Acceptance, adoption and nudging of smart charging

Influencing adoption of smart charging solutions through nudging

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Abstract

Smart charging is seen as an effective way to reduce grid loads and demand peaks resulting from the charging of electric cars, but until now little research has been done on user acceptance and the willingness to adopt this system. This study focuses on the motives underlying acceptance and adoption of smart charging. Moreover, a nudging experiment within the context of a letter is carried out to investigate if adding a descriptive social norm or changing the default to opt-out can positively influence acceptance and adoption of smart charging. In this experiment respondents receive a letter which informs them about smart charging and invites them to participate in a smart charging pilot. Respondents are randomly assigned to one of three letters which contains either a descriptive social norm, an opt-out condition or no treatment. For a sample of 50 electric car drivers from The Netherlands our results show that environmental benefits and integration of renewable energy sources are the most important motivations underlying the acceptance of- and the willingness to adopt smart charging solutions. Furthermore, adding a descriptive social norm to the letter has a slight negative effect on the willingness to adopt smart charging, which indicates that one should be cautious with the implementation of nudges. These and other results should be taken into account by policymakers in order to achieve broad adoption of smart charging in the future.

Keywords: smart charging; electric car; user acceptance; nudging; default; social norm; psychological experiment; renewable energy; environment

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1. Introduction

In the fight against global warming electric vehicles (EV's) hold the future for public and private transport. They are seen as an effective way to reduce road transport CO_2 emissions, which have been linked to temperature rises all over the world (Allen et al., 2009, Matthews et al., 2009). EV's are expected to claim a significant market share by 2030 (Hanschke et al., 2009; Kalhammer et al., 2009; Santini, 2007; European Commision, 2006; IEA, 2007; IEA, 2013; Hoekstra, 2017). The European Union proposed a law that demands 40% of the new vehicles in 2030 must be zero- or low emission vehicles (UN, 2015; EU, 2018). The Netherlands is even more ambitious aiming for a 100% zero emission vehicles sold that same year (RVO, 2018). However, this may have serious consequences for the power grid. (Putrus et al., 2009). One of the main challenges of EV's is the coordination of charging patterns (van Vliet et al., 2011; DeForest et al., 2009; Parks et al., 2007; Horst et al., 2009). Currently massive energy demand peaks can be observed at the beginning and ending of a typical workday (Spoelstra, 2014). If nothing changes, this uncoordinated charging behaviour will exceed the capacity of the power grid in the future (van Vliet et al., 2011). Smart charging, a software system that coordinates the charging of the EV on basis of real time grid loads, could help reduce the demand peaks if it is widely implemented (Liu et al., 2011; Garcia et al., 2014). Yet research shows that EV drivers might be reluctant to adopt this system due to various reasons, such as potential reduced mobility (Grahn & Söder, 2011; Will, & Schuller, 2016; Frenzel et al., 2015; Geske, 2014; Deffner et al., 2012). Likewise, new government policy in the Netherlands aiming to install smart meters in 80% of the Dutch households by 2020 endured a lot of criticism from the media leading to reluctancy among citizens to get one installed (Yan et al., 2013; Energieleveranciers, 2015). Customer research showed that one in ten household did not want the new electricity meter that transforms household energy consumption into digital data, which is then sent to the utility to give them insight in peak demands and energy generation (Yan et al., 2013; Essent, 2019; Energieleveranciers, 2015). However, the smart meter is seen as a key factor in the smart grid solutions (Yan et al., 2013). Smart charging may be even more important in the future (Liu et al., 2011; Garcia et al., 2014; van Vliet et al., 2011). Nudging, a variety of techniques to guide people towards the desired choice or behaviour by changing the context in which decision are made, has proven to be successful in changing energy usage (Fischer, 2008; Delmas et al., 2013; Allcott et al., 2010) and smart-grid solutions like the smart meter (Ölander & Thøgersen, 2014). Even adding small nudges to customer letters could increase response rates and participation (Service et al., 2014; Garner, 2005; Adams & Hunt, 2013).

1.1. Research approach

Currently little is known about the likelihood of adopting smart charging solutions by the general public. An ambitious German study gave a first broad insight in the motives behind user acceptance of smart charging (Will & Schuller, 2016). However, most if not all participants in the study did not have any experience with smart charging, nor was there a realistic scenario in which they would adopt smart charging in the near future (Will & Schuller, 2016). Besides, acceptance was tested with a 9 items scale on attitudes (Van der Laan, 1997). Therefore, more research is warranted to test if a higher acceptance would lead to a larger adoption of smart charging, as the causal relation between attitudes and behaviour has been a subject of discussion for the past 60 years (Ajzen & Fishbein, 2005). A few actual smart charging pilots provided some first-hand user responses, yet target groups were very small (Bauman et al., 2016; Schmalfuss et al., 2015). Moreover, the few people participating in a smart charging pilot might have been more positive towards smart charging in the first place. In response to the study by Will & Schuller (2016) on the acceptance of smart charging and research by Ölander & Thøgersen (2014) on the nudging of energy consumption and the adoption of the smart meter, the current study will begin with testing the findings of Will & Schuller (2016) in the Dutch context. Secondly, the relation between acceptance and adoption of smart charging will be researched. Finally, this study will explore whether certain nudging techniques can provide a positive change in the acceptance and adoption of smart charging. These goals relate to the following questions:

> Q1: *"What motives do people have to accept smart charging solutions?"*
>
> Q2: *"What is the relation between acceptance and adoption of smart charging solutions?"*
>
> Q3: *"To what extent can nudging increase adoption of smart charging and does it also influence acceptance?"*

In order to answer these questions a survey-based experiment is set up consisting of multiple survey questions regarding user acceptance (Will, & Schuller, 2016) as well as an experiment to test the effects of two different nudges on the willingness to adopt smart charging.

Briefly, this manipulation is presented in the context of a bogus pilot study, in which either a social norm nudge or a changing the default nudge is presented in a letter that invites respondents to participate in a smart charging pilot. Three different letters are randomly assigned to participants containing either the descriptive social norm treatment, the changing the default (from opt-in to opt-out) treatment or no treatment. This study aims to fill the gap of knowledge in user adoption of smart charging solutions as well as adding to the growing body of knowledge about applying nudging techniques. Moreover, as broad adoption of smart charging is necessary to prevent the exceedance of the power grid (Liu et al., 2011; Garcia et al., 2014), the findings of this study can serve as input for the creation of policy regarding the implementation of smart charging solutions.

2. Theoretical Framework

2.1. Smart charging

Most EV’s are charged on a daily basis (Spoelstra, 2014). Opposed to fuelling a car, charging a car takes a lot of time. The length depends on the size of the battery and the charging station. For example, the Tesla Model S takes between 5:45 and 9:45 hours to fully recharge (EV-database, 2019). The charging of electric cars puts a lot of pressure on the power grid, due to the high electricity consumption of these cars (Putrus et al., 2009). Moreover, the charging of EV’s mostly happens in an uncoordinated manner, potentially overloading the power grid during peak hours, yet leaving it unused at other times (Putrus et al., 2009; Spoelstra, 2014). In the future peak loads resulting from uncoordinated charging may exceed the capacity of the current power grid (van Vliet et al., 2011; Putrus et al., 2009). The clustering of EV’s in certain areas can add to this problem (DeForest et al., 2009). Smart charging has the potential to solve this problem (Liu et al., 2011; Garcia et al., 2014).

Normally charging your EV is just like charging your phone, you plug it in and it starts charging until it is full. With smart charging your EV does not charge in a continuous manner. A software system coordinates the charging of the EV on basis of real time grid loads and energy prices, reducing peak loads and optimizing energy usage (Liu et al., 2011; Garcia et al., 2014). It is also possible to enable charging only when your solar panels are supplying energy, so that you drive on sustainable and free energy (Mountox, 2019). Via an app you can get insight in your energy use, customize the way your car is being charged and set the time your car needs to be fully charged (Mountox, 2019; Bauman et al., 2016; Schmalfuss et al., 2015).

An innovation that is one step beyond is Vehicle-to-Grid (V2G) Discharge. This system makes it possible to use your electric car as a separate energy storage, discharging it via a special power station to supply other devices with energy (Liu et al., 2011). If for instance a household generates electricity during the day with solar panels, this energy can be stored in the car battery and used during the day. At night the car can be charged off-peak against lower energy tariffs (Liu et al., 2011). V2G can also be used to help balance the supply and demand within the electricity grid. During demand peaks electric car owners can 'sell' their surplus energy to providers (Newmotion, 2018). It should be noted that there is a large variety of technical smart charging methods and thus not (yet) one optimal system (Hilshey et al., 2013; Mal et al., 2013; Liu et al., 2011; Newmotion, 2018). However, going into detail on the technical aspects of the smart charging solutions exceeds the capacity and the goal of this study.

In sum, smart charging is a software system that coordinates the charging of EV's based on, among other things, current grid loads. When power demand is high the system delays charging until power demand is lower, thus reducing peaks in energy demand (Liu et al., 2011; Garcia et al., 2014). While smart charging holds many benefits such as grid support and integration of renewable energy sources (Liu et al., 2011; Garcia et al., 2014; Mountox, 2019; Will & Schuller, 2016), research shows that a broad adoption of smart charging solutions by EV drivers might not come naturally (Grahn & Söder, 2011; Will, & Schuller, 2016; Frenzel et al., 2015; Geske, 2014; Deffner et al., 2012).

2.1.1. Range anxiety and flexible mobility

One reason why people might be reluctant to adopt smart charging is the need for flexible mobility. This can partly be explained in the context of range anxiety. Range anxiety is a relatively new phenomenon related to electric driving. It is the fear of a driver that his EV has insufficient range to reach the desired destination, which is amplified by the inability to- or length of charging to increase range. (Rauh et al., 2015; Jung et al., 2015). Range anxiety can lead to stress avoidance by reserving substantial range buffers to stay within one's range comfort zone. This is averagely 80% of one's available range (Franke & Krems, 2013a; Franke, Neumann, et al., 2012). As a result EV drivers charge more often and longer than needed (Franke & Krems, 2013b). Range anxiety is thus related to the need for flexible mobility, as the desire to lower range anxiety leads to a higher need for flexible mobility (i.e.

always keep your car as fully charged as possible). One ‘downside’ of smart charging is the reduction of this flexible mobility, since your EV will not be charged as soon as possible unless you overwrite the system. The need for flexible mobility is found to decrease smart charging acceptance (Will & Schuller, 2016; Geske, 2014; Deffner et al., 2012). Therefore, we hypothesize that the need for flexible mobility has a negative effect on the acceptance of smart charging (H1); and a negative effect on the adoption of smart charging (H1.1).

2.1.2. Vehicle type

Currently there are two types of plug-in electric vehicles: the plug-in hybrid (PHEV) and battery electric vehicle (BEV). The PHEV has a small battery that allows for short trips of approximately 50 km as well as a ‘standard’ internal combustion engine (ICE) for longer driving (van Vliet et al., 2011). The BEV is fully electric with a large battery that allows for trips of 200-530 km (van Vliet et al., 2011; Schreurs, 2019).

PHEV drivers might experience less range anxiety than BEV drivers, because they can always rely on their ICE generator when their battery runs out, whereas BEV’s are fully depended on the battery (Spoelstra, 2014). Indirectly this could affect the negative effect of reduced flexible mobility on smart charging acceptance (Will & Schuller, 2016; Geske, 2014; Deffner et al., 2012). Because PHEV drivers can rely on their ICE generator, we hypothesize that the acceptance of smart charging is lower for BEV than for PHEV drivers (H1.2); and adoption of smart charging is lower for BEV than for PHEV drivers (H1.3).

2.1.3. Data privacy

Since some smart charging solutions make use of real time data on energy consumption, it could be seen as a potential risk for data privacy. It is suggested that operators could deduct mobility patterns from this data (Frenzel et al., 2015). One of the major reasons for the setback of the smart meter was the potential data privacy violation and increased vulnerability of the data (Yan et al., 2013; Energieleveranciers, 2015). Therefore we expect a similar effect for smart charging solutions. We hypothesize that the higher concern for data privacy has a negative effect on acceptance of smart charging (H1.4); and a negative effect on adoption of smart charging (H1.5).

