Four measures consist of forms of communication through the *education* and *persuasion* intervention functions. Examples include information on desirable charging behaviour and technical information about the charging infrastructure. Three measures from the *incentivisation* intervention function emphasise financial and non-financial rewards. For instance, both shorter charging times and shorter connection times between the EV and the charging point might be rewarded. *Coercion* as an intervention function contains the most measures, with four out of six aimed at sanctioning behaviour financially. Two of these six measures also focus on influencing the use of the charging spot specifically. Three measures from the *environmental restructuring (physical)* and *enabling* intervention functions emphasise technological and environmental alterations. These measures could influence charging behaviour through improved EV battery technology, additional charging points, and additional sockets per charging point.

5.2.2. Interpersonal interaction

In the second category, seven measures aim to influence the interpersonal interactions between individuals. These measures of the *environmental restructuring (social)*, *modelling* and *enabling* intervention functions address the social dimension of charging and sharing the charging point. For instance, interpersonal interaction can be influenced by encouraging discussions about charging behaviour amongst neighbours or by facilitating interactions between charging point users who might not talk to each other. Several measures focus on a collective of users, such as stimulating conversation about charging behaviour in existing local neighbourhood networks and providing neighbourhoods with shared ownership of the charging point.

5.2.3. Barriers and considerations

Although these 23 measures provide various opportunities for behaviour change, we highlight two noteworthy caveats for implementing measures. First, interviewees perceived barriers that would make implementing certain measures difficult or not feasible. Multiple barriers were mentioned for facilitating social interactions, in particular, for instance through digital applications. These barriers were data related, such as privacy issues with data exchange with commercial platforms, but also include organisational aspects. Questions were, for instance, raised about the demarcation of user groups per charging point if users frequently charge at multiple different charging points and visitors also charge occasionally. Perceived barriers also concern user behaviour, raising questions about whether people want to join a platform and respond to messages or requests from other users. Several

Table 4
Measures to influence the social dimension of charging behaviour. The numbers at the behaviour change techniques correspond with the source for the technique. 1 = Behaviour Change Technique Taxonomy (v1) [20], 2 = Intervention Mapping Approach Taxonomy [48], 3 = formulated by authors.

Intervention function	Type of interaction to influence	Measure	Example	Behaviour change technique
Education	Human–technology	Information about the consequences of (one's own) charging behaviour	Inform individual EV drivers about neighbours' charging needs	Information about social and environmental consequences **1**
		Communicate charging etiquettes	Communicate rules for desirable charging behaviour	Instruction on how to perform a behaviour **1**
		Technical information	Provide information on charging sessions, charging point availability, and local charging infrastructure developments	Information about technology **3**
Persuasion	Human–technology	Appeal to morals or a sense of humour	Use written or verbal communication to appeal to the moral of good behaviour	Persuasive communication **2**
Incentivisation	Human–technology	Point reward system	Reward desired behaviour with points that can be used for discounts on a charging session	Reward (outcome) **1**
		Financial reward	Provide a financial reward when the EV is moved directly or shortly after the vehicle is fully charged	
		Non-financial reward	Provide the option for increased charging speed for EV drivers who often remove their vehicle for others on request	
Coercion	Human–technology	Idle fee	Charge a fee when the EV is connected to the charging point but is not, or is no longer, charging	Punishment **1**
		Adjust charging rate (structure)	Increase existing or add new charging rates	
		Non-financial sanction	Temporarily suspend the possibility of sending charging request messages to other users in an app when no requests are answered	Behaviour cost **1**
		Fines and enforcement	Enforce local, regional, or national legislation on charging point hogging by issuing fines when violated	Creating and enforcing laws and regulations **2**
		Paid parking	Charge a parking fee during and/or after charging (applicable to all parked vehicles)	
		Maximum parking time	Apply a maximum parking time for the dedicated parking spot(s) at the charging point, regardless of charging	
Training	No measures with this intervention function were identified			
Restriction	This intervention function was not used in the analysis			
Environmental restructuring (Social)	Interpersonal	Existing local networks	Integrate talking about sharing charging points into existing neighbourhood social networks	Mobilising social networks **2**
		Discuss behaviour	Make charging behaviour a topic of conversation amongst neighbours	Restructuring the social environment **1**
		Make mutual agreements	Have local EV drivers create rules amongst themselves for sharing the charging point	Social comparison **1**
		Social pressure	Provide apps that display other users' charging data to allow for social comparison or naming and shaming	Adding objects to the environment **1**
Environmental restructuring (Physical)	Human–technology	Install more public charging points	Expand the residential public charging infrastructure with more charging points	Adding objects to the environment **1**
		Add additional parking spots and sockets to existing charging points	Allow four vehicles to park and connect to the charging point, but charge only two vehicles simultaneously	Restructuring the physical environment **1**
Modelling	Interpersonal	Ambassadors	Assign a local EV driver as an ambassador to a public charging point and have them set a good example for other users	Modelling **2**
Enablement	Interpersonal	Facilitating social interactions	Facilitate or organise social interactions between local EV drivers through digital communication	Community development **2**
		Locally shared ownership	Give the neighbourhood, as a social collective, (more) ownership of the charging point	
	Human–technology	Improved batteries	Increase battery range to decrease charging-need frequency	Improving technology **3**

