

Perception of range in pioneer drivers of the MINI E

Sarah Mansbridge

Oxford Brookes University

This thesis is submitted in partial fulfilment of the requirements of
the award of Doctor of Philosophy

March 2018

Supervisors: Dr Mark Burgess (Director of Studies)
Professor Margaret Harris (Second Supervisor)

Acknowledgements

I would like to thank my PhD supervisors, Dr Mark Burgess (Director of Studies) and Professor Margaret Harris (second supervisor) for the help and support they have given me throughout my PhD. Their advice, guidance and encouragement has been invaluable. I am also very grateful to them for making my time at Oxford Brookes an enjoyable one – it has been a great experience working with them over the past few years, and I will always be very proud of our electric vehicle research.

I would also like to thank my fellow research students in the Department of Psychology for their friendship and support. I would especially like to thank Dr Naomi King and Alfred Veldhuis - their words of wisdom and laughter have been a lifeline to me, particularly in the darkest moments of the project when I have needed inspiration and a shoulder to cry on.

I will also be eternally grateful to the MINI E drivers. Without their insightful comments and feedback this PhD would not have been possible. I thoroughly enjoyed interviewing them all – they were a very friendly and witty group of pioneers, and I have some very fond memories of them. I would also like to thank Alastair Scott, Carl Schmidt and Suzie Hunter from the BMW Group for always taking the time to answer my queries. I don't think I have ever worked with such an organised and professional group of individuals.

Finally, I would like to thank my parents for their love and support throughout this project.

Abstract

Background: In an attempt to combat climate change, the UK Government has set ambitious targets to substantially decrease CO₂ emissions by 2050. Battery electric vehicles (BEVs) could play a critical role in reaching these targets. To-date, however, BEV uptake remains low in the UK. A potential explanation for this is „range anxiety“ – drivers’ fear of running out of battery power. Range anxiety has risen in recent times, and now ranks as one of the main barriers to BEV acceptance. It is also proposed as a reason why drivers underutilize the battery power and leave substantial energy reserves.

Aims: Range anxiety is a poorly understood psychological state. The limited literature has applied Lazarus’s Transactional Model of Stress, to examine ways of increasing stress resistance to range. To-date, no research has explored why drivers’ perceive range a concern, or the impact of this on their behaviour. This research project aimed to address this critical gap in the literature, by examining pioneer BEV drivers’ perception of range over time. Recommendations could then be made for effective interventions to reduce range anxiety and enhance battery utilization.

Methods: This thesis predominantly took a qualitative approach. It drew upon the interview data collected from 30 drivers who participated in the UK MINI E trial (6 month field trial of the electric MINI). Interviews were conducted at four time points - pre-trial, immediately after training on the vehicle, 1-week and 3-month post pickup. Thematic analysis was used to analyse them. Questionnaire and data logger information was used to support the interview data. Social cognitive theory was used to interpret the analysis.

Findings: Drivers’ range concern was underpinned by uncertainty (i.e., in the recharging network) and unpredictability (i.e., how far they could travel). To safeguard against experiencing a critical range situation, drivers constructed a priori strategies vis-à-vis range (e.g., leaving an energy reserve). Thus, before stepping foot in the BEV, they had prevented range being an issue. Drivers’ anticipatory strategies guided their behaviour, and led to them confining their use of the vehicle to within their comfortable range. Therefore, drivers were not motivated to prolong range, and seldom made changes to their normal driving habits (i.e., when travelling on a low state of charge).

Implications: Practical real-world solutions are discussed with regards to making range more predictable and controllable for drivers. For example, setting a BEVs stated range under real-world conditions, would enhance their ability to predict the battery power. In addition, the development of a device that informed a driver if a plug-in point was already in use, or out of order would improve their ability to control range. These findings are of relevance to stakeholders in the electric vehicle field.

Contents

<i>Heading</i>	<i>Page</i>
Acknowledgements	ii
Abstract	iii
Contents	v
List of tables and figures	x
List of tables	x
List of figures	xi

Chapter 1: Why is uptake of battery electric vehicles low in the UK?

1.1	New attempts at BEV integration in the UK: An overview	1
1.2	History of the battery electric vehicle	3
1.2.1	The social and cultural impact of the ICEV on UK society.....	5
1.3	Modern day BEV verses ICEV	6
1.4	Drivers’ attitudes towards the range of the modern day BEV	8
1.4.1	Drivers’ attitudes towards the range after direct BEV exposure	10
1.5	Conclusions.....	12
1.6	Chapter summary.....	13

Chapter 2: Range anxiety

2.1	Range anxiety: The background	14
2.2	Research examining range anxiety	16
2.2.1	Background to research.....	16
2.2.1.1	Psychological range levels: Competent, performant and comfortable....	17
2.2.1.2	Theoretical framework to understand comfortable range.....	19
2.2.2	The influence of individual differences on comfortable range.....	20
2.2.2.1	Comfortable range: Assessment.....	20

2.2.2.2	Comfortable range: Personality traits.....	22
2.2.2.3	Comfortable range: System competence variables.....	23
2.2.2.4	Comfortable range: Experience	25
2.2.3	Experienced verses inexperienced BEV drivers.....	26
2.2.4	BEV drivers’ first encounter of a critical range situation.....	30
2.3	Conclusions from research examining range anxiety.....	34
2.4	Aims of research.....	36
2.5	Chapter summary	37

Chapter 3: Theoretical accounts of behavioural change

3.1	Introduction.....	39
3.1.1	Theory of Planned Behaviour (TPB).....	40
3.1.2	Technology Acceptance Model (TAM).....	44
3.1.3	Reasons for not applying TPB or TAM to the present research.....	47
3.2	Social Cognitive Theory (SCT).....	48
3.2.1	Background to SCT.....	48
3.2.2	The core features of human agency.....	51
3.2.2.1	Forethought.....	51
3.2.2.2	Vicarious capacity.....	53
3.2.3	Self-regulation and examination of action.....	54
3.2.4	Self-efficacy beliefs.....	56
3.2.4.1	Development of self-efficacy beliefs.....	57
3.2.4.2	Self-efficacy and anxiety.....	62
3.2.5	Habitual behaviour.....	65
3.3	Conclusions.....	67
3.4	Specific research questions	68

Chapter 4: Methodology

4.1	Outline of the UK BMW MINI E Project	70
4.2	Participant sample	72
4.3	Details of the MINI E and charging process	73
4.3.1	The MINI E	73

4.3.2	The charging process	74
4.4	Procedure of data collection	75
4.4.1	Interview procedure and schedule	77
4.4.2	Questionnaires	78
4.4.3	Mileage data	78
4.5	Analytical approach	79
4.5.1	Mixed methods approach	79
4.5.2	Thematic analysis	80
4.5.3	The researcher.....	83
4.6	Chapter summary	83

Chapter 5: Pre-trial perceptions of range

5.1	Introduction	85
5.2	Results and discussion	87
5.2.1	Ideal for short commutes.....	89
5.2.1.1	Viable in everyday life	89
5.2.1.2	Impractical for all car trips	91
5.2.2	Uncertain and unpredictable	93
5.2.2.1	Contributory factors to drivers' range uncertainty	93
5.2.2.2	Anticipatory range concerns	96
5.2.2.3	Anticipatory strategies to manage the range	98
5.2.3	Intended conservative behaviour	105
5.3	Conclusions	106

Chapter 6: Perceptions of range after first BEV contact

6.1	Introduction	109
6.2	Results and discussion.....	111
6.2.1	Unpredictable and uncontrollable	113
6.2.1.1	Unpredictable	113
6.2.1.2	Uncontrollable.....	116
6.2.2	Interpretative and attentional bias	119
6.2.2.1	Interpretative bias.....	119

6.2.2.2	Attentional bias.....	120
6.3	Conclusions	121

Chapter 7: Perceptions of range over a sustained period of BEV usage

7.1	Introduction.....	123
	Part One: Perceptions of range after initial real-world BEV exposure.....	126
7.2	Results and discussion.....	126
7.2.1	Ideal for short commutes.....	128
7.2.1.1	MINI E used for short trips.....	128
7.2.1.2	Range fulfils intended use.....	129
7.2.1.3	Reinforced ideal short commuter car perception.....	131
7.2.2	Unpredictable and uncontrollable.....	132
7.2.2.1	Range.....	132
7.2.2.2	Recharging.....	136
7.2.2.3	Anticipatory range concerns.....	138
7.2.2.4	Strategies implemented to manage the range.....	139
	Part Two: Perceptions of range after a sustained period of BEV usage.....	144
7.3	Results and discussion.....	144
7.3.1	Ideal for short commutes.....	146
7.3.1.1	MINI E used for short trips.....	146
7.3.1.2	Range fulfils intended use.....	147
7.3.1.3	Reinforced short commuter car perception.....	149
7.3.2	Unpredictable and uncontrollable.....	151
7.3.2.1	Range.....	151
7.3.2.2	Recharging.....	154
7.3.2.3	Anticipatory range concerns.....	156
7.3.2.4	Strategies implemented to manage the range.....	158
7.3.3	Conclusions.....	164

Chapter 8: General Discussion

8.1	Overall research aims	169
8.2	Summary of specific findings	170

8.2.1	Qualitative and quantitative data findings	170
8.2.2	Why range was a perceived concern and barrier to usage	171
8.2.3	The effect drivers' perception of range had on their behaviour.....	172
8.2.4	The effect of experience on drivers' perception of range.....	173
8.2.5	The effect drivers' typical trip length had on their adaptation to range	175
8.3	What are the implications of these findings?	176
8.4	Practical real-world solutions	177
8.4.1	Practical real-world solutions to improve range predictability and controllability	177
8.4.1.1	Displays.....	177
8.4.1.2	Recharging	178
8.4.2	Practical real-world solutions to improve the reliability of the stated range.....	178
8.4.3	Practical real-world solutions to encourage energy efficient behaviour	179
8.4.4	Practical real-world solutions to breakdown „commuter car“ image	179
8.5	Relevance of research findings today	180
8.5.1	Advances in BEV technology and associated recharging	180
8.5.1.1	Advances in BEV technology	180
8.5.1.2	Advances in the public recharging infrastructure	180
8.5.1.3	Advances in test procedures to measure the drive range of the BEV....	181
8.5.2	What relevance are the findings from this thesis today?	182
8.5.2.1	Relevance of research findings in relation to BEV technology	182
8.5.2.2	Relevance of research findings in relation to the recharging infrastructure	182
8.5.2.3	Relevance of research findings in relation to improving the reliability of the stated range	183
8.6	Limitations and directions for future research	184
8.6.1	What are the limitations of this research?	184
8.6.2	What are the additional potential directions for future research?	185
8.7	Final conclusions	186
References		187
Appendices.....		i

List of tables and figures

List of Tables

<i>Title</i>	<i>Page</i>
Table 5.1: Ideal Short Commuter Car: Summary Table for Pre-Trial Travel Diary Data.....	90
Table 5.2: Uncertain and Unpredictable: Summary Table for Pre-Trial Interview Data.....	93
Table 5.3: Anticipatory Range Concerns: Summary Table for Pre-Trial Interview Data.....	96
Table 5.4: Energy Reserve: Summary Table for Pre-Trial Questionnaire Data.....	98
Table 5.5: Anticipated Strategies Prior To Driving: Summary Table for Pre-Trial Interview Data.....	100
Table 5.6: Anticipated Strategies While Driving: Summary Table for Pre-Trial Interview Data.....	103
Table 6.1: Unpredictable: Summary Table for Post-Technical Instruction Interview Data.....	113
Table 6.2: Interpretative Bias: Summary Table for Post-Technical Instruction Interview Data.....	119
Table 6.3: Attentional Bias: Summary Table for Post-Technical Instruction Interview Data.....	120
Table 7.1: MINI E Used For Short Trips: Summary Table for 1-Week Data Logger Information.....	128
Table 7.2: Unpredictable and Uncontrollable: Summary Table for 1-Week Interview Data.....	132
Table 7.3: Anticipatory Range Concerns: Summary Table for 1-Week Interview Data...	138
Table 7.4: Strategies Implemented Prior To Driving: Summary Table for 1-Week Interview Data.....	140

Table 7.5: Strategies Implemented While Driving: Summary Table for 1-Week Interview Data.....	142
Table 7.6: MINI E Used For Short Trips: Summary Table for 3-Month Data Logger Information.....	146
Table 7.7: Range Fulfils Intended Use: Summary Table for 3-Month Questionnaire Data.....	147
Table 7.8: Reinforced Ideal Short Commuter Car Perception: Summary Table for 3-Month Questionnaire Data.....	149
Table 7.9: Improved Understanding of the SoC Estimate: Summary Table for 3-Month Interview Data.....	151
Table 7.10: Increased Confidence in the Battery Power: Summary Table for 3-Month Interview Data.....	153
Table 7.11: Anticipatory Range Concerns: Summary Table for 3-Month Interview Data	156
Table 7.12: Energy Reserve: Summary Table for 3-Month Questionnaire Data.....	158
Table 7.13: Strategies Implemented Prior To Driving: Summary Table for 3-Month Interview Data.....	159
Table 7.14: Strategies While Driving: Summary Table for 3-Month Questionnaire Data	162

List of Figures

<i>Title</i>	<i>Page</i>
Figure 3.1: Schematic diagram of Ajzen's Theory of Planned Behaviour.....	43
Figure 3.2: Schematic diagram of Davis's Technology Acceptance Model.....	46
Figure 3.3: Schematic diagram of the Triadic Model of Reciprocal Causation.....	50
Figure 4.1: The BMW MINI E	73
Figure 4.2: Energy consumption display	73
Figure 4.3: State of charge and digital reader	74
Figure 4.4: Charging unit	75
Figure 4.5: Charging cable	75
Figure 4.6: Occasional charging lead	75
Figure 4.7: Methods applied at each stage of the MINI E trial	76

Figure 5.1: Thematic map of Chapter 5 themes and attached subthemes.....	88
Figure 6.1: Thematic map of Chapter 6 themes and attached subthemes.....	112
Figure 7.1: Thematic map of Chapter 7: Part 1 themes and attached subthemes.....	127
Figure 7.2: Thematic map of Chapter 7: Part 2 themes and attached subthemes.....	145

Chapter 1

Why is uptake of battery electric vehicles low in the UK?

This opening chapter establishes the background for this thesis. It is divided into six sections. Section 1.1 offers an overview of the current situation for battery electric vehicles (BEVs). It explains that in spite of them offering a promising form of sustainable transport, uptake in the UK remains low. Section 1.2 (divided into a further subsection) then gives a brief history of the BEV, including the series of technological and economic events that saw the demise of the BEV and rise of the internal combustion engine vehicle (ICEV). Section 1.3 compares the performance and range – distance achievable on a single charge – of these two types of vehicles. Section 1.4 (divided into a further subsection) then examines drivers’ attitudes towards the range. This emphasises they require substantial increases in battery power, despite it being sufficient to fulfil their routine activities. Section 1.5 concludes by highlighting the importance of understanding why range is a psychological barrier to uptake, rather than simply attempting to meet drivers’ ambitious range demands. Lastly, section 1.6 provides an overall summary of the chapter.

1.1 New attempts at BEV integration in the UK: An overview

Car use is an integral part of daily life in the United Kingdom (UK) and shows no sign of decline (Anable, 2005; Beirao & Sarsfield Cabral, 2007; Steg, 2005). Indeed, cars are now used for 64% of all journeys made in the UK (DfT, 2013). What is more, the proportion of households owning one car or more has nearly doubled since 2008 to 44% and 32% of the total UK population respectively. In comparison, the number of households without access to a car has fallen to 24% over the same period of time (Anable, Schuitema, & Stannard, 2014). Yet growing awareness of global warming and dependency on foreign oil, increasingly brings the sustainability of the ICEV (currently the dominant type of car on the roads in the UK) into question.

In an attempt to combat climate change, the U.N. has intensified pressures to reduce CO₂ emissions. In the UK the Climate Change Act (2008) was passed by the Government, which committed the UK to reducing CO₂ emissions by at least 80% in 2050 from 1990 levels (OLEV, 2013). This commitment was reiterated clearly at the Paris Climate Change Conference (COP21) in December 2015 (DfT, OLEV, & Jones, 2015). The transportation sector currently accounts for about a quarter of all CO₂ emissions in the UK (DECC, 2013). This motivated the Government to set targets for an almost entirely ultralow carbon fleet by 2050. As part of a series of steps to help achieve this goal, the Government aims for 60% of new cars and vans to be ultralow emission vehicles (ULEVs) by 2030, and for all new cars to be ULEVs by 2050 (Element Energy, 2013; OLEV, 2013). The Government's classification of ULEVs currently includes pure battery electric vehicles (BEVs), extended range electric vehicles (EREV), plug-in hybrid electric vehicles (PHEVs) and hybrid electric vehicles (HEV) (OLEV, 2013). The BEV is the only one of these vehicles that is entirely battery powered (i.e., has no internal combustion engine), as a result it is completely tailpipe emission free.

This provided fresh new impetus for BEV integration into the UK national fleet. Car manufacturers (e.g., BMW, Nissan, Ford and Mitsubishi) once again commenced efforts into improving BEV technology, and launched mass-production models for the first time (Bakker, 2011). A total of 14 BEV models are currently available on the commercial market in the UK (Gibbs, 2015). BEV sales in the UK are gathering momentum as new models enter the market and costs continue to fall. However, despite the recent surge in sales the number of non-commercial BEVs registered in the UK remains low; in 2016 they comprised only 0.38% of the overall number of non-commercial cars registered in the UK (Society of Motor Manufacturers & Traders [SMMT], 2016). So why is BEV uptake low in the UK when they offer a promising form of sustainable transport?

We know that BEVs are not a new form of alternative transport. In the UK the BEV has a longstanding history that dates back over 100 years (Kirsch, 2000). What is more, in the formative years of the car, the BEV actually held a significant market share (Guarnieri, 2011a). Therefore, in order to understand the challenges of BEV uptake and why they have a negative image, it would be useful to gain insight into the reason(s) that led to their decline.

1.2 History of the battery electric vehicle

In the 1800s the market was divided between three types of car that were competing for domination: steam-powered vehicles, ICEVs and BEVs. Each technology had its own advantages and disadvantages. Steam-powered vehicles had the best top speed and were least expensive. However, they suffered from long start-up times of up to 45 minutes, as a result of the engine having to be fired up. They also required frequent stops for water (Ajanovic, 2015). The ICEV had a reasonable top speed. They could also travel long distances, but without the need to stop for water (Ajanovic, 2015). However, they were difficult to start with the engine having to be manually „cranked“ by hand (Kirsch, 2000). BEVs did not suffer from the vibration, noise, dirt or smell associated with their competitors. This was a consequence of them being battery operated, rather than driven by an engine (Guarnieri, 2011b). They were also easy and effortless to operate as a result of having no engine to crank start or manually change gear (Tamor, Gearhart, & Soto, 2013). However, BEVs had unimpressive top speeds, short drive ranges and were most expensive (Kirsch, 2000).

In the formative years of the car, the simple, clean and quiet operation of the BEV made them a popular choice of personal transport (Anderson & Anderson, 2005). They also proved to be dependable and required little maintenance. In contrast, the engine of the ICEV frequently broke down and had to be rebuilt after every 500 miles (Kirsch, 2000). What is more, the BEV's limited drive range was not an imposing factor at this time, with roads outside cities being little more than dirt tracks (Ajanovic, 2015; Kirsch, 2000). Therefore, the early signs for market domination looked promising for BEVs. Indeed, the period from 1880 to 1920 was known as the „golden age“ of the BEV (Guarnieri, 2011b; Høyer, 2008). During this era BEVs were actually outselling their opponents and accounted for roughly 30% of the market; global sales of BEVs reached a historical peak of 30,000 in 1912 (Ajanovic, 2015; Guarnieri, 2011a). In this early period of the car, there was nothing to suggest that just twenty years later the BEV would have essentially vanished as a form of personal transport in the UK. The rapid decline of the BEV was attributed to a series of technical and economic developments, occurring between 1900 and 1920, that marked a shift towards conditions that more and more favoured the ICEV.

1. Technical reasons contributing to the decline of the BEV

ICEV technology developed rapidly in the early years of the 20th century. Manufacturers soon found solutions to overcome the limitations of the engine. For example, the invention of electric starting in 1912, eliminated the need for hand cranking and made the engine effortless to start (Ajanovic, 2015; Cowan & Hultén, 1996). In contrast, BEV technology stagnated. There was little improvement in battery technology, with progression essentially stopping around 1915 (Cowan & Hultén, 1996). This was a partial consequence of the batteries having become an integral part of the ICEV engine, as an outcome of electric starting. This marked a change in battery development away from increasing capacity and towards mass production (Cowan & Hultén, 1996). By 1910 there was a marked difference in the performance of the vehicles (Kirsch, 2000).

An improved road network and refuelling infrastructure existed in the UK in the era following World War I (Anderson & Anderson, 2005; Høyer, 2008). This created a demand for vehicles that offered longer ranges and a new found trend for touring (Kirsch, 2000). Marketers of ICEVs capitalised on consumers' „dream of the long-distance journey“, and promoted their cars as „adventure machines“ that offered the potential for freedom and exploration. Marketers of BEVs attempted to counter these campaigns by emphasising the reality of people's typical journeys. They stressed that 99% of the usefulness of a vehicle lay within a 35 miles radius (Kirsch, 2000). Yet people did not want to have their dreams of touring dashed, no matter how rarely they might occur. They considered the BEVs' limited range to be a major disadvantage. Therefore, by 1920 the BEVs limited drive range had already emerged as a barrier to acceptance.

2. Economic reasons contributing to the decline of the BEV

The first mass production of the ICEV occurred in 1908: Henry Ford mass produced his Model T (Kirsch, 2000). This created a marked reduction in the price of ICEVs and opened them up for broader use amongst the working classes (Ajanovic, 2015). In contrast, BEV production remained less efficient causing their prices to remain high (Kirsch, 2000). What is more, new discoveries of large petroleum reserves markedly reduced the price of petrol. This made the ICEV cheap to run over long distances (Cowan & Hultén, 1996). At the same time electricity prices continued to rise (Ajanovic, 2015).

The above chain of events saw the demise of the BEV and domination of the ICEV. The BEV essentially disappeared as a form of personal transport in the UK by the late 1920s. It was relegated to use as short-distance manual labour transport (i.e., milk floats, fork lift trucks and golf carts). In the second half of the 20th century, concerns over air pollution and responses to oil crises led to several brief resurgences of interest, however, they failed to create a shift towards large-scale BEV application (Bakker, 2011). So why were these attempts to integrate the BEV into the UK national fleet unsuccessful? To understand why, it would be useful to gain insight into how the ICEV gave rise to a „car culture“ that has now become an integral part of modern UK society.

1.2.1 The social and cultural impact of the car on UK society

Since the ICEV became the preferred choice of transport at the beginning of the 20th century, it has radically redefined movement (Dennis & Urry, 2009). The speed and unlimited range of the ICEV gave rise to it quickly becoming associated with *freedom* and *independence* (Jensen, 1999; Ellaway, Macintyre, Hiscock, & Kearns, 2003). The autonomy provided by the ICEV has not been found with any other form of transport (Anable & Gatersleben, 2005; Gardner & Abraham, 2007). It allows drivers to travel wherever they want, whenever they want to. The ease and convenience of movement offered by the ICEV, has led to it reshaping modern society in a manner unparalleled to any other product (Dennis & Urry, 2009). The ICEV has revolutionised the way people live their lives, by creating dispersed home, work and leisure environments that were historically within a relatively short distance of each other (Urry, 2004). This has given rise to the unique attributes of the ICEV having become highly valued within UK society, enabling people to live the lives they have come to aspire to (Anable et al., 2014; Beggs, Cardell, & Hausman, 1981; Beirao & Sarsfield Cabral, 2007).

Today, car usage is taken for granted having become an integral part of UK culture. This has led to dependency on the ICEV, with drivers now undertaking daily activities with little consideration to how far apart they are (Dennis & Urry, 2009). Indeed, drivers have proven resistant to attempts to reduce their reliance on this form of personal transportation (Anable, 2005; Anabel & Gatersleben, 2005; Beirao & Sarsfield Cabral, 2007). Any alternative form of transport being introduced now needs to be considered against the „car culture“ that has become established within the UK. Therefore, in order for BEVs to gain

mass market acceptance, the performance and drive aspects need to be similar, or superior, to that offered by the ICEV.

To-date, the BEV has not fared favourably in comparison to the ICEV. The limitations of the batteries (e.g., underpowered performance, limited drive range and lengthy charge times), has given rise to the longstanding image of the BEV as technically and practically inferior. For example, the G-Wiz that became popular in London in the early 2000s, had a top speed of 40 mph and a drive range of 40 miles. It was also infamous for breaking down (Boxwell, 2010). Indeed, the BEV has become as synonymous for its poor performance (e.g., milk-float) and restricted mobility within UK society, as the ICEV has come to symbolize freedom and independence. Therefore, it is unsurprising that the technological deficiencies of the batteries, have been cited as a key reason for the failure of past efforts at widespread BEV adaption (Beggs et al., 1981; Bunch, Bradley, Golob, Kitamura, & Occhiuzzo, 1993; Chéron & Zins, 1997). However, in recent times key stakeholders and policymakers have invested large sums of money into improving BEV technology, to enhance their performance and increase battery capacity; the new BMW i3, for example, now has a top speed limited to 93mph, can go from 0-60mph in under 8 seconds and has a drive range of about 125 miles. This raises the question, how does the new and improved modern day BEV now shape up to the ICEV?

1.3 Modern day BEV verses ICEV

1. Performance

Recent research has shown that drivers' negative perceptions regarding the performance of the BEV were often greatly improved after exposure. The Final Report for the UK's Technology Strategy Board (TSB) Ultra Low Carbon Vehicle Demonstrator (ULCD) programme (currently the world's largest multi-vehicle, multi-location BEV trial) found that drivers using BEVs in long-term, UK-wide trials rated the instantaneous power as impressive from a standstill and while overtaking (98% reported the BEV had good acceleration from a standing start; 78% responded the acceleration was very good when the car was already moving). The unique features of the BEV that initially made them a popular choice of personal transport (e.g., low background noise, smooth operation and ease of driving) were also found to re-emerge as positive attributes (Carroll et al., 2013).

These findings have been echoed in other studies. For instance, Bühler and colleagues (2014) found the lower background noise was the most frequently reported experiential advantage of driving a BEV, with 56% of the drivers referring this as a positive attribute (Bühler, Cocron, Neumann, Franke, & Krems, 2014). Skippon and Garwood (2011) found 62% of drivers reported the drive performance of the BEV as smoother in comparison to their ICEVs. In light of these findings, it was hardly surprising that drivers no longer found the drive performance of the BEV inferior to the ICEV. Instead, they reported deriving the same amount of pleasure (if not more) from driving the BEV than the ICEV (Bühler et al., 2014; Burgess, Harris, Walsh, Carroll, Mansbridge, & King, 2013b; Carroll et al., 2013; Gärling, 2001).

An exception to this was a study by Graham-Rowe and colleagues (2012). This study found that drivers rated the power and performance of the BEV as substandard in comparison to their ICEVs. Some of them even modified their routes because they did not feel safe using the BEV on fast stretches of road. This led to many of the drivers reporting the BEV as less pleasurable to drive than their ICEV (Graham-Rowe et al., 2012). However, it must be noted that the BEV primarily used in this study was the Citroën C1, which had a top speed of 60 mph. In contrast, other BEVs being trialled at the time, such as the MINI E, Smart electric and i-MiEV had superior top speeds (96mph, 80mph and 81mph respectively). Therefore, the performance of the Citroën C1 was not only substandard in comparison to the ICEV, but also when compared to other BEVs. This may partially account for drivers' negative attitudes towards the performance of the vehicle.

The above evidence is encouraging news for BEV acceptance, with it providing some indication that drivers' evaluations of the overall performance of the BEV, had once again become more favourable. So how does the BEV now compare in terms of drive range and associated recharging?

2. Drive range and associated recharging

Despite advances in battery technology, the range and associated recharging of the BEV currently remains inferior to the ICEV; the modern day BEV has a drive range of approximately 100+ miles (in comparison to the +400 mile range of the ICEV), a recharge time of 4-10 hours (in comparison to a refuelling time of 5-10 minutes) and a limited

recharging network across the UK (in comparison to an established refuelling network). However, it must be acknowledged that data from the UK National Travel Survey (NTS), revealed the average journey length made by car in the UK was 7 miles. It also showed that 95% of car journeys did not exceed 50 miles (DfT, 2013). Thus, the range of the modern day BEV still far exceeds the distance people actually travel by car on a typical day, and should not be a limiting factor.

Numerous studies that have analysed the travel patterns of ICEVs over the period of a year, have demonstrated the 100+ mile range of the modern day BEV would satisfy 80-90% of household needs (Chéron & Zins, 1997; Greene, 1985; Khan & Kockelman, 2012; Pasaoglu, Fiorello, Zani, Zubaryeva, & Thiel, 2014). Indeed, the BEV's limited drive range should only cause drivers to adapt their behaviour, and use an alternative form of transport on very few occasions a year (i.e., no more than nine times) (Pearre, Kempton, Guensler, & Elango, 2011; Tamor, Gearhart, & Soto, 2013). However, it should be noted that this research also indicated that to cover the extreme ends of the distances drivers travelled, would require a substantial rise in range to about 300 miles (Greene, 1985; Tamor, Moraal, Reprogle, & Milačić, 2015). The extant literature, therefore, strongly suggests the battery power is currently sufficient to meet the demands of a large market segment. It also indicates that a public charging infrastructure maybe comforting, but not essential for a high proportion of car journeys. In addition, this research showed that ICEVs were parked for relatively substantial periods of time in between usage during the day (i.e., up to 6 hours) (De Gennaro, Paffumi, Martini, & Scholz, 2014; Pasaoglu et al., 2014). What is more, the average parked time after the last trip of the day to the first trip the following day was 16 hours. This implies the slow recharging time of the BEV should not be an issue for drivers, with their being sufficient periods of time for them to recharge. Despite these favourable findings, the acceptability of range and recharging depends not only on an objective measure of sufficiency, but also drivers' attitudes towards them. So how do drivers now view the range of the modern day BEV?

1.4 Drivers' attitudes towards the range of the modern day BEV

The vast majority of research into drivers' attitudes towards the range of the BEV, has come from revealed and stated preference surveys. This body of research has shown that drivers expect the current range of the BEV to satisfy a high proportion of their daily

activities (i.e., 80-90% of all trips) (Gärling, 2001; Vilimek, Keinath, & Schwalm, 2012). What is more, this research has shown that the 100+ mile range of the BEV has now passed the „threshold of inconvenience“ (Kurani, Turrentine, & Sperling, 1996; Tamor et al., 2013); after this point, drivers start to report the limited drive range as acceptable for their daily activities. The extant literature even revealed a sharp decline in the amount drivers were willing to pay for extra miles, once the perceived threshold of inconvenience had been reached (Bunch et al., 1993; Daziano, 2013; Dimitropoulos, Rietveld, & van Ommeren, 2011; Hidrue, Parsons, Kempton, & Gardner, 2011; Van Harren, 2011). What is more, drivers most suited to a limited range vehicle (e.g., commuting distance under 15 miles) were least likely to pay for additional range (Bunch et al., 1993). This indicates that substantial increases in range above 100 miles could be detrimental to BEV acceptance, with the cost of the batteries outpricing them from the mainstream consumer market (Knutsen & Willén, 2013). In addition, this research also revealed that drivers did not expect a public charging infrastructure would be necessary for their use of the vehicle. They also did not anticipate the lengthy charging time to be an inconvenience to them (Carroll et al., 2013).

Despite drivers' positive attitudes towards the viability of the range on a daily basis, the extant literature has also shown that their range demands remained unrealistically high. Drivers wanted a driving range much closer to that of an ICEV (Carley, Krause, Lane, & Graham, 2013; Deloitte, 2011). It is of interest to note, that the amount of range drivers require has actually risen over the years, in keeping with improvements in fuel consumption (i.e., from about 200 miles in the 1980s to roughly 300 miles today) (Tamor et al., 2013). What is more, improvements in the public infrastructure and speed of charge also remained of importance to them. For example, a study of over 7,000 individuals in 13 countries around the world, found that half of the respondents rated factors such as the availability of public charging and fast charging options (20-30 minutes for a full charge) as very important to them (Accenture, 2011).

In light of these findings, it is unsurprising that the limited drive range and associated recharging, have once again resurfaced as key reasons thwarting new attempts at large-scale BEV application (Carley et al., 2013; Daziano & Chiew, 2013; Egbue & Long, 2012; Eggers & Eggers, 2011). It also indicates that there is still only a small market for a limited range vehicle, with their low running costs (i.e., approximately £3 for 100 miles) and

Government incentives for them (e.g., exemption from having to pay congestion charge, free parking and use of bus lanes) proving insufficient to overcome this major disutility (Anable et al., 2014). For example, Ewing and Sarigöllü (2000) actually found that a drive range of 100 miles cut the odds of choosing a BEV by more than half. What is more, the drivers targeted in these studies had often been selected because of their potential amenability to BEV usage (e.g., short daily commutes) (Beggs et al., 1981) making the actual prospects of successful large-scale BEV integration an even bleaker one. So why is there this current lack of coherence between drivers' perceptions of what a vehicle can do, and the actual reality of car usage?

A potential explanation is that the drivers participating in these studies had no direct experience of the BEV. Thus, their preferences of the unfamiliar features of the vehicle (e.g., range) would not have been accurate. Indeed, this has been a major criticism of this research, as it brings the validity of the findings into question (Ewing & Sarigöllü, 2000; Golob & Gould, 1998). In light of this, it has been proposed that actually getting drivers behind the wheel of a BEV, might be useful in bringing their range preferences in-line with their actual range needs (Franke & Krems, 2013a; 2013b). Indeed, previous research found that drivers' range preferences became more aligned with their actual range needs, when they were asked to think about their daily car usage (Kurani et al., 1996). The limited available literature on drivers' attitudes towards the range, has primarily come from field trials of the vehicles. Thus, the range was mainly examined as part of the drivers' general adaptation to the vehicle. So has this literature found direct BEV exposure successful in reducing this „range paradox“?

1.4.1 Drivers' attitudes towards the range after direct BEV exposure

Drivers had no difficulties adapting to the limited drive range; they all reached their maximum distance travelled in the vehicle within a 3-month timeframe (Pichelmann, Franke, & Krems, 2013). They also adjusted well to the other new features of the BEV – displays (i.e., energy consumption and state of charge), charging and regenerative braking – this feature recaptures the energy from braking back into the batteries. Drivers reported the displays were clear and that plugging-in at home was straightforward (Carroll et al., 2013). They adapted almost immediately to regenerative braking (i.e., usually within the first trip) (Carroll et al., 2013; Cocron, Bühler, Franke, Neumann, Dielmann, & Krems,

2013). These findings suggest that the drivers' adaptation to the range mainly occurred within the first 3 months of BEV usage.

This research also showed the energy consumption of a trip was related to the trip's distance – high energy consumption was associated with shorter trips and lower energy consumption rates with longer trips (Carroll et al., 2013). Thus, drivers adapted their driving style dependent on the journey length. This suggests that the drivers' typical journey length could potentially affect the level of competency they develop in prolonging the range. Indeed, drivers who challenged the range showed a greater awareness of the interconnected nature of driving style, regenerative braking, route selection, state of charge and the information fed back from the displays (Carroll et al., 2013). The extant literature also showed that very few drivers actually pushed the range; Carroll and colleagues (2013) found that only 15% drivers reported that they deliberately attempted to exhaust the battery power (Carroll et al., 2013; Turrentine et al., 2011). Hence, their typical journey length could be a particularly salient factor in their adaptation to the range.

The existing literature also revealed that drivers had no difficulties integrating a limited range vehicle into their daily lives. Drivers reported the range fulfilled a large proportion of their daily mobility needs (80-95% of all their car trips) (Bühler et al., 2014; Carroll et al., 2013; Gärling, 2001; Turrentine, Garas, Lentz, & Woodjack, 2011; Vilimek et al., 2012). Hence, the BEV was actually used as the household's primary vehicle. Drivers simply adopted a multicar solution, and reverted back to their ICEV on occasions they needed to travel further afield (Anable et al., 2014). . Thus, they did not report any loss of freedom, indeed, they actually used the BEV more for short trips (Franke et al., 2012b). However, the multicar solution drivers adopted did result in the BEV being used differently to the ICEV; studies showed the average journey length of the BEV was shorter than the average journey length of the ICEV (Anable et al., 2014; Gärling, 2001). In addition, drivers seldom used the available public charge points, and did not consider a recharging network personally important to them (Bühler et al., 2014; Bunce, Harris, & Burgess, 2014). They were not inconvenienced by the lengthy charge times, and found home charging preferable to having to make special trips to a petrol station (Carroll et al., 2013). What is more, they were found to charge less frequently with experience (Bunce et al., 2013; Helmbrecht, Monreal, Bengler, Vilimek, & Keinath (2014).

Despite these favourable findings, the extant literature revealed that drivers still desired a range more comparable to an ICEV, before they would be willing to purchase a BEV (Anable et al., 2014; Carroll et al., 2013). They also continued to demand a growth in infrastructure and faster recharging times. Critically, this indicates that direct experience of the range, had not diminished the discrepancy that exists between drivers' range preferences and their actual range needs (Bunce et al., 2014; Carroll et al., 2013; Shaw & Bunce, 2015; Shaw, Bunce, & Kottasz, 2014).

1.5 Conclusions

To-date efforts to resolve range-related issues have focused on removing the practical barriers. Vehicle manufacturers, stakeholders and policymakers have attempted to meet drivers' ambitious demands for increased drive range, extensive public charging infrastructure and fast charging times. However, it must be acknowledged that these measures are not without their own issues. Indeed, they will require high financial investment, time and labour to come anywhere near satisfying mainstream market demands. For example, the UK Government is currently testing „electric highway“ technology, which could remove the barrier of limited range by using cables buried under roads to generate electromagnetic fields, and recharge BEV batteries whilst the cars are being driven (Highways England & Jones, 2015; Kelion, 2015). However, large-scale installation of this technology would involve substantial digging up of motorways. Solving practical problems also involves a number of „chicken and egg“ situations (Accenture, 2011). It is unlikely that stakeholders will want to make substantial investments in BEV technology and recharging infrastructure until a demand for this type of car exists, but the majority of drivers will want to see these major barriers removed before considering a shift over to this unfamiliar technology. It should also be acknowledged that simply increasing battery size is not a sustainable solution, because of its link to the ecological footprint and cost-effectiveness (McManus, 2012).

An alternative solution could be to turn to addressing the psychological barriers in relation to the range i.e., why are drivers demanding substantial increases in battery power, when the range already far exceeds their daily travel demands. This would require a shift in focus to understand why they currently hold negative perceptions of the range. Appropriate strategies could then be developed to counter them. A useful starting point for this would

be to gain an understanding of the psychological state „range anxiety“, which has become a commonly reported phenomenon in the UK in recent times. The next chapter examines this in greater detail.

1.6 Chapter Summary

Climate change and oil dependency have created a cultural impetus for revisiting the possibility of BEV personal transport. Despite policymakers and key stakeholders investing considerable sums of money to help make BEVs a success, the most recent figures indicate that BEV sales are currently much lower than predicted. One of the main reasons for this cited in the literature is drivers’ perceptions of the BEV’s inferior drive range being a major disutility to usage. This is despite an overwhelming amount of research providing evidence to the contrary.

We know that since the ICEV became the dominant form of car at the beginning of the last century, car use has become increasingly important to people, and that the cultural meanings of driving have become deeply entrenched within UK society. A vehicle’s potential range now has powerful consequences for a person’s ability to go anywhere they want, whenever they choose to, enabling the way of life we have now become accustomed to. Over time this has led to a lack of coherence between drivers’ perceptions of what a vehicle can do, and the actual reality of car usage. To ensure the most recent attempts at widespread BEV application are successful, where past attempts have failed, it is imperative that we gain insight into why this loss in a vehicle’s range now evokes such strong emotional responses amongst drivers. In order for us to begin to understand drivers’ range concerns, the next chapter will focus on the existing literature on “range anxiety”.

Chapter 2

Range Anxiety

The preceding chapter highlighted the importance of understanding why the limited drive range was a psychological barrier to BEV acceptance. This chapter provides an overview of the related psychological state, „range anxiety“. It is divided into five sections. Section 2.1 begins by providing a background to range anxiety. Section 2.2 (divided into four further subsections) outlines the main findings from research examining this psychological state. Next, section 2.3 draws together conclusions from this research, narrowing down to the gap in the literature the current research intends to position itself within. Section 2.4 outlines and justifies the specific aims of this research. Finally, section 2.5 provides an overall summary, and synopsis of the following chapters.

2.1 Range anxiety: The background

Range anxiety is currently defined as a fear of running out of charge and being stranded (Nilsson, 2011a; Tate, Harpster, & Savagian, 2009). This broad definition incorporates different psychological states, ranging from anticipated worry to actual experienced distress (Franke, Rauh, Günther, Trantow, & Krems, 2016b). Range anxiety is not unique to the BEV and can be experienced in all types of car (e.g., ICEVs, EREVs, HEVs and PHEVs). However, it is most commonly associated with the BEV because of the current limitations of the battery (Nilsson, 2011b; Rauh, Franke, & Krems, 2015). Range anxiety in the BEV was first reported in the media in 1997 (Nilsson, 2011a; Van Harren, 2011). This was in connection with the range worries experienced by drivers of the EV1; a pure battery electric vehicle produced by General Motors (GM) from 1996 to 1999 (Shnayerson, 1996; Paine, 2006). The term remained relatively unheard of until recently, when the media publicity surrounding several events, sparked a rise in this psychological state, in the US and many European countries including the UK (Nilsson, 2011a).

One of the most salient of these episodes occurred in 2010, when GM controversially filed to trademark the term, „range anxiety“. GM claimed this was in the interest of promoting

public awareness of electric vehicle capabilities (Blanco, 2010). However, some sceptics argued this was actually a tactical marketing manoeuvre on the part of GM. They were about to launch the Chevrolet Volt (EREV) at the same time that Nissan were launching the Leaf (pure BEV). It was suggested that GM did this in an attempt to give the Volt the competitive edge over the Leaf, claiming it had the answer to overcoming range anxiety (Blanco, 2010). This raises the possibility that GM exploited the term to deliberately evoke fear into the hearts of drivers. Since then it has been jumped on by journalists, who have revelled in describing the terror experienced by drivers when the battery power of their BEV has fallen low (Lyon, 2014). This has led to the general (mis)conception that the range was a concern to drivers. It could also explain why range anxiety has risen in recent times, despite improvements in battery capacity: the fear of running out of charge now ranks as one of the main barriers to BEV uptake in the UK (DfT, 2014). Thus, range anxiety has been proposed as a potential explanation to account for drivers unrealistically high range demands (Franke & Krems, 2013b).

The controversial surroundings around range anxiety have led some researchers to question, „Does range anxiety actually exist?“ (Nilsson, 2014) or can this phenomenon simply be attributable to media hype, creating misconceptions that are only loosely linked to the reality of BEV usage today. Indeed, drivers’ experience of range has been characterised by the absence of range stress, with them seldom encountering critical range situations; Franke and colleagues (2012b) revealed that on average drivers reported experiencing stressful range situations about once a month. What is more, only 12% of them agreed that they often worried about the range while driving. However, drivers’ fear of running out of charge was shown to actually increase on initial BEV exposure (Carroll & Walsh, 2010; Garling, 2001; Golob & Gould, 1998; Wellings, Binnarsley, Robertson, & Khan, 2011). In addition, they also remained overcautious when estimating the remaining battery power over the trial period; Franke and Krems (2013a, 2013c) demonstrated that drivers left substantial energy reserves and only utilized 75-80% of the battery power. These findings suggest that range anxiety cannot simply be explained by media hype. Interestingly, it also indicates that this psychological state is primarily an anticipatory concern to running out of battery power, rather than an actual experienced one (Franke et al., 2012b). What is more, these results imply that range anxiety had a lasting negative effect on drivers’ adaptation to the range. This is in contrast to the research presented in Chapter 1, which suggested drivers had no difficulties adjusting to the range (Pichelmann

et al., 2013). These results highlight the critical importance of understanding range anxiety, in breaking down the range as a perceived barrier to BEV acceptance, and enhancing drivers' range utilization behaviour (i.e., amount of charge they utilize). So what is known about this psychological state?

The vast majority of research on the BEVs limited drive range, has examined this from a practical perspective. It has essentially focused on: 1) assessing the demand for a limited range vehicle (Beggs et al., 1981; Bunch et al., 1993; Carley et al., 2013; Eggers & Eggers, 2011) and, 2) the battery power required to make BEVs acceptable to the mainstream consumer market (Greene, 1985; Pasaoglu et al., 2014; Pearre et al., 2011; Tamor et al., 2013). In contrast to this wealth of research dating back over the past thirty years, only a handful of studies have attempted to explore the limited range from a psychological perspective. This has resulted in range anxiety being a poorly understood psychological state to-date. The next section outlines what is currently known about range anxiety from these studies. It begins by giving a background to this research, before presenting the main findings.

2.2 Research examining range anxiety

2.2.1 Background to research

The few available studies on range anxiety have primarily come from one group of researchers. In light of the negative consequences of attempting to meet drivers' ambitious range demands (i.e., increased cost and ecological footprint of the BEV), this research instead examined the role individual differences played in drivers' range utilization behaviour. This was so alternative strategies could be developed to reduce range anxiety and improve the amount of battery power used. More specifically, the extant literature primarily focused on BEV drivers' experience of range in isolated moments of crisis. This was because they proposed such situations represented the most prototypical context for range anxiety (Franke et al., 2016b). However, this assumption is questionable in view of research characterising range anxiety as primarily an anticipatory concern (Franke et al., 2012b). To understand the findings from this research, it would first be useful to gain insight into: 1) how drivers' range utilization behaviour was conceptualized, and 2) the theoretical framework applied to this research.

2.2.1.1 Psychological range levels: Competent, performant and comfortable

The actual range utilized by a driver is affected by multiple factors (e.g., their own skill in conserving the battery power). To help understand the complexities of the „usable“ range of a driver, the extant literature proposed four levels of range utilization: cycle, competent, performant and comfortable range.

Cycle range was defined as the maximum assumed range of the vehicle, according to the vehicle manufacturer. This range level acts as an objective point of reference for the following three psychological levels of range utilization (Franke & Krems, 2013a). The second range level was termed *competent range*. This was defined as the maximum range a driver is able to achieve, based on their prior knowledge of the BEV (e.g., regenerative braking system) and eco-driving competence (e.g., skill and ability to prolong the range) (Franke et al., 2012b). To achieve this range level would require a driver to continuously monitor the range in relation to implemented actions (Franke & Krems, 2013a). Competent range was assumed to be less than cycle range, as the differences in drivers“ prior knowledge of the BEV and eco-driving competency, were presumed to result in some inevitable loss in battery power (Franke, Günther, Trantow, Rauh, & Krems, 2015). The third level of range utilization was coined *performant range*. This was defined as the range usually achieved by a driver, based on their eco-driving related motivational strengths and habits (Franke et al., 2012b). Driving behaviour is influenced by various motives, with range optimisation being only one amongst many. For this reason, performant range was assumed to be lower than competent range (Franke et al., 2015).

Although competent and performant range were defined as psychological range levels, it could be argued that they reflect different mental states that guide behaviour. Competent range was described as the range a driver could achieve, when they were intentionally attempting to optimize the battery power. This manner of driving would require conscious thought. As a result, this range level would be cognitively demanding and effortful. In contrast, performant range referred to battery utilization under normal driving habits. Habitual behaviour has been characterised by the automaticity of action (Bargh & Chartrand, 1999; Verplanken, 2006). This is attributed to routinized actions no longer being reliant on conscious thought (this will be explained in greater detail in Chapter 3). As a consequence, habituated behaviour is less cognitively demanding and effortful.

The final level of range utilization was termed *comfortable range*. This was defined as the lowest remaining range status a driver experiences as comfortable or non-stressful (Franke et al., 2015; Franke et al., 2012b). The comfortable range of a driver and range stress were proposed as similar constructs. It was assumed that the higher a drivers' comfortable range limit, the less range stress they would experience. In contrast, lower comfortable range levels were inferred as being indicative of higher levels of experienced range stress (Franke et al., 2015). Comfortable range was reported as being partially influenced by a variety of personal factors (e.g., personality traits and coping resources) (Franke et al., 2012b). Competent and performant range levels were also proposed as contributing to comfortable range (Franke et al., 2012b). It was conceptualised as falling on a continuum between these two psychological range levels (Franke & Krems, 2013a).

Comfortable range was based on the *comfort zone model* (Luckner & Nadler, 1997). This concept originated from Piaget's theory of cognitive development and Festinger's theory of cognitive dissonance (Brown, 2008). According to this concept, personal development is dependent upon an individual being placed in situations that challenge their capabilities. These experiences force an individual to move outside of the area they feel comfortable and give rise to an expansion of their comfort zone (Brown, 2008; Eccelstone, 2004). By inference, personal growth and development is viewed as mainly occurring outside an individual's comfort zone. However, it should be noted that this concept has been heavily criticised by researchers, who have argued that there is nothing inevitable about achieving positive results from confronting one's comfort zone. In fact, this experience could potentially even induce greater levels of anxiety (Davis-Berman & Berman, 2002; Leberman & Martin, 2003).

The extant literature primarily focused on the comfortable range, as this range level was considered most important in understanding ways of reducing range stress (Franke & Krems, 2013a). For this reason, the findings presented specifically concentrate on the comfortable range. Before these results are presented, it would first be useful to gain an understanding of the theoretical concept applied to this range level.

2.2.1.2 Theoretical framework to understand comfortable range

To-date, most of the research on the BEVs limited drive range has been atheoretical. This body of research has been the only to apply a theoretical framework. These researchers selected Lazarus' Transactional Model of Stress and Coping (TMS) (Lazarus & Folkman, 1984) as a suitable psychological perspective. Indeed, they proposed similarities between a driver having insufficient battery power to meet their mobility needs, and the common definition of stress as a critical person-environment imbalance (Franke et al., 2012b, Franke, & Krems, 2013a; Rauh et al., 2015). According to TMS, transactions (interactions) occur between a person and the environment. Stress results from an imbalance between (a) demands and (b) resources. Thus, an individual becomes stressed when demands (pressure) exceed their abilities to cope and moderate stress (Lazarus & Folkman, 1984). This would be a situation where range resources and personal resources were perceived to be insufficient to successfully manage the situation. This led these researchers to define range anxiety as a domain specific form of psychological stress, which can occur in a present or anticipated critical range situation (Bühler et al., 2014; Rauh et al., 2015). Hence, they used the term range stress when referring to the concerns drivers' experience in such isolated moments of crisis.

TMS is a dynamic model because it looks at the way people interpret a stressful event (Scott, 2012). In other words, a stressor only becomes a stressor when people perceive it as such, and feel that it will strain or overcome their resources for dealing with it (Lam, 2015). According to TMS, when people encounter a stressful situation they first evaluate the significance of the encounter (i.e., primary appraisal) which either has: 1) no significance for the person (e.g., trip distance is well within the range), 2) is a positive (desirable) encounter (e.g., recharging opportunity exists at destination) or 3) as harmful, threatening or challenging (e.g., range resources are only just sufficient to make the trip, and no charge point exists at destination) (Lazarus & Folkman, 1984). If a person decides the event is negative, they then further appraise the situation in terms of their perceived coping abilities and resources to deal with the stressor (i.e., secondary appraisal) (Scott, 2012). From this perspective, whether a person experiences distress depends on both primary and secondary appraisal (Perrewé & Zellars, 1999). In accordance with TMS, drivers were viewed as managing the range by critically monitoring and assessing the fit between available energy resources against trip length (Rauh et al., 2015). This was with

the overall goal of avoiding a critical range situation. However, once a driver has experience of range in similar situations, would it be necessary for them to engage in this level of cognitive work? I will return to this point later in the thesis.

TMS suggests that reducing stressors (e.g., increasing battery power) is only one way of coping with stressful situations. It proposes an alternative solution lies in influencing an individual's appraisal process, which can in turn lead to higher stress resistance (Lazarus & Folkman, 1984). Personal resources have been shown to be vital for stress resistance. Indeed, certain personality traits (e.g., ambiguity tolerance) and effective coping resources (e.g., prior knowledge and skill) have all been linked to lower levels of experienced stress, in the original work of Lazarus and Folkman (1984) and more recent contributions (Conner-Smith & Flachsbart, 2007; Contrada & Baum, 2009; Greco & Roger, 2003). We know from the earlier discussion that comfortable range was assumed to be partially comprised of personality traits and coping resources (Franke et al., 2015). This led these researchers to examine the role of individual differences, as an alternative way of reducing range stress and improving battery utilization.

The next subsection begins by outlining how comfortable range was assessed (subsection 2.2.2.1). It then turns to presenting the main findings from this research, first in relation to personality traits (subsection 2.2.2.2) and then coping resources (subsection 2.2.2.3). It should be noted that these researchers referred to coping resources as system competence variables. The findings reported are from two studies (Franke et al., 2012b; Franke & Krems, 2013a). Each of the studies consisted of 40 drivers (primarily male) who had participated in BEV field trials. The findings were from data collected after 3 to 6 months of sustained BEV usage. At this stage, drivers were adapted to the BEV.