2.1.4. Renewable energy sources and grid stability

Smart Grid European Technology Platform found that problems with the current grid occurred when renewable energy sources (RES), such as solar panels were connected (IqtiyaniIlham et al., 2017). Shifting the charging time as a result of smart charging could help integration of RES and stimulate more efficient use of one’s own energy generation (Mountox, 2019; Will & Schuller, 2016; Liu et al., 2011). Subsequently, the integration of RES is beneficial for the environment (Owusu, 2016; Sims, 2004; Dincer, 2000). Moreover, brought adoption of smart charging is also beneficial for the stability of the power grid (Will & Schuller; Wörner et al, 2014). The acknowledgement and appreciation of these benefits were found to have a positive effect on acceptance on smart charging (Will & Schuller, 2016). We therefore hypothesize that integration of RES will have a positive effect on acceptance of smart charging (H1.6); and a positive effect on adoption of smart charging (H1.7). Furthermore, we expect increase of grid stability will have a positive effect on acceptance of smart charging (H1.8); and a positive effect on adoption of smart charging (H1.9).

2.1.5. Monetary incentives

While smart charging is beneficial for multiple distant factors like the stability of the power grid, many studies suggest the importance of monetary incentives in increasing acceptance of the smart grid (Grahn & Söder, 2011; Paetz et al., 2012; Dütschke et al., 2013; Geske, 2014). A way to reduce electricity costs is through Time-of-Use (TOU) tariffs in households. TOU schedules offer a reduced rate during off-peak hours, motivating people for instance to let their car be charged during the night (Liu et al., 2011). Will & Schuller (2016) found no evidence for the effect of monetary incentives on the acceptance of smart charging. However, most respondents did request some degree of financial compensation (Will & Schuller, 2016). This discrepancy might be a result from the way of questioning. Respondents were asked at what percentage of their energy tariffs they would participate in smart charging, which may be difficult for someone to determine (Will & Schuller, 2016). We therefore changed this question into a statement stressing the importance of monetary incentives to participate in smart charging, regardless of the actual figure. In this manner the way of questioning is also more consistent with the rest of the survey. Given this change in approach, we hypothesize that monetary incentives will have a positive effect on accepting smart charging (H1.10); and a positive effect on adoption of smart charging (H1.11).

2.2. Knowledge, attitudes and behavior

The current study is partly built upon research by Will & Schuller (2015) on user acceptance of smart charging. Apart from broadening the view from the German to the Dutch case, this study aims to find out whether the concept of acceptance measured with a 9 items attitude scale (Van der Laan, 1997) as used by Will & Schuller (2015) and the current study, and the underlying user motivations are a good predictor for actual adoption of smart charging solutions.

The field of social psychology was originally known as the study of attitudes (Thomas & Znaniecki, 1918; Watson, 1925) as it was assumed that attitudes were the most important factor in understanding and predicting behavior (Ajzen & Fishbein, 2005). However, the relation between attitudes and behavior would be challenged by many researchers in the decades to come (e.g. LaPiere, 1934; Deutscher, 1966; Howerton, Meltzer, & Olson, 2012). Many sociologists emphasized that not individual dispositions, but social norms and context were key factors in understanding behavior (DeFleur & Westie, 1958; Deutscher, 1969; LaPiere, 1934). Ever since multiple models on behavior were suggested combining attitudes, norms and context (e.g. Fazio, 1989; Ajzen & Fishbein, 1980). A more recent and ambitious model by Aertsens et al. (2011) also includes knowledge among other factors. Based on Brucks' (1985) ideas they make a distinction between two types of knowledge relevant to consumer behaviour: subjective knowledge, i.e. what individuals perceive that they know, and objective knowledge, what an individual actually knows (Aertsen et al., 2011). Knowledge and attitudes were found to be closely related to each other. Arcury (1990) found a direct relation between environmental- and energy knowledge on environmental- and energy attitudes. In an experiment with high school students the relation between environmental knowledge and attitudes was tested before and after exposure to a 10 day environmental science course. The results showed a significant positive increase in both knowledge and attitudes (Bradley et al., 1999). Aertsen et al. (2011) tested the difference in effect of subjective and objective knowledge on consumption of organic food. While both types had a positive relation with attitudes towards organic food only subjective knowledge had a significant effect on actual consumption of organic food (Aertsens et al., 2011).

The acceptance scale by Van der Laan (1997) is divided into two dimensions: usefulness and satisfaction. While usefulness mirrors the practical aspects of a system, satisfaction reflects the pleasantness of use (Van der Laan, 1997). To test both factors properly Van der Laan (1997) advices to use the acceptance scale before and after experience with system of interest. However, in the study by Will & Schuller (2015) acceptance is only measured prior to experience with smart charging. This might explain why they found a higher score for usefulness opposed to satisfaction (Will & Schuller, 2015).

In the current study we anticipate that most respondents will not have any experience with smart charging either. Therefore we expect that the subjective knowledge of smart charging by respondents will play a big role in their attitudes towards smart charging and their willingness to participate in the pilot. We hypothesize that subjective knowledge will have a positive effect on acceptance of smart charging (H2) and a positive effect on adoption of smart charging (H2.1). Thereby, we hypothesize that acceptance will have a positive effect on adoption of smart charging solutions (H2.2), since it is unlikely that one would adopt a system that he does not perceive as useful or satisfying.

2.3. Nudging

Besides individual factors that influence behaviour, environmental influences could also stimulate behavioural change. There are a lot of ways to influence behaviour, from providing information to applying monetary incentives, to simply prohibiting unwanted behaviour. Take smoking for instance. Governments have tried to 'fight' smoking by banning advertisements and providing information about the hazards of smoking, increasing taxes on cigarettes and restricting smoking in public places (Wasserman et al., 1991; Public Health England, 2018). While restricting smoking in public places is found to have a negative effect on cigarette demand, the effect of tax increases seem small (Wasserman et al., 1991). Some studies found that higher taxes even let smokers to switch to more harmful cigarettes containing more tar and nicotine (Evans and Farrelly, 1998; Farrelly et al., 2004) and maximizing nicotine intake per cigarette (Adda and Cornaglia, 2006) to compensate for the higher prices. Nudging is a strategy that aims to change behaviour not by forbidding other options or through economic incentives, but by changing the environment in which people make choices mostly automatically, steering them towards the desired choice (Benartzi et al., 2017; Lehner et al., 2016). It is based on the assumption that people have bounded rationality and often make undeliberate choices that are not necessarily in their best interest (Lehner et al., 2016). According to Daniel Kahneman (2011) people possess two systems of thinking. System 1 is fast, automatic, intuitive and depended on one's context. These decisions cost little energy and attention, but are prone to biases and systematic errors. System 2 is slow, deliberate and conscious, a rational way of thinking about important choices, for instance whether you want to get married. Nudging aims to guide behaviour resulting from system 1 thinking by changing the context in which people make these decisions (Lehner et al., 2016; Ölander & Thøgersen, 2014). Generally the desired choice or behaviour is made easier (Service et al., 2014).

Nudging techniques are used in a variety of social problems from guiding people to eat healthier by reframing healthy and unhealthy food to tackling the shortage of organ donors by changing default policy to being a donor unless you unregister (Lehner et al., 2016; Johnson, 2003). Nudging also proved to be successful in changing residential energy consumption, for instance by giving feedback on electricity bills (Fischer, 2008; Delmas et al., 2013; Allcott et al., 2010) and even in increasing the adoption of smart grid technologies, again by changing the default option from opt-in to opt-out; a smart meter would be installed in one's house unless he stated he did not want it (Ölander & Thøgersen, 2014).

2.3.1. Nudging by the letter

Nudging techniques can differ from promoting a product in the supermarket by simply placing it at eye level to entirely changing policy like the organ donor case (Lehner et al., 2016; Johnson, 2003). Nudging can also be applied to written letters by making small changes in the text or adding images (Service et al., 2014). According to the EAST model by the Behavioural Insights Team (BIT) in order to encourage behaviour you have to make it easy, attractive, social and timely (Service et al., 2014). A few examples are simplifying the message (easy), attract attention, for instance through pictures (attractive), show that most people perform the desired behaviour (social) and consider the immediate costs and benefits (timely) (Service et al., 2014). Due to the limited focus group of this study we will focus on two effective nudging techniques: changing the default from opt-in to opt-out and including a descriptive social norm.

2.3.2. Changing the default

People tent to stick with the default option, either because they do not what to choose right now or because the default is perceived as being chosen for a reason (Service et al., 2014; Keller et al. 2011). Even if people spend a lot of effort in making a deliberate choice they might still choose for the default, because the potential losses from changing to another option weigh heavier than the potential gains (Johnson & Goldstein, 2003; Keller et al. 2011). Therefore, changing the default from opt-in to opt-out can be a powerful tool to increase participation (Johnson & Goldstein, 2003). Because of the power of this particular nudge it is debatable when or whether at all policy makers should use it (Ölander & Thøgersen, 2014; Service et al., 2014). In contrary to other nudges, with changing the default option the desired choice is already made for you, making it harder to choose the undesired option instead of making it easier to choose the desired option. It is argued that people are being tricked into a choice that is not necessarily in their best interest (Brown & Krishna 2004). Yet research shows that the default option is still effective when people are aware and informed about the intervention (Loewenstein et al., 2015). Changing the default has proven to be an effective way to increase participation in schemes that are beneficial for the common good like organ donation, insurances and smart grid solutions like the smart meter (Ölander & Thøgersen, 2014; Johnson & Goldstein, 2003; Johnson et al. 1993). The latter is particularly interesting since the concerning solution shows great similarities to the smart charging system. In the study respondents read a short text about the Smart Grid technology and its benefits before being asked whether they wanted to adopt a smart meter in their homes (free of charge) that would control some of their energy consumption remotely (Ölander & Thøgersen, 2014). The opt-in group received the notion: *"Tick the box below if you accept installation. If not, please continue to the next question"*, while the opt-out group had to *"Tick the box below if you do not accept installation. If you accept installation, please continue to the next question."* followed by either *"Yes, I would like to have a Smart meter with remote control installed in my home"* or *"No, I would not like to have a Smart meter with remote control installed in my home"*. Even though the idea of this smart meter being installed was purely hypothetical the opt-out condition had a significant positive effect on adoption (Ölander & Thøgersen, 2014). Therefore, we hypothesize that including an opt-out condition will have a positive effect on adoption of smart charging (H3).

2.3.3. Include social norms

Social norms are the rules constructed within a group for acceptable behaviors, values and beliefs of the group members (Aronson et al., 2005). Social norms tent to have an important effect on individual behavior, given that one always operates within a social field (Cialdini et al., 1991; Schultz et al., 2007). Including social norms has proven to be a successful nudging technique to influence behavior (Service et al., 2014), depending on the way it is used (Stok et al., 2014). Generally there are two types of social norms: descriptive and injunctive. While descriptive norms describe others' behavior, injunctive norms proscribe behavior, indicating what others think you should do (Aronson et al., 2005; Cialdini et al., 1991; Stok et al., 2014).

Two researches by the Behavioral Insight Team tested the effectiveness of adding social norms to influence debt payment and donating to charity (Service et al., 2014). In the first study regarding paying debts, adding the descriptive norm to a letter stating that the majority of people with debt in the respondents area and/or people with similar debts already paid let to a maximum increase in paying of 5% (Service et al., 2014). The second study showed an increase of 15% in leaving a gift to charity in one's will when the descriptive norm *"Many of our customers like to leave money to charity in their will"* and the question *"are there any causes you're passionate about?"* were added to a telephone script (Service et al., 2014). A research at a Dutch school tested the influence of descriptive and injunctive peer norms on fruit consumption of adolescents (Stok et al., 2014). Participants read a short informal text about fruit consumption before filling in a questionnaire about motivations to eat fruit, tendency towards social comparison and intention to eat fruit. For the descriptive norm group information that a majority of high school students try to eat sufficient fruit was added to the text, while the injunctive norm group received information that a majority of high school students think other high school students should eat sufficient fruit (Stok et al., 2014). The injunctive norm actually had a small negative effect on fruit consumption, while the descriptive norm had a positive effect. Interestingly, the descriptive norm had no effect on the intention to eat fruit (Stok et al., 2014). This is supposedly because the descriptive norm functions as a decisional shortcut for behaviour, which does not require the individual to process the descriptive norm information consciously (Stok et al., 2014; Cialdini, 2008). This is in line with the concept of system 1 thinking (Daniel Kahneman, 2011). We therefore hypothesize that adding a descriptive social norm will have a positive effect on adoption of smart charging (H3.1), but does not influence acceptance (H3.2).

2.4 Current study

In the current study we test the effects of multiple motives on the acceptance of smart charging. Additionally, we test the effects of these motives on adoption of smart charging. Secondly, we test the relation between acceptance and adoption of smart charging. Finally, we will investigate if two nudging techniques, changing the default and adding a descriptive social norm, positively influence the acceptance and adoption of smart charging.

