Transportation Research Part A 92 (2016) 26–42

Contents lists available at ScienceDirect

Transportation Research Part A

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

How experience of use influences mass-market drivers' willingness to consider a battery electric vehicle: A randomised controlled trial

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ARTICLE INFO

Article history:
Received 17 April 2015
Received in revised form 18 May 2016
Accepted 30 June 2016
Available online 26 July 2016

Keywords:
Electric vehicle
Consumer
Adoption
Randomised controlled trial
Symbolic
Performance

ABSTRACT

Uptake of electric vehicles (EVs) by consumers could reduce CO_2 emissions from light duty road transport, but little is known about how mass-market consumer drivers will respond to them. Self-Congruity theory proposes that products are preferred whose symbolic meanings are congruent with personal identity. Further, Construal Level theory suggests that only those who are psychologically close to a new product category through direct experience with it can make concrete construals related to their lifestyles; most drivers lack this for EVs. For instance, potential performance benefits of EVs might offset range limitations for consumers who have such direct experience. The effect of direct experience was tested in a randomised controlled trial with 393 mass-market consumer drivers. An experimental group were given direct experience of a modern battery electric vehicle (BEV), and a control group an equivalent conventional car. Despite rating the performance of the BEV more highly than that of the conventional car, willingness to consider a BEV declined after experience, particularly if the range of the BEV considered was short. The participants willing to consider a short-range BEV were those high in self-congruity, for whom the BEV could act as a strong symbol of personal identity.

1. Introduction

Electric vehicles (EVs) offer a potential option to reduce CO_2 emissions from light duty road transport. Their success, however, will depend critically on their uptake by mass-market consumer drivers (MMCDs). If they meet or exceed these consumers' needs, uptake is likely to be high, but if they fail to meet such needs, uptake could be low. The question of how mass-market consumers will respond to the various attributes of EVs is therefore of some importance. Vehicle performance and symbolic value can be important factors in car use decisions (Steg, 2005) and so may affect mass-market consumer drivers' willingness to consider BEV adoption.

To explore their potential influences, we report a large-scale randomised controlled trial to measure UK MMCDs' willingness to consider having a battery electric vehicle (BEV), their evaluations of the performance of a modern (2012) BEV, and their attributions of symbolic meanings to BEVs. The research design addressed three methodological issues relevant to research on uptake of new product categories: psychological distance, sample bias, and Hawthorne effects.

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http://dx.doi.org/10.1016/j.tra.2016.06.034
0965-8564/

1.1. Evaluations of EV performance

It can be argued that BEVs could have better performance than ICE vehicles, and that this might help to offset adverse perceptions of limited range. Skippon (2014a) found that consumer drivers construe vehicle performance in terms of two independent dimensions, dynamic performance and cruising performance. There has been relatively little research to date on how drivers evaluate either aspect of the performance of BEVs. Axsen et al. (2013) reported that participants perceived the smoothness of the driving experience (cruising performance) with a BEV as a benefit. However there was a mixed response to dynamic performance, with fast acceleration at low speeds seen as a benefit, but poor overall acceleration as a drawback. Graham-Rowe et al. (2012) found that "drivers felt that the power and performance of the EV was substandard" (p. 145). Participants in the study by Skippon and Garwood (2011) rated acceleration from 0 to 30 mph as somewhat better, acceleration from 30 to 50 mph as similar, responsiveness as somewhat better, power as somewhat worse, smoothness when cruising as substantially better and noise when cruising as substantially lower than a conventional ICE car. The picture that emerged from these studies was that BEVs of the time were considered to have better cruising performance, and either worse or similar dynamic performance than ICE cars. However, all were uncontrolled studies with small or biased samples, using an early generation of BEVs, and, except for Skippon and Garwood (2011), qualitative evaluations.

1.2. Symbolism of EVs

Symbolic goals to signal personal identity to self and others are known to be important in consumer choices in general (Dittmar, 1992) and vehicle use in particular (Steg, 2005). A substantial part of the value of products, including cars, arises from the meanings they convey about the identities of their users. Heffner et al. (2007) studied symbolism in California's early market for hybrid electric vehicles (HEVs), finding that personal meanings signified by HEVs included being an ethical person, community orientation, concern for others, intelligence, maturity, sensibility, independence and individuality. Participants were early adopters of HEVs, so it is perhaps risky to extrapolate too much from these findings to the symbolism of plug-in EVs among MMCDs. Graham-Rowe et al. (2012) identified symbolic meaning as a major theme (referred to as *impression management*) in their participants' responses to the experience of using a BEV or PHEV. Drivers of EVs were perceived as being:

- People with limited mobility needs, for whom the restricted utility of a BEV would not be a problem, and who saw cars from a functional perspective.
- People who prioritise environmental concerns.
- People who derive social identity gains from being seen to adopt new technologies.

Most participants tended to distance themselves from the first two meanings, but saw the third in a positive light.

Skippon (2014b) used an attribution-vignette method to quantify the symbolic meaning of the major European categories of light duty vehicle (small hatchback, sports car, etc.) in terms of public attributions of personality traits using the five-factor model (Costa and McCrae, 1995; McCrae and Costa, 2003), plus status, gender, age, relationship investment, and physical attractiveness to a typical user of each category. This approach is based on Miller's (2009) evolutionary perspective that the ultimate symbolic meanings of a consumer product are the personality traits of its users, because products act in modern cultures as costly signals of reproductive fitness. The method draws on attribution theory (Hewstone, 1989; Jones and Davis, 1965; Kelley, 1967): when an actor is observed using a consumer product, the observer will attribute certain personality traits to the actor by inference from that behaviour. These traits will be those that the observer associates with the product, i.e. its symbolic meaning according to Miller. Skippon and Garwood (2011) used an early version of this method to characterise the symbolic meaning of BEVs. BEV users were seen by their small sample as being above average in the five-factor traits openness, conscientiousness, and agreeableness, and average in extraversion and neuroticism.

Self-congruity theory (Sirgy, 1982, 1985) predicts that people will tend to purchase consumer products whose symbolic meanings are congruent with their perceived self-identities. Schuitema et al. (2013) found that people with self-reported pro-environmental identities had more positive expectations of EVs than others, while those who saw themselves as authorities on cars did not.

This literature tends to suggest that EVs, and particularly BEVs, have symbolic meanings associated with pro-environmental identity, high openness, conscientiousness, and agreeableness. They also suggest that people whose self-identities are congruent with these meanings will be more favourably disposed towards EVs than those whose self-congruity is lower. However none of the studies measured the specific symbolic meaning of EVs compared to other vehicle types, or the relationship between self-congruity and potential uptake of EVs, with MMCDs who have directly experienced using an EV themselves.

1.3. Methodological issues for research on mass-market consumer drivers' responses to BEVs

To MMCDs, BEVs are currently a new, unfamiliar type of car. A number of methodological issues can limit the validity or generalizability of research on responses to "really new" product categories (Hoeffler, 2003). The study design addressed three methodological challenges that are relevant for research on responses to BEVs.

1.3.1. Psychological distance: the importance of direct experience of really new products

Stated preferences for alternative fuelled vehicles (including EVs) have been explored (see Dimitropoulos et al., 2013; Hackbarth and Madlener, 2013; Jensen et al., 2013; Lebeau et al., 2012; Lieven et al., 2011; and Ziegler, 2012 for recent examples), and the importance of their various attributes has been investigated in other quantitative studies (e.g. Axsen and Kurani, 2013; Carley et al., 2013; Delang and Cheng, 2012; Energy Technologies Institute, 2013; Shin et al., 2012; Schuitema et al., 2013). Such research has yielded valuable insights, but their participants have generally had no direct experience of using electric vehicles to draw on when making their responses.

Construal Level Theory (Liberman et al., 2007; Trope and Liberman, 2003) proposes that *psychological distance* affects the level of abstraction with which a product is construed. Something is psychologically distant when it is detached from a person's direct experience: the more psychologically distant an object, the more it is construed in abstract terms rather than concrete terms that relate its utility to the person's particular needs in everyday life. Thus research in which participants have not directly experienced electric vehicles may be subject to substantial uncertainties.

