The Impact of Information Systems on Stress and Behavioral Outcomes

By

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Preface

What would life be without technology? Technological developments have changed our society fundamentally. There is no denying that these developments have created several advantages and opportunities for people. For many, a life without technology is a scary thought. However, technological progress is a double-edged sword. It is often forgotten that individuals might struggle in healthily dealing with technologies. Studying the impact of technologies on humans has not only enriched my knowledge in this area but also changed my personal attitude towards using technologies.

This cumulative thesis is the second part of the conjoint dual degree program (Cotutelle) between Macquarie University in Australia and the University of Goettingen in Germany. I feel very privileged to have had the chance to pursue my research project at two excellent research institutions. This would not have been possible without the support of many others whom I would like to thank.

Firstly, I would like to thank my mother and my father for supporting me through the writing of this thesis and my life in general. Words cannot express how grateful I am to you for all of the sacrifices that you've made on my behalf. Without your patience and unconditional love, I would not have been able to achieve the things that I have achieved so far. You are the two most important people in my life and I proudly dedicate this thesis to you. Большое спасибо. Я вас очень люблю!

Furthermore, I would like to express my sincere gratitude to my supervisors and mentors, Mauricio Marrone and Lutz M. Kolbe, for their continuous support towards my research project. You gave me the opportunity, freedom, and confidence to explore the research topics that fascinate me. Your commitment and encouragement made it possible to continue my research in Australia. Thank you for enabling and motivating me to take and continue on this scientifically innovative path. At this point, I want especially thank Mauricio for encouraging me to remove the phrase "moreover" from my research ☺.

Last but surely not the least, a thank you to all of my friends and colleagues who helped along this PhD journey for the patience, generous support and help, and for always providing a sympathetic ear. Thank you for all the wonderful times we enjoyed together and will enjoy in the future.

Sydney, June 2018   *Ilja Nastjuk*

Statement of Originality

I declare that I have prepared the submitted dissertation *The Impact of Information Systems on Stress and Behavioral Outcomes* independently and without prohibited aids. I did not make use of any aids and papers other than those indicated by me. Any help and assistance that I have received in my research work and the preparation of the thesis itself have been appropriately acknowledged.

The Doctoral Research was conducted in Macquarie University, Australia and Georg-August-Universitaet Goettingen, Germany under a specific agreement. No equivalent doctoral studies have been applied for at a different university in Australia or abroad; the dissertation submitted or parts thereof have not been used in any other doctoral project outside the scope of the agreement.

The research presented in this thesis was approved by the Macquarie University Ethics Review Committee.

Abstract

The aim of this thesis is to understand how information systems affect the perception of stress and what consequences this effect has on behavioral outcomes. Previous research in the area of information systems, stress, and behavior has highlighted either stress resulting from interaction with information systems or the potential usefulness of information to reduce stress. Limited research has set out to understand how this dual effect of information systems on stress influences behavioral outcomes. This thesis claims that behavioral outcomes can be better predicted when considering both emphases on the stress-information systems relationship simultaneously.

To achieve this research aim, five studies – that set the focus on battery electric vehicles – were conducted. One study provides insights into the positive effect of information systems on the perception of stress and its consequences for behavioral outcomes. A conceptual model was developed that enables investigation of the relationship among information systems, stress, and behavioral outcomes. The results show that the general provision of timely and relevant information through information systems is suitable to reduce stress originating from the limited driving range of battery electric vehicles, thus positively influencing the attitude towards using these vehicles. Two further studies investigate the opposite effect of information systems on the perception of stress. It is shown that the inappropriate provision of information through information systems might increase the perception of stress in the user, which, in turn, may negatively influence the willingness to use battery electric vehicles. Another study integrates both emphases in the stress-information systems relationship, showing that both directional effects influence behavioral outcomes. Finally, one study expands the research focus to mobility-related sustainable business models, revealing the importance of considering the actual impact of information systems on individuals in the design of mobility-related sustainable business models. It is shown that information systems-enabled pricing schemes – an important characteristic of mobility-related sustainable business models – influence the stress perception in users of e-car sharing, which, in turn, impacts behavioral outcomes.

The thesis provides important implications to researchers and practitioners by challenging the single viewpoint approach on the information systems–stress relationship when assessing behavioral outcomes.

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Acronyms

AMCIS	Americas Conference on Information Systems
AVE	Average Variance Extracted
BEV	Battery Electric Vehicle
CA	Cronbach's Alpha
CR	Composite Construct Reliability
DtE,	Distance to Empty
EV	Electric Vehicle
GAS	General Adaptation Syndrome
ICIS	International Conference on Information Systems
ICT	Information and Communication Technology
IS	Information Systems
IT	Information Technology
IVIS	In-Vehicle Information Systems
PLS	Partial Least Squares
RQ	Research Question
SD	Standard Deviation
SEM	Structural Equation Modelling
SoC	State of Charge
TAM	Technology Acceptance Model
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action

A. Foundations

The first part of this cumulative dissertation is divided into two chapters. The first chapter describes the motivation for studying the topic of this thesis, outlines the research gaps and research questions, illustrates the structure, presents the research design, and describes the anticipated contributions. The second chapter provides the relevant theoretical background.

1   Introduction

Section 1.1 describes the motivation and relevance for the research, followed by the research questions (1.2) and structure of the thesis (1.3). Section 1.4 explains the research design. Finally, Section 1.5 outlines the anticipated contributions for research and practitioners.

1.1   Motivation

Stress has been declared "the health epidemic of the 21st century" by the World Health Organization and is estimated to cost annually hundreds of billions of dollars at the societal and organizational levels (Hassard et al. 2014; Fink 2016). It constitutes the main culprit of a variety of psychological and physiological health problems, including asthma, depression, burnout, or coronary heart diseases (Avey et al. 2003; House 1974; Marin et al. 2011; Vitaliano et al. 2002). The American Institute of Stress estimates that 75–90 percent of all visits to primary care physicians are attributed to stress-related problems (AIS 2017).

Information systems (IS) are one of the leading sources of stress, as the interaction with technologies often demands high physical, social, and cognitive skills (Ragu-Nathan et al. 2008; Tarafdar et al. 2007). Although IS offer numerous benefits to individuals, societies, and organizations, such as enabling connectivity over distances (Kolb 2008), supporting sociability (Maier et al. 2011), contributing to individuals' health and well-being (Lohaus 2010), or improving business performance (Ravichandran and Lertwongsatien 2005), they possess a "*dark side*" (Tarafdar et al. 2015a), which reflects the individual's struggle in dealing with IS in a healthy manner (Brod 1984). Within the IS community, this dark side has garnered popularity in association with the term *technostress,* defined as "any negative impact on attitudes, thoughts, behaviors, or body physiology that is induced either directly or indirectly by technology" (Weil and Rosen 1997, p. 5). Conditions in which IS lead to an increased workload for the individual, the perception of being permanently connected, or the feeling of not catching up with the frantic pace of IS development constitute powerful stimuli that can lead to adverse behavioral responses such as reduced end-user performance or intention to stop using a technology (Maier et al. 2014; Owusu-Ansah et al. 2016; Ragu-Nathan et al. 2008).

While much research in the fields of IS and stress has been done on the sources, characteristics, and outcomes of technostress (see Riedl et al. 2012; Riedl 2013; Tarafdar et al. 2017), studies have also emphasized that IS can be useful to mitigate stress by, for example, providing IS-supported biofeedback about the stress level (Al Osman et al. 2016). Biofeedback sys-

tems are based on the principle that awareness of the stress levels enables alteration of the behavior to better manage stress (Riedl and Léger 2016). Since stress is strongly dependent on the information available about a situation and the degree of uncertainty related to the situation (Jerusalem and Schwarzer 1992; Monat et al. 1972; Zakowski 1995), research has also proposed that IS are able to reduce situational uncertainties and thus lower stress through the provision of context-related information (Eisel et al. 2014). In that regard, studies have shown that IS are a useful asset in stress reduction in, for example, the managerial, clinical, educational, or vehicular contexts (Astor et al. 2013; Eisel et al. 2016; Garg et al. 2005; Lohaus 2010; MacLean et al. 2013).

As illustrated, previous research has shown that IS can affect stress in two different ways: while the interaction with IS can cause stress, they also possess the ability to reduce stress. However, there are no studies capturing both emphases on the stress-IS relationship at the same time. The main research objective of this dissertation is therefore to better understand the dual effect of IS on stress, to ultimately predict behavioral outcomes more accurately. In this context, IS pose the risk of inducing stress, on one hand, thus leading to negative behavioral outcomes such as a reduced willingness to use a technology or reduced performance (Maier et al. 2014; Maier et al. 2015; Tarafdar et al. 2015b), while, on the other hand, IS can contribute to the reduction of stress, and thus lower such negative outcomes (Eisel et al. 2014). This thesis claims that a simultaneously consideration of both directional effects could be useful to predict such behavioral outcomes more precisely.

The thesis relies on the transactional stress model of Lazarus and Folkman (1984) to explore the effects of IS on stress. According to the transactional stress model, stress is characterized by the interaction of two cognitive appraisal processes – primary and secondary appraisal. In this context, stress evolves in situations in which an individual's coping resources (secondary appraisal) are perceived as not sufficient to manage a stressful appraised encounter with the environment (primary appraisal). In stressful appraised situations, individuals classify events as either threatening, challenging, or harmful. This thesis explicitly excludes harm/loss appraisals, as these refer to situations in which damage or loss has already been experienced and as these appraisals are reflected to a certain extent in threat appraisals by considering future negative implications (Lazarus and Folkman 1984). Regarding the secondary appraisal process, the thesis relies on two main psychological coping resources (Thoits 1995) – locus of control and self-concept of own abilities. Locus of control refers to degree to which an individual feels in control over a situation (Rotter 1966), while self-concept of own abilities is

characterized by the individual's perceived ability to manage a specific situation (Campbell 1990; Crocker and Major 1998; Stein 1995). These essential coping resources have been chosen because they partly reflect the degree to which further existing coping resources (e.g., material or social resources; see Jerusalem and Schwarzer 1989; 1992) can efficiently be applied to reduce stress (Lazarus and Folkman 1984).

The link to behavioral outcomes in this thesis is theorized through an attitude towards performing specific behavior, as the attitude construct has been found to be a powerful predictor of intentions and actual behavior (Ajzen 1991; Ajzen and Madden 1986) and also is crucial in explaining the acceptance of an innovation (Venkatesh et al. 2003). In addition, the affective component of the attitude construct includes the individual's feelings and emotions with respect to performing a specific behavior (Ajzen 2005; Breckler 1984; Greenwald 2014) and is therefore inextricably connected with stress. Negative emotions such as anger, fear, or anxiety usually arise from stressful situations (Lazarus 1993a; 1993b; 2006). Hence, due to the special properties of the attitude construct, considering the relationship between stress and attitude seems logically reasonable.

To explore the dual effect of IS on stress and its consequences on behavioral outcomes, the research context of battery electric vehicles (BEVs) is used for the following reasons. First, BEVs are a paramount example, in which a dual effect of IS on stress can be observed. On one hand, IS can be valuable to counteract a particular type of stress in drivers of BEVs, referred to as the term *range stress* (Rauh et al. 2015; Tate et al. 2008). Range stress is the worry of not reaching an intended destination due to a discharged battery and is mainly triggered by BEVs' limited driving range of approximately 150 kilometers (Eisel and Schmidt 2014) and the underdeveloped charging infrastructure (Dong et al. 2014). To compensate or avoid the negative driving experience associated with range stress, users generally demand additional IS in and around BEVs (Nilsson and Habibovic 2013). Hence, research has proposed integrating additional context-specific IS in BEVs that display more range-related information than current IS in BEVs do (Ferreira et al. 2011; 2014; Rauh et al. 2015b) or adjusting the design of in-vehicle IS (Jung et al. 2015; Lundstroem 2014) to counteract range stress. On the other hand, the secondary task of interacting with in-vehicle IS poses a heavier workload on the driver in addition to the highly demanding driving task itself (Pereira et al. 2008). This extra workload relies on the same limited mental capacities needed for the primary task of driving (Bach et al. 2009), which, in turn, leads to a certain degree of competition between these capacities (Ma and Kaber 2005). These effects limit the driver's attention to traffic sce-

ne and hence may lead to driver distraction and stress (Bach et al. 2009; Horberry et al. 2006; Sheridan 2004). In-vehicle IS-related driver stress is an especially critical topic for users of BEVs, as the information presented by the in-vehicle IS is often confusing, thus boosting insecurity, frustration, and stress (Lundstroem 2014; Stroemberg et al. 2011; Wellings et al. 2011).

Second, the limited driving range and the associated phenomenon of range stress generally constitute a main barrier to the widespread adoption of these vehicles (Dimitropoulos et al. 2011; Duke et al. 2009; Egbue and Long 2012; Pearre et al. 2011). As outlined above, the appropriate deployment of IS in and around BEVs bear the potential to overcome range stress, and thus can accelerate the market penetration of this sustainable mode of transportation. In addition, BEVs constitute an important component in the sustainable transformation of the transportation sector by lowering the carbon emission caused by road transport (Capros et al. 2012; McCollum et al. 2014; Tang et al. 2013; Thiel et al. 2010; Thomas 2009). According to the European Commission (2016), the road transportation sector contributes to more than one-fifth of total carbon dioxide emissions in the European Union. This is not a surprising number, as, for example, in 2015 diesel and petrol vehicles accounted for over 97 percent of new sales in Europe (European Environmental Agency 2017). As a response to the devastating consequences of the road transportation sector for the environment, BEVs are also increasingly integrated in sustainable business models, such as e-car sharing (Seign and Bogenberger 2012).

Finally, the amount of IS applied in and around BEVs is expected to increase in the future (Abdelkafi et al. 2013; Burns 2013; Dijk et al. 2013). Yoo et al. (2010) state that "as most subsystems of an automobile are becoming digitized and connected through vehicle-based software architectures, an automobile has become a computing platform on which other firms outside the automotive industry can develop and integrate new devices, networks, services, and content" (p. 729). New paradigms, such as the Internet of Things bring a new variety of functionalities into the automobile, thus enabling the communication between vehicles and other objects, further enhancing comfort and driver safety (Brandt 2013; Tielert et al. 2010; Vermesan and Friess 2014; Xie and Wang 2017). However, apart from the enormous advantages of IS for drivers of BEVs in general, especially in reducing range stress, the increased digitalization in and around BEVs affects the interaction between driver and vehicle (Weng et al. 2016). As explained above, the interaction with IS can lead to driver distraction and stress, thus increasing the risk of fatal car accidents (Brooks and Rakotonirainy 2007;

Kontogiannis 2006; Neale et al. 2005). It is estimated that approximately 30 percent of the time that a vehicle is in motion, drivers are distracted by secondary tasks (Ranney 2008). In this context, over 25 percent of crashes involve some degree of driver distraction, among which the interaction with in-vehicle IS accounts for a high percentage (Horberry et al. 2006; Stutts et al. 2001). Birrell and Fowkes (2014) found that drivers spend, on average, 4.3 percent of their time on looking at the in-vehicle IS while driving.

In summary, this thesis enhances existing literature in stress-related IS research by emphasizing the importance of considering both directional effects of IS on the perception of stress when assessing behavioral outcomes. While much research has been dedicated to the sources, characteristics, and consequences of stress that result from the interaction with IS in an organizational setting, the value of IS for reducing stress in specific situations with particular focus on the appraisal processes of stress is missing in IS research (Tarafdar et al. 2017). In addition, an understanding of the ambivalent role of IS on stress and its consequences for behavioral outcomes (Califf et al. 2015; Lauwers and Giangreco 2016) remains unclear. As mentioned above, behavioral outcomes can be predicted more accurately when considering the dual effect that IS can have on stress.

Despite deriving important implications for research, this thesis aims to support practitioners who are concerned with the design and development of IS within the automotive industry. Here, the research at hand helps overcome the challenge for designers in seeking a balance between introducing new in-vehicle IS to the driver and ensuring the primary task of safe arrival to a destination (Lisboa et al. 2016). However, the findings of the thesis are not limited only to the automotive industry but can be useful for a variety of other applications in which individuals interact with IS, for example, e-learning applications (Lohaus 2010), accounting information systems (Grabski et al. 2011), or biofeedback systems (Al Osman et al. 2014). While such systems are capable of reducing context-related stress, the interaction with these systems might also induce stress and thus adversely affect behavioral outcomes (Ragu-Nathan et al. 2008; Tarafdar et al. 2007). Considering the potential dual effect of IS on stress when designing these systems can increase the related user experience and contribute to an increased market penetration.

1.2   Research Gaps and Research Questions

Previous research in the field of IS and stress has mainly focused on the dark side (Tarafdar et al. 2015a) of IS usage, specifically, on the causes, characteristics, and consequences of stress

resulting from interaction with IS in an organizational context (Riedl et al. 2012; Tarafdar et al. 2017). Although much is known about stress that is induced due to the interaction with IS (e.g., Ayyagari et al. 2011; Ragu-Nathan et al. 2008; Tarafdar et al. 2007; Tu et al. 2005), the opposite effect, specifically, the potential value of IS to reduce stress in certain situations, is not well understood. Previous research indicates that the ability of IS to reduce stress could have a positive effect on healthcare (Garg et al. 2005) and education (Lohaus et al. 2010). In the context of BEVs, research has emphasized that the provision of timely and relevant information can be useful to reduce stress that originates from the uncertainty of whether a final destination can be reached with the given range of a BEV (e.g., Eisel and Schmidt 2014; Ferreira et al. 2011; Rauh et al. 2015b). However, an understanding of the ability of IS to reduce stress in specific situations with a particular focus on the underlying appraisal processes (Lazarus and Folkman 1984) is still missing in IS research. Thus, the first part of the thesis aims at exploring the extent to which IS can reduce stress in the context of BEVs.