While the motives underlying user acceptance of smart charging were already researched by Will & Schuller (2016), their study limited itself to the German context. What is more, acceptance was measured with a 9-item attitude scale. Since the relation between attitudes (acceptance) and behaviour (adoption) is highly contested (Ajzen & Fishbein, 2005), the current study, besides testing the finding of Will & Schuller (2016) in the Dutch context, aims to find out whether the acceptance of smart charging can predict adoption of smart charging and if the motives underlying acceptance also explain adoption of smart charging. To our knowledge, the current study is the first to research what motives lie beneath the adoption of smart charging, while we acknowledge the importance of user acceptance. On top of this, the current study will test if nudging techniques which were proven to be successful in, among other things, influencing the adoption of the smart meter (Ölander & Thøgersen, 2014), can lead to an increase in smart charging adoption, with an experiment that compares three letters containing either a social norm nudge, changing the default nudge or no nudge.

We hypothesize that the higher need for flexible mobility, concern for data privacy and driving a BEV opposed to a PHEV will negatively influence the acceptance and adoption of smart charging (H1 to H1.5). The integration of renewable energy sources and other environmental benefits, increase of grid stability and monetary incentives are expected to positively influence the acceptance and adoption of smart charging (H1.6 to H1.11). More subjective knowledge is hypothesized to positively influence acceptance and adoption (H2; H2.1) and acceptance is expected to positively relate to adoption (H2.2). Finally, we hypothesize that including an opt-out condition will have a positive effect on adoption of smart charging (H3) and adding descriptive social norms will have a positive effect on participation in the smart charging pilot (H3.1), but does not influence acceptance (H3.2).

Understanding why people would want to adopt or reject smart charging is crucial in pursuing broad adoption of smart charging, which is necessary to prevent the exceedance of the power grid in the future (Liu et al., 2011; Garcia et al., 2014). In addition, the current study will reveal if nudging techniques can increase adoption of smart charging, adding to the growing body of knowledge about nudging as well as providing a practical implication.

3. Methodology

3.1. Participants

Participants were recruited via multiple Dutch electric car user groups on social media. Via a link they were directed to the survey. A total of 126 responses were collected, yet only 53 participants finished the survey. Another 3 participants were excluded from the sample, because they did not drive an EV. Due to the small sample size we chose to include the 8 participants who failed the manipulation check. This will be addressed further in the discussion. The final sample thus included 50 participants. Participants were between 28 and 88 (M = 51.10, SD = 12.38) and 54% was 50 or higher. Only 7 participants were female.

Almost all participants (90%) drove a fully electric car (BEV) as primary vehicle and only 4 participants drove a plug-in hybrid (PHEV). This is not representative for the Dutch composition of EV drivers where approximately 96.894 (±64%) people drive a PHEV opposed to 55.616 (±36%) BEV drivers (RVO, 2019). A comparison between BEV and PHEV drivers is therefore not possible and the results of this study mostly reflect the view of BEV drivers.

3.2. Procedure

Electric car users were asked to participate in a study on smart charging by filling in a small survey. Before filling in the survey participants read a description of the study, they were informed that their answers would remain anonymous and participation was voluntary. They indicated informed consent prior to starting the survey.

The survey began with informing the respondents about a company called Slim Laden NL® which supposedly manufactures smart charging solutions for individual consumers. They were then presented with a model letter by the company which invited people to participate in a smart charging pilot. Respondents were asked to read the letter carefully and to imagine that they would receive this letter for real in the near future. The company and the model letter were fictional.

There were three types of letters containing either a social norm, an opt-out option (changing the default) or no treatment (see 3.3 Experimental manipulation). Respondents were randomly assigned to one of the three letter. After reading the letter they were asked if they wanted adopt smart charging by participating in the pilot with two questions. The first question, asking respondents whether they wanted to participate, offered a dichotomous choice (‘yes’ or ‘no’), while the second question, asking respondents to what extend they were willing to participate, was measured on a 7-point likert scale (‘not at all’ to ‘very much’).

Next all respondents received questions regarding their driving and charging behaviour, their knowledge of smart charging and multiple statements regarding their motivations to adopt smart charging. The respondents were then asked to evaluate the smart charging system. Finally, respondents had to answer a few control questions to test whether they were aware that the company and the letter were fictional.

After filling in the survey respondents were informed and debriefed about the actual goal of the study and told that the company and the pilot were in fact fictional. They were asked not to discuss the intentions of the study with other potential respondents.

3.3. Experimental manipulation

All letters contained a short introduction to the smart charging pilot, the way it works and its benefits. In the letter containing the descriptive social norm treatment the following line was added (translated to English): *“In a prior smart charging pilot 84% of the participant wanted to keep using smart charging after the pilot was finished”.*

The control- and descriptive social norm group were presented with the regular opt-in condition: *“Tick the box if you want to participate in the smart charging pilot of Slim Laden NL®. If you don’t want to participate you can continue to the next question.”* followed by a check box saying: □ *Yes, I would like to participate in the smart charging pilot of Slim Laden NL®.*, while the changing the default group was presented with the opt-out condition: *“Tick the box if you don’t want to participate in the smart charging pilot of Slim Laden NL®. If you do want to participate you can continue to the next question.”* followed by a check box saying: □ *No, I would not like to participate in the smart charging pilot of Slim Laden NL®.* The changing the default group thus participated in the pilot by default and had to actively opt-out of participation.

3.4. Measures

Adoption of smart charging was measured in two ways:

Ad_dich (Adoption1) was measured with a simple ‘yes’ or ‘no’ question as explained in the previous section.

Ad_like (Adoption2) was measured with the question *"To what extend would you like to participate in the smart charging pilot by Slim Laden NL®"* to which respondents had to indicate a score on a 7-point Likert scale ranging from 1 (not at all) to 7 (very much).

Motives for the adoption of smart charging were assessed with multiple statements derived from prior research (Will & Schuller, 2016) as well as some new statements to which respondents had to indicate a score on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). A factor analysis (see Appendix 9.1.) produced four motives with corresponding statements:

Flexible Mobility (α = .651): *"I always want my electric car to be fully charged as quickly as possible"* and *"To me it is very important to have full access to my car at any time"*. The mean of these statements was computed, with a higher score indicating more need for flexible mobility

Data Privacy (α = .783): *"My charging parameters and settings should only be transferred anonymously to the aggregator"*, *"My consumption data should be processed by my electricity supplier only in summarized form and without details"*, *"When it comes to smart charging, I have great concerns about the safety of my private information"** and *"I believe that privacy of personal data is generally seen too skeptical and to some extent almost hysterical"*. After the negative statement (*) was reversed a mean of these statements was computed, with a higher score indicating a bigger concern for data privacy.

RES (α = .898): *"I do not believe that smart charging positively impacts the environment"**, *"By participating in smart charging I want to substantially reduce my individual carbon footprint"*, *"By participating in smart charging I want to contribute to an increased use of renewable electricity generation"* and *"By participating in smart charging I want to contribute to climate protection"*. After the negative statement (*) was reversed a mean of these statements was computed, with a higher score indicating more appreciation of the integration of renewable energy sources and environmental benefits related to smart charging.

Grid Stability (α = .855): *"By participating in smart charging I want to contribute to a more stable electricity grid and thereby support the reliability of its supply"*, *"By participating in smart charging I want to contribute to avoiding construction of additional high-voltage transmission lines"*, *"I would not participate in smart charging even if it is beneficial to a reliable electricity supply"* and *"I would not participate in smart charging even if it is necessary for a reliable electricity supply"**. After the negative statement (*) was reversed a mean of these statements was computed, with a higher score indicating more appreciation of the benefits for the power grid associated with smart charging.

Subjective Knowledge (α = . 887) was assessed through a short, reliable and valid measure by Flynn and Goldsmith (1999). Following their approach and implication by Aertsen et al. (2011) three statements were presented to which respondents had to indicate a score from 1 (strongly disagree) to 7 (strongly agree):

(1) I know pretty much about smart charging

(2) Among my circle of friends, I'm one of the "experts" on smart charging

(3) Compared to most other people, I know less about smart charging (reversed)

After statement 3 was reversed a mean score of the statements was computed. A higher score indicated more subjective knowledge.

Acceptance was measured using a simple measurement scale created by van der Laan et al. (1997) to asses user acceptance of advanced transport telematics. The scale consists of nine mirrored semantic differentials on a five-point scale: *My judgement of the (...) systems are…*

(1) Useful	[ ] [ ] [ ] [ ] [ ] Useless (reversed)
(2) Pleasant	[ ] [ ] [ ] [ ] [ ] Unpleasant (reversed)
(3) Bad	[ ] [ ] [ ] [ ] [ ] Good
(4) Nice	[ ] [ ] [ ] [ ] [ ] Annoying (reversed)
(5) Effective	[ ] [ ] [ ] [ ] [ ] Superfluous (reversed)
(6) Irritating	[ ] [ ] [ ] [ ] [ ] Likeable
(7) Assisting	[ ] [ ] [ ] [ ] [ ] Worthless (reversed)
(8) Undesirable	[ ] [ ] [ ] [ ] [ ] Desirable
(9) Raising alertness	[ ] [ ] [ ] [ ] [ ] Sleep inducing (reversed)

Acceptance was divided into two variables:

Usefulness (α = .888) contained items 1, 3, 5, 7 and 9. After items 1, 5, 7 and 9 were reversed a mean score was computed for Usefulness, with a higher score indicating that respondents perceived smart charging as more useful.

Satisfaction (α = .877) contained items 2, 4, 6 and 8. After items 2 and 4 were reversed a mean score was computed for Satisfaction, with a higher score indicating that respondents were more satisfied with the smart charging solution.

3.4.1. Control variables

Although our sample did not allow us to test whether there was a difference in effects between PHEV and BEV drivers, we were able to control for EV driving range.

EV driving range was measured from 0 to 600, indicating how far one's EV can drive on electricity.

More driving range could possibly lower the negative effect of reduced flexible mobility, as there is a bigger range buffer. However, it could also be argued that respondents with more driving range charge less frequent, but longer than respondents with less driving range, which could negatively influence the willingness to adopt smart charging, as this will further lengthen the charging time.

Additionally, demographics Age and Gender were controlled for.

3.4.2. Manipulation check

A manipulation check was carried out for each of the nudging conditions. The social norm group received the additional question: *"In a prior smart charging pilot 84% of the participant wanted to keep using smart charging after the pilot was finished"*, to which they could answer *"Nobody"*, *"34%"* or *"84%"*, the latter being the right answer. The changing the default group received the additional question: *"What did you have to do if you didn't want to participate in the smart charging pilot by Slim Laden NL®"*, to which they could answer *"Check the box "No, I don't want to participate in the smart charging pilot by Slim Laden NL®""*, *"Leave the box "Yes, I would like to participate in the smart charging pilot by Slim Laden NL®" blank"* or *"Sign out via the telephone"*, the first answer being the right one.

3.5. Theoretical model

To test our hypotheses this study uses two mediation models. As depicted in Figure 1, the first model tests the direct effects of Motives on Acceptance (a), Acceptance on Adoption2 (b), Motives on Adoption2 (c') and the indirect effects (mediation) of Motives on Adoption2 (a*b), controlled for Subjective Knowledge and Driving Range. The second model, as shown in Figure 2, tests the direct effects of Nudge on Acceptance (a), Acceptance on Adoption2 (b), Nudge on Adoption2 (c') and the indirect effect (mediation) of Nudge on Adoption2 (a*b), controlled for Subjective Knowledge and Driving Range. Both models are tested with a regression analysis using PROCESS macro Version 3, model 4 (Hayes, 2017).

Because Adoption1 is a dichotomous variable (yes/no), which was necessary to perform the change default manipulation and to give people a more realistic choice whether or not to participate, we will also run a couple of binomial logistic regressions to test the effects of Motives, Acceptance, Nudge and Subjective Knowledge on Adoption1. Adoption2 was included to make more analyses possible and to show a more subtle change in the willingness to adopt smart charging.