In the survey by the UK Energy Technologies Institute (ETI) (Energy Technologies Institute, 2013; Schuitema et al., 2013), psychological distance was partially reduced by providing information about electric vehicles to participants before the main survey. There is also now a growing body of literature exploring drivers' responses to EVs following direct experience of their use (Axsen and Kurani, 2012; Axsen et al., 2013; Bunce et al., 2014; Burgess et al., 2013; Caperello et al., 2013; Cocron et al., 2011; Franke and Krems, 2013a, 2013b; Graham-Rowe et al., 2012; Golob and Gould, 1998; Gould and Golob, 1998; Jensen et al., 2013; Klockner et al., 2013; Skippon and Garwood, 2011). Much of this research has used small samples, or samples that might be considered to be potential "early adopters".[1]

1.3.2. Sample bias in EV research

A further issue that can potentially limit the validity of research on uptake of "really new" product categories is that of biased sampling. Experimental research samples are of course always biased to some degree in the sense that they are inevitably drawn from the population sub-set that is willing to participate in the research in question. However a common *additional* sample bias in EV research has been that, for pragmatic reasons in the early marketplace, participants have tended to be either early owners of EVs, or people especially interested in them – i.e. actual and prospective "early adopters". Useful though this research is in understanding the potential for the earliest stages of uptake, there is no *a priori* case to assume that their responses will be representative of mass-market consumer drivers (MMCDs). Indeed in the ETI's (2013) segmentation analysis, attitudes of the 2% of participants who formed the "Pioneer" segment were much more favourable to EVs, and unrepresentative of the attitudes of the other segments. This suggests that findings from early adopter samples have limited validity in relation to MMCDs.

A few studies have avoided the "early adopter" bias. Skippon and Garwood (2011) and Axsen et al. (2013) gave UK participants brief direct experiences of using a small hatchback BEV. These samples were not comprised of "early adopters", but were more highly educated than the general UK population. Graham-Rowe et al. (2012) gave a diverse sample of 40 UK MMCD households direct experience of using a BEV or PHEV for a week, and Jensen et al. (2013) gave several hundred members of the Danish general public a three month experience of using a BEV.

1.3.3. "Hawthorne" effects

Hawthorne effects occur when participants change their behaviours, attitudes or preferences because they are aware that they are being observed, rather than in response to the research stimuli (Landsberger, 1958; McCartney et al., 2007). In a systematic review of interventions to reduce car use, Graham-Rowe et al. (2011) found that effect sizes in uncontrolled studies were substantially larger than those in studies using research designs that controlled for Hawthorne effects. However such research designs are less common in transport research (Graham-Rowe et al., 2011), and so far almost absent from the EV literature.

1.4. Research questions

This study was designed to explore MMCD willingness to consider BEVs, and the roles of perceived performance and symbolism, while addressing these methodological challenges. Specifically it addressed the following questions:

1. How far are MMCDs willing to consider having a BEV as a main or second household car, as a function of its available range on a fully charged battery?
2. How do MMCDs evaluate the dynamic and cruising performance of modern (2012 model) BEVs, compared to equivalent ICE cars?
3. What symbolic meanings do MMCDs attribute to BEVs?
4. How does the willingness of MMCDs to consider having a BEV relate to their evaluations of the performance of BEVs?

[1] "Early adopter" is a term taken from Rogers' (2003) diffusion of innovations theory, and strictly refers to those whose time of adoption lies between two and one standard deviations before the mean time to adoption in the population. Those who adopt even earlier (sooner than two standard deviations before the mean adoption time) are termed "Innovators" by Rogers. In EV discourses, however, this distinction is often ignored and "Early Adopter" tends to be used for "Innovator" or both. We conform to this imprecise usage here, for consistency with existing discourses.

5. Does congruity between personal identity and the symbolic meaning attributed to BEVs impact on MMCDs' willingness to consider owning a BEV?
6. How far and in what direction are MMCD responses to 1, 2, and 3 affected by direct experience of the use of a modern BEV?

In relation to question 6 the study tested four specific hypotheses:

H1. Participants' willingness to consider having a BEV as a main car in the household will increase after direct experience of BEV use.

H2. Participants' willingness to consider having a BEV as a second car in the household will increase after direct experience of BEV use.

H3. Evaluations of the performance of a modern BEV by participants who have had direct experience of using it will be more positive than evaluations of performance of an equivalent unfamiliar ICE car by participants who have had recent direct experience of using that.

H4. Participants' attributions of symbolic meanings to BEVs will change after direct experience of BEV use.

1.5. Methodology

The study was conducted as a randomised controlled trial (RCT). This is a research design in which participants are randomly allocated to groups that receive specific differences in treatment during the study. Random allocation of a sufficiently large sample ensures that all other differences between the groups (including all differences between individuals) are controlled for. Results for experimental groups that receive specific treatments are compared with those from a control group that participates in the trial but does not receive any of the specific treatments being tested. This controls for Hawthorne effects, since participants in all groups are affected equally by the process of participation. Inter-group differences can therefore be *causally* attributed to the specific treatment.

In this study, all participants experienced the use of an unfamiliar vehicle of similar size to their own, for the same time, using the same procedures, and responded to the same questionnaires. The difference in treatment was that the experimental group experienced use of a BEV, while the control group experienced the use of a conventional ICE car. This enabled assessment of the extent to which participants' responses to BEVs were affected by the reduction in psychological distance associated with the experience of using them. Hypotheses H1–H4, that direct experience of a BEV would cause changes in participants' responses to BEVs, would be supported to the extent that any changes in those responses between the before-usage and after-usage measurements of them were different for the experimental and control groups.

2. Method

2.1. Design

The RCT used a 2×2 mixed factorial design, with one between-participants independent variable (Group: Experimental (experienced BEV) or Control (experienced ICE)) and one within-participants variable (Time: before/after usage experience). Participants were randomly allocated to either the experimental or control groups.

Dependent variables were of three types:

- Evaluations of the performance of the vehicle used in the experiment, based on the attributes of performance identified by Skippon (2014a).
- Symbolic meaning of a BEV, measured using the attribution-vignette method before and after the usage experience.
- Willingness to consider a BEV as a main or second household car (if the BEV had a range on a full charge of 50, 100, 150, 200 or 250 miles), measured before and after the usage experience.

In addition, participants completed a five-factor personality inventory prior to the experiment. In combination with the symbolic meaning data, this enabled a measure of self-congruity to be calculated for each participant.

2.2. Participants

Participants were intended to be MMCDs, and specifically *not* people with a special interest in or enthusiasm for electric vehicles. They were recruited via:

- Direct email to the Transport Research Laboratory (TRL) volunteer participant pool.[2]
- Adverts on social media sites including Facebook, Twitter and forums.
- Adverts in local doctors' practices, sports clubs and supermarkets.
- Adverts on local companies' intranet sites.
- Word of mouth through TRL employees.

This elicited 961 initial responses. A pre-recruitment questionnaire was then used to recruit from amongst these a stratified sample that ensured representation of both genders, a range of participant ages, drivers with low, medium and high mileages, and drivers living in both urban and rural locations. Potential participants without access to off-road parking and an off-road external electricity supply at home (for safe recharging) were excluded. Drivers with a record of motoring offences were also excluded for safety and insurance reasons.

Eleven participants dropped out prior to the use experience. In addition data from two participants was not used as the car they were using broke down during the experiment. A total of 393 participants completed all stages of the experiment. Table 1 shows the stratification achieved in the sample.