While IS undoubtedly provide plenty of advantages in different contexts (e.g., Kolb 2008; Maier et al. 2011; Lohaus 2010; Roberts 2000; Velcu-Laitinen and Yigitbasioglu 2012), they demand high individual cognitive skills that might lead to the perception of stress (Ayyagari et al. 2011). As mentioned above, research in the field of IS and stress traditionally focused on the institutional context as a type of "stress experienced by end users in organization as a result of their use of ICTs" (Ragu-Nathan et al. 2008, pp. 417–18). However, in recent decades, the practical usefulness of IS has changed. Instead of being valuable exclusively for organizational users, the importance and field of application of IS for private consumers has increased, as emphasized by McKenna et al. (2013):

> "Today, the development and use of information systems is changing dramatically. Instead of being developed for (and used by) organizational "users", information systems are more and more being developed for consumers. The over-riding concern when developing consumer information systems […] changes from that of efficiency and effectiveness to that of facilitating consumers' service encounter and how they experience it" (p. 248).

This shift, moreover, describes a new interdisciplinary field in IS research that is called *Digital Life*, reflecting the increased digitalization throughout everyday life (Hess et al. 2014). Hence, it is not a big surprise that the phenomenon of technostress has gained increasing importance in usage cases apart from the organizational context (Maier et al. 2015). In the specific context of BEVs, previous research has emphasized the importance of IS in mitigating

concerns resulting from the limited range in this sustainable mode of transportation (Eisel and Schmidt 2014; Rauh et al. 2015b), but neglects that unreliable, too much, or too complex IS might lead to distraction and stress in drivers (Lundstroem 2014; Matthews and Desmond 1995; Pereira et al. 2008; Ragu-Nathan et al. 2008). The second part of the thesis aims to assess to what extent IS can induce stress in the context of BEVs, thus shifting the traditional organization-focused research stream of technostress to a new field of application.

Building upon the first two parts of the thesis, this research strives to break off the single point of view on the stress-IS relationship, emphasizing the importance of its ambivalent role (Califf et al. 2015; Lauwers and Giangreco 2016). In this regard, the thesis aims at exploring to which a bi-directional effect of IS on the perception of stress, in particular, the extent to which IS can reduce stress while at the same time lead to stress perceptions, exists. This bi-directional effect is referred in this thesis to the dual effect of IS. To do so, this thesis connects the research stream of technostress with the paradigm of the potential value of IS in reducing stress, thus capturing both perspectives at the same time. As explained above, IS can, in the context of BEVs, contribute to the reduction of range stress by providing relevant and accurate information but might, at the same time, lead to stress perceptions due to, for example, IS complexity or information overload. Considering both directional effects at the same time enables a more precise prediction of the outcomes associated with the usage of IS. In this context, technology-induced stress can lead to adverse behavioral outcomes, for example, reduced performance and productivity, resignation from a job, or decreased willingness to use a technology (Lei and Ngai 2014; Maier et al. 2014; Tarafdar et al. 2010), while, at the same time, appropriate implemented IS bears the potential to reduce stress, thus lowering such adverse outcomes (Eisel et al. 2014). To address both directional effects of the IS-stress relationship, this thesis aims to answer the following research question:

RQ1: To what extent do information systems have a dual effect on stress?

IS research relies mainly on social psychological theories, for example, the theory of reasoned action (TRA; Ajzen and Fishbein 1980), its extension, the theory of planned behavior (TPB; Ajzen 1991), or adaption of these theories, such as the technology acceptance model (TAM; Davis 1989) to explain individuals' acceptance related to technologies (Venkatesh et al. 2003; Williams et al. 2009). In most of these theories, the attitude construct – defined as "a disposition to respond favorably or unfavorably to an object, person, institution, or event" (Ajzen 2005, p. 3) – plays a major role in predicting behavioral intentions and thus actual behavior. While research traditionally focused on cogitation rather than affect when investigating the

acceptance of technological innovations (Furneaux and Nevo 2008; Zhang and Li 2005), the integration of affective responses becomes increasingly important, especially in the consumer context, as stated by Kulviwat et al. (2007):

> "The emphasis on cognition might be appropriate for an organizational context where adoption is mandated and users have little choice regarding the decision. But it is an insufficient explanation for consumer contexts in which potential users are free to adopt or reject new technology based on how they feel as well as how they think" (p. 1061).

The importance of IS-related affective emotional responses have been shown to be an important predictor of attitudinal dispositions (Brown et al. 2004; Djamasbi et al. 2009; Kulviwat et al. 2007). As mentioned above, research has revealed that stress-creating factors lead to adverse behavioral outcomes such as reduced performance or decreased disposition to use a technology. In this context, Maier et al. (2015) found in their study on behavioral responses to social networking services that users that were stressed by using such services were likely to develop discontinuous usage intentions. However, the decision to initially accept a technology through, for example, a positive attitude towards using the technology, and the decision to continue using a technology is based on different theoretical foundations (Bhattacherjee and Lin 2014; Karahanna et al. 1999). The direct effect of IS-related stress on attitudes as a behavioral outcome has not been investigated in detail. Building upon both directional effects of IS on stress, this thesis elaborates on the following research question:

RQ2: **How does the dual effect of information systems on stress influence behavioral outcomes in terms of an attitude towards performing a behavior?**

While this thesis sets its focus on BEVs to explain how the dual nature of IS stress effects direct behavioral outcomes, it goes, in the last step, beyond this usage case, aiming to apply the research knowledge to a broader context of sustainability, i.e., mobility-related sustainable business models. Due to the expected large positive environmental benefits of BEVs (Tang et al. 2013), this sustainable mode of transportation is increasingly integrated in mobility-related sustainable business models, such as e-car sharing (Seign and Bogenberger 2012). In general, a sustainable business model "creates competitive advantage through superior customer value and contributes to a sustainable development of the company and society" (Luedeke-Freund 2010, p. 23). The diffusion of digital technologies (Yoo et al. 2010) and the growing range of digital infrastructure (Tilson et al. 2010) support an increased connectivity, which, in turn, is considered to facilitate sustainable business models (Chen et al. 2008). In this context, IS

have demonstrably increased the viability of these business models, for example, by enabling access to information in real time (Amey et al. 2011; Teubner and Flath 2015) or the potential to control and monitor the sustainable service offered (Hildebrandt et al. 2015). Much research in this field has focused on the conceptualization and analysis of the relationship between IS and sustainable practices, while the actual impact of these systems has been neglected, as concluded by Malhotra et al. (2013):

> "While a lot of focus has been on the lower levels (conceptualization and analysis of IS), more needs to be done in actual design. Going further, researchers must not only work on the actual design of future IS but also establish the "in-field" impact of such systems" (p. 1270).

In this context, Bui and Veit (2015) emphasize that research needs to pay more attention to the individual as a unit of analysis for the impact of IS. Using the example of the mobility-related sustainable business model of e-car sharing, this thesis aims to shed light on the extent to which IS, as a crucial enabler for this sustainable mode of transportation, influence the individual, placing a particular focus on stress and behavioral outcomes. Figure A-1 illustrates the research questions and the addressed topics of the thesis.
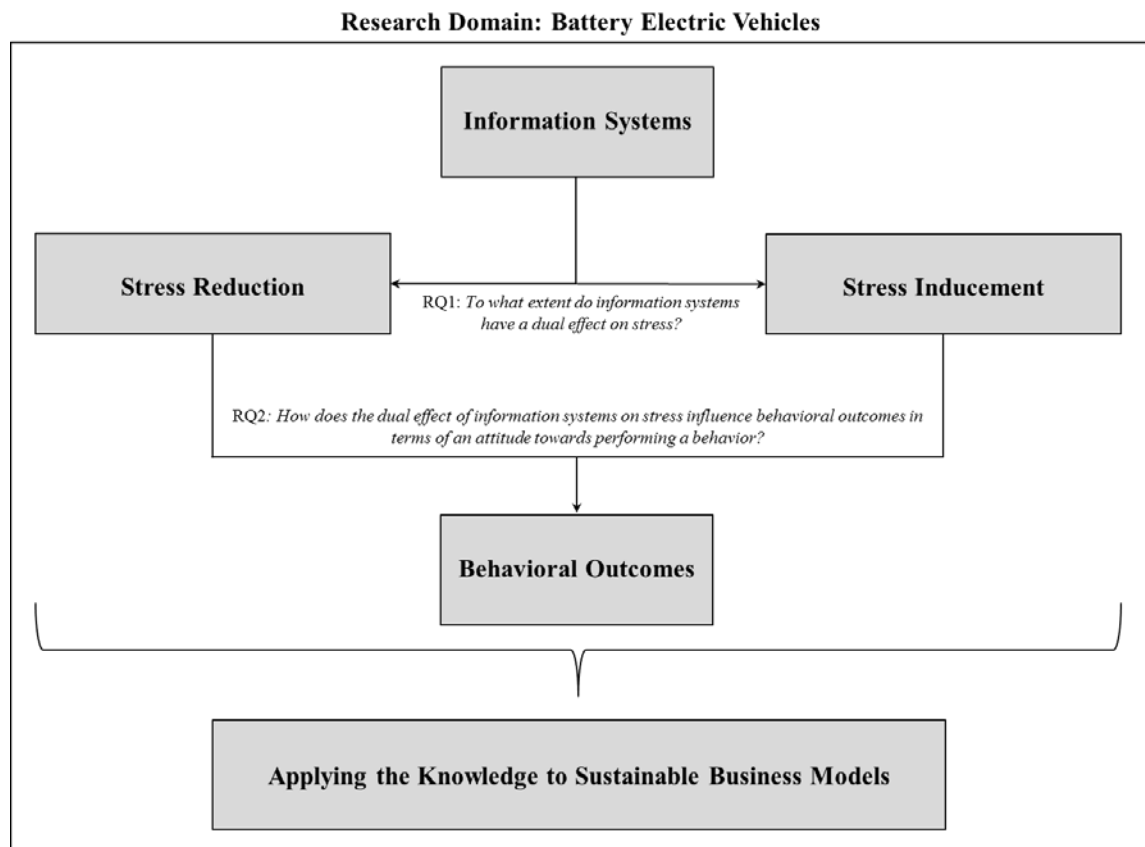
Figure A-1 Overview of Research Questions

1.3   Structure of the Thesis

This thesis is cumulative in nature and contains six parts. Part A is divided into two sub-chapters. Chapter A1 explains the motivation of the thesis (A.1.1), the research gaps and the research questions (A.1.2), the structure of the thesis (A.1.3), the research design (A.1.4), and the anticipated contributions (A.1.5). Chapter A2 provides the theoretical fundament for the thesis in Sections A.2.1–A.2.3.

Parts B, C, D, and E present the main body of the thesis (see Table A-1), covering the five integrated studies.

Part B includes one study which develops and validates a research model to evaluate the relationship between IS, stress, and behavioral outcomes. Using the example of range stress in BEVs, the study points to the general value of IS in reducing stress. In addition, the study provides insights into the congruence of psychometric and psychophysiological measurement methods when assessing range stress.

Part C includes two studies that point to the negative consequences of the interaction with IS in the vehicular context. In particular, the studies show that too much range-related information and volatile information increase range stress and thus negatively influence attitudes towards using BEVs.

Drawing on these insights, part D presents a study that emphasizes the importance of considering both directional effects of IS on the perception of stress when assessing behavioral outcomes. The study shows that IS are a useful asset in reducing range stress, while they also can induce stress at the same time.

Finally, part E includes one study that applies the generated knowledge from the previous studies to the context of mobility-related sustainable business models. The study reveals that IS-enabled business model designs, i.e., consumption-based pricing systems, can influence psychological stress in an unfavorable manner, and hence reduce the willingness to use e-car sharing.

Part F summarizes the results of the conducted studies (F.1), outlines the major contributions for research and practice (F.2), and concludes with the limitations and avenues for further research (F.3). Figure A-2 presents the overall structure of the thesis.

A. Foundations

A.1 Introduction

A.1.1 Motivation

A.1.2 Research Gaps and Research Questions

A.1.3 Thesis Structure

A.1.4 Research Design

A.1.5 Anticipated Contributions

A.2 Theoretical Background

A.2.1 The Concept of Stress

A.2.2 Stress in Information Systems Research

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B.-E. Integrated Studies

Part B

Exploring the degree to which information systems are suitable in reducing stress. Investigating the effect of stress on behavioral outcomes, i.e., attitude towards performing a behavior.

Study B1

Part C

Exploring the degree to which information systems lead to stress and thus influence behavioral outcomes.

Study C1
Study C2

Part D

Exploring the dual effect of information systems on stress. Studying the importance of considering the dual effect in predicting behavioral outcomes.

Study D1

Part E

Exploring how information systems-supported sustainable mobility business model designs influence stress and behavioral outcomes.

Study E1

F. Contributions

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F.2.1 Implications for Research

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F.3 Concluding Remarks

F.3.1 Limitations

F.3.2 Future Research

Figure A-2 Structure of the Thesis

Table A-1 Overview of Studies Included in this Thesis

No	Outlet*	Status	Chapter	Contribution
B1	Transportation Research Part F: Traffic Psychology and Behaviour	Published	B.1	Insights into the general potential value of IS in reducing stress. Evaluating the congruence of psychometric and psychophysiological measurement methods in assessing range stress.
C1	International Conference on Information Systems 2016	Published	C.1	Understanding the individual's perception of different in-vehicle IS categories with regards to range stress and attitudes towards using BEVs.
C2	Transportation Research Part F: Traffic Psychology and Behaviour	2nd round of revisions	C.2	Insights into the impact of range-related information – which differs in terms of displayed accuracy and volatility – on the perception of range stress, trust, and behavioral outcomes.
D1**	International Conference on Information Systems 2015	Published	D.1	Understanding the duality in the effect of IS on stress perceptions and the consequences for behavioral outcomes.
E1	International Conference on Information Systems 2016	Published	E.1	Understanding the impact of IS on the perception of stress and behavioral outcomes in the context of mobility-related sustainable business models.

*   The studies included in the thesis might slightly deviate from the original published studies due to the revision process of the thesis.

**   Revised version, prepared for submission to the Journal of the Association for Information Systems.

1.4   Research Design

Information systems research is generally considered as "a discipline that concerns the use of information technology-related artifacts in human–machine systems" (Gregor and Hevner 2013, p. 339). Two main paradigms, namely design science and behavioral science, characterize this broad research discipline (Hevner et al. 2004). While design science is technology-oriented and aims at creating new artifacts that serve a specific human purpose (March and Smith 1995), the behavioral science paradigm (or natural science; see Hevner and Chatterjee 2010) is characterized by developing and verifying theories that aim at predicting individual or organizational behavior (Hevner et al. 2004). Kuechler and Vaishnavi (2008) conclude that in behavioral science research "the experimental procedure and apparatus are (ideally) constructed in such a way as to minimize confounds that might interfere with clear interpretation of the results; theory is either supported or disconfirmed" (p. 498), while in the design science research "both the artifact and the experimental setting are intentionally complex (and thus

confounded) in order to develop methods and artifacts that are useful in practice" (p. 498). This thesis follows the behavioral science paradigm, as it seeks to discover and justify the relationship between IS, stress, and behavioral outcomes (March and Smith 1995) rather than creating new IS artifacts. Within this paradigm, this thesis can be assigned to the IS research stream of human-computer interaction (Banker and Kauffmann 2004), as it follows a user-centered instead of system-centered perspective by focusing on a task level on the match between user's needs and the technologies' functions (Booth 2014).

Epistemology refers to the study of knowledge acquisition (Hirschheim 1985) and can be classified in IS research in the following three categories: positivist, interpretive, and critical studies (Orlikowski and Baroudi 1991). Positivism can be characterized as an epistemology that is driven by the drive to search for regularity and causal relationship, which in turn, leads to a belief that is intended to be demonstrated by empirical testing (Hirschheim 1985). The interpretivism perspective is based on the assumption that the reality is a construct of interpretation by individuals, as emphasized by Lee (1991):

> "This school of thought takes the position that people, and the physical and social artifacts that they create, are fundamentally different from the physical reality examined by natural science. Unlike atoms, molecules, and electrons, people create and attach their own meanings to the world around them and to the behavior that they manifested in that world" (p. 347).

The critical perspective assumes that although individuals are able to consciously change their social and economic environment, they are restricted by social, cultural, and political circumstances, which in turn, shifts the focus of research to a critical perspective (Myers 1997).

This thesis is based on a positivistic epistemology, as it uses accepted scientific methods for the knowledge acquisition and validation (quantitative research), searches causal relationships for the studied elements (IS, stress, behavioral outcomes), uses data for the research that is experienced via the senses, relies on a value-free perspective for the research process, and bases its assumptions on logical reasoning (Hirschheim 1985).

Besides the distinction into positivistic, critical, and interpretive approaches, epistemology is, in addition, concerned with the question of research methodology (Gregor 2006). According to Boudreau et al. (2001), laboratory experiments, field experiments, field studies, and case studies are common research methods in the top-ranked IS journals. Laboratory experiments occur in settings that are created by the experimenter, while field experiments take place in a

natural setting in which at least one of the researched variables is manipulated. Field studies are non-experimental explorations in natural systems, in which none of the researched variables can be manipulated or controlled by the researcher (Boudreau et al. 2001). With the exception of study D1, field experiments were used to study the relationship between IS, stress, and behavioral outcomes. Field experiments have the advantage of being carried out in a natural setting, thus participants often behave more normally (Eysenck 2000). Mental simulations experiments were used for study D1, as the general set-ups for this study were practically difficult to implement in field experiments. Mental simulations are characterized as mental activities in which the individual mentally creates a hypothetical situation (Zeimbekis 2011). They are considered important in cognitive and emotional-related evaluation processes, as emphasized by Gavanski and Wells (1989):

> "To act purposefully on our physical and social environment, we must not only evaluate reality, but also imagine alternatives to reality. Our thoughts, emotions, and actions are guided not only by what is, but what might be and what could have been" (p. 315).

The research design for each study is illustrated in Table A-2.