Figure 1

Mediation model 1. Motives, Acceptance & Adoption2

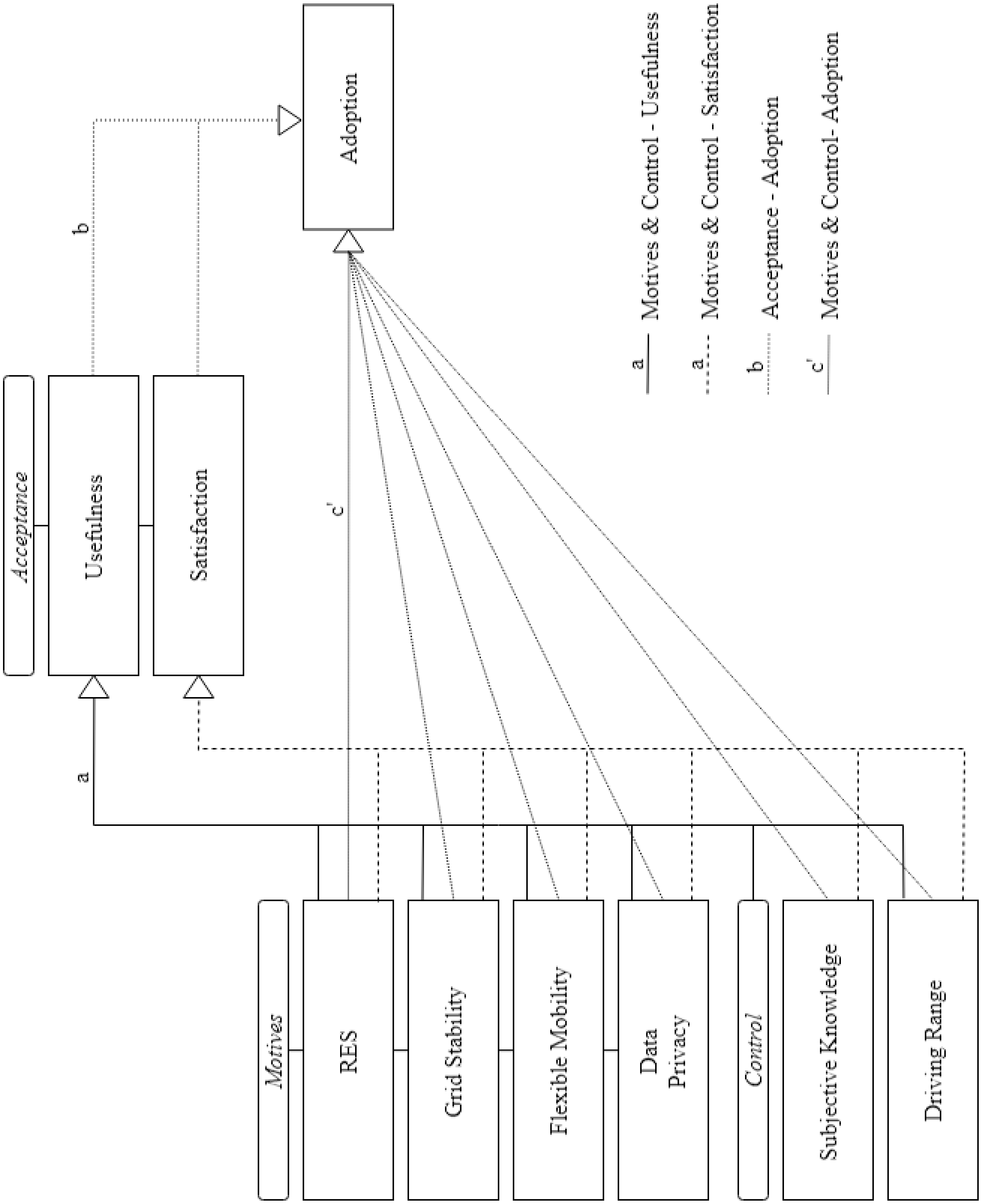
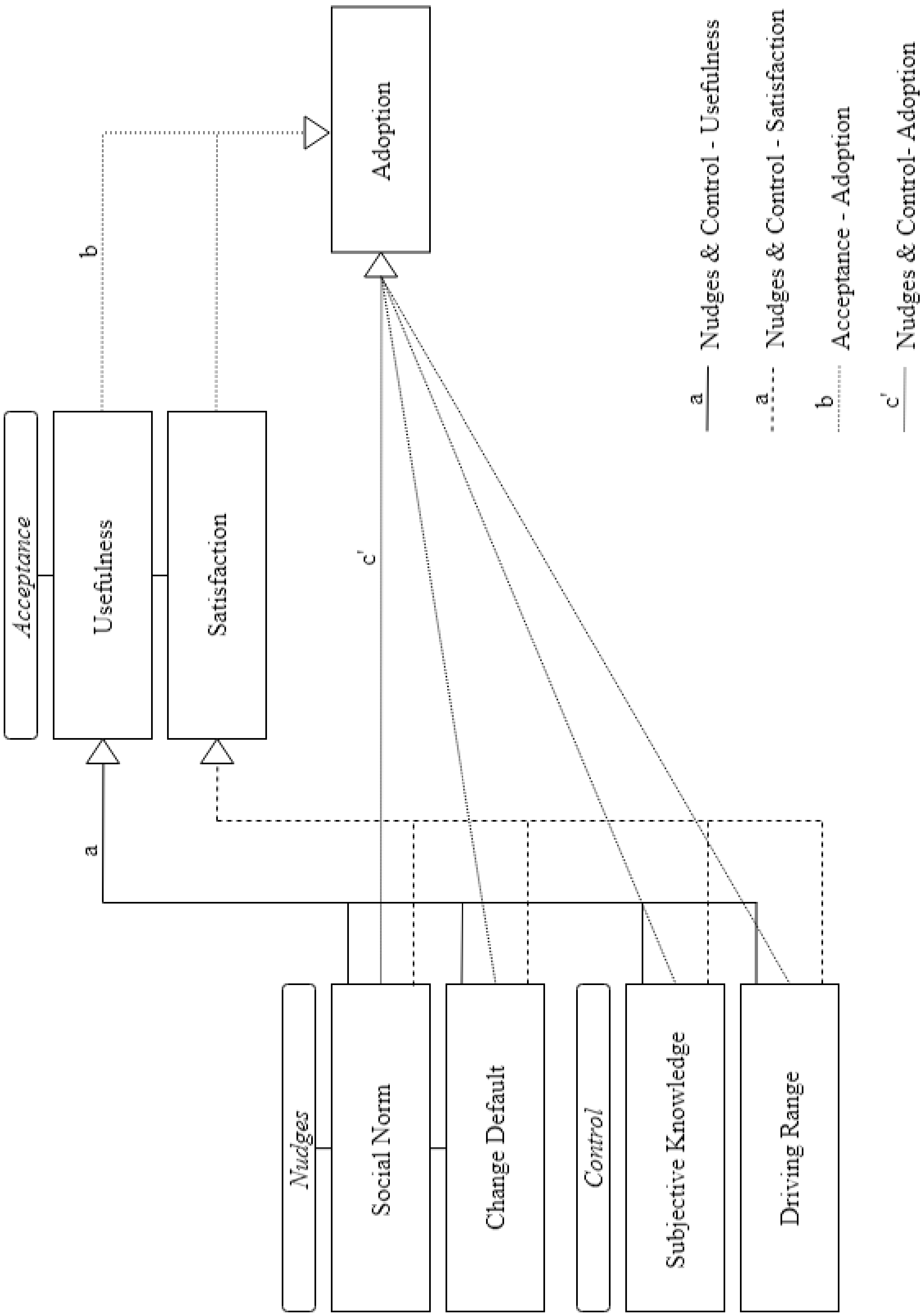


Figure 2

Mediation model 2. Nudge, Acceptance & Adoption2



4. Results

4.1. Descriptives

The driving range of the participants cars on electricity differed from 40 to 516kms (*M* =262.70, *SD* = 136.79). They made an average of 3 trips on a typical weekday (*SD* = 1.28), driving between 50 and 1352 kms a week (*M* = 381.44, *SD* = 309.82) and 4.6 trips in the weekend (*SD* = 2.23), driving between 15 and 396 kms (*M* = 165.34, *SD* = 88,77). On average participants charged their car roughly 7 times a week (*M* = 6.88, *SD* = 4.39) and 64% had their own private charging station at home.

A large majority of 82% reacted positive on the statement that smart charging would be widely implemented in the future and 62% felt smart charging could become the new standard. Most participants (70%) agreed to some extend with the statement *"I trust Slim Laden NL® to carry out a decent and reliable smart charging pilot"*. Only one participant mildly disagreed, the others were neutral. These results indicate that the majority of the participants is positive about the future of smart charging and believes Slim Laden NL® is a real and trustworthy company. Finally, though monetary incentives were excluded from further analysis as a result of the factor analysis (see Appendix 9.1.), 76% of the participants agreed to some extend with the statement *"By participating in smart charging I want to save on my energy costs"* (*M* = 5.10, *SD* = 1.57).

4.2. Acceptance

Acceptance was conceptualized by two sub-components: Usefulness and Satisfaction. Approximately 64% of the respondents scored a 4 or higher on Usefulness (*M* = 4.08, *SD* = 0.815), opposed to 48% on Satisfaction (*M* = 3.89, *SD* = 0.862). This difference could be related to the lack of experience the respondents had with the system. Overall around 54% scored a 4 or higher on Acceptance (*M* = 3.98, *SD* = 0.800), which indicates that smart charging is accepted by the majority.

4.3. Motives, Acceptance and Adoption (Q1 & Q2)

To investigate the main research questions of *What motives do people have to accept smart charging solutions?* (Q1) and *What is the relation between acceptance and adoption of smart charging solutions?* (Q2), a mediation model was built to test whether the individual effects of motives (the independent variables; RES, Grid Stability, Data Privacy & Flexible Mobility) on Adoption2 (the dependent variable) were mediated by Usefulness and Satisfaction (the potential mediators), controlled for Subjective Knowledge and Driving Range (Age and Gender). The mediation analysis was performed using SPSS macro (PROCESS Version 3; model 4) recommended by Hayes (2017).

The model with Usefulness as a dependent variable was significant, $F(8,41) = 7.92$, $p < .001$, $R^2 = 0.607$. Results indicated there was a significant effect for RES on Usefulness, $\beta = 0.39$, 95% CI (0.19, 0.59). The model with Adoption2 as a dependent variable was also significant, $F(10,39) = 9.23$, $p = .003$, $R^2 = 0.4680$. Results indicated Usefulness did not have a significant effect on Adoption2, $\beta = 0.28$, 95% CI (-0.88, 1.44). However, RES did have a significant effect on Adoption, $\beta = 0.83$, 95% CI (0.14, 1.52).

The model with Satisfaction as a dependent variable was significant, $F(8,41) = 5.87$, $p < .001$, $R^2 = 0.534$. Results indicated there was a significant effect for RES on Satisfaction, $\beta = 0.40$, 95% CI (0.17, 0.63). A marginally significant effect was found for Gender on Satisfaction, $\beta = 0.55$, 95% CI (-0.03, 1.14), indicating that women are more satisfied with smart charging than men. As mentioned before the model with Adoption2 as a dependent variable was significant, $F(10,39) = 9.23$, $p = .003$, $R^2 = 0.468$. Yet Satisfaction was found to have no significant effect on Adoption2, $\beta = 0.45$, 95% CI (-0.56, 1.45). RES did have a significant direct effect on Adoption2, $\beta = 0.83$, 95% CI (0.14, 1.52). The total effect model was significant, $F(8,41) = 3.92$, $p = .002$, $R^2 = 0.437$. RES also had a significant total effect on Adoption2, $\beta = 1.12$, 95% CI (0.54, 1.70). These results are depicted in Table 1.

A mediation effect was tested using a percentile bootstrap estimation approach with 10000 samples (Shrout & Bolger, 2002), implemented with the SPSS macro (PROCESS Version 3; model 4) recommended by Hayes (2017). Yet results indicated the indirect effect of RES on Adoption2 was insignificant, $\beta = 0.83$, 95% CI (0.14, 1.52). There were also no significant effects found for the other Motives on either Usefulness and Satisfaction or Adoption2.

A logistic regression was performed to ascertain the effects of RES, Grid Stability, Data Privacy, Flexible Mobility, Usefulness, Satisfaction and Subjective Knowledge (the independent variables) on Adoption1 (the dependent variable). Unfortunately neither the logistic regression model, $\chi 2(10) = 17.112$, $p = .10$, nor any of the relations were significant (all p's > .059).