2.2.2 The influence of individual differences on comfortable range

2.2.2.1 Comfortable range: Assessment

The comfortable range of the driver was obtained from the sub-scores of the following three tasks:

Comfortable range scenario task (CRST): In this task drivers were presented with the following scenario: “Imagine you are on a trip with your BEV on a familiar road in a rural area (rather flat terrain, light traffic, good weather, 20°C). You have already driven 30km (16 miles) and you still have 60km (37 miles) to drive before reaching your destination. There are no charging possibilities en route. Yet at the destination there is both time and an opportunity to recharge the BEV.” Drivers were then given 10 cards containing information about the remaining range to complete the 60km (37 miles) journey (presented in random order). Each card contained a different level of remaining range (range values varied from 45km (27 miles) to 90km (55 miles); graded in 5km (3miles) intervals). Drivers then had to answer the following question, “Given that I still have to drive 60km (37 miles) and I have X km range remaining in the battery – am I comfortable with this situation (i.e., am I sure I will reach the destination)?” They rated their response to this for each range value using a response grid that was also included on each card. This contained two positively formulated items (i.e., “I am sure I will reach the destination with my BEV” and “On this trip, I will not be worried about range”) and two negatively formulated items (i.e., “I am concerned about reaching the destination” and “I wish I had another car to make this trip”).

The comfortable range threshold was defined as the point of transition from (a) the best-feeling state, where the drivers were still perfectly comfortable with the range resource situation (i.e., lowest remaining range down to which drivers still mark the response scale value 6 on the Likert scale) to (b) decreased range comfort (i.e., highest remaining range where drivers mark value <6). The mean of these two remaining range values were used for scoring (e.g., a=75km; b=70km, score=72.5km). This was done for each of the four item scores. By dividing 60 (i.e., trip distance) by the mean score value (i.e., preferred range), the proportional comfortable range utilization was derived (e.g., 83%). The inverse of this percentage was the preferred range safety buffer (e.g., 17%). It should be acknowledged that by scoring the comfortable range as the point at which the scale value changed from 6 to 5 (i.e., from perfectly comfortable) could have resulted in a drivers’ comfortable range being underestimated, as they would only experience very minimal discomfort at this point (if any at all).

Minimal range safety buffer: Drivers were asked to indicate a numerical value in km to the item, “Which range buffer do you set yourself, below which you would not be willing to

drive an EV anymore (except in exceptional circumstances).” Drivers were asked to frame their responses to conditions of moderate daytime temperatures of 10-20°C.

Primary appraisal secondary appraisal (PASA) scale: The PASA is comprised of two sub-scales – primary appraisal (perception of threat and challenge) and secondary appraisal (rating one’s own abilities to cope and control expectancies) – that assess elements of stress appraisal with reference to TMS. Each sub-scale contains 8-items. Drivers were asked to imagine a situation where the displayed range of the BEV and remaining trip distance were equal. They then indicated their response to the items on a 6-point Likert scale. It should be noted that to assess the comfortable range of a driver, a numerical value of the proportion of battery power they felt comfortable utilizing would be required (e.g., as provided by the CRST). The PASA would instead have provided a measure of their appraisal of a critical range situation (e.g., how threatening verses challenging they perceived it to be). Indeed, the composite criterion for comfortable range (derived from the sub-scores of the three measures using factor analysis) showed the PASA did not correlate as strongly as the other two measures. The factor loading for the PASA was .37, in comparison the factor loadings for the CRST and the minimum range buffer were .73 and .47 respectively (Franke & Krems, 2013a).

2.2.2.2 Comfortable range: Personality traits

Franke and colleagues (2012b, 2013a) examined the effect of five personality traits on the comfortable range of a driver: internal control beliefs (i.e., the degree to which people believe that they can control events that affect them), ambiguity tolerance (i.e., tendency to experience ambiguous stimuli as desirable and challenging instead of threatening), need for cognition (i.e., tendency to enjoy complex information processing demands), impulsivity (i.e., tendency to control and plan insufficiently) and driving style (i.e., speedy driving and risk propensity). The first four personality traits were selected because of their association with increased stress resistance. However, the rationale for including driving style was not evident. It must also be noted that driving style is not usually treated as a personality trait, as it is comprised of a mixture of multiple traits (e.g., risk propensity) and other factors (e.g., time constraints) (Taubman-Ben-Ari & Yehiel, 2012). Multi-item personality trait scales were essentially used to assess these constructs, such as the 8-item internal control beliefs in dealing with technology scale (KUT). This was with the exception of impulsivity

and risk propensity. These two constructs were assessed using two single items from the German socio-economic panel. Thus, it must be acknowledged that while this research reported the reliability of all multi-items as satisfactory (Cronbach's alpha $>.70$), this estimate would not have included these two constructs.

The results revealed only moderate success in showing that internal control beliefs and impulsivity were positively linked to comfortable range. High scores on internal control beliefs and low on impulsivity were associated with high comfortable ranges (or small energy reserves). No significant association was found between ambiguity tolerance, need for cognition or driving style and comfortable range. The moderate success of these findings could perhaps be partially explained by the use of general trait measures, for instance, internal control beliefs were assessed towards technology generally (e.g., "technological devices are often inscrutable and hard to handle"). General measures are known to be less predictive than domain-specific ones (Arts, Frambach, & Bijmolt, 2011). These findings suggest that certain individuals may be more naturally predisposed to utilizing a greater proportion of the battery capacity than others. It also indicates that individuals scoring low on these personality traits (high on impulsivity) may need more support to help them minimise energy reserves (Franke et al., 2012b). However, personality traits are not easily amenable to interventions (Cattell, 1996). Thus, they may not have been the most useful to examine, in terms of developing strategies to increase stress resistance to range.

2.2.2.3 Comfortable range: System competence variables

Franke and colleagues (2012b, 2013a) also examined the explanatory power of three system competence variables on comfortable range: prior knowledge of BEV technology, daily range practice and subjective range competency. The last variable was defined as drivers' subjective skill for dealing with the remaining range of the vehicle (Franke et al, 2012b). These constructs reflected that TMS views competency as incorporating both a knowledge base and skill base component that results in performance (Lazarus & Folkman, 1984). They were assessed using the following measures.

Prior knowledge of BEV technology was assessed using a questionnaire administered pre-trial. The questionnaire was devised by the authors of this research, and was reported to

have good reliability (Cronbach's $\alpha = .85$). However, it was a very general measure and assessed not only drivers' prior knowledge of the drivetrain of the BEV (e.g., the recovery of energy back into the batteries through regenerative braking), but also units of electricity and different types of batteries.

Daily range practice included: 1) the number of trips drivers made in a day, and 2) the daily distance driven in the BEV. The mean scores for both measures were combined to comprise an overall score for daily range practice. This measure was obtained from travel diary data administered after 3 months BEV exposure. It contained all the journeys drivers made in 1-week (i.e., Monday to Friday). However, such a short record of travel behaviour may not have captured drivers' typical driving patterns in the vehicle. Furthermore, the reliability for this construct was not satisfactory (Cronbach's $\alpha = .43$).

Subjective range competence was measured using four items on a 6-point Likert scale. The items consisted of "I know the energy consumption of my BEV", "I know how far I can go on a full charge", "I can precisely estimate the influence of different factors on range" and "The range of my BEV is mostly affected by factors that I have no influence over." These items were administered after 3 and 6 months BEV exposure. For the analysis a mean score was computed that included both scale values. The reliability of the scale was just about acceptable (Cronbach's $\alpha = .75$ (3 months) and $.61$ (6 months)). However, it could be argued that these items did not conceptually map onto the definition of this construct (i.e., drivers' subjective skill for dealing with the range). Two of the items assessed the degree to which a driver perceived range-influencing factors to be within or outside of their personal control. The other two items asked the degree to which they can estimate the effect of different factors on range. Therefore, these items provide a measure of the degree to which the driver feels they can predict the remaining range. Yet critically none of these items required a statement of the drivers' actual confidence in their skills to control these factors. What is more, the construct subjective range competence is conceptually very similar to the secondary appraisal sub-scale of the PASA. This sub-scale was defined as one's own ability to cope and control expectancies. This suggests these two scales could potentially be assessing the same underlying psychological concept.

Analysis of these variables revealed that prior knowledge of BEV technology only had a weak effect on comfortable range. This could be attributable to the general measure

devised to assess this construct. Daily range practice was positively related to comfortable range. This led these researchers to propose encouraging regular daily range practice (i.e., actively exploring the range) may help drivers expand their comfortable range and achieve maximum performance (Franke & Krems, 2013a). However, regular daily range practice and actively exploring the range do not necessarily go together, indeed, a driver could have a high daily range practice score but never push the capabilities of the battery power. It was explained in Chapter 1 that the driving style drivers adopted was dependent on their trip length (Carroll et al., 2013). Thus, was the expansion in drivers' comfortable range simply attributable to regular daily range practice, or the extent to which their regular trip length pushed the battery power? Finally, subjective range competence was also positively related to comfortable range.

Experience has shown to be a key factor that can promote high coping resources (Lazarus & Folkman, 1984). This led these researchers to conduct a further study examining the influence of experience on comfortable range (Franke, Cocron, Bühler, Neumann, & Krems, 2012a). So what were the findings from this research?

2.2.2.4 Comfortable range: Experience

Franke and colleagues (2012a) assessed 40 drivers (33 male; 7 female) comfortable range at two time points: pre-trial and after 3 months BEV experience. This study only used the CRST to measure comfortable range. The findings revealed positive experience-related effects; pre-trial drivers required an average of 77.06km (48 miles) of range to make the remaining 60km (37 miles) journey. This had decreased to an average of 72.74km (45 miles) of range after 3 months sustained BEV usage. However, it must be acknowledged that this research only revealed a moderate growth in the drivers' comfortable range with experience. This implies the range had remained a psychological concern. Importantly, the findings from this research suggest that pre-trial, drivers' anticipatory range concern had led to them forming an intention to leave an energy reserve. It also indicates that their intended behaviour could potentially have influenced their actual behaviour, as they left an energy reserve.

This study also found that drivers who indicated having directly challenged the range, showed a moderately stronger experience effect in comfortable range scores. The extent to

which a driver reported having actively tested the range, was assessed by the questionnaire item, “I deliberately attempted to exhaust the range of the vehicle.” Importantly, this finding implies that it was the extent to which the drivers’ regular trip length challenged the range that had led to the growth in comfortable range reported earlier (Franke & Krems, 2013a), rather than simply their daily range practice.

The positive experience-related effects led these researchers to conduct two further studies. The first study examined the differences between experienced and inexperienced BEV drivers’ experience of a stressful range situation (i.e., range stress and appraisal) (Rauh et al., 2015). The second study examined the changes that occurred in BEV drivers’ eco-driving strategies over time (Neumann, Franke, Cocron, Bühler, & Krems, 2015). The findings from these studies are presented next.

2.2.3 Experienced versus inexperienced BEV drivers

The study by Rauh and colleagues (2015) consisted of 24 drivers: 12 experienced BEV drivers (average 7.5 years of experience with a BEV) and 12 inexperienced BEV drivers (no prior BEV experience). Drivers were asked to complete a round trip designed to lead to a critical range situation (i.e., range situation involving a short or even negative available range buffer). Drivers were shown a map of the route which was 68km (42 miles). They also received a short briefing on the BEV (e.g., technical parameters, relevant displays and regenerative braking system) and were taken on a short accompanied test drive. A cover story was used to ensure the occurrence of a critical range situation. Drivers were told at the beginning that the BEV was not fully charged because of unexpected technical problems. The state of charge that all drivers started with was on average 50%, corresponding to an average available range buffer of 17km (11 miles) at the beginning of the trip. Additionally, the first section of the route was designed to lead to a particularly high consumption level (i.e., mostly uphill). Hence, drivers experienced a situation where the available remaining range was hardly, or not even sufficient, to complete the trip. In reality, drivers only drove the first section of the route (27 km; 17 miles). They were then debriefed and afterwards drove the shortest way back.

It should be acknowledged that the critical range situation was designed from a purely objective perspective (i.e., battery power insufficient to complete the remaining distance).

However, a drivers' appraisal also plays a key role in determining a critical range situation. For example, the relation between trip distance and information conveyed on remaining battery power, will be interpreted differently by each driver and in different situations. This indicates that a critical range situation also includes a subjective element, which the authors of this research had not taken into account. It highlights that just because the route would have led to a situation where the battery power was only just sufficient to complete the route, does not guarantee drivers would have interpreted the situation as stressful.

Range stress was assessed by two items that were verbally asked by the researcher ten times during the test drive ("Do you have any concerns regarding the remaining range?" and "How stressed did you feel by the changes in the range display on the last part of the trip?"). Drivers indicated their response on an 11-point Likert scale ranging from 0 (not at all) to 10 (very strong). Range appraisal was assessed using the 16-item PASA. Drivers indicated their response on a 6-point Likert scale ranging from 1 (very strongly disagree) to 6 (very strongly agree). It could be argued that the PASA was appropriate to use in this instance, as the researchers were wanting to examine drivers' appraisal of a stressful range situation (i.e., how threatening verses challenging they perceived it to be).

This study also revealed positive experience-related effects. Experienced BEV drivers reported less range stress while actually driving than inexperienced ones. In addition, experienced BEV drivers appraised the critical range situation as less threatening than inexperienced ones. No significant difference was found between the two groups in terms of how challenging they found the situation. However, the researchers did not offer an explanation to account for these differences (i.e., what mechanism underpinned the psychological changes that had occurred with experience). When interpreting these findings it must be acknowledged that the overall scores for range stress and range appraisal were low for both groups of drivers. On average experienced and inexperienced BEV drivers rated their level of stress while driving as 3.53 and 5.27 respectively. In addition, the mean perceived threat ratings for experienced and inexperienced BEV drivers were 1.85 and 1.19 respectively; perceived challenging ratings for experienced and inexperienced BEV drivers were 3.75 and 3.69 respectively. This indicated that neither group of drivers interpreted the critical range situation as particularly stressful, threatening or challenging.

The results also revealed a significant difference between the two groups in terms of their perceived abilities to conserve the battery power; experienced BEV drivers reported higher self-confidence in their abilities than inexperienced ones. This finding was supported by data logger information. Indeed, a significant difference was found between the average remaining range of the two groups, after completing the first section of the test route; experienced and inexperienced BEV drivers had an average remaining range of 36.08km (22 miles) and 30.17km (18 miles) respectively. This indicates that experienced BEV drivers were more proficient than inexperienced BEV drivers in reducing the energy consumption rate of the vehicle. The next study examined the changes that occurred in BEV drivers' eco-driving strategies over time in greater detail. This research consisted of 40 BEV drivers (35 male; 5 female).

Neumann and colleagues (2015) compared drivers' knowledge of eco-driving strategies in the BEV, to their knowledge of eco-driving strategies in the ICEV at two time-points: pre-trial and after 3 months. This was assessed using two open-ended questions, "Which strategies do you know to actively prolong the BEVs range" and "Which strategies do you know to drive energy efficiently with the ICEV?"

The findings revealed that drivers' knowledge of BEV eco-driving strategies deepened with experience; prior to BEV exposure, drivers reported knowing significantly more eco-driving strategies in the ICEV than the BEV. However, this difference had disappeared by the 3-month time point. It should be noted that the mean number of eco-driving strategies reported by drivers, pre-trial and after 3 months was 3 and 4 respectively. This indicates that drivers' knowledge of BEV eco-driving strategies had not substantially changed over time. What is more, the proportions of BEV eco-driving strategies stated by the drivers changed with experience; the results showed a significant difference for avoiding using ancillary features and accelerating moderately. Drivers were more likely to report these strategies after 3 months BEV exposure. Critically, these findings suggest that drivers' experience of range had resulted in them making adjustments to their eco-driving strategies. However, this research did not give insight into what had caused these changes to occur. Interestingly, this research showed pre-trial drivers were aware that some eco-driving strategies were unique to both car types (e.g., maintaining the highest gear possible in the ICEV; regenerative braking in the BEV), while others were the same for both (e.g., slow smooth acceleration). Importantly, this highlights that drivers' understanding of BEV

eco-driving strategies was not just drawn from their (limited) prior knowledge of this type of car, but also their extensive knowledge and experience of the ICEV.

This study also examined how effective drivers' eco-driving strategies were in conserving battery power at the 3-month time point. Drivers were asked to complete a short test drive twice, but under different instructions. In the first test drive they were asked to, "Please drive the given route as you would normally do." For the second test drive they were instructed to, "Please drive the given route as energy efficiently as possible. Please drive in a way which does not obstruct traffic." The test route was 4km (2.5 miles) in a typical urban area. Data loggers recorded the amount of energy consumed in both rounds of the test drive. Analysis of this information revealed that drivers were able to significantly reduce the energy consumption of the BEV, when instructed to drive as energy efficiently as possible. Drivers reduced their speed, accelerated significantly less and had less energy recaptured through regenerative braking.

Interestingly, this research suggested that drivers did not automatically adopt an energy efficient driving behaviour (only when instructed to do so). Indeed, it highlighted a division between drivers' knowledge of eco-driving strategies and them actually implementing them. However, it did not provide insight into why these strategies were not routinely implemented, despite drivers being aware of them. For instance, could it be that because the test route was very short (4 km; 2.5 miles), there was no incentive for them to attempt to reduce the energy consumption rate of the vehicle? Indeed, it was explained in Chapter 1 that Carroll and colleagues (2013) found that drivers adapted their driving style dependent on their trip distance. This also implied that drivers' primary motivation to conserve the battery power was range.

These findings bring into question whether examining eco-driving strategies was the most relevant in understanding effective ways of improving drivers' range utilization behaviour. Indeed, drivers actively avoided critical range situations, suggesting they seldom experienced instances when it was necessary for them to prolong the range. What is more, the fact that drivers actively avoided such isolated moments of crisis, implies they had constructed a priori strategies vis-à-vis range. Thus, to develop effective interventions to improve drivers' adaptation to the range, it is of critical importance to gain insight into the strategies they anticipate implementing to manage the range.

The results from these two studies led to two further ones, examining BEV drivers' first encounter of a critical range situation. This was to understand ways of improving new BEV drivers' adaption to the range. Study one focused on investigating the influence of individual differences on drivers' first encounter of a critical range situation (i.e., range stress) (Franke, Rauh, & Krems, 2016a). Study two examined if a first-time experience of a critical range situation had a positive or negative effect on drivers' range experience (i.e., range stress and appraisal). It also examined if providing coping information (i.e., information on eco-driving strategies) could enhance the effect (Rauh, Franke, & Krems, 2017). These studies drew on the same data collected from 34 drivers (25 male; 9 female). None of the drivers had practical driving experience with a BEV.

Similar to the study by Rauh and colleagues (2015), drivers went on a 94km (58 miles) round trip designed to lead to a critical range situation. The whole trip consisted of four sections (A to D). Section A consisted of a part within an urban area, followed by a part within hilly country roads. Section B and C also included hilly country roads and small villages. Section D consisted of a German Autobahn and part within an urban area. Drivers started the test drive with an average available range of 114 km (70 miles), resulting in a range buffer of about 20 km (12 miles). Sections A and B were mainly uphill, resulting in drivers experiencing a situation where the available remaining range was hardly (or not even) sufficient to complete the trip. Before starting the trip all drivers received a short briefing to the route (i.e., they were shown a map of the route) and to the BEV (e.g., displays and regenerative braking), followed by a short test drive. To manipulate coping information, drivers were randomly assigned into two groups differing in the coping information they received. One group of drivers received standardised verbal information on eco-driving strategies while driving (e.g., effective use of regenerative braking) at the beginning of the test drive. They also received additional information at predefined locations during the test drive, when calling the experimenter. The other group received just minimal information necessary to drive safely with the BEV at the beginning of the test drive.

The next subsection presents the main findings from this research: first in relation to study one (Franke et al., 2016a) and then study two (Rauh et al., 2017).

2.2.4 BEV drivers' first encounter of a critical range situation

Franke and colleagues (2016a) examined the effects of six personal factors on drivers' first encounter of a stressful range situation (i.e., range stress): route familiarity, trust in range estimates, emotional stability, internal control beliefs, prior knowledge and subjective range competence. The latter three variables (i.e., internal control beliefs, prior knowledge and subjective range competence) had previously been examined by these researchers. They were assessed using the same measures outlined earlier in this chapter. The former three variables (i.e., route familiarity, trust in the range estimate and emotional stability) had not previously been investigated. The rationale for their inclusion in this study, and how they were assessed are briefly outlined next.

Route familiarity was examined in view that higher uncertainty about the (future) state of the environment (i.e., state uncertainty) can lead to higher experienced stress, as it makes anticipatory coping more difficult. Therefore, it was proposed that if drivers were more familiar with the route ahead (i.e., if they can better anticipate the future state of the environment) they should experience less range stress. Route familiarity was assessed for three route sections that could have resulted in different ratings, because they belonged to typical trip routes in the area. Two items were administered for each section, "I was already familiar with the route section between x and y" and "I know how the route profile (e.g., elevation and speed profile) would look like" (6-point Likert scale; 1=completely disagree to 6= completely agree).

Trust in range estimates was included as the range display can provide certainty if accurate or uncertainty if inaccurate. Hence, this was determined as being of importance in terms of the amount of stress experienced in a critical range situation. However, it should be noted that this was the drivers' first experience of a BEV. This brings into question whether the test drive was a sufficient period of time, for them to build-up trust in the range estimate. With so much for drivers to concentrate on, it is possible that they may not have focused on the range estimate very much at all. The 12-item Trust in Automated Systems scale was administered after driving to assess trust in the range estimate. The scale was adapted to specify the system as follows: "For the following statements the term „system“ relates to the km-based range display and the calculation algorithms behind it (i.e., the range estimate of the Active-E) (7-point Likert scale).

Emotional stability (i.e., low neuroticism) was included as it is a personality dimension commonly linked to lower experienced stress. Hence, it was viewed that high emotional stability would be related to lower experienced range stress. Emotional stability (i.e., low neuroticism) was assessed using the 2-item neuroticism scale of the BFI-10 (5-point Likert scale). High values indicate high emotional stability. The reliability for this measure was questionable (Cronbach's alpha .60).

Range stress was assessed using two measures administered after each section of the test route: the stress index score of the PASA, which was obtained from the ratio of primary appraisal and secondary appraisal. Possible score values range from -5 to +5 (higher values indicating higher experienced stress). A mean score was computed from the sub-scores. A single item indicator was also used, "How stressed do you currently feel by the development of range (the relation of remaining trip distance to remaining range)?" (11-point Likert scale; 0=no stress at all to 10=highest possible stress). This item was developed from an earlier version used by Rauh and colleagues (2015). A mean score was computed from the sub-scores.

The results revealed that high route familiarity and trust in the range estimation system were linked to lower range stress. Both stress indicators showed significant effects. These findings indicated that state certainty was important in enhancing anticipatory coping and reducing range stress. They highlighted the importance of providing drivers with information on the route and reliable range estimates. Importantly, these results demonstrated that range stress was not simply affected by individual differences, but also by environmental factors. However, when examining state (un)certainty the public recharging infrastructure was not investigated. This was a critical oversight, as the recharging network will play a key role in state (un)certainty and hence range stress. Importantly, these findings imply that uncertainty (e.g., in the figure conveyed by the range estimate) was underpinning drivers' range stress.

This study had moderate success in showing that high internal control beliefs were linked to lower range stress. However, the effect of emotional stability on range stress was not very pronounced. Only the PASA stress index showed a significant positive effect. The effect was only significant for primary appraisal, but not for secondary appraisal. This could potentially be attributable to the questionable reliability of the BFI-10 (2-item scale)

in assessing this construct. It must also be noted that understanding the influence of these factors on drivers' experience of a stressful range situation, was of limited usefulness in developing strategies to improve their adaption to the range.

High system knowledge and subjective range competence were both linked to lower range stress. However, only the PASA stress index showed a significant effect for both variables. These findings indicated that providing new BEV drivers with coping information could potentially be useful in reducing their range stress, and improving their adaption to the range. This was examined further in the next study.

Rauh and colleagues (2017) investigated the effect of a first-time critical range situation on drivers' experience of range (i.e., range stress and appraisal). This was in light of the finding that drivers who challenged the range showed a moderately stronger experience effect in comfortable range scores (Franke et al., 2012a). It also examined if providing coping information could improve this effect. Range stress, range appraisal and subjective range competence were assessed three times; before and after the test drive via a questionnaire, and during the test drive via a telephone interview and a short questionnaire after each section of the route. These constructs were assessed using the same measures outlined in the previous study (Franke et al., 2016a). It must be noted that prior knowledge of BEV technology was not examined in this study.

This study showed that first-time experience of a critical range situation had a significant positive effect on drivers' range stress (i.e., reduced range stress), primary appraisal (i.e., reduced primary appraisal) and subjective range competence (i.e., increased range competency). No effect was found on secondary appraisal. This could be viewed as contradictory to the finding that first-time experience of a critical range situation increased subjective range competence (Franke et al., 2016a), as both constructs tap drivers' own abilities to manage the range. From these findings it was concluded that it would be beneficial to provide a test drive to future BEV drivers, on which they experienced a critical range situation in a protected environment. However, it is not known if these positive effects transfer into real-world conditions. Indeed, is a first-encounter of a critical range situation in a protected environment enough to encourage drivers to actively explore the range in real-world conditions? If so, does it continue to have positive effects or could it potentially have negative outcomes, if drivers were to misjudge the situation and run out

of battery power. This would be a particular consideration in the early stages of BEV exposure, when drivers were building up experience and knowledge of the range. All drivers also received at least minimal coping information on the range. This raises the possibility that it was the information they received, rather than the critical range situation itself that accounted for the positive effects found in this research.

This study also revealed that coping information had a significant effect on drivers' subjective range competence during the test drive (no effect for pre-post difference scores). Results also showed that coping information had a significant effect on secondary appraisal during the test drive (no effect for pre-post difference scores). No effect was found for primary appraisal on range stress (neither during the test drive or pre-post difference scores). Although this study showed that coping information only resulted in a slight enhancement in drivers' perceived ability to manage the range, it could be that this encourages them to actively explore the range, which in turn may result in reduced range stress.

2.3 Conclusions from research examining range anxiety

The extant literature highlighted the important role human factors played in drivers' range utilization behaviour. It showed that certain personality traits (e.g., internal control beliefs) were associated with increased stress resistance to range. Subjective range competence was also associated with a growth in comfortable range, and reduced range stress. Two factors were found to increase subjective range competence: experience and coping information. Interestingly, the latter suggests drivers' perception of range was altered vicariously through the information they received on the vehicle. Daily range practice (i.e., actively exploring the range) also had a positive effect on comfortable range. However, it could be argued that drivers could make a number of short trips in a day, without necessarily challenging the battery power. This brings into question whether the effect of daily range practice was attributable to the amount of exposure drivers had to range on a daily basis, or the extent their daily needs pushed the battery power. It must also be acknowledged that the extant literature had focused on increasing stress resistance to range. Therefore, it provided limited insight into why drivers perceived range a concern (i.e., their thoughts, feelings and emotions in relation to range). Also, it had not taken into consideration how external factors (e.g., public charging infrastructure) contributed to this.

The existing literature revealed that drivers' range stress decreased with experience. However, the amount of battery power they felt confident using only showed a moderate rise over time. This suggests range had remained a psychological concern to them, and had a lasting negative effect on their behaviour. It also implies that drivers' perception of range had altered with experience. However, the extant literature had not given insight into the psychological mechanisms that underpinned these changes. Interestingly, this research indicated that challenging the range enhanced the adaptation effect. This suggests drivers' typical trip length could affect their adaptation to range. For example, a driver with a longer typical journey length, would be forced to use a greater proportion of the battery power. This could result in them more frequently using the vehicle in challenging range situations. However, to-date no research has examined this, as the extant literature instead focused on individual differences. This is a critical gap in the literature, as we know very few drivers deliberately attempted to exhaust the battery power. Thus, drivers' typical trip length could play a key role in their adaptation to range.

The eco-driving strategies drivers implemented changed with experience. What is more, the alterations they made improved the efficiency of their driving style (i.e., lowered the energy consumption rate). This suggests drivers had made self-regulatory changes to their behaviour. However, the literature showed a division between drivers' knowledge of eco-driving strategies, and them actually implementing them. One reason for this could be that drivers were not motivated to change their normal driving habits to conserve range, as they were not pushing the battery capacity. This implies the focus should be on understanding the coping strategies they implement to prevent range being an issue, rather than examining their eco-driving strategies.

In conclusion, the extant literature has not given insight into why drivers' perceived range a concern over time. This is a critical gap in the literature in terms of understanding how to overcome range anxiety, and enhance drivers' range utilization behaviour. So why was this body of research unable to address this important issue?

The existing literature focused on a specific facet of range anxiety – the stress drivers experienced in isolated moments of crisis. However, we know that range anxiety does not simply relate to actual experienced distress, but also anticipated worry (Franke et al., 2016b). Indeed, range anxiety was primarily characterised as an anticipatory concern

(Franke et al., 2012b). Thus, it is a critical gap in the literature that to-date no research has examined this psychological state from this perspective. This implies a shift in focus is now required away from examining drivers' experience of range stress, to exploring why it was an anticipatory concern. The extant literature also primarily took a quantitative approach, focusing on a limited range of issues determined by TMS. Thus, to-date a comprehensive evaluation of drivers' range concern is missing from the literature. Finally, TMS views stress as occurring as a result of an imbalance between personal and environmental factors (i.e., critical person-environment imbalance). However, it does not provide an explanation of the affect this imbalance may have on a person's behaviour, or how this may change over time with experience.

2.4 Aims of research

This research aimed to extend on the existing literature by examining drivers' perception of range (and associated recharging), over time and over a variety of situations. It specifically focused on the first 3 months of BEV usage, as previous research suggested drivers' adaptation to the range had mainly occurred within this timeframe. In addition, it also took into consideration the influence drivers' typical trip length had on their adjustment to the range. It was intended that recommendations for developing effective strategies to reduce range anxiety, and improve drivers' range utilization behaviour would be made from this research. Social Cognitive Theory (SCT) was used as a conceptual framework to interpret the findings, and provide a comprehensive account of drivers' range psychology. A detailed explanation of this theoretical perspective is given in the next chapter.

This research primarily drew upon the interview data collected from the UK MINI E Project (6 month field trial of the electric MINI). This project was both part of the wider international MINI E field trials and the UK TSB ULCV demonstrator programme (full details of these trials are provided in Chapter 4). As previously stated, drivers' range concern had received limited empirical attention, therefore a potentially wide range of issues needed to be explored. It could also be argued that quantitative research tends to focus on a limited range of issues determined by a priori decisions resulting from theory. For these reasons, it was decided a qualitative research method should be used because it permits identification of, and investigation into, a broader range of topics.

I worked full-time as part of a team from Oxford Brookes University, collecting the questionnaire and interview data from the drivers in the TSB ULCV demonstrator trials before starting this PhD. A number of papers and reports have already been published from this dataset (Burgess, King, Harris, & Lewis, 2013a; Bunce et al., 2013; Carroll et al., 2013). Thus, it is important to clarify the unique contribution of this thesis in relation to our earlier research. The previous papers focused on different aspects of BEV usage. The first paper identified the image of BEVs that existed in the UK public imagination, by analysing drivers' reports of interactions and communication with a wide range of non-BEV driving people (e.g., strangers, acquaintances, colleagues, friends and family members) (Burgess et al., 2013a). The second paper examined BEV drivers' attitudes and experiences of recharging (Bunce et al., 2014). Thus, there was very little overlap between these papers and the present research.

The TSB ULCV Final Report fed back information on all aspects of drivers' expectations and experiences of BEV usage (e.g., regenerative braking, low background noise, recharging, range and performance). Thus, it provided a broad overview of drivers' general adaptation to the vehicle. What is more, this report was atheoretical, hence the account was descriptive rather than interpretive. For example, it reported the percentage of trips drivers had completed in the MINI E, and what range they considered ideal. In contrast, this thesis specifically focused on drivers' perceptions and experience of range. It also used a conceptual framework (SCT) to interpret the data. Thus, it provided a more in-depth and integrated account of range than had been provided in the TSB report.

2.5 Chapter Summary

To summarise, this chapter justified the choice of topic for this research, narrowed down to specific research aims. It outlined the background to range anxiety and presented the limited research that had explored drivers' experience of range from a psychological perspective. It highlighted that this research had focused on a specific facet of range anxiety (i.e., the stress drivers experienced in isolated moments of crisis). This left a critical gap in the literature in terms of understanding why drivers perceived the range to be a concern, and the psychological affect this had on their behaviour over time. The current research project intended to position itself within this gap in the literature. It was explained that these issues were of critical importance to answer, in order to develop

effective strategies to reduce drivers' range concern and ensure their successful adaption to the battery power.

To give an overview of the structure of this thesis, it is divided into six remaining chapters (eight in total). The next chapter (Chapter 3) provides a detailed explanation and justification of the theoretical approach applied to this research. Chapter 4 describes the MINI E project, including: 1) the subsample of drivers used in this research, and 2) the time points and methods of data collection. It also outlines and justifies the analytical approach used to analyse the interview data. Chapters 5 to 7 present the findings of drivers' expectations and experiences of range over time: Pre-trial (Chapter 5), following first contact with the MINI E (Chapter 6), and finally over a period of sustained BEV usage (Chapter 7). Chapter 8 offers a discussion and conclusion, which draws together the findings of the research by outlining and evaluating its key contributions, and suggesting how the findings could be applied strategically in a real-world context.

One important point to note here is that the word „range anxiety“ and associated term „range stress,“ are both deliberately avoided throughout the remainder of this research. Range anxiety was avoided to avert the possibility of it being confused with more severe anxiety disorders (e.g., phobias, panic disorders and social anxiety disorders). The intense feelings of anxiety experienced by people suffering from these disorders can be extremely debilitating. It can have a serious impact on their psychosocial wellbeing (Caske & Stein, 2016). This severe level of anxiety overemphasises the mild discomfort experienced by drivers when travelling on a low state of charge. In addition, range stress was avoided as the word stress refers to the emotional strain resulting from adverse or demanding circumstances. Hence, it could be argued that this term was appropriate to describe the tension drivers' experienced in a critical range situation. However, it did not adequately incorporate the anticipatory element of range anxiety. The term „range concern“ was used instead. This was because it conveyed a lesser degree of emotional intensity than range anxiety. What is more, the word concern refers to a more general state of apprehension, not simply to the stress experienced in a demanding situation.

Chapter 3

Theoretical Accounts of Behavioural Change

The last chapter established the aims of this research project. This chapter focuses on the theoretical perspective used as a conceptual framework to examine drivers' perception of range over time. It is divided into four sections. Section 3.1 (divided into three further subsections) introduces three theories of behavioural change that were initially selected as potentially relevant for this research: Theory of Planned Behaviour (TPB), Technology Acceptance Model (TAM) and SCT. It then turns to outline why the first two models were discarded, and the third one was chosen as the most appropriate to apply. Section 3.2 (divided into a further five subsections) gives a background to SCT and the core features of this theoretical perspective. Section 3.3 concludes by justifying why SCT was an appropriate perspective for use in this research. Finally, section 3.4 presents the specific questions for this thesis.

3.1 Introduction

The present research intended to explore drivers' perceptions of range over time and over a variety of situations. This required a cognitive approach to exploring behaviour that centred on a person's attitudes and beliefs. On this basis three theoretical perspectives were initially selected as potentially relevant: TPB, TAM and SCT. In addition, it also required a theoretical perspective that could explain the longitudinal changes that occurred in drivers' range psychology, as they reflected on their actions with experience. On this basis TPB and TAM were discarded, and SCT was selected as the most appropriate to use. To understand why, the remainder of this section gives an overview of TPB (subsection 3.1.1) and TAM (subsection 3.1.2). It then outlines and justifies why they would have been inappropriate for the purposes of this research (subsection 3.1.3).

3.1.1 Theory of Planned Behaviour (TPB)

TPB was developed by Icek Ajzen in 1985. It originated from the Theory of Reasoned Action (TRA), which was based on rational decision-making (Dreiling, 2015). TPB proposed that a person's behavioural intention was the best predictor of actual behaviour (Ajzen, 1991). Intention was assumed to be an outcome of three conceptually distinct determinants: attitudes towards the act or behaviour, subjective norms and perceived behavioural control (PBC) (Armitage & Conner, 2001) (please see Figure 3.1). Attitudes towards the act or behaviour and subjective norms were retained from the TRA. PBC was added to overcome the limitation with the original model, in not being able to adequately predict behaviours that were not under complete volitional control (Ajzen, 2011).

Attitudes towards the act or behaviour was defined as the degree to which a person has a favourable or unfavourable evaluation of the behaviour in question (Ajzen, 1991). TPB argues the more favourable a person's attitude towards the behaviour, the stronger their behavioural intention and actual behaviour to perform the act (Ajzen & Madden, 1986). For example, if a person has a favourable attitude towards owning a BEV, their behavioural intention and actual behaviour to purchase one should be stronger.

Subjective norms reflect a person's perceptions of social expectations to adopt a given behaviour (Ajzen, 2001). Distinctions have been made between *descriptive norms* and *injunctive norms*. Descriptive norms were defined as descriptions of the existing behaviour of some collective or group (Ajzen, 1985). For example, if the existing car culture within a society was to drive an ICEV then this might act against a person driving a BEV. In contrast, injunctive norms were defined as a person's beliefs about whether the people they care about (e.g., close friends and family members) would approve or disapprove of the behaviour in question (Ajzen, 1985). TPB suggests this will result in a person being more (or less) likely to intend to perform the act and actual behaviour (Ajzen, 1991). For example, if a person perceives a close friend or relative as endorsing them owning a BEV, this will strengthen their behavioural intention and actual behaviour to purchase one.

PBC refers to a person's perceptions of the ease or difficulty of performing the behaviour of interest (Ajzen, 1991). It provides information about a person's perceptions of potential constraints on action. For example, a person may believe BEV usage was beneficial in

terms of lowering CO₂ emissions and combating climate change, but they may lack the financial resources to be able to afford one. In this instance, PBC would be low as the constraints are high, so the behaviour would be unlikely to occur. PBC was proposed as having an indirect effect on behavioural intention, and helps explain why intentions did not always predict behaviour. It was also assumed to have a direct influence on a person's actions in situations where behaviour was not completely under their control (Ajzen, 1991).

PBC was proposed as being a mix of two dimensions – self-efficacy and controllability (Armitage & Conner, 2001). Self-efficacy refers to a person's beliefs in their own abilities (Bandura, 1997) - this construct is explained in detail later in this chapter. Controllability refers to outside factors, and a person's beliefs that they personally have control over the behaviour, or if it is controlled by externally, uncontrollable factors (Armitage & Conner, 2001). Hence, PBC reflects internal factors (e.g., ability and skill) as well as external factors (e.g., time, money and social support) (Armitage & Conner, 2001). It must be acknowledged that Ajzen (1991) suggested that PBC and self-efficacy beliefs were synonymous constructs, however, other researchers have disagreed with this suggestion. For example, Bandura (2005) argued that control and self-efficacy beliefs were quite different constructs; self-efficacy was concerned with cognitive perceptions of control, whereas PBC also reflects more general, external factors.

In summary, TPB suggests as a general rule, the more favourable the attitude and subjective norms with respect to a behaviour and the greater the PBC, the stronger should be a person's behavioural intention and actual behaviour to perform the act under consideration (Smith, 2013).

Since the introduction of TPB about thirty years ago, it has become one of the most influential and frequently cited models for predicting human social behaviour (Armitage & Conner, 2001). It has been widely applied to a diverse range of areas, in particular health-related behaviours such as addictive behaviours (e.g., smoking, alcohol and drugs), driving-related behaviours (e.g., use of seatbelts and drunk driving), clinical and screening behaviour (e.g., getting a routine mammogram and breast self-examination), eating behaviours (e.g., consuming vegetables), exercising behaviour (e.g., jogging and biking) and oral hygiene behaviour (e.g., brushing and flossing teeth) (Godin & Kok, 1996). TPB

has also been used to study a range of pro-social behaviours such as charitable giving (Van der Linden, 2011) and antisocial behaviours such as deception or faking (Grieve & Elliott, 2013). This model has also been applied within environmental psychology, to help understand the contradictions between people's generally positive intentions to act in an environmentally responsible manner and their unsustainable behaviour (Stern, 2005). For example, a person may intend to recycle their waste produce, but if there was a lack of accessible recycling infrastructure PBC would be low, and constraints would be high, so the behaviour would be unlikely to occur. Finally, TPB has been widely applied within transportation psychology, including as a framework to examine factors influencing people's intention to purchase a BEV (Moons & De Pelsmacker, 2012, 2015).

Research using TPB has essentially applied it as a tool to test the predictive value of the model, in explaining behavioural intention and / or actual behaviour at a specific point in time. Hence, this research has primarily taken a quantitative approach (Smith, 2013). TPB has shown to have relatively good predictive validity across the diverse range of behavioural domains in which it has been applied: a review of the application of TPB by Godin and Kok (1996) revealed that attitudes towards the act and PBC were the most significant variables responsible for the explained variation in intention. In general, subjective norms were reported as less predictive of intention than the other two variables. This construct reached significance levels less often. What is more, in situations where it contributed to the explained variance in behavioural intention, its weight was generally reported as lower than the other two variables. This review of the literature also found that TPB performed moderately well in predicting behaviour. Intention was found to be the most important predictor of behaviour, but in half of the studies reviewed PBC added to the prediction.

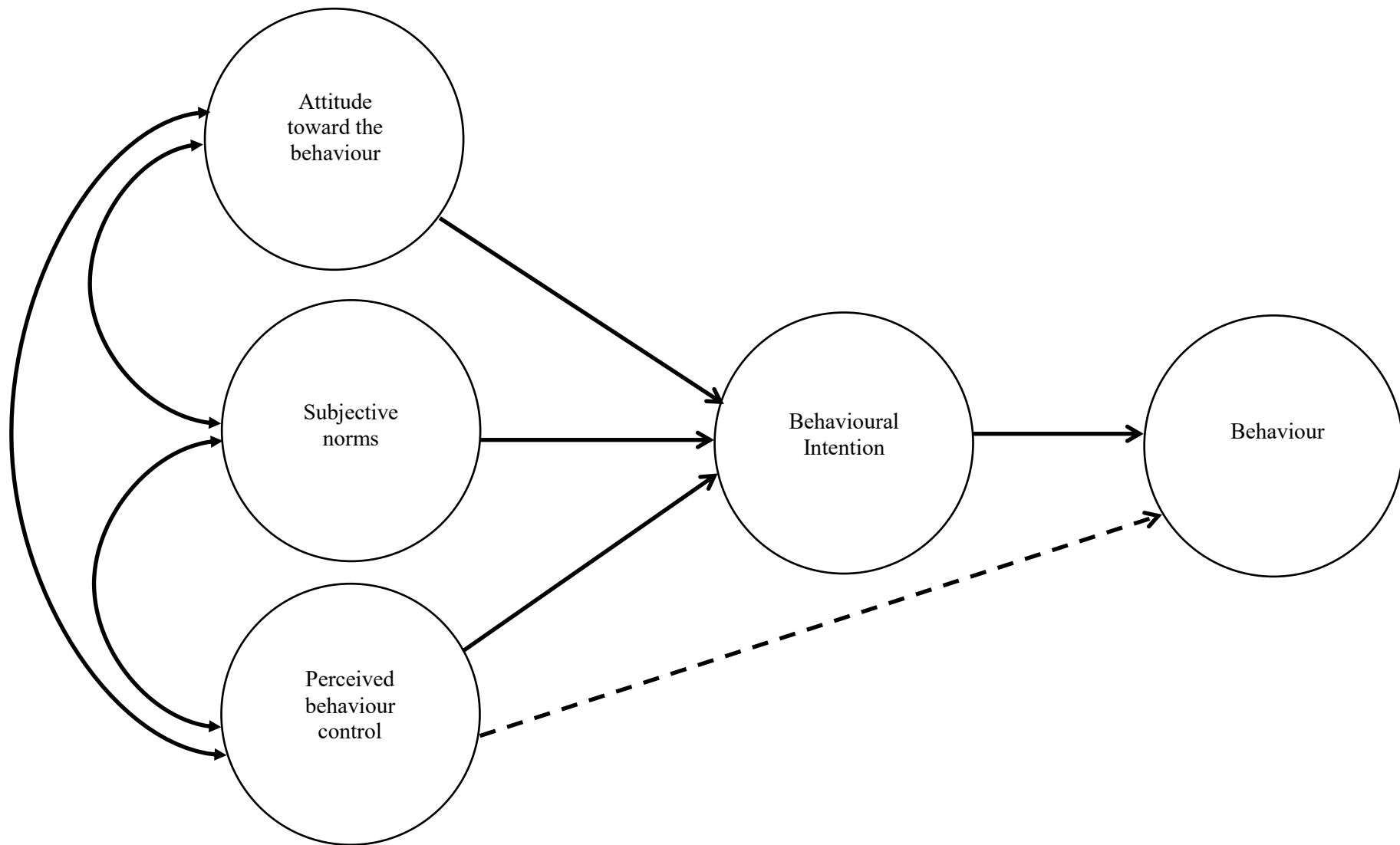


Figure 3.1: Schematic diagram of Ajzen's Theory of Planned Behaviour (from Ajzen, 1991; p.182)

3.1.2 Technology Acceptance Model (TAM)

TAM was originally developed by Fred Davis in 1989. It was initially designed to explain computer usage and acceptance of information technology (I.T.) within the workplace (Lee, Kozar, & Larsen, 2003). Predicting the usage of I.T. systems was an area of interest for many researchers at the time, because of growing technology needs and increasing failures of I.T. system adoption within organisations (Chuttur, 2009). TAM also evolved from the TRA (Dillon & Morris, 1996). The main difference between these two models was that TAM assumed a person's attitude towards a new technology was determined by two major factors: perceived usefulness (PU) and perceived ease of use (PEOU) (Venkatesh, 2000). Therefore, it replaced the TRA's attitude measures with these two technology acceptance measures (please see Figure 3.2). It should also be noted that TAM did not include subjective norms. This was because it was not found to be an important predictor of behavioural intention in work validating the TAM (Davis, 1989).

PU was defined as the extent to which a person believes that using a particular system would enhance their job performance (Davis, 1989). In non-work settings job performance was replaced with personal objectives. TAM assumed the stronger a person's perceptions that a technology would be useful in enhancing their performance, the greater their behavioural intention and actual usage of the system would be (Venkatesh, 2000). For example, if a person perceives the BEV as useful in terms of reducing the amount of money they spend on fuel, the stronger their behavioural intention and actual behaviour to use one would be. TAM proposes that PU can directly influence behaviour, as well as indirectly through attitudes to use. TAM argues that even if a person dislikes an I.T. system the probability of them using it would remain high, if they believe the system will enhance their work performance (Chuttur, 2009).

PEOU was defined as the degree to which a person believes that using a particular system will be free of effort (Davis, Bagozzi, & Warshaw 1989). TAM suggests that if a new technology was perceived as being easy to use, the greater the intention to adopt and actual system usage will be (Dillon & Morris, 1996). For example, if a person perceives a BEV as easy to use (e.g., in terms of being easy to recharge), the greater behavioural intention and actual behaviour to use one will be. PEOU was also assumed to affect a person's sense of control. For example, a technology perceived as being easy to use will make a person feel

they had greater control over their actions or behaviour (Bagozzi, Davis, & Warshaw, 1992; Gefen & Straub, 2000). TAM posits a direct link between PEOU and PU. According to this model, if a person was presented with two systems offering identical functioning, they should find the easier one to be more useful (Keil, Beranek, & Konsynski, 1995). However, PU was not assumed to influence PEOU (Davis et al., 1989).

In summary, TAM suggests that the stronger the PU and PEOU of a particular system, the stronger the behavioural intention to adopt the technology and actual system usage will be (Davis, 1989).

TAM is one of the most widely applied theoretical models for predicting and explaining system usage in the I.T. field (Chen, Li, & Li, 2011). It has been used to examine communication systems (e.g., emails), general purpose systems (e.g., internet), office systems (e.g., word processor, spreadsheet and database programs) and specialised business systems (e.g., expert support systems) (Lee et al., 2003). The application of TAM has not simply been limited to I.T. systems. For example, in more recent times it has been used within the transportation area to predict acceptance of electric bicycles (Wolf & Seebauer, 2014) and BEVs (Ambak et al., 2016; Jabeen, Olaru, Smith, Brauni, & Speidel, 2012). Within these diverse areas, TAM has been applied in a similar way to TPB (i.e., as a tool to predict and explain the acceptance and usage of a system) (Chuttur, 2009). This research has also been predominantly quantitative in nature; a meta-analysis by Lee and colleagues (2003) of 101 papers that had used the TAM, reported all but three studies had used quantitative methods. TAM was also found to have relatively good predictive validity across the areas in which it had been applied (Chen et al., 2011). In particular, PU was found to be a strong predictor of behavioural intention and behaviour, suggesting that people's willingness to adopt a technology was driven by a critically useful functionality (Lee et al., 2003). PEOU was generally reported as a less important predictor of behavioural intention. However, PEOU was found to be a significant antecedent of PU, rather than a direct determinant of technology acceptance (Lee et al., 2003).

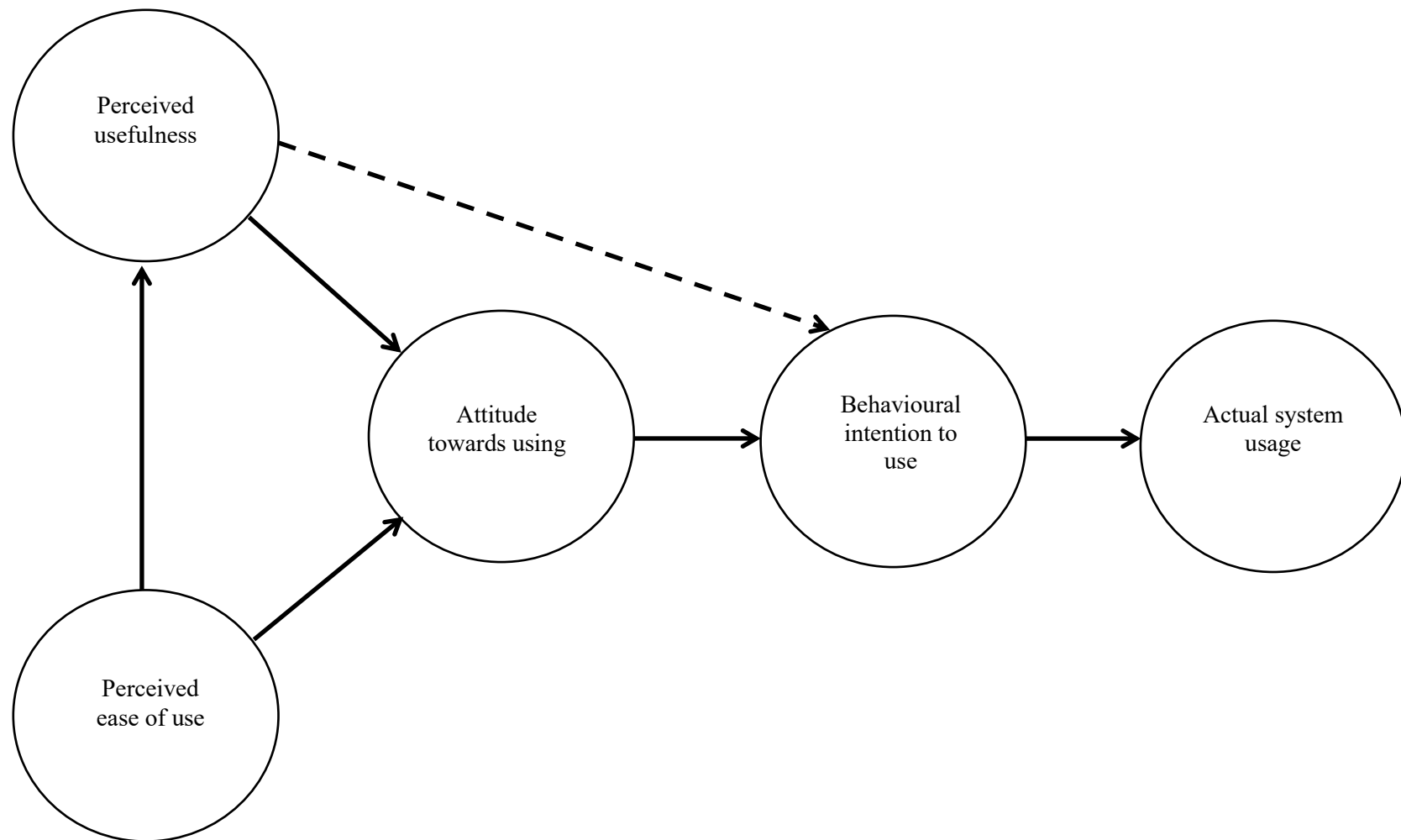


Figure 3.2: Schematic diagram of Davis's Technology Acceptance Model (from Davis et al., 1989; p.985)

3.1.3 Reasons for not applying TPB or TAM to the present research

We know from the existing literature, that TPB and TAM were used as tools to predict behavioural intention and actual behaviour at a specific point in time. However, the objective of the present research was not to predict, for example, factors influencing drivers' intentions to buy a BEV and / or actual purchasing behaviour. Instead, it aimed to conduct a comprehensive exploration of drivers' perceptions of range over time. Hence, these models would not have been suitable for the purposes of this research.