barriers were also presented for fines and enforcement. These barriers included a lack of enforcement capacity and budget, data privacy, and enforcement officers' inability to access charging data and conclude how long a charging session might have lasted.

Second, several interviewees remarked that the measure deployed should be proportional to the behaviour that it seeks to influence, highlighting a sense of the moral desirability of measures. Examples include heavily sanctioning unintentional antisocial charging behaviour (e.g., hefty fines for forgetting to move a car), providing charging opportunities for one user to the disadvantage of another user (e.g., exclusivity on charging point reservation options), or using measures that are unlikely to voluntarily induce prosocial behaviour (e.g., naming and shaming of antisocial behaviour).

6. Discussion

6.1. The social dimension of charging behaviour from a social-psychological perspective

We have taken a social-psychological approach to charging behaviour to answer RQ1: How can we define the social dimension of charging behaviour at residential public charging infrastructure? Based on expert interviews in the Netherlands, we identified 17 distinct behaviours that all affect the opportunity for (other) EV drivers to charge their vehicles at the charging point. All these behaviours either are influenced by the presence of other charging point users or have consequences for these other users, highlighting that residential public charging points are shared commodities.

These behaviours can be categorised as prosocial or antisocial. In line

with the concept of prosocial behaviour in social psychology [42,43], prosocial charging behaviour benefits fellow charging point users by making the public charging point accessible to these users. In contrast, antisocial charging behaviour, in line with the concept of antisocial behaviour [44], disadvantages other charging point users by making it difficult for them to charge their vehicles.

The differentiation between prosocial and antisocial charging behaviour results in two definitions. We have defined prosocial charging behaviour as behaviour that provides or enhances the opportunity for other users to charge their vehicle at a public charging point. Similarly, we have defined antisocial charging behaviour as behaviour that prevents or diminishes the opportunity for other users to charge their vehicle at a public charging point. This opportunity can be provided or enhanced, or prevented or diminished, through interactions between individuals and technology or through interpersonal interactions between individuals. Within these two definitions, we have encapsulated the various behaviours mentioned in previous studies [12,13,15–17,26,29] and provided an overview to interpret all these behaviours from a social-psychological perspective.

Intentionality appears to be an important aspect for understanding the social dimension of charging behaviour, given that interviewees occasionally referred to users' intentions to behave prosocially or antisocially. These references about intentionality were, however, based on assumptions. Still, intentionality is relevant not only for the analysis of the individual's motivation but also for how other charging point users view this behaviour. Observers might ascribe the behaviour of others to specific intentionality, thinking, for instance, that the observed user is intentionally acting antisocially and lacks the willingness to cooperate. Alternatively, however, this apparent lack of cooperation might be the result of situational factors rather than an intention to act antisocially [27]. This misinterpretation could result in the observer resorting to antisocial behaviour, no longer willing to cooperate with other users but instead aiming to maximise their outcomes and perhaps retaliate [49].