Table 1

Model coefficients, standard errors, p-values, and model summary information of PROCESS Mediation model 4

	Consequent							
	M_1 (Usefulness)				M_2 (Satisfaction)			
Antecedent		Coeff.	*SE*	*p*		Coeff.	*SE*	*p*
X_1 (RES)	a_1	0.387	0.099	<.001*	a_2	0.400	0.114	.001*
X_2 (Data)	a_3	0.010	0.061	.872	a_4	-0.034	0.070	.625
X_3 (Flex)	a_5	0.017	0.062	.782	a_6	0.053	0.071	.463
X_4 (Grid)	a_7	0.079	0.133	.591	a_8	0.038	0.153	.806
Constant	i_1	1.434	1.035	.174	i_2	0.667	1.192	.579
Sub.kn		-0.040	0.064	.538		0.021	0.074	.777
Range		0.001	0.001	.288		0.001	0.001	.277
Age		-0.009	0.007	.224		-0.005	0.008	.570
Gender		0.307	0.252	.231		0.551	0.290	.065**
	R^2=0.607 $F(8,41)$ =7.919, p = <.001				R^2=0.534 $F(8,41)$ = 5.867 , p < .001			

	Y (Adoption$_2$)			
Antecedent		Coeff	*SE*	*p*
X_1 (RES)	c_1'	0.831	0.341	.019*
X_2 (Data)	c_2'	-0.241	0.177	.182
X_3 (Flex)	c_3'	0.297	0.180	.108
X_4 (Grid)	c_4'	-0.300	0.387	.442
M_1 (Usef)	b_1	0.279	0.574	.630
M_2 (Sati)	b_2	0.445	0.499	.378
Constant	I_3	-2.740	3.074	.378
Sub.kn		0.215	0.189	.264
Range		0.003	0.002	.151
Age		0.025	0.021	.239
Gender		-1.143	0.762	.141
	R^2=0.468 $F(10,39)$ =9.232, p = .003			

RES = Renewable energy sources; Data = Data privacy; Flex = Flexible mobility; Grid = Grid stability; Usef = Usefulness; Sati = Satisfaction; Sub.kn = Subjective knowledge; Range = Driving range; *significant; **marginally significant.

4.4. Nudging, Acceptance and Adoption (Q3)

In order to investigate the research question *To what extent can nudging increase adoption of smart charging and does it also influence acceptance?* (Q3) a separate mediation model was built to test whether the effects of the nudging conditions (control condition vs. changing the default vs. adding a descriptive social norm) on Adoption2 (the dependent variable) were mediated by Usefulness and Satisfaction (the potential mediators), controlled for Subjective Knowledge and Driving Range as well as RES, since the latter was a significant predictor in the previous model. The mediation analysis was performed using SPSS macro (PROCESS Version 3; Model 4) recommended by Hayes (2017). The SPSS macro created two dummy variables for the three nudging conditions, with the control condition being the reference category. Thus, the results of the social and changing the default nudge as depicted in Table 2 are in comparison to the control condition. The cases were weighted to equalize the distribution of respondents between the different nudging conditions, however this hardly influenced the outcomes of the analysis (i.e. the following effects remained the same).

The model with Usefulness as a dependent variable was significant, $F(7,42) = 9.57$, $p < .001$, $R^2 = 0.615$. Results indicated the effect of RES on Usefulness remained significant in this model, β = 0.43, 95% CI (0.31, 0.55). The social nudge had no significant effect on Usefulness, β = 0.18, 95% CI (-0.20, 0.57), neither did the changing the default nudge, β = -0.03, 95% CI (-0.42, 0.35). The model with Adoption2 as a dependent was significant, $F(9,30) = 3.76$, $p = .002$, $R^2 = 0.458$, but once again Usefulness had no significant effect on Adoption2, β = - 0.29, 95% CI (-0.88, 1.45).

The model with Satisfaction as a dependent variable was also significant, $F(7,42) = 6.68$, $p < .001$, $R^2 = 0.527$. Results indicated a significant effect for RES on Satisfaction, β = 0.41, 95% CI (0.27, 0.54), as well as a significant effect for Gender on Satisfaction, β = 0.59, 95% CI (0.01, 1.18). The latter indicates that women are more satisfied with smart charging than men. Again, the social nudge had no significant effect on Satisfaction, β = 0.10, 95% CI (-0.35, 0.55), nor did the changing the default nudge, β = -0.02, 95% CI (-0.47, 0.43). As said the model with Adoption2 as a dependent was significant, $F(9,30) = 3.76$, $p = .002$, $R^2 = 0.458$, yet Satisfaction had no significant effect on Adoption2, β = 0.58, 95% CI (-0.41, 1.57).

The final model with Adoption2 as a dependent variable did reveal that there was a marginally significant negative direct effect for the social nudge on Adoption2, β = -1.08, 95% CI (-2.23, 0.07). While the total effect model with Adoption2 as a dependent variable was significant, $F(7,42) = 4.11$, $p = .002$, $R^2 = 0.407$, there was no significant total effect for the social nudge on Adoption2, β = -0.97, 95% CI (-2.13, 0.19). RES did still have a significant total effect on Adoption2, β = 0.81, 95% CI (0.46, 1.17). These results are depicted in Table 2.

A logistic regression was performed to ascertain the effects of Usefulness, Satisfaction, Subjective Knowledge and the other motives (e.g. RES) as well as the social and changing the default nudges (the independent variables) on Adoption1 (the dependent variable). Overall, choices whether or not to participate in the smart charging pilot were almost equal, with 56% of the participants choosing No opposed to 44% choosing Yes. Unfortunately, neither the logistic regression model, $\chi2(12) = 18.621$, $p = .10$, nor any of the relations were significant (all *p*'s > .075). This might be related to the small sample size in the current study. Nonetheless a negative effect of the social nudge like we found for Adoption2 could also be seen for Adoption1. Frequencies for Adoption1 (weighted) across the nudging conditions are depicted in Figure 3. As mentioned before the respondents who failed the manipulation check were included in the analysis due to the small sample size of this study. The results of the analysis without these respondents can be found in the appendix (see Appendix 9.2.).

Figure 3

Frequencies of Adoption1 (weighted) for different conditions

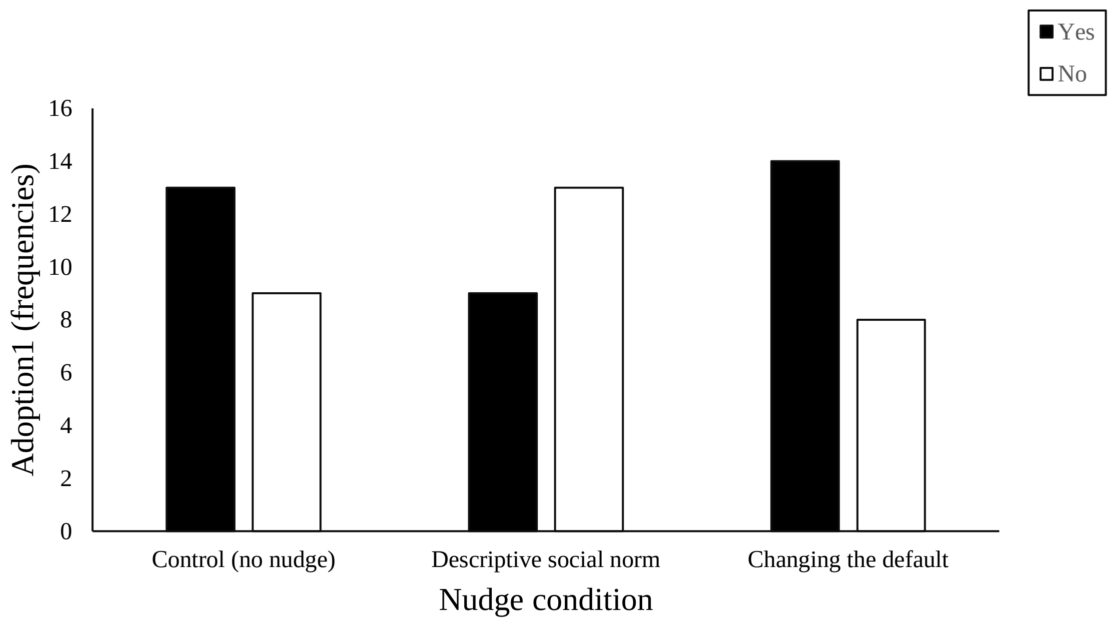


Table 2

Model coefficients, standard errors, p-values, and model summary information of PROCESS Mediation model 4

	Consequent							
	M_1 (Usefulness)				M_2 (Satisfaction)			
Antecedent		Coeff.	*SE*	*p*		Coeff.	*SE*	*p*
X_1 (Social)	a_1	0.185	0.191	.338	a_2	0.984	0.810	.662
X_2 (Default)	a_3	-0.035	0.191	.857	a_4	-0.020	0.224	.931
Constant	i_1	1.697	0.691	.018*	i_2	0.969	0.810	.238
RES		0.432	0.059	<.001*		0.406	0.069	<.001*
Subj.kn		-0.035	0.062	.579		0.011	0.072	.883
Range		0.001	0.001	.237		0.001	0.001	.255
Age		-0.009	0.007	.188		-0.006	0.008	.464
Gender		0.319	0.247	.189		0.593	0.290	.047*
	R^2=0.615 F(7,42) =9.569, p = <.001				R^2=0.527 F(7,42) = 6.680 , p < .001			

	Y (Adoption$_2$)			
Antecedent		Coeff	*SE*	*p*
X_1 (Social)	c_1'	-1.080	0.569	.065**
X_2 (Default)	c_2'	-0.635	0.565	.268
M_1 (Usef)	b_1	0.287	0.575	.620
M_2 (Sati)	b_2	0.581	0.491	.243
Constant	i_3	-1.836	2.184	.406
RES		0.453	0.266	.096
Subj.kn		0.116	0.184	.531
Range		0.002	0.002	.242
Age		0.019	0.020	.332
Gender		-0.831	0.765	.284
	R^2=0.468 F(10,39) =9.232, p = .003			

Social = Descriptive social norm nudge; Default; Changing the default nudge; RES = Renewable energy sources; Usef = Usefulness; Sati = Satisfaction; Sub.kn = Subjective knowledge; Range = Driving range; *significant; **marginally significant.

5. Discussion

Smart charging is believed to be the solution for the increasing grid loads and demand peaks resulting from the charging of EV's (Liu et al., 2011; Garcia et al., 2014). Yet little was known about the acceptance and adoption of this system by EV drivers (Will & Schuller, 2016). The current study not only aimed to shed light on what motives lie beneath user acceptance, but also attempted to directly influence adoption of smart charging using the changing the default and descriptive social norm nudges. The main results will be discussed here.

The first aim of this study was to find out what motives lie beneath the acceptance of smart charging. Although most motives, including grid stability benefits, need for flexible mobility and data privacy, were found to have no significant effect on the acceptance of smart charging, we did find a rather convincing effect for the environmental and renewable energy sources aspect of smart charging on both the acceptance and the willingness to adopt smart charging solutions. These results show that by participating in smart charging respondents wanted above all to reduce their carbon footprint and contribute to climate protection and an increased use of renewable energy sources. These results are in line with findings of Will & Schuller (2016). It could be argued that these pro-environmental motives are inherent to EV drivers. Multiple studies show that environmental motives are a strong predictor of EV adoption among early adopters (Barbarossa et al, 2017; Bockarjova & Steg, 2014). These same motives could explain the willingness to adopt smart charging in the current study. Further research should confirm if potential future adopters share these motives. What is more, we found no motives that negatively influenced acceptance or adoption, yet less than half of the respondents was willing to adopt. Thus further research should also examine why so many EV drivers are reluctant to adopt smart charging.

Interestingly, we did not find any effect of acceptance on adoption, which relates to the second aim of this study. This implies that positive or negative attitudes towards the smart charging system do not necessarily lead to the corresponding behavior, namely adopting or rejecting smart charging. Though we hypothesized the opposite, these findings are supported by a review article about attitudes, behavior and social practice, which states that the relation between attitudes and behavior is not symmetrical (Chaiklin, 2011). Nonetheless, environmental motivations proved to positively influence both acceptance and adoption. Thus, even though the acceptance scale as used in this study might not be a good predictor of behavior, the pro-environmental facet of smart charging should be highlighted in order to increase the adoption of smart charging systems, while also enlarging peoples satisfaction with the system and there perceived usefulness of it. This further strengthens the findings of Will & Schuller (2016) regarding the effect of the integration of renewable energy sources.

The final aim of this study was to find out whether acceptance and adoption could be influenced by nudging. Opposed to prior research we found no effect for the change to default nudge (Ölander & Thøgersen, 2014; Johnson & Goldstein, 2003). One of the reasons why this nudge can work is because people tend to think the default is chosen for a reason (Service et al., 2014; Keller et al. 2011). This might at the same time be the reason why it did not work in the current study, because respondents may have thought this reason was purely in the interest of the company carrying out the pilot, namely gathering more participants. Another possible explanation for the absence of an effect is that in reality the op-out conditions might only be implementable through a governmental law as was the case with the smart meter and organ donation scheme (Ölander & Thøgersen, 2014; Johnson & Goldstein, 2003; Johnson et al. 1993). A company like Slim Laden NL® cannot make someone use their system by default. This is where smart charging currently lacks behind compared to for instance the smart meter, there is no governmental policy in place yet (Yan et al., 2013; Essent, 2019; Energieleveranciers, 2015).