Table A-2 Overview of Research Design

No	Epistemology	Paradigm	Methodology	Data Analysis
B1	Positivistic	Behavioral Science	Field Experiment (Gerber and Green 2012)	Hierarchical Regression Analysis, Effect Size, and Mean Comparison
C1	Positivistic	Behavioral Science	Field Experiment (Gerber and Green 2012)	Structural Equation Modeling, Effect Size, and Mean Rank Comparison
C2	Positivistic	Behavioral Science	Field Experiment (Gerber and Green 2012)	Linear Regression Analysis, Effect Size, and Mean Rank Comparison
D1	Positivistic	Behavioral Science	Mental Simulation Experiment (Zeimbekis 2011)	Structural Equation Modeling, Effect Size, and Mean Comparison
E1	Positivistic	Behavioral Science	Field Experiment (Gerber and Green 2012)	Structural Equation Modeling, Effect Size, and Mean Rank Comparison

1.5 Anticipated Contributions

By exploring the duality in the effect of IS on stress and its consequences for behavioral outcomes, this thesis makes several contributions to research and business practices in the fields of IS, behavior, transportation research, and business model innovation management.

First, the findings of the thesis provide important implications for the IS community, especially within the research stream of human-computer interaction (Banker and Kauffmann 2004). This research increases the understanding of how individuals perceive the interaction with IS,

as the perceptual perspective constitutes an important view of technologies in IS research (Orlikowski and Iacono 2001). The thesis contributes to an understanding of the consequences of the increased pervasion of IS in the era of *Digital Life* (Hess et al. 2014), which also includes the increased penetration of IS into the vehicular context. By emphasizing the potential adverse consequences of IS on the perception of stress, this work responds to the recent research call on the dark side of IS, which refers to the negative consequences of IS for the well-being of individuals, organizations, and societies (Tarafdar et al. 2015a).

Previous research in the field of IS and stress has predominantly focused on technostress in an organizational context (Riedl et al. 2012; Tarafdar et al. 2017). By emphasizing the significance of technostress in the new field of application of sustainable mobility, i.e., IS in BEVs, this thesis contributes to the increased recognition of the importance of this phenomenon in the private context (Maier et al. 2014; 2015b). Besides emphasizing the negative consequences of IS usage, this work also seeks to determine the potential value of IS in stress reduction, thus shedding light on the yet understudied opposite perspective in IS research. In addition, the thesis sets the objective to propose a research model to capture both effects. The simultaneous consideration of both emphases on the stress-IS relationship creates new implications for the development and design of IS, and thus enables a more precise measuring of behavioral outcomes. In this context, studies that, on one hand, focus on stress that results from the interaction with IS and the subsequent consequences for behavioral outcomes should also consider that at the same time such systems have the potential to reduce context-related stress, which, in turn, can positively influence behavioral outcomes. On the other hand, studies that emphasize the potential positive effect of IS in reducing stress should also be aware that there exists an opposite effect referred to as technostress, which, in turn, might diminish the intended positive behavioral outcomes. Thus, the thesis challenges the predominantly single point of view on the IS-stress-behavior relationship (Califf et al. 2015; Lauwers and Giangreco 2016).

With its focus on the behavioral research paradigm, this work aims to extend the knowledge base on behavioral research in information systems, in particular, technology acceptance research. Theories of human behavior, i.e., the theory of planned behavior (Ajzen 1991) serve as a fundament for explaining the acceptance of technologies (Venkatesh et al. 2003). In this context, the attitude construct acts as an important instance in predicting behavior (Ajzen 1991; Ajzen and Madden 1986) and hence in technology acceptance (Venkatesh et al. 2013). Thus, the thesis emphasizes the importance of considering affective components (Furneaux and Nevo 2008; Kulviwat et al. 2007), i.e., IS-influenced stress in this research domain.

In addition, the transportation-science community, in particular, researchers concerned with sustainable mobility and the design of in-vehicle IS, are expected to profit from the insights of this work. In this context, this thesis aims to investigate the phenomenon of range stress (Rauh et al. 2015a) against the backdrop of the potential value of IS to mitigate this concern (Eisel and Schmidt 2014). At the same time, the research points to the danger that results from the interaction with IS in terms of technostress (Ragu-Nathan et al. 2008). As emphasized by Tarafdar et al. (2017), more research is needed on the appropriate design of IS to mitigate the negative effects of IS-related stress. With its focus on the evaluation of in-vehicle IS, the thesis therefore offers insights into the effects of specific design features on stress in the context of BEVs. By integrating physiological responses (Lykken and Venables 1971) into the assessment of IS-related stress, this thesis responds to the research lack of using such measurement methods when assessing IS-induced stress (Riedl et al. 2012) and range stress (Nilsson 2011). By doing so, the thesis allows the generation of insights as to what extent physiological measures constitute a useful extension for psychometric assessment methods.

Apart from its expected contribution for research, the thesis aims to offer recommendations for practitioners in the automotive industry. With its focus on the dual role of IS on the perception of stress in the context of BEVs, the work guides practitioners through the potential opportunities and challenges resulting from the digitalization in and around BEVs (Abdelkafi et al. 2013; Burns 2013; Dijk et al. 2013). In this context, this research strives to derive practical suggestions for decision makers to find a balance between the dilemma of providing sufficient information to the driver to overcome range-related barriers, while not eliciting an information overload (Neumann and Krems 2016). A profound understanding of the influence of IS on the perception of stress is especially important because a higher level of stress might negatively affect the acceptance of a technology (e.g., Maier et al. 2015), especially in the context of BEVs (Carroll and Walsh 2010; Dimitropoulos et al. 2011; Duke et al. 2009; Egbue and Long 2012; Rezvani et al. 2015).

Finally, the thesis supports managers concerned with the design of sustainable business models (Luedeke-Freund 2010) by outlining to what extent specific IS-enabled business model designs influence the individual perception of stress and acceptance of related services. However, apart from this usage case, the findings are expected to be adaptable for a variety of further scenarios in which the human-computer experience is crucial for the success of technologies. For example, the user experience and behavioral outcomes associated with accounting IS or other management decision support systems (Bharati and Chaudhury 2004; Grabski et al.

2011; Shim et al. 2002) can be optimized by balancing the effects that IS can have on the perception of stress.

Table A-3 provides an overview of the anticipated contributions for research and practitioners. At this point, it should be noted that the respective subdomains of research (information systems science, behavioral science, and transportation science) should not be considered as strictly separated parts, as they overlap to a certain degree.

Table A-3 Anticipated Contributions for Research and Practice

Target Audience		Anticipated Contributions
Research	Information systems science	Insights into the duality in the effect of IS on stress, in particular, the role of IS in reducing and inducing stress.
		Insights into the relationship between IS-related stress and behavioral outcomes, i.e., attitudes towards performing a specific behavior.
	Behavioral science	Pointing to the importance of integrating affective components, i.e., stress, in behavioral-oriented research models such as the theory of planned behavior.
	Transportation science	Insights into the effects of in-vehicle IS design features on the perception of stress with particular focus on the underlying appraisal processes.
		Insights into the congruence of psychometric and psychophysiological measurement methods when assessing stress in a vehicular context.
Practice	Practitioners in the fields of mobility and business model design and innovation	Providing assistance for the challenge of providing sufficient information through IS to drivers of BEVs against the backdrop of reducing range stress while not overloading the driver.
		Understanding the impact of specific IS-enabled sustainable business model designs on the individual's stress perception and the resulting consequences for behavioral outcomes.
	Practitioners in further fields of application for the design and development of IS	Pointing to the importance of considering the duality in the effect of IS on stress to increase user experience and to optimize behavioral outcomes.

2   Theoretical Background

2.1   The Concept of Stress

The nature of stress is difficult to comprehend and leads to a lack of conceptual clarity and agreement on the following elementary question (Levine and Scotch 2013): Is stress best

characterized by the kind of stimulus, the manner in which stress is perceived, or the way individuals handle stressful encounters? As a result, the conceptualization of the stress process has been plagued by inconsistent definitions and, moreover, led to noticeable debates about its meaning (Cohen et al. 1997; Lazarus 1993a; Levine 2005b; Mason 1975). The resulting ambiguity about a consistent definition is not surprising, as emphasized by Levine (2005a):

> "The major problem with the concept of stress is that we are confronted with a composite, multidimensional concept. All existing definitions include some components. We can identify three main subclasses. These subclasses can be identified as the input (stress stimuli), the processing systems, including the subjective experience of stress and the output (stress responses)" (p. 940).

Following this line of argumentation, most explanatory approaches of stress can be best classified into stimulus-based, response-based, and transaction-based definitions (Bartlett 1998; Burchfield 1979; Cohen et al. 1997; Evans and Cohen 1987; Hobfoll 1989; Lyon 2000).

2.1.1   *Stimulus-based Perspective*

Stimulus-based explanatory approaches for stress emphasize stressors that are likely to cause stress and the stress-related conditions emerging within the individual, for example, drive stimuli such as sex or hunger (Lazarus and Folkman 1984). Events are considered stressful if they lead to stress reactions, especially emotional upset, psychological distress, or physical impairment (Hobfoll 1989). Wheaton (1999) proposes a more specific definition, referring to stressors as "a condition of threat, demand, or structural constraint that, by its very occurrence or existence, calls into question the operating integrity of the organism" (p. 281). This definition emphasizes that stressors can be evaluated by the individual in different ways. Stressors related to threats refer to events with potential future harms, while demands categorized stressors refer to challenging situations that result from current life circumstances. Structural constraints result from reduced opportunities due to social disadvantages (e.g., discrimination).

Elliot and Eiersdorfer (1982) outline four different kinds of stimuli that trigger the stress process. Acute, time-limited stressors, such as encountering a cobra or waiting for an exam result, arise suddenly (acute) and are over relatively quickly. Stressor sequences occur over an extended period of time and are characterized as a series of events that is caused by an initiating stressful event such as a divorce or bereavement. Chronic intermittent stressors, such as sexual difficulties, entail repeated exposures to stressors. Chronic stressors persist continuous-

ly for a long time and may result from exposure to traumatic events (e.g., traumatic brain inju-
ries) or ongoing distress (chronic job stress). Another categorization of environmental stress-
ors has been proposed by Evans and Cohen (1987), classifying environmental stressors into
cataclysmic events (sudden catastrophes, such as floods, that require significant adaptive re-
sponse from all the individuals concerned), stressful life events (timely restricted major inci-
dents in the individual's life cycle such as a divorce), daily hassles (reflect common, short-
lived daily annoyances that may lead to frustration, tension, irritation, for example, a noisy
party or a crowded shopping center), and ambient stressors (continuous and relatively stable
stressors that are a part of the background environment, for example, chronic air pollution).
Moreover, stressors can be characterized along few dimensions, for example, the degree of
which a stressor is perceptually salient, the degree of control over or predictability of an envi-
ronmental stressor, the physical property of a stressor (e.g., chemical, thermal, electrical stim-
uli), importance of the source of a stressor for an individual, or the duration and periodicity of
a stressor (Bohus et al. 1986; Evans and Cohen 1987; Ladewig 1986).

2.1.2   *Response-based Perspective*

In contrast to stimulus-based definitions of stress, response-based approaches define stress by
an organismic response to certain events. The response-based perspective was mainly popu-
larized by one of the foremost stress researchers, Hans Selye (see Lyon 2000), defining stress
as "a state manifested by a specific syndrome which consists of all the nonspecifically-
induced changes within a biologic system" (Selye 1959, p. 403). According to Selye (1946),
stressors elicit a common physiological response which proceeds in a three-stage pattern re-
ferred to as the general adaptation syndrome (GAS). The first stage, the alarm stage, reflects
the individual's initial physiological change to sudden exposure of a stressor which is subdi-
vided into two less distinct shock phases: an initial shock phase and a countershock phase.
The shock phase is reflected by an increased excitability, higher adrenaline discharge, and
gastro-intestinal ulcerations (Krohne 2001). The countershock phase is characterized by in-
creased adrenocortical activities and follows when the stressor persists and/or the individual is
too weak. As a consequence, individuals may suffer, for example, from chest pain, feelings of
lightheadedness, muscle tremors, racing heart, or headache (Rice 2000). In case the individual
is exposed to the stressor for a prolonged period, the organism tries to keep up with the stress-
ful situation in the second stage, the resistance stage. The symptoms of the alarm stage disap-
pear and, moreover, organism's adaptation to the stressor is characterized by an increased
resistance to other types of stress (Selye 1946). Finally, the stage of exhaustion occurs when

the stressor persists and the somatic defense is insufficient to resist the stimuli. In such a case, the symptoms are similar to those of the alarm stage but the resistance is no longer possible. If the stimulation persists, vulnerable organs will break down and cause illness and, in the last resort, ultimately death (Cohen et al. 1997).

Selye (1976) refers to the GAS as the response of the organism to a wide range of chemical, biological, or physical stimuli that occur in a stereotypical manner. Although the pattern of the stress response is specific, the effects and the cause of the stress response is nonspecific. Moreover, Selye (1976; 1979) points out that stress is not inherently a negative experience and hence distinguishes between eustress (beneficial stress) and distress (harmful stress). Eustress is associated with positive feelings and healthy bodily states resulting from positive events (e.g., marriage or the birth of a baby), while distress is related to negative feelings and detrimental physiological state. The organism undergoes basically the same nonspecific response during both types of stress but distress is more likely to cause disease.

2.1.3   *Transaction-based Perspective*

Both stimulus-based and response-based definitions have been criticized for their narrowed, one-sided consideration of the complex, multidimensional concept of stress. Lazarus and Folkman (1984), for example, argue that it is difficult to establish a consistent taxonomy or characterization of environmental stressors in stimulus-based approaches, as individual's vulnerability to such stressors varies widely. Thus, a taxonomy of stressful situations is mainly dependent on the individual's response to stress, which in turn, cannot be generalized. Moreover, the authors explain that it is crucial integrate the properties of an individual for understanding the process of stress. Krohne (2001) points out that response-based definitions of the stress process fail to integrate the cognitive evaluation process that is necessary for understanding the transformation of a stressful encounter into the individual's experience of being distressed. In addition, Krohne (2001) argues that it is crucial to consider coping mechanisms to explain the stress–outcome relationship. Levine and Ursin (1991) summarize that a holistic view of stress is characterized by the interaction between input (stress stimuli), output (stress response), and the processing systems (subjective experience of stress). Transaction-based definitions of stress address these aspects and conceptualize stress as a result of psychological appraisal processes that consider the meaning of an event for an individual and the available coping resources (Cohen et al. 1997). Thus, the transaction-based perspective goes far beyond the determination of stress solely as the stimulus condition or the response reaction.

One of the most influential stress models of the transaction-based perspective has been proposed by Lazarus and colleagues (Lazarus 1966; Lazarus and Folkman 1984) by emphasizing the bilateral relationship (transaction) between the environment and the individual. In this context, Lazarus and Folkman (1984) define stress as "a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being" (p. 19). Lazarus and Folkman (1987) highlight that stress cannot be explained solely from the standpoint of one of the two basic subsystems – person and environment – but rather it needs a consideration of the relationships (transaction) between both entities. This relationship is characterized as being dynamic, mutually reciprocal, and bidirectional (Folkman et al. 1986b).

Two basic constructs are central in the transaction-based stress model: cognitive appraisal and coping. Cognitive appraisal refers to the individual's evaluation of encounters with the environment with respect to its significance for well-being and is classified in primary appraisal, secondary appraisal, and reappraisal (Lazarus 1966; Lazarus and Folkman 1984; Lazarus and Folkman 1987). In this context, Lazarus and Folkman (1984, p. 31) emphasize that cognitive appraisals are "largely evaluative, focused on meaning or significance, and takes place continuously during waking life." Within the primary appraisal process, individuals evaluate whether and in what way a particular encounter with the environment will affect their well-being now or in the future. In that regard, each environmental encounter is classified for the individual's well-being as either irrelevant, benign-positive, or stressful. Situations evaluated as irrelevant do not carry any implication for the individual's well-being, while benign-positive encounters with the environment are appraised as preserving or enhancing the individual's well-being evoking pleasurable emotions including love, happiness, or joy. However, as both irrelevant and benign-positive appraisals do not affect the well-being in an unfavorable manner, they do not trigger the stress process. In contrast, stressful appraised situations are evaluated by the individual as either a harm/loss, threat, or a challenge. Harm/loss appraisals refer to individual-environment relationship in which a damage has already occurred, for example, a loss of a valued person or an advancing illness. Threat appraisals refer to harmful situations that still have not occurred but are anticipated by the individual. Lazarus and Folkman (1984) emphasize that harm/loss appraisals and threat appraisals are merged, as every harm/loss implies negative consequences for the future. Finally, challenge appraisals refer to encounters with the environment that is evaluated by the individual as demanding but still manageable when effectively mobilizing coping efforts. According to Lazarus and Folkman

(1984), challenge appraisals can be accompanied by pleasurable emotions including eagerness or excitement, while threat appraisals elicit negative emotions including fear, anxiety, or anger. Both appraisals are closely related, as stated by Lazarus and Folkman (1984):

> "Threat and challenge are not necessarily mutually exclusive. A job promotion, for example, is likely to be appraised as holding the potential for gains in knowledge and skills, responsibility, recognition, and financial reward. At the same time, it entails the risk of the person being swamped by new demands and not performing as well as expected. Therefore, the promotion is likely to be appraised as both a challenge and a threat." (p. 33).

Generally, the primary appraisal process is influenced by a range of personality characteristics (for example, values, beliefs about oneself, commitments, goals) as well as by the social and cultural environmental conditions (Folkman et al. 1986b; Lazarus and Folkman 1987).

If an individual appraises a situation as stressful for its well-being, s/he considers coping resources in the secondary appraisal process (Lazarus 1990). In this complex psychological appraisal process, the individual evaluates the likelihood that the existing coping resources will be useful in dealing with the stressful encounter on the one hand, and if the individual is able to effectively apply the respective coping resources on the other hand (Lazarus and Folkman 1984). The belief that a behavior (e.g., effectively using a coping resource) will lead to a certain outcome (e.g., successful management of a stressful situation) is referred to as *outcome expectation*, while the belief that the individual can successfully execute a specific behavior (e.g., using coping resources) is related to the term *efficacy expectation* (Bandura 1977).