2.3. Stimuli: BEV and control ICE car

Participants in the experimental group were given the use of a modern medium family hatchback BEV with a manufacturer's claimed range (on a full battery) of >100 miles. Controlled testing on a chassis dynamometer found that these vehicles achieved a range of 83 miles in repeated NEDC test cycles and 44 miles in constant 75 mph driving. Recharging a fully discharged battery to the fully charged condition by connecting the charging cable to a standard UK domestic 13A supply took around 12 h. Four of these cars were used, all of similar age and mileage.

Participants in the control group were given the use of a 1.6 L modern medium family hatchback diesel ICE car.

2.4. Procedure

Participants completed three online questionnaires, two before the usage experience, one after. The measures relevant to this study were included in the second and third questionnaires, referred to as the pre-experience and post-experience questionnaires. When completing the pre-experience questionnaire participants were unaware as to which vehicle they would be experiencing.

Participants collected their cars from TRL after a licence check. Participants were shown their car, briefed on its safe operation, and given the opportunity to drive it under supervision so that they were comfortable with driving it before doing so on their own. They were briefed that they would complete a further questionnaire that would include items on their evaluation of the experience of driving their car.

Participants were given approximately 36 h to use the car as they wished. The experiences of Axsen et al. (2013) and Skippon and Garwood (2011) suggested that this would be long enough to enable participants to experience and understand the capabilities and limitations of BEVs, and to reflect on how BEVs might or might not fit with their lifestyles and vehicle usage patterns. We emphasise that the purpose of the direct experience was to reduce participants' psychological distance from BEVs, not to provide them with comprehensive direct experience of use in all major aspects of their lifestyles. Vehicles were collected on either Monday afternoons, Wednesday afternoons, or Friday afternoons, and returned on the mornings of the following Wednesdays, Fridays, or Sundays respectively. Thus two thirds of each group had their direct experience predominantly on weekdays, and one third had theirs predominantly at the weekend. Participants in both groups were randomly allocated to start days, and the frequency of each start day was the same for each group. This design ensured that if there were differences in the extent to which weekend and weekday use reduced psychological distance, both types of experience were included (and to the same extent for both experimental and control groups). Using four vehicles per group the total elapsed time for the fieldwork was approximately four months, during UK spring and summer.

After the usage experience,[3] participants returned the car to TRL, and were paid an incentive of £10 for their partial completion of the study to this point. Between two and three days later, they were emailed a link to the online post-experience questionnaire. Once that was completed they were paid a further £50 incentive for their participation.

2.5. Measures

2.5.1. Sample characterization

The IPIP-NEO 120-item personality inventory (Goldberg et al., 2006) was used in the pre-experience questionnaire to measure participants' five-factor personality traits (openness, conscientiousness, extraversion, agreeableness, and neuroticism). Responses to a sub-set of these items were used to calculate self-congruity (see below).

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[2] A pool of over 1500 people living within approximately 25 miles of TRL, all of whom have volunteered to take part in research with TRL.

[3] A detailed examination of usage behaviour (based on onboard GPS data logging) showed similar mean numbers of trips for each group (control: 10.8; experimental: 10.0) but the experimental group had a lower mean trip length (9.5 km) than the control group (12.5 km). Also mean speeds were significantly lower for the experimental group (32.3 kph) than the control group (44.5 kph). These differences perhaps reflect the range restrictions of the BEV.

Table 1
Stratified sample.

Residence	Age group	Male			Female			Total
		Low mileage[a]	Medium mileage[b]	High mileage[c]	Low mileage	Medium mileage	High mileage	
Rural[d]	17–30	8	16	8	6	14	6	58
	31–50	6	18	10	10	24	10	78
	Over 50	8	16	4	4	14	6	52
Urban[e]	17–30	8	18	8	10	18	8	70
	31–50	8	18	12	10	24	8	80
	Over 50	12	18	8	8	16	4	66
Total		50	104	50	48	110	42	404

[a] 5000 miles per year or fewer.
[b] 5001–15,000 miles per year.
[c] Above 15,000 miles per year.
[d] Codes 2, 3 or 4 in the Experian Rural/Urban Code for the UK.
[e] Codes 5, 6, 7 or 8 in the Experian Rural/Urban Code for the UK.

Participants also responded to a battery of items in the pre-experience questionnaire to record other individual characteristics: age; rural vs. urban residence; education level; employment status; annual income; relationship status; numbers of driving licence holders and cars, and fuel types of cars, in household; annual mileages of main and (if applicable) second cars in household; use of other transport modes; and driving style.[4] Inter-group differences with respect to these could potentially have confounded the study: the measures were used to test that these had in fact been controlled for by the random allocation of participants between the experimental and control groups.

2.5.2. Dependent measures: evaluation of vehicle performance

To compare participants' post-experience evaluations of BEV performance with their pre-experience expectations of BEV performance would have limited validity, as the pre- and post-experience measures would relate to different mental constructs. Instead we compared the post-experience evaluations of the performance of the BEV by the experimental group with the post-experience evaluations of the performance of the control ICE car by the control group.

The evaluation part of the post-experience questionnaire contained eleven items measuring participant ratings of performance of the vehicle experienced, plus other aspects of the driving experience. The items covered those aspects of performance identified by Skippon (2014a, 2014b) as the ways in which drivers construe vehicle performance: acceleration from 0 to 20 mph, acceleration from 30 to 50 mph, smoothness of gear changes,[5] responsiveness, power, smoothness and noise when cruising. Top speed was not included because the top speed of both vehicles in the experiment substantially exceeded the UK national speed limit, so asking drivers to evaluate it would not have been ethical. In addition, participants were asked to rate overall performance, and three other aspects of the driving experience: comfort, safety and enjoyment. The questionnaire used the Borg CR-10 Category-Ratio scale. This scale is "able to describe a psychophysical stimulus-response function over a wide range of stimulus intensities with a mathematical function that as accurately as possible reflects the genuine growth of the sensory perception" (Borg, 1998, p. 39), i.e. it is intended to reflect the form of mental "scales" of perceived stimulus intensity better than, say, Likert-type ordinal scales. The scale has a non-linear, positively accelerating growth function for perceived intensity, with verbal anchors ranging from "no (stimulus) at all" up to "extremely high" (the maximum the participant has ever experienced). There is also a final category, "maximal (stimulus)", defined as the highest value of the stimulus that the participant could imagine experiencing. The scale was developed to measure perceived exertion and perceived pain, but has also been used for perception of vehicle performance attributes (perceived loudness of engine idle noise and perceived intensity of steering wheel vibration; Ajovalasit and Giacomin, 2007). Table 2 shows an example of a Borg CR-10 scale item to measure perceived acceleration from 30 to 50 mph.

2.5.3. Dependent measures: symbolic meaning and self-congruity

In both the pre-experience and post-experience questionnaires, participants' attributions of symbolic meaning to BEVs were measured using the attribution-vignette method (Skippon, 2014b; Skippon and Garwood, 2011). Eighteen items measured participants' attributions of personal characteristics to an imagined typical user of a BEV (Table 3). Responses were compared to norms recorded in Skippon's (2014b) study of the symbolic meanings of the major types of European light duty cars, and recorded as z-scores relative to those norms.

Ten of the items were used to measure participants' attributions of the five-factor personality traits[6]: openness, conscientiousness, extraversion, agreeableness, and neuroticism to an imagined typical user of a BEV. The remaining eight items

[4] Measured by inter-group comparison of scores on the Multi-Dimensional Driving Style Inventory (MDSI; Taubman-Ben-Ari et al., 2004).

[5] Smoothness of gear changes is an important performance attribute from a consumer driver perspective (Skippon, 2014a). However the BEV had automatic transmission, so smoothness of gear changes was expected to be rated very highly by experimental group participants.

[6] The ten symbolic meaning personality items were selected from the IPIP-NEO inventory, based on the pair of items for each trait that had the strongest correlations with the overall trait scores in an earlier UK survey using IPIP-NEO. Each trait pair consisted of one positively valenced and one negatively valenced item in relation to the trait. To achieve this two items were adjusted to have opposite valence than the equivalent IPIP-NEO item. In the self-congruity analysis this valence change was corrected for before the self-congruity calculation.