We did find a marginally significant effect for the social nudge on adoption, which was surprisingly a negative effect. Due to the small sample size in the current study it is up to future research to confirm our suspicions. Nonetheless, the unexpected negative relation is worth a short discussion. The willingness to participate in the smart charging pilot dropped by quite a bit when the social norm was included in the letter. This shows that the composition and wording of a letter could influence behavior and that the wrong wording might have an unintended negative effect. In the current study the sentence *"In a prior smart charging pilot 84% of the participant wanted to keep using smart charging after the pilot was finished"* did more harm than good. Supposedly the nudge was to salient and let people to think that they were manipulated in some way. A review article on the use of social nudges states that the nudge can backfire if the messenger, in this case Slim Laden NL®, is not trusted, because there is a suspicion of hidden intentions (Bicchieri & Dimant, 2019). It could also be that the respondents did not feel connected to the 84% that supposedly endorsed smart charging. While we did check if respondents read and remembered the nudge correctly, we did not ask them to what extend they identified with the people who carried out the social norm. The 'reference network' is found to have great influence on the effectiveness and direction of a social norm nudge (Bicchieri & Dimant, 2019). For instance, you may want to imitate your friends behaviour, but not the behaviour of someone you dislike or mistrust. In our case it was unclear to the reader who the reference network was, hence it was open to the reader's interpretation. Nonetheless the nudge did have a marginal effect, be it in the wrong direction, without influencing acceptance. A similar mechanism was revealed in a prior study were a subjective social norm nudge let to an increase in fruit consumption, but did not influence the intention to eat fruit (Stok et al., 2014). This could be explained by Kahneman's concept of system 1 thinking (Kahneman, 2011). The nudge creates a behavioural shortcut, which does not require the participant to rethink his attitudes towards the system, unlike the environmental motivations which influenced both acceptance and adoption. These findings support a more sociologist view of behavior in which not individual dispositions, but social norms and context are the key in understanding behavior (DeFleur & Westie, 1958; Deutscher, 1969; LaPiere, 1934).

5.1. Limitations

The results of this study should be interpreted with some caution. Firstly, the experiment was set up in the form of a pilot to make it more realistic, yet this may have lowered the threshold of adoption (i.e. participation was free and without further obligation). This means that there could be a difference in the willingness to participate in a smart charging pilot and the actual willingness to adopt a smart charging system indefinitely. Moreover, people were aware of the fact that they were not actually going to participate. However, in prior nudging studies were this was the case significant effects were still found (Ölander & Thøgersen, 2014). Besides, all statements underlying motives were with regards to actual adoption. A final point of discussion is the small sample size in this study. It proved to be quite difficult to find enough EV drivers who were willing to participate in the current study, not only because it is a relatively small target group, but also because they are the focus of many researches as some respondents explained.

5.2. Recommendations for future research

Given the limitations and surprising findings of the current study there are a few recommendations for future research to be made. Firstly, the most evident limitation was the small sample size of this study and therefore we recommend to carry out a similar study with a bigger sample. This sample should also include more PHEV drivers as they were almost absent in the current study and they are the largest group of EV drivers. Moreover, it would be interesting to include non EV drivers, to test if the motives of potential future EV drivers for the acceptance and adoption of smart charging differ from those of the current EV driver (i.e. early adopters). Secondly, the construction of the nudging experiment could be altered to test if the given nudges could positively influence adoption if they were carried out differently. In case of the changing the default nudge the use of a governmental authority instead of a private company is recommended, in the case of the social norm it would be interesting to see if a different sentence or the addition of a positive reference network alters the results.

6. Policy recommendations

Currently there is no official governmental policy on smart charging in the Netherlands, but this should change when more people switch to EV's. There are a few private parties who manufacture smart charging systems for brought distribution, like Elaadnl and Living Lab Smart Charging. If the current study shows one thing, it is the importance of the support to renewable energy sources and the environment smart charging has to offer. The named companies seem to be fully aware of this. On the frontpage of Elaad *"Live off the wind and drive on the sun"* is the first thing you read. Living Lab Smart Charging says something similar on their frontpage: *"Live, work and drive on energy from the sun and wind"*. Yet words alone are not going to change the world, policy might. In the current study we found no motives that negatively influence the acceptance or adoption of smart charging. Still more than halve of the respondents retained from adopting the system. If smart charging solutions are desired to be widely implemented, governmental policy is needed.

While there is a growing interest for using nudging techniques in policy, this study shows no real evidence for the effectiveness of two popular techniques. If this study shows one thing it is that one should be very cautious with it, as the social norm nudge did more harm than good. Many studies show very promising results almost making one wonder why nudging is not used more frequently (Service et al., 2014, Stok et al., 2014, Ölander & Thøgersen, 2014; Johnson & Goldstein, 2003; Johnson et al. 1993). Yet the wrong nudge can lead to a worse outcome just as easily (Stok et al., 2014). That being said, multiple studies show significant improvements when the default option is changed to opt-out, if this is done so by the government (Ölander & Thøgersen, 2014; Johnson & Goldstein, 2003; Johnson et al. 1993). UK respondents revealed the government is seen as a trusted authority to implement nudges (Junghans et al., 2015). Moreover, governmental policies on subsidizing EV use possibly let to the strong increase in EV adoption (RVO, 2019). A Dutch study showed that the financial driver, highly related to governmental financial incentives, was the largest group of EV users (Branderhorst, 2018). And though no significant effect for financial incentives on smart charging adoption was found in the current study, 76% of the participants agreed to some extend with the statement *"By participating in smart charging I want to save on my energy costs"*.

We therefore strongly recommend that the government should take action in stimulating smart charging adoption in several ways. Firstly, financial incentives can help stimulate smart charging use, compensating for the possible decline in flexible mobility (Will & Schuller, 2016). Though we understand the government does not have an inexhaustible treasury, these subsidies might eventually save money, because brought adoption of smart charging will prevent the government from unnecessarily having to strengthen the power grid (Putrus et al., 2009; van Vliet et al., 2011; Liu et al., 2011; Garcia et al., 2014). Secondly, the government could experiment with the use nudging to increase adoption, for instance by changing the default like in the case of the smart meter (Yan et al., 2013; Essent, 2019; Energieleveranciers, 2015). However, more research is needed to test if nudging can indeed help to stimulate adoption of smart charging as this study concluded nudging does not always work and can even potentially lead to a decrease in adoption.

7. General conclusion

The rise in electric vehicles usage for public and private transport is great news for the environment (Allen et al., 2009, Matthews et al., 2009), but less so for the current power grid (Putrus et al., 2009; Spoelstra, 2014; van Vliet et al., 2011). While smart charging may reduce demand peaks, preventing the need for the unnecessary and expensive strengthening of the grid (Liu et al., 2011; Garcia et al., 2014), broad adoption of smart charging will not come naturally. The current study aimed to give insight in the motives behind acceptance and adoption of this new system by EV drivers, as well as trying to influence adoption using nudges. The study revealed that even though smart charging is accepted by the majority of the EV drivers, less than halve of them wanted to adopt the system. This implicates much is yet to be done to achieve broad adoption in the future. Reducing one's carbon footprint, contributing to climate protection and an increase use of renewable energy sources were found to be the most important motivations in accepting and adopting smart charging. We therefore recommend that these aspects are highlighted in the construction and encouragement of smart charging systems. In contrast to other studies (Ölander & Thøgersen, 2014; Johnson & Goldstein, 2003; Stok et al., 2014; Stok et al., 2014), this research found no evidence for the positive effectiveness of the use of nudging techniques. That being said, the current study is the first to provide a clear insight in the mechanisms underlying user adoption of smart charging. Moreover, the study revealed that enhancing acceptance is not enough to increase adoption. Governmental policy is needed if broad adoption of smart charging is desired, be it by monetary incentives or effective use of nudging.

8. Literature

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9. Appendix

9.1. Factor Analysis

Since some of the statements in this study regarding user motivations were translated from German to Dutch and some new statements were introduced a factor analysis was performed to check whether these statements lead to the expected factor-solution (Will & Schuller, 2016; Flynn and Goldsmith, 1999). Bartlett's test of sphericity was significant (χ 2 (231) = 754.491, $p<0.001$) and the Kaiser-Meyer-Olkin measure was acceptable (KMO = .692), therefore we could proceed the factor analysis.

Seven factors had an Eigenvalue above 1. The RES, Subjective Knowledge and Data Privacy items each loaded on one factor as expected (respectively 2, 3 & 4). Results of the factor analysis are depicted in Table 3. Four of the six items on Grid Stability loaded on factor 1, as well as one item on Monetary Incentives. Since the latter has nothing to do with Grid Stability we chose to exclude it from this factor. The same goes for the item on Monetary Incentives loading on factor 2 (RES). Two of the three items on Flexible Mobility loaded on factor 7. Factor 5 and 6 both had only one factor loading and were therefore excluded from further analysis. Thus, the factor analysis gave us five factors: Flexible Mobility, Data Privacy, RES, Grid Stability and Subjective Knowledge.

A reliability test showed that most factors had a high level of internal consistency; Data Privacy (α = .783), Grid Stability (α = .855) Subjective Knowledge (α = . 887), RES (α = .898), Flexible Mobility (α = .651). Acceptance, divided into Usefulness (α = .888) and Satisfaction (α = .877) also proved to be reliable scales.

Table 3

Correlation matrix for the 22 initial items

	Grid.Sta	RES	Sub.kn	Data.pri	x	x	Flex.mo
fmn1_1	-,142	-,052	-,283	-,007	-,084	-,623	,444
fmn2__1	-,458	-,192	-,038	,252	-,642	,118	-,013
fmn3_1	-,089	-,102	-,178	-,018	-,219	-,127	,815
dp1_1	-,067	-,002	-,026	,838	,028	-,162	,107
dp2_1	,173	-,098	,129	,761	,076	-,113	,237
dp3_1	-,172	,001	-,131	,741	-,083	-,177	-,309
dp4__1	-,063	,162	,004	,767	-,134	,261	-,125
res1_env__1	,441	,614	,047	-,067	-,170	-,178	-,369
res2_co2_1	,380	,781	,106	,047	,189	,125	,037
res3_res_1	,441	,781	-,007	-,018	,107	,029	-,014
res4_clim_1	,266	,888	-,013	,016	,186	,060	-,099
gs1_stabl_1	,732	,342	,098	-,001	,046	,330	,152
gs2_trans_1	,702	,384	,095	,036	,167	,271	,243
gs3_ben__1	,759	,405	-,029	-,075	,192	,114	-,057
gs4_nec__1	,767	,235	-,118	-,113	-,007	-,161	-,406
gs5_flex_1	,155	,179	,020	,008	,866	-,004	-,177
gs6_gen__1	,255	,087	,039	-,240	-,080	,782	,037
mi1_1	-,031	,442	,111	,123	,388	,300	-,116
mi2__1	,823	,168	-,010	-,001	,200	,165	-,162
sk1_1	-,203	-,050	,915	,030	,005	,015	,009
sk2_1	,090	,077	,875	-,047	-,018	,207	-,117
sk3__1	,108	,077	,896	,003	,085	-,008	-,085

Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization; a. Rotation converged in 12 iterations.

9.2. Results of the second mediation analysis without respondents who failed the manipulation check

This analysis had N = 42 , results are depicted in Table 4.