According to Folkman et al. (1986b), a variety of coping options are evaluated, including changing or accepting the situation, seeking more information about the situation, or actively controlling their behavior. Jerusalem and Schwarzer (1989; 1992) propose material resources, social support, or personal resources (e.g., the individual's skills, abilities, competences) as main coping resources to re-establish the imbalance between environment and individual. Folkman (1984) emphasize that – besides physical (e.g., person's health or energy), social (e.g., social network and support systems), and material assets (e.g., money or tools) – psychological resources are evaluated by the individual with respect to the demands of the situation. The two main psychological resources which are evaluated by the individual are referred to as locus of control and self-esteem (Thoits 1995). Locus of control is defined by the belief of being in control over a specific situation (Rotter 1966), while self-esteem is defined by the positive attitude toward oneself (Pearlin and Schooler 1978). Self-esteem is intertwined with

the self-concept of own abilities which describes the perceived degree of being able to manage a specific situation (Campbell 1990; Crocker and Major 1998; Stein 1995). Both psychological constructs have been related to the secondary appraisal process of the transactional stress model of Lazarus and Folkman (1984) (Gaab et al. 2005). In addition, research on range stress has shown that locus of control and self-concept of own abilities constitute powerful psychological coping resources within the secondary appraisal process (Eisel et al. 2014; Franke et al. 2016b; Rauh et al. 2015a).

The individual perceives psychological stress when the coping resources assessed in the secondary appraisal process are perceived as insufficient to overcome a stressful appraised situation from the primary appraisal process. In this situation, the individual puts cognitive and behavioral effort into re-establishing the imbalance in the person-environment relationship with the aim to reduce, master, tolerate, or minimize the demand that is perceived as taxing or exceeding the individual's coping resources (Folkman et al. 1986b). Two main coping strategies are applied by the individual. While problem-focused coping targets managing the problem that causes psychological stress, emotion-focused coping aims at the regulation of the stress-related emotions (Folkman 1984). Folkman and Lazarus (1980) found that individuals tend to favor problem-focused coping strategies (e.g., making a plan of action and following it) in situations that are evaluated as changeable, whereas emotion-focused coping strategies (e.g., trying to forget the whole thing) were favored in situations that were perceived as not amenable to change. The changed person-environment relationship due to problem-focused and emotion-focused coping leads to reappraisals that trigger further coping efforts.

Moreover, the entire evaluation processes in the primary and secondary appraisals can be influenced when new information from the environment is considered (Lazarus and Folkman 1984). Such reappraisals might lead to, for example, an event initially appraised as a threat to being reappraised as irrelevant when the individual processes new information. Lazarus (1993a) brings in the following example:

> "if a person can reinterpret a demeaning comment by his/her spouse as the unintended result of personal illness or job stress, the appraisal basis for reactive anger will dissipate" (p. 8).

Primary and secondary appraisals do not occur in a chronological order, as emphasized by Lazarus and Folkman (1984):

> "The choice of terminology, "primary" and "secondary," was unfortunate for two reasons. First, these terms suggest, erroneously, that one is more important (i.e., primary) than the other, or that one precedes the other in time. Neither of these meanings is intended" (p. 31).

Figure A-3 schematically illustrates Lazarus' transactional model of stress.
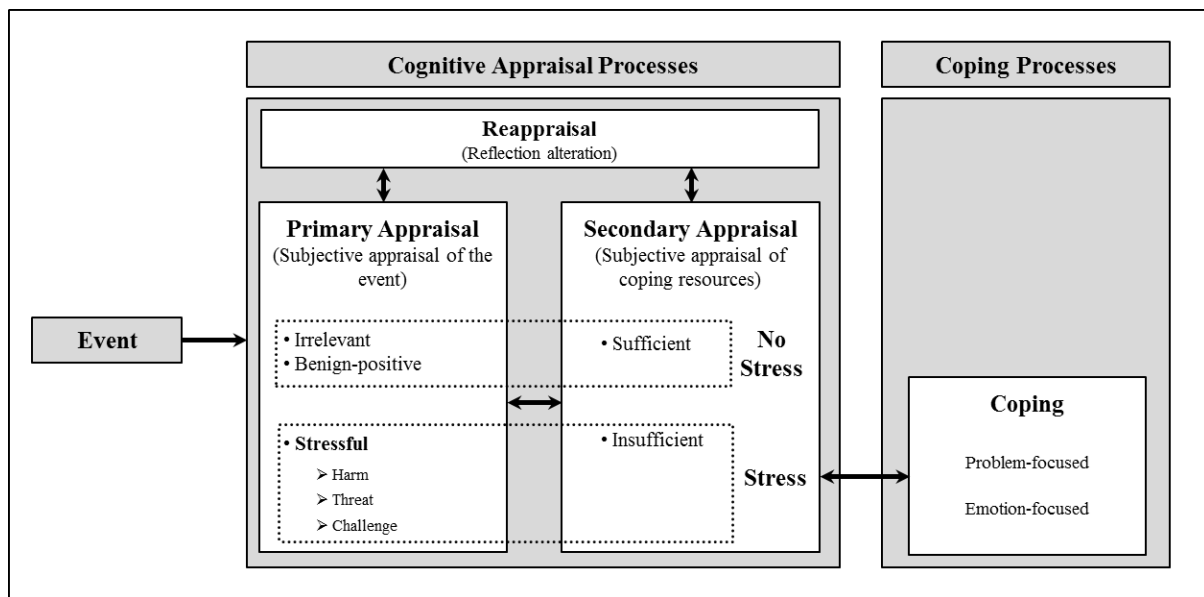
Figure A-3 Transactional Stress Model (adapted from Nastjuk et al. 2015)

2.2 Stress in Information Systems Research

The theoretical link between the relationship of IS and stress is often associated with the umbrella term *technostress* that first became popular in the 1980s and is defined as "a modern disease of adaptation caused by an inability to cope with new technologies in a healthy manner" (Brod 1984, p. 16). Weil and Rosen (1997) provide a more specific definition, conceptualizing technostress as "any negative impact on attitudes, thoughts, behaviors, or body physiology that is induced either directly or indirectly by technology" (p. 5).

Although technostress is a phenomenon that plays a key role in both the organizational and private setting (Maier et al. 2014; Ragu-Nathan et al. 2008; Riedl 2013), most research has centered on the antecedents, characteristics, and consequences of technostress in an organizational context (Riedl et al. 2012; Riedl 2013; Tarafdar et al. 2017). With respect to the antecedents of technostress, several technostress creators and technostress inhibitors have been

identified and discussed in literature (e.g., Ayyagari et al. 2011; Ragu-Nathan et al. 2008; Tarafdar et al. 2015b). Technostress creators refer to the source of stress that mainly determines the perceived level of technostress (Tarafdar et al. 2007). According to Ragu-Nathan et al. (2008), the mechanisms of technostress creators result from several properties of organizational technologies that adversely influence employees. First, information and communication technologies enable constant connectivity that extends the regular working day of employees (e.g., pressure to respond to E-Mails). Second, employees are enforced to handle simultaneously different streams of information from a variety of devices, which in turn, expose individuals to more information that they can process. Third, businesses permanently update their technologies due to competitive pressure. The associated rapid changes make it difficult for employees to build experience with technologies, thus forcing them to be up-to-date. This becomes especially problematic, as innovative ICTs are perceived as complex in terms of functionalities and terminology. Ragu-Nathan et al. (2008) finally emphasize that these technologies are often accompanied by data loss, errors, and technical problems, which, in turn, leads to frustration and job dissatisfaction.

Based on these theoretical deliberations, research has identified five main dimensions of stress creators used to capture the phenomenon of technostress (Ragu-Nathan et al. 2008; Tarafdar et al. 2007; Tu et al. 2005). First, *techno-overload* refers to situations in which the interaction with information and communication technologies leads to an increased workload for the user. Second, *techno-invasion* refers to the invasive character of technologies (being permanent connected) that leads to a blurred work-private boundary and hence decrease the time spent with family or on vacation. Third, *techno-complexity* is related to situations in which the individual perceives their computer skills insufficient, thus spending more time and effort in educating themselves to understand the complexity associated with ICTs. Fourth, *techno-insecurity* is related to the concern of becoming replaced because of a) automation from ICTs or b) more technology-skilled people. Finally, *techno-uncertainty* is described as a perceived insecurity to keep up with changes and upgrades of ICTs and the associated pressure of self-education regarding new technologies.

In contrast to the factors that trigger the stress process, technostress inhibitors refer to mechanism that offset negative outcomes of technostress (Tarafdar et al. 2011b). Literature has suggested five main technostress inhibitors (Ragu-Nathan et al. 2008; Tarafdar et al. 2011a; 2011b; 2015b). First, *literacy facilitation* aims at reducing stress in employees by supporting them in understanding and using ICTs in companies. Ragu-Nathan et al. (2008) emphasize

that especially ICT-related knowledge sharing within the organization supports the user in coping with demands of learning new technologies. Second, t*echnical support provision* is described as an inhibitor that reduces negative outcomes of technostress by providing the end-user with appropriate support in technical questions, especially solving end-user's ICTs-related problems. Third, *involvement facilitation* aims at increasing the involvement of the user in ICTs. In this context, ICT-related stress can be reduced by keeping end-users informed about the reasons for and consequences of introducing new ICTs. Fourth, *technology self-efficacy* refers to the end-user perception of being able to use technologies to accomplish an intended task. Tarafdar et al. (2011b) emphasize that especially end-user training and helpdesk support constitute necessary mechanism to increase technology self-efficacy. Fifth*, innovation support* is described as a set of mechanisms that support the end-user in learning and accepting about ICT-driven changes with respect to routines and tasks. Tarafdar et al. (2011a) points out that it is important to promote a supportive climate between employees by creating an open communication environment.

The reactions to technostress on an individual level are associated with changes in social, physical, and cognitive responses (Ragu-Nathan et al. 2008). Such responses can lead to psychological strain-related outcomes and behavioral strain related outcomes (Tarafdar et al. 2011b). Psychological strain-related outcomes encompass, for example, responses in terms of decreased job satisfaction, reduced commitment to the organization, increased role stress, social overload, or perception of being exhausted from using technologies (Maier et al. 2014; Ragu-Nathan et al. 2008; Tarafdar et al. 2011b), while behavioral strain-related responses refer to outcomes such as decreased productivity, poor task performance, ceasing the use of technology, or quitting a job (Lei and Ngai 2014; Maier et al. 2014; Tarafdar et al. 2010). In addition, technostress can also lead to adverse physiological reactions, for example, the excretion of stress hormones such as cortisol (Riedl 2013; Tams et al. 2014).

Research has also emphasized that technology-related characteristics influence the perception of technostress. Ayyagari et al. (2011), for example, revealed that technology characteristics in terms of usability features (usefulness, complexity, reliability of a technology), intrusive features (in terms of being reachable and anonym), and dynamic features (degree to which changes in technology are perceived as being rapid) are related to certain stressors, such as work overload, intrusion of privacy, conflicts regarding the boundary between work and home, or job insecurity. Another characteristic of ICTs was investigated by Galluch et al. (2015), arguing that ICT-enabled dimensions of interruptions in terms of quantity and content

influence the perceptions of stress and strain. In addition to technological attributes, the organizational environment is important in describing the phenomenon of technostress. In this context, Weinert et al. (2015) argue that teleworkers are exposed to different environmental conditions than employees in common work places and therefore face different stressors. The researchers found that an undersupply of information and increased flexibility to allocate the workload according to one's own preferences are associated to work overload, role-ambiguity, and work-home conflict, which in turn, influence teleworking-exhaustion and the tendency to continue teleworking.

Research also found that an individual's reaction to technostress is dependent on the cultural background and individual characteristics such as age, gender, experience, or education. Tu et al. (2005) point out that Chinese employees older than 35 years perceived more technostress than their younger counterparts, especially associated with techno-overload and techno-complexity. The researchers state that the "Chinese culture often tells employees to endure work overload rather than quit their jobs" (p. 79), thus emphasizing the importance of cultural differences. Ragu-Nathan et al. (2008) revealed that female employees experienced less technostress than male employees, and that technostress increased with decreasing age, computer confidence, and education. In alignment with these results, a study of Tarafdar et al. (2011a) found that male professionals experience more technostress than female ones, older professionals are less vulnerable to technostress, and professionals with higher levels of education, computer experience, and computer confidence suffered less from technostress.

While most research has been focused on technostress in an organizational setting (see Riedl et al. 2012; Riedl 2013), recent research has also stressed the importance of investigating technostress in a private setting. It has been shown, for example, that users of IS-supported social networks like Facebook might perceive stress due to due to social overload: giving too much social support to friends in online network sites (Maier et al. 2014). Maier et al. (2012) identified five main technostress creators that are applicable in the context of social network sites. First, *invasion* reflects the increasing importance of online social network sites in daily life. Second, *patterns* refer to certain changes in behavioral patterns, such as using online social network sites as a predominant communication tool. Third, *disclosure* is related to the perception of releasing certain information online, and moreover, to the force to be kept up-to-date about activities of friends. Fourth, *complexity* describes situations in which users are not able to use all functions of online social network sites. Finally, *uncertainty* focuses on changes in technology. The researchers revealed that these stressors statistically significantly

reduce user satisfaction and continuous usage intention. In another study, Maier et al. (2014) found that too much social overload – which is influenced, for example, by the extent of usage, type of relationship, or number of friends – leads to psychological (e.g., exhaustion, low user satisfaction) and behavioral reactions (e.g., decreased intention to use such online social network sites). The researchers extended their findings in another study (Maier et al. 2015), revealing that switching stress creators (i.e., transition costs, sunk costs, and replacement overload) leads to switching exhaustion, which in turn, is negatively associated to discontinuous usage intention and, thus, discontinuous usage behavior.

Apart from the negative consequences resulting from the interaction with IS, literature indicates that IS can also contribute to reduce and manage stress. Computerized clinical decision support systems, for example, are a valuable supporting technology to regulate stress in patients (Garg et al. 2005; Goud et al. 2009; Hunt et al. 1998). Such systems support practitioners in the processes of chronic care (e.g., diagnosis, treatment, or monitoring) and thus can generate recommendations for stress management programs for patients (Roshanov et al. 2011). Within the *Employee Stress and Alcohol Project (ESAP)*, researchers have developed an interactive computerized alcohol abuse and stress intervention program that aims at supporting employees to deal with alcohol abuse and work-related stress. The web site offers individualized strategies for reducing alcohol consumption, dealing with work stress, and improving coping strategies (Matano et al. 2000). Brown et al. (2011) developed a computerized stress management training for HIV+ women. The training aims at improving coping skills and fostering psychological adjustments among HIV+ women.

Apart from the clinical context, researchers found that IS can also be useful to reduce stress in the educational setting. Lèon et al. (2008), for example, propose that IS-supported learning tools reduce stress in students by adapting to students' learning preferences. In a similar vein, Lohaus (2010) developed and validated a stress computer-supported stress prevention program for adolescents. The e-learning platform aims at providing knowledge about stress, stress symptoms, and suitable coping strategies. The prevention program not only increased the motivation in participating in the program but also was able to improve stress management capabilities.

The positive effects of IS for managing stress has also been emphasized by IS research. In this context, biofeedback systems combine computing with physiological sensing technologies to ameliorate stress disorders by detecting physiological changes and communicating them back to the target subject in real time (Allanson 2002). Riedl and Léger (2016) relate biofeedback

systems to neuroscience and psychophysiological approaches of IS research and explain the functional principle of these systems as follows:

> "Such systems are based on the principle that awareness of a biological indicator makes better control of that indicator possible. For example, if a person observes his or her own level of arousal in the form of a visualized curve on a computer screen, or hears an acoustic signal that reflects the arousal state (e.g., based on non-obtrusive measures such as skin conductance), this greater awareness improves conscious control of the arousal level" (p. 17-18).

According to the Mayo Clinic, one of the largest integrated medical centers in the world, biofeedback systems have been recognized to be useful in treating more than 100 mental and physical illnesses including stress, asthma, chronic pain, headache, high blood pressure, motion sickness, or urinary incontinence (Al Osman et al. 2014; Mayo Clinic 2016).

Al Osman et al. (2014) classify biofeedback devices into the following categories: stationary versus mobile, wired versus wireless, analog versus digital, and binary versus proportional. Stationary devices involve big instrumentation in a wall unit whereas mobile systems are usually small that can be embedded in the human body or carried as a portable device. Wired systems are connected to the computing and processing system with, for example, copper wires or fiber optic cables, while wireless devices use Bluetooth or infra-red as a medium for connecting the device to the computing and processing unit. Analog devices rely on analog information while digital systems process digitized signals. Finally, binary systems process physiological parameters in terms of on/off information (i.e., the system informs the individual when s/he about the physiological state when a certain threshold is exceeded) whereas proportional devices capture the amount of changes of particular physiological parameters.

Given the promising value that biofeedback systems offer to individuals, IS research has described and examined its role in reducing stress in a wide variety of case studies. Al Osman et al. (2014), for example, developed and validated a *Ubiquitous Biofeedback* reference model to manage stress in individuals working in an office setting. In contrast to traditional biofeedback systems, Ubiquitous Biofeedback is not bound by time or setting and is designed to continuously monitor and manage the individuals' physiological processes. In another study, Al Osman et al. (2016) developed a biofeedback system for serious games (games that are designed for other purposes than pure entertainment). The mobile app graphically illustrates a tree which shows the status of the Autonomous Nervous System of the player. When players experience stress, the tree's health starts to deteriorate, with leaves yellowing and falling.