Table 2
Example of a self-report Borg CR-10 scale item measuring perceived acceleration from 30 to 50 mph during the experiment.

None at all	Extremely low	Very low	Low	Moderate		High		Very High			Extremely high	Maximal
0	0.5	1	2	3	4	5	6	7	8	9	10	X

Please rate the acceleration from 30 mph to 50 mph of the car you used in the experiment, by selecting one number from the scale provided and placing a tick in the white box under it.

Table 3
Measurement of self-congruity: questionnaire items.

Personality trait or personal characteristic	Item ("*Please imagine the kind of person who would drive an electric car. Now describe what that person is like, by indicating how far you feel each of the following statements fits them:*")
Openness	Likes philosophical discussions Prefers to stick to things that he or she knows
Conscientiousness	Likes to tidy up Makes rash decisions
Extraversion	Has a lot of fun Feels uncomfortable around people
Agreeableness	Sympathises with the homeless Gets back at others
Neuroticism	Feels able to deal with things Worries about things
Status	Has a low status job Has a high income
Relationship investment	Frequently has casual sexual relationships Is in a long term relationship with a spouse or partner
Physical attractiveness	Is physically unattractive Is physically attractive
Age	Is aged 35 or under
Gender	Is female

measured participants' attributions of other characteristics of an imagined typical user salient to reproductive fitness: status, gender, age, relationship investment (focus on long-term vs. casual relationships), and physical attractiveness.

Responses to each personality item were compared with participants' own self-report responses to the same items in the IPIP-NEO personality inventory, to calculate a measure of self-congruity:

$$SD_i = \frac{1}{N}\left(\sum_{n=1}^{N}|Att_{ni} - SR_{ni}|\right) \quad (1)$$

where SD_i is self-discongruity[7] for the ith participant, N is the total number of personality items in the summation (ten, two for each five-factor trait), Att_{ni} is the attribution made by the ith participant in response to the nth item, and SR_{ni} is the ith participant's self-report in response to the same item in the IPIP-NEO part of the questionnaire. Since each Att_{ni} or SR_{ni} score could take a value from 1 to 5, this measure ranged from 0 (maximum self-congruity – the personality attributed to a typical user of a BEV exactly matched the participant's self-report of his/her own personality) to 4 (maximum self-discongruity - the personality attributed to a typical user of a BEV was as mismatched as possible to the participant's self-report of his/her own personality).

Self-discongruity was then converted to a normalized self-congruity score using the simple transformation:

$$SC_i = \frac{1}{4}(4 - SD_i) \quad (2)$$

The normalized self-congruity SC_i measure ranged from 0 for maximum self-discongruity to 1 for maximum self-congruity.

[7] Other authors have described similar expressions to Eq. (1) as measures of self-congruity (e.g. Eriksen, 1996). However since SD_i decreases towards zero as self-congruity increases, it is better described as a measure of the opposite: self-discongruity. The transformation of Eq. (2) yields an appropriate measure of self-congruity.

2.5.4. Dependent measures: willingness to consider a BEV as a main or second household car

In both the pre- and post-experience questionnaires, participants were asked to indicate (by selecting *yes* or *no*) whether they would consider owning an electric car as a main car in their household, if it had a range when fully charged of 50, 100, 150, 200 or 250 miles. These questions were repeated for ownership of an electric car as a second car in their household.

3. Results

3.1. How far was matching of control and experimental groups achieved?

Random allocation of participants to the experimental and control groups should lead to good matching between the groups, so that any differences between their responses can be causally attributed to the experimental manipulation (i.e. experience of using a BEV versus a conventional ICE car). Controlling for multiple hypothesis tests, statistical analyses (*t*-test or χ^2 test as appropriate for the variable) found no significant ($p < 0.05$) differences between the groups in terms of: mean age; rural vs. urban residence; education level; employment status; mean annual income; relationship status; numbers of driving licence holders and cars, and fuel types of cars, in household; annual mileages of main and (if applicable) second cars in household; use of other transport modes; driving style; and personality traits.

The remainder of the results section is structured in relation to the research questions set out in the introduction.

3.2. How far are MMCDs willing to consider having a BEV as a main or second household car, as a function of its available range on a fully charged battery? How was this affected by direct experience of using one?

Fig. 1 shows the proportion of participants who would choose a BEV as their main household car, as a function of the range the car would travel on a fully charged battery. Before the usage experience, the percentage of participants who would consider owning a BEV as their main household car was similar for both groups at all range values. It was very low for 50 miles range (around the realistic extra-urban driving range of the BEV used in the RCT) but increased for higher ranges. At every range the percentage of participants who would consider choosing a BEV decreased after the usage experience in both groups; however the decrease was larger in all cases for the experimental group than the control group (the between-groups difference being statistically significant (Wald[8] chi-square = 8.284, $p = 0.004$) for the 150 mile range).

Fig. 2 shows the proportion of participants who would choose a BEV as a second household car, as a function of the range the car would travel on a fully charged battery. The broad patterns were the same as for a main car. Before the usage experience, the percentage who would consider owning a BEV was approximately the same in both groups, starting low for 50 miles range but increasing as the range increased. The percentage of participants responding positively decreased after the usage experience, and for the lower three range categories the decrease was larger for the experimental group (the between-groups difference being statistically significant (Wald chi-square = 4.972, $p = 0.026$) for the 100 mile range, and almost so for the 50 mile range (Wald chi-square = 3.688, $p = 0.055$)).

The percentages who would consider choosing a BEV as a second household car were higher for all ranges than they were for a main car, suggesting that lower ranges were considered more acceptable for a second car.

3.3. How do MMCDs evaluate the dynamic and cruising performance of modern BEVs, compared to equivalent ICE cars?

Fig. 3 shows how participants in the experimental group evaluated the performance of the BEV, and the experience of driving it, compared to equivalent data from the control group concerning their evaluations of the diesel control vehicle.

The pattern of results was clear: the BEV was rated as having substantially better dynamic performance (acceleration from 0 to 20 mph ($t(391) = 8.804$, $p < 0.001$)), (acceleration from 30 to 50 mph ($t(391) = 5.710$, $p < 0.001$)), smoothness of gear changes (($t(391) = 8.269$, $p < 0.001$), responsiveness ($t(391) = 7.454$, $p < 0.001$), power ($t(391) = 8.804$, $p < 0.001$)) and significantly better cruising performance (smoothness when cruising ($t(391) = 9.234$, $p < 0.001$), lower noise when cruising ($t(391) = -2.439$, $p = 0.015$)). Overall performance was also rated higher ($t(391) = 6.315$, $p < 0.001$).

The other aspects of the driving experience – feelings of comfort ($t(391) = 4.910$, $p < 0.001$), enjoyment ($t(391) = 8.423$, $p < 0.001$), and safety ($t(391) = 7.234$, $p < 0.001$), – were also rated higher for the BEV than for the ICE car.

3.4. How did the willingness of MMCDs to consider having a BEV relate to their evaluations of the performance of BEVs?

Fig. 4 compares the mean overall performance rating of the BEV they experienced, given by participants who reported being willing to consider owning an electric car as a main household car, alongside the equivalent mean rating by those who were not willing to, for each range. The data is based on post-experience responses by the experimental group only.

Participants who were willing to consider owning a BEV as a main household car on average also rated the overall performance of the BEV they had experienced more highly than did participants who were unwilling to consider owning a BEV. This was especially so for those participants willing to consider a BEV as a main car even if its range was relatively low. The

[8] See Agresti (2002).