Table 4

Model coefficients, standard errors, p-values, and model summary information of PROCESS Mediation model 4

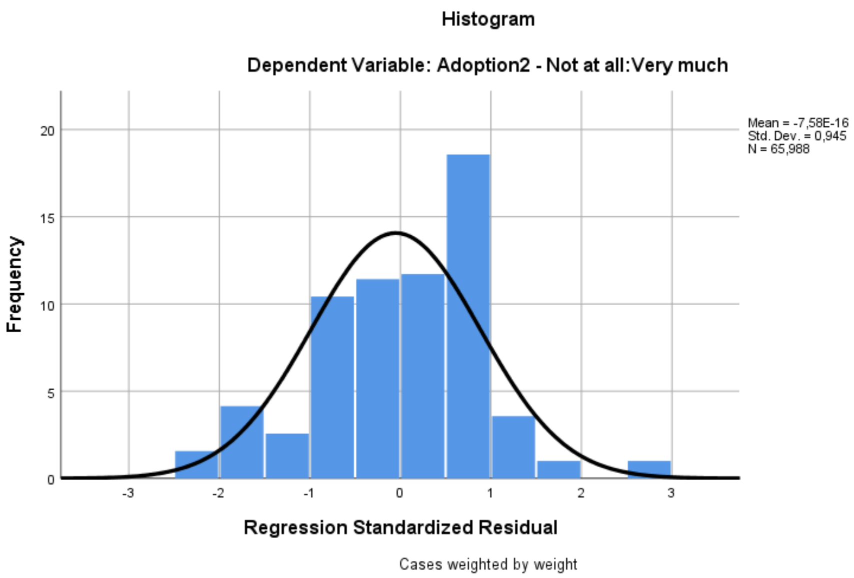
		Consequent						
		M_1 (Usefulness)				M_2 (Satisfaction)		
Antecedent		Coeff.	*SE*	*p*		Coeff.	*SE*	*p*
X_1 (Social)	a_1	0.237	0.214	.276	a_2	0.120	0.248	.632
X_2 (Default)	a_3	-0.082	0.187	.663	a_4	-0.127	0.217	.561
Constant	i_1	2.091	0.677	.004	i_2	1.429	0.786	.078
RES		0.455	0.056	<.001		0.414	0.066	<.001
Subj.kn		-0.063	0.065	.333		0.008	0.075	.921
Range		0.001	0.001	.470		0.001	0.001	.337
Age		-0.014	0.007	.038		-0.011	0.008	.139
Gender		0.278	0.256	.285		0.448	0.298	.142
		R^2=0.701 $F(7,34)$ =1.373, p = <.001				R^2=0.600 $F(7,34)$ = 7.285 , p < .001		

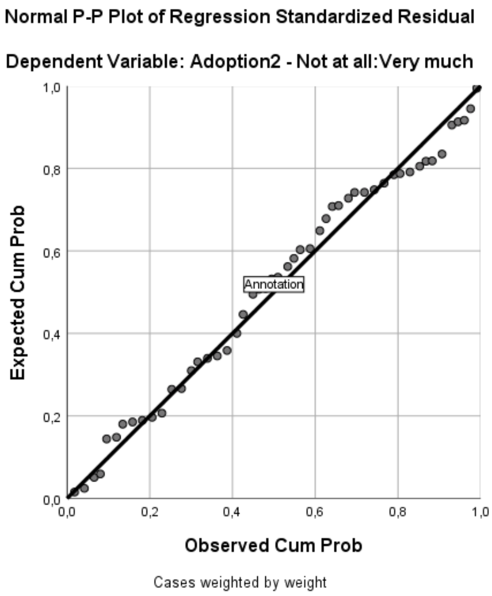
		Y (Adoption$_2$)		
Antecedent		Coeff	*SE*	*p*
X_1 (Social)	c_1'	-0.777	0.675	.258
X_2 (Default)	c_2'	-0.728	0.582	.220
M_1 (Usef)	b_1	0.075	0.615	.903
M_2 (Sati)	b_2	0.606	0.529	.261
Constant	i_3	-1.835	2.378	.446
RES		0.605	0.309	.059
Subj.kn		0.026	0.204	.901
Range		0.002	0.002	.274
Age		0.019	0.022	.392
Gender		-0.484	0.823	.561
		R^2=0.507 $F(9,32)$ =3.651, p = .003		

Social = Descriptive social norm nudge; Default; Changing the default nudge; RES = Renewable energy sources; Usef = Usefulness; Sati = Satisfaction; Sub.kn = Subjective knowledge; Range = Driving range.

9.3. Assumptions for regression analysis

Tests to see if the data met the assumption of collinearity indicated that multicollinearity was not a concern (*VIF* = 4.38 for Usefulness; *VIF* = 3.33 for Satisfaction; *VIF* = 4.90 for RES; *VIF* = 3.12 for Grid Stability; *VIF* = 1.35 for Flexible Mobility; *VIF* = 1.17 for Data Privacy; *VIF* = 1.23 for Subjective Knowledge; *VIF* = 1.21 for Driving Range; *VIF* = 1.30 for Age; *VIF* = 1.17 for Gender).





9.4. Syntax

The following syntax contains a few errors. PROCESS Version 3 doesn't offer the option to effectively paste and rerun the analysis. Instead one has to enter the variables manually via the PROCESS menu. The menu specifically states "do not use PASTE button". Stubborn as I am I did it anyway, producing a chain of over 30000 word of meaningless syntax code. Therefore, if you wish to rerun the analysis of this study I recommend using the syntax up to and including the binary logistic regressions. To rerun the mediation analysis using PROCESS Version 3 follow these steps (see images 1 & 2):

- Open the PROCESS menu via: Analyze; Regression; PROCESS v3.0 by Andrew F. Hayes.

- For the analysis with motives as independent variable enter ad4_lik_1 as Y variable, RES as X variable, Usefulness & Satisfaction as M (mediators) and Grid.stab, Flex.mob, Data.priv, Subjec.know, Driving_range_2, Age & Gender as Covariates.
- Options: Show total effect model
- Model number: 4
- Number of bootstrap samples: 10000

- For the analysis with the nudges as independents variables enter ad4_lik_1 as Y variable, nudge_condition as X variable (multicategorical; coding: indicator), Usefulness & Satisfaction as M (mediators) and RES, Subjec.know, Driving_range_2, Age & Gender as Covariates
- Multicategorical; Variable X: Multicategorical; Coding system: Indicator
- Options: Show total effect model
- Model number: 4
- Number of bootstrap samples: 10000
- For the analysis with the nudges as independents variables without respondents who failed the manipulation check, exclude the cases with incorrect answers and follow the previous steps

Image 1

Instructions for mediation analysis with motives as independent variables

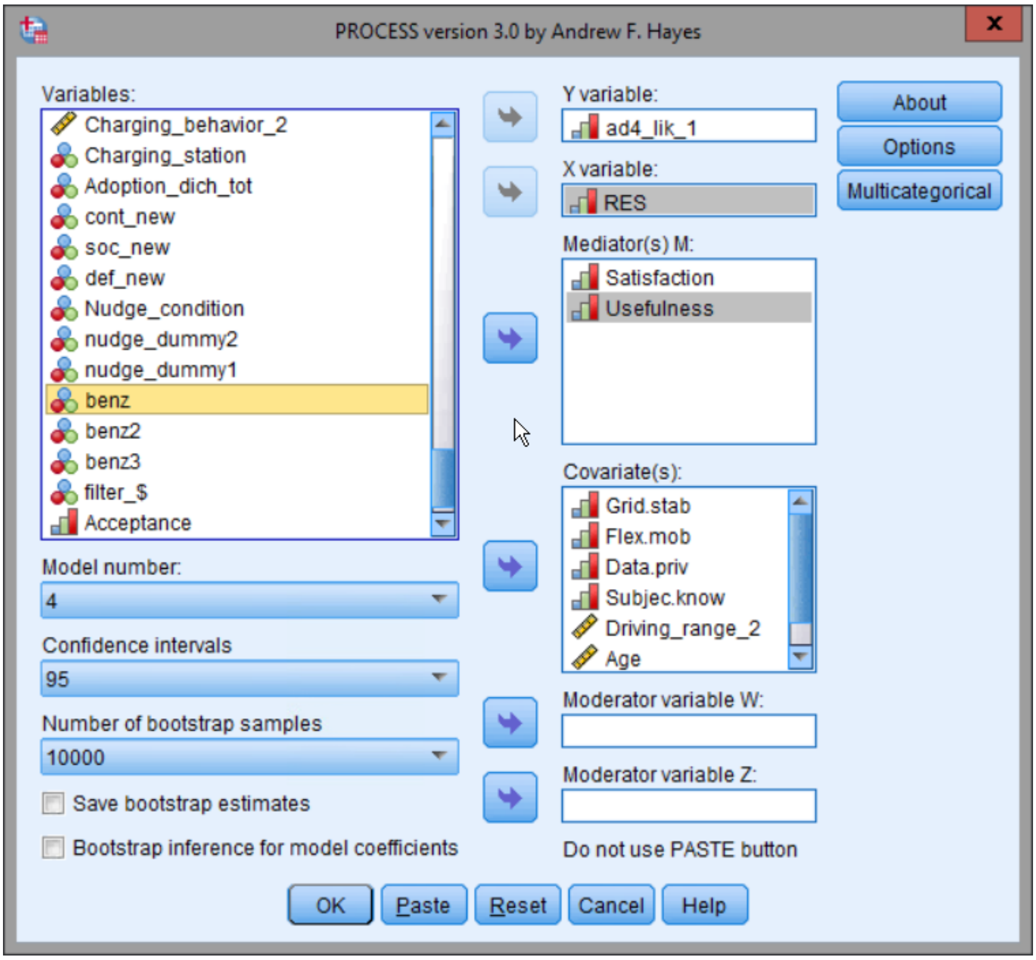
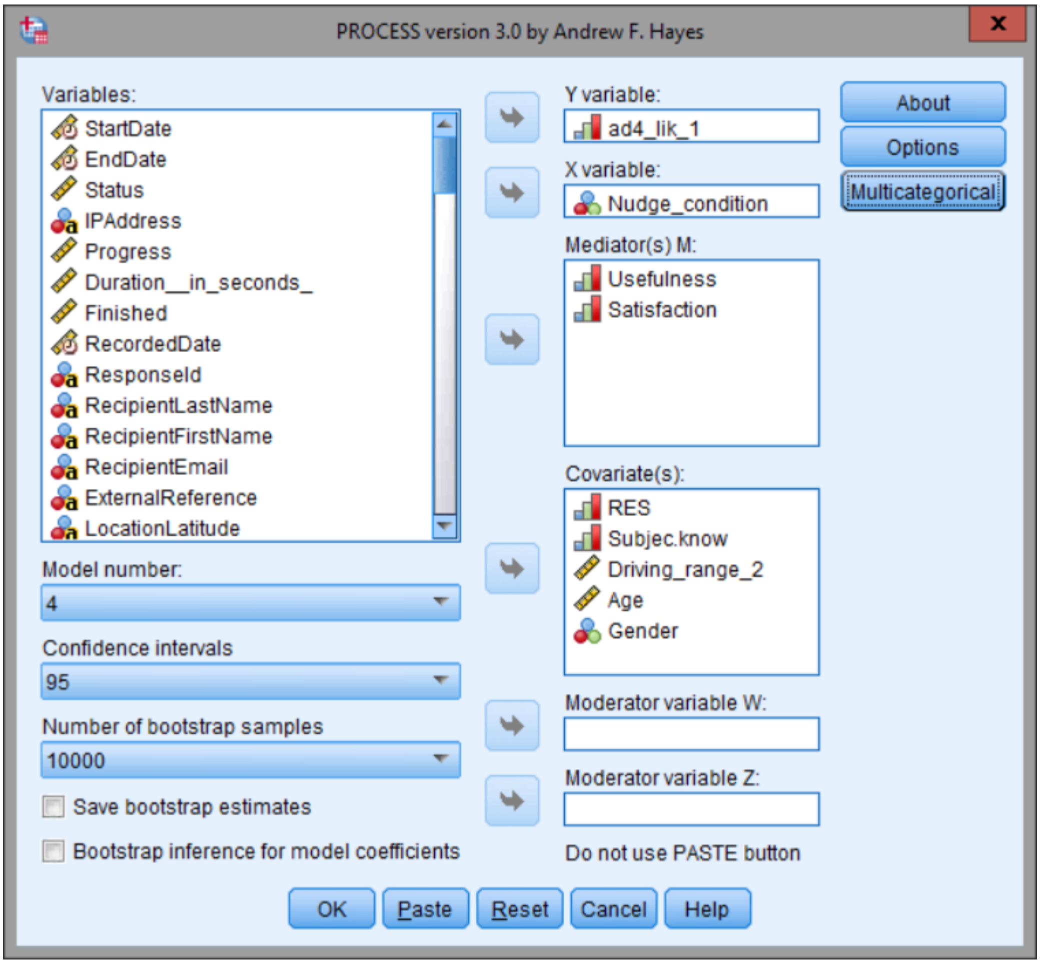
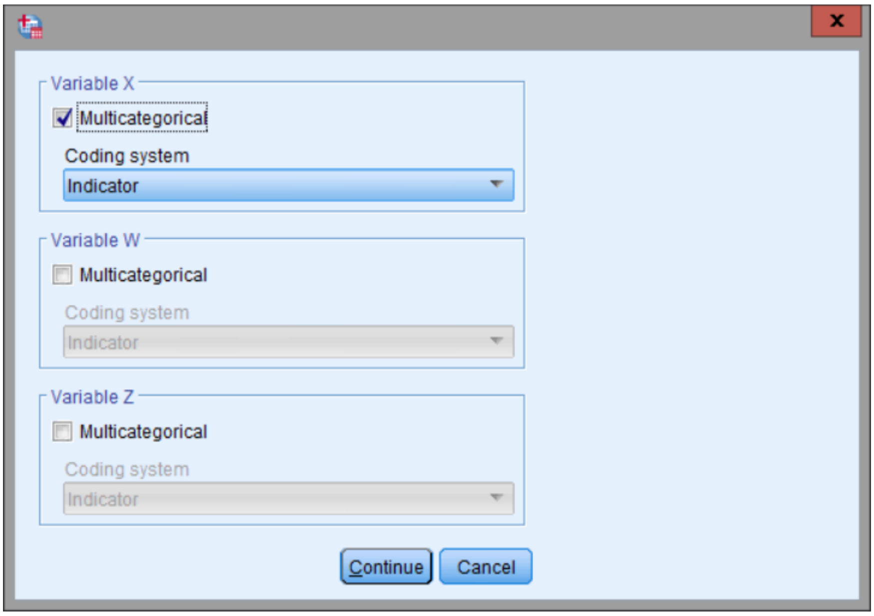