When the player relaxes, the tree begins to flower. Mental stress is monitored by using Heart Rate Variability analysis. Astor et al. (2013) designed a serious game-based NeuroIS tool that aims at teaching how to better manage financial decisions. The player is mentally put into the position of a trader that continuously buys and sells goods. The game difficulty is affected by the level of physiologically measured arousal. Leahy et al. (1998) developed a computer aided biofeedback systems that aims to support patients with the stress-related disorder of irritable bowel syndrome. The game-related biofeedback system monitors electrodermal activity and presents the animated feedback on the game interface with the goal of teaching deep relaxation. MacLean et al. (2013) developed and tested a wearable butterfly (MoodWings) that monitors the individuals' real-time stress level when driving. The early-stress-warning system aims at supporting the user to perform better at a stressful task by providing feedback on the stress level through actuated wing motion. Ahmed et al. (2011) presents a computer-based biofeedback system that assists clinicians in the process of stress-related patient classification, parameter setting for the personalized biofeedback treatment, and stress management. To support research outside the laboratory setting, Garbarino et al. (2014) developed a wearable wireless multi-sensor device for acquisition of biofeedback-related data in real-time. The wristband is small and light, which enables collection of stress-related feedback in many real-life applications. While most biofeedback systems rely on numeric or graphic interfaces for feedback provision, Yu et al. (2014) took an opposite approach and designed a biofeedback system that supports the user in regulating breathing patterns for stress reduction through changes in ambient light. The researchers found the system for the home environment more acceptable than a traditional graphic interface. On a related note, Liu et al. (2009) present a software architecture for a biofeedback system that provides stress-related biofeedback to airplane passengers by recommending personalized stress reduction music. Nacke et al. (2011) conclude that most biofeedback systems use physiological measures that can't be directly controlled by the player. The researchers therefore integrated in their study physiological measures that a player can manipulate and control directly (e.g., muscle flexion or breathing patterns) to derive design implications for physiologically controlled games.

2.3   Battery Electric Vehicles, Stress and the Role of Information Systems

Electric vehicles can be defined as a sustainable mode of transportation partly or entirely powered by an electric motor, including hybrid electric vehicles, fuel-cell electric vehicles, and BEVs (Chan 2007; Chan and Wong 2004). Fuel-cell electric vehicles rely on fuel cells to generate electricity from hydrogen which is used to operate the vehicle, while hybrid electric

vehicles combine a conventional internal combustion engine propulsion system with an electric propulsion system. BEVs use electricity stored in a battery pack to operate the vehicle. Despite the variety of advantages that BEVs offer compared to conventional vehicles, for example, less noise (Skippon and Garwood 2011), fewer tailpipe emissions (Sharma et al. 2013), lower recharging costs (Buehler et al. 2014), or an increased fun factor (Turrentine et al. 2011), the widespread adoption of these vehicles is still low (ICCT 2013; Lieven et al. 2011; Zhang et al. 2014). The main disadvantages of BEVs are the initial high purchasing costs (Chan 2007), the limited driving range (Skippon and Garwood 2011), the underdeveloped charging infrastructure (Tate et al. 2008), and the long charging time (Kumar and Jain 2014).

However, the limited driving range in BEVs of approximately 150 kilometers (Eisel and Schmidt 2014) per cycle of battery charge constitutes the major bottleneck of this technology (Egbue and Long 2012; Neumann et al. 2010; Pearre et al. 2011) and leads to a psychological phenomenon referred to as *range stress* (Rauh et al. 2015a). Tate et al. (2008) define range stress as a "continual concern and fear of becoming stranded with a discharged battery in a limited range" (p. 158). Enhancing this definition, range stress can be conceptualized as a certain type of driver stress described by an imbalance between the individual's mobility resources available, for example, driving range or coping skills and the specific mobility needs, for example, timely and relaxed arrival to the final destination (Franke et al. 2012b). In addition to the limited range, the underdeveloped charging infrastructure and the long charging time cause this specific type of discomfort in drivers of BEVs (Philip and Wiederer 2010; Wynn and Lafleur 2009). Moreover, the concern of becoming stranded with a depleted BEV may also be evoked due to mistrust of the range feedback provided by these vehicles (Lundstroem 2014; Wellings et al. 2011).

Rauh et al. (2015a) propose the following different factors that account for the extent to which drivers of BEVs experience range stress: (a) individual differences, for example, personality traits or trust in the technology; (b) system features, for example, availability of fast charging points on the route to the destination or the degree to which the in-vehicle IS support the driver; (c) environmental factors, for example, time of day or regional structure. Nilsson (2011) state that range stress is temporal and dynamic, in other words, it can changes over time and in intensity, depending on the range stress-evoking stimuli. Thus, driving style, road conditions, outside temperature, usage of internal devices, or age of battery might also influence the perception of range stress.

According to Nilsson (2011) and Rauh et al. (2015a), range stress is expressed on four differ-ent levels. On a behavioral level, range stress is characterized by, for example, tapping with fingers on the steering wheel, re-planning activities, or avoidance of usage. Walsh et al. (2010) found in their study that 93 percent of trips with electric vehicles were not undertaken when the battery charge display undershot a threshold of 50 percent of the maximum state of charge. Moreover, range stress negatively influences the driver's confidence in using a BEV for longer distances, which in turn, might lead to an adaption of driving style to avoid poten-tially stressful range situations and increased cautiousness when planning journeys (Carroll and Walsh 2010; Franke et al. 2012b; Morton et al. 2011). On an emotional level, range stress is associated with changes in affect, for example, feeling concerned, worried, or nervous. On the cognitive level, range stress is associated with negative thoughts about the range situation, which can be transferred to the vehicle. Rauh et al. (2015a) revealed that inexperienced BEV users perceived more stress on the cognitive and emotional level compared to experienced drivers. Finally, on a physiological level, range stress is expressed by an increased physiolog-ical arousal, for example, sweaty palms or increased heart rate.

Although studies revealed that the current driving range of BEVs would objectively meet most needs of many car drivers (e.g., Neumann et al. 2010; Pearre et al. 2011), the limited driving range and the associated range stress is perceived as a main barrier for considering the use of such vehicles (Dimitropoulos et al. 2011; Duke et al. 2009; Rezvani et al. 2015). The results of a study of Hidrue et al. (2011) revealed the importance of driving range for users of BEVs. The researchers found that users of BEVs were willing to pay approximately between 35 and 75 Dollars for a mile of added driving range. However, range stress must not neces-sarily be experienced in real situations but can also be evoked by the thought of a critical range situation or the consequences of getting stranded due to a depleted battery (Nilsson 2011).

Several strategies have been suggested to counteract range-related concerns in drivers of BEVs. As range stress is considered to be primarily a psychological barrier (Franke et al. 2012b), many strategies are concerned with the assistance of psychological interventions. In that regard, Franke et al. (2016b) propose that an increased system knowledge (e.g., about the electric vehicle propulsion technology or specific features of technical components in the ve-hicle) helps the driver in dealing with the unfamiliar critical system state of a low remaining range, thus bearing the potential to reduce range stress. Furthermore, the researchers found that route familiarity (e.g., elevation, speed profile, course of the road), emotional stability

(i.e., degree of neuroticism), and the belief to be in control over BEVs as a technology are related to lower range stress and thus should be considered in current strategies aimed at reducing range stress. In addition, drivers should reflect their daily mobility behavior, by, for example, using travel diaries which help users to increase the estimation of the fit between the individual mobility needs and the available range resources. In another study, Franke et al. 2012b propose comprehensive trainings and continual feedback on the individual driving behavior to support the driver in, for example, judging distances. Rauh et al. (2015a) revealed that experienced drivers perceive less range stress compared to inexperienced drivers in standardized critical range situations. In this regard, the researchers stress the importance of teaching drivers relevant knowledge and skills, for example, strategies for driving energy-efficiently with BEVs or knowledge about range-influencing factors as relevant approaches for reducing range stress. However, research also found that BEV drivers perceive the range as a higher barrier with increasing experience (Buehler et al. 2014) and that with increasing driving experience the users tend to mistrust the range estimate in electric vehicles and thus may perceive more range stress (Wellings et al. 2011).

Besides psychological-oriented interventions, further strategies to counteract range stress contain the enhancement of public charging stations to increase the driver's confidence in reaching the target destination (Chen et al. 2015; Neubauer and Wood 2014) or advances in the powertrain electric system including the battery and further components to increase the actual driving range in electric vehicles (Burke 2007; Dellnitz et al. 2014; Masjosthusmann et al. 2012; Sakhdari and Azad 2015). In addition, a considerable body of literature is concerned with the improvement of technical factors, especially the range prediction accuracy, as sudden drops in the displayed driving range of up to 20 percent is nothing out of ordinary in BEVs (Lundstroem 2014). Most electric vehicles' range estimates base the calculation of the remaining range on the driving style of previous trips and do not incorporate other factors that affect a vehicle's energy consumption (Neaimeh et al. 2013). General factors that drain the vehicle's battery to a great extent and are thus incorporated in the range algorithm by researchers include: (a) external conditions like elevation profile, traffic condition or weather, (b) internal factors, for example, vehicle load, internal energy consumers like air conditioner, lighting, heater, or radio, and (c) factors that are related to the driver, for example, acceleration, speed level, deceleration (Bolovinou et al. 2014; Ferreira et al. 2012; Kondo et al. 2013; Pichler and Riener 2015; Rui and Lukic 2011). However, although the approach of incorporating different factors in the range calculation seem to be to be promising for increasing the

range prediction accuracy, even the best algorithm cannot account for high prediction accuracy in every situation due to, for example, the driver's unpredictable change in driving behavior (Jung et al. 2015).

Research has also begun to highlight the importance of the provision of range-related information through automobile IS in order to alleviate range stress in drivers of BEVs. In this context, Kantowitz and Moyer (1999) classify automobile IS into safety and collision avoidance systems (e.g., automatic cruise control, yaw control, theft detection), advanced traveler information systems (route guidance, automated tolls, vehicle status), and convenience and entertainment systems (radio- and CD-based audio systems, television, telefax). However, as the development of in-vehicle IS progresses rapidly, Brandt (2013) picked up this this categorization and propose a classification of in-vehicle IS according to the object of interest the systems provides information about and derive four main categories: (a) convenience, communication, and entertainment systems focus on the entertainment of the driver and make travelling more convenient, for example, Bluetooth, radio, mobile-phone docking stations; (b) vehicle monitoring systems typically keep track of different functions within the vehicle and provide the driver about the current vehicle's condition through a display, for example, light and door status, speed, remaining range; (c) geo IS and navigation systems, for example, global positioning system (GPS) or traffic information systems, are made possible through technological advances in radios and satellites and support the trip planning activities by providing information about road and traffic conditions; (d) safety and collision avoidance systems focus on the vehicle surroundings and aim to make cars more safer while preserving the driving experience.

Within this classification, information systems of the categories vehicle monitoring and geo IS and navigation are considered especially suitable in mitigating range stress, as these systems provide to the driver relevant range-related information, such as information on trips, power consumption, traffic condition, distance to the next charging station, driving patterns, or battery conditions (Eisel and Schmidt 2014). In a similar vein, Franke et al. (2012b) suggest the provision of adequate range safety buffers that are defined as a minimum remaining range that drivers of are comfortable when using a BEV as useful for reducing range stress. Research found that a minimum range buffer that increases the confidence in drivers in reaching the intended destination varies between approximately 10 km (Rauh et al. 2015b); 20 km (Franke et al. 2012b; Eisel and Schmidt 2014), or 30 km (Pearre et al. 2011). In that regard, Rauh et al. (2015b) propose that electric vehicles should automatically calculate range safety

buffers and display this information to the driver by, for example, a heads-up display. Franke et al. (2016b) state that the "quality of the range estimation system is a prerequisite for a good range-related user experience of BEV drivers (p. 32)" and found that trust in the range estimation system of BEVs is negatively related to range stress. Ferreira et al. (2011) introduce an information system that helps the driver to efficiently use the driving range of BEVs, and thus minimize the problem of range stress. Based on geographical positioning information, user profile, energy prices, proximity to public transportation scheme, and loading preferences, the system aims to control the vehicle's range and to recommend the driver the optimal nearest charging point. To reduce range-related concerns, Ferreira et al. (2014) propose a mobile application (V2Anything App) that provides the driver information about charging locations, range autonomy (reachable area based on, for example, previous driving behavior, weather information, internal energy consumers), electricity markets (e.g., information about prices, energy production). Moreover, the system provides a smart route planner that takes public transportation and bike or car sharing systems (e.g., availability, prices, schedules, ticket reservation) into account.

Apart from providing range-related information through in-vehicle IS, research has also pointed on the significance of design elements to reduce range stress. Stroemberg et al. (2011), for example, evaluate in a driving simulator experiment the influence of two concepts of and electric vehicle information cluster that differ in the way how the information are presented to the driver in terms of either innovatively or in a more familiar way (i.e. similar to that of a conventional internal combustion engine vehicle). The researchers found that the design of both concepts influenced the participant's judgement of relevance of range-related information. In this regard, users had some issues in understanding and comprehending some information of the innovative design (e.g., Ecometer, practical relation of the battery temperature, practical translation of the unit Watt). Jung et al. (2015) developed two in-vehicle dashboards that displayed the remaining range as (a) highly precise with numbers and (b) ambiguously with a diffuse color band that shrank in width with decreasing remaining driving range. Their findings indicated that displaying range information ambiguously improved the driving experience and trust towards the vehicle, even in range critical situations. Moreover, drivers reported that they were able to better adapt to road and remaining range conditions when provided with ambiguous instead of precise range information. With the aim to increase the driver's comprehension of the correlation between speed and remaining range, Lundstroem

(2014) designed an alternative remaining range display that is based on different levels of speed.

Despite the potential advantages that these systems offer to range-related stress in drivers of BEVs, the driver is forced to process further amount of information that might lead to driver distraction and increased risk to get involved in car accidents (Harms and Patten 2003; Horberry et al. 2006; Klauer et al. 2006). Bach et al. (2009) define driver distraction as anything that takes the attention away from the primary task of driving resulting from an increased workload, as the driver's attention resources are additionally employed on the interaction with in-vehicle IS. According to Ranney et al. (2000) driver distraction is reflected in four different ways: visual distraction (e.g., shifting away attention from the current traffic situation), auditory distraction (e.g., listening to music), bio-chemical distraction (e.g., manually adjusting settings of in-vehicle IS), and cognitive distraction (e.g., to be lost in thought). The interaction with in-vehicle IS lead to driver overload because the driver draws on the same cognitive resources as needed for the driving task (Bach et al. 2009). Hence, the restricted cognitive resources necessary for the primary task of driving competes with that one demanded for the interaction with in-vehicle IS (Ma and Kaber 2005). This supplementary load becomes especially critical for the driver because s/he is faced – in comparison to a stable environment such as interacting with a laptop at home – with a permanent changing environment while driving in which the limited mental resources are already utilized to a high extent (Osswald et al. 2012).

In addition to, for example, fatigue or drowsiness, one main negative effect of driver distraction is general driver stress (Sheridan 2004). Gulian et al. (1989) define driver stress as a "set of responses associated with the perception and evaluation of driving as being demanding or dangerous relative to the individual's driving capabilities" (p. 585), which can be expressed on an emotional level (e.g., increased driver anxiety), a physiological level (e.g., increased pulse rate), and on a behavioral level (e.g., adapting an aggressive driving behavior). Matthews and Desmond (1995) point out that three main driver performance-related mechanisms affect the relationship between the interactions with in-vehicle IS and driver stress. First, the limited mental resources needed for the driving task are additionally exploited by in-vehicle IS, hence resulting to an overload of attentional capacity and stress. Second, the interaction with in-vehicle IS creates a competition between the available attentional resources in drivers. In particular, the driver must decide how to divide his or her attention in critical traffic situations and develop an efficient strategy to allocate the attention to such situations. The interac-

tion with systems in the vehicle increases the risk to disrupt this strategy. This becomes an especially important issue for in-vehicle IS with high visual demand such as navigation systems. Finally, if the driving task itself is underdemanding, drivers often tend to reserve driving-related performance resources, which, in turn, might lead to under-mobilization of effort to manage easy tasks. Paradoxically, the additional load imposed by in-vehicle IS might lead to an increased driving performance, as the extra workload prevents under-mobilization. However, Matthew and Desmond (1995) emphasize, that in-vehicle IS that focus on preventing the driver of being in danger might lead to an under-mobilization of performance resources, thus negatively affecting driver performance.

In summary, while in-vehicle IS can be useful to reduce stress in certain situations, i.e., range stress, the interaction with such systems might lead to driver distraction and driver stress, thus increasing the risk of getting involved in car accidents. With respect to the trend of displaying more and more information in BEVs, the thesis contributes to overcome the dilemma when it comes to the design and application of in-vehicle IS for BEVs, as emphasized by Neumann and Krems (2016):

> "The challenge will be to provide enough information for the driver to manage the driving task and the limited range issue, but not to overload or frustrate the driver with too many information" (p. 341).

B. The Bright Side of Information Systems

While previous research in the area of IS and stress has rather focused on antecedents, characteristics, and consequences of stress that result from the interaction with information and communication technologies, the opposite effect, i.e., how IS can influence stress in a positive manner and thus influence behavioral outcomes, is not well understood. Therefore, this section presents a study that points on the usefulness of IS in reducing stress, using the example of range stress in BEVs. By doing so, the study proposes and validates a research model that allows to investigate the relationship between IS, stress, and behavioral outcomes. In addition, the study provides a deeper insight into this relationship by evaluating the congruence of psychometric and psychophysiological measurement methods. The findings show that by providing context-related information IS are capable to reduce uncertainties associated with a critical range situation in users of BEVs and thus positively influence psychometric range appraisal and psychophysiological feedback. Reduced range stress is associated with an increased attitude towards using BEVs.