Additional empirical research could extend our findings and offer further insight into prosocial and antisocial charging behaviour. We have two recommendations in particular. First, interviews with EV drivers could validate whether this study's categorisations of behaviours match their perceptions, validate our assumptions about the intentionality of specific behaviours, and reveal potential additional prosocial or antisocial charging behaviours that the current study did not identify. Additionally, the interviews could explore differences in EV drivers' perceptions of charging behaviours, such as when charging is perceived as necessary or when a parked vehicle is perceived as occupying the charging point for too long. Survey data from EV drivers could then show how frequently certain behaviours occur, how often specific behaviours are performed intentionally, and how beneficial or detrimental EV drivers experience the behaviour of others regarding the opportunities to charge their vehicle.

Second, survey data from EV drivers could determine the most influential factors for *each* specific behaviour. These factors can be divided into individual (e.g., charging habits during weekdays), social-psychological (e.g., conformity to shared rules [50] on desirable charging behaviour), and contextual (e.g., number of charging points in the neighbourhood) level factors. Identifying which factors significantly influence which specific behaviour, for instance through regression analysis, is vital for developing tailored behaviour-change strategies that target these specific factors effectively to change behaviour.

6.2. The social dimension: charging points and the grid

The time an EV is connected to the charging point is an essential aspect of prosocial and antisocial charging behaviour from the user-centric perspective we have taken in this study: the shorter the connection time and the sooner the EV is moved to a different location, the more opportunity is offered to other charging point users to charge. However, long connection times can be beneficial from a grid perspective. Smart charging and grid-conscious charging, whereby EVs are charged slower or outside of peak hours [39], are beneficial for alleviating peaks in energy demands and avoiding grid congestion. As some interviewees highlighted, charging sessions in favour of the grid have a social dimension, as they enable other electricity users, such as households, to use electricity during peak hours and avoid costly grid reinforcements.

Thus, smart charging and grid-conscious charging focus on distributing energy amongst all grid users, highlighting a social dimension from a grid perspective aimed at electricity users. Prosocial and antisocial charging behaviour, on the other hand, concerns the distribution of charging point availability, highlighting a social dimension from a local charging point perspective aimed at EV drivers. While prosocial and antisocial charging behaviour and grid-conscious and smart charging behaviour are contradicting in terms of providing charging point availability, both forms of charging behaviour are aimed at providing benefits to others, albeit on different scales and aimed at different subgroups. Additional research could explore how EV drivers perceive the social dimension of grid-conscious and smart charging, and whether this is an important motivation for changing their charging behaviour.

6.3. Measures to influence the social dimension of charging behaviour

Having defined the social dimension of charging behaviour, we arrive at RQ2: What measures to influence the social dimension of charging behaviour at residential public charging infrastructure can we identify? We have identified 23 measures that influence the social dimension of charging behaviour and analysed these measures using the Behaviour Change Wheel's intervention functions and behaviour change techniques [20]. Each measure targets human–technology or interpersonal interactions, building on the distinction between these interactions as identified for the prosocial and antisocial charging behaviours.

Sixteen measures target human–technology interactions. These measures range from informing and persuading users through communication, to punishing or rewarding specific behaviour at the charging point, to altering the charging spot and the charging point. Financial sanctions are prominent in this category, possibly reflecting the current standard practice of influencing charging and parking behaviour through existing measures such as fines and enforcement, idle fees, and paid parking. Similarly, measures aimed at providing information might also reflect current practices, such as websites communicating charging etiquettes [51] or charging apps providing technical information [52]. These measures are often implemented top-down by municipalities and charge point operators. Expanding residential charging infrastructure could increase charging opportunities for EV drivers, although the accompanying increase in EVs does not automatically mean more opportunities to charge are granted if the charger-to-EV ratio remains the same. Similarly, increasing battery range could result in fewer charging sessions per EV but simultaneously lengthen charging sessions as well. Therefore, the effects of these two measures on charging point availability remain debatable.

In contrast, seven measures target interpersonal interactions. These measures directly target the social dimension of charging behaviour and emphasise the importance of local networks and increased mutual interactions. EV drivers can take the initiative to implement these measures. Research points out that some EV drivers take that initiative, for instance by making mutual agreements [33]. Similarly, the opportunity to engage in mutual interactions is made significantly easier by digital platforms facilitating social interactions between EV drivers based on using the same charging point [32].