A further limitation of TPB and TAM for the present research was that they were both based on rational decision making. The process of rational decision making favours logic and objectivity as a consequence affective states (e.g., anxiety) are not accounted for (Bandura, 2005). Indeed, this has been a criticism of these models, as affective states are known to affect human judgements and behaviour (Ajzen, 2011). For this reason, it was decided that TPB and TAM were not the most appropriate theoretical perspectives to contextualise drivers' range concern and the impact this had on their behaviour over time.

TPB and TAM take a uni-directional perspective that cognition directs behaviour. They do not account for other influences (e.g., environmental factors) that also impact on behaviour. What is more, these models view behaviour as a linear decision-making process. They do not explain how it changes over time, as people reflect and regulate their actions with experience. Finally, TPB and TAM assume that behaviour is primarily guided by intentional thought. They do not consider the behavioural changes that occur with routinization. This is in spite of a wealth of research suggesting that cognitive processes alter with repeat experience to a stimulus, which results in actions instead being directed by past behaviour (Ouellette & Wood, 1998). For these reasons, TPB and TAM would not have provided suitable structures to explain the psychological changes that occur in drivers' range behaviour over time.

SCT was selected as the theoretical perspective of choice to examine drivers' perception of range over time. To understand why, it would be useful to gain insight into this theoretical perspective. The next section begins by providing a background to SCT. It then turns to outline the key tenets of this model.

3.2 Social Cognitive Theory (SCT)

3.2.1 *Background to SCT*

SCT was developed by Albert Bandura and evolved from his Social Learning Theory. It was based on the assumption that learning occurs in a social context, and that much of the knowledge people acquire is learnt through observing others (i.e., vicarious learning) (Bandura, 1997, 2005). The effectiveness of learning by observing others had been acknowledged since the times of the ancient Greeks. However, Bandura's theory was the first to include this form of social learning (Zimmerman & Schunk, 2003). In 1986, Bandura renamed his theory social "cognitive" to emphasise the important role cognition plays in people's capacity to construct reality, self-regulate and perform behaviours (Bandura, 1986a).

Bandura's social cognitive perspective arose out of his dissatisfaction with unidirectional models of human behaviour, such as behaviourism, psychodynamic and trait theories, which were popular at the time. He argued that these models overemphasised either the role of environmental or biological factors, in the development of human behaviour and learning (Bandura, 1997, 2005). Behaviouristic theories, for example, showed very little interest in self-processes because they viewed external stimuli as giving rise to human functioning. Indeed, this approach assumed that self-generated influences either did not exist, or had no effect upon behaviour. As a consequence, they were not acknowledged as a causal factor of behaviour. For Bandura (1986a), „a theory that denies thought can regulate actions does not lend itself readily to the explanation of complex human behaviour“ (p.15). Similarly, Bandura argued that to reason that human behaviour is a direct result of innate states such as instincts, drives or traits fails to acknowledge that environmental influences partially determine what people attend to, perceive and think (Bandura, 1986a, 1997, 2005; Zimmerman & Schunk, 2003). Instead, Bandura proposed environmental and personal factors not as independent entities that produce behaviour, rather as affecting each other in a reciprocal manner (Bandura, 1986a).

Bandura's final grievance with unidirectional models of human functioning was that behaviour itself was simply treated as an outcome of a person-situation interaction. It was not acknowledged as a factor in the causal process (Bandura, 1997). He argued that people

cannot be considered causes independent of their behaviour, as the experiences generated by behaviour also partly determine what individuals think, expect and can do, which in turn, affects their subsequent behaviour (Bandura, 1986a). Bandura viewed behaviour instead as an interacting determinant of human functioning, rather than just a by-product of it (Bandura, 1997).

SCT emphasises human behaviour in terms of a triadic reciprocal determinism. From this theoretical perspective, human functioning is the product of continuous bidirectional interactions between (a) personal factors (e.g., drivers' abilities to manage the range), (b) behaviour, and (c) environmental events (e.g., recharging opportunities, outside temperature and terrain) (Bandura, 1986a, 2006) (please see Figure 3.3). However, this reciprocal interaction does not mean that all sources of influence are of equal strength. SCT assumes that the strength of the interactions between the three factors will differ based on the person, the particular behaviour being examined, and the specific situation in which the behaviour occurs (Bandura, 1986a, 1997; Zimmerman & Schunk, 2003). For example, when having to undertake a journey that would challenge the battery power, environmental factors (e.g., recharging opportunities or outside temperature) may have a stronger influence on drivers' behaviour (e.g., use of the BEV, or reverting to the ICEV) than personal factors (e.g., drivers' perceived ability to prolong the range while driving).

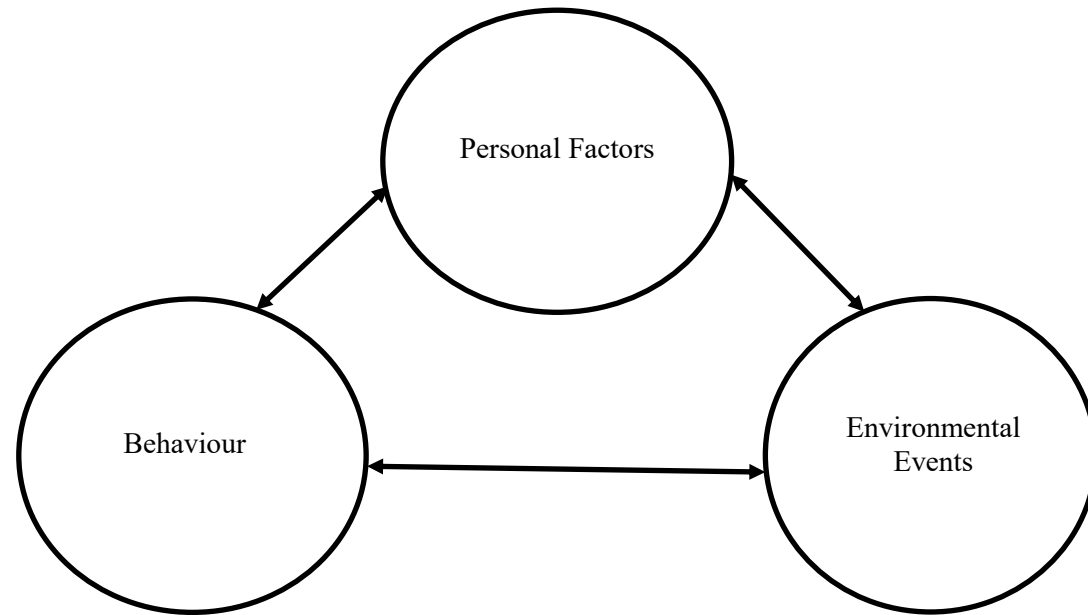


Figure 3.3: Schematic diagram of the Triadic Model of Reciprocal Causation (from Bandura, 1997; p.6.)

Since its introduction about thirty years ago, SCT has been used in a diverse range of areas to bring about behavioural change, including health psychology (Bandura, 1998), educational learning (Zimmerman & Schunk, 2003), people suffering from anxiety disorders (Bandura, 1986b, 1988; Ozer & Bandura, 1990) and improving adaption to new technologies (Compeau, Higgins, & Huff, 1999; Hill, Smith, & Mann, 1987; Ratten & Ratten, 2007; Scholder, Bearden, & Sharma, 1991). The constructs of SCT have also been readily applied to tackle urgent global issues, such as the benefits of family planning, educational opportunities for women, injustice of forced marriage, risks of early childbearing, prevention of HIV infection, embroilment in drug activities and genital mutilation (Bandura, 1990, 2005, 2007).

We know that SCT emphasises the important role cognition plays in human functioning. It adopts an agentic perspective to development, adaption and change (Bandura, 2001a). According to Bandura (2005), „to be an agent is to influence intentionally one’s functioning and life circumstances“ (p.9). In this view, people are not simply passive recipients of their environment, but pro-active, self-regulating and self-reflecting. They are contributors of their actions and environments (Bandura, 1997, 2005). Human agency is founded on a set of cognitive structures. SCT assumes it is through these core features that people are able to act in a self-directed manner. They allow them to exert a measure of control over their actions, the choices they make and their immediate environment (Bandura, 1986a). The next subsection provides an overview of the key tenets on which human agency is based. It begins by outlining how people are viewed as forethinkers and planners of action (subsection 3.2.2.1). Next, it turns to explain how agency also involves the self-influence of actions through the process of self-reaction and self-reflection (subsection 3.2.2.2).

3.2.2 The core features of human agency

3.2.2.1 Forethought

From a social cognitive perspective people do not approach a situation devoid of any impression about themselves or the world around them. Instead, it proposes that through forethought a person motivates and guides their actions anticipatorily (Bandura, 1986a). According to SCT, the temporal extension of forethought is possible through a person’s

extraordinary capacity to symbolize (Bandura, 1997). A person's symbolic capabilities allow them to draw on their past experiences to extract meaning from their environment. Through the process of forming symbols, people are able to represent future events cognitively in the present. Critically, it enables them to plan future courses of action and anticipate the likely outcomes of them. This prevents people from having to learn from trial and error. Therefore, SCT assumes that an act includes self-produced influences and, as a result, is purposeful in nature (Bandura, 1982).

In the process of planning future courses of action people set goals and standards, which motivate their efforts anticipatorily. From this perspective, lower goals or standards are insufficiently challenging to arouse much effort. In contrast, relatively challenging goals or standards produce greater levels of effort (Bandura & Jourden, 1991). It must be noted that goals reflect what a person desires to achieve. For instance, a driver may wish to visit a friend in the BEV 100 miles away. In contrast, personal standards act as a benchmark for future performance. Hence, they set the minimum expected level of performance. For example, a driver may expect the batteries to be capable of about 100 miles. This would then act as a basis for them to compare the actual range the vehicle was capable of reaching under real-world conditions. We know from Chapter 1 that people have become dependent upon the ICEV to complete their daily activities (Anable, 2005; Beirao & Sarsfield Cabral, 2007; Steg, 2005). Hence, drivers' anticipated usage of the BEV is likely to be driven by a functional or practical element (i.e., what they need or require the vehicle to do), rather than goal orientated. For this reason, personal standards could be more relevant motives of action than goals, for the drivers in this research.

According to SCT, the initial goals and personal standards a person sets themselves, are also important markers in determining the level of competency they will develop. For example, drivers who intend using the vehicle for short trips may exert less effort to prolong the range. This could potentially have negative consequences on their skill development in managing the range. In contrast, drivers who contemplate using the vehicle for more challenging trips (i.e., would push the battery capacity) may exert greater levels of effort. This could have positive effects on their skill development. Similarly, higher personal standards are likely to give rise to greater levels of effort, which in turn may foster a growth in competency. For example, a driver who sets a higher personal standard of recharging the BEV when it has 10% remaining energy or less, may develop a greater

level of competency over the range, than a driver who sets a lower standard of recharging the vehicle as soon as it reaches 50% remaining energy. It could also be that this has implications for their anticipatory range concern. For example, the reluctance of a driver to engage in challenging trips could potentially be detrimental to them overcoming their range concern, as they would not be entering into situations that would develop their competency in managing the range. Thus, the avoidance of a critical range situation does not necessarily mean their anticipatory concern would have subsided.

3.2.2.2 *Vicarious capacity*

As previously stated, people learn not only from their past experiences, but also vicariously by observing the behaviours of others. Vicarious learning is important, as it enables people to learn behaviour quickly and also without trial and error consequences. It should be noted that vicarious learning is no longer confined to behaviours exhibited within a person's community (e.g., by a friend, family member or colleague). Today, the accelerated growth of social media (e.g., internet and television) enables people to observe the attitudes and competencies of both different segments of their own societies and cultures (Bandura, 2001a, 2001b, 2005). Hence, vicarious capabilities allow a person to explore situations and activities for the attainment of new knowledge that would otherwise be unobtainable to them (Bandura, 1991). For example, a driver interested in buying a BEV could learn about other drivers' accounts of owning one (e.g., what it was like to recharge, or the viability of the range) from the internet.

SCT views vicarious learning as dependent upon four interrelated processes: attention, retention, production and motivation. *Attention* refers to a person's ability to selectively observe the actions of a model (Bandura, 1997). This is critical because people must attend to a model and the relevant aspects of behaviour in order to learn. Attentional processes determine what is selectively observed and what information is extracted from ongoing modeled events. Observed behaviours are then retained in memory so they can be reproduced at a later date when necessary. *Retention* refers to the process necessary for reducing and transforming what is observed into a symbolic form that can be stored for later use (Bandura, 1986a). Therefore, a person's symbolic capability also enables them to store the information required to guide future behaviour. This is possible through generative codes that extract the underlying structure from observed events. These then

serve as generative guides for constructing actions to fit changeable circumstances, rather than simple mimicry of an act (Bandura, 1997). *Production* refers to the process of drawing on stored information and translating or reconstructing them into appropriate courses of action (Bandura, 1982). The final sub-function is *motivation*. SCT distinguishes between acquisition and performance. From this perspective, a person can learn but not demonstrate this behaviour until motivated to do so (Pajares, 2002). For example, a driver might learn how to drive in an energy efficient manner, but not put this into practice until they are travelling on a low state of charge.

This section outlined how SCT views people as forethinkers and planners of action. This offered a useful structure to examine drivers' anticipatory range beliefs (e.g., the standards they set, and the strategies they anticipated implementing to manage the range) and how this influenced their intended use of the vehicle. It must be acknowledged that from a social cognitive perspective, agency also involves the self-regulation and examination of functioning. Hence, SCT also provided an appropriate structure to explore the psychological changes that occurred in drivers' perception of range over time, as they reflected on their actions and thinking with experience. The next section outlines the core features through which this operates and enables self-influence.

3.2.3 Self-regulation and examination of action

SCT proposes that the process of self-regulation allows a person to self-evaluate their actions and make corrective changes if necessary (Bandura, 1986a). Three self-regulatory sub-functions are assumed to be of importance in the self-evaluation of action: self-observation, self-judgment and self-reaction (Bandura & Wood, 1989). Self-observation reflects a person's ability to monitor or keep track of their own behaviour and outcomes. Self-judgment is the process through which a person compares their performances against a personal standard. Finally, self-reactions can occur when a person responds to the evaluations they have made, by modifying their behaviour if necessary (Bandura, 1986a, 1997).

Self-observation serves at least two important functions in the process of self-regulation: it provides the information necessary for setting realistic performance standards and for evaluating on going changes in behaviour (Bandura, 1986a; Schunk, 1990). It should be

noted that self-observation is not simply limited to the monitoring of naturally occurring events. It can also include the effects noted through personal experimentation. By systematically varying things in their daily lives and noting the accompanying changes, people can discover the influence of these factors (Bandura, 1986a). For example, by noting the amount of energy used on a trip with the heater off and then turned on, a driver could determine its influence on the range.

Self-observation is the first step towards affecting behaviour, but in itself provides little basis for self-directed reactions. Actions give rise to self-reactions through a judgemental function. According to SCT, a person compares their performance attainment against their personal standard (Wood & Bandura, 1989). Whether a performance is regarded favourably or negatively depends upon the personal standard against which it is evaluated. Without this people would have little basis for gauging their capabilities, and the standards they set themselves would have no lasting motivational impact (Jourden, Bandura, & Banfield, 1991). From a social cognitive perspective, a person's previous behaviour is continuously used as the reference against which on-going performance is judged. It is this self-comparison that supplies the measure of adequacy (Wood & Bandura, 1991). For example, a driver may draw on their previous experiences to gauge the adequacy of their performance, in terms of reducing the energy consumption rate of the vehicle. In addition, people can also use social comparisons (e.g., people engaging in similar endeavours) as a comparative measure to judge their performance. For example, a driver in a BEV field trial may compare the range they are achieving to that obtained by other drivers participating in the trial.

SCT assumes that dissatisfactory performances give rise to negative reactions, whereas satisfactory performances activate positive reactions. Both favourable and unfavourable self-reactions can provide incentives for actions to either increase the likelihood of achieving a successful performance attainment, or reaching a more challenging goal or standard respectively. SCT assumes that a person's judgment of the importance of the activity also plays a key role in the self-regulation of the performance. People are unlikely to be concerned about their performance on tasks they consider of little or no personal significance to them. Therefore, such activities are unlikely to generate reactions either way (Bandura, 1978, 1991). For example, a driver making a short journey is unlikely to care about preserving the battery power. As a result, they are unlikely to monitor or

evaluate their performance, as it would not be of relevance to them. This could result in no self-reactions or alterations being made to their performance.

According to SCT, the standards people set for themselves at the start of an endeavour can be readjusted depending on the perceived level of progress they are making. Standards may be lowered when not much progress is being made. Alternatively, even more challenging goals may be adopted as standards are surpassed (Bandura, 1997). For example, a driver may lower the maximum distance they perceive the BEV as capable of achieving, if this continually falls short of their expectations. Alternatively, they may raise their standards if the range surpasses their expectations. From a social cognitive perspective, a person may also maintain their goals, as they will not always necessarily expect to surpass every set standard (Bandura, 1991). For example, a driver may not expect to achieve ever increasing distances on a single charge. It should be noted that people also judge the correctness of their thinking against the outcomes of their actions. By reflecting on their actions people can verify the soundness of their thinking (Bandura, 1986a). For example, a driver may reflect on their actions to judge whether the range has met their expectations in terms of fulfilling their daily activities.

The next subsection outlines a further key construct that SCT proposes as being both a product and constructor of action: self-efficacy beliefs. It begins by providing a brief overview of this construct, and the affect it has on human functioning. Next, it outlines the four modes of influence through which self-efficacy beliefs are developed, and how they could potentially alter drivers' self-appraisal of the range (subsection 3.2.4.1). Finally, it moves to explain the role efficacy beliefs play in the initiation and regulation of affective states (i.e., anxiety) (subsection 3.2.4.2). This is to understand how SCT offers a framework to examine the underpinnings of drivers' range concern, and its impact on their range utilization behaviour.

3.2.4 Self-efficacy beliefs

Self-efficacy is defined as people's beliefs in their capabilities to organise and execute courses of action needed to meet given situational demands (Bandura, 1997). According to SCT, having knowledge and skills does not automatically produce high attainment, if people lack the assurance to use them well (Bandura, 1995). Perceived self-efficacy instead

reflects what people believe they can do, with the skills they have under a variety of circumstances. Efficacy beliefs contribute to the quality of human functioning through their effect on cognitive, motivational, affective and decision-making processes. Hence, they act as a key factor influencing the choices people make and the activities or situations they chose to engage in (Bandura, 1994, 2012). Efficacious beliefs give rise to the initiation of active engagement in challenging activities, which can contribute to a growth in competencies (Bandura, 1993; Maddux, 1995). For example, a driver who has a strong sense of efficacy in their abilities to exert control over the range, may be more inclined to engage in situations that would challenge the battery capacity. This in turn may develop their skill in being able to prolong the range. In contrast, inefficacious beliefs can have a debilitating effect on personal development. People tend to avoid engaging in activities they believe to be beyond their capabilities. This gives rise to restricted choice behaviour and an impeded growth in competence (Bandura, 1977, 1989). For example, a driver with a low sense of efficacy in their abilities to exert control over the battery power may be more inclined to avoid challenging range situations. This in turn could have a negative effect on the skill they develop over the energy resources of the BEV.

3.2.4.1 Development of self-efficacy beliefs

According to SCT, self-efficacy beliefs are developed through four main sources of information: mastery performance, vicarious experiences, verbal persuasion and physiological arousal (Bandura, 1997; Maddux & Lewis, 1995). A variety of factors (i.e., personal, social and situational) affect how efficacy-relevant experiences are interpreted. Hence, the information conveyed by these different modes of influence is not automatically instructive, but gains its significance through cognitive processing. Therefore, the information relevant for judging personal efficacy should be distinguished from the cognitive processing by which that information is selected, weighted and integrated into self-efficacy judgements (Bandura, 1995, 1997). This subsection outlines each of the four major modes of influence and the factors that affect their integration into efficacy beliefs.

1. Mastery performance

From a social cognitive perspective, enactive mastery experiences are the most powerful source of efficacy information, because they provide real evidence as to whether a person possesses the capabilities to succeed (Bandura, 1997). People act on their efficacy beliefs and assess the adequacy of their self-appraisal from the performances they manage to achieve. Performance successes generally raise beliefs of personal efficacy, repeated performance failures lower them, particularly if the failures occur early in the course of events (Bandura, 1982, 1995). However, it must be acknowledged that performance alone does not provide sufficient information to judge one's level of capability. This is because many factors that have little to do with ability can affect performance (Bandura, 1995). Changes in perceived efficacy result from cognitive processing of the information that performances convey, rather than the performance itself. Hence, performance successes do not automatically raise efficacy beliefs, or performance failures necessarily lower them. The extent to which people alter their perceived efficacy through performance experiences depends on various factors including: the perceived difficulty of the task, the circumstances under which they are performed, and the way these enactive experiences are cognitively organised and reconstructed in memory (Bandura, 1997).

The value of a performance in judging personal efficacy partially depends on the perceived difficulty of a task. To succeed at an easy task is redundant with what one already knows and, therefore, does not require any efficacy reappraisal (Bandura, 1995). For example, the successful completion of a routine trip well within the range is unlikely to reveal any new efficacy information. As a consequence, it is unlikely to call for any efficacy reappraisal. In contrast, mastery of difficult tasks conveys new efficacy information for raising beliefs in one's capabilities. For example, the successful completion of a one-off trip that challenges the battery power is likely to uncover new efficacy information, which could potentially raise drivers' beliefs in their capabilities. However, it should be noted that when performing an activity people may discover new things about the task, as well as about themselves. These discoveries can sometimes have the paradoxical effect of lowering perceived self-efficacy (Bandura, 2005). For example, if in the course of completing a challenging journey drivers encounter potentially formidable aspects of the undertaking (e.g., another car already parked in a charging bay they had intended using). This could have the effect of lowering their perceived efficacy, despite their successful performance.

This indicates that challenging range situations may not necessarily have a positive effect, as was suggested in the research reviewed in the previous chapter (Franke et al., 2012a; Rauh et al., 2017).

The circumstances under which an activity is performed can also affect how it is cognitively processed. For example, successes achieved with external assistance (e.g., under the instruction of a technical expert) may carry little efficacy value, if they are credited to the external aid rather than to personal capabilities (Bandura, 1997). Similarly, faulty performances under adverse conditions have weaker efficacy implications than those executed under optimal conditions (Bandura, 1995). For example, in cold weather conditions a driver may attribute the high energy consumption rate to factors such as the heater, rather than their personal capabilities in conserving the battery power.

Perceived self-efficacy is not only affected by how performance success and failure are interpreted, but also by biases in the self-monitoring of the performance themselves. Pre-set efficacy beliefs are proposed as playing a powerful role in determining what information is noticed and remembered. From a social cognitive perspective, people attend to information that is congruent with the self-beliefs they hold. In contrast, experiences that are inconsistent with their pre-existing beliefs tend to be minimised or discounted from memory. This is known as confirmation bias (Bandura, 1986a, 1997). For example, people who doubt their efficacy are more likely to attribute repeated successes to be the result of their hard effort than as evidence of their own capabilities, whereas self-assured people are more inclined to ascribe them to their own capabilities. Pre-set self-beliefs of efficacy provide people with essential continuity. Without their stabilizing effects their views of themselves would continuously change with each success or failure (Bandura, 1997). A self-enhancing confirmatory bias serves people well as this gives rise to a resilient sense of efficacy, with occasional setbacks being unlikely to undermine beliefs in their capabilities. A self-debilitating confirmatory bias, on the other hand, tends to result in poor performance that further undermines a sense of personal efficacy (Bandura, 1997). This emphasises the importance of examining drivers' pre-existing beliefs of range, as it will act as a foundation for their future interaction with the vehicle.

2. Vicarious experiences

People do not rely on enactive mastery experience as the only source of information about their capabilities. Efficacy appraisals are partly influenced by vicarious experiences mediated through modeled attainments. Hence, modeling serves as another effective tool for promoting a sense of personal efficacy (Bandura, 1997). Vicarious experiences are generally assumed to have a weaker effect on self-efficacy beliefs compared to mastery experiences. Nevertheless, there are certain conditions under which self-efficacy appraisals are especially susceptible to change by modeling influences. For example, when people have had little prior experience on which to evaluate of their capabilities, they rely more heavily on modeled indicators (Bandura, 1995).

The impact of modeled information on self-efficacy appraisals also depend on how that information is cognitively processed. Factors such as the perceived competence of the model are especially relevant to the cognitive processing of modeled information (Bandura, 1997). Competent models command more attention and exert greater instructional influence than incompetent ones (Bandura, 1986a). Model competency is an especially influential factor when people lack direct experience (i.e., drivers prior to BEV). Hence, the information conveyed by technical experts on the BEV could be particularly powerful in altering drivers' self-appraisals in the early stages of BEV adaption.

3. Verbal persuasion

Verbal persuasion can also strengthen people's beliefs in their capabilities, if the positive appraisal is within realistic bounds (Bandura, 1978). It also has an especially noticeable impact on the development of a sense of personal efficacy, in the early stages of skill development (Bandura, 1997). When significant others convey confidence in a person's abilities, it is easier for them to sustain a sense of efficacy than if they express doubts about them. Although appraisals set within realistic bounds can enhance a person's beliefs in their capabilities, equally SCT cautions that unrealistically inflating beliefs of personal capabilities can have detrimental effects. Misleading persuasory appraisals that overinflate a person's beliefs in their capabilities are easily disconfirmed by disappointing results. This can undermine personal capabilities and the credibility of the persuader (Bandura, 1982). For example, a technical expert unrealistically inflating the distance a driver is able to

travel in the vehicle, could have the effect of undermining the capabilities of the battery power and the drivers' confidence in them.

According to SCT, confidence is mediated through the perceived credibility and expertness of the persuader (Bandura, 1997). People are more likely to change and hold strong beliefs in their own abilities when they perceive the persuasory source of information to be believable (Bandura, 1986a). People are more inclined to trust the evaluations of their capabilities by those who are themselves skilled, or possess a rich knowledge base in the activity. In contrast, when people are more confident in their own self-appraisals than in the judgments of others, their beliefs in their capabilities are not altered by what they are told (Bandura, 1997). For example, drivers' beliefs in their capabilities is more likely to be changed by the persuasory information received from a technical BEV expert than a member of the public, as they would perceive them as an authentic source of information on the vehicle.

4. Physiological states

Finally, people also rely on information conveyed through physiological states when judging their capabilities. The other sources of self-efficacy information are usually given greater weight, as they are more reliable indicators of personal capabilities than physiological states (Bandura, 1997). The sheer intensity of physiological reactions plays a key role in determining how the information conveyed by physiological states is judged. As a general rule, moderate levels of physiological arousal heighten attentiveness and facilitate deployment of skills, whereas high levels of arousal disrupts the quality of functioning (Bandura, 1991). It is because high arousal can debilitate performance, that people often read their physiological activation in stressful situations as signs of vulnerability to dysfunction. Stress reactions can generate further stress through anticipatory self-arousal. This elevates the level of distress, which in turn, results in the very dysfunction they feared (Bandura, 1995).

The situational context also plays a key role in determining how physiological reactions are interpreted. Physiological arousal occurring in situations that contain threatening cues is interpreted as fear (Bandura, 1986a). For example, a driver experiencing physiological arousal when travelling on a low state of battery power is likely to interpret this as being a

fear response. How people read their physiological states is also partially dependent on their pre-existing efficacy beliefs, which heightens sensitivity to them. According to SCT, people with a high sense of efficacy will generally regard arousal as a facilitatory factor, whereas people with a low sense of efficacy regard it as a debilitating factor. For example, a driver with a strong sense of efficacy may interpret physiological arousal in response to a low state of charge as a facilitatory factor, whereas a driver with a low sense of efficacy may interpret this as a fear response. It must be noted that SCT acknowledges that situational factors limit the effects of pre-existing beliefs of efficacy. For example, a driver about to run out of battery power with nowhere close by to recharge, is unlikely to interpret their physiological reactions as facilitating.

As previously stated, self-efficacy beliefs are assumed to play a key role in the arousal and regulation of affective states. The next subsection specifically focuses on their effect on anxiety. This is to gain an appreciation of how SCT could offer a useful structure to explore the origins of drivers' range concern, and the potential impact on their intended behaviour and subsequent actions.

3.2.4.2 Self-efficacy and anxiety

Anxiety arousal was originally thought to be triggered by a potential environmental threat. The avoidant behaviour frequently accompanied with this affective state was presumed to be motivated by a drive to reduce its arousing effects (Williams, 1995). To eliminate avoidant behaviour, it was considered necessary to eradicate the underlying anxiety. Therapeutic procedures were centred on extinguishing anxiety arousal, primarily through repeated exposure to the aversive stimuli (i.e., desensitisation) (Bandura, 1997). This traditional view that anxiety controls avoidant behaviour has remained firmly entrenched in psychological thinking, despite there being no support for this notion. For instance, avoidant behaviour has shown to be performed without anxiety arousal, and to persist long after anxiety reactions to threats have been completely eradicated (Bandura, 1986a). SCT proposes an alternative explanation for anxiety arousal and the regulation of this affective state.

According to SCT, efficacy beliefs play a central role in anxiety arousal, as they create attentional biases that influence whether life events are constructed, cognitively

represented and retrieved in ways that are benign or emotionally disturbing (Bandura, 1997). From a social cognitive perspective, it is the perceived mismatch between beliefs of coping self-efficacy and task demands that give rise to anxiety arousal (Bandura, 1986a; Williams, 1995). Perceived coping self-efficacy refers to a person's beliefs in their capabilities to exercise control over potentially threatening, or difficult situations (Bandura, 1997). People who view themselves as inefficacious in being able to cope with a potentially hazardous situation will perceive it as threatening, whereas people who regard themselves as efficacious in being able to handle such encounters will not. Research has supported the influential role of perceived control in anxiety reactions (Bandura, 1990; Miller, 1980). Interestingly, it has also shown that it is a person's self-knowledge that they can exert control over a potentially threatening event, should they choose to, rather than the actual application of control that reduces anxiety arousal. Therefore, SCT emphasises that to understand people's appraisals of external threats and their affective reactions to them, it is of critical importance to analyse their judgements of their coping capabilities (Bandura, 1997).

Efficacy beliefs are also viewed as playing a central role in the regulation of affective states once aroused. SCT assumes that efficacy beliefs facilitate courses of action that alter the emotive potential of the environment from potentially hazardous to benign (Bandura, 1986a, 1997; Ozer & Bandura, 1990). For example, a driver may avoid facing the potentially risky situation of running out of battery power by erring on the side of caution and leaving a reserve of energy. Therefore, SCT does not view anxiety arousal as a causal factor of avoidant behaviour. Instead, both factors are proposed as co-effects stemming from a weak sense of coping self-efficacy. There is much empirical evidence to support this assumption (Bandura, 1983, 1986b, 1988). Results from these studies have consistently shown that perceived coping self-efficacy predicts behaviour when anticipatory anxiety is controlled. However, anxiety arousal does not predict avoidant behaviour when perceived coping self-efficacy is partialled out.

SCT recommends diminishing anxiety arousal and avoidant behaviour through instilling a strong sense of coping self-efficacy. Research on people suffering from a diverse range of severe anxieties (e.g., victims of sexual assault and people suffering from phobias) has provided support for this (Bandura & Menlove, 1968; Bandura, Adams, & Beyer, 1977; Bandura, Reese, & Adams, 1982; Ozer & Bandura, 1990). In these studies, participants'

self-efficacy beliefs are predominantly raised through modeled performances designed to alter coping behaviour. Modeled performances emphasise two factors (i.e., predictability and controllability) that are conducive to the enhancement of efficacy beliefs (Bandura et al., 1982). The results from this literature consistently showed that as the participants' self-efficacy levels were raised, they experienced progressively less anticipatory and actual anxiety. What is more, coping behaviour was found to correspond closely to instated levels of perceived self-efficacy; higher levels of perceived self-efficacy were accompanied by greater performance attainments. The severe anxiety experienced by the participants examined in these studies will differ markedly from the mild apprehensions drivers' experience regarding running out of charge. Nonetheless, this does suggest the possibility that drivers' range concern could potentially stem from their perceived inability to exert control over the range. This further highlights the importance of examining drivers' range beliefs, so areas of anticipated uncertainty can be identified and strategies developed to improve their perceived control over them.

Despite perceived coping self-efficacy being viewed as a major contributor to anticipatory anxiety arousal, it is not the only determinant. External factors can also contribute to anxiety arousal (Bandura, 1986a). The more unpredictable and uncontrollable external factors are perceived to be, the greater affect they will have on anxiety arousal. Thus, even a person with a strong sense of coping self-efficacy will still experience some apprehension, if the situational contexts are unpredictable (Bandura, 1997). For example, a driver with high coping self-efficacy in their abilities to prolong the range, may still experience some apprehensions when travelling on a low state of charge, if there is no plug-in point nearby for them to recharge. The evidence reviewed in the previous chapter provided some support for this suggestion. It revealed that state certainty (i.e., route familiarity and trust in range estimates) was important in improving drivers' anticipatory coping, which in turn reduced their range stress. This highlights a further benefit of applying SCT, as this triadic model of reciprocal causation allows an examination of the role external factors play in shaping drivers' range beliefs and subsequent actions. Hence, it could facilitate a comprehensive and integrated evaluation of drivers' range psychology, which has to-date been missing from the literature.

In the process of examining drivers' perceptions of range over time, it is important to acknowledge that much of everyday life is performed frequently and in stable

circumstances (e.g., particular locations, specific times or with certain individuals) (Bamberg, Rölle, & Weber, 2003). To-date, however, no research has examined the effect repeat exposure to range in similar situations, has on drivers' experience of range. The social cognitive perspective offered a useful framework to explore this, and provide a more comprehensive understanding of drivers' range psychology. From this perspective, the repetition of action in stable contexts induces a shift away from intentional control of action to stimulus control (Aarts, Verplanken, & van Knippenberg, 1998; Ouellette & Wood, 1998; Verplanken, Aarts, van Knippenberg, & Moonen, 1998). This process is referred to as habituation, as a consequence changes occur in cognitive and emotional processing. The next section examines these changes in greater detail. First it begins by providing a brief overview of habituated behaviour.

3.2.5 Habitual behaviour

Habitual behaviour originated from behavioural psychology (Bargh & Chartrand, 1999). This early perspective of habituation viewed habits as arising in direct response to an environmental stimulus. Habits were considered „empty constructs“ and were simply characterised by the frequency of the action (Lally, van Jaarsveld, Potts, & Wordle, 2010). Behaviouristic accounts of habituation made no reference to the involvement of cognitive processes in explaining the development, or activation of habitual behaviour (Verplanken, 2006). In more recent times, a social cognitive perspective of habituation was proposed. This viewed cognitive processes as playing a central role in the formation and activation of habitual behaviour (Aarts & Dijksterhuis, 2000b; Aarts, Verplanken, & van Knippenberg, 1997). According to this perspective, habits emerge from intentional behaviour. Repetition of behaviour in consistent settings was assumed to result in the strong formation of a goal-action association. This eventually gives rise to intentional thought being bypassed, with behaviours instead being triggered by environmental cues (Danner, Aarts, & de Vries, 2008). Therefore, goals are critical to the formation of a habit, as without the automatic activation of a goal habituation will not occur. It should be noted that in this instance, the goal-action association refers to desires as well as needs (Aarts & Dijksterhuis, 2000a).

The bypassing of intentional thought results in cognitive processes becoming less complex and strategic. Non-habituated actions benefit from strategic planning to help form goal-action associations (Aarts & Dijksterhuis, 2000a). For example, on initial BEV exposure a

driver may intentionally pre-plan where they are going to use the vehicle, to ensure the range will be sufficient. In contrast, habitual acts do not benefit from strategic planning. This was attributed to the already established goal-action association resulting in strategic preplanning being unnecessary (Aarts & Dijksterhuis, 2000a). Hence, habitual behaviour requires only minimal focal attention and cognitive monitoring. As a result, it is a relatively effortless and non-cognitively demanding process. Indeed, habitual behaviour has been characterised by a lack of conscious awareness, efficiency, unintentionality and uncontrollability (Bargh, 1994). This is in contrast to intentional thought, which is an effortful and cognitively demanding process (Aarts & Dijksterhuis, 2000b). This indicates that drivers may become less aware of the range with experience, as it becomes less cognitively demanding (i.e., requiring less attention and monitoring) with repeat exposure.

Habitual behaviour has also been associated with less feelings of emotional intensity. For example, Wood and colleagues (2002) conducted a self-report diary study asking participants (70 undergraduate students) to record their behaviours, thoughts and emotions once an hour over two days. Behaviours performed habitually were associated with lesser change in emotional intensity than behaviours performed non-habitually. This effect was attributed to the increased exposure to a stimulus. It must be noted that habitual performance was not only associated with lower intensity emotions overall, but these feelings were specifically reflected in lesser feelings of stress and lack of control. These findings indicate that drivers' range concern may reduce with repeat exposure to range in similar situations. Indeed, this could partially explain why drivers' range concern was found to decrease with experience (Franke et al, 2012a; Rauh et al., 2015). However, despite drivers potentially experiencing reduced anxiety with habituation, they may still continue to avoid using the BEV for longer trips, as their use of the vehicle would now be automatically triggered by contextual cues. For example, the goal of going to work could automatically activate the use of the BEV.

Research has shown that once a habit is established it becomes difficult to suppress (Verplanken, 2006). Intentional thought alone was found to be insufficient to displace habitual behaviour, especially in cognitively demanding situations (Aarts & Dijksterhuis, 2000a). For example, Wood and colleagues (2005) examined the habits of college students (57 male; 58 female) as they underwent naturally occurring changes in performance contexts throughout a transfer to a new university. One month before and after the transfer,

students reported on their habits, intentions and aspects of the performance context with regards to three behavioural domains; exercising, reading the newspaper and watching television. The findings were consistent in showing that students maintained strong habits across the transfer regardless of their intentions, when the perceived context remained similar, for example, when they continued to exercise in the same location (e.g., home or gym). However, for students with (a) weak or no habits and (b) strong habits who perceived that the context changed with the transfer, intentions guided their behaviour. This study highlighted the dependence of everyday habits on supporting stimulus cues, as changes in context were interpreted as disrupting habit and bringing them back under intentional control.

Important contextual features will remain similar when drivers switch from the ICEV to the BEV. For example, both vehicles are operationally very similar in terms of handling and acceleration. What is more, the environment the drivers would be using the BEV in would be the same as they are used to driving the ICEV. Thus, drivers' normal driving habits are likely to remain strong across the transfer between the two vehicles. This could partially explain why they were not automatically adopting eco-driving strategies, despite their awareness of them (Neumann et al., 2015). It also implies that drivers' adaptation to the range may not simply be guided by conscious thought, but also past behaviour.

This chapter has provided an overview of the main features of SCT. The next section concludes by outlining and justifying why it was an appropriate theoretical perspective to examine drivers' range psychology over time.

3.3 Conclusions

This chapter outlined that SCT is an agentic perspective. Through forethought people are viewed as able to construct future courses of action, which motivates and guides their behaviour anticipatorily. Therefore, SCT offered an appropriate structure to explore how drivers constructed the range (e.g., their expectations of the range, and the strategies they intended implementing to manage the battery power) and the potential affect this could have on their adaption to the BEV. Critically for the purposes of this research, SCT accounted for the role beliefs play in the arousal and regulation of affective states (i.e., anxiety). Therefore, it could also serve as a useful structure to examine the underpinnings

of drivers' range concern, and the potential impact this could have on their anticipated use of the vehicle, and subsequent actions.

It was also outlined in this chapter that SCT viewed human agency as also including a person's capabilities to reflect on their actions, and make corrective alterations to their thinking if necessary. Therefore, it enabled a framework to examine the longitudinal changes that may occur in drivers' range psychology, as they evaluate their actions and soundness of thinking with experience. Finally, it was explained that from a social cognitive perspective, changes occur in cognitive processing with repeat exposure to a stimuli (e.g., to the range). This gives rise to past behaviour becoming a direct guide for future actions. As a consequence, behaviour becomes less cognitively demanding (i.e., requiring less attention and monitoring) and decreases in emotional intensity. Hence, the application of SCT as a theoretical framework was also beneficial in gaining deeper insight into the psychological changes that arise in drivers' range psychology over time, as a result of their use of the vehicle having become routinized.

3.4 Specific Research Questions

Eight specific questions were formulated in line with the aims and conceptual framework of this thesis. Two research questions related to the drivers' pre-trial perception of range:

1. Why was the range an anticipatory concern and barrier to BEV usage (i.e., where did drivers anticipate potential difficulties in relation to the range)?
2. What strategies did drivers anticipate implementing vis-à-vis range, specifically was this effected by their typical trip length?

Two research questions related to drivers' perception of range after first BEV contact:

3. What effect did first BEV contact have on drivers' perception of range?
4. What effect did drivers' perception of range have on the processing of the information they received during their first BEV encounter, specifically was this affected by their typical trip length?

Four questions related to drivers' perception of range over a sustained period of BEV usage:

5. Why did the range remain a psychological concern and barrier to usage (i.e., where did the drivers experience difficulties in relation to the range)?
6. What effect did drivers' perception of range have on their adaptation to the BEV?
7. What changes occurred in drivers' perception of range with experience, specifically did this influence the strategies they implemented to manage the range?
8. What effect did the drivers' typical trip length have on their adaptation to the range, specifically did this influence the strategies they implemented to manage the range?

The next chapter focuses on the methodological approach used to examine drivers' range psychology over time.

Chapter 4

Methodology

This chapter outlines the methods used for selecting and analysing the data in this research. It is divided into six sections. Section 4.1 presents an overview of the UK BMW MINI E Project. Section 4.2 provides details of the subsample of MINI E drivers selected for analysis. Section 4.3 (divided into a further two subsections) describes the MINI E and charging process. Section 4.4 (divided into a further three subsections) explains the procedure by which the data were collected, in terms of the interviews, questionnaires and travel data. Section 4.5 (divided into a further three subsections) explains the analytical approach used, and why it was appropriate for the present research. Lastly, section 4.7 presents an overall summary of the methodological approach.

4.1 Outline of the UK BMW MINI E project

The UK BMW MINI E project was a 6 month field trial of the electric BMW MINI E. This project was both part of the wider international BMW MINI E field trials (involving trials in the United States, Germany, United Kingdom, France, Japan and China) and the United Kingdom Technology Strategy Board (TSB) Ultra Low Carbon Vehicle (ULCV) Demonstrator Programme (involving low-emission vehicles from eight consortia). These programmes supported research, development and assessment of BEV technologies, with an aim of providing a sustained real-world test of everyday usage. Throughout the trials, analytic research data was collected from both the cars (through on-board data loggers) and the drivers (through questionnaires and interviews). In the UK, the data logger information from the cars was collected by the Centre of Excellence for Low Carbon and Fuel Cell Vehicles (CENEX). Oxford Brookes University was responsible for collecting the questionnaire and interview data from the drivers. I worked full-time as part of this team for 3 years before starting this PhD. My responsibilities included collecting, collating and analysing large amounts of data; producing a number of reports for stakeholders and contributing to various co-authored presentations and publications.

The MINI E project took place in the South-East region of England between December 2009 and March 2011. The study was divided into two separate trials, each lasting 6 months. The first trial (phase-1) took place from December 2009 until June 2010; the second trial (phase-2) ran from September 2010 until March 2011. The trials incorporated drivers in both a private and corporate setting. Twenty MINI Es² were available for members of the public to lease for the 6 month trial period. A further 20 were distributed among members of the four public sector organisations that were part of the MINI E consortium (South East England Development Agency (SEEDA), Scottish and Southern Energy (SSE), Oxford City Council and Oxfordshire County Council). The MINI E trials were launched with an event at the MINI plant in Cowley, where the vehicles were handed over to the drivers. Maintenance, servicing and technical assistance was provided by BMW technical experts (also known as 'flying doctors'). These technicians were supported by selected MINI dealers within the MINI E research area.

Private drivers applied to participate in the MINI E trial either through online or newspaper applications. Corporate drivers were recruited from the aforementioned organisations via internal advertisements. To be eligible to participate in the trials, the selection criteria specified that applicants had to, 1) reside within a geographical triangle running from Andover, Oxford and West London, 2) have a private garage or parking space that would enable the installation of a 240V charging unit, 3) indicate that they drove 300 miles per month. In addition, private drivers had to pay a monthly lease fee of £330 (including VAT, insurance and maintenance); corporate drivers were exempt from having to pay this. Both groups of drivers applied to participate in the trial of their own free volition.

The present research specifically focused on drivers who trialled the MINI E because they had the most extensive data collected. For example, only this group of drivers had data collected immediately after receiving one-to-one training on the vehicle by a BMW technical instructor (full details of the training session are given in Chapter 6). This time point was especially relevant for this research, so that a comprehensive understanding of drivers² self-appraisal of the range prior to BEV exposure could be elicited. As previously stated, the MINI E trial region covered a large geographical area in the South-East of England, incorporating both urban (e.g., Oxford and Guildford) and rural areas (e.g., Wantage and Farringdon). Hence, it provided a unique opportunity to capture drivers² experiences of range in a diverse variety of situations. In contrast, the test areas of the other

car groups were mainly centred in urban locations (e.g., London, Birmingham and Coventry).

4.2 Participant sample

The data from a subsample of 30 drivers (20 private drivers; 10 corporate drivers) were selected for analysis. The drivers were primarily male (21 men; 9 women) and ranged in age from 21-62 years. This sample was chosen on the basis that all drivers had complete datasets to analyse (i.e., interviews, questionnaires and mileage data). All but one driver had access to an ICEV for the duration of the trial. None of the drivers had any prior experience with a BEV. Both private and corporate drivers had sole access to their MINI E for the trial period. Hence, no distinctions were made between them.

Distinctions were made between the drivers with regards to their typical journey length in a normal day. Drivers were categorised as having either a „shorter“ or „longer“ typical journey length. This split was determined by the national average journey length in the UK (7 miles) (DfT, 2013). Sixteen of the drivers (14 private; 2 corporate) were grouped as having a shorter typical journey length; their average journey length was around the UK national average i.e., under 10 miles (single trip). What is more, the majority of these drivers stated their car usage was relatively routine. The other 14 drivers (6 private; 8 corporate) had a typical journey length that was at least double the UK national average. These drivers“ typical journey lengths ranged from 15-42 miles (single trip). Their use of the car also tended to be less routine. For example, some of the corporate drivers in this group stated frequently (i.e., once or twice a month) having to make business trips of up to 150 miles away. This information was obtained from the pre-trial interview question, „What sort of length of journey do you typically have in a normal day?“ Differences between these two groups of drivers are reported in the result sections of Chapters 5 to 7. To ensure both driver groups are clearly and easily identifiable, drivers with shorter typical journey lengths have an „S“ at the end of their driver ID; drivers with longer typical journey lengths have an „L“ (please see Appendix F for a copy of the drivers“ typical journey lengths).

4.3 Details of the MINI E and charging process

4.3.1 The MINI E

The MINI E was a prototype vehicle developed by BMW as a two-seater conversion of the MINI Cooper (please see Figure 4.1). It was a pure battery electric vehicle, powered by a 204hp electric motor and a 35kWh lithium-ion battery. The MINI E was tested according to the California Test Procedure for 2005 specifications, and had an official range of 156 miles under ideal conditions. It was fitted with displays that conveyed information on *energy consumption*, *state of charge (SoC)* and *remaining range* (miles):



Figure 4.1: The BMW MINI E

Energy consumption in the MINI E was displayed through a series of orange lights (please see Figure 4.2). Lights going towards the bottom of the circle indicated energy recovery; lights going towards the top of the circle indicated energy usage.



Figure 4.2: Energy consumption display

The SoC was presented in an analogue format. It indicated how much energy was left in the battery on a scale of 0 to 100 (0 being empty; 100 being fully charged). The remaining range was presented in digital format. This was a predictive assessment of the number of miles remaining, based on the SoC and energy consumption over the last 18 miles driven (please see Figure 4.3).



Figure 4.3: State of charge and digital reader

The MINI E was fitted with regenerative braking which recovered energy back into the battery. It works by converting kinetic energy into electrical energy. Energy regeneration in the MINI E was triggered via the accelerator pedal. As soon as the driver released the pedal, the vehicle decelerated rapidly.

4.3.2 The charging process

Charging units (240V/32 Amp) were installed by Southern Electric at the drivers homes (either in their garage or driveway) and at the organisations participating in the trial. The charging units could fully charge the MINI E's lithium-ion battery from empty in about 4 hours. It should be noted that smart meters were installed, so charging would not begin until the cheaper rate electricity came into operation around midnight. There was a boost function on the charging units, which drivers could press if they wanted to override this (i.e., if they needed to recharge during the day) (please see Figure 4.4).



Figure 4.4: Charging unit

A 6.5m charging cable was supplied with every charging unit (please see Figure 4.5). In addition, each driver was provided with an occasional charging lead. This allowed them to plug the MINI E into any ordinary 13 Amp socket. The lower energy capacity increased charging times to around 10 hours for a full charge. Hence, it was only intended for occasional use (please see Figure 4.6).



Figure 4.5: Charging cable

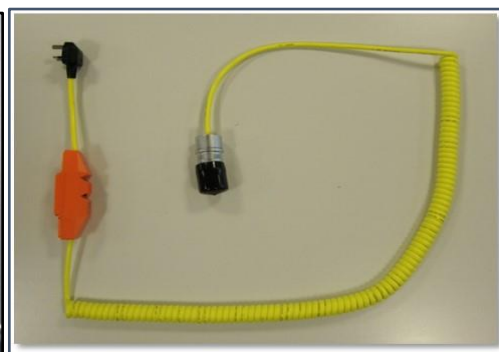


Figure 4.6: Occasional charging lead

4.4 Procedure of data collection

During the MINI E trials, data was collected at the following stages: pre-trial, immediately after drivers had received one-to-one training on the vehicle, and 1 week, 3 and 6 months into the trial. Data was collected via interviews (telephone, face-to-face and focus groups), questionnaires and travel diaries (please see Figure 4.5). Data was only collected from drivers recruited into the trial. Data collected at the 6-month time point was not included, as the focus of this research project was specifically on drivers' perception of range in the first 3 months.

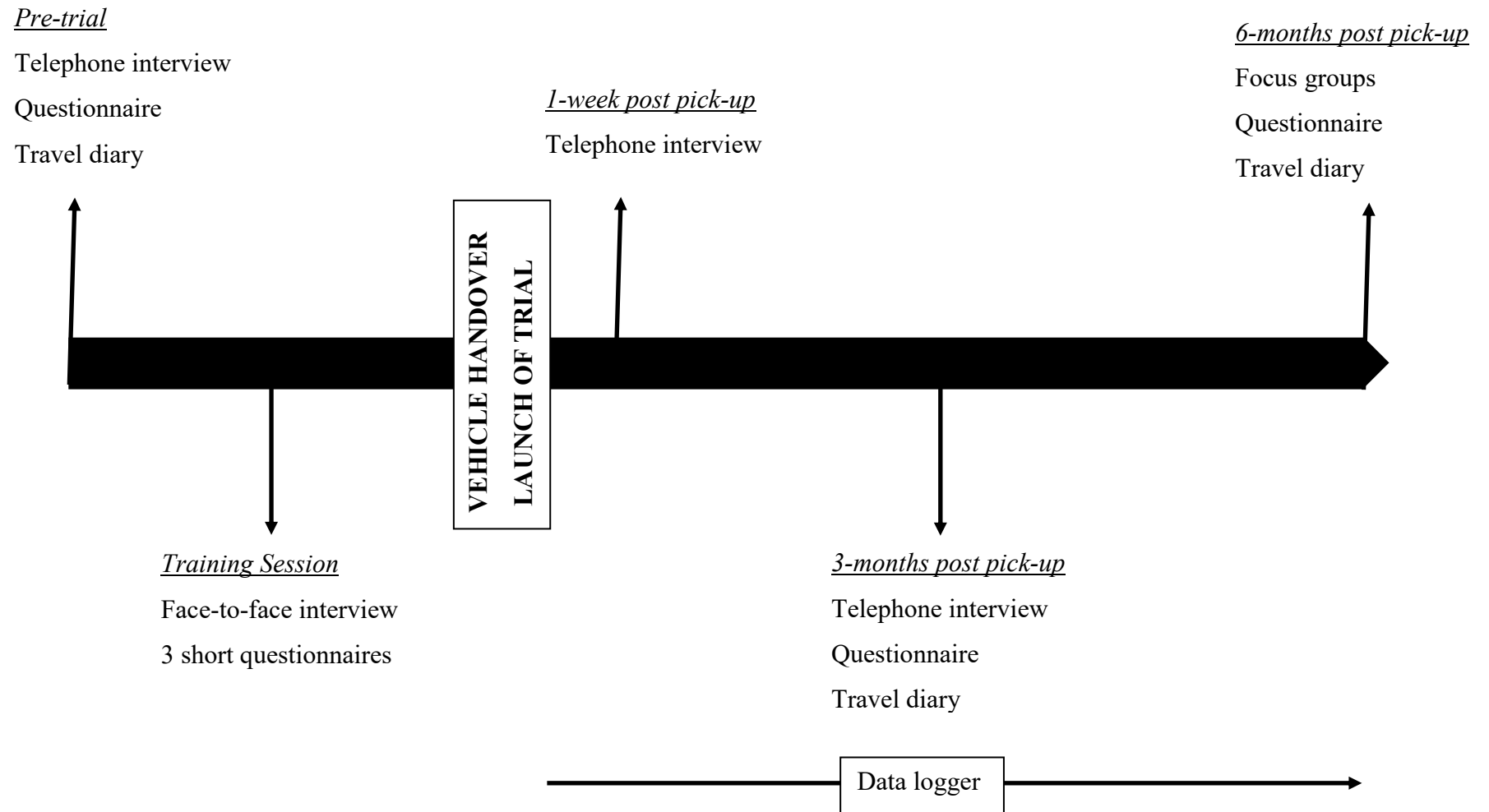


Figure 4.7: Methods applied at each stage of the MINI E trial

4.4.1 Interview procedure and schedule

Interviews were conducted in a one-on-one manner primarily over the telephone at a time convenient to the driver. This was with the exception of the face-to-face interviews conducted immediately after each driver had received training on the vehicle. These interviews were held in a meeting room at the BMW training headquarters, Bracknell. Interviews lasted between 30-90 minutes. They were recorded using a digital voice recorder and later transcribed verbatim. Interviews were conducted by two researchers (including myself) from Oxford Brookes University. Prior to conducting the interviews, training was given on the techniques of interviewing by the project supervisor.