1   The Influence of In-Vehicle Information Systems on Range Stress

Table B-1 Fact Sheet of Study No. B1

Title	Understanding the Influence of In-Vehicle Information Systems on Range Stress – Insights from an Electric Vehicle Field Experiment
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Abstract	Battery electric vehicle (BEV) drivers frequently report concerns of becoming stranded as a result of battery depletion, widely referred to as range stress, which constitutes a main obstacle to the adoption of these vehicles. One promising solution identified to mitigate range stress is to provide appropriate and accurate information through in-vehicle information systems (IVISs). Therefore, we aim to gain a broader understanding on the influence of specific IVISs on drivers' range stress perception. To accomplish this, we performed a BEV field experiment in real traffic situations. By placing participants in a critical range situation, we could measure their psychometric range appraisal and psychophysiological feedback. The results of the psychometric evaluation revealed that individuals perceived the critical range situation as less challenging and threatening with the provided IVISs. Physiological indicators were found to be useful in complementing questionnaire-based evaluation methods within the field of range stress. Although the findings of the psychophysiological measurement revealed that IVISs-equipped participants exhibited increases in stress perception over time due to volatile range feedback, the average stress level was observed to be lower throughout the entire driving task. *Keywords: Range Stress, In-Vehicle Information Systems, Electric Vehicles, Range Anxiety*

1.1   Introduction

1.1.1   Background

With the advent of battery electric vehicles (BEVs), a new source of driver stress has merged, triggered by their limited driving range. This subject – generally referred to as range anxiety – has been widely discussed by researchers and practitioners alike and was initially observed in a General Motor's electric vehicle study, which described range anxiety as the fear of becoming stranded in a BEV due to an empty battery (Acello 1997). Alongside the limited driving range, an additional underlying source that leads to range anxiety is the underdeveloped charging infrastructure (Tate et al. 2008). Despite a BEVs standard range having the ability to meet typical usage patterns of most drivers (Pasaoglu et al. 2014; Pearre et al. 2011), its lack of distance per charge-up is still considered as one of the main barriers to the adoption of these vehicles (Buehler et al. 2014; Egbue and Long 2012). Therefore, consumers interested in vehicle use for longer distances lack confidence in the BEVs range ability, negatively affecting the buying decision (Carroll and Walsh 2010; Egbue and Long 2012; Franke and Krems 2013b).

Some researchers refer to range anxiety as stress that evolves when BEV drivers perceive there are insufficient mobility resources available to satisfy specific mobility needs, such as timely arrivals to target destinations (Franke and Krems 2013a; Franke et al. 2012b). Rauh et al. (2015b) suggest that range stress is expressed on four different levels. On the cognitive level, negative associations with range are formed, such as the concern of failing to reach a destination. In regards to the emotional level, range stress is associated with changes in affect, such as increased nervousness or fear, while on the behavioral level it is expressed by certain behaviors, an example being frequent checking of the BEV battery meter. Lastly, on the physiological level, drivers experience increased heart or respiratory rates.

Range stress is a multidisciplinary topic which has been discussed from a psychological (e.g., Franke et al. 2016a; Rauh et al. 2015b), engineering (e.g., Dellnitz et al. 2014; Neaimeh et al. 2013), design-oriented (e.g., Lundstroem 2014; Stroemberg et al. 2011), and information systems point of view (Eisel and Schmidt 2014; Eisel et al. 2014). Recent research in this field discusses several approaches for a better understanding of range stress. For example, Chen et al. (2015), suggest an existing correlation of decreased range stress with an increased number of available charging stations. Moreover, Franke et al. (2016a) examined several resilience

factors (e.g., practical experience, tolerance of low range, or trustworthiness of range estimation), observing them to potentially limit or prevent range stress in everyday BEV users. With respect to the impact of BEV experience on range anxiety, Rauh et al. (2015b) arrived to similar results, as BEV-experienced participants in their critical range study were identified as more resistant to range stress. Following an extension of that study, other factors such as increased route familiarity and system knowledge in regards to BEV technology revealed a relation to reduced range stress (Franke et al. 2016a). Moreover, appropriate in-vehicle information systems (IVISs) may be beneficial in overcoming range-related barriers (e.g., Eisel et al. 2014; Franke et al. 2012b; Lundstroem 2014). In particular, range-related IVISs have been considered to be crucial for human–system interaction and thus user experience with BEVs (Franke et al. 2015). In this regard, researchers primarily focus on improving the accuracy of range prediction technologies (e.g., Dellnitz et al. 2014; Neaimeh et al. 2013; Oliva et al. 2013), as it is currently considered to be insufficient (Birrell et al. 2014). Neumann and Krems (2016), for example, suggest a reliable prediction of important range information that drivers can trust. Notably related, Franke et al. (2015) emphasized that increasing the trustworthiness of range-information user interfaces can help develop more positive user experiences with BEV mobility resources. Moreover, the authors suggest increasing the flexibility of options users have in parameter adjustments of range-related IVISs. With the goal of creating a more accurate range-predicting mechanism for BEVs, Neaimeh et al. (2013) used the approach of implementing an algorithm within the system that determines the route to the destination requiring the least amount of energy based on topography and traffic conditions. In addition to increasing the range prediction accuracy, the system also assists the driver in optimizing energy consumption, permitting an extended driving range. These outputs support the driver by providing confidence and can thus help alleviate range anxiety effects. On a related note, Pichler and Riener (2015) investigated the impact of external conditions (e.g., elevation profile or outdoor temperature) and internal conditions (e.g., consumption of air conditioner) on operating distance range, and later applied this information to the system to allow a more precise range to be provided. To further optimize the range, the authors even considered the benefit of gamification concepts that motivate users to drive more economically. In contrast, Jung et al. (2015) analyze the effect of displaying remaining range ambiguously as a diffuse color band and demonstrate that it might be advantageous to display uncertainty for better adapting driving behavior to remaining range conditions. Research has also focused on whether to present range-related information in a traditional or innovative way to drivers of BEVs (Stroemberg et al. 2011). In this regard, Lundstroem (2014) proposed an alternative

concept to the current way of presenting range-related information to drivers of BEVs. In the form of a mobile application, the interactive design displays the remaining driving range in contrast to climate control usage and vehicle speed. Moreover, Lundstroem and Bogdan (2012) addressed another approach by reshaping the IVISs based on coping strategies that were developed based on the know-how of experienced users in order to mitigate range problems. Recently, research also proposed IVISs that provide users feedback about the charge status of the BEVs in an intuitive and easily interpretable style. In this regard, Loehmann et al. (2014), for example, designed Heartbeat, an innovative IVIS that communicates the energy level of BEVs by providing visual and haptic feedback.

Despite the plethora of studies that discuss IVISs as being appropriate to alleviate range concerns, little research has been conducted on how IVISs affect drivers' stress appraisal processes in detail. Eisel and Schmidt (2014) refer to two main categories of information systems (IS) within vehicles, vehicle monitoring and geo IS and navigation, that seem to be particularly suitable for tackling the problem of range stress. Following Brandt (2013), IS within the vehicle monitoring category aim to provide the driver with accurate information about the vehicle's status (e.g., range gauge), whereas IS within the geo IS and navigation category provide information about planned trips and assist the driver in reaching them (e.g., navigation systems). For a similar set of IS, Eisel et al. (2014) found in their mental simulation experiment that IVISs are generally suitable for overcoming range-related concerns. Building upon two hypothetical scenarios, participants appraised the situation of driving a BEV to be less stressful when equipped with appropriate IVISs, such as a navigation device for calculating the optimal route to the destination, car-to-car communication systems, and internet-based services capable of anticipating traffic development and suggesting alternative routes. However, a lack of research remains regarding the influence of IVISs on drivers' range-related stress appraisal in real-traffic situations. Therefore, the objective of the present research is to put forth an initial step toward examining the potential of IVISs on influencing the respective appraisal processes of range stress in real-traffic situations. Hence, we elaborate upon the following research question:

RQ: How do IVISs influence the perception of range stress while driving a BEV?

To answer this question, we first investigate the influence of IVISs on perceived range stress with a particular focus on the psychological appraisal processes of Lazarus's transactional stress model (Lazarus and Folkman 1984). We examine this influence in real-traffic situations

using specific range-related IVISs. According to our research purpose, IVISs refers to the two categories vehicle monitoring and geo IS and navigation. Furthermore, range-related concerns are considered to be a main barrier to the adoption of BEVs (e.g., Buehler et al. 2014; Egbue and Long 2012). Therefore, we aim to explore how IVISs-influenced range stress impacts the attitude toward using a BEV – a construct that represents an important role in predicting behavioral tendencies. In addition, we extend our research by applying psychophysiological stress measurements during the experiment to investigate whether the biofeedback constitutes an appropriate method to assess range stress, as well as if it supports the findings from the psychometric evaluation.

1.1.2   *Research Model and Hypothesis Development*

Our study adopts Lazarus's cognitive-transactional approach, which defines stress as ''a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources, thus endangering his or her well-being'' (Lazarus and Folkman 1984). This conceptualization emphasizes stress as a complex psychological process determined by the way an individual appraises a situation (primary appraisal), relates the demands involved to available resources (secondary appraisal), and reassesses any new relevant stimuli (reappraisal) (Lazarus 1966; Lazarus and Folkman 1984). These concepts are brought together in the framework of Lazarus's transactional model of stress, schematically illustrated in Figure B-1.

The primary appraisal process classifies an individual's evaluation of an event as irrelevant, benign-positive, or stressful to one's well-being (Lazarus and Folkman 1984). Determining the relevance of environmental stimuli is crucial to the process, as the stress process is only triggered if necessary. Events appraised as irrelevant have no effect on well-being; those appraised as benign-positive are interpreted as enhancing one's well-being and are therefore often associated with positive emotions, such as happiness or pleasure. In both of these cases, coping mechanisms are deemed unnecessary. However, if an event is determined to be stressful, it will be assessed in terms of harm (damage already caused by the event), threat (potential of causing future damage), or challenge (ability to effectively overcome the event) (Lazarus and Folkman 1987). While events perceived as harmful or threatening are generally accompanied by negative emotions such as fear or anxiety, challenges can foster both negative emotions as well as elicit positive emotions such as eagerness (Lazarus 1993b; Lazarus and Folkman 1984). According to the transactional model, if an event is appraised as stressful in the primary appraisal process, individuals then proceed to secondary appraisal. In this stage,

which occurs simultaneously with primary appraisal, an individual evaluates his or her abilities to prevent or overcome a stressful situation, determining which personal resources and options are available for coping with the source of stress (Folkman et al. 1986). Lazarus and Folkman (1984) claim that psychological stress results from the feeling of having insufficient resources for dealing with a stressful event; stress is thus characterized by an unfavorable person–environment relationship. Within this paper, we aim to assess the influence of IVISs on range related stress perceived during a BEV driving experience and the effect of the range stress on attitude toward BEV utilization. In this regard, we apply stress theory with a particular focus on Lazarus's stress model (see Figure B-1).
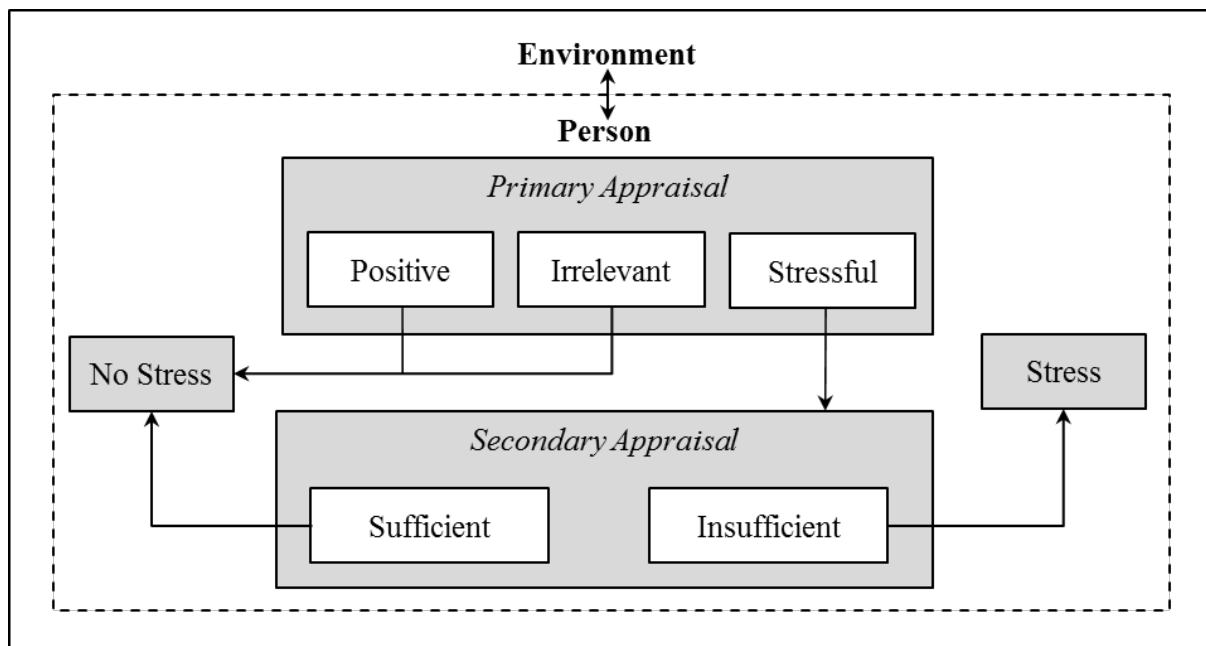
Figure B-1 Schematic Illustration of the Transactional Stress Model

Generally, uncertainty is a key factor affecting an individual's appraisal of a situation as challenging or threatening (Blascovich and Mendes 2000). In this regard, uncertainty can be considered as an inability to accurately predict the outcome of a particular decision (Downey and Slocum 1975; Milliken 1987). Gifford et al. (1979) suggest that individuals can also experience uncertainty due to lack of information or by feeling unconfident in distinguishing relevant from irrelevant information. In this context, some researchers found that uncertainty can pose as a powerful stressor (e.g., Monat et al. 1972; Zakowski 1995). Therefore, we assume that IVISs negatively influence both subscales of the primary appraisal process (threat and challenge) in critical range situations when providing relevant information to the driver in the following way:

H1: Critical range situations are appraised as less threatening when using IVISs.

H2: Critical range situations are appraised as less challenging when using IVISs.

Furthermore, we also aim to assess the impact of IVISs on two main constructs of the secondary appraisal process: locus of control and self-concept. Rotter (1966) introduced the concept of locus of control, referencing it as the degree in which an individual believes to be in control of one's own behavior (Prusak 2007). Self-concept, on the other hand, concerns an individual's perception of oneself, derived from prior interactions with the environment (Crocker and Major 1989; Shavelson et al. 1976). Folkman et al. (1986a) suggest that individuals seek additional information to overcome demanding or uncertain situations. An action possibly leading to greater self-confidence and an increased perception of control over a situation. In line with this argumentation, the degree of uncertainty about a situation can also be associated with the individual's ability to predict a proximate event. In turn, this ability determines the individual's capability in successfully managing a specific situation (Babrow et al. 2000; Brashers 2001). Moreover, Kienhues and Bromme (2011) state that the perception of one's own abilities is reinforced by consistent information about a situation, which accordingly empowers individuals to manage a specific demand. The provision of relevant information supports an individual's capabilities, thus simplifying various tasks related to driving a BEV. Therefore, we assume that the provision of IVISs leads to an increased self-concept of own abilities and locus of control. We summarize our assumptions in the following hypotheses:

H3: The self-concept is enhanced when using IVISs in critical range situations.

H4: The locus of control is enhanced when using IVISs in critical range situations.

Moreover, we posit range stress, which is identified by the interaction of primary and secondary appraisal, negatively influences the attitude toward BEV use. Generally, attitude is defined as a favorable or unfavorable response to an object, person, or event and is separated in three classes of responses (Ajzen 2005). First, the cognitive response reflects thoughts and knowledge about the attitude object. Second, the affective component includes the individual's sense, feelings, and emotions associated with an object or act. Finally, the conative (behavioral intention) response indicates the probability that a person will engage in a given behavior. This classification is crucial for our research objective because the affective attitude component reflects the emotional evaluation of an event, and stress is considered to be a subset of emotions (Lazarus 1993b). In this context, negative emotions such as anxiety, shame, or anger arise from stressful situations and can thus negatively influence attitude (e.g., Duhachek 2005; Moons and Pelsmacker 2015; Soscia 2007). Following this relationship, we suggest the following hypothesis:

H5: Range stress has a negative influence on the attitude toward using a BEV.

Finally, we decided to also include affinity for technology and experience with BEVs as control variables, as previous research has highlighted the importance of experience (e.g., Buehler et al. 2010) and affinity for technology (e.g., Neumann et al. 2010) when evaluating attitude toward using a BEV. Our assumptions are illustrated in the research model depicted in Figure B-2.
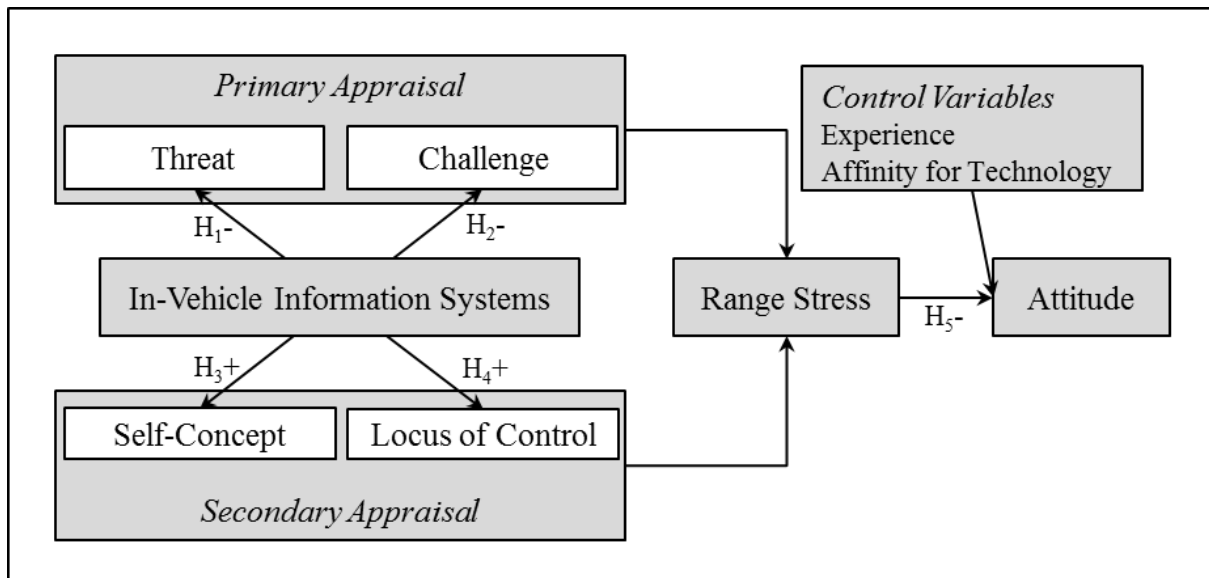
Figure B-2 Schematic Illustration of the Suggested Research Model

1.2 Method

1.2.1 Participants

To recruit participants for the experiment, various information channels were used. First, we used social media sites to announce and spread the information about the research endeavor. Second, we advertised on a job portal with an expiration time of two weeks. We also distributed leaflets and notices at the local university. Regardless of the method, participation in the experiment was voluntary without financial incentives, and possession of a driving license was a necessary precondition.