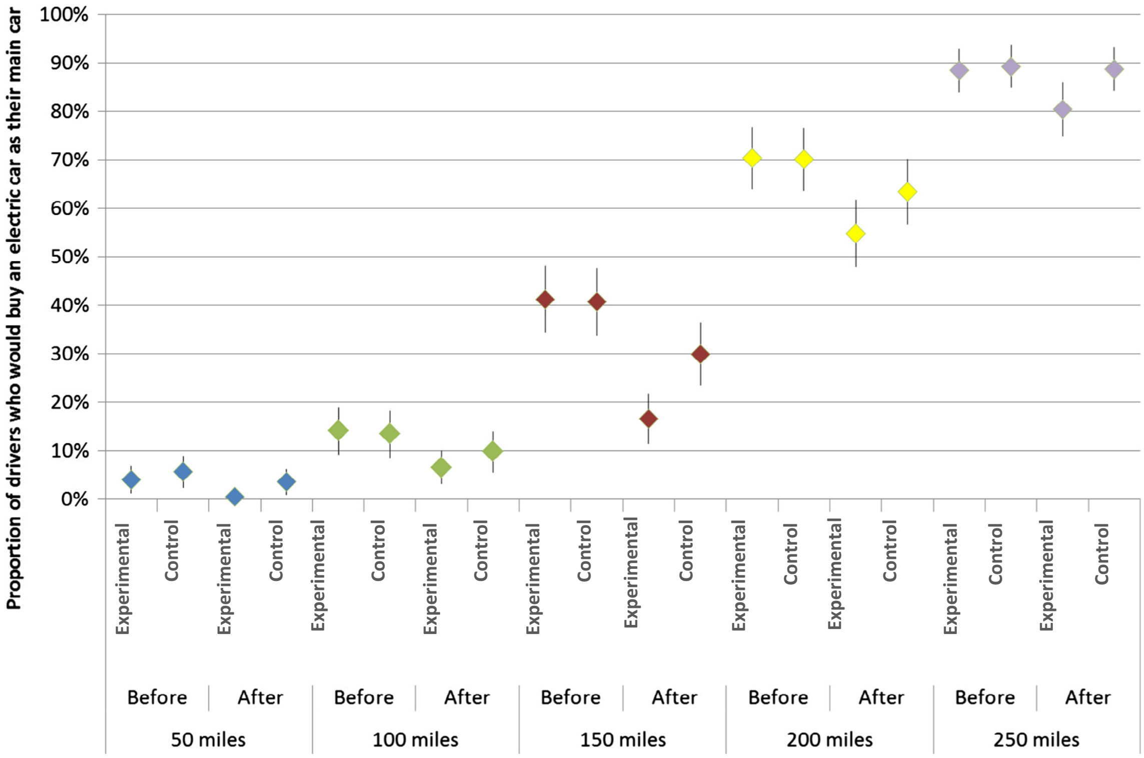

Fig. 1. Percentage of participants who would consider owning an electric car as a main household car for various possible ranges on a fully charged battery, before and after the usage experience, in experimental and control groups.

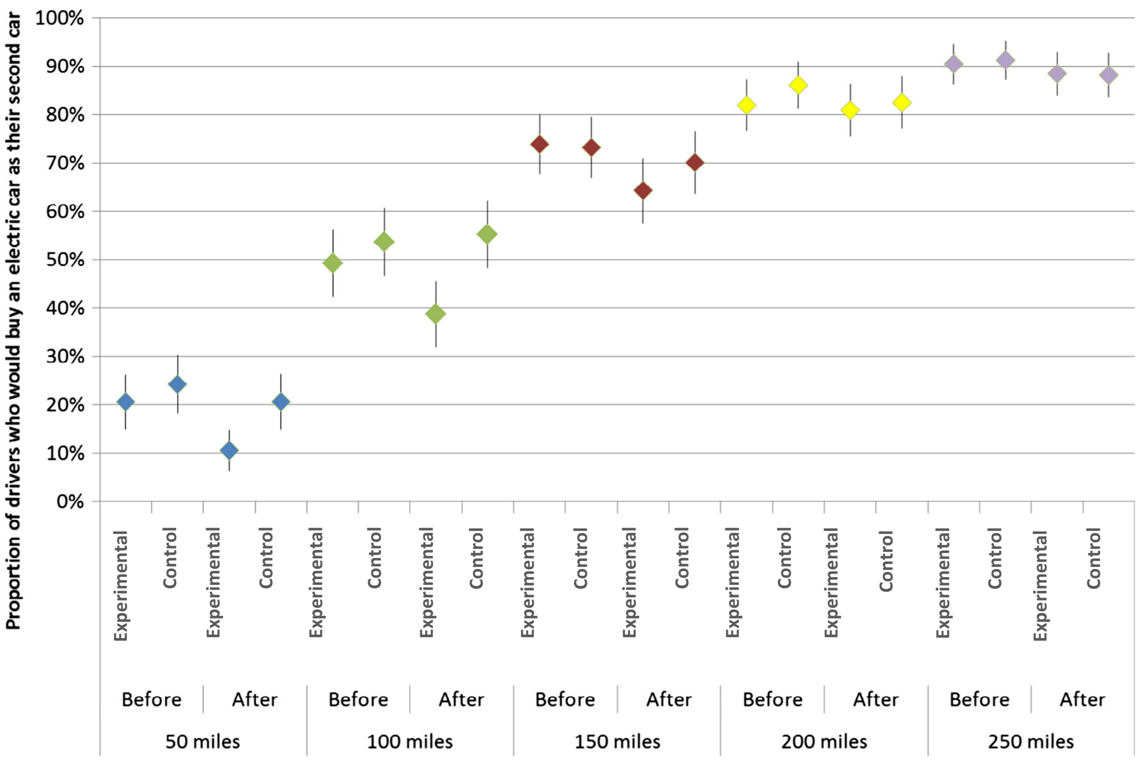

Fig. 2. Percentage of participants who would consider owning an electric car as a second household car for various possible ranges on a fully charged battery, before and after the usage experience, in experimental and control groups.

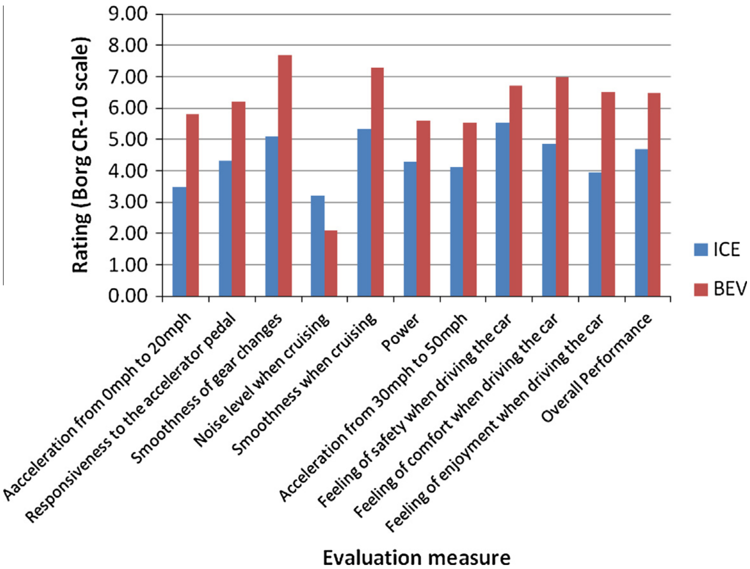

Fig. 3. Evaluations of performance and driving experience: BEV compared to conventional diesel ICE car. *Note:* for noise level when cruising (only), a higher value is a demerit (noisier).

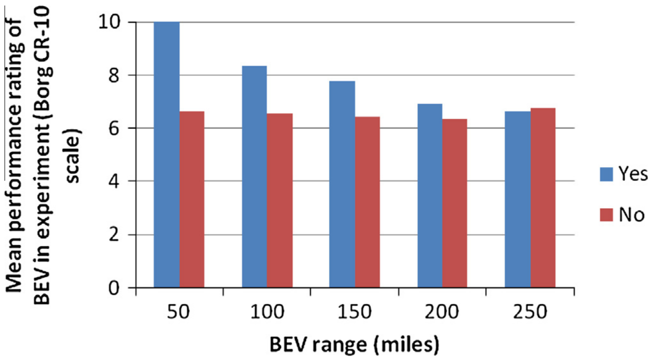

Fig. 4. Mean performance rating of the BEV experienced in the experiment, for participants willing to consider (yes) and unwilling to consider (no) a BEV as a main car if its range on a full charge was 50, 100, 150, 200 or 250 miles.

effect diminished as the potential range of the BEV increased (and more participants were willing to consider owning one). The differences were significant for ranges of 100 miles ($t(196) = 2.875$, $p = 0.004$) and 150 miles ($t(196) = 3.190$, $p = 0.002$). The "yes" rating for 50 miles was based on a single participant so a *t*-test was not appropriate.