The interview schedule dealt with all major aspects of the drivers' expectations and experiences of BEV usage. This included purely practical aspects of using the BEV (e.g., drivers' attitudes towards the recharging of the vehicle) to deeper, psychological engagement with their cars (please see Appendix B for copies of all four schedules). This research focused on drivers' perceptions of range-related issues. A small number of interview questions directly addressed this topic (e.g., „How will you deal with the range?“). In addition, a number of broader questions also prompted the drivers to remark on these issues (e.g., „What needs to be overcome for the successful widespread adoption of electric vehicles?“). All relevant information provided by drivers was analysed, regardless of the specific questions used to elicit it.

The drivers were prompted by the interviewers to give concrete examples in response to each question, and were encouraged to elaborate on their initial responses with follow-up, narrative inducing probes. This was in accordance with Wengraf's (2001) suggestions for optimal narrative-based interviewing. These probes were rooted in statements which the drivers had made, and the interviewer perceived of interest and wanted to know more about (e.g., „You said that you had experienced a critical range situation once since picking-up the MINI E. Can you tell me more about that?“). This technique leads to additional narrative data, as it allows the interviewer to enter the psychological world of the interviewee (Parker, 2005; Smith & Eatough, 2007). It acknowledges the respondent as an „experiential expert“, who is capable of steering the direction of the interview through accounts of their personal experiences (Smith & Osborn, 2008).

4.4.2 Questionnaires

Questionnaires were distributed to drivers in paper format pre-trial and at the 3 month stage. These questionnaires also covered all major aspects of drivers' expectations and experiences of BEV usage (please see Appendix C for partial copies of both questionnaires). Drivers returned completed questionnaires in the pre-paid envelopes provided. It must be noted that no questionnaire was administered at the 1-week time point.

Three short questionnaires were also handed to each driver in the interview immediately following the training session. These questionnaires specifically focused on drivers' attitudes towards the two new displays (state of charge and energy consumption) and the charging process (please see Appendix C for copies of all three questionnaires). Drivers completed the questionnaires at the end of the interview and handed them back to the researcher. Most of the questions asked drivers to rate statements on a 6-point scale (1=very strongly disagree to 6=very strongly agree). Forty-two questions relevant for this research were identified: 12 pre-trial, 2 after the training session and 28 at the 3-month stage. The mean responses and standard deviation are presented (e.g., $M=5; SD=.89$). The number of responses to each questionnaire item is also presented (e.g., $N=28$) as the drivers sometimes left a question blank (e.g., if they turned over two pages of the questionnaire).

4.4.3 Mileage data

Travel diaries were distributed to drivers at the beginning of the trial and at the 3-month time point (please see Appendix E for a partial copy). Drivers were asked to complete the travel diary for a continuous week of travel (i.e., Monday to Sunday). They were asked to record the start and end time of each trip, and the approximate distance (in miles). Drivers returned completed travel diaries in the pre-paid envelopes provided. The present research did not include the 3 month travel diary. Instead, data logger information was used in the latter two analytical chapters to assess drivers' travel behaviour in the BEV. Data loggers recorded the date, start and end times of each trip, and the distance (in miles). A single trip was counted as key-on to key-off. Data logger information was analysed for the first week of usage and for one week at the 3-month time point. In addition, the maximum distance made in each vehicle over the entire 3-month period was obtained from this data.

4.5 Analytical approach

4.5.1 Mixed methods approach

This research used a mixed methods approach, drawing on interview, questionnaire and travel data. It focused primarily on qualitative analysis of the interview data, supported by the other two methods of data collection. As previously stated in Chapter 2, the existing literature on drivers' experience of range relied on quantitative methods (e.g., CRST and standardised critical range situation). This had led to a number of key range-related issues remaining unanswered, for example, why drivers anticipated the range to be a concern, despite it exceeding their daily needs. The qualitative orientation of the current research enabled an in-depth exploration of drivers' range psychology, and helped deepen knowledge and understanding of the subtleties and complexities surrounding the range. The interview data collected from the MINI E trial was well suited for a predominantly qualitative approach. The semi-structured interviews were designed to encourage drivers to explain and discuss their expectations and experiences, while the use of specific questions ensured that their answers did not differ too widely.

The embedded design most suitably describes the mixed methods approach used in the current research project. This design combines the collection and analysis of both qualitative and quantitative data within a traditional qualitative research design or quantitative research design. Hence, one dataset provides a supportive secondary role in the study (Creswell & Plano Clark, 2011). For example, in this thesis the quantitative data (i.e., questionnaire and data logger information) was used to supplement the interview data. In addition, the collection of the qualitative and quantitative data can occur at the same time with the embedded design (Creswell & Plano Clark, 2011), as was the case with this thesis. This differs to other mixed methods approaches (e.g., explanatory or exploratory) that tend to use a two phase approach. For example, the explanatory design typically begins by conducting a quantitative phase. The second qualitative phase is then implemented for the purposes of explaining the initial results in more depth.

Qualitative methods are regarded by some authors as lacking validity and reliability (Black, 1999). This research attempted to make its findings as credible as possible, by following the guidelines by Braun and Clarke (2006) for conducting a good thematic

analysis (TA) (these systematic steps of analysis are outlined in greater detail in the next subsection). With regard to the presentation of the findings, numbers and percentages are provided for all themes and subthemes presented in the result sections of Chapters 5 to 7. This clarifies the distribution of drivers quotes, in contrast to less clear phrases such as „many“ and „some“ used in other studies (e.g., Graham-Rowe et al., 2012).

4.5.2 *Thematic analysis*

A 120 interview transcripts (30 drivers x 4 time points) were analysed in accordance with the TA guidelines provided by Braun and Clarke (2006, 2012). TA originated from content analysis and is a method for systematically identifying and organising patterns of themes across an entire dataset (Howitt, 2010). This is in contrast to other analytical approaches (e.g., interpretative phenomenological analysis (IPA)) that focus on identifying the unique and idiosyncratic meanings and experiences of only a few participants (i.e., within case approach) (Clarke & Braun, 2016). This was one reason why TA was chosen to analyse the interview data, as this research project aimed to identify what was common to the way drivers talked about range, and to give meaning to these commonalities. The analytical approach TA adopts (i.e., identifying major themes that recur across a dataset) also means it is less labour intensive than either IPA or grounded theory (GT) (Terry, 2016). Thus, it was appropriate for analysing the relatively large qualitative dataset used in this thesis.

TA is a flexible approach, as it is not bound to a particular theoretical perspective. This is the reverse of other analytical approaches (e.g., discourse analysis (DA) or IPA) that require the researcher to first be familiar with the theoretical perspectives on which they are based (e.g., language) (Clarke & Braun, 2016). It is essential that the research knows this background, as it guides how they code and analyse the data. However, the flexible approach offered by TA means that it can be linked to a particular theoretical perspective. Thus, TA can be conducted both inductively (i.e., bottom-up or data driven) or deductively (i.e., top-down or theory-driven) (Braun & Clarke, 2006). This was another reason why TA was selected for use in this thesis. A data driven approach was required to broadly examine how drivers talked about range, as this was an under researched topic. This research project also aimed to use SCT to interpret the dataset. Hence, it would predominantly guide the analysis. Thus, it was essential the analytical approach used could be linked to this concept.

As outlined by Braun and Clarke (2006, 2012), the process of TA involves six steps: 1) data familiarisation, 2) generating initial codes, 3) searching for themes, 4) reviewing themes, 5) defining themes, and 6) producing the report.

1. Data familiarization

The idea of this stage is to allow the researcher to become immersed in the data. During the process of familiarisation, the researcher should begin to develop an understanding and knowledge of the data. This helps prepare them for the more formal stages of initial coding conducted next. I became immersed in the data in a variety of different ways. In the first instance, I was actively involved in interviewing the drivers and transcribing the data. In the second case, on commencing my PhD I listened to the audio recordings of all the interviews from the subsample of drivers used in this research, checking them for accuracy in the process. Finally, I read and re-read each of the transcripts to become familiar with the breadth and depth of information. On the second time of reading each transcript, I highlighted all parts I considered pertinent to the topic of range. This ensured the initial coding of the data was focused on data relevant to this research. I also recorded my initial thoughts and ideas in a notebook to encourage active (or analytical) reading of the data.

2. Generating initial codes

In this step, I coded each line of highlighted text. Codes were noted in the left-hand margin of the transcript. Each code consisted of a word or phrase (e.g., anticipatory range concern). The codes produced were principally descriptive, and stayed as close as possible to the drivers' accounts. I conducted the coding manually by hand.

3. Searching for themes

In this stage, I produced a list of initial codes for each driver and compared them across all drivers. I then collapsed and clustered the initial codes into emerging themes by identifying areas of similarity and overlap between them. At this stage all emerging themes were considered of equal importance. Next, I organised the list of emerging themes into overarching themes and subthemes that shared similar characteristics. During this stage I also collated all the data extracts relevant to each overarching theme (and subthemes) in a

table created in Microsoft Word. This enabled the next step of reviewing the themes to begin.

4. Reviewing themes

The reviewing of themes was an iterative process that involved comparing the developing themes against each other and the collated extracts of data. If there appeared to be too much similarity or diversity, then themes (and codes) were reflected upon again and either separated or collapsed. When the process of theme refinement was complete, the themes were then reviewed in relation to the entire dataset for each time point. This involved a final re-read of all the data, to ensure the themes meaningfully captured the most important and relevant aspects of the data. This stage was mainly about quality checking, which is particularly important when working with larger datasets.

5. Defining and naming themes

When the process of theme building and checking was complete, the central feature of each theme was identified and summed up clearly. The coded extracts within each theme were then compared to ensure consistency. This process sometimes led to further refinement (i.e., merging or separation) of a theme. Next, I produced thematic maps as a means of assisting with the linking of themes, and structuring the data into a coherent overall story. The thematic maps produced are presented throughout the preceding analytical chapters. In this stage, extracts from drivers' interview transcripts were selected to present in the analysis. Extracts were carefully chosen on the basis that they provided the best illustrative example of the point being made.

The above stages of analysis were repeated for each of the four time points of data collection. When this process had been completed, the entire dataset was reviewed for consistency as a whole.

6. Producing the report

The results of the thematic analysis were then written up. The findings from this analysis are presented in Chapters 5 to 7. Throughout the analytical chapters, each theme and

subtheme is discussed and illustrated with two relevant quotes. It must be noted that not all emerging themes were included. A few themes were discarded due to them either not being of relevance to the research aims or only occurring infrequently. Despite some themes being omitted from the results, I believe the following analysis is an accurate and representative account of the MINI E drivers' reports of range.

Qualitative methods acknowledge the researcher as an integral part of the research process, and recognise their experiences, actions and observations in the interpretation of the data (Flick, 2009; Patton, 1990). Therefore, it is important that I reflect upon my own experiences and observations as a researcher, and the influence this had on the interpretation of the analysis.

4.5.3 *The researcher*

My experiences as a researcher on the MINI E project influenced how I interpreted the analysis in various ways. I was able to develop a good rapport with the drivers through interviewing them, and talking to them at various events (e.g., the launch of the trials). This allowed me to develop a deeper level of familiarity with the dataset. I attended all the driver training sessions, and directly observed the information and advice given by the BMW technical instructors. In addition, I was copied into email correspondence between the BMW technical team and the drivers, such as the tips circulated on how to improve the charging of the vehicle in cold weather. This enhanced my understanding of the drivers' accounts of the range, and led to a richer interpretation of the data. Finally, I also had several test drives in the MINI E, which helped me relate to drivers' descriptions of the displays and regenerative braking system. It must also be noted that my interpretations of the analysis was also influenced by SCT, as the theoretical perspective applied to this research.

4.6 Chapter summary

This chapter explained that its dataset was drawn from the MINI E project. It gave a background to this BEV field trial, including the time points and methods of data collection. It described and justified the subsample of MINI E drivers selected for this research. Finally, it explained the analytical methods and defended the use of them. The

methodological limitations of the existing literature (as discussed in Chapter 2) were taken into account, when explaining why the predominantly qualitative orientation was the most appropriate for the present research. This sets the scene for the following three analytical chapters, which chart drivers' range psychology from pre-trial (Chapter 5) through to 3 months sustained BEV usage (Chapter 7).

Chapter 5

Pre-trial perceptions of range

5.1 Introduction

The literature reviewed in Chapter 1 showed the 100+ mile range of the modern day BEV, far exceeds the travel needs of a large market segment (Greene, 1985; Khan & Kockelman, 2012; Pasaoglu et al., 2014; Pearre et al., 2011). Importantly, the research in that chapter implied that at about 100 miles, the range had reached a critical point surpassing the „threshold of inconvenience“ (Tamor et al., 2013). Drivers began to report this range as acceptable for them, and expected it to satisfy 80-90% of all their car trips (Vilimek et al., 2012; Gärling, 2001). What is more, the literature in that chapter demonstrated that substantial increases in range beyond 100 miles, could be detrimental to BEV uptake, with the cost of the batteries out pricing them from the mainstream consumer market (Knutsen & Willén, 2013).

Evidence presented in Chapter 1 suggested the lack of a public charging infrastructure should not be an issue for drivers; it was revealed unnecessary for the vast majority of car trips (Bunce et al., 2014; De Gennaro et al, 2014; Shaw & Bunce, 2015). Thus, the development of a recharging network may not be required to support BEV usage. In addition, the literature in that chapter showed that ICEVs were stationary for long periods of time during the day and overnight (De Gennaro et al, 2014). Hence, the current lengthy charge time of the BEV should not be problematic for drivers. Critically, the drivers themselves did not anticipate a public charging infrastructure would be necessary for them (Bühler et al, 2014; Bunce et al., 2014). What is more, they did not expect the speed of charge would inconvenience them (Carroll et al., 2013; Turrentine et al., 2011).

Despite these favourable findings, the literature in Chapter 1 demonstrated that drivers continued to report the range (and associated recharging) as main barriers to BEV uptake (Bühler et al., 2014; Carley et al., 2013; Carroll et al., 2013; Egbue & Long, 2012). They desired an increase in battery capacity to about 200 miles, a growth in infrastructure and

faster charge times before considering buying one (Bühler et al., 2014; Carroll et al., 2013; Turrentine et al., 2011). So what could account for this discrepancy between the range drivers actually need, and the range they required for BEV acceptance?

Chapter 2 explained that drivers' range concern was proposed as an explanation to account for this „range paradox“ (Franke & Krems, 2013b). It was described in that chapter how drivers' fear of running out of battery power had risen in recent times (Nilsson, 2011a, 2011b); it now ranks as one of the main barriers hindering large-scale BEV application, despite increases in battery capacity (DfT, 2014). It was also outlined in Chapter 2, that to-date no research has examined why drivers perceived the range to be a concern, instead the extant literature focused on increasing stress resistance to range (Franke et al., 2012a, 2012b, 2016a; Franke & Krems, 2013a, 2013c; Rauh et al., 2015, 2017). This was despite drivers' range concern primarily being characterised as an anticipatory one, with them actively avoiding critical range situations (Franke et al., 2012b). Furthermore, this suggests they had already constructed future courses of action to stop them running out of battery power. Indeed, research reported in Chapter 2 revealed that pre-trial, drivers intended leaving a reserve of energy (Franke et al., 2012a). Thus, to develop effective interventions to breakdown range as a barrier to usage, it is of critical importance to understand why drivers anticipated the range to be a concern. In addition, to improve drivers range utilisation behaviour, it is vital to gain insight into the strategies they anticipated implementing to manage the range, and how this affected their intended behaviour.

It was explained in Chapter 3 that through the construction of future courses of action, people set goals and standards that motivates action anticipatorily (Bandura, 1986a, 1997). Thus, subtle differences could exist between the a priori strategies of drivers with longer typical trip lengths in comparison to drivers with shorter ones, as there would be greater motivation for them to conserve the battery power.

The aim of the present chapter was to examine:

- Why range was an anticipatory concern and barrier to BEV usage (i.e., where drivers anticipated potential difficulties in relation to the range), as stated in Research Question 1.

- The strategies drivers“ anticipated implementing vis-à-vis range, specifically if this was effected by their typical trip length, as stated in Research Question 2.

5.2 Results and discussion

Thematic analysis of the pre-trial interview data revealed two overarching themes. In the first instance, drivers“ perceived the range as „*ideal for short commutes*“ (5.2.1). In the second case, they perceived the range as „*uncertain and unpredictable*“ (5.2.2). Drivers“ perceptions of range gave rise to their intended conservative use of the MINI E (5.2.3). The subthemes attached to each overarching theme are outlined in Figure 5.1. Each subtheme is presented in the results with supportive illustrative quotes.

The subthemes attached to each overarching theme were formed through the clustering of distinct data-driven codes. The codes that formed the subthemes in the first overarching theme, *ideal for short commutes*, arose from all 30 drivers“ responses to specific questions asked in the pre-trial interviews. For instance, „What do you think are the biggest barriers for the introduction and acceptance of electric vehicles?“ The second overarching theme, *uncertain and unpredictable*, took a broader perspective and included data drawn from the entire body of the interview. This approach was necessary because the pre-trial interview was not specifically designed to elicit information on drivers“ range concern. The structure provided by these two overarching themes, allowed an examination of the subtleties and complexities of range from a psychological perspective. Critically, it provided insight into why drivers perceived the range to be a concern and barrier to adaptation. It also exposed the strategies they anticipated implementing to manage the range, and the influence this had on their intended behaviour. These two overarching themes were, therefore, felt to provide a structure that addressed the aims of the chapter in the most comprehensive way possible. They also provide a foundational basis for the rest of the analytical structure. Pre-trial questionnaire and travel diary data was drawn upon to support the interview data.

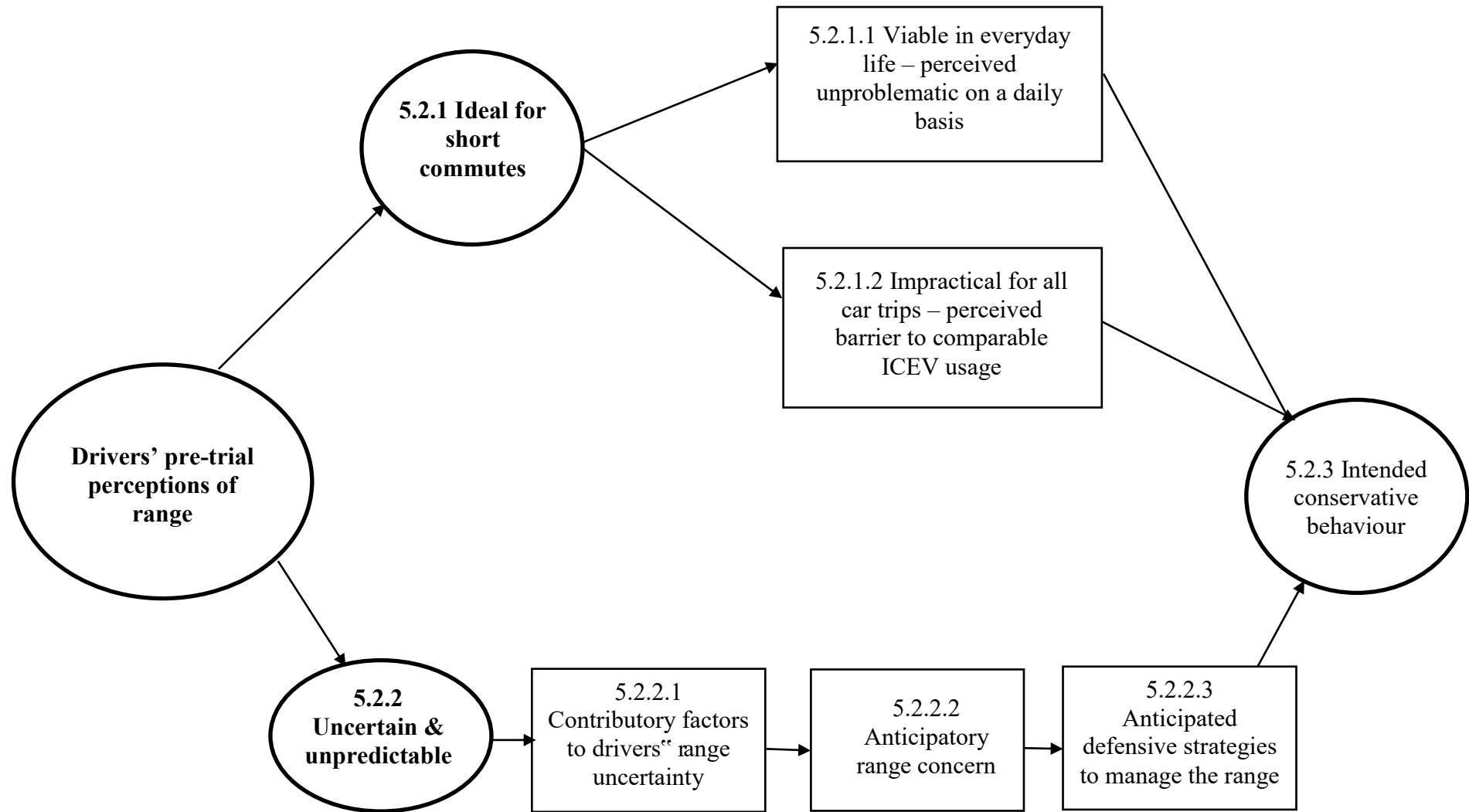


Figure 5.1: Thematic map of Chapter 5 themes and attached subthemes.

5.2.1 *Ideal for short commutes*

The limited range and associated difficulties of recharging (e.g., limited recharging network and lengthy charge times) gave rise to 18 of the 30 drivers (60%) referring to BEVs as a specific type of vehicle. The BEV was perceived as presently ideal for short commutes, but impractical for longer trips. These drivers viewed the BEV as a niche market product. They felt it should be targeted at the second car market, until the battery limitations were resolved:

I think as soon as people realise that the range of these things is currently around [...] 60 to 100 miles, that kind of [...] takes it out of the running for a general purpose car and into the short range [...] short commute type vehicle (Driver 18S)

I think the issue though is that at this moment in time because of primarily the battery technology and the limitations to it, is that EV really is target for secondary car use rather than primary car use. (Driver 26L)

The next two subthemes examine how this image of the BEV influenced drivers' expectations of the viability of the MINI E in their everyday lives (subsection 5.2.1.1), and in terms of being able to completely replace their ICEVs (subsection 5.2.1.2).

5.2.1.1 *Viable in everyday life*

The vast majority of drivers (28/30, 93%) expected the limited range to satisfy their relatively short daily trips. They did not anticipate the battery limitations would interfere with their routine activities. Several of the drivers even referred to themselves as „*lucky*“ (Driver 9S) or „*fortunate*“ (Driver 1S, Driver 7S) that because of their relatively short commutes, they expected the MINI E would be viable for them. This indicates the drivers did not anticipate the range to be a concern to them on a daily basis:

Yeah, it's very suitable for my work requirements. I lead a very regular schedule, you know, I kind of do the same thing every day [...] I'll have more than enough range to sort of make a few stops on the way home. (Driver 9S)

The journeys I'm doing presently, I should be able to do within the range of the MINI E. I'm doing about 100 miles daily and some days less than that. So it fits in nicely with the vehicle at the present time. (Driver 25L)

Pre-trial questionnaire data showed that drivers *agreed* with the statement, „The MINI E will satisfy my daily mobility needs“ (M=4.72;SD=.99;N=29). On average they expected to complete about 87% of their daily trips in the vehicle. Thus, drivers *agreed* with the statement, „Electric vehicles are suitable for daily use“ (M=4.73;SD=.78;N=30). This finding was consistent with the existing literature, which also revealed that drivers anticipated the range would satisfy the vast proportion of their daily trips (Vilimek et al., 2012; Gärling, 2001).

Table 5.1

Ideal Short Commuter Car: Summary Table for Pre-Trial Travel Diary Data

Single Trip Distance		Daily Car Mileage	
Trip Distance	% Accumulative	Daily Car Mileage	% Accumulative
25 miles or under	88%	25 miles or under	41%
50 miles or under	95%	50 miles or under	67%
75 miles or under	98%	100 miles or under	87%
<i>Total number of trips = 603</i>		150 miles or under	94%

Analysis of the pre-trial travel diary data indicated that drivers could have marginally underestimated the viability of the range in their everyday lives. This data showed that 98% of the trips they made in their ICEVs did not exceed 75 miles (single trip distance). What is more, it also revealed that 95% of their trips were under 50 miles (single trip distance). It should be noted that this figure was concordant with the UK National Travel Survey (NTS) data, reported in Chapter 1. This statistical data showed that 95% of all car trips made in the UK were less than 50 miles (DfT, 2013). The travel diary data indicated that a high percentage of drivers' car trips were within the theoretical range of the MINI E. Chapter 4 explained that the BMW Group initially communicated the range of the MINI E as 156 miles. In addition, this data also showed that 87% of drivers' daily car mileage (e.g., total distance they travelled by car in a day) was under 100 miles. Ninety-four percent did not exceed 150 miles. This suggests the theoretical range of the MINI E could have fulfilled a high proportion of drivers' daily needs (please see Table 5.1).

In light of these findings, it was not surprising that 16 of the 30 drivers (53%) anticipated their daily car usage would be unaffected by having the MINI E:

No, I think my [car] usage will be about the same. (Driver 4S)

I don't think my [car] usage is going to change particularly, ok. No it probably won't [...] I would probably do much the same mileage. (Driver 23S)

The above findings suggest the drivers did not expect the range to be an issue on a daily basis. However, they did anticipate the limitations of the batteries would stop them from completing all their car trips in the MINI E. The next subtheme examines this in greater detail.

5.2.1.2 Impractical for all car trips

We know the inferior range, limited recharging infrastructure and lengthy charge times were widely acknowledged as main barriers to BEV acceptance (Bühler et al., 2014; Carley et al., 2013; Carroll et al., 2013; Egbue & Long, 2012). Therefore, it was unsurprising that the vast majority of drivers (23/30, 77%) also cited these factors as hindering BEV adaption. These drivers expected the battery limitations would prevent them using the MINI E in the same way as their ICEVs:

Certainly the speed [of charge] at the moment, as I understand it, is 4½ hours at these special charging stations. And that still is a bit long, if you are going to be using the vehicle in the same way as you would use a petrol or diesel vehicle. (Driver 2S)

I think the barrier at the moment is the range. That's fine for short journeys, but if I was going on a long trip then [...] it would mean I would definitely have to include a big break in my drive. And if I'm doing a nine, ten hour drive to Scotland that would be a hefty add on. (Driver 20S)

This led drivers to assume the BEV could not completely replace the ICEV at the present time. Pre-trial questionnaire data revealed that drivers *agreed* with the statement, „A household would not be able to have an electric car as its only vehicle“ (M=4.00; SD=1.16; N=30). It could also explain why they responded that it was *important* to them that improvements occurred in the „drive range“ (M=5.30; SD=.73; N=19) and the „public

charging infrastructure" ($M=5.15; SD=.98; N=19$), before they would consider buying a BEV in the future. They also stated that it was of *some importance* to them that improvements occurred in the „charging time" ($M=4.50; SD=1.05; N=19$). Developments in these areas could result in the BEV becoming completely comparable to the ICEV.

The results from this overarching theme suggest the stereotypical image of the BEV (i.e., short commuter car because of the battery limitations) played a critical role in influencing drivers' range perceptions. Based on this image, they judged the range as practical for their daily needs. They also inferred the MINI E would be suited to short trips only. This suggests the stereotypical image of the BEV, resulted in the drivers setting lower standards for the role they expected the MINI E to fulfil (i.e., short commuter car). Chapter 3 explained that SCT proposes that people draw on symbolic representations to construct and guide future courses of action in an anticipatory fashion (Bandura, 1986a, 2001a). According to this perspective, symbolic representations can be formed directly from past experiences. They can also be formed indirectly through vicarious experiences (e.g., media sources) (Bandura, 1997, 2001b). In the absence of any direct BEV experience, drivers' understanding of the range would be formed vicariously. Chapter 1 outlined that since the BEV was first invented, its limited drive range has been heavily criticised. Indeed, news articles as early as 1902 referred to the BEV as being „a slave to the wire" (Kirsch, 2000 p.187), with the limitations of the batteries restricting the potential drive range. Over time, this image of the BEV as a limited range vehicle has become embedded within UK culture. It is, therefore, unsurprising that drivers drew upon this image to inform their expectations of how they would operate the MINI E.

These findings also provide some insight into the lack of coherence between drivers' perceptions of what a vehicle can do, and the actual reality of car usage reported previously (Franke & Krems, 2013b; Tamor et al., 2013). The results suggest that drivers' desire for increased range, growth in infrastructure and faster charge times did not manifest from unrealistic expectations of how far they travelled on a daily basis (Franke & Krems, 2013b); they anticipated the range would be (more than) sufficient for their routine activities. The findings, instead, suggest drivers considered improvements in range (and associated recharging) as necessary for the BEV to act as a total replacement for the ICEV. Research presented in Chapter 1 provided evidence in support of this. It revealed that while a range of about 100 miles was sufficient for about 90% of drivers' daily needs, a

substantial rise to about 250-300 miles was necessary to fulfil them all (Greene, 1985; Tamor et al., 2015). This emphasises the critical importance that BEV usage is able to match that offered by the ICEV, for large-scale BEV application to occur within the UK.

Analysis of the pre-trial interview transcripts revealed that drivers also perceived the range as uncertain and unpredictable. The next overarching theme examines this in greater detail. It is divided into three subthemes. The first subtheme describes four factors which contributed to drivers' range uncertainty (subsection 5.2.2.1). The next subtheme outlines how these factors could have given rise to their anticipatory range concern (subsection 5.2.2.2). The third subtheme outlines the strategies they anticipated implementing to prevent the range from being an issue (subsection 5.2.2.3). Numbers and percentages for each of the main categories are presented in Tables 5.2 to 5.6.

5.2.2 *Uncertain and unpredictable*

Table 5.2

Uncertain and Unpredictable: Summary Table for Pre-Trial Interview Data

Relevant Statements	No. and % N=30
Reference to uncertainty in how far the MINI E could go	14 (47%)
Reference to uncertainty in being able to find a plug-in point	10 (33%)
Reference to uncertainty in being able to use a plug-in point	4 (13%)
<i>In relation to non-standardisation of connectors</i>	2 (6.5%)
<i>In relation to charge point already being occupied by another vehicle</i>	2 (6.5%)
Reference to uncertainty in the speed of charge	6 (20%)

5.2.2.1 *Contributory factors to drivers' range uncertainty*

Uncertainty in how far the MINI E could go

Fourteen of the 30 drivers (47%) were unsure how far the MINI E could go, with a fully charged battery:

The concept of how far you can actually go. When I'm driving as soon as the petrol gauge goes into the red I fill up immediately. I'm conscious of that

already, but I'd be even more conscious of that because I don't really know how long a percentage of the battery is going to last. (Driver 3L)

You know how far you can get on a tank of petrol. You always know [...] what you can do. And the only time it changes, is if your car starts to act up. In this case, yeah, it's how long is a piece of string, exactly how far are you going to get? (Driver 28L)

This was most likely attributable to drivers having no direct experience of the range, and the effect external factors (e.g., the heater) had on it. At this stage, they also had no awareness of the accuracy of the range estimates conveyed by the displays.

Uncertainty in finding and using a plug-in point

Ten of the 30 drivers (33%) also cited being unsure if they would be able to find a plug-in point. This could be explained by the public recharging network being in limited availability in the UK, at the time of the MINI E trials:

I'm down in Cornwall at the moment and it was [...] a 4 hour drive down here. So I would probably have to stop somewhere to charge it up, and I wouldn't be quite sure where. And you're not quite sure what service stations are prepared to allow you to plug in somewhere. (Driver 23S)

The unknown part of this, of course, is managing distance against your ability to recharge. (Driver 27L)

A minority of the drivers (4/30, 13%) also reported concerns regarding the reliability of plug-in points. Half of these drivers (2/4, 50%) envisaged potential issues, if the connectors were not standardised:

From what I've read you can't use the charge points in London [...] because it's different connectors. (Driver 4S)

I would imagine that all the car manufacturers have got different plug sockets, so there isn't a standard charge connection. I know that some of the car parks in Westminster have got charging points, but again I don't know what the plug connections are like, and whether they are compatible or not. (Driver 5S)

The other half of these drivers (2/4, 50%) anticipated potential problems, if the charging bay was already occupied by another car:

The only problem I did notice was one place that I went to had lots of charge points, but they made it clear that anybody can park there and it ended up being cars that didn't need charging that parked there. So that's a bit frustrating, you sort of see the spot and think "Oh, next time when I come I'll be able to get there." I walked past it a little bit later and realised that all the cars there, I didn't read the fine print, if these aren't being filled then please take this parking spot, so I thought "Okay, well what's the point?" (Driver 7S)

I know there are recharging [...] points in London, so that's the theory according to the TFL website, how accessible those are in practicality is another matter. (Driver 29L)

Interestingly, these findings indicate that drivers' uncertainty in the public charging infrastructure did not simply relate to its limited availability, but also to potential issues accessing existing charge points.

Uncertainty in the speed of charge

Six of the 30 drivers (20%) also cited being unsure how long the vehicle would take to recharge, but assumed it would be pretty slow. This gave rise to them being uncertain how long they would have to be at their destination, to allow the battery to recharge:

I mean they kind of said to me that at work they had a place that did a quick charge [...] and in a quarter of an hour that would get you home, about 10 miles. But I've no idea whether a quarter of an hour would get you a lot further or whatever, but my guess is that [charging is] not that quick. (Driver 10S)

For instance, whilst I'm at a meeting for three hours would it be possible to charge it up before coming back? Don't know, but it'll be useful to find out because presumably the mains charger adapter thing must be pretty slow. (Driver 15L)

This finding suggests that drivers' uncertainty in the speed of charge, could also have contributed to their apprehensions in using a plug-in point. Contrary to this, the vast majority of drivers (26/30, 87%) did not anticipate any problems recharging at home. They expected this procedure to be as straightforward as plugging in any other electrical appliance:

I don't expect any problems. I'll be interested to find out how you do it in the rain, just because [...] I've no urge to get a perm. (Driver 7S)

Rightly or wrongly I’ve just almost considered it like plugging in any other electrical appliance [...] I don’t see it being any different to that. (Driver 13S)

Drivers also did not anticipate the recharging time to be an issue on a daily basis. Pre-trial questionnaire data showed they *strongly disagreed* with the statement, „I am worried that the charging times will not suit my daily routine“ (M=2.76; SD=1.18;N=29). This was most likely attributable to the lengthy charge time being unproblematic, when charging overnight. These findings are consistent with the previous literature reported in Chapter 1 (Bunce et al., 2014; Carroll et al., 2013; Turrentine et al., 2011). They also suggest that drivers’ concerns regarding recharging were primarily centred on charging outside the home.

The next subtheme examines in greater detail how drivers’ uncertainty in the range (and associated recharging) potentially led to their anticipatory range concerns.

5.2.2.1 Anticipatory range concerns

Table 5.3

Anticipatory Range Concerns: Summary Table of Pre-Trial Interview Data

Relevant statements	No. and % N=30
Reference to anticipatory concern to running out of battery power	15 (50%)
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	10 (67%)
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	5 (33%)
No reference to anticipatory concern to running out of battery power	15 (50%)
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	4 (27%)
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	11 (73%)

Half of the drivers (50%) reported anticipatory concerns to the prospect of running out of charge and being stranded:

If you live in a town and you did run out of electricity, hopefully you would be near somebody that would plug you in for a while. But where I live, I would be stranded. I live in the middle of nowhere, and there’s nobody’s got any extension lead that long. (Driver 6L)

What happens if it breaks down, if it runs out of charge? That's the biggest thing. (Driver 30L)

It should be noted that the majority of these drivers (10/15, 67%) had longer typical journey lengths (15-42 miles) (please see Table 5.3). This suggests the thought of running out of battery power was of greater concern to these drivers, compared to those with shorter typical journey lengths (10 miles or under). This could be explained by the longer journey profile of these drivers, increasing the likelihood of them actually encountering such a situation. Pre-trial questionnaire data supported this finding. It revealed that drivers with longer typical journey lengths (15-42 miles) *agreed* more strongly, than drivers with shorter typical journey lengths (10 miles or under) with the statement, „While driving the MINI E I will be more concerned about the range than I would be in a conventional car with a combustion engine“ (M=5.21;SD=.80;N=14 and M=4.47;SD=1.06;N=15 respectively). This difference was significant (U=62;n=29;p=.045).

Chapter 3 explained that from a social cognitive perspective, it is a person's perceived inability to exert control over a potentially threatening or difficult situation (i.e., low coping self-efficacy), which gives rise to their anticipatory concern (Bandura, 1986a, 1986b, 1997; Ozer & Bandura, 1990). The findings presented in subsection 5.2.2.2 suggested that drivers' uncertainty in: 1) how far they could go on a full charge, and 2) the public charging infrastructure, led them to perceive the range as uncertain and unpredictable. These factors would also limit their ability to avert running out of battery power, should they find themselves in a critical range situation. From a social cognitive perspective, it could be argued that these factors had given rise to drivers' range concerns. This finding carries a number of implications.

In the first instance, the literature reviewed in Chapter 2 proposed the BEVs limited drive range (i.e., distance available on a single charge), as a potential explanation for drivers' range concern (Franke & Krems, 2013b). However, the results from this chapter did not support this assumption. Interestingly, analysis of the pre-trial interviews revealed it was drivers' uncertainty in how far they could go on a single charge that was the contributory factor. This point was illustrated well by one of the drivers, when he commented:

“It would be a shame to find out that [the range] didn't work out and you got stranded, so predictability rather than range. Whatever the range is, live with it,

accept that, but I’d want to know that range is true.” (Driver 15L)

In the second case, the findings from the pre-trial analysis showed the recharging network was heavily intertwined with the range, in giving rise to drivers’ range concern. Indeed, it was a main contributory factor. This indicates that external factors were contributing to drivers’ range concern.

Drivers mentally constructed various strategies to reduce their anticipatory range concern, and safeguard against running out of battery power. These are outlined in greater detail next.

5.2.2.2 Anticipatory strategies to manage the range

Table 5.4

Energy Reserve: Summary Table for Pre-Trial Questionnaire Data

Relevant Questions	Response N=29	
	Mean	SD
Under optimal conditions (low vehicle payload, economical driving etc.) and a fully charged battery I can go for <i>X</i> miles with the MINI E	123 miles	27.00
With a fully charged battery I can confidently drive <i>X</i> miles from the next wall box	94 miles	29.27

Energy reserve

Pre-trial questionnaire data showed that drivers’ expected the MINI E to reach a distance of about 123 miles in optimal conditions with a fully charged battery. However, they only felt confident in travelling approximately 94 miles in the vehicle themselves (please see Table 5.4). These results suggest that drivers anticipated leaving a reserve of energy (or comfortable range). This finding was consistent with previous research reported in Chapter 2, which indicated that drivers had not intended utilizing the full amount of battery power (Franke et al., 2012a). Chapter 3 explained that from a social cognitive perspective, efficacy beliefs play a central role in the regulation of affective states once aroused (Bandura, 1986a, 1986b, 1997). SCT assumes that efficacy beliefs facilitate courses of action that alter the emotive potential of the environment from potentially hazardous to

benign (Bandura, 1986a). This suggests that drivers' intention to leave an energy reserve had enabled them to regulate their range concern. Indeed, it would have the expected outcome of preventing them from running out of charge. However, it would also have the negative consequence of restricting the potential distance they travelled in the vehicle.

These findings also imply that drivers did not expect the MINI E would reach the 156 miles communicated by the BMW Group. This could partially be explained by some of them being unaware of the theoretical range at the time. Interestingly, however, the analysis revealed this was also a partial consequence of drivers' lacking confidence in this estimate. A minority of them (4/30, 13%) spontaneously referred to distrusting this figure:

I think the official range is 150, but we say don't count of more than 100, so I've not counted on more than 90. (Driver 1S)

I know it says 150, but realistically 100 -120, so say [if] it's going to be over 90 miles at the weekend I'll take another car. (Driver 4S)

This suggests the information conveyed on the range did not enhance drivers' confidence in the capabilities of the battery power. It was explained in Chapter 3 that according to SCT, efficacy appraisals are partially influenced by vicarious experiences (Bandura, 1986a, 1995, 1997, 2001b). From this perspective, it could be argued that the information communicated on the range should have instilled a sense of confidence in the drivers, rather than creating distrust. Indeed, this would have been a particularly strong source of influence at this stage, with drivers having no direct BEV experience. Furthermore, the information was conveyed by experts, which should enhance confidence. One potential explanation for this was the theoretical range (156 miles) quoted by the BMW group was obtained under optimal conditions. This could have led to drivers perceiving this as an unrealistic estimate of the distance they could expect under normal driving conditions. This finding indicates that vehicle manufacturers may want to reconsider how they present information on the range to new consumers.

Once drivers had established a comfortable range, they next anticipated strategies (both prior to and while driving) to prevent the battery power becoming an issue within this radius. These are discussed next.

Anticipated strategies prior to driving

Table 5.5

Anticipatory Strategies Prior to Driving: Summary Table for Pre-Trial Interview Data

Relevant Statements	No. and % N=30
Reference to forward thinking of trips	16 (53%)
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	12 (75%)
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	4 (25%)
No reference to forward thinking of trips	14 (47%)
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	2 (14%)
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	12 (86%)
Reference to keeping the battery as charged as possible	15 (50%)

Forward thinking of trips

Sixteen of the 30 drivers (53%) anticipated having to give more thought to the range, in comparison to a tank of fuel. They expected to have to „think ahead“ and be more „aware“ of their plans for the day, to ensure the battery power would be sufficient:

I“ll have to think more about the car that will become more central I think. It will become higher in my list of priorities as I do the job. Whereas, with the car at the minute you just get in, and I know that about every other week I have to fill it up. Whereas, I will have to think about that every day now and indeed every journey perhaps. All times of day I“ll have to think “well I can’t take that car because it won’t get me there and back.” It’s just more perimeters to consider isn’t it really. (Driver 6L)

With a normal vehicle [...] you can just go and fill it up in five minutes at a garage, whereas this is a bit more of a think ahead exercise. (Driver 12L)

This finding could be partially explained by the drivers not yet having any direct experience of the BEV. Thus, their own behaviour would not yet help them automatically determine if the range would be sufficient for their mobility needs. It should be acknowledged that the majority of these drivers (12/16, 75%) had longer typical journey lengths (15–42 miles) (please see Table 5.5). This could be attributable to the range being of greater significance to these drivers, as they would be using a greater proportion of the battery power on a daily basis.

The anticipated forward planning of trips gave rise to half of these drivers (8/16, 50%) referring to a potential loss in spontaneity of travel on a daily basis. They anticipated the limited battery power could potentially prevent them from being able to make ad hoc trips, which suddenly arose during the day:

At the moment [...] especially if I'm not at work, my plans are quite fluid and if I'm in one place and I want to go somewhere else that's absolutely fine, you can just shoot off no problem. But I think it will probably have to be a bit more sort of planned. (Driver 16S)

It just means that [...] journeys that you might make on an ad hoc basis, I might be in Reading heading to x y or z, you might not be able to go to that because you need an additional charge in there, to get there and then back, and then onto home. (Driver 30L)

This provides some evidence that drivers' perceived a certain amount of the freedom and independence now associated with car usage, would be lost with the BEV (Dennis & Urry, 2009; Jensen, 1999; Urry, 2004).

Keeping the battery as charged as possible

Fifteen of the 30 drivers (50%) anticipated keeping the battery as charged as possible. The vast majority of these drivers (10/15, 67%) referred to implementing this strategy to ensure the battery power was sufficient for their mobility needs:

I think it's going to be one of those things, that as soon as you get anywhere with a charging point, you'll want to maintain the charge level in the battery as close to 100 per cent as possible. Just to counter those unexpected events. (Driver 21L)

I'll plug it in at the end of the previous working day to make sure I've got charge. (Driver 26L)

At this stage, drivers would have no awareness of how long a percentage of the battery would last. Therefore, this strategy could have increased their confidence that the range would not be an issue.

It should be noted that not all drivers referred to recharging every night to increase their confidence in the battery power. Four of these 15 drivers (27%) anticipated adopting this

strategy, based on information they had received from the BMW Group. The advice was that it was best to keep the battery as fully charged as possible:

I read somewhere in some of the blurb, that you want to leave it charging every night, so that the thing is fully charged every morning and I would just use it. (Driver 1S)

I've read that it's a good idea to charge daily, even if you haven't used the whole charge, or a lot of the charge. Just to plug it in when you get back and let it charge overnight. (Driver 18S)

This suggests the information drivers received from the BMW Group had actually encouraged them not to push the capabilities of the battery power.

Interestingly, one driver referred to simply plugging-in every night, so that charging became a „no brainer“ or routine activity:

I anticipate just putting it in the garage every night and plugging it in when I get home and then it's kind of a „no brainer“, that if you do it every day you should be fine, rather than leaving it a day and then living a bit too close to the edge. (Driver 12L)

It was explained in Chapter 3 that habituation was associated with frequency of action. The more regularly a behaviour is performed, the more likely it is to become routinized (Bargh & Chartrand 1999; Verplanken, 2006). The establishment of a daily charging routine could help this procedure to become an automatic process. This would make recharging a less cognitively demanding behaviour for the drivers. It could also reduce the likelihood of them forgetting to plug-in at the end of the day, as they would not have to consciously remember to do so.

Anticipated strategies while driving

Table 5.6

Anticipated Strategies While Driving: Summary Tables for Pre-Trial Interview Data

Relevant Statements	No and % N=30
Adapting driving style to conserve energy	5 (17%)
<i>Changing routes to avoid fast stretches of road</i>	2 (40%)
<i>Driving steadier and smoother</i>	3 (60%)
Reference to recharging on route	16 (53%)
<i>To extend the distance travelled in the MINI E</i>	8 (50%)
<i>In an emergency situation only</i>	8 (50%)
<i>Using a public plug-in point</i>	4 (25%)
<i>Using a standard 13A socket</i>	12 (75%)

Adapting driving style to conserve energy

A minority of drivers (5/30, 17%) reported potentially adjusting their normal driving habits, to reduce the energy consumption rate of the vehicle. In the first instance, 2 of the 5 drivers (40%) considered selecting different routes (e.g., to work) in order to avoid fast stretches of road:

I think I'm going to stop going on the motorway and take the back roads [to work]. (Driver 9S)

I think probably what you're gonna look at is shortest distances, rather than quickest journey times. I mean my journey into work, I can either go by back roads or I can come up, come down motorways. I mean at the moment I go down the motorways, but I can see that I may be going cross country. (Driver 21L)

In the second case, 3 of the 5 drivers (60%) anticipated adopting a more sensible driving manner (e.g. steadier and smoother), in an attempt to prolong the battery life:

You might be slightly more aware of your driving style. Assuming this thing has some sort of miles you need to plug in type readout, so you can tell when you are about to embarrass yourself and have to stop. So I can imagine that might kind of concentrate your mind on driving more smoothly, more sensibly

to maximise your mileage. (Driver 12L)

I think it will probably just make me much more aware of the way that you're driving, and the way that you use the energy that the car has really [...]. Now I'm guessing with an electric car it also makes a difference whether you're driving at one speed or another [...] so I think just much more aware of the speeds I'm going and how much [...] energy [I'm using]. (Driver 16S)

Interestingly, these findings suggest the strategies drivers anticipated implementing to manage the range primarily occurred prior to driving, rather than while they were actually in the vehicle. Indeed, very few drivers anticipated making changes to their normal driving habits. This point is discussed in greater detail in subsection 5.2.3.

Recharging on route

Sixteen of the 30 drivers (53%) referred to recharging on route. This was primarily at a standard 13A socket, rather than at a public charging point (please see Table 5.6) - it was outlined in Chapter 4 that the MINI E came equipped with an occasional charging lead, allowing the vehicle to be plugged into a 13A socket. Half of these drivers (8/16, 50%) anticipated recharging at their destination, as a strategy to extend the distance they could travel:

I have contemplated slightly longer journeys, in which I could envisage either the option of doing a commute up to the range of the vehicle, or maybe plugging it in at friends or relatives. Because I am aware that you can do that as long as you are prepared to do that for 10 or 11 hours, but that would certainly be possible for an overnight trip. (Driver 2S)

If it's quite a long way, and I wouldn't be able to do the round trip without recharging, then I'd have to make sure they had an appropriate charge area, or electricity point that I could charge the vehicle. (Driver 24L)

The other half of the drivers (8/16, 50%) anticipated recharging on route in an emergency situation only. For instance, if they miscalculated the distance of a trip, this gave them some reassurance they could find somewhere to plug-in:

If you do get stuck there is a charging facility with the 13 amp plug, which takes a lot longer, but then you don't need to charge it up fully to get home. So I think that is not a thing I would intend to use, apart from in cases where I made a mistake. (Driver 1S)

I know there are electric charging points in certain places as well, which is great because that's certainly something that would help out if you got stuck. (Driver 19S)

These results indicate that very few drivers anticipated using the vehicle in situations that would challenge the battery capacity. It also suggests that only a minority of them anticipated using a public charging point. This point will also be discussed further in subsection 5.2.3.

The next theme outlines how drivers' perceptions of the range (and anticipated strategies) affected their intended behaviour.

5.2.3 *Intended Conservative Behaviour*

The vast majority of drivers (25/30, 83%) intended using the MINI E whenever possible, there and back, on a single charge. They anticipated avoiding using the vehicle for exceptional, longer, trips such as, „going to Scotland at Christmas time" (Driver 7S), „visiting family up in Norfolk and down in Wiltshire" (Driver 18S) and „attending board meetings in Cambridge" (Driver 1S):

Obviously we have other cars, so for the longer journeys we won't use [the MINI E], but for the majority of our journeys we will. (Driver 11S)

I don't envisage taking the Mini for long journeys really. Yeah, I'm kind of thinking it'll be great round Oxford. (Driver 17S)

This finding could be explained by drivers having set low standards for the role they expected the BEV to fulfil. For example, they perceived this type of car as currently ideal for short commutes because of the battery limitations. This could have led to them developing intentions to use the BEV conservatively.

The findings from this analysis also reveal that the vast majority of drivers (25/30, 83%), did not expect to make any changes to their normal driving habits to conserve the battery power (e.g., driving smoother and steadier):

Well I doubt it, no. Because I like to drive in a sporty fashion and this one appears to allow me to carry on in a sporty fashion, without worrying too much about other aspects of doing that. (Driver 11S)

It's difficult to say at this stage, but I don't expect it to change. (Driver 14S)

This finding was supported by pre-trial questionnaire data, which showed drivers *strongly disagreed* with the statement, „My manner of driving will change as a result of using an electric vehicle“ ($M=2.55; SD=1.38; N=29$). It was explained in Chapter 3 that SCT viewed personal standards and goals as motivators of action. From this perspective, people mobilize their efforts on the basis of their anticipatory estimates of what it would take to reach those standards (Bandura, 1991; Bandura & Woods, 1989). The results from the pre-trial analysis indicates that drivers did not anticipate pushing the battery capacity. This could have led to there being little motivation for them to conserve the battery power, and explains why they did not intend changing their normal driving habits.

These findings also provide further insight into why only a minority of the drivers (4/30, 13%) anticipated using the existing public charging infrastructure. By restricting the use of the MINI E to journeys within the range, drivers could also avoid using plug-in points. This extends on the research presented in Chapter 1, which reported drivers did not expect a public charging infrastructure would be necessary for them (Bühler et al., 2014; Bunce et al., 2014). While this may be true for the vast majority of their trips, the pre-trial analysis suggests drivers did not intend using the vehicle for trips that would require them to recharge.