Altogether, the study draws from a 24 participant-sample size ranging from 19 to 47 years of age (M = 26.08, SD = 6.81), one-third of which were women. Moreover, 42% of the participants did not own a car while 75% of the participants had no experience with any form of electric vehicles. Most participants (83%) lived in the city of Goettingen, Germany; the remaining lived in the surrounding rural area. Furthermore, the majority of the participants had

attained a university degree (63%), while 21% completed qualification for university admission and the rest attained a lower level of education (16%). In alignment with Franke et al. (2016b), we assume that the sample reflects drivers particularly interested in BEVs (including potential customers), as participants were not compensated. To compare the influence of IVISs on perceived driving stress, we chose a between-subjects design. The two participating groups were differentiated by the information devices provided to them (see Section 2.3). We assigned participants alternatingly to the treatment and control groups based on chronological receipt of registration. The two groups differed slightly in terms of age ($M_{Treat} = 25.92$, $SD_{Treat} = 6.69$; $M_{Control} = 26.25$, $SD_{Control} = 7.23$) and BEV experience (treatment group: 33% experienced users; control group: 17% experienced users). Gender was equally distributed (treatment group: 33% female; control group: 33% female).

1.2.2 Measurement of Constructs

1.2.2.1 Psychometrical Evaluation

For the psychometrical evaluation of range stress, we refer to the Primary and Secondary Appraisal (PASA) questionnaire proposed by Gaab et al. (2005). Based on the transactional stress model of Lazarus and Folkman (1984), the PASA questionnaire assesses the primary and secondary appraisals, each with two subscales. Primary appraisal is measured with the subscales ''threat'' and ''challenge'', while secondary appraisal is measured with the subscales ''self-concept of own abilities'' and ''locus of control''. Each subscale is operationalized by four items, resulting in a 16-item questionnaire for evaluating appraisal processes (Gaab et al. 2005). We adjusted the items of the questionnaire to the context of limited range (such as ''the remaining range is very unpleasant to me'' or ''the remaining range is relevant to me''). To ensure that participants refer strictly to range stress, we stated at the beginning of the questionnaire that the following questions refer explicitly to the participants' perception of driving range. The questionnaire is based on a 6-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree). To compute the range stress, we adopted the approach of Gaab (2009) and subtracted the mean of the secondary appraisal's subscales from the mean of the primary appraisal's subscales. Moreover, we adopted the attitude construct from the well-established theory of planned behavior (Ajzen 1991). The five related items were operationalized on a 7-point Likert scale (Ajzen 2002). In this context, individuals were asked to express different affective attitude responses when using the BEV for the route, for example, pleasant vs. unpleasant or useful vs. worthless. Furthermore, we used five items from a previous study of

Edison and Geissler (2003) to measure technology affinity and recorded BEV experience on a nominal scale.

1.2.2.2   Psychophysiological Evaluation

Research has shown that both emotions and stress are accompanied by arousals, typically relating to a change in physiology (Grandey 2000). Many researchers examining these changes in physiology utilize several means of biofeedback measurements, such as measuring heart rate, cortisol levels, and electrodermal activity. These parameters are established in psychophysiology as emotion indicators (e.g., Brownley et al. 2000; Dawson et al. 2000). Although cortisol levels are generally a reliable measurement for arousal, saliva samples are unsuitable for providing continuous live biofeedback (Riedl 2013). To integrate live biofeedback into the field experiments and shed more light on the temporal progression of stress, we measured the corresponding psychophysiological changes while focusing on analyzing the electrodermal activity, which describes different electrical characteristics of the human skin, such as skin conductance, skin admittance, and skin potential. The most relevant of these characteristics for psychophysiological research is skin conductance (and its reciprocal value, skin resistance), with an average latency of 1.4 s (Lockhart 1967). Skin conductance corresponds to the electrical conductivity of the human skin and is measured exosomatically in microsiemens (µS) by applying a low current to the skin. In this regard, the electrical conductivity of the human skin is heavily dependent on the amount and activity of sweat glands, and therefore differs between individuals.

1.3   Experimental Setting

To meet our research objective and test the impact of IVISs on drivers' stress perception, we performed field experiments in real traffic situations involving participants driving a BEV along a predefined route (city and highway) in the urban area of Goettingen. The design and process of the entire experiment is illustrated schematically in Figure B-3. The vehicle used in this study was a Volkswagen e-up!, equipped with an electromotor of 60 kW maximum engine power and a maximum speed of 130 km/h. Moreover, the vehicle was equipped with a lithium-ion battery holding a capacity of 18.7 kWh that provides an average driving range between 120 km and 160 km (Volkswagen 2015). Additionally, the vehicle could recover energy while decelerating via recuperation.

The experiment was divided into two phases. In Phase 1, the vehicle was prepared by the experimenter. In this context, the vehicle's battery charge needed to be adjusted, as a predetermined state of charge (SOC) was required for conducting comparable and reproducible field tests. Thus, the BEV was prepared to provide a displayed driving range of 75 km for each participant. Furthermore, the experimenter placed measuring instruments in the vehicle, along with any additional equipment required. Following the vehicle's preparation, the participants received a brief introduction about the experimental setting and using the BEV. Moreover, two electrodes were adhered on the participants' index and middle fingers to measure skin conductance. We placed the electrodes on the weak hand's fingers, as calluses are normally less pronounced there compared to the strong hand (Dawson et al. 2007). Subsequently, the participants performed a test drive to become familiarized with the BEV and the experimental surroundings. The test drives usually led to arousal, reflecting increased values for the driver's skin conductance because of the experimental setting and, in most cases, also due to the inexperience with BEVs.

Following the test drive, the treatment group's vehicle was then equipped with a navigation system (maps + more, 12.7 cm diagonal) and a smartphone using the application ChargeMap, which provided detailed information about nearby charging points. The range gauge was located in the dashboard while the navigation device and smartphone were located in the center console. In contrast, the control group's vehicle was equipped with neither of the above-mentioned IVISs. Moreover, we chose to hide the range information for these participants to assess whether the range gauge affects the perception of range stress. Although every modern BEV has a range display, this decision was based upon previous research indicating that BEV range estimations are inconsistent and thus might influence range stress perception (Birrell et al. 2014; Jung et al. 2015). Furthermore, after discussing the destination route and ensuring that the participants would find it, they were equipped with physical maps laying out the designated route.

In the beginning of Phase 2, the participants received two questionnaires: one with general questions, such as gender, age, and education, the other with questions concerning their experience with BEVs and affinity for technology. Before initiating the actual field experiment, participants were given a rest period of several minutes with the car in idle. This was deemed necessary to provide participants a recovery opportunity from possible arousal induced by the test drive, thus ensuring almost constant skin conductance values prior to starting of the field experiment. Meanwhile, the experimenter observed the measurement signal on a tablet. If a

decrease in the signal was observed with no meaningful upward swings within the rest period, then the physiological stress level was classified as reassured. In this regard, an acceptable threshold of the stress level and the duration of the observation were both subjective decisions of the experimenter. Participants with ongoing arousal were instructed to exercise progressive muscle relaxation (PMR) prior to performing the experiment (e.g., McCallie et al. 2006).

Initiating the trip in the city, participants were directed to drive with the partly charged BEV to a neighboring city 68.9 km away, where the vehicle would be required for further testing purposes, thereby putting the participants in a range stress prone situation. Participants were informed their return after reaching the destination would be provided by another vehicle. The route to the destination was chosen to be relatively simple to better reflect a typical traffic situation and consisted of three parts: a city track (6.3 km), an Autobahn (22.5 km), and a federal road (40.1 km). In reality, all participants only drove about 12 km – the city track and part of the Autobahn route – before being asked to pull over for parking. The participants then received questionnaires about their situational cognitive assessment (PASA), attitude toward using the BEV, and manipulation check. Moreover, we conducted interviews with the participants to evaluate their range-related concerns. Afterward, they were debriefed and returned to the start. The experiments lasted an average of 60 min for each participant, which included introduction, test drive, rest period, and questionnaires. Throughout the experiment, the experimenters sat in the driver side rear seat to avoid disturbing the driver's natural behavior. Moreover, communication between the driver and experimenter was prohibited.
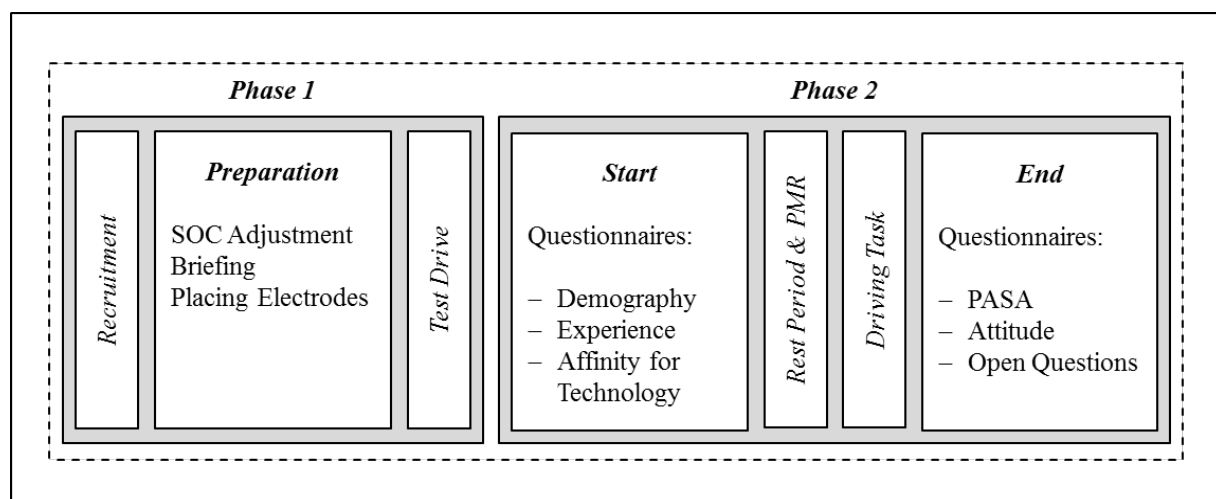
Figure B-3 Schematic Illustration of the Experiment

1.4 Results

1.4.1 Psychometrical Evaluation

We checked whether participants perceived the intended manipulation by asking them various questions concerning certain aspects of the IVISs provided. Participants were asked questions such as ''Were you provided with a range gauge?'', ''Did you have concerns about not reaching the planned destination due to a lack of information?'', or ''Were the systems provided useful for reaching the planned destination?'' All participants of the treatment group confirmed to be IVISs-equipped and stated that the IVISs were used and helpful for mitigating range concerns. Furthermore, we asked participants whether any problems occurred with the IVISs provided; no issues were mentioned. Hence, all participants were considered suitable for further analyses; none needed to be excluded.

We used the software SPSS Statistics Version 21.0 to analyze the psychometric data. To estimate the internal reliability of each construct, we first calculated Cronbach's Alpha (a). All constructs yielded acceptable internal reliability with a > .60 (Clark and Watson 1995). Moreover, we tested for non-normality and homoscedasticity to select an appropriate method for checking differences between the groups. The Shapiro–Wilk W-test for non-normality shows significant results for the scales challenge, locus of control, and attitude, thus indicating non-normal distributions. The other scales are assumed to be normally distributed. With the exception of the primary appraisal construct, the Levene's test for the homogeneity of variances demonstrates non-significant results for all constructs, indicating homoscedasticity. The results are summarized in Table B-2.

As our data appears to be homoscedastic but not normally distributed, we decided to use the non-parametric Mann–Whitney U test for further analysis. The Mann–Whitney U test is particularly useful for small sample sizes where the assumption of normal distribution is questionable (Nachar 2008). Additionally, we calculated the effect size by dividing the resulting z-score from the Mann–Whitney U test by the square root of the total sample size (Field 2009). The effect size measures the importance of an effect and defines values between 0.10 and 0.30 as small to medium, and between 0.30 and 0.50 as medium to large (Cohen 1992). The findings of the Mann–Whitney U test are presented in Table B-3. The results reveal a significant negative effect of IVISs on threat, challenge, primary appraisal, and range stress while driving a BEV. In contrast, we could not identify any significant effect of IVISs on locus of control, self-concept, and attitude.

In the further course of the analysis, we conducted a hierarchical regression analysis to determine the hypothesized effect of range stress on attitude toward using a BEV, with affinity for technology and experience as control variables. This was done by entering the control variables in regression equations and then integrating the construct of range stress to assess the incremental contributions to the variance accounted in attitude. Several assumptions were checked before running the regression (Berry 1993). First, we tested for multicollinearity of the predictor variables (range stress, experience, and affinity for technology); the results do not indicate a strong correlation between the predictor variables (variance inflation factors: 1.025; 1.176; 1.167). Second, we used the Durbin–Watson test to check for autocorrelation; the results reveal that the residuals are uncorrelated (Durbin–Watson statistics: 1.860). Third, we graphically tested the homoscedasticity of the residuals using a plot of normalized residuals against normalized predicted values. The results indicate that the residuals at each level of the predictors have the same variance (homoscedasticity). Finally, the Kolmogorov–Smirnov test on the residuals indicates a normal distribution. Table B-4 summarizes the results of the regression. Our model explained a significant proportion of variance in attitude scores ($R^2 = .22$, $F(3,20) = 3.15$, $p = .048$, $d = .76$). In this context, both control variables were not significantly accountable for the change in variance. Moreover, attitude ($M = 2.76$, $SD = .76$) is negatively correlated with range stress ($M = -.14$, $SD = 1.06$, $r(22) = -.40$, $p = .026$), affinity for technology ($M = 3.29$, $SD = 1.12$, $r(22) = -.39$, $p = .027$), and experience ($M = .25$, $SD = .44$, $r(22) = -.36$, $p = .045$).

Table B-2 Results for Internal Reliability, Distribution, and Homoscedasticity

Scales	Internal reliability	Distribution (Shapiro–Wilk)		Homoscedasticity (Levene's test)	
	Cronbach's α	W-statistics	Significance	F-statistics	Significance
Threat	0.83	0.95	0.30	0.86	0.36
Challenge	0.77	0.92	0.04	1.33	0.26
Self-concept	0.76	0.95	0.33	0.21	0.89
Locus of control	0.68	0.85	<0.01	<0.01	0.99
Primary appraisal	0.84	0.97	0.36	6.67	0.02
Secondary appraisal	0.73	0.98	0.88	1.47	0.24
Attitude	0.86	0.84	<0.01	2.10	0.16

Table B-3 Results of the Mann–Whitney U Test

Scales	Control group		Treatment group			Mann–Whitney U			
	Mean	SD	Mean	SD	d_m	U-statistics	z-score	p-value	Effect size
Threat	3.81	.73	3.06	.98	-.75	38.00	-1.98	.04	.40
Challenge	4.13	.98	3.35	.65	-.77	35.00	-2.15	.03	.44
Self-concept	2.90	.72	3.38	.74	.48	44.50	-1.60	.11	.33

Locus of control	4.23	1.04	4.42	.84	.19	67.50	-.26	.79	.05
Primary appraisal	3.97	.64	3.21	.79	-.76	31.50	-2.35	.02	.48
Secondary appraisal	3.57	.69	3.90	.66	.33	54.00	-1.04	.32	.21
Range stress	.40	.84	-.69	.99	-1.10	29.50	-2.46	.01	.50
Attitude	2.90	.92	2.62	.57	-.28	62.50	-.56	.58	.11

Note: SD: standard deviation; d_m: Difference between the mean values (mean treatment group – mean control group)

Table B-4 Results of the Hierarchical Regression

Model		B	SE b	ß
Step 1	Constant	3.55	.47	
	Experience	-.41	.36	-.24
	Affinity for technology	-.21	.14	-.31
Step 2	Constant	3.52	.44	
	Experience	-.35	.34	-.20
	Affinity for technology	-.19	.14	-.29
	Range stress	-.25	.13	-.34*

*Note: * p<.10, ** p<.05, *** p<.01; SE: Standard Error*

Furthermore, our results reveal a significant prediction effect of range stress on attitude ($t(20) = 1.83$, $p = .082$, $d = .76$) on a 10% significance level. However, we could not find a significant prediction effect of experience ($t(20) = −1.00$, $p = .329$, $d = −.44$) and affinity for technology ($t(20) = −1.43$, $p = .168$, $d = −.58$) on attitude.

1.4.2   Psychophysiological Evaluation

In addition to the psychometric evaluation, we analyzed the data from the skin conductance measurement gathered for each participant during the field experiment. In this context, we used an eSense Skin Response sensor to measure skin conductance with a scanning frequency of 0.2 s per measuring point. Afterward, we used the software products Origin and R to analyze and plot the data. Due to technical problems with affixing the sensors that caused biased measurements, we decided to exclude one participant from the further analysis.

To account for individual differences regarding the duration of the experiment, we computed a scaled time unit as 1/100 of the total time it took each participant to complete the driving task (see also Salvucci and Liu 2002). In doing so, we divided each individual's measurement signal into 100 equal parts and aggregated the data accordingly. By this method, we produced 100 aggregated data points for each participant, representing the temporal progression of the skin conductance related to the scaled time unit. This approach allows for a comparison that is independent from individual differences regarding the total time to complete the driving task.