In the equivalent data for a BEV as a second household car the differences were smaller than for a main car and none were statistically significant.

3.5. What symbolic meanings did MMCDs attribute to BEVs? How was this affected by direct experience of using one?

Figs. 5 and 6 show the symbolic meanings attributed to the BEV by the experimental group after the usage experience. Fig. 5 shows the personality traits attributed to a typical BEV user: she/he would be significantly higher than average in the traits openness, conscientiousness, and agreeableness, and no different than average in extraversion and neuroticism. Fig. 6 shows the status, relationship investment, age, and physical attractiveness and gender attributed to a typical BEV user: he/she would be of higher than average status, more likely than average to have high relationship investment (i.e. to be in a stable relationship), and more likely to be over 35 years old. His/her physical attractiveness would not be different from average and she/he would be no more likely to be female than male or vice versa.

Figs. 7 and 8 show the differences in the same attributions made by the experimental and control groups, before and after the usage experience. A mixed factorial ANOVA was carried out for the five personality traits, with Trait and Time as within-participant factors and Group as a between-participant factor. The main effect of Trait was significant ($F(4, 1564) = 225.393$, $p < 0.001$) as was the Trait $\times$ Time interaction ($F(4, 1564) = 10.870$, $p < 0.001$) but the effect of Group was not. Thus the

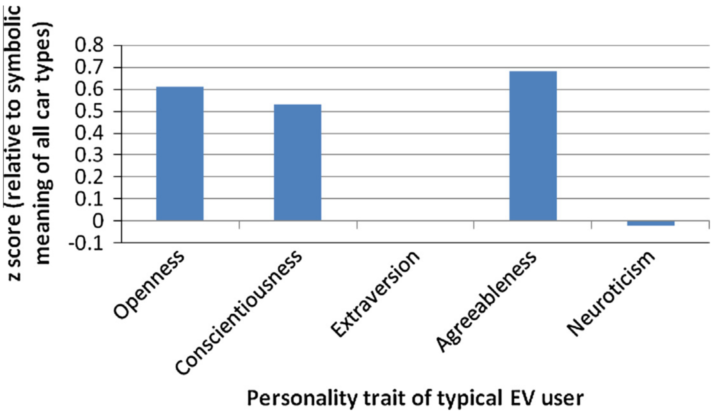

Fig. 5. Symbolic meaning of a BEV: personality traits attributed to a typical BEV user by experimental group participants after the usage experience.

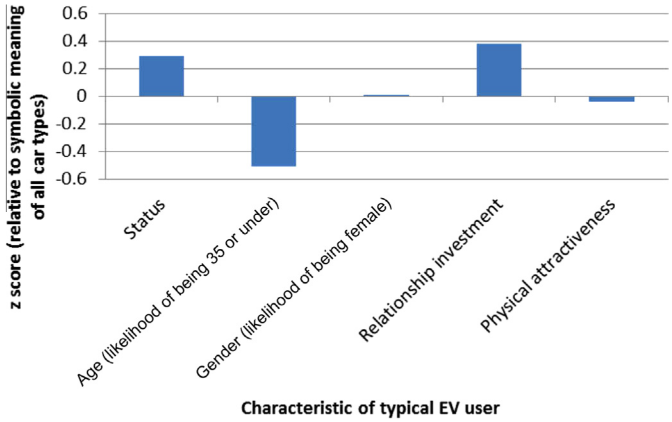

Fig. 6. Symbolic meaning of a BEV: status, age, gender, relationship investment and physical attractiveness attributed to a typical BEV user by experimental group participants after the usage experience.

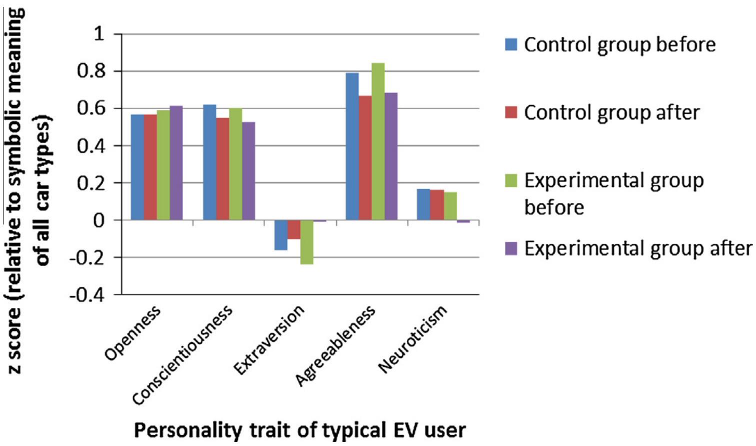

Fig. 7. Symbolic meaning of a BEV: personality traits attributed to a typical BEV user by both groups, before and after the usage experience (z score expresses mean of participants' attributions, in relation to a norm group mean and in units of the norm group standard deviation: see text for source of norm group data).

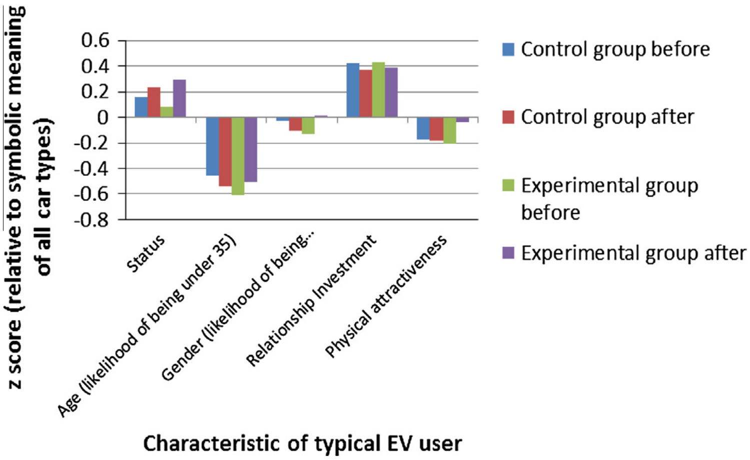

Fig. 8. Symbolic meaning of a BEV: status, age, gender, relationship investment and physical attractiveness attributed to a typical BEV user by both groups, before after the usage experience (z score expresses mean of participants' attributions, in relation to a norm group mean and in units of the norm group standard deviation: see text for source of norm group data).

patterns of attributions were similar for both groups, though there were minor differences in attributions before and after the usage experience.

A mixed factorial ANOVA was also carried out for the non-personality characteristics (age, gender, relationship stability, status, and physical attractiveness) with Characteristic and Time as within-participant factors and Group as a between-participant factor. The main effect of Characteristic was significant ($F(4,1564) = 462.278$, $p < 0.001$) as was the Characteristic $\times$ Time interaction ($F(4,1564) = 2.559$, $p = 0.037$) but the effect of Group was not.

3.6. Does congruity between personal identity and the symbolic meaning attributed to BEVs impact on MMCDs' willingness to consider owning a BEV?