5.3 Conclusions

The present chapter aimed to examine why drivers perceived range a psychological concern and barrier to usage (i.e., where they anticipated challenges in relation to range). Pre-trial analysis showed that drivers were unsure how far they could go on a single charge. We know SCT views anxiety arousal as arising from a person's perceived inability to exert control over a situation (i.e., low coping self-efficacy). Thus, this theoretical perspective was useful to contextualise that drivers' uncertainty in estimating range could partially explain their anxiety arousal, as the battery power would have been unpredictable and uncontrollable to them. The public charging infrastructure was a further area of uncertainty for drivers. This did not simply relate to the limited availability of charge points, but also to plugging in at one (e.g., if the charge point was out of order or already occupied). SCT proposes that external factors can also contribute to anxiety arousal. The

more unpredictable and uncontrollable external factors are perceived to be, the greater affect they have on anxiety arousal. Thus, SCT could argue that the underdeveloped state of the public charging infrastructure had also contributed to drivers' range concern.

Pre-trial analysis revealed drivers perceived the BEV as ideally suited for short trips because of the battery limitations. Thus, they foresaw range as a barrier to them using the BEV in exactly the same way as their ICEV. This contradicts previous research that proposed drivers' range concern could potentially account for this (Franke & Krems, 2013a). SCT posits that people draw on direct and vicarious experiences to construct future courses of action. In the absence of any direct BEV exposure, this concept was beneficial in contextualising that the „short commuter“ image of BEVs in the UK was instrumental in forming drivers' perception of range. It also implies this stereotypical image was critical in informing drivers' judgements of the role they expected the MINI E to fulfil, and could have contributed to them setting how aspirations for the use of the vehicle.

This chapter also aimed to examine the strategies drivers anticipated implementing vis-à-vis range, specifically if this was affected by their typical trip length. Pre-trial analysis showed drivers anticipated erring on the side of caution and leaving an energy reserve. SCT proposes that self-efficacy beliefs also play a key role in the regulation of affective states (e.g., anxiety) once aroused. Through the construction of future courses of action, people turn potentially hazardous situations into benign ones. Thus, a social cognitive perspective could suggest that drivers anticipated leaving an energy reserve, to safeguard against finding themselves in a critical range situation. Thus, prior to stepping foot in the BEV, they had already constructed strategies to prevent range being problematic.

Drivers anticipated having to think ahead to ensure they had sufficient range for their needs. SCT states non-habituated behaviour is guided by conscious thought. Thus, it benefits from strategic planning, as the goal-action association that automatically triggers habituated behaviour has not yet formed. SCT was useful to contextualise that this finding could be attributable to drivers having no previous BEV exposure. Thus, their use of the vehicle would be guided by conscious thought, and rely to a greater extent on the strategic planning of trips. Interestingly, drivers with longer typical trip lengths primarily anticipated implementing this strategy. This could be a result of their daily needs using a larger proportion of the battery power. Hence, there would be greater need for the forward

planning of trips to ensure they had enough battery power. Importantly, this implies drivers' typical trip length had an effect on the strategies they anticipated implementing vis-à-vis range.

Drivers did not intend adjusting their normal driving habits to prolong range. SCT suggests that through the construction of future courses of action, people set goals and standards that mobilize action anticipatorily to reach them. This concept was useful to interpret this finding, as drivers anticipated using the vehicle within their comfortable range. Hence, there was very little incentive for them to adjust their driving style to extend range, as they did not intend pushing the battery power. The findings from this chapter were published in the conference proceedings of the 5th international conference on Applied Human Factors in Ergonomics held in Krakow, Poland (Mansbridge, Burgess, & Harris, 2014).

As stated in Chapter 4, the MINI E drivers received one-to-one training on the vehicle from BMW technical experts. We know from Chapter 3 that mastery experiences provide the most influential source of efficacy information (Bandura, 1997). Vicarious experiences and verbal persuasion can also affect a person's efficacy beliefs. It was noted that these modes of influence are particularly strong source in: 1) the early stages of development, and 2) when it is received from a credible source (Bandura, 1986a, 1995, 1997). This implies the training session was a critical period of time, when drivers' self-appraisal of the range could undergo substantial changes. The next chapter examines this in greater detail.

Chapter 6

Perceptions of range after first BEV contact

6.1 Introduction

All MINI E drivers received one-to-one training from a BMW technical expert. Training sessions were held at the BMW headquarters in Bracknell, and lasted about three hours. During each session, drivers were introduced to the vehicle's unfamiliar features (i.e., new displays and regenerative braking - outlined in Chapter 4). They then had a test drive, accompanied by a BMW technical expert; this was a 10 mile standardised route close to the BMW training headquarters.

The new displays in the vehicle (i.e., SoC and energy consumption) were designed to assist the drivers in estimating the remaining battery power. In addition, the primary function of regenerative braking was to save energy, and enable drivers to extend the potential range. It was outlined in Chapter 3 that mastery experiences are the most influential source of efficacy information (Bandura, 1995, 1997). Thus, the MINI E drivers' first experience of these features could have enhanced their perceived ability to predict and exert influence over the range, which in turn could have reduced their anticipatory range concern. Research presented in Chapter 2 provided some support for this; trust in the range estimate was found to enhance anticipatory coping and reduce range stress (Franke et al., 2016a).

Although first contact with the BEV's unfamiliar features could influence drivers' perceptions of the range, how this information is cognitively processed will partially depend on the self-beliefs it is integrated into. Chapter 3 explained that pre-set beliefs exert a selective self-influence. People attend to aspects of their environment perceived to be of importance, and ignore non-relevant features. Thus, pre-set beliefs bias what people look for, and how they interpret and integrate the efficacy information generated from dealings with their environment (Bandura, 1986a, 1997). Range is likely to be salient for drivers with longer typical trip lengths, as they would use more of the battery power. In contrast, it would be less relevant for drivers with shorter typical trip lengths, as they would use only a fraction of the battery power. Thus, the drivers' typical trip length could potentially

influence what they select as important, and attend to during the training session. For example, a driver with a short typical trip length may not perceive the SoC estimate as personally important to them. As a consequence, minimal cognitive monitoring and attention may be given to this feature.

During the MINI E training sessions, the BMW technical experts gave advice and demonstrations on how to use the unfamiliar features. For example, drivers were told the maximum real-world range was between 100-110 miles. It was also pointed out to them that this made it easy to calculate the remaining range, as 100% charge roughly equated to 100 miles. Chapter 3 explained that vicarious experiences and verbal persuasion can strengthen a person's beliefs in their capabilities. These modes of influence are particularly salient in the early stages of skill acquisition, and when the persuader themselves possess a rich knowledge base in the activity (Bandura, 1986a; 1997). Thus, the advice from the technical experts is likely to have had a particularly strong influential effect on drivers' perception of range, and could have enhanced their confidence in the battery capacity. Research presented in Chapter 2 provided some support for this; it showed that providing drivers with coping information (i.e., advice on eco-driving strategies) prior to their first BEV encounter improved their subjective range competence (Rauh et al., 2017).

In conclusion, BEV training sessions represent a critical period of time, when substantial changes may occur in drivers' perception of range that could potentially reduce their anticipatory range concern. Thus, it is a critical gap in the literature that to-date this has not been investigated.

The present chapter aimed to examine:

- The effect first BEV contact had on drivers' perception of range, as stated in Research Question 3.
- The effect drivers' perception of range had on the processing of the information they received during their first BEV encounter, specifically if this was influenced by their typical trip length, as stated in Research Question 4.

6.2 Results and discussion

Thematic analysis of the post-technical instruction interview data revealed two overarching themes for this chapter: „*Unpredictable and uncontrollable*”(6.2.1) and „*Interpretative and attentional bias*”(6.2.2). The subthemes attached to each theme are outlined below (please see Figure 6.1). Numbers and percentages for each of the main categories are presented in Table 6.1 to 6.3. The first overarching theme addresses the impact first BEV contact had on the drivers’ perception of the range (i.e., how predictable and controllable they perceived it to be). The second overarching theme provides insight into the effect drivers’ pre-set beliefs had on the processing of the information they received during the training session. Each overarching theme builds on the analytical structure established in the last chapter. The interview data is supported by the post-technical instruction questionnaire data. It should be noted that a 5-point scale was used at this stage (1=strongly disagree to 5=strongly agree).

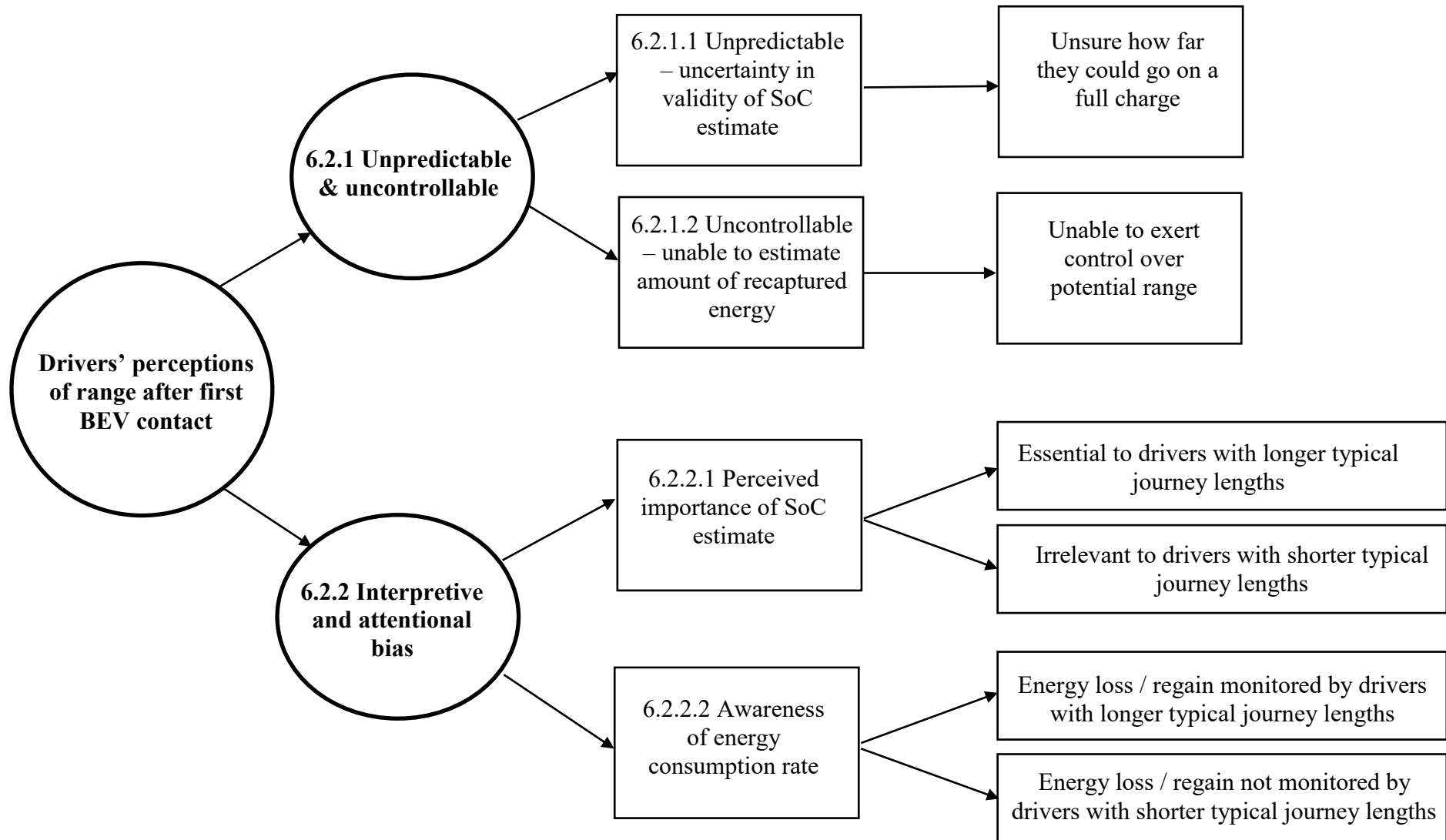


Figure 6.1: Thematic map of Chapter 6 themes and attached subthemes.

6.2.1 Unpredictable and uncontrollable

6.2.1.1 Unpredictable

Table 6.1

Unpredictable: Summary Table for Post-Technical Instruction Interview data

Relevant Statements	No and % N=30
Reference to uncertainty in how far the MINI E could go	13 (43%)
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	9 (70%)
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	4 (30%)
Reference to uncertainty in accuracy of SoC estimate	21 (70%)
Reference to suspecting the SoC estimate may be inaccurate	9 (30%)

SoC estimate

Thirteen of the 30 drivers (43%) remained unsure how far they could go in the MINI E after their first experience of the vehicle.

So what I'm really trying to understand is how many more miles have I got.
(Driver 21L)

It's the unpredictability of am I going to make this journey. (Driver 29L)

Drivers' uncertainty in predicting the range could be attributable to them not yet having built-up confidence in the SoC estimate. Indeed, the vast majority of them (21/30, 70%) were unable to judge if this was an accurate measure.

No idea. I mean I've not had one go wrong on me yet! (Laughs) (Driver 11S)

I'll come back to you on that after I've tested it for a while. (Driver 13S)

Interestingly, over half of these drivers (13/21, 62%) reasonably expected the SoC would be pretty accurate. With no previous experience of the range, they would be completely

reliant on this estimate. Thus, it would be problematic for them if they were to discover it was inaccurate:

Oh well I'd be assuming it's reliable. That's my assumption. If it's not then I'll be disappointed. I mean it's got to be somewhere near hasn't it? And if actually it can somehow be tricked, then that would be a major problem with it, because I would trust that it was correct. (Driver 15L)

I have no idea. I would assume pretty reliable, otherwise I'm going to get stranded. (Driver 26L)

These results bring into question whether the findings by Franke and colleagues (2016a) were actually reflecting confidence in the accuracy of the range estimate, or simply a „forced trust“ with no other means of calculating the remaining miles.

A minority of the drivers (9/30, 30%) noticed the SoC had dropped faster than expected during the test drive. As a consequence, they suspected this estimate was not completely accurate:

I did notice that the battery consumption was slightly different to what I'd expected. Because it started off with a near full charge and [...] we did drop about 20%. I don't think we did 20 miles, so I was wondering about the precision of the gauge (laughs). (Driver 3L)

[The SoC display] seem[ed] to drop a section quite quickly. And then the next section goes quite slowly, [...] but it may be more reliable than that. (Driver 10S)

Thus, the findings from the present analysis imply that initial exposure to the SoC estimate had not improved drivers' confidence in predicting the range. To the contrary, it could actually have increased uncertainty in their ability to judge the distance remaining.

It is noteworthy to mention that a minority of the drivers (5/30, 17%) did anticipate becoming more familiar with how far they could go over time:

I think that [...] over time you'll get to know how far you're travelling, „Oh yeah, I've got 50%“ without looking at it constantly [...] you'll know how much you can go each week. (Driver 17S)

I would imagine that you would be over cautious to start with and constantly having it charged up, but as you get into a pattern you get more confident with what you do. (Driver 27L)

Interestingly, this implies drivers already realised their own behaviour would help them determine the range. It also suggests they could become less reliant on the SoC estimate with experience.

A minority of the drivers (7/30, 23%) expected calculating the remaining miles from the SoC would be easy. This was based on the assumption that the information communicated to them was correct (i.e., 100% charge roughly equated to 100 miles):

[The technical instructor] made the very valid point that although the ultimate range of the car is about 150, as expected it will really be between 100 – 110, so the fact that gauge goes up to 100 is a good indication of how many miles you've got left, which is probably a good tip, because you could say if it's at 100% it will do 100 miles, 50% would be 50 miles so that's quite nice. (Driver 2S)

So with a range of a hundred miles and a scale of 0-100 you can tie the two together quite easily. As its 100% and its 100 miles it's quite easy to work out. (Driver 20S)

Post-technical instruction questionnaire data supported this finding, it revealed that drivers *agreed* with the item, „I thought the state of charge was easy to use“ (M=4.35; SD=.81;N=20). It also implies that this advice led them to expect a maximum range of about 100 miles under normal driving conditions. Chapter 3 explained that verbal persuasion can strengthen a person's beliefs in their capabilities, if set within realistic bounds. In contrast, misleading persuadory appraisals that overinflate them can have an undermining effect (Bandura, 1995, 1997). Thus, this advice could enhance drivers' confidence in the range, providing it does not overstate the battery capabilities under normal driving conditions.

6.2.1.2 Uncontrollable

Consumption display

Post-technical instruction questionnaire data showed that drivers *agreed* with the questionnaire item, „I thought the consumption display was easy to use“ (M=4.12; SD=1.12; N=20). However, the vast majority of them (26/30, 87%) had no understanding of how much energy had been saved:

Don't know, it's difficult to judge [...] I don't know without having taken the car. (Driver 4S)

I have no idea at the moment. (Driver 5S)

This resulted in about half the drivers (14/30, 47%) referring to the consumption display as uninformative; it only indicated where energy was lost or regained, but critically not the amount:

It's a rough guide of what's happening. [...] As it stands it just tells me you are using or you are generating [...] 2 notches, 1 notch, 1½ notches or a flashing second one. Doesn't really tell me too much today. (Driver 3L)

I think it gives an indication if it's earning or exerting, that's the impression I get. But it doesn't have a quantity, it's not quantified. I think it's just an indication rather than an actual measurement. (Driver 9S)

The majority of the drivers (20/30, 67%) questioned the usefulness of the display. They viewed it as a „*gimmicky*“ feature that would be of limited value to them:

I'm not sure how much I really would look at it, once I get use to the car because you're probably going to know that it's obvious that if you're accelerating it's going to go up one side, and it's obvious that if you're not accelerating it might be the other way. So in some ways is it a bit gimmicky? Could be, I don't know. So it's slightly more in the toy area from my point of view anyway. (Driver 12L)

Not really that useful. It's interesting but probably not that useful. (Driver 19S)

Regenerative braking system

Seventeen of the 30 drivers (57%) rapidly adapted to regenerative braking. Some of them referred to this as a very „natural“ (Driver 4S) or „intuitive“ (Driver 20S, Driver 22L) way of driving:

[Regenerative braking is] surprisingly easy to get used to actually. I mean, by the end of that journey I was just using it completely normally. (Driver 18S)

[Regenerative braking] takes no time to get used to, just a few minutes and I was away. (Driver 28L)

These results are consistent with findings from previous research (Carroll et al., 2013; Cocron et al., 2013; Turrentine, 2011).

The vast majority of the drivers (28/30, 93%) were surprised how quickly it slowed the vehicle down to a virtual standstill:

The regenerative braking was a bit of a surprise because that does virtually stop the car. (Driver 22L)

The moment I take my foot off the accelerator the car slows down [...] and quite significantly. (Driver 24L)

The regenerative braking was so abrupt that 26 of the 30 drivers (87%) reported only having used the normal brakes very occasionally (e.g., when bringing the vehicle to a complete halt). These findings have important implications for vehicle manufacturers, as it suggests the sharp set-up of the regenerative braking system was optimal for maximising energy recovery – irrespective of how motivated drivers were to save energy, it forced them to use this feature.

Seventeen of the 30 drivers (57%) viewed regenerative braking as advantageous in making driving easier:

It's just quite easy to drive. I mean I said to one of those guys, it's quite nice not to have to move your foot, apart from just do that. You haven't got to split between pedals or anything. If you're thinking ahead a little bit you don't need to. So it's pretty easy to drive it, it's easy to drive it lazy mode. (Driver 12L)

It's easier to drive. It's not that difficult to drive using two pedals, but only having to use one makes it even easier. Something that was already simple is even simpler. (Driver 20S)

Only a minority of them (7/30, 23%), however, reported saving energy as a benefit; this was despite energy recovery being the primary function of this feature. What is more, less than half these drivers (3/7, 43%) cited regenerative braking as advantageous in extending the range:

If you're taking the car to the limits of its distance [...] you can actually see well that's alright I know there's a few hills on the way back, you can add that to your equation, because at one stage you might think you've only got enough to get you say 30 miles, but you know you've got to go 40 miles, you could then make allowances, hold on a minute I'm going down all those hills [...] I've done all the uphill struggle and that's the reason why I've used so much, but now I'm going down a little bit [...] so I'm actually going to gain on that. So then you can think well now that's showing me that, but I think I can get there. (Driver 25L)

The regenerative bit will actually put the power back in and you've found that if you drive in a certain way, then you actually have that little extended range with it as well. (Driver 27L)

The other drivers (4/7, 57%) referred to it as a feel good factor in preventing energy wastage and providing free energy:

[The regenerative braking] makes you feel good I suppose [...] free energy. (Driver 1S)

What is really good is that you know it's regenerating, so it's not wasting that energy [...] which is good. (Driver 15L)

These findings imply that very few drivers saw the benefits of regenerative braking in extending the distance they could travel. This could be partially attributable to the training session not being a long enough period of time for them to determine this. However, it could also be a consequence of the consumption display not indicating the amount of energy recovered. Introduction to regenerative braking was, therefore, unlikely to have altered their perceived ability to exert influence over the potential range.

Analysis of the post-technical instruction interview data revealed that drivers' pre-existing beliefs had a selective self-influence. The next theme examines this in greater detail.

6.2.2 Interpretive and attentional bias

6.2.2.1 Interpretative bias

Table 6.2

Interpretative Bias: Summary Table of Post-Technical Instruction Interview Data

Relevant Statements	No. and %
Reference to SoC being an important display	N=13
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	8 (62%)
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	5 (38%)
Reference to SoC not being an important display	N=8
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	2 (25%)
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	6 (75%)

Importance of SoC estimate

Thirteen of the 30 drivers (43%) perceived the SoC as a critical display that conveyed essential information. Thus, some of them stated its focal position in their eye-line was correct:

[The SoC display] will be critical to me. Yeah, it will be everything.
(Driver 8L)

[The SoC display] is definitely essential. You have to have it. It's not just useful, it's essential. It's part of all the indicators that you need. Yeah, you can't live without it. (Driver 30L)

Eight of these 13 drivers (62%) had a longer typical journey length (15-42 miles) (please see Table 6.2). These drivers are likely to have a greater awareness of diminishing battery power, and rely on the display for information. In contrast, 8 of the 30 drivers (27%) reported the SoC estimate as less important. Some of them cited a preference for other

displays to have been in front of them (e.g., speedometer), as they perceived this information as more relevant to them:

If you say I've got 100 miles and I know that it is fully charged and I'm not going anywhere near 100 miles then frankly the [SoC] display isn't relevant. (Driver 14S)

I would rather have seen the speedometer in front of me, where it is on a standard car because [...] I think really you should be more focused on what speed you're doing because that's what's important when you're driving on the road. So the actual power left in the battery [...] is not something that you should worry about that much, so it doesn't need to be right in front of you. (Driver 23S)

Six of these 8 drivers (75%) had shorter typical journey lengths (10 miles or under). The diminishing battery power is unlikely to be such an issue for these drivers. As a consequence, they are unlikely to be so reliant on this estimate.

6.2.2.2 Attentional bias

Table 6.3

Attentional Bias: Summary Table of Post-Technical Instruction Interview Data

Relevant Statements	No. and %
Reference to awareness of energy consumption rate	N=5
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	5 (100%)
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	0 (0%)
Reference to minimal awareness of energy consumption rate	N=11
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	4 (36%)
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	7 (64%)

Five of the 30 drivers (17%) had shown awareness of the energy consumption rate during the test route:

I looked at [the consumption display] whenever we changed environments. Like if we were going up a hill as opposed to down a hill, or out in the country and town; just when it was significantly a different area to compare. (Driver 6L)

I would say I was a bit kind of [...] quite focused on looking at the dial that says how much you're regenerating and how much power you're using. I was surprised where it was regenerating as well because roads that I would have thought were flat, there was a bit of regen [...]. I wasn't accelerating or was just slightly decelerating and it was regenerating there. (Driver 21L)

All these drivers had longer typical journey lengths (15-42 miles) (please see Table 6.3). Hence, understanding where energy loss and recovery occurred would be of greater relevance to them. In comparison, 11 of the 30 drivers (37%) had taken little notice of where energy was used or regained:

I wasn't transfixed on the little dial trying to get maximum regenerative points, because I was just using what was required for the driving really. (Driver 1S)

I didn't take a huge amount of notice of [the consumption display] I confess! (Driver 7S)

The majority of these drivers (7/11, 64%) had shorter typical journey lengths (10 miles or under). Thus, the rate of energy consumption would be less relevant to them.

SCT could argue the above results suggest drivers' beliefs (i.e., how personally relevant the range would be to them) had exerted a self-selective bias, affecting their perceptions of the displays (i.e., how important they perceived them) and how closely they monitored them. It also implies that range was a key factor that influenced drivers' interpretation of the BEV's unfamiliar features during the training session.

6.3 Conclusions

The present chapter aimed to explore the effect first BEV contact had on drivers' perception of range. Post-technical instruction analysis revealed that drivers remained uncertain how far they could go on a single charge. This implies that introduction to the SoC display had not improved their confidence in estimating this. One reason could be that the test drive was not long enough for them to have built-up confidence in the display. The findings also showed that although all drivers adapted virtually immediately to regenerative braking, they were unable to judge how much energy they had recovered. This suggests drivers were unable to use this effectively to extend the range. A potential explanation could be that the test drive was not long enough for them to determine this.

Alternatively, the consumption display may not have enabled them to quantify the amount of recaptured energy. We know SCT proposes that anticipatory arousal is the result of a person's perceived inability to exert control over a situation (i.e., low coping self-efficacy). Thus, the above findings could be interpreted as suggesting that first contact of the unfamiliar features had not reduced drivers' range concern, as they had not enhanced their perceived ability to either predict or prolong range.

Post-technical instruction analysis also revealed that drivers expected a real-world range of about 100 miles, after being told that 100% charge roughly equated to 100 miles. SCT proposes that vicarious experiences can strengthen efficacy beliefs, if they are set within realistic bounds. The effect of this mode of influence is particularly strong when it comes from an authoritative source (e.g., BMW technical instructors) and in the early stages of skill development. This suggests the advice from the BMW technical instructors could enhance drivers' confidence in the battery power, providing it accurately reflected the battery capabilities under real-world conditions. It must also be acknowledged that this advice would have reinforced drivers' belief that the MINI E was not capable of 156 miles.

This chapter also examined the effect drivers' perception of range had on the processing of the information they received during their first BEV encounter, specifically if this was influenced by their typical trip length. The findings suggested drivers with longer typical trip lengths tended to perceive the SoC display as essential. In contrast, drivers with shorter typical trip lengths were more inclined to perceive this display as less important to them. In addition, drivers with longer typical trip lengths showed greater awareness of where energy was lost and recovered during the test drive; drivers with shorter typical trip lengths were less focused on this. SCT was a useful concept to contextualise these results. This perspective suggests pre-set beliefs can exert a self-selective bias, causing people to select and monitor those aspects of their environment considered personally relevant to them. Thus, SCT could argue that drivers' beliefs (i.e., how personally relevant the range would be to them) had affected their perceptions of the displays (i.e., how important they perceived them) and how closely they monitored them. Hence, drivers' typical trip length had played a role in how the information on the unfamiliar features was interpreted.

The next chapter examines drivers' perception of range over a sustained period of time.

Chapter 7

Perceptions of range over a sustained period of BEV usage

7.1 Introduction

The extant literature reported in Chapter 1, showed that drivers had no difficulties adapting to the range; all drivers reached their maximum range within a 3-month timeframe (Pichelmann et al., 2013). They also soon learnt to modify their driving style dependent on their trip length (Carroll et al., 2013). In addition, the drivers had no issues adapting to the other new features of the BEV (i.e., new displays, regenerative braking and recharging). Drivers stated the displays were clear and that plugging-in at home was straightforward (Carroll et al., 2013). They adapted almost immediately to regenerative braking (i.e., usually within the first trip) (Carroll et al., 2013; Cocron, Bühler, Franke, Neumann, Dielmann, & Krems, 2013). It was also reported in that chapter that challenging the range enhanced the adaptation effect and was associated with reduced range stress (Carroll et al., 2013; Franke et al., 2012a). This indicates that a drivers' typical journey length could influence their adaptation to the range. For example, a driver with a longer trip length could be forced to challenge the range, which in turn may enhance their adaptation to the vehicle and reduce their range concern.

Research reported in Chapter 1, also showed that drivers had no problems integrating a limited range vehicle into their daily lives. They reported the range was sufficient for 80-90% of their daily mobility needs (Carroll et al., 2013; Turrentine et al., 2011; Vilimek et al., 2012). They adapted a multicar solution and simply reverted back to their ICEV on occasions they needed to travel further afield. Thus, they were not inconvenienced by the drive range or experienced any loss of freedom. However, the multicar solution did result in the BEV being used for shorter trips than the ICEV (Anable et al., 2014; Gärling, 2001). In addition, drivers were not inconvenienced by the lengthy charging times (Bunce et al., 2014). They also reported a public charging infrastructure was not necessary for them, suggesting the limited available recharging network was not problematic (Bunce et al., 2014; Shaw & Bunce, 2015).

Despite these favourable findings, the research reported in Chapter 1 also showed that the range (and associated recharging) remained a perceived barrier to adaptation; drivers continued to demand an increase in battery capacity, a growth in the recharging infrastructure and faster charging times before they would consider purchasing a BEV (Bühler et al., 2015; Carroll et al., 2013; Turrentine et al., 2011). This is contrary to research that was also reported in that chapter, which proposed overcoming that lack of coherence between drivers' range preferences and actual range needs by getting them behind the wheel of a BEV (Khan & Kockelman, 2012; Franke & Krems, 2013b). To-date however, the vast majority of studies in this area have focused on the range required for the BEV to become an attractive proposition (Pasaoglu et al., 2014; Pearre et al., 2011; Tamor et al., 2013). Thus, no research has examined why the range remained a perceived barrier to BEV acceptance. This is a limitation as unnecessarily high increments in battery capacity could out price the BEV from the mainstream consumer market (Knutsen & Willén, 2013).

Chapter 2 outlined that drivers remained overcautious when estimating the remaining range; on average drivers only utilized 75-80% of the battery power (Franke & Krems, 2013a). This indicates the range had also remained a psychological concern, and had a lasting negative effect on their behaviour. Critically, it was outlined in that chapter that drivers anticipated leaving an energy reserve. The findings presented in Chapter 5 supported this; analysis of the pre-trial interview data revealed that drivers had constructed future courses of action to prevent range being problematic. This highlights that their perception of range had a direct effect on their behaviour. It was also explained in chapter 2 that the extant literature had focused on increasing stress resistance to range (Franke et al., 2012a, 2012b, 2016b; Rauh et al., 2017). Thus, it had not explored the effect drivers' range concern had on their behaviour, or why it remained a psychological concern. This is a critical gap in the literature in understanding effective ways to enhance drivers' adaptation to range, and the amount of battery power they utilized.

Evidence presented in Chapter 2 suggested that drivers' fear of running out of charge increased on initial BEV exposure, before decreasing slightly with experience (Gärling, 2001; Franke et al., 2012b). What is more, the literature reported in that chapter showed that drivers made adjustments to their eco-driving strategies over time. In particular, there was a significant increase in the number of drivers reporting switching off ancillary

features and driving at steadier speeds (Neumann et al., 2015). This indicates that changes had occurred in drivers' perception of range with experience, and had effected the strategies they implemented to manage the range. To-date, however, the existing literature has primarily focused on the experienced BEV drivers' experience of range (Franke & Krems, 2013a; Franke et al., 2012a, 2012b, 2016b; Rauh et al., 2015). Thus, no research has conducted a longitudinal examination of drivers' adaptation to range, to explore the psychological changes that occurred. In particular, very little is known about their early experiences of the range. This is a critical gap in the literature in understanding effective ways to support drivers' adaptation to the range.

The present chapter aimed to examine:

- Why the range remained a psychological concern and barrier to usage (i.e., where drivers experienced difficulties in relation to range), as stated in Research Question 5.
- The effect drivers' perception of range had on their adaptation to the BEV, as stated in Research Question 6.
- The psychological changes that occurred in drivers' perception of range with experience, and the effect this had on the strategies they implemented to manage the range, as stated in Research Question 7.
- The impact drivers' trip length had on their adaptation to range, specifically the strategies they implemented to manage the range, as stated in Research Question 8.

The chapter is divided into two sections; Part one examines drivers' perception of range after their first week of BEV usage. Part two examines the changes that occurred in their perception of range after 3 months sustained BEV usage.

Part One: Perceptions of range after initial real-world BEV exposure

7.2. Results and discussion

Thematic analysis of the interview data revealed two main overarching themes for this chapter: „*Heal for short commutes*”(7.2.1) and „*unpredictable and uncontrollable*”(7.2.2). The subthemes attached to each theme are outlined below (please see Figure 7.1). Numbers and percentages for each of the main categories are presented in Tables 7.1 to 7.5. Each overarching theme is linked to the themes presented in the earlier analytical chapters. The first overarching theme provides an understanding of why the battery limitations of the BEV remained a perceived barrier with experience. The second overarching theme addresses the effect drivers’ anticipatory concern had on their behaviour, and why range remained a psychological concern. It also gives insight into how drivers’ perception of range was shaped by their early BEV experiences. The interview data is supported by data logger recorded in the first week of usage. As previously stated in Chapter 4, no questionnaire was administered at this time point.

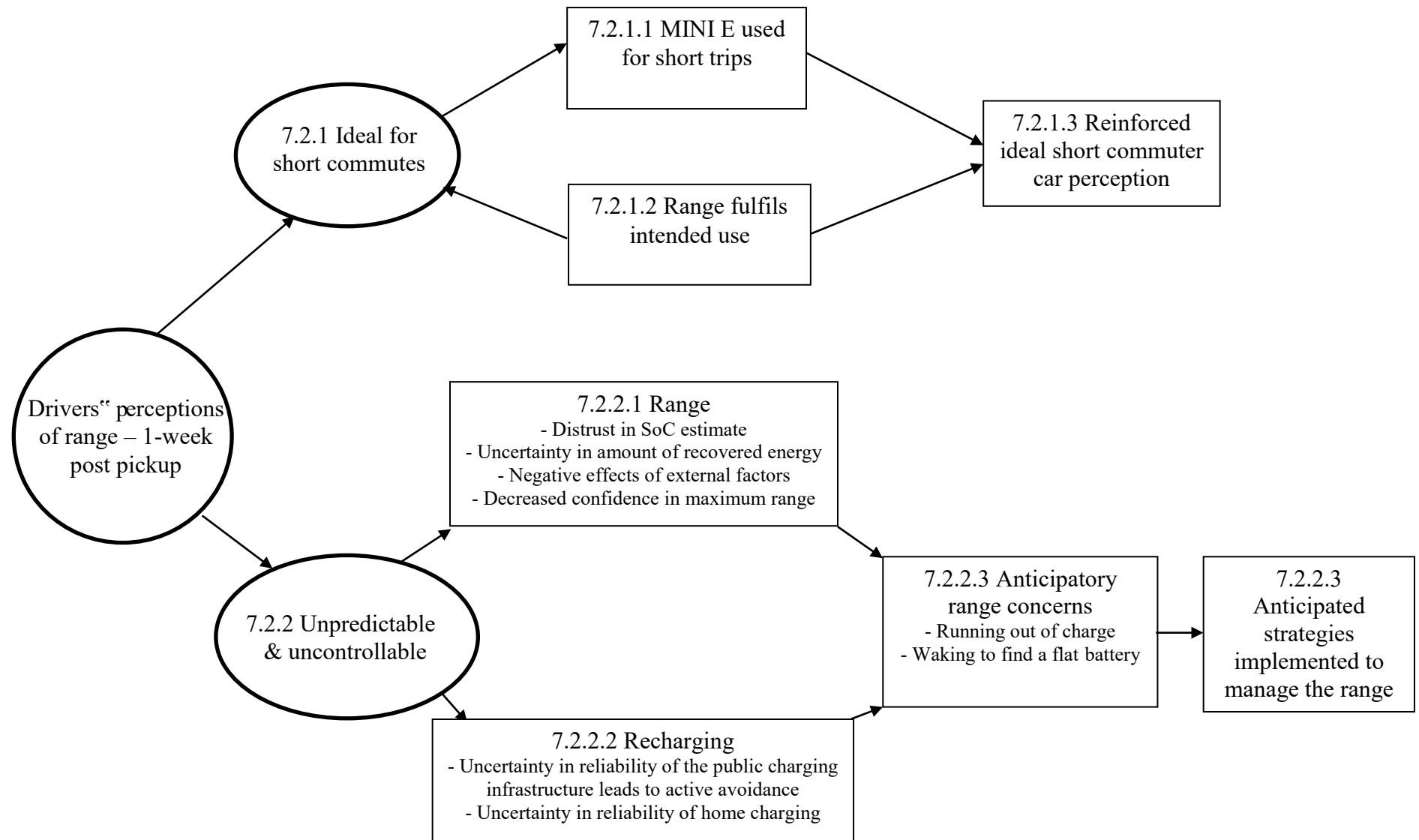


Figure 7.1:Thematic map of Chapter 7 - Part 1 themes and attached subthemes

7.2.1 *Ideal for short commutes*

7.2.1.1 *MINI E used for short trips*

The vast majority of the drivers (23/30, 76%) stated they had initially used the vehicle for short trips that had not challenged the battery power:

It's probably been about 20–30 miles each day. I haven't got myself into a position where I've been ooh I wonder how much power I'll have left. (Driver 20S)

Well I have to admit that the biggest journey has been when I brought the car home [...] otherwise it's sort of been 15 mile maximum trips [...] so it's really been very much localised commuting. (Driver 27L)

Table 7.1

MINI E used for Short Trips: Summary Table for 1-Week Data Logger Information

Single Trip Distance		Daily Car Mileage	
Trip distance	% Accumulative	Daily Car Mileage	% Accumulative
10 miles or under	70%	25 miles or under	66%
25 miles or under	93%	50 miles or under	89%
50 miles or under	99%	75 miles or under	96%
Total trips	527		

Data logger information confirmed the MINI E's had mainly been used for short trips. This data showed that 99% of the trips made in them were less than 50 miles; 93% were under 25 miles. Only 1% of the journeys exceeded 50 miles – these were all made on the first day (i.e., return journey home from the MINI E handover event). Thus, the vast proportion of the trips should have been possible, there and back, on a single charge. In addition, the total daily distance travelled in the vehicles was also found to be well within the capabilities of the batteries; 96% were under 75 miles. Only 4% exceeded 75 miles – the highest of these was 91 miles. Thus, the daily distances made in the vehicles should all have been possible on a single charge.

Data logger information also revealed the MINI E's were used for shorter trips than the ICEVs; the average maximum journey length made in the MINI E's was 39 miles compared to 55 miles in the ICEVs. This finding is consistent with previous research reported in Chapter 1, which showed the average distance made in the BEV was shorter than the ICEV (Anable et al., 2014; Gärling, 2001).

The range was sufficient to fulfil the drivers' intended role for the MINI E (i.e., short commuter car). The next subtheme examines this in greater detail.

7.2.1.2 Range fulfils intended use

Over half the drivers (16/30, 53%) reported they had used the MINI E for the vast majority of their car trips:

I haven't taken any journeys that I haven't been able to use the Mini E for.
(Driver 5S)

I had to use my other car once, because I had to take it in to get it serviced, so that was the only reason I didn't use it for that one day. So I've used it every day to go anywhere I want to. (Driver 23S)

This finding supports the research presented in Chapter 1, which showed the range had satisfied a large proportion of drivers' daily mobility needs (Carroll et al., 2013; Turrentine et al., 2011; Vilimek et al., 2012). Thus, 19 of the 30 drivers (63%) reported that the limited range had not affected their daily driving routine:

It doesn't affect at all my day to day driving, the fact it can only do 70 miles.
(Driver 4S)

I've still been doing the same journeys I've been doing in the past, so I haven't had any major problems. (Driver 25L)

Analysis of the 1-week interview data, therefore, suggests the drivers had no difficulties integrating a limited range vehicle into their daily lives. It also implies the MINI E had met their expectations in being viable for them on a daily basis.

The drivers also had no difficulties adapting to the other new features of the BEV (i.e., regenerative braking and home charging). These are briefly outlined next.

Regenerative braking

The vast majority of the drivers (23/30, 77%) reported they had used regenerative braking in preference to the conventional brakes:

The one thing I am doing is probably keeping my foot off the brake and only using it in emergency situation. I'm learning [...] to take my foot off the accelerator, so the regeneration works. But essentially, you know, taking your foot off the accelerator kicks in the brake and does the regeneration. So I'm kind of getting use to that, and using that a lot. (Driver 11S)

The regenerative charging on leaving your foot off the accelerator [...] it's actually quite a useful little thing. Because it allows you not to use the brakes, you use it as a general brake motion coming up to standstill traffic or roundabouts and things like that. (Driver 25L)

Half the drivers (15/30, 50%) now cited instances where the energy recaptured through regenerative braking had substantially increased the battery power:

My goodness the regeneration works really well. I'll give you a good example [...] I think as I was coming off Hammersmith. I was about 36% of battery life and by the time I got to Westfield's, thanks to stopping in traffic it went up to 43. So the regeneration makes hell of a difference! (Driver 7S)

It certainly does regenerate a lot. Because going on the motorways you use a lot and then all of a sudden you hit the hills and then on the hills you kind of regenerate. So like this morning I noticed that it was on 100%, and it was below 75% on the course of the journey, but now that I'm here it's kind of I think on about 80%. So the last bit of the journey sort of makes up for some of the power that you lose on the motorway. (Driver 9S)

This finding indicates they could see regenerative braking was useful in saving energy.

Home charging

Twelve of the 30 drivers (40%) reported that plugging-in the vehicle to recharge was straightforward:

Well the charging process has been far easier than I thought it would be. I mean you just get out of the car and plug it in. (Driver 6L)

I think the charging process itself is very straightforward, yeah, really easy, just plug it in one end, plug it in the other, turn the switch and off you go, so very, very easy. (Driver 16S)

Thirteen of the 30 drivers (43%) also cited the lengthy charging times had not been an issue to them:

No, no, I have no problem with [...] the time it takes for the power and everything else. (Driver 14S)

No we don't even notice it, we just wakeup in the morning and it's charged. So it doesn't matter whether it's three hours or ten hours probably for us. As long as it's charged in the morning I don't really care. (Driver 18S)

These findings are consistent with the previous research presented in Chapter 1 (Bunce et al., 2014; Carroll et al., 2013; Turrentine et al., 2011). They also suggest home charging was as straightforward as expected.

Despite these favourable findings, however, the range had remained a perceived barrier to usage. The next subtheme examines this in greater detail.

7.2.1.3 Reinforced ideal short commuter car perception

Sixteen of the 30 drivers (53%) continued to cite the BEV as being unable to completely replace the ICEV because of the battery limitations:

I don't want to give the impression that it hasn't fulfilled its role in what we wanted it to do because it has completely, even with half the capacity it would still be able to do what we are asking of it at the moment. But if we wanted to replace both of our cars with electric cars [...] the MPV, sort of going on holiday, long journey one [...] then for that to be viable it would need to be the same as a petrol I think. (Driver 18S)

Yeah, I think electric cars definitely have a future. I think it would be a second car at the moment because of the range. (Driver 30L)

This indicates that the range had remained a perceived barrier to usage with experience.

It was explained in Chapter 3 that SCT proposes that pre-set beliefs act as a confirmatory bias, causing people to behave in ways that strengthen them (Bandura, 1986, 1997). We also know from the analysis presented in Chapter 5 that the drivers“ perceived the BEV as an ideal short commuter car because of the battery limitations. Thus, they intended using the MINI E primarily for short trips. The analysis presented in this overarching theme suggests the drivers had actually used the MINI E for short trips. It also indicates the MINI E had fulfilled the role they had intended using it for. Thus, the drivers“ beliefs could have exerted a self-confirmatory influence over their behaviour, which reinforced the perception that BEVs were ideal for short commutes. This could also give insight into why the range remained a perceived barrier to usage, as it could also have strengthened the perception that the BEV could not be used in precisely the same way as the ICEV.

Analysis of the 1-week interview data also revealed that the range had remained a psychological concern to the drivers. The next theme examines this in greater detail.

7.2.2. Unpredictable & uncontrollable

7.2.2.1 Range

Table 7.2

Unpredictable & Uncontrollable: Summary Table for 1-Week Interview Data

Relevant Statements	No and % (N=30)
Reference to distrust in SoC estimate	12 (40%)
Reference to uncertainty in the amount of recaptured energy	15 (50%)
Reference to negative effects of external factors on the range	23 (76%)
Reference to uncertainty in the effect of each external factor on the range	9 (30%)
Reference to decreased confidence in the maximum range	18 (60%)

Distrust in SoC estimate

Twelve of the 30 drivers (40%) continued to express distrust in the SoC estimate:

I've been getting used to the fact that [the display is] not entirely accurate. Yesterday it took me three hours to get back to Maidenhead, and I'd been sitting in the traffic listening to the radio [...] and the mileage gauge continued to be at about 50% with 40 miles left. However, as soon as the traffic moved on a bit, about two miles down the line, it dropped down to 29 miles left. Yeah, so there's that kind of [...] do the numbers reflect an accurate picture? (Driver 22L)

It seems to be using charge at a significantly higher rate than would have been expected. Do you want an example? Friday morning I took my daughter to school, it was at 95 percent charge on the Friday morning, but I used 20 percent of the charge to do 3-3½ miles. (Driver 28L)

Three of these 12 drivers (25%) reported having learnt from the other pioneers (e.g., via email) that they too had found the range estimate unreliable:

That comes to another issue, which I think other people have noticed as well, and that is the actual battery meter isn't particularly accurate when you're driving. (Driver 2S)

Somebody was saying that when they switched their car off it came back on with more power, and things like this have been going on. (Driver 13S)

The inaccurate SoC estimate would have made it difficult for the drivers to predict the battery power. They would be especially dependent on this range estimate in the early adaptation stages, as they would be unaware of the battery power used for routine trips.

Uncertainty in the amount of recaptured energy

Half the drivers (15/30, 15%) remained unsure how much energy they had saved through regenerative braking:

I've absolutely no idea. I wouldn't like to hazard a guess, I wouldn't know. (Driver 13S)

I haven't got a clue. It's quite hard to call. I wouldn't know what it is. (Driver 15L)

This implies they were still unable to quantify the amount of energy they had recaptured, despite having noticed it could substantially increase the overall battery power. Thus, their ability to use the recovered energy to exert influence over the range (i.e., extend the distance they could travel) may still have been limited.

Negative effects of external factors on the range

The vast majority of the drivers (23/30, 76%) cited that various external factors - cold outside temperatures, heater, lights and fast stretches of road – had rapidly decreased the battery power:

[Motorway driving] definitely has more impact on the battery. It's definitely better using it on B roads, that's made quite a difference. (Driver 14S)

It's unbelievable in fact how quickly the gauge goes down because it's drained, the heating and the lights and the windscreen wipers and the radio drains it incredibly. (Driver 27L)

A minority of these drivers (4/23, 17%) reported having learnt this vicariously (e.g., from other pioneers), rather than through direct experience:

There was someone who said they went out to dinner 16 miles away and used the heater and everything and came back with almost nothing left, so that's what someone said, one of the other pioneers, and so I sort of noted that and thought ok. (Driver 15L)

I'm aware after having read the handbook that I need to be aware of that in the winter when I've got the heating fully on. (Driver 17S)

Nine of the 30 drivers (30%) stated they were unaware of the precise drain of each external factor on the range:

I don't have an estimation of what the drain is, but as soon as I turn [the heater] on the range drops. Would it have affected my overall mileage if it had been on all the time yesterday? Possibly if it had been on all the time I would have imagined. (Driver 6L)

[It's] quite confusing [...] because you have to suss out how much energy the other goodies are using. It would be interesting to find out how much energy the lights use and the windscreen wipers and the radio. (Driver 24L)

The vast majority of these drivers (8/9, 88%) had longer typical journey lengths (15-42 miles). Understanding the impact of external factors would be more salient to these drivers, as their trips would use a greater proportion of the energy resources. These findings suggest that the effects of external factors made the range even more difficult to estimate. What is more, the drivers' limited experiences would have made this especially

challenging, for example, they would have been unable to compare the battery power used on a routine journey with the heater on versus switched off. In addition, the drivers could have perceived their control over the external factors as limited, for example, they would have no influence over the outside temperature. Furthermore, turning off ancillary features (e.g., headlights or windscreen wipers) or avoiding fast stretches of road may not always be possible.

Decreased confidence in the battery power

The drain of external factors on the battery power also resulted in the range not achieving the expected 100 miles. In the very cold weather it was substantially less than this; drivers reported a fully charged battery only displayed a range of about 70 miles. This led to 18 of the 30 drivers (60%) feeling the range had been oversold to them by the BMW Group:

Well when I'm fully charged the dial always says 100%, but the indicator says anything between 70 and 83. So all that stuff about 100 miles is probably a bit flattering. (Driver 1S)

The car is not what I expected as far as range is concerned. Because do you remember in our training we were told it was between 120-150 miles. There is absolutely no way that the car would have a range of 120 or up to 150. I mean the maximum is probably 90, but that would be on a very, very good day, without using heating, without using the radio, without using anything. I think that it's more like 70. (Driver 24L)

This finding suggests the advice drivers received during the MINI E training session (i.e., maximum range was 100-110 miles) decreased their confidence in the battery power, as they soon realised it was not capable of achieving this. As a consequence, the drivers had reappraised the range and had lowered their internal standards for the capabilities of the battery capacity.

A minority of these drivers (4/18, 22%) reported having learnt from other pioneers that they too had found the range was substantially lower than expected:

I've been swapping notes [...] there's been loads of emails flying around between all of us now, and the one common issue seems to be the weather and how far it goes. (Driver 8L)

I think all of us are seeing that the range on the car is substantially impacted by the cold temperatures. (Driver 26L)

It was explained in Chapter 3 that because for most activities there is no absolute measure of adequacy, people have no meaningful basis for self-appraisal without knowing how others have performed (Bandura, 1986a). Thus, the performances of the other pioneers acted as a social comparison, that allowed the drivers to determine how the range of their vehicle had fared to the others and thus gave context to their appraisal.

7.2.2.2 Recharging

Public charging

A minority of the drivers (7/30, 23%) expressed a reluctance to depend upon using a plug-in point, even if one existed at their destination. If they found themselves unable to use it then they could be stranded:

What I would worry about with [using the public charging infrastructure] is becoming dependent on it, because the only time we'd use a public charging infrastructure is when we're exceeding the round trip range, so somewhere where you'd need to charge before you get back, otherwise I just wouldn't be able to go home. So I'm reluctant to try it, if the experiment for me fails I'm stuck. (Driver 18S)

I think I've been reluctant to make journeys that I know are probably doable [...] even if there is a charging point. I'm thinking of the shopping centre at Westfield's, I was thinking of taking the car there. But I mean I'm fairly confident that I could get it there and back on one charge, but I'd quite like to charge it there, and my concern is that because they're not allocated spaces for electric vehicles you risk chancing it. (Driver 30L)

Previous research has suggested that a public charging infrastructure was unnecessary to support BEV usage (Shaw & Bunce, 2015). Although this may be true for the vast majority of trips, this finding implies that drivers were actually avoiding using a charge point because they lacked confidence in them.

The experiences of the few drivers who had attempted to use a plug-in point, largely confirmed their negative perceptions of them. One driver reported having turned up to use one, only to find they were all occupied by ICEVs:

Even though when I went [to Westfield's] on Sunday they had well over 1500, 1600 spots in the building, but the 16 spots that were there for electric vehicles were filled with [...] petrol cars. And I do think if [...] they are going to offer charge points they need to make them available always for electric vehicles. I wrote them a note to say that I just managed to get one because someone had just left a parking spot. So I was in competition with a petrol car that was coming in the other direction, and he realised why I needed it and he was like, ok, and raised a hand. (Driver 7S)

Two drivers referred to having been unable to locate a plug-in point at their destination:

When I was getting a bit sort of desperate over the weekend, I had a look down the list and it said [...] at one of the Park & Ride sites there was meant to be one. I think it was the Water-Eaton Park & Ride, so I drove down to the Water-Eaton Park & Ride and I couldn't see anything. And [the BMW technical instructor] basically said there probably wasn't one there yet. (Driver 10S)

I've checked out the three car parks nearest to the station and none of them have a charging point. (Driver 29L)

Home charging

The majority of the drivers (18/30, 60%) reported having experienced issues with the charging units, as a consequence the vehicles had failed to charge overnight:

At the beginning there was a problem with the charging, but that was related to a problem with the meter. [...] The meter wasn't picking-up the correct time, so it wasn't going over to cheap rate until about 5 o'clock in the morning. [...] So it wasn't charging fully. (Driver 2S)

I put the car onto charge and everything was all plugged in [...] thinking that I would come out in the morning and find it fully charged, as I had on other days, but it had tripped the switch. (Driver 29L)

This finding implies that the drivers' experiences of home charging could have created uncertainty in the reliability of this process.