Still, such a platform requires an active userbase to function adequately. User concerns about data privacy might, for instance, prohibit adequate facilitation of social interactions via digital platforms. Thus, to implement any measure, it is vital to assess potential barriers.

Additionally, measures should be proportional to the behaviour that they aim to influence. Heavy financial sanctions for behaviour of only minor inconvenience to other charging point users might not be morally desirable.

In categorising the measures, we used behaviour change techniques that reflected the measure's content. Accordingly, the measures in the results section are described form free: we did not specify how measures are to be designed and strategically implemented or which actors are to be involved, because this can vary per measure. For example, charging etiquettes can be communicated by a municipality through a local poster campaign, by a car dealership with flyers for new EV owners, or by the charge point operator with a sticker on the charging point. All three approaches would differ in form, sender, and, arguably, effectiveness. Consequently, certain measures can be the result of other measures: a municipality giving locally shared ownership of a charging point to a neighbourhood could result in local EV drivers making mutual agreements on desirable charging behaviour, who then communicate charging etiquettes to newcomers to reinforce these agreements.

Field experiments could test which measures effectively influence specific behaviours by targeting the behavioural factors of each behaviour. Experiments could also test the difference in efficacy between measures targeting either interpersonal interaction or human–technology interaction. For instance, research could show the difference in efficacy between a direct and personalised text message from a neighbour to move a vehicle (interpersonal interaction) and a standardised automated app notification from the charging point referring to the positive effects of the behaviour for unspecified neighbours in general (human–technology interaction) (e.g., [29]).

6.4. Reflection on generalizability and methodology

The Netherlands has an extensive public charging infrastructure [22,23], making the Dutch context particularly suitable for exploring the social dimension of charging behaviour. However, the extensive charging infrastructure might also reduce the need for prosocial charging behaviour. Research on the social dimension of charging behaviour in other countries, where the average number of charging points is (much) lower, would provide valuable insight into the generalizability of the results. Additionally, research has shown the importance of social interactions for sharing workplace charging infrastructure [33,34]. The similarities between public residential and workplace charging infrastructure, such as a delineated and recurring user group, highlight the generalizability of our study's results to this type of charging infrastructure. To evaluate the results of this article for a different context, notable differences and similarities in charging infrastructure and share of EVs should be considered.

Moreover, we highlight two aspects of this study's methodology that are important to consider for interpreting the results. First, although we selected experts from various organisations, the sample selection might have resulted in an emphasis on specific answers. For example, experts from municipalities might be prone to suggest fines and enforcement as a measure to influence behaviour, as this is common practice for local governments. Hence, the list of measures presented here might not be exhaustive.

Second, five interviewees were driving an EV at the time of the interview, and three others indicated prior experience with driving and charging an EV on multiple occasions. This makes these interviewees both experts as well as private persons [36] who can reflect on their own personal experiences with EVs and public charging infrastructure. Although we did not probe for their personal experiences, some answers might have still implicitly included a personal bias.

7. Conclusion

The social dimension of charging behaviour is becoming an increasingly important topic in the transition to full electric mobility. We highlight the social complexity of charging behaviour by viewing charging behaviour from a social-psychological perspective. We have identified prosocial and antisocial charging behaviour and have provided a comprehensive definition for each. These prosocial and antisocial charging behaviours are rooted in interpersonal and human–technology interactions. Building on this distinction between interactions and using the Behaviour Change Wheel framework, we have identified and analysed a range of measures that can influence these behaviours. Implementing measures to address the social dimension of charging at residential public charging infrastructure opens up opportunities to increase charging point availability. Policymakers can use the variety of behaviour change techniques ascribed to the measures listed in the results section to gain inspiration for developing measures that are not currently standard practice [47].

We are confident that the definitions of charging behaviour and the range of measures provided in this paper will give researchers and public charging infrastructure stakeholders, including policymakers and charge point operators, new insights and tools to address this behaviour.

CRediT authorship contribution statement

Milan Tamis: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gerdien de Vries:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Reint Jan Renes:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Floor Alkemade:** Writing – review & editing, Funding acquisition.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The authors do not have permission to share data.

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