Fig. 9 compares the mean normalized self-congruity $\widehat{SC}_{yes}$ of experimental and control group participants who responded "yes", i.e. that they were willing to consider owning an electric car as a main household car, alongside the equivalent $\widehat{SC}_{no}$ of those who were not willing to, for each range. The data is based on post-experience responses. For both groups, $\widehat{SC}_{yes}$ was higher than $\widehat{SC}_{no}$ when the range was short, but the difference disappeared for ranges of 200 miles and above. For the experimental group the difference for 100 miles range was statistically significant (independent samples *t*-test, equal variances not assumed, $t(16.99) = 2.403$, $p = 0.028$ while the "yes" data for 50 miles range came from a single participant; for the control group, the differences for 50 miles range $t(10.40) = 3.093$, $p = 0.01$) and 100 miles range $t(26.05) = 2.221$, $p = 0.035$ were significant. The apparent difference for control group participants in respect of 250 miles range was not significant.

In the data from both groups in relation to willingness to consider owning a BEV as a second household car there was some tendency for $\widehat{SC}_{yes}$ to be higher than $\widehat{SC}_{no}$, but none of the differences were significant, and the pattern of bigger differences for shorter BEV ranges seen in the responses for BEVs as main household cars was not repeated.

4. Discussion

4.1. How do MMCDs evaluate the dynamic and cruising performance of modern BEVs, compared to equivalent ICE cars?

Christensen (2013) proposed that range, top speed, and acceleration would be the key performance metrics needed to predict the potential uptake of electric cars. In the present study both the dynamic performance and cruising performance of the BEV were perceived by participants as significantly better than those of the equivalent ICE car. Objectively, the manufacturer's stated test figure for the 0–60 mph acceleration time of the BEV was 5% faster than that of the control ICE vehicle, so the measured subjective rating differences for acceleration (a central aspect of dynamic performance) appear to reflect the objective reality.[9] This suggests that the 2012 generation of BEVs was a considerable advance, in terms of perceived performance, on the immediately preceding generation of vehicles experienced by MMCD participants in earlier studies (Axsen et al., 2013; Graham-Rowe et al., 2012; Skippon and Garwood, 2011). The study therefore confirms that electric powertrains can now offer performance advantages over equivalent ICE vehicles, in both the dimensions that are relevant to

[9] Although we note that few drivers directly experience 0–60 mph accelerations in everyday driving, so a direct comparison cannot be made.

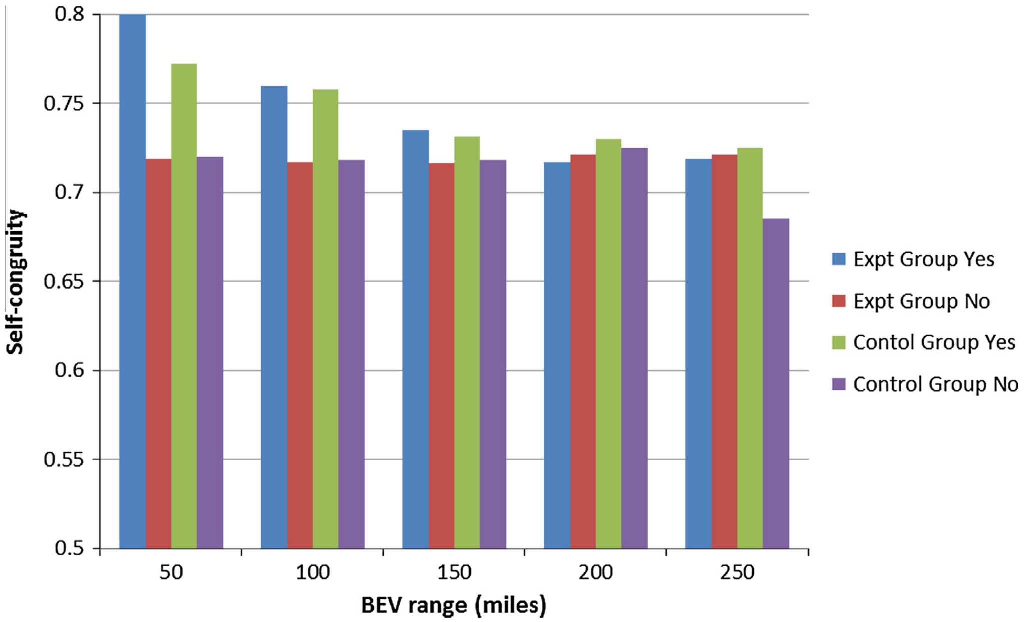

Fig. 9. Mean normalized self-congruity of experimental and control group participants willing to consider (yes) and unwilling to consider (no) a BEV as a main car if its range on a full charge was 50, 100, 150, 200 or 250 miles (based on post-experience responses).

consumer drivers. Thus performance benefits might potentially offset some of the disutilities of BEVs (short range, long recharge times, high costs), at least for some drivers.

4.2. How does the willingness of MMCDs to consider having a BEV relate to their evaluations of the performance of BEVs?

On average, experimental group participants who were willing to consider owning a BEV rated the performance of the BEV they had driven more highly than did those experimental group participants who were unwilling to consider one. Since the objective performance of the BEV was the same for all participants, this suggests that those willing to consider owning a BEV either (a) had, on average, lower expectations of performance from all vehicles, so their ratings for any vehicle were higher; or (b) were favourably disposed towards BEVs in general, leading them to evaluate BEV performance more favourably. Since there was no significant effect among members of the control group (i.e. those willing to consider a BEV rating the performance of the control ICE vehicle higher than those unwilling to consider one), (b) is the more likely explanation.

4.3. What symbolic meanings do MMCDs attribute to BEVs?

The attribution-vignette method expresses the symbolic meaning of a product in terms of the five-factor personality traits and other characteristics of a typical user. The experiment found that a typical BEV user would be significantly higher than average in the five-factor traits openness, conscientiousness and agreeableness, and no different than average in extraversion and neuroticism. He/she would be of higher than average status, more likely than average to have high relationship investment, and more likely to be older than 35.

The personality trait findings were in close agreement with those of Skippon and Garwood (2011) using an earlier version of the attribution-vignette method with a different sample. They were also fairly consistent with the findings of Heffner et al. (2007) who studied symbolism in California's early market for HEVs, using the entirely different method of analysis of owners' qualitative narratives. They found that the meanings signified by HEVs included concern for others (related to agreeableness), maturity/sensibility (related to conscientiousness), and individuality in the embracing of new technology (related to openness). Schuitema et al. (2013) found that "pro-environmental identity" predicted favourable attitudes towards EVs, while "car authority identity" did not; meanwhile Axsen and Kurani (2012) and Axsen et al. (2013) suggested that aspects of lifestyle related to identity (such as "liminal" lifestyles,[10] which imply openness) could influence willingness to consider EVs. Our findings add further support and specificity to this emerging picture.

[10] "Liminal" refers to lifestyles that are undergoing, or are in some sense ready for, substantial change.

4.4. Does congruity between personal identity and the symbolic meaning attributed to BEVs impact on MMCDs' willingness to consider owning a BEV?

The results suggest that self-congruity is a factor in willingness to consider owning a BEV as a main car which has the short range typical of BEVs available on the market at the time of writing (50–100 miles depending on type of driving). Participants willing to consider these vehicles tended to have higher self-congruity with the symbolic meanings of BEVs than those who were unwilling to consider them. Note, however, that few participants were willing to consider a BEV with short range as a main car at all. Thus the small number who were willing to consider owning a BEV as a main car despite the limitations of short range were also those most self-congruent with the symbolic meanings of BEVs, as predicted by self-congruity theory.

The effect disappeared for BEVs with longer ranges (⩾200 miles). We speculate that the utility of shorter-range BEVs is low in relation to most MMCDs' instrumental goals, is also low in relation to the symbolic goals of non-self-congruent drivers, but is high in relation to the symbolic goals of self-congruent drivers. Therefore their appeal is likely to be restricted to self-congruent people for whom symbolic goals also happen to outweigh instrumental goals in relative importance. The utility of longer-range BEVs for most drivers' instrumental goals is likely to be higher, so for self-congruent drivers, their symbolic goals and instrumental goals might be simultaneously met by using a longer-range BEV. Less self-congruent drivers for whom instrumental goals outweigh symbolic goals may also find BEVs appealing.