Image 2

Instructions for mediation analysis with nudges as independent variables





9.4.1. Syntax code

```
* Encoding: UTF-8.

DATASET ACTIVATE DataSet1.

*Invert items Acceptance 1 2 4 5 7 9

RECODE acceptance_1 acceptance_2 acceptance_4 acceptance_5 acceptance_7
acceptance_9 (5=1) (4=2)
    (3=3) (2=4) (1=5).
EXECUTE.

*Invert items fmn2__1 dp4__1 res1_env__1 gs3_ben__1 gs4_nec__1 gs6_gen__1
mi2__1 sk3__1 aut2__1 imp2__1

RECODE fmn2__1 dp4__1 res1_env__1 gs3_ben__1 gs4_nec__1 gs6_gen__1
mi2__1 sk3__1 aut2__1 imp2__1 (7=1) (6=2) (5=3) (4=4) (3=5) (2=6) (1=7).
EXECUTE.

*Correct value labels for  fmn2__1 dp4__1 res1_env__1 gs3_ben__1 gs4_nec__1
gs6_gen__1 mi2__1 sk3__1 aut2__1 imp2__1.

add value labels  fmn2__1 dp4__1 res1_env__1 gs3_ben__1 gs4_nec__1 gs6_gen__1
mi2__1 sk3__1 aut2__1 imp2__1 1 "Helemaal eens" 2 "Eens" 3 "Een beetje eens" 4
"Neutraal" 5 "Een beetje oneens" 6 "Oneens" 7 "Helemaal oneens".
EXECUTE.

*Recode adoption

DO IF (control <= 3).
RECODE ad1_control_1 (SYSMIS=0).
END IF.
EXECUTE.
```

```
DO IF (social <= 3).
RECODE ad2_soc_1 (SYSMIS=0).
END IF.
EXECUTE.

DO IF (default <= 3).
RECODE ad3_def__1 (SYSMIS=0).
END IF.
EXECUTE.

*Recode adoption default

RECODE ad3_def__1 (0=1) (1=0).
EXECUTE.

*Change labels adoption

VALUE LABELS ad1_control_1 ad2_soc_1 ad3_def__1 0 "No" 1 "Yes".
EXECUTE.

*Create new variable Adoption total

DATASET ACTIVATE DataSet1.
COMPUTE Adoption_dich_tot=SUM(ad1_control_1,ad2_soc_1,ad3_def__1).
EXECUTE.

*Create new variables condition

RECODE control (1=1) (2=1) INTO cont_new.
VARIABLE LABELS  cont_new 'cont_new'.
EXECUTE.

RECODE social (1=2) (2=2) INTO soc_new.
```

```
VARIABLE LABELS  soc_new 'soc_new'.
EXECUTE.

RECODE default (1=3) (2=3) INTO def_new.
VARIABLE LABELS  def_new 'def_new'.
EXECUTE.

*Create new variable condition group

COMPUTE Nudge_condition=SUM(cont_new,soc_new,def_new).
EXECUTE.

*Add value labels adoption

VALUE LABELS Adoption_dich_tot 0 "No" 1 "Yes".
EXECUTE.

*Add value labels Nudge condition

VALUE LABELS Nudge_condition 1 "Control" 2 "Social" 3 "Default".
EXECUTE.

*Create new variable Usefulness

COMPUTE
Usefulness=MEAN(acceptance_1,acceptance_3,acceptance_5,acceptance_7,acceptanc
e_9).
VARIABLE LABELS  Usefulness 'Usefulness'.
EXECUTE.

*Create new variable Satisfaction

COMPUTE
Satisfaction=MEAN(acceptance_2,acceptance_4,acceptance_6,acceptance_8).
```

```
VARIABLE LABELS  Satisfaction 'Satisfaction'.
EXECUTE.

*Create dummy variable Nudge condition

RECODE Nudge_condition (3=1) (1=0) (2=0) INTO nudge_dummy2.
VARIABLE LABELS  nudge_dummy2 'nudge_dummy2'.
EXECUTE.

RECODE Nudge_condition (1=0) (2=1) (3=0) INTO nudge_dummy1.
VARIABLE LABELS  nudge_dummy1 'nudge_dummy1'.
EXECUTE.

*Factor analysis motivations

FACTOR
  /VARIABLES fmn1_1 fmn2__1 fmn3_1 dp1_1 dp2_1 dp3_1 dp4__1 res1_env__1
res2_co2_1 res3_res_1
    res4_clim_1 gs1_stabl_1 gs2_trans_1 gs3_ben__1 gs4_nec__1 gs5_flex_1
gs6_gen__1 mi1_1 mi2__1 sk1_1
    sk2_1 sk3__1
  /MISSING PAIRWISE
  /ANALYSIS fmn1_1 fmn2__1 fmn3_1 dp1_1 dp2_1 dp3_1 dp4__1 res1_env__1
res2_co2_1 res3_res_1
    res4_clim_1 gs1_stabl_1 gs2_trans_1 gs3_ben__1 gs4_nec__1 gs5_flex_1
gs6_gen__1 mi1_1 mi2__1 sk1_1
    sk2_1 sk3__1
  /PRINT INITIAL CORRELATION INV EXTRACTION ROTATION
  /FORMAT BLANK(.30)
  /PLOT EIGEN
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
```

```
  /METHOD=CORRELATION.

*Reliabilty test RES

DATASET ACTIVATE DataSet1.
RELIABILITY
  /VARIABLES=res1_env__1 res2_co2_1 res3_res_1 res4_clim_1
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE
  /SUMMARY=TOTAL.

*Reliabilty test Flexible Mobility

RELIABILITY
  /VARIABLES=fmn1_1 fmn3_1
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE
  /SUMMARY=TOTAL.

*Reliability test Grid Stability

RELIABILITY
  /VARIABLES=gs1_stabl_1 gs2_trans_1 gs3_ben__1 gs4_nec__1
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE
  /SUMMARY=TOTAL.

*Reliability test Data Privacy

RELIABILITY
  /VARIABLES=dp1_1 dp2_1 dp3_1 dp4__1
```

```
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE
  /SUMMARY=TOTAL.

*Reliabilty test Subjective Knowledge

RELIABILITY
  /VARIABLES=sk1_1 sk2_1 sk3__1
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE
  /SUMMARY=TOTAL.

*Create new variable RES

DATASET ACTIVATE DataSet2.
COMPUTE RES=MEAN(res1_env__1,res2_co2_1,res3_res_1,res4_clim_1).
EXECUTE.

*Create new variable Flexible

COMPUTE Flex.mob=MEAN(fmn1_1,fmn3_1).
EXECUTE.

*Create new varIiable Data Privacy

COMPUTE Data.priv=MEAN(dp1_1,dp2_1,dp3_1,dp4__1).
EXECUTE.

*Create new variable Grid Stability

COMPUTE Grid.stab=MEAN(gs1_stabl_1,gs2_trans_1,gs3_ben__1,gs4_nec__1).
EXECUTE.
```

*Create new variable Subjective Knowledge

```
COMPUTE Subjec.know=MEAN(sk1_1,sk2_1,sk3__1).
EXECUTE.
```

*Filter out unfinished responses

```
USE ALL.
COMPUTE filter_$=(Finished = 1).
VARIABLE LABELS filter_$ 'Finished = 1 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.
```

*Create new variable for gasoline car drivers

```
DATASET ACTIVATE DataSet1.
RECODE Car_type (1=1) (ELSE=0) INTO benz.
VARIABLE LABELS  benz 'benz'.
EXECUTE.

RECODE Second_car_type (2=1) (ELSE=0) INTO benz2.
VARIABLE LABELS  benz2 'benz2'.
EXECUTE.

COMPUTE benz3=SUM(benz,benz2).
EXECUTE.
```

*Filter out gasoline car drivers (I filtered them out by hand, because I couldn't use two seperate filters at once; only three gasoline drivers)

```
USE ALL.
```

```
COMPUTE filter_$=(benz3 < 2).
VARIABLE LABELS filter_$ 'benz3 < 2 (FILTER)'.
VALUE LABELS filter_$ 0 'Not Selected' 1 'Selected'.
FORMATS filter_$ (f1.0).
FILTER BY filter_$.
EXECUTE.

*Frequencies and boxplot

FREQUENCIES VARIABLES=Usefulness Satisfaction
  /STATISTICS=RANGE MINIMUM MAXIMUM MEAN MEDIAN MODE
  /BARCHART FREQ
  /ORDER=ANALYSIS.

EXAMINE VARIABLES=Usefulness Satisfaction
  /COMPARE VARIABLE
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL
  /MISSING=LISTWISE.

*Create variable Acceptance

COMPUTE Acceptance=MEAN(Usefulness,Satisfaction).
EXECUTE.

*Compare means and frequencies conditions

SORT CASES  BY Nudge_condition.
SPLIT FILE SEPARATE BY Nudge_condition.

DESCRIPTIVES VARIABLES=ad4_lik_1 Adoption_dich_tot
  /STATISTICS=MEAN STDDEV MIN MAX.
```

```
FREQUENCIES VARIABLES=Adoption_dich_tot
  /ORDER=ANALYSIS.

SPLIT FILE OFF.

*weight cases, controlN=22 socN=22 defN=22

AGGREGATE
  /OUTFILE=* MODE=ADDVARIABLES
  /BREAK=Nudge_condition
  /ResponseId_n=N(ResponseId).



RECODE Nudge_condition (1=1) (2=1.5714) (3=1.5714) INTO weight.
VARIABLE LABELS  weight 'weight'.
EXECUTE.

WEIGHT BY weight.

*Create variable age

DATASET ACTIVATE DataSet1.
COMPUTE Age=100 - Year_of_birth_1.
EXECUTE.

*check assumptions

REGRESSION
  /DESCRIPTIVES MEAN STDDEV CORR SIG N
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS BCOV R ANOVA COLLIN TOL
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ad4_lik_1
```

```
  /METHOD=ENTER Gender Driving_range_2 Usefulness Satisfaction RES Grid.stab
Flex.mob Data.priv
    Subjec.know Age
  /SCATTERPLOT=(*ZPRED ,*ZRESID)
  /RESIDUALS HISTOGRAM(ZRESID) NORMPROB(ZRESID).

*Binary logistic regression motives on adoption1

LOGISTIC REGRESSION VARIABLES Adoption_dich_tot
  /METHOD=ENTER RES Grid.stab Flex.mob Data.priv Subjec.know Age Gender
Driving_range_2 Usefulness
    Satisfaction
  /CONTRAST (Gender)=Indicator
  /CRITERIA=PIN(0.05) POUT(0.10) ITERATE(20) CUT(0.5).

*Binary logistic regression nudging on adoption1

DATASET ACTIVATE DataSet1.
LOGISTIC REGRESSION VARIABLES Adoption_dich_tot
  /METHOD=ENTER Nudge_condition Usefulness Satisfaction RES Grid.stab
Flex.mob Data.priv
    Subjec.know Age Driving_range_2 Gender
  /CONTRAST (Nudge_condition)=Indicator(1)
  /CRITERIA=PIN(.05) POUT(.10) ITERATE(20) CUT(.5).
```