7.2.2.3 Anticipatory range concerns

Table 7.3

Anticipatory Range Concerns: Summary Table for 1-Week Interview Data

Relevant Statements	Pre-Trial N=30	1-Week N=30
Reference to anticipatory concern to running out of charge	15 (50%)	21 (70%)
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	<i>10 (67%)</i>	<i>12 (57%)</i>
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	<i>5 (33%)</i>	<i>9 (43%)</i>
Reference to concern to waking to find a flat battery	0 (0%)	8 (27%)

Anticipatory concern to running out of charge

Twenty-one of the 30 drivers (70%) now reported an anticipatory concern to running out of charge:

Well I think that once or twice I haven't used [the MINI E] whereas I would have done, because I've been concerned I wouldn't get back. (Driver 13S)

I think the surprise is the anxiety about how far you can go in cold damp weather. (Driver 14S)

In line with previous research (Gärling, 2001), the number of drivers reporting this had risen slightly from pre-trial (please see Table 7.3). The findings from this chapter extended on the existing literature by suggesting this could be attributable to various factors (e.g., distrust in the SoC estimate and negative effects of external factors) making the range more unpredictable and uncontrollable. From a social cognitive perspective, this could have lowered the drivers' coping self-efficacy and increased their range concern. It could also be a partial consequence of the lower than expected battery power making the range more of a concern. Hence, the particular rise amongst drivers with shorter typical journey lengths. However, it must be acknowledged that an exact McNemar's test determined that there was not a statistically significant difference in the proportion of drivers reporting range concern compared to pre-trial ($p=.180$).

Concern to waking to find a flat battery

A minority of the drivers (8/30, 27%) now also expressed concerns about waking to find the vehicle had not charged overnight:

You're relying on everything happening at midnight, so I'm waking up in the morning and praying it worked and didn't trip out. So there's that anxiety in trusting the reliability of it. (Driver 12L)

It would be good to know that you've at least plugged it in properly and it's ready to go, because if we were using it for a commute and we were to find out it hadn't charged overnight, that would be a complete disaster. (Driver 21L)

This was not something the drivers had anticipated pre-trial (please see Table 7.3). It could imply that the issues with the charging units had led to them developing this concern.

To prevent the range from being an issue, drivers' pre-trial beliefs were found to exert a self-directed influence. The next subtheme discusses this in greater detail.

7.2.2.4 Strategies implemented to manage the range

Energy reserve

In keeping with previous research (Carroll & Walsh, 2010; Franke et al., 2012b; Franke & Krems 2013a), half the drivers (15/30, 50%) cited that they had erred on the side of caution and left an energy reserve:

I've erred on the side of caution. [...] I wouldn't want to sort of go right down to close to zero, when you don't have a charging ability nearby. [...] And that's why you give yourself a little bit more leeway around that, to allow you to get to where you need to go. (Driver 19S)

I'm giving myself a very wide comfort factor whilst this weather is with us. Last Thursday I had an 80 mile round trip to do and I took my diesel, so that shows you where my propensity was to take risk. Given the characteristics in the cold I wouldn't risk it above 80 miles. (Driver 26L)

Thus, only a minority of them (10/30, 33%) had experienced any actual range concern in the first week – this was primarily on the way home from the handover event:

I was quite nervous driving it back from Oxford [...] because of what the [BMW technical instructor] had said, that in the cold you might not make it back. So I like drove with no heating on, no radio on [...] and I think I made it back with 25%. (Driver 8L)

The longest journey was from Oxford back home and that was quite worrying. I got to the turn off before my turn off on the M25 and I had 8 miles left on the dial and I had about 18 miles to travel. So I was very nervous, I actually took the turn off the highway and I went along the back roads. And it regenerated and when I got home I think I had about 12 miles left. (Driver 24L)

The pre-trial analysis presented in Chapter 5 revealed that the drivers anticipated leaving an energy reserve to turn the potentially hazardous situation of running out of power into a benign one. This indicates that their beliefs had allowed them to exert some self-directed influence to stop the range being problematic. Indeed, it had the expected outcome of preventing them from experiencing a critical range situation. However, it also resulted in suboptimal range utilization behaviour, with them not using the full amount of battery power available to them. Next, the strategies drivers actually implemented to keep their usage of the vehicle within their comfortable range are examined. It must be acknowledged that all pre- to 1-week trial comparisons in this subsection, compare the anticipated use of strategies (pre-trial) with the actual use of these strategies (following 1 week of experience of driving the MINI E).

Strategies implemented prior to driving

Table 7.4

Strategies Implemented Prior to Driving: Summary Table for 1-Week Interview Data

Relevant Statements	Pre-Trial N=30	1-Week N=30
Reference to forward thinking of trips	16 (53%)	19 (63%)
<i>Drivers to longer typical journey lengths (15-42 miles)</i>	12 (75%)	11 (58%)
<i>Drivers with shorter typical journey lengths (under 10 miles)</i>	4 (25%)	8 (42%)
Reference to keeping battery as charged as possible	15 (50%)	16 (53%)

Reference to using the boost function to check the vehicle was connected correctly to charge	0 (0%)	6 (20%)
--	--------	---------

Forward thinking of trips / keeping battery as charged as possible

Nineteen of the 30 drivers (63%) referred to having to think ahead to ensure the range was sufficient for their needs:

So yeah I just have to think about like, you know, I just constantly check how far have I driven, how far have I got to go and what's the range and do I think that I'm going to make it. (Driver 9S)

[...] I'm aware of thinking more about my journeys and the distance that they're going to take [...] I think I'm just much more aware of planning my journeys. (Driver 30L)

An exact McNemar's test determined that there was not a statistically significant difference in the proportion of drivers reporting this compared to pre-trial ($p=.508$). However, it is noteworthy to mention that the 1-week interview data indicated a slight rise amongst drivers with shorter typical journey lengths (under 10 miles) reporting this strategy (please see Table 7.4). This could be attributable to the lower than expected range increasing its salience in their everyday lives, to ensure they had sufficient charge for their daily needs.

Sixteen of the 30 drivers (53%) also reported that they had kept the battery as charged as possible:

I plug it in every night anyway, just in case. (Driver 1S)

At this point I am deliberately charging it every night. (Driver 6L)

An exact McNemar's test determined that there was not a statistically significant difference in the proportion of drivers reporting this strategy compared to pre-trial ($p=1.000$). As previously stated, this could be a consequence of the drivers not yet having developed an understanding of the amount of power used for their routine trips.

Using the boost function to check the vehicle was connected correctly to charge

Interestingly, a minority of the drivers (6/30, 20%) had adapted the use of the boost function on the charging unit, to check the vehicle was primed and ready to begin charging when the cheap rate electricity came into operation around midnight:

I give it a bit of an extra boost as soon as I arrive back, so that's become a bit of a routine. Because with the night charger not being 100% reliable, I feel I need to use the boost. (Driver 3L)

You need to know that it's sort of primed and ready to charge as soon as the off peak signal, or whatever, kicks in overnight. And the only way of doing that at the moment is to just press boost and give it a tiny little [...] few second charge, to make sure the lights come on. (Driver 17S)

There was nothing to let the drivers know the MINI E was charging, or alert them if it suddenly stopped during the night. Thus, pressing the boost function was the only way of providing some reassurance the vehicle was connected correctly to charge.

Strategies implemented while driving

Table 7.5

Strategies Implemented While Driving: Summary Table for 1-Week Interview Data

Relevant Statements	Pre-Trial N=30	1-Week N=30
Reference to adapting driving style to conserve energy (e.g., driving steadier / avoiding fast stretches of road)	5 (17%)	12 (40%)
Reference to switching off ancillary features (e.g., heater)	0 (0%)	10 (33%)

Adapting driving style to conserve energy

Twelve of the 30 drivers (40%) referred to actually having made adjustments to their normal driving habits to conserve the battery power:

I'm checking my journeys and may be changing routes a little to ensure that I avoid stretches of road where I'm going to be driving fast. (Driver 2S)

I find I'm tootling along and not going as quick as I might do normally. So I've probably been taking a bit more of a relaxed way of driving the car than I would do normally, because hanging around 70 doesn't do the battery a great deal of good. (Driver 12L)

An exact McNemar's test determined that there was a statistically significant difference in the proportion of drivers reporting this compared to pre-trial ($p=.039$) (please see Table 7.5). A potential explanation for this could be the lower than expected range under real-world conditions, increased the need for drivers to take action to conserve the battery power. However, it must be acknowledged that over half these drivers (7/12, 58%) stated only attempting to prolong the range (i.e., drive energy efficiently) when travelling on a low state of charge. Thus, most drivers had not (or very rarely) adjusted their driving style. This implies their normal driving habits had survived the transfer from the ICEV to the BEV and was guiding their driving behaviour. It was explained in Chapter 3 that habituated behaviour is difficult to suppress once established (Verplanken, 2006). It can survive a change in circumstance (e.g., switching from ICEV to BEV) when the core features of the context remain consistent (Wood et al., 2005). It was also stated in that chapter that the handling and operation of both vehicles were very similar. What is more, both car types would have been used in the same environments. This could partially explain why drivers' normal driving habits had remained strong across the transfer. We also know from Chapter 5 that drivers did not intend changing their driving habits when switching to the BEV, making it more unlikely that their driving behaviour would be brought back under conscious thought.

Switching off ancillary features

A minority of the drivers (10/30, 33%) now also reported switching off ancillary features (e.g., heater) to conserve the battery power:

Yesterday I turned the heater off to try and preserve battery. (Driver 3L)

I've had the heating on a couple of times. I only have it on for a short period of time because I'm aware it uses up the battery. (Driver 19S)

Drivers had not referred to implementing this strategy pre-trial (please see Table 7.5). This could be attributable to external factors having a greater impact on the range than expected.

The previous research presented in Chapter 2 provided support for this finding; it revealed the proportion of drivers who reported switching off ancillary features as an eco-driving strategy had significantly increased by 3-months (Neumann et al., 2015). It should be noted that the majority of these drivers (8/10, 80%) had longer typical journey lengths (15-42 miles). This could be attributable to the greater necessity for these drivers to conserve the battery power.

The next part of this chapter examines drivers' perceptions of range after three months sustained BEV usage.

Part Two: Perceptions of range after sustained BEV usage

7.3 Results and discussion

Thematic analysis revealed two main overarching themes for this chapter: „*ideal for short commutes*“ (7.3.1) and „*unpredictable and uncontrollable*“ (7.3.2). The subthemes attached to each theme are outlined below (please see Figure 7.2). Summary tables are provided at the start of each subtheme to give a clear overview of the proportion of drivers falling into each main category of responses. Each overarching theme builds on the framework established in the earlier analytical chapters. The first overarching theme provides an understanding of why the range remained a perceived barrier over a sustained period of usage. The second overarching theme addresses why the range persisted to be a psychological concern. It also gives insight into the changes that occurred in drivers' perception of range over time, and the affect this had on their behaviour. The interview data is supported by the 3-month questionnaire and data logger information (i.e., all trips made in the vehicles at the 3-month time point for one week, plus the maximum distance made in each vehicle from post 1-week pick-up until the end of the 3 month period).

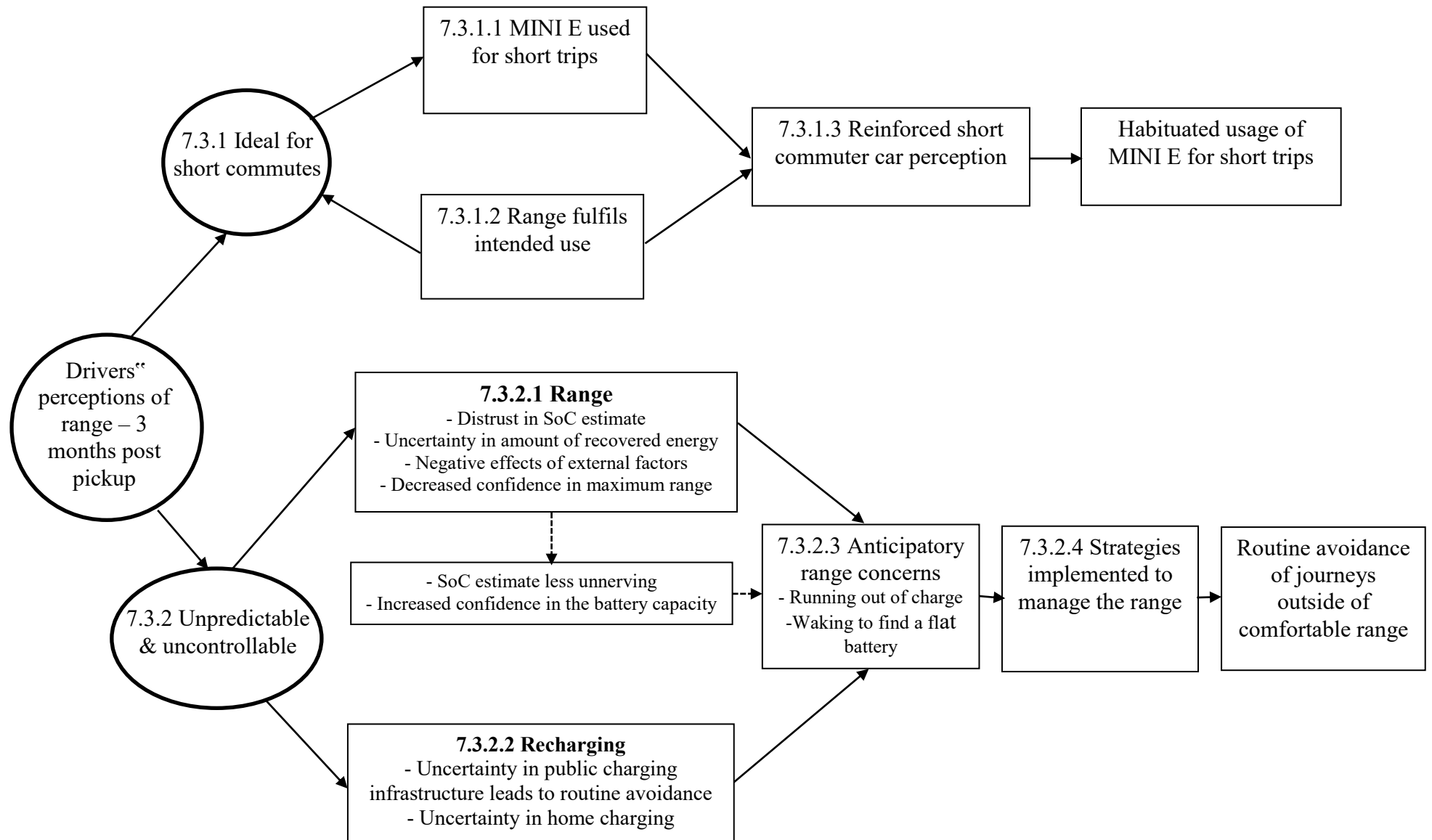


Figure 7.2: Thematic map of Chapter 7: Part 2 themes and attached subthemes

7.3.1 Ideal for short commutes

7.3.1.1 MINI E used for short trips

Half the drivers (15/30, 50%) stated they had continued to use the MINI E primarily for short trips over the 3 month period that had not challenged the battery power:

I mean it's only rarely that I have lots of days driving sort of 40 or 50 miles, so I don't often tend to stretch the capacity. (Driver 4S)

I'm perfectly happy to [...] go to and from work, perfectly comfortably [...] and that's what it's been really since I've picked it up. (Driver 23S)

Three month questionnaire data revealed that drivers *disagreed* with the statement, „I deliberately tried to exhaust the range in order to see how far I could go with the MINI E“ (M=3.39; SD=1.31; N=28).

Table 7.6

MINI E used for Short Trips: Summary Table for 3-Month Data Logger Information

Single Trip Distance		Daily Car Mileage	
Trip distance	Accumulative %	Daily car mileage	Accumulative %
10 miles or under	70%	25 miles or under	72%
25 miles or under	94%	50 miles or under	90%
50 miles or under	99%	75 miles or under	98%
Total trips	450		

Data logger information confirmed the MINI E's had been used for short commutes. This data showed that 99% of the trips made in the vehicles had not exceeded 50 miles (94% were less than 25 miles). In addition, the vehicles' daily mileages were largely well within the battery capacity; 98% were under 75 miles (72% had not exceeded 25 miles). Only one of the vehicle's daily mileage had exceeded 100 miles on one day (119 miles in total). Interestingly, data logger information revealed that the maximum distance made in the MINI E's had not substantially changed over the duration of the trial; a Wilcoxon test revealed no significant difference between the maximum distances made in the vehicles

during the first week, compared to the maximum distances made over the remainder of the 3 month period ($Z=-.072$, $p=.943$).

7.3.1.2 Range fulfils intended use

Table 7.7

Range fulfils Intended Use: Summary Table for 3-Month Questionnaire Data

Relevant Questions	Responses	
	Pre-Trial M(SD) N	3-Months M(SD) N
The MINI E will satisfy / satisfied my daily mobility needs	4.72 (.99) N=29	4.00 (1.41) N=29
What percentage of your daily trips could you successfully make with the MINI E	87% N=18	86% N=24
Electric vehicles are suitable for daily use	4.73 (.78) N=30	5.00 (.96) N=29

Three month questionnaire data showed that drivers *agreed* with the statement, „The MINI E satisfied all my daily mobility needs“ ($M=4.00$; $SD=1.41$; $N=29$). On average they reported having completed 86% of their journeys in the MINI E. In addition, they *disagreed* with the statement, „The MINI E has changed my mobility behaviour significantly“ ($M=3.06$; $SD=1.39$; $N=29$). They also *strongly agreed* with the statement, „Electric vehicles are suitable for daily use“ ($M=5.00$; $SD=.96$; $N=29$). These results suggest the range had remained satisfactory for the drivers“ daily needs. Thus, the MINI E had continued to meet their expectations in fulfilling the role of a short commuter car. Indeed, a Wilcoxon test showed no significant difference between the percentage of trips drivers expected to complete in the MINI E, compared to the percentage they had used it for ($Z=-.631$, $p=.528$). There was also no significant difference in their perceptions that electric vehicles were suitable for daily use pre-trial to 3 months ($Z=-1.698$, $p=.090$). Drivers did agree more strongly pre-trial than at 3 months that the MINI E would satisfy their daily mobility needs. What is more, this difference was significant ($Z=-2.620$, $p=.009$). This could be attributable to the maximum range being less than expected (please see Table 7.7).

Drivers also showed no difficulties with their longer term adaptation to the other new features of the vehicle (i.e., regenerative braking and home charging). These are briefly outlined next.

Regenerative braking

Drivers had continued to use regenerative braking in preference to the conventional brakes. Three month questionnaire data revealed they *agreed* with the statement, „I rely on regenerative braking“ (M=4.34; SD=1.11; N=29). On average they stated having used regenerative braking for about 88% of braking situations. This suggests regenerative braking had become part of their normal driving habit. Although all drivers had used regenerative braking for the vast majority of braking situations, a minority of them (11/30, 36%) had implemented it in a more sophisticated way than a simple replacement to the conventional brakes. For example, they used it in conjunction with the energy consumption display to keep the energy rate as low as possible:

We’ve become quite good at regenerative charging, driving, we really, really have and you know we realise that if you go back routes it really, really charges the car up. The [...] more carefully you drive, and the more you are aware of the fact that [...] you need to only go up to a maximum of two bars on the charge dial, and also [...] you need to try and take your foot off the accelerator as much as possible. (Driver 24L)

The only thing I’ve done to prolong the battery life is reduce the speed of the vehicle and more use of obviously any hills and especially down, going down the A34 there’s quite a lot of hills and there’s certain ones that I know how to regenerate and pick up the speed, you know, and get the battery to regenerate. (Driver 26L)

Seven of these 11 drivers (64%) had longer typical journey lengths (15-42 miles). This suggests their longer journey profile could have led to a growth in competency in conserving the battery power.

Home charging

Three month questionnaire data showed drivers *agreed* with the statement, „Plugging in the MINI E at a wall box is simple and easy to handle“ (M=4.11; SD=.93; N=27). What is more, the drivers also *agreed* with the statement, „The current charging times suited my

daily routine” (M=4.14;SD=1.56;N=28). This demonstrates they had continued to find home charging straightforward, and had not found the lengthy charging times an inconvenience.

Despite these favourable findings, the range (and associated recharging) was still found to be a perceived barrier to usage. The next subtheme examines this in greater detail.

7.3.1.2 Reinforced ideal short commuter car perception

The vast majority of the drivers (22/30, 73%) continued to refer to the BEV as ideal for short commutes, until the limitations of the batteries were resolved:

As it stands it’s very much a local vehicle, fine for ninety percent of what I do.
(Driver 12L)

I think until there’s a [...] useable charging infrastructure in terms of public charging, they will remain niche cars for people [...] who only have to do limited miles, potentially in urban surroundings. (Driver 26L)

Consistent with previous research, this indicates the range had remained a perceived barrier over a sustained period of usage (Bühler et al., 2014; Carroll et al., 2013; Turrentine et al., 2011).

Table 7.8

Reinforced Ideal Short Commuter Car Perception: Summary Table for 3-Month Questionnaire Data

Relevant Questions	Responses	
	Pre-trial M(SD)	3 Month M(SD)
How important would changes in drive range be to you	5.30 (.73) N=20	5.31 (.88) N=19
How important would changes in construction of the public charging infrastructure (grid coverage) be to you	5.15 (.98) N=20	4.78 (1.18) N=19
How important would changes in charging time be to you	4.50 (1.05) N=20	4.84 (.89) N=19

Three month questionnaire data supported this finding. It revealed that drivers continued to rate improvements in „drive range“ as *important* to them, before they would consider buying a BEV ($M=5.31;SD=.88;N=19$). They also reported that changes in the „construction of a public charging infrastructure“ and „charging times“ were *of some importance* to them ($M=4.78;SD=1.18;N=19$ and $M=4.84;SD=.89;N=19$ respectively). What is more, Wilcoxon tests revealed no significant difference in drivers“ desires for changes to the „drive range“ and „charging times“ pre-trial to 3 months sustained BEV exposure ($Z=-.247, p=.805$ and $Z=-1.342, p=.180$ respectively). Changes in the construction of a public charging infrastructure did become significantly less important to them over the 3 month period ($Z=-2.008, p=.045$). This could be attributable to their experiences having confirmed that a recharging network was not necessary for how they used the vehicle (please see Table 7.8).

The results from the 3 month analysis indicate that the self-confirmatory influence of drivers“ pre-set beliefs had led to the routinized usage of the vehicle as a short commuter car. The MINI E was used for short trips throughout the trial period. Indeed, the maximum journey lengths made in the vehicles had not significantly changed over the 3 months. Thus, the drivers“ behaviour would have continuously reinforced the perception that the BEV was ideally suited for short trips. This could explain why range remained a perceived barrier, as their behaviour would also have strengthened their belief that the battery limitations prevented the BEV being used in the same way as the ICEV. This implies that getting drivers behind the wheel of the BEV, actually reinforced this negative perception of range rather than overcoming it (Franke & Krems, 2013b). Contrary to previous research, it also suggests that the drivers“ adaptation to the battery power had been virtually immediate (Pichelmann et al., 2013). Indeed, the findings from this analysis suggest within this 3-month timeframe habituation had occurred.

Analysis of the 3 month interview data also revealed that the range remained a psychological concern over the trial period. The next theme examines this in greater detail.

7.3.2 Unpredictable and uncontrollable

7.3.2.1 Range

Three month questionnaire data suggested drivers continued to distrust the SoC estimate; they did not strongly agree with the statement, „The charge level display reliably estimates the remaining energy of the battery“ ($M=3.96;SD=1.29;N=28$). It also implied they were still unable to estimate the amount of recaptured energy; drivers did not strongly agree with the statement, „The energy consumption display is helpful in estimating the energy recovered by the regenerative braking system“ ($M=3.71;SD=1.18;N=28$). This data also revealed that drivers remained unaware of the precise impact of external factors on the range; they did not strongly agree with the statement, „I am able to precisely estimate the influence of different factors on the range“ ($M=3.64;SD=.98;N=28$). These results indicate that the drivers continued to have difficulties estimating how far they could go on a single charge. It also implies their ability to exert influence over the range had remained limited. In addition, the 3-month questionnaire data showed that the drivers remained dissatisfied with the maximum range of the MINI E; they did not strongly agree with the statement, „The MINI E produces the range that I expected“ ($M=3.24;SD=1.24;N=29$). Analysis of the 3-month interview data did, however, reveal that with experience the drivers found the SoC estimate less unnerving. They had also developed a greater understanding of the capabilities of the batteries. This is discussed in greater detail next.

Improved understanding of the SoC estimate

Table 7.9

Improved Understanding of the SoC Estimate: Summary Table for 3-Month Interview Data

Relevant Statements	No. and % (N=30)
Reference to initial rapid drop in battery power	10 (33%)
Reference to reserve of energy after zero	12 (40%)
Reference to substantial rise in charge level when vehicle switched off then on	8 (27%)

A minority of the drivers (10/30, 33%) reported having learnt that the battery power dropped rapidly at first:

When you [...] start driving that first bit will disappear quite quickly. So yeah, you kind of get to [...] understand that. (Driver 10S)

The first 6 miles seem to use about sort of 18 miles of charge up, and then the last 6 seem to use no charge. So once you get used to that idea [...] you can deal with it. But it would seem very odd to lots of people, who perhaps don't completely understand about electricity. (Driver 14S)

Twelve of them (40%) also cited having discovered that there was a reserve of energy after zero, although they did not know exactly how much:

I suppose [...] from that experience I've learnt that you do have more range than it says you've got, but then it's a very sort of grey area as to how much range you actually have (laughs). (Driver 9S)

So I think when it tends to get down to the last dregs of juice then it will, it almost sort of miraculously finds some odd power out of its back pocket and keeps going. (Driver 25L)

A minority of the drivers (8/30, 27%) also recognised that if they switched the vehicle off, the battery power substantially recovered:

I mean you kind of learn about [...] I've sort of called it „the bounce“. In that you drive somewhere, and it says 50% charge when you leave it, and when you come back it's like 65% charge [...] because the battery has warmed up. (Driver 10S)

The actual analogue gauge itself, it drops and then actually recovers once you've stopped the car, sometimes quite considerably. (Driver 16S)

These findings indicate that drivers had developed a greater understanding of the SoC estimate, and recognised it conveyed a pessimistic reflection of the remaining battery power. Thus, with experience they found this estimate less unsettling.

Increased confidence in the battery capacity

Table 7.10

Increased Confidence in the Battery Power: Summary Table for 3-Month Interview Data

Relevant Statements	No. and % (N=30)
Reference to awareness of energy required for routine trips	15 (50%)
Reference to understanding of battery capabilities under different conditions	21 (80%)

Awareness of energy required for routine trips

Half the drivers (50%) also reported a greater awareness of the amount of energy required for their routine trips, which had increased their confidence in the capabilities of the batteries:

Once I'd established, yes, with this power I can make it and come back, and I've still got something to top up, then a bit of confidence in knowing what [...] the battery can do. (Driver 3L)

So as I've sort of understood, oh well it takes me 25% of my battery to get to Reading and back, then I know that [...] that's how much I can allow, and I know that if I've got that left, or a bit more than that left then I'm fine. And so I suppose as you lean, you become more confident of what you can do and where you can get to. (Driver 19S)

This finding implies that repeat exposure to the range in similar situations had allowed the drivers to judge if the battery power was sufficient for their needs. Thus, it also indicates that the accuracy of the SoC estimate could have become less relevant to them.

Understanding of battery capabilities under different conditions

The vast majority of the drivers (21/30, 80%) noticed that warmer outside temperatures had a positive effect on the battery capacity:

Now that it's warmer it's giving me more miles, so that went from about 68 to 92 or something like that now, when I first unplug it. (Driver 3L)

As you know it has been rather hellish this winter, so very cold mornings, frosty mornings and things. It's charged up but really sort of 55, 60 miles later it's getting very critical. I have to say over the last week or so, where we've had double digit temperatures it seemed to have had a positive impact. Well I'm getting closer to 75 miles, which is where it ought to be at least, the minimum. (Driver 27L)

This resulted in a minority of the drivers (10/30, 33%) expressing some hope that in the warmer months the vehicle might be capable of even greater distances:

I'm looking forward, shall we say, to what it's going to be like as the weather really warms up. I have noticed recently over the last couple of weeks that maybe things are improving slightly. (Driver 2S)

Now I am hoping that as temperatures improve, I mean we are still in single digits, we've hardly got into double digits yet this year, so I am hoping that once the weather improves [...] that's going to improve with it. (Driver 21L)

This finding indicates that the drivers had reflected on their experiences of range, and compared the battery power under a variety of different conditions. Thus, they had developed a greater awareness of the battery capabilities, which could have improved their confidence in it. This result also implies that the drivers had continually monitored and readjusted the distance they felt the vehicle was capable of reaching throughout the trial period. Interestingly, it also suggests that if the vehicles had been trialled in the summer months, then the drivers may not have experienced such dissatisfaction with the maximum range. Thus, new consumers may benefit from range estimates under a variety of different driving conditions (e.g., summer and winter), providing them with a comprehensive picture of the battery capacity.

7.3.2.2 *Recharging*

Public charging

Thirteen of the 30 drivers (43%) continued to cite the public charging infrastructure as too risky to depend upon using:

To know where they are, and then to know, if you are relying on it when you get there, how can you guarantee it will be free and you can use it, or that it

will be working? I know you can't guarantee for every eventuality, things will go wrong, but it's that whole reliability factor. (Driver 8L)

When you want to go to say Westfield shopping centre, yes they've got electric vehicle parking points, but any car can park there. So if you go on a particular busy day, and you're relying on that charge then it's an issue. [...] And so rather than risk it you would either look for another alternative, or if you do go along you make sure that you can go there and back in one trip without having to recharge, which defeats the purpose of having those charging points. (Driver 30L)

This could partially explain why the vast majority of them (26/30, 87%) had not used one during the trial period. It also implies that their active avoidance of using a plug-in point had become routinized behaviour.

The experiences of the few drivers who had attempted to use a charge point over the trial, continued to reinforce this negative perception of them. Two drivers referred to instances where the plug-in points were not working:

My experience a month or so ago, where around Oxford four charge points weren't working [...] and that was like phew (laughs) this is not good. One charge point not working is ok [...] well you sort of think oh darn it's bad luck, but to have four charge points not work you sort of start thinking [...] the „electric gods“ are not with me today. (Driver 7S)

I had one trip up to Oxford when the weather became colder and [...] I realised that I was really short of range and I was worried of getting stuck in central Oxford, so I actually pulled into the BMW plant at Cowley [...] and unfortunately none of their power towers were working. (Driver 29L)

One driver reported instances of turning up to charging points only to find they were already in use:

Every time I've tried to use them the available bays have already had other electric cars in them. (Driver 5S)

An exact McNemar's test revealed there was not a statistically significant difference in the proportion of drivers reporting uncertainty in the public charging network compared to 1-week ($p=.109$). In addition, the proportion of drivers reporting experiences of public charging facilities not working or already in use, had also not significantly changed from 1-week ($p=1.000$). This could be attributable to no major developments having occurred in

the recharging network over the 3 month period (i.e., it remained in an underdeveloped state). Thus, drivers' perceptions (and experiences) of public charging points had not altered with experience.

Home charging

Nine of the 30 drivers (30%) also still expressed uncertainty in home charging:

Yeah, I'd say another thing, not a big issue, but as I mentioned earlier, I found a couple of times, one through my own fault, the other I just don't know what happened, I plugged the car in presuming it was going to charge and it hasn't. There's a challenge on that, particularly when you're doing it at home, because of course it didn't kick in until 11 or 12 o'clock at night when the cheaper electricity rate comes on. So unless I stay up until 11 or 12 o'clock at night to go and check the little orange light thing, I don't know whether it's going to charge. (Driver 2S)

The other thing is like when I've got it at home the trip switch goes, and [...] so now every time I double check the trip switch is backup, and I double check that it is going to work, but I still like have had problems where it hasn't charged properly. (Driver 22L)

This was despite issues with the charging units primarily having occurred in the first week.

7.3.2.3 Anticipatory range concerns

Table 7.11

Anticipatory Range Concerns: Summary Table for 3-Month Interview Data

Relevant Statements	1-Week (N=30)	3-Month (N=30)
Reference to anticipatory concern to running out of charge	21 (70%)	15 (50%)
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	<i>12 (57%)</i>	<i>9 (60%)</i>
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	<i>9 (43%)</i>	<i>6 (40%)</i>
Reference to concern to waking to find a flat battery	8 (27%)	9 (30%)

Anticipatory concerns to running out of charge

Fifteen of the 30 drivers (50%) continued to cite an anticipatory concern to running out of charge:

Obviously having to be aware of the range of the car because you know if you get stranded, you get stranded. (Driver 25L)

I've probably out of five days in a week, I've probably used it [...] between 2 – 3 because I'm concerned that it won't make it, (Driver 28L)

The number of drivers reporting this had decreased slightly from 1-week (please see Table 7.11). This provided some support for the previous research presented in Chapter 2, which showed drivers' range stress had declined with experience (Franke et al., 2012a). The findings from this analysis extended on the extant literature, by suggesting this could be a consequence of drivers having become more familiar with the SoC estimate, which in turn had lessen their concern. It could also be partially attributable to their own behaviour enabling them to judge if the battery power was sufficient for their needs. However, it must be acknowledged that an exact McNemar's test determined that there was not a statistically significant difference in the proportion of drivers reporting range concern compared to 1-week ($p=.210$). Thus, the range had remained a psychological concern to them over the trial period. Three month questionnaire data supported this finding; drivers *strongly agreed* with the statement, „I am more concerned about the range of the MINI E than I am about the range of a gas-powered vehicle“ ($M=5.04;SD=.77;N=27$). What is more, a Wilcoxon test revealed this had not significantly changed from pre-trial ($Z=-1.068$, $p=.286$). This could be explained by drivers continuing to have difficulties predicting how far they could go, and their limited ability to exert control over the range.

Concern to waking to find a flat battery

Nine of the 30 drivers (30%) continued to cite a concern to waking to find the vehicle had not charged:

I have been caught out twice at least, only one time where it significantly mattered, because I've gone to bed happily thinking „Oh yeah, that's fine, it'll

be charged in the morning”, got up, put the keys in the ignition and had a bit of a shock. (Driver 15L)

So that was a bit [...] worrying because obviously you can’t check all the time. And I might have turned the charge on, it might have come on at half past eleven at night and then when I’ve gone to bed the things switched itself off. So you go to the car in the morning in the anticipation it’s fully charged and it hasn’t, so [laughs] yeah that was a bit worrying. (Driver 24L)

As stated earlier in this chapter, the drivers had no way of knowing if the vehicle had started charging, or suddenly stopped during the night. Some drivers used the boost function on the charging unit, however, this only let them know the vehicle was connected correctly to charge and not if an error occurred while charging. This could explain why their concern had persisted.

Drivers continued to implement strategies to prevent the range from being an issue. This is outlined in the next subtheme.

7.3.2.4 *Strategies implemented to manage the range*

Energy reserve

Table 7.12

Energy Reserve: Summary Table for 3-Month Questionnaire Data

Relevant Questions	Response	
	Mean	Standard deviation
Under optimal conditions (low vehicle payload, economical driving etc.) and a fully charged battery I can go for X miles with the MINI E	93 miles N=27	14.55
With a fully charged battery I can confidently drive X miles from the next wall box	73 miles N=26	16.71

Three month questionnaire data revealed that the drivers had continued to leave an energy reserve. These data showed that on average the drivers felt the vehicle was capable of 93 miles under optimal conditions, but only felt comfortable travelling 73 miles themselves (please see Table 7.12). Thus, in keeping with previous research the drivers had seldom

experienced any actual range concern (Carroll et al., 2013; Franke et al., 2012b); they did not strongly agree with the statement, „While driving I was often concerned about the range“ (M=3.71; SD=1.01;N=28). These findings suggest that the drivers“ self-directed influence had resulted in the routinized avoidance of journeys outside the distance they felt comfortable travelling. Thus, all drivers had continued to use the vehicle relatively cautiously, within the confines of their comfortable range. This had the positive effect of stopping them from experiencing a critical range situation. However, it also had the negative long-term consequence of them underutilizing the battery power and recharging network.

Subtle changes were found to occur in the strategies drivers implemented to manage the range. These are outlined next.

Strategies implemented prior to driving

Table 7.13

Strategies Implemented Prior to Driving: Summary Table for 3-Month Interview Data

Relevant Statements	1-Week N=30	3-Months N=30
Reference to forward thinking of trips	19 (63%)	8 (26%)
<i>Drivers with longer typical journey lengths (15-42 miles)</i>	<i>11 (58%)</i>	<i>4 (50%)</i>
<i>Drivers with shorter typical journey lengths (10 miles or under)</i>	<i>8 (42%)</i>	<i>4 (50%)</i>
Reference to keeping the battery as charged as possible	16 (53%)	9 (30%)
Reference to using the boost function to check the vehicle was connected correctly to charge	6 (20%)	4 (13%)

Forward thinking of trips

Eight of the 30 drivers (26%) now referred to range requiring more thought in their everyday lives (i.e., forward planning of trips):

I think planning is definitely required [...] for any journey, more so than ever, you can't just hop in a car [...] you have to know where you're going. (Driver 7S)

I certainly have to [...] think ahead about what I'm doing definitely [...]. With a petrol car obviously you can just sort of leave the car one evening and then decide to go somewhere the next day, and think oh I'll just go to the petrol station, whereas you have to sort of plan 2 or 3 days ahead of what you're doing, to make sure that you've charged the battery up fully enough to be able to do those things. (Driver 19S)

An exact McNemar's test determined that there was a statistically significant difference in the proportion of drivers reporting this strategy from 1-week ($p=.002$) (please see Table 7.13). One potential explanation for this could be that the drivers' usage of the MINI E had become routinized. Chapter 3 explained that habituated behaviour no longer requires conscious thought, instead it occurs automatically through the triggering of a goal-action association by an environmental cue (Bargh & Chartrand, 1999; Verplanken, 2006). Thus, habituated behaviour has shown not to benefit from strategic planning (Verplanken et al., 1998). For example, going to the gym would now automatically trigger the use of the MINI E, rather than the drivers having to consider if getting to the gym would be within the vehicle's range. This indicates that using the MINI E would have become less cognitively demanding (i.e., effortless). Alternatively, drivers' greater awareness of the proportion of battery power used relative to their typical trip length could also account for the reduction in the forward planning of trips. This could allow them to quickly estimate if the battery power was sufficient for their needs.

Keeping the battery as charged as possible

The number of drivers who reported keeping the battery power as charged as possible had also decreased from 1 week (please see Table 7.13). Indeed, 13 of them (43%) now specifically referred to no longer feeling the urge to charge at every available opportunity:

Well when I got it [...] I would charge it at any availability. I would plug it in if it was less than about 60%, I wanted to charge whereas now I'm much more relaxed about it. (Driver 8L)

I was maybe religious about charging it before, but now I'm fairly relaxed at leaving it a night and running it down to 50% rather than making sure I've got

100% before I set off. I'm comfortable if it's up to 50% or 40% even, if I'm travelling in. (Driver 17S)

This finding is consistent with previous research, which showed that drivers charged less frequently with experience (Bunce et al., 2014; Helmbrecht et al., 2014). This could be attributable to them having become more confident in the amount of charge required for their routine activities. However, an exact McNemar's test determined that there was not a statistically significant difference in the proportion of drivers reporting this compared to 1-week ($p=.180$). This could be a partial consequence of the low outside temperatures. Indeed, a minority of the drivers (9/30, 30%) cited that they had charged more frequently in the cold weather to compensate for the negative effects on the range:

It did when the cold weather started, because even on the rare day when I don't use the car I still charge it up now, I've learnt that, so that you don't have that cold battery when you first start off the next morning, but in the warmer weather I wouldn't have bothered doing that if I had lots of charge. (Driver 6L)

Yes, with the colder weather coming I've plugged it in every night. Before that I was plugging in every two nights, or every three because it was holding a charge a lot longer. (Driver 28L)

This implies that the drivers had also reappraised their charging behaviour and had made adjustments to how frequently they plugged-in, to ensure the battery power stayed within the level they felt comfortable travelling.

Using the boost function to check the vehicle was connected correctly to charge

A minority of the drivers (4/30, 13%) referred to having continued to use the boost function to check the vehicle was setup correctly to charge overnight:

What we do now is we plug it in, press the boost button to make sure it's connecting and then press the boost button again to switch it off and leave it. (Driver 1S)

It's sometimes not clear [...] when you plug the car in that it's actually ready to go at that point. So like I put the boost on to see that it's charging and then turn it off again. (Driver 18S)

An exact McNemar's test determined that there was not a statistically significant difference in the proportion of drivers reporting this strategy compared to 1-week ($p=.754$). Although this strategy may have provided the drivers with some reassurance, the findings from this analysis suggest they would have benefited from the development of specific a device to alert them if a charging issue occurred in the night.

Strategies implemented while driving

The vast majority of the drivers (22/30, 73%) had only made changes to their normal driving habits to conserve the battery power, when travelling on a low state of charge:

Only once or twice when I know the battery is sort of a bit low have I actually slowed down, other than that it's been absolutely normal. (Driver 3L)

If you want to go a long distance, you have to go back roads and [...] sort of long roundabout routes, where [...] it's stop start, stop start. (Driver 11S)

Table 7.14

Strategies Implemented While Driving: Summary Table for 3-Month Questionnaire Data

Relevant Questions	Response	
	Mean	Standard Deviation
How often do you only accelerate moderately N=29	4.41	1.01
How often do you try to maintain a constant speed N=29	4.51	1.05
How often do you chose the most energy saving route to my destination N=28	3.54	1.54
How often do you try to drive more slowly N=29	3.86	.91
How often do you turn off the lights N=29	4.00	1.58
How often do you turn off the air-conditioning N=28	4.25	1.55
How often do you turn off the radio N=29	2.96	1.59

Three month questionnaire data supported this finding. It revealed that 82% of drivers responded *yes* to the statement, „Do you change your driving style at what you consider to be a low state of battery charge.“ It also showed they only *occasionally* „accelerated moderately“ and „maintained a constant speed“ (M=4.41;SD=1.01 and M=4.51;SD=1.05 respectively) to conserve the battery power. They also *rarely* „chose the most energy efficient route“ and tried to „drive more slowly“ (M=3.54;SD=1.54 and M=3.86;SD=.91 respectively). In addition, drivers infrequently turned off ancillary features to save energy; they reported only *occasionally* turning off the lights and air-conditioning (M=4.00;SD=1.58 and M=4.25;SD=1.55 respectively) and *very rarely* turned off the radio (M=2.96;SD=1.59) (please see Table 7.14). Thus, the findings from the 3 month analysis suggested that the drivers“ normal driving habits had continued to guide their manner of driving throughout the trial period. Chapter 3 explained that people cannot attend to all aspects of their environment, thus they self-select those parts that are personally relevant to them (Bandura, 1986a, 1997). This could provide an understanding of why the drivers made very few changes to their driving style to conserve the battery power, as for the vast majority of their trips the range would not have been salient to them. Hence, there would have been no motivation for them to monitor and adjust their behaviour to improve how energy efficiently they drove.

A minority of the drivers (11/30, 37%) reported that they were now more likely to use the performance of the vehicle, when range was not an issue to them:

I mean most of my running is relatively short mileage between 10 and 20 miles, so I can use the performance without any concerns whatsoever and I do. And as a result it does drop down a bit, but as I am not doing long miles, long trips at the time it“s not of any issue to me. (Driver 13S)

Actually it“s the opposite (laughs) [...] I try to put my foot down quite a lot just to see what happens, that“s a bit more fun (laughs). And as I say because I don“t have any real worries about the range, I“m not really that worried about looking after the performance of the batteries too much. (Driver 20S)

This could be attributable to the drivers having become more confident in the capabilities of the battery power. Previous research showed that drivers became more competent in conserving the battery power with experience (Carroll et al., 2013; Franke et al., 2012b;

Franke & Krems, 2013a; Rauh et al., 2015, 2017). Interestingly, however, this implies that when there was no necessity for them to save energy, their behaviour became less efficient.

7.3.3 Conclusions

The present chapter aimed to examine why range remained a psychological concern (i.e., where drivers experienced difficulties in relation to range). The findings revealed drivers had difficulties estimating the remaining range. This was primarily attributable to the inaccurate range estimate. In addition, they were also unsure how much energy they had saved through regenerative braking. This could be a partial consequence of the consumption display not allowing them to quantify this. We know SCT views anxiety arousal as arising from a person's perceived inability to exert control over a situation (i.e., low coping self-efficacy). Thus, the above results could be interpreted as a potential reason why range remained an anticipatory concern. These factors would have made the battery power unpredictable. They would also have limited the drivers' ability to use the recovered energy to prolong range. Thus, drivers' perceived ability to exert control over range is likely to have remained low. These findings also imply that the unfamiliar displays (i.e., SoC and energy consumption) were inefficient in assisting drivers predict and extend range.

This chapter also aimed to examine the effect drivers' perception of range had on their adaptation to the BEV. The results showed drivers had used the MINI E primarily for short commuters, as they had intended pre-trial. SCT proposes a person's pre-set beliefs act as a confirmatory bias, causing them to behave in a manner consistent with them. Thus, this finding could be contextualised as suggesting drivers' beliefs (i.e., BEVs were currently ideally suited for short trips) had exerted a self-confirmatory influence on their actual behaviour. This could also give insight into why range remained a perceived barrier, as drivers' behaviour would have reinforced their belief that BEVs were impractical for longer trips because of the battery limitations. Contrary to previous research, this suggests getting drivers behind the wheel of a BEV only served to reinforce this negative perception of range, rather than overcome it (Franke & Krems, 2013b). Interestingly, the findings also indicated drivers' adaptation to range had occurred virtually immediately, and had not

taken 3 months as previously suggested (Pichelmann et al., 2013). Indeed, drivers' maximum trip length had not significantly changed over the trial period.

Drivers had also left an energy reserve as they had anticipated pre-trial. SCT suggests that through forethought, people construct future courses of action anticipatorily in the present. This allows them to exert some influence over their behaviour, and prevents having to learn from trial and error. Thus, a social cognitive perspective could argue this finding implied that drivers' anticipatory strategies to manage range (i.e., leaving an energy reserve) had exerted a self-directed influence over their actual behaviour. This had the expected outcome of them seldom (if at all) experiencing any actual range concern. However, it also had the negative consequence of them underutilizing the energy resources and public charging infrastructure.

The present chapter also aimed to examine the changes that occurred in drivers' perception of range with experience, specifically if this influenced the strategies they implemented to manage range. The results showed drivers' pre-trial suspicions that the range estimate was inaccurate were soon confirmed. They also quickly realised that external factors (e.g., cold outside temperatures, heater and fast stretches of road) had a sobering effect on the battery power. Interestingly, drivers had partially learnt this through the other pioneers accounts of range. This implies drivers' perception of range had to an extent been shaped by their vicarious experiences. Indeed, this mode of influence is likely to have played a critical role in how they perceived range initially, as their own experiences would have been limited. From a social cognitive perspective, the above factors could partially explain the slight initial rise in drivers' range concern, as they would have made it harder to estimate the remaining battery power. Thus, drivers' perceived ability to exert control over range (i.e., coping self-efficacy) could have decreased on initial BEV exposure, giving rise to increased anxiety arousal. However, although the analysis suggested an initial rise in drivers' range concern, the proportion of them reporting this was not significantly different to pre-trial.

Drivers also became concerned the vehicle would not charge overnight, on initial exposure to range. SCT was helpful in contextualising that this could be attributable to external factors (i.e., issues with the charging units, resulting in instances where the vehicle had not

charged). It could also be a consequence of drivers not knowing if the vehicle failed to charge during the night. Thus, their perceived ability to avert a flat battery situation from occurring would have been low.

Drivers switched off on-board features (e.g., heater) in an attempt to reduce the drain on the battery power. They also adjusted the use of the boost function to check the vehicle was connected correctly to charge. It must be acknowledged that this strategy only informed drivers that the vehicle was set-up correctly to charge, and not if a charging issue suddenly arose. SCT could suggest that this indicates drivers had reflected on their experiences of range. As a consequence of their self-evaluation, they had made self-reactive changes to the strategies they implemented to manage the battery power.

Drivers developed a greater understanding of how the SoC display worked over time. For example, they realised the battery power recovered when the vehicle was switched off, then on again, giving a more accurate estimate. Drivers also became familiar with the amount of power used for their routine trips. This enabled them to judge if the remaining power was sufficient for their needs. Thus, drivers' own behaviour had helped them predict range. It also implies they had become less dependent on the range estimate. SCT was a useful concept to interpret that these factors could partially explain the slight decrease in drivers' range concern over time. They would have made the battery power more predictable, which could have enhanced their perceived ability to exert control over range. Although the findings indicated a slight decline in drivers' range concern with experience, the proportion of drivers reporting this was not significantly different from 1-week.

Drivers became dissatisfied with the vehicle's maximum range with experience, as they soon realised it was not capable of reaching the distance they had expected. SCT could argue that this implied the advice from the BMW technical instructors (i.e., the range was about 100 miles) had undermined drivers' confidence, as it overstated the battery capabilities under real-world conditions. This highlights the critical importance that real-world estimates are disseminated on range. Drivers lowered the distance they felt comfortable travelling, as a consequence of their experience of range. A social cognitive perspective would suggest that this implied drivers had compared the vehicle's potential range (e.g., 70 miles) against their internal standards (e.g., 100 miles). As a result, they

readjusted their range expectations. Thus, drivers' self-evaluative reactions had enabled them to set realistic standards. Interestingly, drivers also compared the potential range of their vehicle to that of the other pioneers. SCT proposes that people also use social comparisons (e.g., performances of similar others) as a measure to compare against internal standards. This is because most performance attainments have no absolute measure of adequacy. Thus, SCT was useful to contextualise that the other pioneers' accounts had given context to drivers' self-appraisal of range. This had enabled them to determine if the potential range of their vehicle was lower, greater or comparable to that of the others. Drivers realised that range improved in warmer temperatures with experience. SCT could argue that this indicated they had continuously compared the potential range against their internal standards, which had allowed them to evaluate on-going changes in range.

Finally, this chapter aimed to examine the effect drivers' typical trip length had on their adaptation to range, specifically if this influenced their strategies to manage the battery power. The results revealed very few differences existed between the strategies the two groups of drivers implemented. The findings showed a slight rise amongst drivers with shorter typical trip lengths, referring to having to think ahead and plan their trips on initial BEV exposure. Thus, a more even proportion of both groups of drivers now reported implementing this strategy compared to pre-trial. This could be attributable to range being more salient to drivers, as a result of the lower than expected battery capacity. Interestingly, the proportion of drivers reporting this strategy significantly decreased over time. SCT was helpful to contextualise that this could be a consequence of habituation; drivers' journeys in the MINI E would be automatically triggered by the formation of a goal-action association, rather than requiring conscious thought. It could also be a result of them having become more familiar with the amount of charge required for their routine trips.

Both groups of drivers rarely made changes to their normal driving habits to prolong range (i.e., primarily when travelling on a low SoC). This implies their typical trip length had not affected the strategies they implemented to manage range. SCT could argue this was a result of range not being of personal relevance to them, as they were all using the vehicle within their comfortable range. Thus, there was no need for them to monitor their behaviour, or make self-reactive changes to improve the efficiency of their driving style.

Thus, drivers' conservative behaviour could also have impeded their ability to prolong range, as they seldom used the MINI E in situations that fostered a growth in competency. Interestingly, the results suggested drivers were more likely to use the performance of the vehicle with experience, when range was not an issue. Contrary to previous research, this suggests their behaviour could actually have become less efficient over time (Neumann et al., 2015).

The final chapter summarises the main findings and implications from this research.

Chapter 8

General Discussion

This concluding chapter draws together the findings from this research. It begins by briefly reflecting on the overall research aims, and why this was of psychological relevance (section 8.1). Next, a summary of specific findings are presented (section 8.2, divided into 5 subsections). It outlines how this research has extended understanding of the psychology of range. It also considers how the methodological and theoretical approaches contributed to the novel findings. Implications from this research are then presented (section 8.3), followed by suggestions for practical real-world solutions (section 8.4, divided into 4 subsections). Next, the implications from this research are discussed in relation to recent technological advances (section 8.5, divided into 2 subsections). It concludes with a discussion of the limitations (subsection 8.6.1) and directions for future research (subsection 8.6.2).

8.1 Overall Research Aims

Chapter 2 outlined that this research aimed to explore pioneer BEV drivers' perceptions of range over a sustained period of usage. This was to expose why range was a psychological concern, and the effect this had on their behaviour. It was also to gain insight into how drivers' perception of range was effected by their experiences of the battery power over time, and over a variety of different situations. This research was of psychological relevance because drivers' range concern was proposed as a main barrier currently hindering new attempts at large-scale BEV application in the UK (DfT, 2014; Nilsson, 2011a, 2011b). What is more, this psychological state was found to have a lasting negative effect on drivers' judgements of the remaining range, resulting in them underutilizing the battery power (Carroll & Walsh, 2010; Franke & Krems, 2013a). By examining drivers' range psychology over time, it was intended recommendations would be made to reduce their concern and improve the overall utilization of the battery power.

The present thesis also explored the effect drivers' typical trip length had on their adaptation to range. This was of psychological relevance as previous research showed challenging the range enhanced the adaptation effect (Franke et al., 2012a). However, very few drivers attempted to exhaust the battery power. This implied their typical trip length played a role in their adaptation to range. For example, a driver with a longer typical trip length would be forced to use a greater proportion of the battery power, which could positively affect how they adapt to range. However, to-date no research had examined this.