We should not expect the symbolic meanings of BEVs to remain constant. Both the purchase cost and novelty of BEVs could change over coming decades, so their capacity to act as costly signals of status and openness may reduce. Nevertheless to the extent that self-congruity influences purchase decisions, people with the kind of profile found in the RCT are likely to form the early-market target audience.

4.5. Reducing psychological distance: the effect of direct experience

The results demonstrated that reducing psychological distance through direct experience of the use of a BEV affected MMCD participants' willingness to consider having one – but in a direction that might be surprising to some. Hypotheses H1 and H2 were refuted by the findings: willingness to consider having a BEV of any range *dropped* after the usage experience, rather than increasing. This may be seen as surprising, given the positive evaluations of performance and driving experience reported by participants. The study did not examine what specific aspects of the experience of using a BEV caused the decrease, but the finding that willingness to consider having a BEV was much lower for shorter range BEVs suggests a plausible explanation. That is that an effect of the direct experience of the BEV was to raise participants' awareness of its limited range compared to the ICE vehicles they were used to, that this perceived disutility outweighed the perceived performance and driving experience benefits, and this led to the post-experience reduction in willingness to consider. The specific influence of this and other attributes such as recharge times could be the subject of further research.

We note that willingness to consider having a BEV also dropped (though to a lesser extent) in the control group, even though they had not themselves experienced the limited range of the BEV. Control group participants changed their attitudes, not as a result of experiencing the BEV, but as a result of their participation in the study – an example of the Hawthorne effect discussed in the Introduction. We might speculate that the process of participation caused participants to reflect further, between the pre- and post-experience questionnaires, on how a BEV might fit with their lifestyle and vehicle use patterns. At least part of the effect in the experimental group can be attributed to the same cause (participation); but the remainder can confidently be attributed to the effect of direct experience of the BEV itself.

Hypothesis H3 was supported: experimental group participants rated the performance of the BEV higher than control group participants rated the performance of the ICE car. It is a reasonable inference that the high ratings resulted from the direct experience, but for the reasons outlined in the Method section, we did not directly test changes in these ratings pre- and post-usage experience.

There was no significant Group × Time interaction in the symbolic meaning data so H4 was not supported: similar attributions were made by both groups, before and after the use experience. This is consistent with the interpretation that these symbolic meanings did not depend on the experience of using a BEV, but rather, were meanings already shared within the UK car-using culture of which the participants were members. The small changes in attributions of agreeableness, conscientiousness, neuroticism, and extraversion that were observed were directionally consistent with the interpretation that participants after the usage experience construed BEVs as having higher performance than they did before it, and adjusted their attributions of symbolic meaning in the direction of cars with higher performance (Skippon, 2014b).

4.6. Implications for the uptake of BEVs

The results showed that people who had driven a modern BEV responded very positively to the driving experience, including both the BEV's dynamic performance and cruising performance. Despite this positive experience, however, willingness to consider having a BEV was relatively low unless its range on a full charge was substantially higher than 2012 models (willingness to consider by >50% of the experimental group (post-experience) required BEVs with a range of 150 miles (for second household cars) or 200 miles (for main household cars). This suggests that the disutility of short range outweighs the perceived benefit of better performance and driving experience.

Exceptions to the general unwillingness to consider a short-range BEV were the small number of people for whom self-congruity was high, and for whom fulfilment of their symbolic goals presumably outweighs fulfilment of their instrumental goals.[11] This suggests that "early adopters" will tend to be people who are high in openness, conscientiousness and agreeableness, and higher than average in status, age and relationship investment.

Others will not consider a BEV until ranges can be substantially improved; but if they can, then the better performance (in both dimensions) and driving experience may then confer greater appeal to a wider audience relative to ICE vehicles. In addition, if BEVs then penetrate the market in larger numbers, their symbolic meanings may change in ways that widen the target audience further.

We note that this research does not enable us to draw valid inferences about uptake by fleets, rather than mass market consumer drivers, since the usage patterns, goals supported by vehicle use, and approaches to total cost of ownership in different types of fleets may be very different than those of mass-market consumer drivers. Ultimately, the ability of fleets to dispose of BEVs into used vehicle markets will depend on MMCD willingness to consider them as used vehicles, and that will depend *inter alia* on factors not considered in this research, such as lifetime battery (and hence range) deterioration.

4.7. Implications for the uptake of Plug-in Hybrid and Extended-Range EVs?

Although the RCT was restricted to BEVs, the results also tentatively inform some speculations concerning uptake of Plug-in Hybrid Electric Vehicles (PHEVs) and Extended-Range Electric Vehicles (E-REVs).[12] Drivers of E-REVs that are driven via an electric motor at all times will be able to experience similar performance benefits to drivers of BEVs, even when the range extender ICE is operating to provide the electricity for the motor. However, E-REVs do not suffer the key disutilities of short range and extended down-time to recharge the battery.[13] From this perspective an E-REV might look like an attractive vehicle to many drivers, and be especially appealing for those who are self-congruent with its symbolic meanings.

The situation may be more complex for PHEVs with parallel drivetrain configurations that may drive under electric power at low speeds, ICE power in high speed cruising, and in blended mode at intermediate speeds and during acceleration transients or under high loads. PHEV drivers will tend not to experience the cruising performance benefits of an electric drive, nor will they experience the full set of dynamic performance benefits, because accelerations will tend to be made in blended mode – but they potentially could still experience some, such as responsiveness and acceleration from standing start.

The RCT did not measure the symbolic meaning of PHEVs and E-REVs, and speculation is perhaps risky. However a starting point might be to assume it is broadly similar to that of BEVs, but that the unrestricted range and higher CO_2 emissions might both contribute to some differences in symbolic meanings, with overall a less pro-environmental flavour. Both E-REVs and PHEVs will continue to be more expensive to purchase than conventional ICE vehicles (Energy Technologies Institute, 2013). Potential buyers will need to trade this off against potential running cost savings and lower CO_2 emissions (when the latter is a motivator). The performance and symbolic benefits discussed above could perhaps be added to this trade-off.

Better understanding of potential MMCD uptake of PHEVs and E-REVs and how this might be influenced by vehicle performance and symbolic meaning could of course be acquired by repeating a study of this kind, with participants experiencing these types of vehicles along with BEVs. Since the present study was completed, such vehicles have become available in many markets.

4.8. Methodological reflections

The observation that the control group's willingness to consider having a BEV changed to some extent after the usage experience is an example of Hawthorne effects in action, and shows the importance of controlling for them using appropriate research designs such as the RCT. Since the change observed in the experimental group was larger, we can conclude with confidence that the direct experience of using a BEV *caused* the additional change.

One limitation of this study was the relatively short duration of the usage experience. This was sufficient for participants to fully experience the performance of the BEV, but it is possible that both MMCD attributions of symbolic meaning, and willingness to consider having a BEV, might have changed after a longer experience (of say several weeks).

The study assumed that participants could respond on behalf of their household in terms of willingness to consider adoption as a main car or second car. However it did not record whether participants saw themselves as users of the main car, second car, or both; and in multi-car households where all adults have travel patterns involving long car journeys, the main/s car distinction may not be valid. Further research could unpick these questions in more depth.

[11] or the few whose instrumental goals can be met by a very short-range vehicle.

[12] PHEVs and E-REVs have both electric motor and ICE. Definitions vary: here we refer to PHEV when there is a parallel configuration in which power can be supplied by both to the road wheels, and E-REV when there is a series configuration in which power to road wheels is always supplied by the motor, but electricity for the motor can be generated by use of the ICE in addition or instead of the battery.

[13] The battery of an E-REV is typically smaller than that of a BEV and so can be fully recharged in a shorter time; and of course an E-REV can be driven with a fully discharged battery, so it is available for use, like an ICE car, whenever there is liquid fuel in the tank.

Acknowledgement

This research was funded by Shell International Petroleum Company.

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