The next section provides a comprehensive summary of the main findings from this research. It outlines how this thesis extended understanding of the psychology of range, and sometimes contradicted assumptions made in previous research. The findings address the specific research questions outlined below:

- Why drivers perceived range a concern and barrier to usage.
- The effect drivers' perception of range had on their behaviour.
- The effect of experience on drivers' perception of range.
- The effect drivers' typical trip length had on their adaptation to range.

First, the section begins with a discussion of the findings from the qualitative and quantitative data (i.e., questionnaire and data logger information). Specifically, it highlights what was gleaned from each aspect of the data.

8.2 Summary of Specific Findings

8.2.1 Qualitative and quantitative data findings

The qualitative and quantitative data complimented each other on the key findings from this thesis including:

- Range was a concern and barrier to usage, and remained so over time.
- MINI E was used for short commutes.
- Drivers left a reserve of energy (i.e., comfortable range)
- Drivers rarely changed their normal driving habits.

The consistency between the different aspects of the data added validity to the results. However, it must be acknowledged that each data also contributed unique insights into these findings. For example, the qualitative data gave insight into why drivers held the views they did of range (e.g., why the battery power was a perceived psychological concern and barrier to usage). The complexity of drivers' strategies to manage the range was also gleaned from this data. In contrast, the objective measures from the quantitative data gave a different dimension to these findings. For example, this data provided a precise measure of the distance drivers felt confident travelling on a full charge (i.e., comfortable range). In addition, it provided a comprehensive picture of their trip distances over the trial period. From this data it was possible to conclude that the maximum distance drivers ventured in the vehicles had not significantly changed over time. Combined together, these two aspects of the data formed a richer interpretation of the results.

8.2.2 *Why drivers perceived range a concern and barrier to usage*

This research made a novel contribution to knowledge, by providing insight into why range was a psychological concern. The findings showed drivers were unsure how far they could go on a single charge. SCT views anxiety arousal as arising from a person's perceived inability to exert control over a situation (i.e., low coping self-efficacy). Thus, this theoretical perspective was useful to contextualise that drivers' uncertainty in estimating range could partially explain their anxiety arousal, as the battery power would have been unpredictable and uncontrollable to them. This was contrary to previous research, which proposed the BEVs limited drive range (i.e., about 100 miles) was the source of the concern (Franke & Krems, 2013a).

The public charging infrastructure was a further source of uncertainty for drivers. This did not simply relate to the limited availability of charge points, but also to potential issues plugging-in at one (i.e., if they were already in use, or out of order). SCT suggests external factors can also contribute to anxiety arousal. The more unpredictable and uncontrollable external factors are perceived to be, the greater affect they have on anxiety arousal. Thus, the application of SCT was helpful to interpret that the underdeveloped state of the recharging network had also contributed to drivers' range concern.

This thesis also extended on previous research by enhancing understanding of why range was a perceived barrier to usage. The findings suggested this was because drivers expected the battery limitations would prevent them using the MINI E in the same way as their ICEV. This contradicted previous research, which proposed drivers' range concern as a potential explanation for this (Franke & Krems, 2013a). SCT posits that people draw on direct and vicarious experiences to construct future courses of action. In the absence of any direct BEV exposure, SCT was beneficial in contextualising that the „short commuter“ image of BEVs in the UK was instrumental in forming drivers' perception of range. It also implies this stereotypical image was critical in informing drivers' judgements of the role they expected the MINI E to fulfil, and could have contributed to them setting how aspirations for the use of the vehicle.

8.2.3 The effect drivers' perception of range had on their behaviour

This research highlighted the critical role drivers' pre-trial beliefs played in their adaptation to range. The findings revealed drivers had used the MINI E primarily for short trips, as expected pre-trial. SCT could argue this indicated drivers' beliefs (i.e., BEVs were ideal short commuter cars) had exerted a self-confirmatory influence, resulting in them using the vehicle in this manner. This result also extends previous research by furthering understanding of why range remained a perceived barrier; drivers' behaviour would have reinforced their perception that BEVs were not practical for longer trips because of the battery limitations. Contrary to previous research, this suggests getting drivers behind the wheel of a BEV only served to reinforce this negative perception of range, rather than overcome it (Franke & Krems, 2013b). Interestingly, the findings also implied that drivers' adaptation to range had occurred virtually immediately, and had not taken 3-months as previously suggested (Pichelmann et al., 2013). Indeed, the maximum distance drivers travelled in the vehicles had not significantly changed over the trial period.

The findings also showed that, pre-trial, drivers anticipated leaving an energy reserve. A social cognitive perspective was advantageous in conceptualising this implied drivers' self-efficacy beliefs had regulated their emotional response to range. Indeed, this anticipatory strategy allowed them to turn the potentially hazardous situation of running out of charge into a benign one. Thus, prior to stepping foot in the BEV, they had already constructed

strategies to prevent range being an issue. Drivers left an energy reserve throughout the trial period, as intended. SCT could suggest this indicated drivers' a priori strategies vis-à-vis range had enabled them to exert a self-directed influence over their behaviour. Indeed, they had the expected outcome of preventing them from experiencing a critical range situation. However, they also had the negative consequence of them underutilizing the battery power and existing charge points.

Drivers made very few changes to their normal driving habits (i.e., primarily when travelling on a low state of charge). Interestingly, the results suggested drivers were more inclined to use the performance of the vehicle with experience, when range was not an issue. Contrary to previous research, this implies their behaviour became less energy efficient over time (Neumann et al., 2015). SCT was a useful concept to contextualise this could be attributable to drivers not attempting to push the battery power. Thus, they were seldom motivated to monitor their behaviour, and make self-evaluative reactions to conserve battery power. This suggests drivers' conservative behaviour also had a negative effect on the efficiency of their driving style.

8.2.4 The effect of experience on drivers' perceptions of range

This thesis furthered understanding of the effect experience had on drivers' perception of range, and the strategies they implemented to manage it. The findings showed drivers' pre-trial suspicions that the range estimate was inaccurate were soon confirmed. They also quickly realised that external factors (e.g., heater and fast stretches of road) noticeably reduced the battery power. The application of SCT was beneficial in interpreting that these factors could partially explain the slight initial rise in drivers' range concern; they would have made the battery power harder to estimate. This could have led to a decrease in drivers' perceived ability to exert control over range (i.e., coping self-efficacy), giving rise to increased anxiety arousal. However, it must be acknowledged that the proportion of drivers reporting range concern had not significantly changed from pre-trial. Drivers also became concerned the vehicle would not charge overnight, on initial exposure to range. SCT was helpful in contextualising that this could be attributable to external factors (i.e., issues with the charging units, resulting in instances where the vehicle had not charged). It could also be a consequence of drivers not knowing if the vehicle failed to charge during

the night. Thus, their perceived ability to avert a flat battery situation from occurring would have been low.

Drivers switched off on-board features (e.g., heater) in an attempt to reduce the drain on the battery power. They also adjusted the use of the boost function to check the vehicle was connected correctly to charge. It must be acknowledged that this strategy only informed drivers that the vehicle was set-up correctly to charge, and not if a charging issue suddenly arose. This could explain why their charging concern persisted over the trial period. SCT could argue the above findings indicated drivers had reflected on their experiences of range. As a consequence of their self-evaluation, they had made self-reactive changes to the strategies they implemented to manage the battery power.

Drivers developed a greater understanding of how the SoC display worked over time. For example, they realised the battery power recovered when the vehicle was switched off, then on again, giving a more accurate estimate. Drivers also became familiar with the amount of power needed for their routine trips. This enabled them to judge if the remaining energy was sufficient. Thus, drivers' own behaviour had helped them predict range. It also implies they had become less dependent on the range estimate. SCT was a useful concept to interpret that the above factors could partially explain the slight decrease in drivers' range concern over time. They would have made range more predictable, which could have enhanced their perceived ability to exert control over range. Although the findings indicated a slight decline in drivers' range concern with experience, the proportion of drivers reporting this was not significantly different from 1-week.

Importantly, the findings implied the new displays (i.e., SoC and energy consumption) were inefficient in assisting drivers' predict and prolong range. The social cognitive perspective was beneficial in contextualising that this could partially explain why range remained a psychological concern over the trial period. This resulted in drivers remaining unsure how far they could go on a single charge. It also limited their ability to use the recovered energy to extend the battery power. Thus, drivers' perceived ability to exert control over range (i.e., coping self-efficacy) would have remained low throughout the trial.

This thesis also highlighted the critical importance that real-world estimates are disseminated on range. Drivers became dissatisfied with the vehicle's maximum range with experience, as they soon realised it was not capable of reaching the distance they had expected. SCT could argue that this implied the advice from the BMW technical instructors (i.e., the range was about 100 miles) had undermined drivers' confidence, as it overstated the battery capabilities under real-world conditions. Drivers lowered the distance they felt comfortable travelling, as a consequence of their experience of range. A social cognitive perspective could suggest this indicated drivers had compared the vehicle's potential range (e.g., 70 miles) against their internal standards (e.g., 100 miles). As a result, they readjusted their range expectations. Thus, drivers' self-evaluative reactions enabled them to set realistic standards. Drivers learnt with experience that range improved in warmer temperatures. SCT was a useful concept to interpret that this indicated drivers had continually compared the potential range against their internal standards, which had allowed them to evaluate on-going changes in battery power.

8.2.5 The effect drivers' typical trip length had on their adaptation to range

This research made a novel contribution to knowledge by exploring the effect drivers' typical trip length had on their adaptation to range. The finding suggested drivers with longer typical trip lengths were more inclined to perceive the SoC display as essential, after first BEV contact. They were also more focused on where energy had been consumed and recovered during the initial test drive. In contrast, drivers with shorter typical trip lengths were less likely to perceive the SoC display as important to them. They were also less aware of where energy loss and recapture had occurred. The application of SCT was advantageous in contextualising this suggested drivers' beliefs (i.e., how critical range would be to them on a daily basis) had exerted a self-selective bias, causing them to monitor and attend to those aspects of the training session they considered personally relevant. Thus, drivers' typical trip length influenced how they interpreted and processed the information received during the technical instruction session.

We know drivers rarely made changes to their normal driving habits. This indicates that their typical trip length had not affected their strategies to manage range. A potential reason for this could be that as all drivers had restricted their use of the vehicle to within

their comfortable range, neither group were motivated to drive energy efficiently. A social cognitive perspective could argue that this suggests drivers' conservative behaviour had impeded their ability to prolong range, as they were not using the vehicle in situations that would foster a growth in competency.

The findings from this research have important implications for vehicle manufacturers, stakeholders and policymakers. These are discussed in greater detail next.

8.3 What are the implications of these findings?

This research has important implications in highlighting that rather than simply increasing battery power, substantial reductions in drivers' range concern could be achieved through making the battery power (and associated recharging) more predictable and controllable for them. Indeed, this could be particularly relevant while the BEV's drive range (and associated recharging network) remain inferior to the ICEV (and associated refuelling network). Critically, this could also improve utilization of the energy resources and plug-in points already available to the drivers.

The findings from this research also emphasises the critical importance of a reliable figure being conveyed on the BEV's drive range. This would instil drivers with confidence in the battery capacity and prevent dissatisfaction in the range. Indeed, the accuracy of this information is vital, as it forms the basis of the parameters in which drivers expect to use the vehicle. More generally, this research indicates that when launching a product to market that consumers have no direct experience of (e.g., autonomous vehicles), it is important that information conveyed on them is set within realistic bounds.

This research also highlights the importance of motivating drivers to adopt an energy efficient driving style. It could be argued that if the range is not an issue then it does not matter if a drivers' behaviour is energy efficient or not. However, a drivers' behaviour can have a profound effect on the battery power. Thus, for the BEV to be as sustainable as possible, it is vital that they are encouraged to drive in an energy efficient manner. This is also of relevance in preventing a drivers' own behaviour from contributing to their dissatisfaction in the achievable range. Indeed, this would be comparable to a driver

expressing disappointment in the MPG they were getting from their ICEV, after accelerating aggressively, braking abruptly and travelling at high speeds. This situation could become worse in the future, with continued improvements in the battery capacity and public charging infrastructure, lessening the need for drivers to conserve energy.

In the future, as technological advances result in the BEV becoming practical to use for longer trips, the findings from this research indicate it will become of critical importance to breakdown the embedded short commuter image of this type of car, within UK society. Indeed, this will help ensure the effective transition of the BEV from niche market vehicle to a multipurpose one.

Finally, this research highlights the importance of gaining the users' perceptive of a new product to understand potential areas for future development. It also emphasises that when launching a new product to market, manufacturers, stakeholders and policymakers need to come together and join forces on the universal aspects of that product (e.g., connectors and payment mechanisms). This would make the product easier for consumers to use. It would also increase their confidence in using it, and thus improve the likelihood of uptake.

The next section suggests some practical real-world solutions that could help address some of these issues.

8.4. Practical real-world solutions

8.4.1. Practical real-world solutions to improve range predictability & controllability

8.4.1.1 Displays

The analogue design used in the MINI E (i.e., 0-100 scale) was particularly sensitive to the slightest variations in battery power. This made estimating the remaining miles difficult and created uncertainty in the drivers. An alternative design could be to present the range estimate in a similar format to the battery power display on a mobile phone. This design would not be so effected by the continuous fluctuations in battery power; bars representing a percentage of charge would simply disappear linearly as energy is used up, thus drivers

may find it less unnerving. They would also soon learn roughly how long a bar of energy lasted (i.e., how many miles they could travel), which would help them estimate the remaining range. It could also help the drivers to make effective use of the energy saved through regenerative braking, as a bar of energy would simply last longer.

A visual display could also show the amount of power consumed by an ancillary feature when switched on. This would allow the driver to calculate the approximate impact of each feature on the range, thus making it more predictable. It would also enable them to learn if a feature was a significant consumer of energy and, therefore, if switching it off would have a substantial effect on the overall range. For instance, a driver could turn the radio off to save energy, when this may only use a negligible amount of energy. Conveying information on the energy used by ancillary features would be particularly useful for drivers in the early stages of BEV adaptation. At this point, they would not have enough experience to compare, for instance, the amount of energy used on a trip with the heater on versus off.

8.4.1.2 Recharging

Various strategies could be implemented to make the public recharging infrastructure more reliable for drivers and encourage usage. Booking systems could be developed allowing drivers to book a charge point in advance. Online systems could also be designed that enable a driver to see if a charge point is available, in working order, and what connectors and payment mechanism is required. Charge bays should also be made available for electric vehicles only. Stakeholders, policymakers and vehicle manufactures need to come together and agree on a standard connector and payment system. In addition, a device could be designed that lets the driver know the vehicle is connected correctly to charge, and alert them if it stops charging in the night.

8.4.2 Practical real-world solutions to improve the reliability of the stated range

The range achievable under real-world conditions is dependent on a wide variety of factors (e.g., driving style, ambient temperature and terrain). This suggests that providing a figure that reliably conveys the maximum distance a driver could expect from the vehicle would

be challenging to say the least. An alternative solution could be for vehicle manufacturers to communicate a range they guarantee the vehicle is capable of at least achieving under normal driving conditions. This could have the effect of instilling drivers with confidence in the battery power, and prevent them from experiencing range dissatisfaction.

8.4.3 *Practical real-world solutions to encourage energy efficient behaviour*

Drivers had no understanding of how the energy saved through regenerative braking converted into money saved on recharging. This could provide an alternative way of motivating them to drive energy efficiently. Information could be conveyed on how much money they had saved through regenerative braking, compared to the money they could have saved if they had driven as energy efficiently as possible. This information could be displayed per trip and accumulatively over a set period of time (e.g., a week).

8.4.4 *Practical real-world solutions to breakdown ‘commuter car’ image*

In the future, marketing strategies aimed at dissociating the BEV from the „commuter“ car image, could be used alongside technological advances to ensure its successful transition to the mainstream consumer market. For example, by ensuring the BEV is not branded as a short commuter car as they currently are today (e.g., Megacity, Comuta-car and Citicar), but as a multipurpose vehicle.

The findings from the TSB demonstrator trials have contributed to significant improvements having occurred in BEV technology (and associated recharging network). Indeed, BEVs available on the market today are radically different E-machines as a consequence of the information that was fed back to vehicle manufacturers. This brings into question the relevance of the findings from this research today, as it suggests that to a certain extent they were unique to the time period. The next section examines this in greater detail. It begins by outlining some of the advances that have occurred (8.5.1). It then moves onto explain how the findings are still of some relevance today to vehicle manufacturers, stakeholders and policy makers (8.5.2).

8.5. Relevance of research findings today

8.5.1 Advances in BEV technology and associated recharging

8.5.1.1 Advances in BEV technology

Battery capacity (and associated recharging time) has continued to improve since the MINI E trials. For example, the BMW i3 has a range of 186 miles (and associated recharging time of 40 minutes). The BMW i3 is also fitted with active air distribution (flaps that can open or close to cool the battery while driving). A 400V heating element is also installed to heat the battery. These features would help maintain a constant battery temperature, and prevent the battery power from being adversely affected by low outside temperatures. Active preconditioning is also available; this heats or cools the vehicle to a pre-set temperature whilst still plugged-in, thus lessening the drain on the battery. Information on ancillary usage is now provided; the range estimate in the BMW i3 will indicate a potential plus value if the heating is turned down slightly, or the economy route is selected within the navigation system. This would allow drivers to accommodate the impact of ancillary features on the range, and thus help make the range more predictable for them. In addition, graphic displays provide detailed feedback on regenerative braking; both current and over a selected period (from 5 minutes to 60 minutes). Feedback on how energy efficiently a driver has driven is also provided. This could improve the drivers' ability to exert some control over the potential range. Finally, an app has been developed which alerts the drivers if the vehicle stops charging. The vehicle can also send a text and / or email message. These new technological developments highlight the need for additional psychological research to examine their potential influence on drivers' perceptions of the range.

8.5.1.2 Advances in the public charging infrastructure

At the time of the MINI E trials less than 300 charge points existed across the UK (SMMT, 2011). Since then the Government has invested over £30 million in developing a recharging network (Blythe, Wardle, Huebner, & Gibbon, 2016). To-date approximately 8,830 public charging points have been installed at just under 5,262 locations across the

UK (GUL, 2016). It has been predicted that if the current growth in plug-in points continues, then by 2020 they will outnumber petrol stations (Blythe et al., 2016). What is more, the UK now has the largest number of rapid charging points in Europe (Nierynck, 2016). Rapid charging has significantly reduced the time required to recharge the batteries; this type of recharger has the ability to recharge a vehicle to 80% capacity within 30 minutes (SMMT, 2011). In addition, online charging maps now exist which claim to list all public charging points across the UK (e.g., ZapMap and Open Charging). They offer information on the service provider, the connectors offered at the point and the operational status of the charging point. These advances could have increased drivers' confidence in using the existing recharging network. Indeed, usage of plug-in points has substantially increased in the past few years. For example, a survey of 178 BEV owners conducted by Next Green Car (2015, cited in Wirgman, 2015) showed that 90% of them stated they regularly used the available plug-in points. What is more, 68% reported doing so at least once per week (36% more than once per week). The developments that have occurred in the recharging network also highlight the need for additional psychological research. Indeed, this could be particularly timely with several large vehicle manufacturers (BMW, Daimler, Ford and Volkswagen Group, including Audi and Porsche), recently announcing they will be working together to create a high powered, recharging network across Europe ("Car firms to build," 2016).

8.5.1.3 Advances in test procedures to measure the drive range of the BEV

Test procedures used to measure the all electric range of a vehicle (e.g., New European Driving Cycle (NEDC) and the California Test Procedure) have been heavily criticised for their lack of real-world repeatability. This is attributable to a variety of factors including: test procedures performed with ancillary features (e.g., heater) switched off, under ambient temperatures of 20-30°C and unrealistically slow acceleration times and maximum speeds. Recently, however, a new global harmonized driving cycle – the Worldwide Light Vehicles Test Procedure (WLTP) – has been developed by experts from the European Union, India and Japan. It will apply to all new car registrations from September 2018. WLTP uses much more realistic testing conditions including: a greater range of driving situations (e.g., urban, suburban, main roads and motorways), more realistic ambient temperatures (23-14°C), ancillary features are taken into account and more representative

braking and acceleration. Thus, WLTP will reduce a lot of the discrepancy between the test range and real-world range.

8.5.2 What relevance are the findings from this thesis today?

8.5.2.1 Relevance of research findings in relation to BEV technology

Despite improvements in BEV technology, the battery capacity and associated recharging remain inferior to the ICEV and associated refuelling. Thus, it is still likely to be viewed as a barrier to usage. In addition, the range estimate in new electric vehicles, such as the BMW i3, is typically presented as a digital readout of the miles remaining. This type of range estimate is still likely to be highly sensitive to continuous variations in battery power, and as a consequence will only provide a snapshot of the remaining miles at that precise moment in time. For example, at the top of a hill the digital reader might display a range of 30 miles. However, after recovering energy coming down the other side this could increase to 35 miles. What is more, although range estimates attempt to accommodate the impact of ancillary features, this may not be completely accurate as it is a predictive value (i.e., potential range minus energy that would be used by the heater). Therefore, drivers may still have some difficulties estimating precisely how far they could go. Finally, although drivers are provided with detailed feedback on how energy efficiently they have driven, this information is unlikely to be beneficial in motivating them to adopt an energy efficient driving style. Indeed, the results of this research highlighted that the range was seldom an issue for the drivers, as the vast majority of their trips were well within the battery capacity. Thus, they are unlikely to pay much attention to this information, as it will be of limited personal relevance to them.

8.5.2.2 Relevance of research findings in relation to recharging infrastructure

Despite the rapid growth in charge points in the UK since the MINI E trials, this has not matched the recent boom in the number of new BEVs licenced on the roads in the UK. What is more, although vehicle manufacturers are coming to recognise the importance of joining forces and working together to provide an integrated recharging network, there is not yet a single connector available that would allow a driver to plug-in anywhere. To

make matters worse, there are at least 20 different companies and organisations installing and running nationwide and regional charging networks in the UK. These all operate different membership schemes, with some operating „pay as you go“ systems, some requiring significant subscription fees and others offering free power and minimal sign-up fees (Kiss, 2015). In addition, the information provided by charging maps is user generated in a proportion of cases, as a result it is not always up to-date. Therefore, it is unsurprising that there continues to be media reports of drivers turning up to a charging point, only to discover that it is already in use (Charlton, 2015). Charging points also continue to be subject to misuse by ICEVs; this has become so common that it is now referred to as „ICE-ing“ within the BEV community (Foxall, 2016). This suggests that drivers today will still experience some concern to turning up to a charge point, only to find they are unable to plug-in. Indeed, research by Next Green Car (2015, cited in Wirgman, 2015) revealed that only 24% of BEV drivers were recharging when the SoC was between 0-20% of remaining power. This implies that the vast majority of them were still not depending on using a charge point to make their journey.

8.5.2.3 Relevance of research findings in relation to improving the reliability of the stated range

Despite the WLTP providing a far more realistic representation of the range under different conditions encountered on the road, it cannot cover all possible variations. For example, hill climbing is not included in the test procedure, which would increase energy consumption rates and lower the potential range. WLTP is still also unrealistically slow; the most rapid 0-50km per hour (0-30 mph) used in the test procedure is 15 seconds, whereas most drivers in the UK accelerate to this speed in 5-10 seconds. Furthermore, each individual driver will continue to have a different driving style; one might accelerate fast, take corners fast or brake more aggressively than another. Thus, there will still be some discrepancy between the range of a BEV as measured by the WLTP, and what is actually achievable under real-world conditions.

8.6 Limitations and directions for future research

8.6.1 *What are the limitations of this research?*

The MINI E trial region covered a large geographical area in the South-East of England, incorporating both urban (e.g., Oxford and Guildford) and rural areas (e.g., Wantage and Farringdon). This was beneficial in terms of gaining insight into the drivers' experiences of range in a wide variety of situations. However, as a consequence the subsample of MINI E drivers was not typical of the drivers used in other BEV trials, who were recruited from urban areas (Carroll & Walsh, 2010; Franke & Krems, 2013a, 2013b, 2013c; Franke et al., 2012a, 2012b; Gärling, 2001; Skippon & Garwood, 2011).

In terms of the design of the project, the MINI E data was collected prior to the PhD, as part of a much larger study designed to examine all aspects of drivers' expectations and experiences of BEV usage. Thus, only a small proportion of questions specifically addressed range related issues, as a consequence some of the drivers' thoughts and feelings may not have been fully captured. For this reason, the numbers and percentages drawn from the interview data must be taken with a degree of caution. In future research developed to extend these findings, a greater number of targeted questions could ensure that all drivers' views were adequately represented.

When interpreting the findings from this research, it should be recognised that all except one driver had access to an ICEV throughout the trial. This could have biased how viable they found the range in their everyday lives, as they simply used their ICEVs on occasions they needed to travel further afield. What is more, the drivers received continued support from the BMW technical team. This could have reduced the degree of range concern they experienced, as they knew if they got into difficulties help was only a phone call away. For example, one driver recalled an occasion when she had phoned the technical experts, because she was concerned she was in danger of running out of power. She received reassurance she had enough charge and continued on her way.

The MINI E trial took place during the winter months in the UK, indeed, the drivers in phase-1 faced using the vehicles in the harshest winter the UK had experienced in over 25-

years. This was good in terms of testing the vehicles. However, it could have also led to some biasing of the results. For instance, the drain on the battery power from the ancillary features would have been greater during this time. The cold outside temperatures also resulted in the vehicles not fully charging. Thus, the drivers' dissatisfaction in the range could have been more evident, than if they had trialled the vehicles in the summer months. Future research to extend on these findings could examine the changes that occur in drivers' perceptions of range over the summer months.

In terms of the content, this thesis focused on drivers' perceptions of range over a sustained period of time. It did not explore how the drivers' interactions with members of the public, could have influenced the views of the people they engaged in conversation with on the range. Indeed, the drivers would have become authoritative sources of information on the BEV over the course of the trial, thus the information they disseminated to other could have had a particularly strong influential effect. Future research could examine this interaction in greater detail, as this would be of importance in understanding how to bridge the gap between the early adopters and early majority of drivers.

Finally, this thesis took an exploratory approach to the study of range, rather than to test specific predictions. This was appropriate for the purposes of this research, which aimed to gain insight into perceptions of range over time. Future research that extends on these findings could test some of the recommendations made from this research. For instance, if guaranteeing a distance the BEV would at least reach under real-world conditions, improved drivers' confidence in the battery power.

8.6.2 What are the additional potential directions for future research?

In addition to the above suggestions, future research could also investigate ways of enhancing drivers' confidence in the battery capacity through the advice and training they receive on the vehicle. As previously stated, to-date no research has examined this, however, this does represent a critical period where effective interventions could alter drivers' perceptions of range and enhance their range utilization behaviour. More broadly, the findings from this thesis highlight the value of applying a social cognitive perspective to help manufacturers launch new products to markets, already dominated by existing

products that do exactly what the user requires of them. For instance, there has recently been a lot of interest in autonomous vehicles; the government has stated that it wants the UK to be at the forefront of developments on this type of car, and is prepared to spend millions on research and development. In response to this, BMW has announced they want a fully autonomous vehicle on the roads in the UK by 2021 (Beckwith, 2017).

8.7 Final conclusions

In conclusion, this thesis identified a critical gap in the existing literature and revealed the importance of examining drivers' perceptions of range in understanding why the limited battery power was a psychological concern and barrier to usage. It explained how the findings could contribute to overcoming drivers' range concern through making the battery power more predictable and controllable for them. This could also have the beneficial effect of helping them to effectively utilize the energy resources and plug-in points already available to them, rather than simply increasing the battery capacity.

References:

- Aarts, H., & Dijksterhuis, A. (2000). Habit as knowledge structures: Automaticity in goal-directed behaviour. *Journal of Personality and Social Psychology*, 78(1), 53-63. doi:10.1037/0022-3514.78.1.53 (a)
- Aarts, H., & Dijksterhuis, A. (2000). The automatic activation of goal-directed behaviour: The case of travel habit. *Journal of Environmental Psychology*, 20, 75-82. doi:10.1006/jevp.1999.0156 (b)
- Aarts, H., Verplanken, B., & van Knippenberg, A. (1997). Habit and information use in travel mode choices. *Acta Psychologica*, 96, 1-14. doi:10.1016/S0001-6918(97)00008-5
- Aarts, H., Verplanken, B., & van Knippenberg, A. (1998). Predicting behaviour from actions in the past: Repeated decision making or a matter of habit? *Journal of Applied Social Psychology*, 28, 1355-1374. doi:10.1111/j.1559-1816.1998.tb01681.x
- Accenture. (2011). Plug-in electric vehicles: Changing perceptions, hedging bets. Retrieved from www.accenture.com/SiteCollectionDocuments/PDF/Accenture_Uilities_Study_Changing_perceptions.pdf
- Ajanovic, A. (2015). The future of electric vehicles: Prospects and impediments advanced review. *WIREs Energy Environ* 2015. Doi: 10.1002/wene.160.
- Ajzen, I. (1985). From intention to actions: A theory planned behaviour. In: J. Kuhl & J. Beckmann, *Action-control: From cognition to behaviour*. Heidelberg: Springer.
- Ajzen, I. (1991). The theory of planned behaviour. *Organizational Behaviour and Human Decision Processes*, 50, 179-211. doi:10.1016/0749-5978(91)90020-T
- Ajzen, I. (2001). Nature and operation of attitudes. *Annual Review of Psychology*, 52(1), 27-58. doi:10.1146/annurev.psych.52.1.27
- Ajzen, I. (2011). The theory of planned behaviour: Reactions and reflections. *Psychology and Health*, 26(9), 1113-1127. doi:10.1080/08870446.2011.613995
- Ajzen, I., & Madden, T. (1986). Prediction of goal-directed behaviour: Attitudes, intentions, and perceived behavioural control. *Journal of Experimental Social Psychology*, 22, 453-474. doi:10.1016/0022-1031(86)90045-4
- Ambak, K., Harun, N.E., Rosli, N., Daniel, B.D., Prasetyo, J., Abdullah, M.E., & Rohani, M.M. (2016). Driver intention to use electric cars using technology acceptance model. *ARPJ Journal of Engineering and Applied Sciences*, 11(3), 1524-1528.

- Anable, J. (2005). Complacent car addicts or aspiring environmentalists? Identifying travel behaviour segments using attitude theory. *Transport Policy*, 12, 65-78. doi:10.1016/j.tranpol.2004.11.004
- Anable, J., & Gatersleben, B. (2005). All work and no play? The role of instrumental and affective factors in work and leisure journeys by different travel modes. *Transportation Research Part A: Policy & Practice*, 39 (2-3), 163-181. doi:10.1016/j.tra.2004.09.008
- Anable, A., Schuitema, G., & Stannard, J. (2014). Consumer response to electric vehicles literature review, University of Aberdeen, Research Report RPN1475.
- Anderson, J., & Anderson, C. D. (2005). Electric and hybrid cars: A history. London: McFarland.
- Armitage, C.J., & Conner, M. (2001). Efficacy of the theory of planned behaviour: A meta-analytic review. *British Journal of Social Psychology*, 40, 471-499. doi:10.1348/014466601164939
- Arts, J.W.C., Frambach, R.T., & Bijmolt (2011). Generalizations on consumer innovation adoption: A meta-analysis on drivers of intention and behaviour. *International Journal of Research in Marketing*, 28, 134-144. doi:10.1016/j.ijresmar.2010.11.002
- Bagozzi, R.P., Davis, F.D., & Warshaw, P.R. (1992). Development and test of a theory of technological learning and usage. *Human Relations*, 45(7), 660-686.
- Bakker, J.J. (2011). *Contesting range anxiety: The role of electric vehicle charging infrastructure in the transportation transition*. Unpublished master thesis, University of Technology, Eindhoven.
- Bamberg, S., Rölle, D., & Weber, C. (2003). Does habitual car use not lead to more resistance to change of travel mode? *Transportation*, 30(1), 97-108. doi:10.1023/A:1021282523910
- Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioural change. *Psychological Review*, 84(2), 191-215. doi:10.1016/0146-6402(78)90002-4
- Bandura, A. (1978). The self-system in reciprocal determinism. *American psychologist*, 33(4), 344-358. doi:10.1037/0003-066X.33.4.344
- Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist*, 37(2), 122-147. doi:10.1037/0003-066X.37.2.122
- Bandura, A. (1983). Self-efficacy determinants of anticipated fears and calamities. *Journal of Personality and Social Psychology*, 45 (2), 464-469. doi:10.1037/0022-3514.45.2.464
- Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. London: Prentice-Hall (a)

- Bandura, A. (1986). Fearful expectations and avoidant actions as co-effects of perceived self-efficacy. *American Psychologist*, 41, 1391-1398. Doi:10.1037/0003-066X.41.12.1389 (b)
- Bandura, A. (1988). Self-efficacy conception of anxiety. *Anxiety Research*, 1, 77-98. doi:10.1080/10615808808248222
- Bandura, A. (1989). Human agency in Social Cognitive Theory. *American Psychologist*, 44(9), 1175–1184. doi:10.1037/0003-066X.44.9.1175
- Bandura, A. (1990). Perceived self-efficacy in the exercise of control over AIDS infection. *Evaluation and Program Planning*, 13, 9-17. doi:10.1016/0149-7189(90)90004G
- Bandura, A. (1991). Social cognitive theory of self-regulation. *Organizational Behaviour and Human Decision Processes*, 50, 248-287. doi:10.1016/0749-5978(91)90022-L
- Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist*, 28(2), 117-148. doi:10.1207/s15326985ep2802_3
- Bandura, A. (1994). Self-efficacy. In V.S. Ramachaudran (Ed.), *Encyclopedia of Human Behaviour*. New York: Academic Press.
- Bandura, A. (1995). Exercise of personal and collective efficacy in changing societies. In A. Bandura (Ed.), *Self-efficacy in changing societies*. Cambridge: Cambridge University Press.
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman & Company.
- Bandura, A. (1998). Health promotion from the perspective of social cognitive theory. *Psychology & Health*, 13(4), 623-649. doi:10.1080/08870449808407422
- Bandura, A. (2001). Social Cognitive Theory: An agentic perspective. *Annual Review of Psychology*, 52, 1–26. doi:10.1146/annurev.psych.52.1.1 (a)
- Bandura, A. (2001). Social Cognitive Theory of mass communication. *Media Psychology*, 3, 265-299. doi:10.1207/S1532785XMEP0303_03 (b)
- Bandura, A. (2005). The evolution of social cognitive theory. In K.G. Smith & M.A. Hill (Eds.), *Great Minds in Management*. Oxford: Oxford University Press.
- Bandura, A. (2006). Towards a psychology of human agency. *Perspectives on Psychological Science*, 1, 164-180. doi:10.1111/j.1745-6916.2006.00011.x
- Bandura, A. (2007, December 11). Everett M. Rogers Award Colloquium 2007. USC Annenberg. Retrieved from <https://www.youtube.com/watch?v=xjIbKaSXM3A&t=242s>
- Bandura, A. (2012). On the functional properties of perceived self-efficacy revisited. *Journal of Management*, 38(1), 9-44. doi:10.1177/0149206311410606

- Bandura, A. & Jourden, F.J. (1991). Self-regulatory mechanisms governing the impact of social comparison on complex decision making. *Journal of Personality and Social Psychology*, 60(6), 941-951. doi:10.1037/0022-3514.60.6.941
- Bandura, A. & Menlove, F.L. (1968). Factors determining vicarious extinction of avoidance behaviour through symbolic modeling. *Journal of Personality and Social Psychology*, 8(2), 99-108. doi:10.1037/h0025260
- Bandura, A., & Wood, R. (1989). Effect of perceived controllability and performance standards on self-regulation of complex decision making. *Journal of Personality and Social Psychology*, 56(5), 805–814. doi:10.1037/0022-3514.56.5.805
- Bandura, A., Adams, N.E., & Beyer, J. (1977). Cognitive processes mediating behavioural change. *Journal of Personality and Social Psychology*, 35(1), 125-139. doi:10.1037/0022-3514.35.3.125
- Bandura, A., Reese, L., & Adams, N.E. (1982). Microanalysis of Action and Fear Arousal as a Function of Differential Levels of Perceived Self-Efficacy. *Journal of Personality and Social Psychology*, 43(1), 5-21. doi:10.1037/0022-3514.43.1.5
- Bargh, J.A. (1994). The four horsemen of automaticity: Intention, awareness, efficiency, and control as separate issues. In R. Wyer & T. Srull (eds.), *Handbook of Social Cognition*. Lawrence Erlbaum.
- Bargh, J.A., & Chartrand, T.L. (1999). The unbearable automaticity of being. *American Psychologist*, 54(7), 462-479. doi:10.1037/003-066X.54.7.462
- Beckwith, J. (2017, May 30). BMW confirms fully autonomous iNext for 2021. Retrieved from: <https://www.autocar.co.uk/car-news/new-cars/bmw-confirms-fully-autonomous-inext-2021>
- Beggs, S., Cardell, S., & Hausman, J. (1981). Assessing the potential demand for electric cars. *Journal of Economics*, 17, 1-19. doi:10.1016/0304-4076(81)90056-7
- Beirao, G., & Sarsfield Cabral, J.A. (2007). Understanding attitudes towards public transport and private car: A qualitative study. *Transport Policy*, 14, 478-489. doi:10.1016/j.tranpol.2007.04.009
- Black, T.R. (1999). *Doing quantitative research in social sciences*. Thousand Oaks, CA: Sage.
- Blanco, S. (2010). GM trying to trademark “range anxiety” to tell you about “electric vehicle capabilities”. Retrieved from <http://green.autoblog.com/2010/09/01/gm-trying-to-trademark-range-anxiety-to-tell-you-about-electric/>
- Blythe, P.T., Wardle, J., Huebner, Y., & Gibbon, J. (2016). Public electric vehicle recharging in the UK – is there a business case? *Proceedings of the 11th Intelligent Transport Systems European Congress*, June 6-9, Glasgow, UK.
- Boxwell, M. (2010). *Owning an electric car (2010 Ed.)*. Warwickshire: Greenstream.

- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, 77–101. doi:10.1191/1478088706qp063oa
- Braun, V., & Clarke, V. (2012). Thematic analysis. In H. Cooper, P.M. Camic, D.L. Long, A.T. Panter, D. Rindskopf, & K.J. Sher (Eds.), *APA handbook of research methods in psychology, Vol. 2* (pp.57-71). Washington, DC: American Psychological Association.
- Brown, M. (2008). Comfort zone: Model or metaphor? *Australian Journal of Outdoor Education*, 12(1), 3-12.
- Bühler, F., Cocron, P., Neumann, I., Franke, T. & Krems, J. (2014). Is EV experience related to EV acceptance? Results from a German field study. *Transportation Research Part F*, 25, 34-49. doi:10.1016/j.trf.2014.05.002
- Bunce, L., Harris, M., & Burgess, M. (2014). Charge up then charge out? Drivers' perceptions and experiences of electric vehicles in the UK. *Transportation Research Part A*, 59, 278-287. doi:10.1016/j.tra.2013.12.001
- Bunch, D.S., Bradley, M., Golob, T.F., Kitamura, R., & Occhiuzzo, G.P. (1993). Demand for clean-fuel vehicles in California: A discrete-choice stated preference pilot project. *Transportation Research Part A*, 27, 237-253. doi:10.1016/0965-8564(93)90062-P
- Burgess, M., King, N., Harris, M., & Lewis, E. (2013). Electric vehicle drivers' reported interactions with the public: Driving stereotype change? *Transportation Research Part F*, 17, 33-44. doi:10.1016/j.trf.2012.09.003. (a)
- Burgess, M., Harris, M., Walsh, C., Carroll, S., Mansbridge, S., & King, N. (2013). Assessing the viability of electric vehicles in daily life: A longitudinal assessment. *Proceedings of the Hybrid and Electric Vehicle Conference: Institute of Engineering and Technology*, November 5-6, London, UK. (b)
- Car firms to build electric charge network. (2016, November 29). Retrieved from <http://www.bbc.co.uk/news/technology-38147478>
- Carley, S., Krause, R.M., Lane, B.W., & Graham, J.D. (2013). Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cities. *Transportation Research Part D*, 18, 39–45. doi:10.1016/j.trd.2012.09.007
- Carroll, S., & Walsh, C. (2010). The Smart move trial: description and initial results. London: Cenex. Retrieved from <http://www.cenex.co.uk/LinkClick.aspx?fileticket=yUKaRDJtWg%3D&tabid=60>
- Carroll, S., Walsh, C., Burgess, M., Harris, M., Mansbridge, S., King, N., & Bunce, L. (2013, September). *The ultra-low carbon vehicle demonstrator programme: Assessing the viability of EVs in daily life*. Retrieved from <http://innovateuk.org/documents/1524978/2138994/ULCV%20Demonstrator%20final%20report>

- Cattell, H.E. (1996). The original big five: A historical perspective. *European Review of Applied Psychology*, 46, 5-14.
- Charlton, A. (2015, July 24). Electric cars are ready for the future – but the UK's charging network is not. Retrieved from <http://www.ibtimes.co.uk/electric-cars-are-readyfuture-uks-charging-network-not-1512437>
- Chen, S., Li, S., & Li, C. (2011). Recent related research in technology acceptance model: A literature review. *Australian Journal of Business and Management Research*, 1(9), 124-127.
- Chéron, E., & Zins, M. (1997). Electric vehicle purchasing intentions: The concern over battery charge duration. *Transportation Research A*, 31, 235-243. doi:10.1016/S0965-8564(96)00018-3
- Chuttur, M.Y. (2009). Overview of the technology acceptance model: Origins, developments and future directions, Indiana University, USA. *Sprouts: Working Papers of Information Systems*, 9(37).
- Clarke, V. & Braun, V. (2016). Thematic analysis. In E. Lyons & A. Coyle, *Analysing qualitative data in psychology (2nd Ed.)* (pp.84-102). London: Sage.
- Cocron, P., Bühler, F., Franke, T., Neumann, I., Dielmann, B., & Krems, J.F. (2013). Energy recapture through deceleration – regenerative braking in electric vehicles from a user perspective. *Ergonomics*, 56(8), 1203-1215. doi:10.1080/00140139.2013.803160
- Compeau, D., Higgins, C.A., Huff, S. (1999). Social cognitive theory and individual reactions to computing technology: A longitudinal study. *MIS Quarterly*, 23(2), 145–158. doi:10.2307/249749
- Connor-Smith, J.K., & Flachsbart, C. (2007). Relations between personality and coping: A meta-analysis. *Journal of Personality and Social Psychology*, 93(6), 1080-1107. doi:10.1037/0022-3514.93.6.1080
- Contrada, R.J., & Baum, A. (2009). *The handbook of stress science: Biology, psychology, and health*. New York: Springer.
- Cowan, R., & Hultén, S. (1996). Escaping Lock-in: The case of the electric vehicle. *Technology & Social Change*, 53(1), 61-79. doi:10.1016/0040-1625(96)00059-5
- Craske, M.G. & Stein, M.B. (2016). Anxiety. *Lancet*, 388 (10063), 3048-59.
- Creswell, J.W. & Plano Clark, V.L. (2011). *Designing and conducting mixed methods research (2nd Ed.)*. London: SAGE
- Danner, U.N., Aarts, H., & de Vries, N.K. (2008). Habit vs. intention in the prediction of future behaviour: The role of frequency, context stability and mental accessibility of past behaviour. *British Journal of Social Psychology*, 47, 245-265. doi:10.1348/014466607X230876

- Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319-340. doi:10.2307/249008
- Davis, F.D., Bagozzi, R.P., & Warshaw, P.R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, 35, 982-1003. doi:10.1287/mnsc.35.8.982
- Davis-Berman, J., & Berman, D. (2002). Risk and anxiety in adventure programming. *Journal of Experiential Education*, 25(2), 305-310. doi:10.1177/105382590202500209
- Daziano, R.A. (2013). Conditional-logit Bayes estimators for consumer valuation of electric vehicle driving range. *Resource and Energy Economics*, 35, 429-450. doi:10.1016/j.reseneeco.2013.05.001
- Daziano, R.A., & Chiew, E. (2013). On the effect of the prior of Bayes estimators of the willingness to pay for electric-vehicle driving range. *Transportation research Part D*, 21, 7-13. doi:10.1016/j.trd.2013.02.005
- De Gennaro, M., Paffumi, E., Martini, A., & Scholz, H. (2014). A pilot study to address the travel behaviour and the usability of electric vehicles in two Italian provinces. *Case Studies on Transport Policy*, 2(3), 116-141. doi:10.1016/j.cstp.2014.07.008
- Deloitte. (2011, October). *Unplugged: Electric vehicle realities versus consumer expectations*. Retrieved from http://www.deloitte.com/assets/DcomUnitedStates/Local%20Assets/Documents/us_auto_DTTGlobalAutoSurvey_ElectricVehicles_100411.pdf
- Dennis, K., & Urry, J. (2009). *After the car*. Policy Press: Cambridge.
- Department for Transport (DfT). (2013, July). *National travel survey: 2012*. Retrieved from <https://www.gov.uk/government/publications/national-travel-survey-2012>
- Department for Transport (2014, June). Public attitudes to electric vehicles. Retried from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/321157/electric-vehicles-2014.pdf
- Department for Transport (DfT), Office for Low Emission Vehicles (OLEV), & Jones, A. (2015, December 3). UK government pledges bold ambition for electric cars [News post]. Retrieved from <https://www.gov.uk/government/news/uk-government-pledges-boldambition-for-electric-cars>
- Department of Energy & Climate Change (DECC). (2013, July). *Electricity generation costs*. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223940/DECC_Electricity_Generation_Costs_for_publication_-_24_07_13.pdf
- Dillon, A., & Morris, M. (1996). User acceptance of new information technology: Theories and models. In M. Williams (ed.), *Annual Review of Information Science and Technology*. Medford NJ: Information Today.

- Dimitropoulos, A., Rietveld, P., & van Ommeren, I. N. (2011). Consumer Valuation of Driving Range: A Meta-Analysis. Tinbergen Institute Discussion Paper.
- Dreiling, A. (2015, March 8). Theory of Planned Behaviour. QUT IFB101. Retrieved from <https://www.youtube.com/watch?v=nZsxuD3gExE>
- Eccelstone, K. (2004). Learning in a comfort zone: Cultural and social capital inside an outcome based assessment regime. *Assessment in Education*, 11(1), 29-47. doi:10.1080/0969594042000208985
- Egbue, O., & Long, S. (2012). Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. *Energy Policy*, 717 -729. doi:10.1016/j.enpol.2012.06.009
- Eggers, F., & Eggers, F. (2011). Where have all the flowers gone? Forecasting green trends in the automobile industry with a choice-based conjoint adoption model. *Technological Forecasting & Social Change*, 78, 51-62. doi:10.1016/j.techforce.2010.06.014
- Element Energy (2013). *Pathways to high penetration of electric vehicles final report*. Cambridge: Element Energy. Retrieved from https://www.theccc.org.uk/wp-content/uploads/2013/12/CCC-EV-pathways_FINAL-REPORT_17-12-13-Final.pdf
- Ellaway, A., Macintyre, S., Hiscock, R., & Kearns, A. (2003). In the driving seat: Psychological benefits from private motor vehicle transport compared to public transport. *Transportation Research Part F*, 6, 217-231. doi:10.1016/S1369-8478(03)00027-5
- Ewing, G., & Sarigöllü, E. (2000). Assessing Consumer Preferences for Clean-Fuel Vehicles: A Discrete Choice Experiment. *Journal of Public Policy & Marketing*, 19(1), 106-118. doi:10.1509/jppm.19.1.106.16946
- Flick, U. (2009). *An introduction to qualitative research (4th Ed.)*. London: Sage.
- Foxall, J. (2016, December 22). Electric car drivers could face queues and quarrels this Christmas. Retrieved from <http://www.telegraph.co.uk/cars/features/electric-car-drivers-could-face-queues-quarrels-christmas/>
- Franke, T., & Krems, J.F. (2013). Interacting with limited mobility resources: Psychological range levels in electric vehicle use. *Transportation Research Part A*, 48,109-122. doi:10.1016/j.tra.2012.10.010 (a)
- Franke, T. & Krems, J.F. (2013). What drives range preferences in electric vehicle users? *Transport Policy*, 30, 56-62. doi:10.1016/j.tranpol.2013.07.005 (b)
- Fanke, T. & Krems, J.F. (2013). Understanding the charging behaviour of electric vehicle users. *Transportation Research Part F*, 21, 75-89. doi:10.1016/j.trf.2013.09.002 (c)

- Franke, T., Rauh, N. & Krems, J.F. (2016). Individual differences in BEV drivers' range stress during first encounter of a critical range situation. *Applied Ergonomic*, 57, 28-35. doi:10.1016/j.apergo.2015.09.010 (a)
- Franke, T., Cocron, P., Bühler, F., Neumann, I., & Krems, J.F. (2012). Adapting to the range of an electric vehicle – the relation of experience to subjectively available mobility resources. In Valero Mora, P., Pace, J.F., Mendoza, L. (Eds.). *Proceedings of the European Conference on Human Centred Design for Intelligent Transport Systems, Valencia, Spain*, June 14-15 (p.95-103). Lyon: Humanist Publications. (a)
- Franke, T., Günther, M., Trantow, M., Rauh, N., & Krems, J.F. (2015). The range comfort zone of electric vehicle users – concept and assessment. *IET Intelligent Transport Systems*. doi:10.1049/iet-its.2014.0169
- Franke, T., Neumann, I., Bühler, F., Cocron, P., & Krems, F. (2012). Experiencing range in an electric vehicle: Understanding psychological barriers. *Applied Psychology*, 61(3), 368-391. Doi:10.1111/j.1464-0597.2011.00474x (b)
- Franke, T., Rauh, N., Günther, M., Trantow, M. & Krems, J.F. (2016). Which factors can protect against range stress in everyday usage of battery electric vehicles? Towards enhancing sustainability of electric mobility systems. *Human Factors*, 58(1), 13-26. doi:10.1177/0018720815614702 (b)
- Gardner, B., & Abraham, C. (2007). What drives car use? A grounded theory analysis of commuters' reasons for driving. *Transportation Research Part F*, 10, 187-200. doi:10.1016/j.trf.2006.09.004
- Gärling, A. (2001). *Paving the way for the Electric Vehicle*. VINNOVA Report 2001:1.
- Gefen, D., & Straub (2000). The relative importance of perceived ease of use in IS adoption. A study of e-commerce adoption. *Journal of the Association for Information Systems*, 1(8), 1-24.
- Gibbs, N. (2015, September 25). Should you join the electric car revolution? Retrieved from <http://www.moneywise.co.uk/cut-your-costs/drive-commute/should-you-join-the-electric-car-revolution>
- Go Ultra Low (GUL). (2016) Charging your electric car. Retrieved from <https://www.goultralow.com/charging-your-electric-car/> (a)
- Godin, G., & Kok, G. (1996). The theory of planned behaviour: A review of its applications to health related behaviour. *Behaviour Change*, 11(2), 87-98. doi:10.4278/0890-1171-11.2.87
- Golob, T.F., & Gould, J. (1998). Projecting use of electric vehicles from household vehicle trials. *Transportation Research Part B*, 32(7), 441-454. doi:10.1016/S0191-2615(98)00001-0
- Graham-Rowe, E., Gardner, B., Abraham, C., Skippon, S., Dittmar, H., Hutchins, R., &

- Stannard, J. (2012). Mainstream consumers driving plug-in battery-electric and plug-in hybrid electric cars: A qualitative analysis of responses and evaluations. *Transportation Research Part A*, 46, 140-153. doi:10.1016/j.tra.2011.09.008
- Greco, V., & Roger, D. (2003). Uncertainty, stress and health. *Personality and Individual Differences*, 34, 1057-1068. doi:10.1016/S0191-8869(02)00091-0
- Greene, D.L. (1985). Estimating daily vehicle usage distributions and the implications for limited-range vehicles. *Transportation Research Part B*, 19(4), 347-358. doi:10.1016/0191-2615(85)90041-4
- Grieve, R., & Elliott, J. (2013). Cyberfaking: I can, so I will? Intentions to fake in online psychological testing. *Cyberpsychology, Behaviour, and Social Networking*, 16(5), 364-369. doi:10.1089/cyber.2012.0271
- Guarnieri, M. (2011, March 25). When cars went electric: Part 1. IEEE Industrial Electronics Magazine, pp. 61-62. doi:10.1109/MIE.2011.940248 (a)
- Guarnieri, M. (2011, June 17). When cars went electric: Part 2. IEEE Industrial Electronics Magazine, pp. 46-53. doi:10.1109/MIE.2011.941122 (b)
- Helmbrecht, M., Monreal, C.O., Bengler, K., Vilimek, R. & Keinath, A. (2014). How electric vehicles affect driving patterns. *IEEE Intelligent Transportation Systems Magazine*, pp.22-33. doi:10.1109/MITS.2014.2315758
- Hidrue, M.K., Parsons, G.R., Kempton, W., & Gardner, M. (2011). Willingness to pay for electric vehicles and their attributes. *Resource and Energy Economics*, 33, 686-705. doi:10.1016/j.reseneeco.2011.02.002
- Highways England, & Jones, A. (2015, August 11). Off road trials for „electric highways“ technology [News post]. Retrieved from <https://www.gov.uk/government/news/off-road-trials-for-electric-highways-technology>
- Hill, T., Smith, N., D., & Mann, M. F. (1987). Role of efficacy expectations in predicting the decision to use advanced technologies: The case of computers. *Journal of Applied Psychology*, 72(2), 307-313. doi:10.1037/0021-9010.72.2.307
- Høyer, K. G. (2008). The history of alternative fuels in transportation: The case of electric and hybrid cars. *Utilities Policy*, 16, 63-71. doi:10.1016/j.jup.2007.11.001
- Howitt, D. (2010). *An introduction to qualitative methods in psychology (2nd Ed.)*. Harlow:Pearson.
- Jabeen, F., Olaru, D., Smith, B., Braunl, T., & Speidel, S. (2012). Acceptability of electric vehicles: Findings from a driver survey. ATRF Proceedings.
- Jensen, M. (1999). Passion and heart in transport – a social analysis on transport behaviour. *Transport Policy*, 6, 19-33. doi:10.1016/S0967-070X(98)00029-8

- Jourden, F.J., Bandura, A., & Banfield, J.T. (1991). The impact of conceptions of ability on self-regulatory factors and motor skills acquisition. *Journal of Sport & Exercise Psychology*, 8, 213-226. doi:10.1123/jsep.13.3.213
- Keil, M., Beranek, P.M., & Konsynski (1995). Usefulness and ease of use field study evidence regarding task considerations. *Decision Support Systems*, 13(1), 75-91. doi:10.1016/0167-9236(94)E0032-M
- Kelion, L. (2015, August 12). England to test charge-as-you-drive „electric motorways“ [News post]. Retrieved from <http://www.bbc.co.uk/news/technology-33886180>
- Khan, M., & Kockelman, K.M. (2012). Predicting the market potential of plug-in electric vehicles using multiday GPS data. *Energy Policy*, 46, 225-233. doi:10.1016/j.enpol.2012.03.055
- Kirsch, D.A. (2000). *The electric vehicle and the burden of history*. Rutgers University Press: London.
- Kiss, J. (2015, September 10). Clean and green, but an electric car can give a driver some shocks. Retrieved from <http://www.theguardian.com/environment/2015/sep/10/electric-car-clean-energy-green-charging>
- Knutsen, D., & Willén, O. (2013). A study of electric vehicle charging patterns and range anxiety.
- Kurani, K., Turrentine, T. & Sperling, D. (1996). Testing electric vehicle demand in „hybrid households“ using a reflexive survey. *Transportation Research Part D*, 1(2), 131–150. doi:10.1016/S1361-9209(96)00007-7
- Lally, P., van Jaarsveld, C.H.M., Potts, H.W.W., & Wardle, J. (2010). How are habits formed: Modelling habit formation in the real world. *European Journal of Social Psychology*, 40, 998-1009. doi:10.1002/ejsp.674
- Lam, A. (2015, August 10). Lazarus & Folkman's Transactional Model of Stress. Retrieved from <https://www.youtube.com/watch?v=4iIJVefJ9iA>
- Lazarus, R.S., & Folkman, S. (1984). *Stress, Appraisal & Coping*. New York: Springer.
- Leberman, S.I., & Martin, A.J. (2003). Does pushing comfort zones produce peak learning experience? *Australian Journal of Outdoor Education*, 7(1), 10-19.
- Lee, Y., Kozar, K.A., & Larsen, K.R.T. (2003). The technology acceptance model: Past, present and future. *Communications of the Association for Information Systems*, 12(1), 752-780.
- Luckner, J.L., & Nadler, R.S. (1997). *Processing the experience: Strategies to enhance and generalise learning* (2nd ed.). Dubuque, IA: Kendall Hunt.

- Lyndon, N. (2014, January 16). Living with a Nissan Leaf. Retrieved from <http://www.telegraph.co.uk/motoring/carmanufacturers/nissan/10564296/Living-with-a-Nissan-Leaf.html>
- Maddux, J.E., (1995). Self-efficacy theory: An introduction. In J.E. Maddux (Ed.), *Self-efficacy, adaption, and adjustment: Theory, research, and application*. New York: Plenum Press.
- Maddux, J.E., & Lewis, J. (1995). Self-efficacy and adjustment: Basic principles and issues. In J.E. Maddux (Ed.), *Self-efficacy, adaption, and adjustment: Theory, research, and application*. New York: Plenum Press.
- Mansbridge, S., Burgess, M., & Harris, M. (2014, July). Electric vehicle drivers“ overcome range anxiety prior to their first trip. Paper presented at the 5th International conference on Applied Human Factors in Ergonomics, Krakow, Poland. (Peer reviewed).
- McManus. M.C. (2012). Environmental consequences of the use of batteries in low carbon systems: The impact of battery production. *Applied Energy*, 93, 288-295. doi:10.1016/j.apenergy.2011.12.062
- Miller, S.M. (1980). Why having control reduces stress. If I can stop the rollercoaster I don’t want to get off. In J. Garber & M.E.P. Seligman (eds.), *Human helplessness: Theory and applications*. New York: Academic.
- Moons, I., & De Pelsmacker, P. (2012). Emotions as determinants of electric car usage intention. *Journal of Marketing Management*, 28(3-4), 195-237. doi:10.1080/0267257X.2012.659007
- Moons, I., & De Pelsmacker, P. (2015). An extended decomposed theory of planned behaviour to predict the usage intention of the electric car: A multi-group comparison. *Sustainability*, 7, 6212-6245. doi:10.3390/su7056212
- Neumann, I, Franke, T., Cocron, P., Bühler, F, & Krems, J.F. (2015). Eco-driving strategies in battery electric use – how do drivers adapt over time? *IET Intelligent Transport System*, 9 (7), 746-753. doi:10.1049/iet-its.2014.0221
- Nierynck, R. (2016, October 25). DfT puts forward plans to improve charge-point access. Retrieved from <http://www.airqualitynews.com/2016/10/25/government-launches-plans-for-ulev-charging-points/>
- Nilsson, M. (2011). Electric vehicle: The phenomenon of range anxiety. Retrieved from http://www.elvire.eu/IMG/pdf/The_phenomenon_of_range_anxiety_ELVIRE.pdf (a)
- Nilsson, M. (2011). Electric vehicles: an interview study investigating the phenomenon of range anxiety. Retrieved from http://www.elvire.eu/IMG/pdf/An_interview_studyinvestigating_the_phenomenon_of_range_anxiety_ELVIRE-2.pdf (b)

- Nilsson, M. (2014). Does range anxiety exist? Experiences from the ELVIRE project. *Proceedings of the 5th International Conference of Applied Human Factors and Ergonomics AHFE*, July 20-23, Kraków, Poland.
- Office for Low Emission Vehicles (OLEV). (2013). *Driving the future today: A strategy for ultralow emission vehicles in the UK*. Retrieved from <https://www.gov.uk/government/publications/driving-the-future-today-a-strategy-for-ultra-low-emission-vehicles-in-the-uk>
- Ouellette, J.A., & Woods, W. (1998). Habit and intention in everyday life: The multiple processes by which past behaviour predicts future behaviour. *Psychological Bulletin*, 124(1), 54-74. doi:10.1037/0033-2909.124.1.54
- Ozer, E.M., & Bandura, A. (1990). Mechanisms governing empowerment effects: A self-efficacy analysis. *Journal of Personality and Social Psychology*, 58(3), 472-486. doi:10.1037//0022-3514.58.3.472
- Paine, C. (2006, August 04). Who killed the electric car? Sony Pictures Classics. Retrieved from <https://www.youtube.com/watch?v=BaZSeulWqEk>
- Pajares, F. (2002). Overview of social cognitive theory and of self-efficacy. <http://www.emory.edu/EDUCATION/mfp/eff/html>
- Parker, I. (2005). *Qualitative psychology : Introducing radical research*. Maidenhead: Open University Press.
- Pasaoglu, G., Fiorello, A., Zani, L., Zubaryeva, A. & Thiel, C. (2014). Travel patterns and the potential use of electric cars – results from a direct survey in six European countries. *Technological Forecasting & Social Change*, 87, 51-59. doi:10.1016/j.techfore.2013.10.018
- Patton, M.Q. (1990). *Qualitative evaluation and research methods*. Newbury Park, CA: Sage.
- Pearre, N., Kempton, W., Guensler, R.L., & Elango, V.V. (2011). Electric vehicles: how much range is required for a day's driving? *Transportation Research Part C*, 19, 1171-84. doi:10.1016/j.trc.2010.12.010
- Perrewé, P.L., & Zellars, K.L. (1999). An examination of attributions and emotions in the transactional approach to the organizational stress process. *Journal of Organizational Behaviour*, 20(5), 739-752. doi:10.1002/(SICI)1099-1379(199909)20:5<739::AID-JOB1949>3.0.CO;2-C
- Pichelmann, S., Franke, T. & Krems, J.F. (2013). The timeframe of adaptation to electric vehicle range. In M. Kurosu (Ed.), *Human-computer interaction. Applications and Services, LNCS 8005* (pp.612-620). Berlin, Germany: Springer.
- Ratten, V., & Ratten, H. (2007). Social cognitive theory in technological innovations. *European Journal of Innovation Management*, 10(1), 90-108. doi:10.1108/14601060710720564

- Rauh, N., Franke, T. & Krems, J. F. (2015). Understanding the impact of electric vehicle driving experience on range anxiety. *Human Factors*, 57, 177-187. doi:10.1177/0018720814546372
- Rauh, N., Franke, T. & Krems, J.F. (2017). First-time experience of a critical range situation in BEV use and the positive effect of coping information. *Transportation Research Part F*, 44, 30-41. doi:10.1016/j.trf.2016.10.001
- Scholder, E.P., Bearden, W.O., & Sharma, S. (1991). Resistance to technological innovations: An examination of the role of self-efficacy and performance satisfaction. *Journal of the Academy of Marketing Science*, 19(4), 297-307. doi:10.1007/BF02726504
- Schunk, D.H. (1990). Goal setting and self-efficacy during self-regulated learning. *Educational Psychologist*, 25(1), 71–86. doi:10.1207/s15326985ep2501_6
- Scott, A. (2012, September 02). Lazarus & Folkman Transactional Model of Stress and Coping. Retrieved from <https://www.youtube.com/watch?v=a8FEMHCRoWM>
- Shaw, S., & Bunce, L. (2015). Electrifying London: Connecting with mainstream markets. In W., Leal Filho, & R. Kotter (eds.), *E-mobility in Europe, green energy and technology* (pp.141-160). Switzerland: Springer.
- Shaw, S., Bunce, L. & Kottasz, R. (2014). *Report to inform the setting up of regional e-mobility information centres*. Retrieved from http://e-mobility-nsr.eu/fileadmin/user_upload/NEWS/New_report_Recommendations_for_setting_up/E-mobility6.8_FinalSS-2-13.06.14.pdf
- Shnayerson, M. (1996). *The car that could: The inside story of GM's revolutionary electric vehicle*. New York: Random House.
- Skippon, S.M., & Garwood, M. (2011). Responses to battery electric vehicles: UK consumer attitudes and attributions of symbolic meaning following direct experience to reduce psychological distance. *Transportation Research, Part D*, 16, 525-31. doi:10.1016/j.trd.2011.05.005
- Smith, N. (2013, November 03). Introduction to the Theory of Planned Behaviour. Retrieved from <https://www.youtube.com/watch?v=DFn-IOcpd8A>
- Smith, J. A., & Eatough, V. (2007). Interpretative phenomenological analysis. In A. Coyle & E. Lyons (Eds.), *Analysing qualitative data in psychology: A practical and comparative guide* (pp. 35-50). London: Sage.
- Smith, J. A., & Osborn, M. (2008). Interpretative phenomenological analysis. In J. A. Smith (Ed.), *Qualitative psychology: A practical guide to research methods* pp.53-80). London: Sage.
- Society of Motor Manufacturers and Traders (SMMT). (2016, January 7). December 2015 – EV registrations [News post]. Retrieved from <http://www.smmt.co.uk/2016/01/december-2015-ev-registrations/>

- Society of Motor Manufacturers and Traders (SMMT). (2011). Electric car guide 2011: Questions and answers. Retrieved from <http://www.theclimategroup.org/assets/files/SMMT-Electric-Car-Guide-2011.pdf>
- Steg, L. (2005). Car use: Lust and must. Instrumental, symbolic and affective motives for car use. *Transportation Research Part A*, 39(2-3), 147-162. doi:10.1016/j.tra.2004.07.001
- Stern, P.C. (2005). Understanding individuals' environmentally significant behaviour. *Environmental Law Reporter: News and Analysis*, 35, 10785-10790.
- Tamor, M. A., Gearhart, C., & Soto, C. (2013). A statistical approach to estimating acceptance of electric vehicles and electrification of personal transport. *Transportation Research Part C*, 26, 125-134. doi:10.1016/j.trc.2012.07.007
- Tamor, M.A., Moraal, P.E., Repogle, B., & Milačić, M. (2015). Rapid estimation of electric vehicle acceptance using a general description of driving patterns. *Transportation Research Part C*, 51, 136-148. doi:10.1016/j.trc.2014.10.010
- Tate, E.D., Harpster, M.O., & Savagian, P.J. (2009). The electrification of the automobile: from conventional hybrid, to plug-in hybrids, to extended range electric vehicles. *SAE International, Journal of Passenger Cars – Electronic Electric Systems*, 1(1), 156–166. doi:10.4271/2008-01-0458
- Terry, G. (2016). Doing thematic analysis. In E. Lyons & A. Coyle, *Analysing qualitative data in psychology* (2nd Ed.) (pp.84-102). London: Sage.
- Taubman-Ben-Ari, O., & Yehiel, D. (2012). Driving styles and their association with personality and motivation. *Accident Analysis & Prevention*, 45, 416-422. doi:10.1016/j.aap.2011.08.007
- Turrentine, T., Garas, D., Lentz, A., & Woodjack, J. (May 2011). The UC Davis MINI E consumer study. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-11-05. Retrieved from http://pubs.its.ucdavis.edu/publication_detail.php?id=1470.
- Urry, J. (2004). The „system“ of automobility. *Theory, Culture & Society*, 21(4-5), 25-39. doi:10.1177/0263276404046059
- Van der Linden, S. (2011). Charitable intent: A moral or social construct? A revised theory of planned behaviour model. *Current Psychology*, 30(4), 355-374. doi:10.1007/s12144-011-9122-1
- Van Harren, R. (2011). *Assessment of electric cars' range requirements and usage patterns based on driving behavior recorded in the National Household Travel Survey of 2009*. Unpublished master thesis, Columbia University, New York.

- Venkatesh, V. (2000). Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model. *Information systems research*, 11(4), 342-365. doi:10.1287/isre.11.4.342.11872
- Verplanken, B. (2006). Beyond frequency: Habit as mental construct. *British Journal of Social Psychology*, 45(3), 639-656. doi:10.1348/014466605X49122
- Verplanken, B., Aarts, H., van Knippenberg, A., & Moonen, A. (1998). Habit verses planned behaviour: A field experiment. *The British Journal of Social Psychology*, 37, 111-128. doi:10.1111/j.2044-8309.1998.tb01160.x
- Vilimek, R., Keinath, A., & Schwalm, M. (2012). The MINI E field study: Similarities and differences in international everyday driving. *Proceedings of the 4th International Conference on Applied Human Factors and Ergonomics*, July 21-25, San Francisco, CA.
- Wellings, T., Binnersley, J., Robertson, D., & Khan, T. (2011). Human machine interfaces in low-carbon vehicles: Market trends and user issues. Coventry: WMG, HMI 2.1.
- Wengraf, T. (2001). *Qualitative research interviewing: Biographic narrative and semi-structured methods*. London: Sage.
- Williams, S.L. (1995). Self-efficacy and anxiety and phobic disorders. In J.E. Maddux (Ed.), *Self-efficacy, adaption, and adjustment: Theory, research, and application*. New York: Plenum Press.
- Wirgman, E. (2015, July 22). Survey supports the need for a public EV charging network. Retrieved from <https://www.zap-map.com/survey-supports-the-need-for-a-public-ev-charging-network/>
- Wolf, A., & Seebauer, S. (2014). Technology adoption of electric bikes: A survey among early adopters. *Transportation Research Part A: Policy and Practice*, 69, 196-211. doi:10.1016/j.tra.2014.08.007
- Wood, R. & Bandura, A. (1989). Impact of conceptions of ability on self-regulatory mechanisms and complex decision making. *Journal of Personality and Social Psychology*, 56(3), 407-415. doi:10.1037/0022-3514.56.3.407
- Wood, W., Quinn, J.M., & Kashy, D.A. (2002). Habits in everyday life: Thought, emotion, and action. *Journal of Personality and Social Psychology*, 83(6), 1281-1297. doi:10.1037/0022-3514.83.6.1281
- Wood, W., Tam, L., & Witt, M.G. (2005). Changing circumstances, disrupting habits. *Journal of Personality and Social Psychology*, 88(6), 918-933. doi:10.1037/0022-3514.88.6.918
- Zimmerman, B.J., & Schunk, D.H. (2003). Albert Bandura: The man and his contribution to educational psychology. In B.J. Zimmerman & D.H. Schunk (Eds.), *Educational psychology: One-hundred years of contributions*. Mahwah, NJ: Lawrence Ea

Appendices

<i>Heading</i>	<i>Page</i>
Appendix A: Letter confirming ethical approval for PhD thesis	ii
Appendix B: Standard interview schedules	iii
B1: Pre-trial interview schedule	iii
B2: Post-technical instruction interview schedule	vii
B3: 1-week interview schedule	xii
B4: 3-month interview schedule	xiv
Appendix C: Partial copy of standard questionnaires	xvii
C1: Pre-trial questionnaire	xvii
C2: Post-technical instruction questionnaires	xix
C3: 3-month questionnaire	xxii
Appendix D: Supportive questionnaire items	xxiv
D1: Supportive questionnaire items relevant to Chapter 5	xxiv
D2: Supportive questionnaire items relevant to Chapter 6	xxvi
D3: Supportive questionnaire items relevant to Chapter 7	xxvi
Appendix E: Partial copy of travel diary	xxx
Appendix F: Typical journey lengths in ICEV	xxxii
Appendix G: Maximum distances (single trip)	xxxiii

NOTE: Format of documents in Appendices A, B, C and E has been adjusted slightly to match thesis margin requirements.

Appendix A: Letter confirming ethical approval for PhD thesis



Dr Mark Burgess
Reader in Psychology
Department of Psychology, Social Work and Public Health
Faculty of Health and Life Sciences
Oxford Brookes University
Gipsy Lane
Headington

12 March 2013

Dear Dr Burgess

UREC Registration No: 130711
Understanding pioneer electric vehicle drivers' range psychology

Thank you for submitting an application to the University Research Ethics Committee on behalf of your research student Sarah Mansbridge. The Committee reviewed the application at its meeting on the 27 February 2013.

As this study involves the secondary analysis of data already collected with consent from participants, ethics approval for this subsequent phase is not required. However, we are content to provide a favourable opinion of the proposed data collection, as described in the ethics application.

Yours sincerely

Hazel Abbott
Chair of the University Research Ethics Committee

cc Margaret Harris, Head of Department
Sarah Mansbridge, Research Student
Morag MacLean, Research Ethics Office
Jill Organ, Graduate Office
Louise Wood, UREC Administrator

**UNIVERSITY RESEARCH ETHICS
COMMITTEE, FACULTY OF HEALTH AND
LIFE SCIENCES**

Headington Campus Gipsy Lane
Oxford OX3 0BP UK

Tel: 01865 482639
heabbott@brookes.ac.uk

Appendix B: Standard Interview schedules

B1: Pre-Trial Interview Schedule

Private User Telephone-interview guideline

ID: _____ Name: _____

[prearrangement:

- Check recorder (record a test sample and check remaining capacity)
- Have a pen and paper ready; print out interview guideline (fill in ID)
- Start recording – read out the test person’s ID and dial the MOBILE telephone number]

NOTE: YOU WILL ALREADY HAVE GIVEN THEM A QUICK CALL TO INTRODUCE YOURSELF (AS BELOW)

Hello, my name is _____. I am from Oxford Brookes
University _____. I am part of the MINI E research team. Is this
_____? [→ add person’s name]

Wait for answer

I’ll be in touch with you throughout the MINI E trial and thought I’d just call to introduce myself [if there’s anything you want to add in terms of saying “so we’ll get to know each other quite well” then do so – do whatever is natural, establishes rapport, and indicates that you will be the sole person contacting them].

I’ll need to call you in the next couple of days to ask you some questions about your participation in the MINI E project. When would be a good time for you? _____ [be prepared for them to say they’d like to go through the questions right now]

Is this the best number to reach you on? [wait for answer and write down the number if they give you a different one from the mobile]

[Say “bye” and that you’ll call at the agreed time]

CALLING BACK AT AGREED TIME:

[Introduce yourself again and say that you're calling back to ask some questions]

Have you received the questionnaire and travel diary? [if yes: ok, good, you'll complete them at home and bring them to the training day. If no: ok, well they'll be arriving soon and you'll complete them and bring them to the training day]

Will anyone else drive the MINI E when you get it? [if so, who and how much]

Thanks for agreeing to be interviewed. If anything's not clear, just let me know. Generally, just say what comes into your mind – there are no right or wrong answers, so please speak freely. I would like to record our talk so that I don't have to take notes all the time. Everything you say will remain confidential and will only be used for this research. ok?

1: First, how did you find out about the opportunity to apply for the MINI E trial? • And how did you feel when you found out you had been selected as a participant?	
2: Could you tell me the most important reasons for your participation in the MINI E trial? • What do you expect from your participation? • What do you hope to gain from your participation?	If too monosyllabic ask further questions.
3: To what extent are you interested in testing a completely new technology? • Are you interested primarily in the environmental aspect of the technology or in the opportunity to use a new toy! [give the opportunity to say it's both]	
4: How important is it for you that your car will be powered in an environmentally friendly manner? • Do you think that adopting this environmentally friendly mode of driving will influence your daily routine?	
5: Does your circle of friends talk about electric vehicles and environmental issues?	

Electro-mobility	
1: <i>The core element of this study is an alternative driving system; that is driving with electricity. We call it electro-mobility. Have you heard/read or seen anything about that lately?</i> <i>(Can you please tell me more about that? / When was that? / In which context?)</i>	Ask questions in brackets if the answer is only YES.
2: <i>What do you think the biggest advantages of electric vehicles are generally?</i> <i>To what extent do you think the MINI E will be environmentally friendly?</i>	Ask further if the answer is not clear: What exactly do you mean by that?
3: <i>And what do you think are the biggest barriers for the introduction and acceptance of electric vehicles generally?</i>	Ask further if the answer is not clear: What exactly do you mean by that?

Adaptations	
1: <i>Do you think that your life will change to a certain extent with the new car?</i> <i>What do you think will be affected most by the MINI E in your daily life? [Break for response]</i> <i>How might the way you use a normal car in a normal day change with an electric vehicle?</i> <i>What are the things you will have to get used to soonest?</i>	
2: <i>[if not already stated in question 1]</i> <i>Do you foresee any additional problems to the ones you've already mentioned?</i> <i>Are there any specific problems that you anticipate with regards to your driving routine?</i>	
3: <i>[if not already stated in question 1, or 2]</i> <i>How will you deal with the range of the MINI E?</i> <i>What sort of length of journey do you typically have in a normal day?</i> <i>How do you think you will deal with unplanned journeys?</i> <i>How many miles a week do you think you drive? Will that change at all?</i>	

4: [if not already stated in question 1, 2, or 3] • Will anything change in the way you drive? • Will different driving conditions have any impact on the way you drive or plan your routes [asked to see if they have any concerns about power being used up by headlights, air-con, etc]	
5: In terms of charging the vehicle, what is of most interest and importance to you? • When, and where, do you think you will charge the car? • Do you anticipate any problems? • How will smart metering influence your charging?	

Knowledge about the MINI E	
1: Almost finished. What kind of car do you drive now? Apart from the things you've already mentioned, what will be the biggest differences between the MINI E and your normal vehicle?	

Finally, I would like to ask some general background questions.

First, could you tell me your age please _____ [if it's not obvious, please ask for gender too!].

How many people are there in your household? _____ Who are they?

What is your annual income approximately? _____

Good Bye: That's the interview done. Could I just remind you to bring the completed questionnaire with you to the technical instruction? It's also important that the travel diary is completed. Will you be able to fill it in from _____ Nov to _____ Nov? [Add dates according to when the person is scheduled to come to the training day]

Your training day will be in the _____ [morning or afternoon] on _____ Nov. I'll meet you there.

[polite parting in own words]

[post-processing: note notes in the record; save file on the drive and title it as INT1<BMW>_<ID>]

B2: Post-technical instruction interview

Interview Guideline: F2F Post First Usage

IMPORTANT, please read before you start each interview!

Dear interviewer,

In the following you will find guidelines for the thinking aloud interview. This interview **takes place at the technical instruction directly after the first ride with the MINI E**.

[Welcome the participant back after the test drive of the MINI E]

As I said before I have some additional questions for you after your first ride and first charging of the MINI E. This will take approximately another 45min.

Okay, let's start with the interview regarding your first impressions of driving the MINI E. Later there will be two short questionnaires concerning the displays in the MINI E as well as the charging of the MINI E. But I will explain that later on. Like before, we are interested in your personal experiences and opinions so there are no right or wrong answers. Given that only very few people have the chance to drive the MINI E and you are one of them it is very important for us to know how you feel about the MINI E and how you feel about the charging. That information will help us to improve electric vehicles further. As with the other questionnaires, we will keep your data confidential.

Before we start I have two more questions:

Have you driven a MINI before? yes no

If so: how often? _____

Have you driven an automatic before? yes no

If so: how often? _____

[It should come clear to what extent the test person is used to the MINI or an automatic car]

General questionnaires	
1. Can you please try to summarize what you noticed during your first ride? • What did you especially like? • What did you not like as much? • What did it feel like to drive the MINI E for the first time? • Tell me about the handling of the MINI E?	

2. [if not already mentioned in 1.:] <i>What did you notice about the MINI E in comparison to a conventional car with a combustion engine?</i> • <i>Where do you see advantages of the MINI E in comparison to a conventional car with a combustion engine?</i> • <i>Where do you see disadvantages of the MINI E in comparison to a conventional car with a combustion engine?</i> [PAUSE and wait for response]	If applicable explain: in comparison to the car you usually drive They have already answered this in previous interviews, but the answers may be different now that they have actually driven the MINI E
3. Was driving the MINI E as you expected it to be? • <i>Were there any surprises?</i> • If so: <i>How did you expect the driving to be?</i> • If not: <i>How did it differ from your expectations?</i> • <i>Are the differences positive or negative?</i> • <i>Why?</i>	These questions should be repeated for every single aspect.

We talked about the MINI E and your first impressions of your first ride in general. Now, I would like to talk about some specific aspects in more detail.

Questions for specific aspects of the MINI E	
4. Let`s begin with some questions concerning the user friendliness: Can you describe the <i>handling of the MINI E in general</i>? • <i>Was the handling of the MINI E easy or difficult for you?</i> • <i>What was easy?</i> • <i>What was difficult?</i>	
5. Can you describe what the <i>acceleration</i> of the MINI E was like for you? • <i>For you, what was the acceleration from standing like?</i> • <i>How about the acceleration while actually driving?</i> • <i>Was the overall acceleration good enough?</i>	Not all questions have to be asked, only if the test person doesn`t talk too much (give encouragement).
6. What do you think about the <i>braking system</i>? • <i>Could you bring the MINI E to a stop (or slow down) as you would like during the whole drive?</i>	

7. How did you like the sound of the MINI E? - Is the low background noise of the MINI E positive or negative? - Is the sound consistent with your sense of the speed you're traveling? - Were there any difficulties in having a low noise level? - In what way?	
8. Can you describe what the regenerate braking was like for you? - What about the way the regenerative braking pedal handles? - How do you evaluate the control (to dose) of the regenerate braking pedal? - Where there any surprising moments while - lane changing, - turning off or - driving constantly?	Should be explained? Ask all aspects
9. How much energy do you think can be saved by regenerative braking?	

Because of its innovative nature, the MINI E has some displays that you would not find in a conventional car with a combustion engine. We are interested now in how you rate these displays: What you like and where you see room for improvement if applicable.

Questions for the displays of the MINI E	
10. Here you can see a picture of the display of the state of charge. [show picture] I would like to ask you some questions before I would like you to rate this display via a short questionnaire. - Was the display immediately understandable? - Where there any aspects you had to go through again with the technical instructor? - What do you like about this display? Why? - What do you not like? Why? - How useful do you think this display will be in helping you to estimate the remaining energy of the battery of the MINI E? - How about in estimating the remaining range of the MINI E? - To estimate the range of the MINI-E, do you think you will look more at the display of the state of charge or at the digital range? - How reliably do you think this display will estimate the remaining energy of the battery?	

11. Now I want you to ask to fill out this short-questionnaire to estimate the display of the state of charge. There are 9 statements you should rate how much you agree.. Please read the instruction and make your ratings. If you have questions feel free to ask me at any time! [hand out short questionnaire – see last three pages of this package (SUS – state of charge display) & pen, if applicable answer questions]	
12. Now we will talk about the consumption display. Here is another picture for you. [hand out the picture of the consumption display] I would like to ask you some questions again before I give you the next questionnaire. • Was the display immediately understandable? • Where there any aspects which you went through again with the technical instructor? • What do you like about this display? Why? • What do you not like? Why? • How useful do you think this display will be in estimating the energy that you regain with the regenerative braking? • How useful do you think will display will be in estimating the energy that you use when driving? • How reliable do you think this display will be in estimating the used and regained energy? [hand out short SUS questionnaire on consumption display]	
At the end of this thematic block I would like to ask you some general questions concerning the display and control concept. 13. What is your evaluation of the displays in the MINI E in general? • Did you notice anything in particular that you like? • Why? • What do you not like as much? • Were there any problems? • Why do you think that might be?	
14. Would you like any additional displays in the MINI E? • If so, which? • What should be displayed? (what kind of information?) • How should it be displayed?	

In the following I have some more questions concerning the charging of the MINI E (which you just have done for the very first time!)

15. How would you evaluate the charging process in general? • Did you have initial difficulties with the charging process? • Are there any aspects that you especially like? • If so, which ones? • Are there any aspects that you do not like as much? • If so, which ones? • Where do you see room for improvement in charging the MINI E? • How important are the differences between charging at the wall box and refueling at a gas station for you? • Do you think you will charge at public wallboxes? • [If so:] How frequently? • [If not:] Why not?	
16. What is your evaluation of the wall box? • Were there any initial problems with handling the wall box? • Was it easy to understand how it works or did the technical instructor have to explain some things further (and if so, what)?	
Now I would like to ask you to fill out the short questionnaire about the wall boxes. [hand out questionnaire (SUS – wallbox) & pen] If you have any questions, please feel free to ask me at any time.	
17. How well did you understand the identification card? • Did you encounter any problems? What were they? • What did you especially like?	
18. How did you like the handling of the charging cable? • Did you encounter any problems with the handling? What were they?	

[say thank you and goodbye in your own words]

[explain the sequence of the research study: which methods will come up next]

[hand out self-addressed envelope for the travel diary]

B3: 1-week interview schedule

1 Week “Post-Car-Pick-Up” Telephone-Interview Guideline

ID: _____ Name: _____

[prearrangement:

- Check recorder (record a test sample and check remaining capacity)
- Have a pen and paper ready; print out interview guideline (fill in ID)
- Start recording – read out the test person’s ID and dial the MOBILE telephone number]

Hello, it’s *Stephen/Sarah* from Oxford Brookes University.

I am calling to have a brief chat with _____ about their first experiences with the Mini E. Is this a good time?

Wait for answer

[if not say “bye” and arrange a mutually convenient time]

General Adaptation Question	
1: <i>First, I’d like to hear about the transition from having your normal vehicle to having your Mini E:</i> • <i>Can you describe the differences between having your normal vehicle and having your Mini E</i> • <i>How much money do you think you’ve saved on fuel?</i> • <i>Has having the Mini E been as you had expected?</i> • <i>What has been the biggest thing you’ve needed to adapt to?</i> • <i>What adaptations have been easy?</i> • <i>Has your typical day changed?</i> • <i>Has your daily driving changed at all?</i> 1. <i>In what way?</i>	Be prepared to give follow-up questions that probe for concrete descriptions of experience (e.g., “You said ‘blah blah’....Can you give me an example”....or... “Can you tell me more about that”).

Specific Adaptation Questions (ask if these areas do not get addressed in response to initial question)	
1: <i>Can you tell about charging the Mini E?</i> ▪ <i>Any difficulties?</i> • <i>Have you established a routine?[In the case of fleet users they may refer to “work charging”]</i>	Again, be prepared to give follow-up probes for more detailed descriptions for these

	areas if necessary.
2: Can you tell me what it's been like to drive the Mini E? ▪ Can you comment on 1. the handling 2. the acceleration 3. the braking 4. the low noise 5. the regenerative power (Follow up probe: "How much power can be saved through regenerative braking?") 6. the displays 7. whether anything (like headlights, air con) has a noticeable impact on battery power?	
3: How are you dealing with the range of the Mini E? ▪ Have you been able to estimate range accurately? ▪ How far have you driven the car on each trip? ▪ Are there any journeys that you decided not to take because you had the Mini E? ▪ What could be done to make that trip possible in the future? ▪ Have you taken journeys that you haven't planned ahead of time?	
4: And what's it been like to be in a car with a left hand drive?	
5: What have other people's reactions been to you driving the Mini E (and to the Mini E)?	
6: Is there anything else that you think it's important to know about your early Mini E experiences that I haven't asked about?	

B4: 3-month interview schedule

Interview Guideline: 3 Month Interview IMPORTANT, please read [before](#) you start each interview

Say hello.

Also, say that these interview questions tend to ask for a bit more detail on topics covered in the questionnaire.

1. <i>Based on your experiences so far, what would you say are the biggest positives of electric vehicles like the MINI E?</i> • <i>What do you especially like?</i> • <i>Has your daily driving changed at all as a result of driving the MINI E?</i> • <i>What are the biggest differences you've noticed in your own behaviour since picking up the MINI E?</i> • <i>Did the fact that you're driving a BMW/MINI give you confidence in the quality of the vehicle?</i>	
2. <i>And what do you think are the negatives for the acceptance of electric vehicles like the MINI E?</i> • <i>What are the most important areas that BMW/MINI need to focus on for future development?</i>	

3. <i>You started driving the MINI E in winter.</i> • <i>What was it like to drive in the cold weather?</i> • <i>Did the cold weather have any noticeable effects on car performance?</i>	
4. <i>Have you had any issues regarding safety in the MINI E?</i> • <i>Were these specifically due to being in a MINI E?</i> • <i>Have you had any critical traffic situations? If so, what happened?</i>	
5. <i>What do you think of the low background noise of the MINI E?</i> • <i>Have there been any incidents as a result of the low noise?</i> • <i>Is the noise level positive or negative?</i>	

6. How have you found the regenerative braking? • Has your driving style changed as a result of the regenerative braking? Do you find yourself using just one pedal rather than using the brake? • Do you save much power through regenerative braking? • Has it ever not worked? If so, why do you think that was?	
7. What do you do to prolong battery life? • What damages the battery?	Also: ask whether the cold weather had an impact
8. Can you tell me about your experiences of the range of the MINI E? • Have there been any occasions where you have been concerned about the range? • Have you taken any unplanned trips? Have considerations of range been an issue? • Do you do anything to increase the range of the MINI E? • Is there anything that noticeably reduces range? • Have there been any trips that you haven't been able to take that you would be able to take with your normal car? • Does the MINI E go as far as you thought on a single charge?	
9. I want to ask about the overall handling of the MINI E. How have you found the handling generally? • How about the acceleration • The braking • Driving a left hand drive	

10. What do you think about the displays in the car? • Is there anything you feel needs changing?	
11. Do you have a routine for charging the battery? • Do you have a personal "rule" for when you'll charge? • On average, how frequently do you charge the MINI E? • Any issues with the time taken to charge? • Has your charging routine changed since you first got the delivery of the MINI E? • If so (above), why? • How would you feel about "inductive charging" – this is a charging that doesn't require a cable for the transfer of the energy	

12. Have you used public charging places? • If so, what has your experience been of these? • Is a public infrastructure necessary for you?	
13. What have other people's reactions been to you driving the MINI E?	
14. Is there anything else that you think it's important to know about your early MINI E experiences that I haven't asked about	

[say thank you and goodbye in your own words]

Appendix C: Partial copies of standard questionnaires

C1: Pre-trial questionnaire

Dear MINI-E customer,

Thank you very much for your participation in this pilot study. Your experiences with the MINI-E are of great importance to us. Your answers to this questionnaire will help us to understand your expectations and attitudes towards the MINI-E. In addition, we will get a better idea of your hopes for the project and any limitations or difficulties you foresee.

The questionnaire will take approximately 30 minutes to complete. Please answer the questions carefully. There are no right or wrong answers to any of the questions. We are primarily interested in your own personal views, so please feel free to tell us what you really think. All your responses will be kept strictly confidential. All data will be made anonymous, and conclusions will only be drawn about the sample as a whole.

Example of Question and Answer Format:

Please state the level of your agreement with the following statement:

The British weather has been excellent this summer.

Very Strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Agree	Very Strongly Agree
X					

For the example above, if you do not think the weather has been good you would put a cross in the circle on the far left.

Now the Real Questionnaire Starts:

Please indicate the degree to which the following issues were important for your application:

I am interested in technology like the one in the MINI-E, because ...

- 01 ... I want to protect the environment.
- 02 ... I want to reduce our dependency on crude oil.
- 03 ... I want to save costs.
- 04 ... I want to support the development of new technologies.
- 05 ... I want to try something novel and innovative.

Very Strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Agree	Very Strongly Agree

06	... I think electric power in the car technology of the future.						
07	... I am very interested in new technologies.						
08	... I am thinking about buying a car with electric power.						
09	... I want to see if electric powered cars are a viable alternative to conventionally powered cars.						
10	... I expect a different driving experience than with a conventionally powered car.						
The following section is about your expectations regarding the MINI-E. Please indicate the degree to which you agree with the following statements:		Very Strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Agree	Very Strongly Agree
11	Having to take into account my route length and charging times will make using the MINI-E a big challenge.						
12	It will be easy to learn how to handle the MINI-E.						
13	I will cope fine with the MINI-E.						
14	I will use the MINI-E for trips that I did not previously use my normal car.						
15	The MINI-E will satisfy my daily mobility needs.						
16	The MINI E will be an additional financial burden.						
17	It will not matter to me that it will take longer to charge the battery than it does to refuel a conventional car.						
18	I am worried that the charging times will not suit my daily routine.						
19	The charging of the MINI-E will be foolproof.						
20	As long as there is a financial advantage to having an electric car, I do not mind having to plan when I will use the car.						

C2: Post-technical instruction questionnaires

Please indicate the degree to which you agree with the following statements about the displays of the MINI E. First the charge display:



The following statements refer to the **charge level indicator** of the MINI E (marked in the picture). To evaluate the 9 statements you should use the 5-point scale on the right (from 1 = **Strongly Disagree** to 5 = **Strongly Agree**). Please make your evaluation as **spontaneously** as possible without thinking much about it. There are no right or wrong answers.

	Strongly Disagree				Strongly Agree
I looked at the state of charge display frequently during driving.					
	1	2	3	4	5
I found the state of charge display unnecessarily complex.					
	1	2	3	4	5
I thought the state of charge display was easy to use.					
	1	2	3	4	5
I think that I would need the support of a technical person to be able to understand the state of charge display.					
	1	2	3	4	5
I found the various functions of the state of charge display were well integrated.					
	1	2	3	4	5
I would imagine that most people would learn to use this display very quickly.					
	1	2	3	4	5
I found the display very difficult to understand.					
	1	2	3	4	5
I felt very confident using this display.					
	1	2	3	4	5
I needed to learn a lot of things before I could get going with this display.					

Please indicate the degree to which you agree with the following statements about the displays of the MINI E. These statements refer to the consumption display:



The following statements refer to the recuperation/consumption indicator of the MINI E (marked in the picture). To evaluate the 9 statements you should use the 5-point scale on the right (from 1 = **Strongly Disagree** to 5 = **Strongly Agree**). Please make your evaluation as **spontaneously** as possible without thinking much about it. There are no right or wrong answers.

	Strongly Disagree				Strongly Agree	
I looked at the consumption display frequently during driving.						
	1	2	3	4	5	
I found the state of consumption display unnecessarily complex.						
	1	2	3	4	5	
I thought the consumption display was easy to use.						
	1	2	3	4	5	
I think that I would need the support of a technical person to be able to understand the consumption display.						
	1	2	3	4	5	
I found the various functions of the consumption display were well integrated.						
	1	2	3	4	5	
I would imagine that most people would learn to use this display very quickly.						
	1	2	3	4	5	
I found the display very difficult to understand.						
	1	2	3	4	5	
I felt very confident using this display.						
	1	2	3	4	5	
I needed to learn a lot of things before I could get going with this display.						

Please indicate the degree to which you agree with the following statements about handling the wall box:

The following statements refer to the **handling the wall box** of the MINI E (marked in the picture). To evaluate the 8 statements you should use the 5-point scale on the right (from 1 = **Strongly Disagree** to 5 = **Strongly Agree**). Please make your evaluation as **spontaneously** as possible without thinking much about it. There are no right or wrong answers.

	Strongly Disagree				Strongly Agree
I found the handling of the wallbox unnecessarily complex.					
	1	2	3	4	5
I thought the handling of the wallbox was easy.					
	1	2	3	4	5
I think that I would need the support of a technical person to be able to understand the handling of the wallbox					
	1	2	3	4	5
I found the various functions of the wallbox were well integrated.					
	1	2	3	4	5
I would imagine that most people would learn to use this system very quickly.					
	1	2	3	4	5
I found the handling of the wallbox very difficult.					
	1	2	3	4	5
I felt very confident handling the wallbox.					
	1	2	3	4	5
I needed to learn a lot of things before I could get going with the handling of the wallbox.					

C3: 3-month questionnaire

MINI E Pioneer Research Questionnaire 2

Dear MINI-E customer,

Thank you very much for your participation in this study. Your experiences with the MINI-E are of great importance to us. Your answers to this questionnaire will help us to understand your experiences of driving the MINI-E. In addition, we will get a better idea of any benefits and difficulties you have encountered and this will help us with our planning for future vehicles.

Please answer the questions carefully. There are no right or wrong answers to any of the questions. We are primarily interested in your own personal views and experiences, so please feel free to tell us what you really think. All your responses will be kept strictly confidential. All data will be made anonymous, and conclusions will only be drawn about the sample as a whole.

Example of Question and Answer Format:

Please state the level of your agreement with the following statement:	Very Strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Agree	Very Strongly Agree
The British weather has been excellent this winter.	X					

For the example above, if you do not think the weather has been good you would put a cross in the circle on the far left.

Now the Real Questionnaire Starts:

<i>The following section deals with your experiences with the MINI E during cold weather.</i> <i>Please indicate the degree to which you agree with the following statements</i>	Very Strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Agree	Very Strongly Agree
01 The MINI E is also suitable for winter usage						
02 Even in cold weather the driving range is sufficient for everyday usage						
03 The cold winter weather changed the nature of the trips I made						
04 The cold winter weather reduced the possible range of the trips the MINI E could make						
05 The cold winter weather had a negative effect on the regenerative braking						
06 The cold winter weather had a negative effect on the normal braking						

- 07 The cold winter weather had a negative effect on the charging
- 08 The cold winter weather had a negative effect on the acceleration of the MINI E
- 09 The cold winter weather had a negative effect on the initial start up of the MINI E
- 10 The cold winter weather had a negative effect on the function of on- board features in the MINI E (e.g., heating, air conditioning)
- 11 The cold winter weather had a negative effect on the battery life
- 12 The cold winter weather had a negative effect on the overall performance of the MINI E

Please indicate the degree to which you **agree** with the following statements on the **general handling of the MINI E**

- 13 Handling the MINI E was easy to learn
- 14 I like the MINI E's fast pick-up and quick acceleration
- 15 At start up the gas pedal responds fast enough
- 16 While driving the MINI E I was able to stop the car anytime in the manner I wanted
- 17 Having used the MINI E I find that I need to make a big readjustment when I drive a conventional vehicle again

Very Strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Agree	Very Strongly Agree

Please indicate the degree to which you **agree** with the following statements on **space**

- 18 The space provided in the MINI E has been sufficient for my needs
- 19 My daily baggage is stowable in the MINI E.
- 20 I always have to consider exactly what and who I am going to take with me in the MINI E.

Very Strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Agree	Very Strongly Agree

Appendix D: Supportive questionnaire items

D1: Supportive questionnaire items relevant to Chapter 5

Questionnaire item	Mean	Standard deviation	Mean response	Response number
The MINI E will satisfy my daily mobility needs	4.72	.99	Agree	29
What percentage of your daily trips could you successfully make with the MINI E	87%	13.80	-	18
Electric vehicles are suitable for daily use	4.73	.78	Agree	30
A household would not be able to have an electric car as its only vehicle	4.00	1.16	Agree	30
How important would changes in driving range be to you	5.30	.73	Important	19
How important would changes in construction of the public charging infrastructure (grid coverage) be to you	5.15	.98	Important	19
How important would changes in charging time be to you	4.50	1.05	Of some importance	19
I am worried that the charging times will not suit my routine	2.76	1.18	Strongly	29

			disagree	
While driving the MINI E I will be more concerned about the range than I would be in a conventional car with a combustion engine (drivers with longer typical journey lengths)	5.21	.80	Strongly agree	14
While driving the MINI E I will be more concerned about the range than I would be in a conventional car with a combustion engine (drivers with shorter typical journey lengths)	4.47	1.06	Agree	15
Under optimal conditions (low vehicle payload, economical driving etc.) and a fully charged battery I can go for X miles with the MINI E	123 miles	27.00	-	29
With a fully charged battery I can confidently drive X miles from the next wall box	94 miles	29.27	-	29
My manner of driving will change as a result of using an electric vehicle	2.55	1.38	Strongly disagree	29

D2: Supportive questionnaire items relevant to Chapter 6

Questionnaire item	Mean	Standard deviation	Mean response	Response Number
I thought the state of charge was easy to use	4.35	.81	Agree	20
I thought the consumption display was easy to use	4.12	1.08	Agree	20

D3: Supportive questionnaire items relevant to Chapter 7

Questionnaire item	Mean	Standard deviation	Mean response	Response Number
I deliberately tried to exhaust the range in order to see how far I could go with the MINI E	3.39	1.31	Disagree	28
The MINI E satisfied all my daily mobility needs	4.00	1.41	Agree	29

What percentage of your daily trips could you successfully make with the MINI E	86%	26.06	-	24
The MINI E has changed my mobility behaviour significantly	3.06	1.39	Disagree	29
Electric vehicles are suitable for daily use	5.00	.96	Strongly agree	29
I rely on regenerative braking	4.34	1.11	Agree	29
For what percentage of braking situations did you use the regenerative braking instead of using the brake pedal	88%	11.26	-	28
Plugging in the MINI E at a wall box is simple and easy to handle	4.11	.93	Agree	27
The current charging times suited my daily routine	4.14	1.56	Agree	28
How important would changes in driving range be to you	5.31	.88	Important	19
How important would changes in construction of the public charging infrastructure (grid coverage) be to you	4.78	1.18	Of some importance	19
How important would changes in charging time be to you	4.84	.89	Of some importance	19
The charge level display reliably estimates the remaining energy of the battery	3.96	1.29	Disagree	28

The energy consumption display is helpful in estimating the energy recovered by the regenerative braking system	3.71	1.18	Disagree	28
I am able to precisely estimate the influence of different factors on the range	3.64	.98	Disagree	28
The MINI E produces the range that I expected	3.24	1.24	Disagree	29
I am more concerned about the range of the MINI E than I am about the range of a gas-powered vehicle	5.04	.77	Strongly agree	27
Under optimal conditions (low vehicle payload, economical driving etc.) and a fully charged battery I can go for X miles with the MINI E	93 miles	14.55	-	27
With a fully charged battery I can confidently drive X miles from the next wall box	73 miles	16.17	-	26
While driving I was often concerned about the driving range	3.71	1.01	Disagree	28
Do you change your driving style at what you consider to be a low state of battery charge? (Yes/No)	82%		Yes	29
How often do you accelerate moderately	4.41	1.01	Occasionally	29
How often do you try to maintain a constant speed	4.51	1.05	Occasionally	29
How often do you chose the most energy saving route to my destination	3.54	1.54	Rarely	28

How often do you try to drive more slowly	3.86	.91	Rarely	29
How often do you turn off the lights	4.00	1.58	Occasionally	29
How often do you turn off the air-conditioning	4.25	1.55	Occasionally	28
How often do you turn off the radio	2.96	1.59	Very rarely	29

Appendix E: Partial copy of Travel Diary

Travel Diary: Routes per Person and Day			
Date:	Route 1	Route 2	Route 3
Time: Start of the Trip			
Time: End of the Trip			
Nature of the Trip: ▪ From Home to Work ▪ While at Work ▪ From Work to Home ▪ While at Home Purpose of the Trip: ▪ Please specify the nature of the trip (e.g., meeting clients; shopping; recreation; run errands)	☐ ☐ ☐ ☐ _____ _____ _____ _____ _____ _____ _____ _____ _____	☐ ☐ ☐ ☐ _____ _____ _____ _____ _____ _____ _____ _____ _____	☐ ☐ ☐ ☐ _____ _____ _____ _____ _____ _____ _____ _____ _____
Which means of transportation did you use on your trip? 1. By foot 2. Bicycle 3. Motorcycle, Moped 4. Car 5. Public Transport 6. Other (please specify)	☐ ☐ ☐ ☐ ☐ ☐ ☐ _____	☐ ☐ ☐ ☐ ☐ ☐ ☐ _____	☐ ☐ ☐ ☐ ☐ ☐ ☐ _____
In which order did you use these means of transportation? (Please state the number)	____ → ____ → ____ → ____	____ → ____ → ____ → ____	____ → ____ → ____ → ____
How many minutes did you spend in each mode of transportation?	____ min ____ ____ min ____ ____ min ____ ____ min ____	____ min ____ ____ min ____ ____ min ____ ____ min ____	____ min ____ ____ min ____ ____ min ____ ____ min ____
Why did you choose this combination of means of transportation? (state most important reason) ▪ Shortest Journey Time ▪ Lowest Costs ▪ Habit ▪ Heavy Luggage ▪ Enjoyment	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐

▪ Lack of Alternatives ▪ Other (please specify)	☐ ☐ ☐ 	☐ ☐ ☐ 	☐ ☐ ☐
How many people accompanied you?			
What is the approximate distance of your trip?	miles	miles	miles

Appendix F: Typical Journey Lengths in ICEV

Typical Journey lengths in ICEV – obtained from Pre-Trial Interview

Driver ID	Miles (single trip distance)
Shorter Typical Journey Length Drivers	
Driver 1S	10 miles
Driver 2S	8 miles
Driver 4S	5 miles
Driver 5S	10 miles
Driver 7S	9 miles
Driver 9S	7 miles
Driver 10S	10 miles (up to 30 miles with work)
Driver 11S	5-10 miles (up to 25 miles with work)
Driver 13S	5 miles
Driver 14S	6 miles
Driver 16S	10 miles

Driver 17S	7 miles
Driver 18S	6 miles
Driver 19S	5-8 miles
Driver 20S	4 miles
Driver 23S	10 miles
Longer Typical Journey Length Drivers	
Driver 3L	28 miles
Driver 6L	35 miles
Driver 8L	35 miles
Driver 12L	35 miles
Driver 15L	25 miles
Driver 21L	25-40 miles
Driver 22L	22 miles (up to 43 miles with work)
Driver 24L	25 miles (up to 50 miles with work)
Driver 25L	42 miles (up to 100 miles with work)
Driver 26L	20 miles (up to 75 miles with work)
Driver 27L	25-30 miles (up to 100 miles with work)
Driver 28L	15 miles (up to 50 miles with work)
Driver 29L	34 miles (up to 75 miles with work)
Driver 30L	20-25 miles (up to 100 miles with work)

Appendix G: Maximum distances (single trip)

Driver ID	Pre-trial max distance in ICEV Obtained from pre- trial travel diary	Maximum distance in MINI E during the first week Obtained from data logger	Maximum distance in MINI E from week 2-12 Obtained from data logger
Driver 1S	17	19.9	18.0
Driver 2S	8	34	51.5
Driver 3L	21	37.3	69.6
Driver 4S	75	46	19.3
Driver 5S	90	41.6	38.5
Driver 6L	35	76.3	40.4
Driver 7S	10	62	45
Driver 8L	62	34.2	26.70
Driver 9S	13	76	46
Driver 10S	94	16	29.8
Driver 11S	81	78.8	55.9
Driver 12L	35	49.1	37.9
Driver 13S	45	14.9	23.6
Driver 14S	4	21.1	19.9
Driver 15L	26	23.6	32.9
Driver 16S	20	21.5	23.7

Driver 17S	2	15	27
Driver 18S	15	46.2	24
Driver 19S	55	28	40
Driver 20S	180	17	21
Driver 21L	94	30	34.7
Driver 22L	148	29	86.8
Driver 23S	35	22	62.8
Driver 24L	45	57.1	54.6
Driver 25L	100	19	80.7
Driver 26L	60	37.3	30.4
Driver 27L	24	68.3	14.9
Driver 28 L	52	35.2	39.9
Driver 29L	107	84.7	80.2
Driver 30L		46.2	24