Moreover, the measurement signals of skin conductance are heavily dependent on the activity and amount of sweat glands and therefore differ from person to person, thus leading to individual assessments that are hardly comparable in absolute values (μS). However, the assumption can be made that individual measurement signals are comparable when normalized by an appropriate factor (e.g., Lykken and Venables 1971), enabling comparisons based on relative values (%). Therefore, we normalized the data for each participant by dividing the measured values in the field test by the corresponding mean values of the test drive. This procedure seems particularly suitable, as the test drives did not differ between the groups considered (due to identical equipment). Therefore, distorting effects due to the group comparison are excluded. This approach ensures comparability between the participants' stress levels on a percentage basis in multiples of their test drive's mean values. The normalized and averaged signal for all 23 remaining participants is illustrated in Figure B-4. Both short-term fluctuations and a long-term trend can be seen in the average signal. We assume a linear relationship between skin conductance and driving time, depicted as a trend line with a slope of 0.12% per scaled time unit for skin conductance (with regard to the corresponding average values of the test drives). This assumption is additionally supported by a correlation coefficient of $r(98) = .78$, $p < .001$ that indicates a high correlation between both variables. Moreover, we compared the measurement signals for both the treatment and control groups against each other (see Figure B-5).
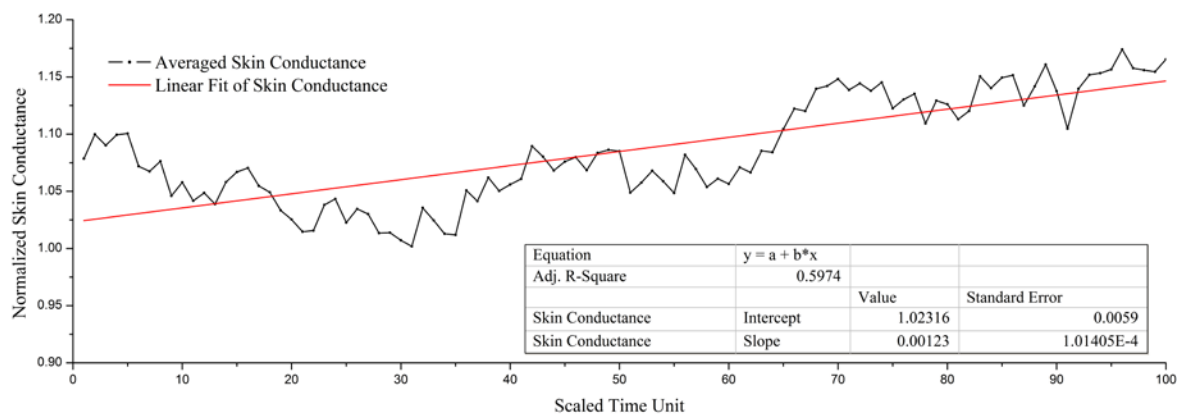
Figure B-4 Averaged and Normalized Measurement Data for Skin Conductance
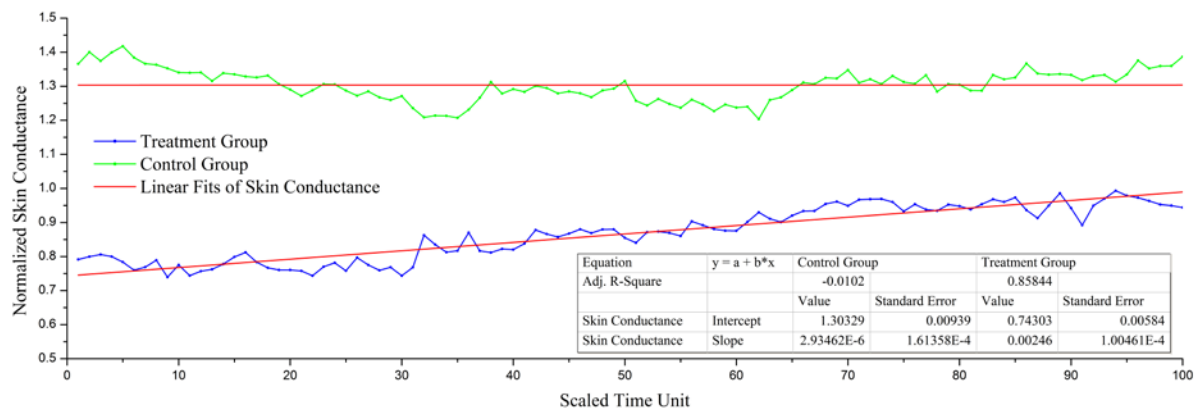
Figure B-5 Group Comparison of the Skin Conductance Measurement

The main findings of this comparison are presented in Table B-5, with three particularly conspicuous elements. First, the initial values for participants of the treatment group are significantly lower than those of the control group. Confirmation of this finding could be done by means of a t-test ($t(21) = -2.35$, $p = .029$, $d = -1.03$). Second, the initial increase of skin conductance also affects the mean value of the measured data, reflected in larger values for the control group ($t(198) = -48.48$, $p < .001$, $d = -6.86$). Third, the slopes of the measurement signals differ greatly among each other. We compared the individual slopes between both groups with a t-test and found the differences to be significant ($t(21) = 2.18$, $p = .041$, $d = .90$).

Table B-5 Summarized Results of the Skin Conductance Measurements

	Mean[1]	Initial value[2]	Mean[2]	Normalized mean[2]	Normalized slope[2]
Treatment group	1.03 µS	0.84 µS	0.97 µS	0.87	0.0025/time unit
Control group	1.16 µS	1.49 µS	1.45 µS	1.30	<0.0001/time unit
Total	1.09 µS	1.15 µS	1.21 µS	1.09	0.0012/time unit

Note: [1] *Relates to the test drive,* [2] *Relates to the driving task*

1.5 Discussion

1.5.1 Psychometric Data Evaluation

A closer consideration of the primary appraisal process indicates that the provision of IVISs had a significant negative effect on both subscales threat and challenge. The primary appraisal process is generally influenced by the individual's expectation of managing demanding events, and is strongly affected by available information about the specific demand an individual is confronted with (Krohne 1997). We assume that participants perceive the provided IVISs as supportive resources that enable them to better evaluate the likelihood of experienc-

ing range problems. This led participants to a higher degree of security and thus to reduced threatening and challenging appraisals of reaching the planned destination.

Regarding the secondary appraisal processes, our results indicate no significant effect of the IVISs on locus of control and self-concept. We expected that both constructs would be enhanced when using IVISs, because the provision of relevant information (e.g., nearby charging stations) can increase an individual's ability to detect alternative actions that may counteract uncertainties regarding critical range situations. Uncertainty about a situation may influence the perception of having control of a situation and confidence of one's own competencies in the short run (Babrow et al. 2000; Brashers 2001; Kienhues and Bromme 2011). However, self-concept and locus of control are related to personality traits and therefore considered as rather stable (Asendorpf et al. 2002; Bowsher and Keep 1995). Moreover, both factors are primarily shaped by a person's experience with the environment and thus influence one's ability to act (Shavelson et al. 1976). Most participants, however, were unexperienced with using BEVs and the systems within the vehicle (e.g., range device). Because participants completed only a single driving task during the study, we assume that the provision of IVISs did not have a strong enough impact to shape the participant's experience, and thus affect the individuals' ability to manage the critical range situation.

Finally, our results indicate that an increased range stress level leads to a more negative attitude toward using the BEV for the designated route. During the interviews, some participants reported feeling nervous due to the limited range of the vehicle, and would prefer a conventional vehicle for the route. We assume that participants associate a higher level of perceived range stress with some form of adverse emotional reactions, as negative emotions such as anxiety or anger generally arise from stressful encounters (Lazarus 1993b). In this regard, a negative attitude reflects an unfavorable individual response to performing a specific behavior and is accompanied by negative emotions (Ajzen 2005). Although a medium to high effect size for the relation between attitude and range stress was identified, the practical relevance is questionable because of our research design not being able to identify whether the effect is transient or stable over time.

1.5.2   *Psychophysiological Data Evaluation*

A deeper analysis of the measurement signals revealed three main findings when comparing the treatment group and the control group (see Table B-5). First, the initial values of the control group's skin conductance are significantly higher than those of the treatment group. As

interviews following the driving task stated, the navigation system seems to be especially beneficial in helping participants overcome or suppress initial concerns. This result is of particular interest, as it seems that most users are already accustomed to navigation devices and feel uncomfortable when they are unavailable. Hence, the absence of a navigation device likely evoked stress reactions prior to the driving task.

Second, the test group shows a significantly higher average stress level compared to the treatment group throughout the whole experiment, mainly as a consequence of the missing range and navigation feedback. This finding indicates that these devices are generally suitable in mitigating stress effects when driving a BEV. As the measurement signal reflects a general stress level, it is almost impossible to distinguish different types of stress. Therefore, it is not explicitly possible to draw conclusions about range stress solely based upon the measurement signal.

Third, the average slope for skin conductance was calculated to be significantly higher for the treatment group than that of the control group (see Figure B-5). This finding indicates a faster increasing stress perception when driving a BEV equipped with the examined IVISs. Because the single difference between these two groups is the provision of the IVISs, we assume that the disparity of the slopes within the groups' skin conductance signals originates consequentially from interaction with the provided IVISs. Moreover, we expect a range-related cause of increasing stress levels, because throughout accomplishing the driving task the treatment groups' participants become increasingly aware about the critical range situation, as they were permanently confronted with the range feedback. Also, as stated in the interviews, the range feedback was perceived as volatile. In this regard, volatile range feedback might also lead to mistrust against the information provided, further increasing the concerns of becoming stranded en route (Osswald et al. 2012). We assume that the treatment group's participants spent more time checking the range device when compared to using conventional vehicles, as they are usually unfamiliar with volatile range feedback in BEVs. In this regard, Rauh et al. (2015b) state that range-related stress perception on a behavioral level is expressed by frequent checking of the corresponding devices. This effect might lead to an information overload if the driver constantly compares the remaining range reported and distance left to drive, which could partially explain the increased slope for the skin conductance. Ragu-Nathan et al. (2008) point out that individuals are unable to efficiently cope with an information overload caused by information and communication technologies, resulting in stress reactions. Such behavior competes with the primary task of driving the vehicle and thus affects the demands

of the driving task (Fuller 2005). In this regard, some researchers (e.g., Lee et al. 2014) warn of the potential danger of devices that distract the driver, as they contribute to more than 20% of road vehicle accidents (Brooks and Rakotonirainy 2007).

1.5.3   Comparing Psychometric and Psychophysiological Evaluations

Questionnaire-based approaches reflect only a mental state at a certain point in time. For our experiment, the point in time when the participants' mental states are reflected is directly after completing the driving task. Therefore, most recent impressions are likely to be predominant, which could lead to shortcomings when assessing the driving task as a whole. To counteract this, it would be necessary to provide frequent questionnaires throughout the experiment. This is impractical because frequent interruptions could affect the intended realistic procedure of the experiment. However, questionnaires can be adjusted to the research focus, making it possible to explicitly measure the intended type of stress. In this regard, the PASA-questionnaire constitutes an appropriate measurement method to assess the impact of IVISs on range stress. In contrast, by using psychophysiological measurements, all types of stress are measured by using biological feedback and it is thus hard to filter range stress. Although all types of stress are measured by using biological feedback, we found indication that the differences between both groups' skin conductance signals have also a range-related cause. Moreover, it is possible to observe the temporal progression of the stress value over time without intervening, thereby making it possible to not only to assess stress from a momentum perspective but also its development throughout the driving process. Therefore, it seems useful to extend questionnaire-based evaluations of range stress by applying skin conductance measurements.

1.5.4   Limitations and Future Research

The following limitations should be considered when interpreting the results. First, experiments carried out in natural settings suffer generally from less controllability of extraneous variables. In our context, we could not control for certain traffic-related influences, such as traffic jams or risky overtaking maneuvers. These factors may lead to additional perception of driver stress and thus bias our results. Moreover, drawing from a small sample size of 24 participants does not allow for our results to be generalized. We suppose that the non-significant effect of IVISs on the secondary appraisal processes may be a result of the small sample size. Therefore, we suggest extending the sample size to allow for more powerful hypothesis tests. Furthermore, the absence of the range gauge in the control group's BEV limits the practical relevance of the findings, as every modern BEV is equipped with a range display. Moreover,

the presence of the experimenter might have led participants to feel less concerned about becoming stranded with a depleted battery. We therefore suggest improving the experiment by conducting it without a co-driver. Finally, we are unable to make statements of whether the relationship between attitude and range stress is stable over time or only a transient effect.

Future research should investigate the influence of other IVISs on stress perception with a focus on different designs and contents, as an evaluation of different types of information is outside the scope of the study. Moreover, drivers' glance behavior could be worthy for investigating which information devices are actually utilized, and therefore, helpful for overcoming range-related concerns (e.g., Birrell et al. 2014). Furthermore, based on the observed trend, the treatment group's skin conductance signal seems dependent on the duration of the driving task and could possibly exceed the control group's signal at a certain point. Therefore, we suggest expanding the experimental setting within the framework of a long-term field study. In this regard, future research should also investigate the impact of IVISs on range-related stress perception under everyday conditions (e.g., commuters).

1.6   Conclusion

The objective of this paper was to achieve a broader understanding of how IVISs influence range-related stress perceptions when driving a BEV in a critical range situation as part of an experiment with real traffic situations, using psychometric and psychophysiological measurement methods. The results indicate that using physiological indicators can be beneficial in supporting questionnaire-based evaluation methods in the field of range stress. The findings from the psychometric evaluation reveal that the examined IVISs are useful for mitigating range stress: because of the provided IVISs, individuals' perceived the critical range situation as less challenging and threatening. However, the IVISs had no significant impact on the individuals' self-concept of their own abilities and beliefs regarding control over the situation. Moreover, greater range stress was linked to a more negative attitude toward using the BEV for the designated route. With respect to the psychophysiological biofeedback, we found indication that the absence of certain IVISs, especially navigation devices, increases the driver's stress level prior to the actual driving task. While IVISs led to a reduced mean value for skin conductance throughout the entirety of the driving task, we also found evidence that participants from the treatment group exhibited faster increases in stress perception over time than the control group did, thus indicating that the provision of IVISs led to an increased awareness of reduced range resources over time.

C. The Dark Side of Information Systems

While the previous section has emphasized the potential value of IS in reducing stress, the following section is dedicated to the opposite effect. Two studies were conducted that put emphasis on the potential adverse effects of IS on stress perception and thus behavioral outcomes in the research context of BEVs. The first study (C1) shows that the provision of too much and volatile information leads to an increased stress perception, which in turn, negatively affects behavioral outcomes, i.e., the attitude towards using BEVs. Drawing on these insights, the second study (C2) focuses on the role of the range gauge as a main stressor in drivers of BEVs. The findings show that – in comparison to less accurate and less volatile range information – the provision of accurate but volatile range information leads to higher psychological range stress and a reduced attitude towards using BEVs. In addition, these effects are reflected by a lower trust towards the range estimate.

1 Less is Sometimes More?

Table C-1 Fact Sheet of Study No. C1

Title	Less is Sometimes More – The Impact of In-Vehicle Information Systems on Perceived Range Stress
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Outlet	Proceedings of the International Conference on Information Systems (ICIS) 2016
Abstract	Recent research has emphasized a new dimension of driver stress, the concern of getting stranded with an electric vehicle due to a depleted battery, referred to as range stress. One promising solution is seen in the appropriate provision of relevant information through in-vehicle information systems. We aim to investigate how individuals perceive the interaction of these systems with a particular focus on range stress. Thus, we employed an experimental research design in real traffic situations consisting of 70 participants. We put participants in a critical range situation and showed that the provision of volatile and too much range-related information leads to increased range stress perception, and hence, negatively affects the willingness to use electric vehicles. This research contributes to the existing body of knowledge, as it points to the importance of accounting for potential dysfunctional consequences of increased use of information systems. *Keywords: Range Stress, Range Anxiety, Electric Vehicles, Electric Mobility, In-Vehicle Information Systems*

1.1 Introduction

Mobility and accessibility are an indispensable part of an individual's independence, well-being and quality of life. However, despite the comfort of being autonomous with a vehicle, the driving process constitutes a potential source of frustration, irritation, and psychological stress (Hennessy and Wiesenthal 1999). According to Gulian et al. (1989), driver stress is defined as a "set of responses associated with the perception and evaluation of driving as being demanding or dangerous relative to the individual's driving capabilities." The authors base their definition of driver stress on the popular transaction-based stress model of Lazarus and Folkman (1984) that conceptualize stress as an imbalance between the individual and environment that endangers the individual's well-being. Driver stress can cause a variety of physiological and mental health problems, such as depression, sleeplessness, burnout, or heart disease (Avey et al. 2003; Marin et al. 2011; Novaco et al. 1979; Richardson et al. 2012). Moreover, driver stress has been found to be a key factor in the increased risk of accidents (Matthews et al. 1998). Such road traffic accidents are globally considered to be the fifth leading cause of death by 2030 (WHO 2008). Research has emphasized a variety of dimensions that trigger the stress process while driving. In that regard, Gulian et al. (1989) refer to the dimensions of driver aggression as a result of being hindered by other traffic; irritation and frustration that is connected with the overtaking process; general dislike of driving; and an increased alertness with respect to permanently monitor others' traffic behavior.

Recent research has also emphasized a new dimension of driver stress that is particularly observed in drivers of electric vehicles (EVs), referred to as range stress (Rauh et al. 2015a). According to Tate et al. (2008), range stress is defined as the "continual concern and fear of becoming stranded with a discharged battery in a limited range." This concern mainly originates from the limited range of EVs of approximately 150 kilometers, and the underdeveloped charging infrastructure (Eisel and Schmidt 2014). Research and practice have suggested several strategies to overcome this type of stress, such as increasing the number of charging stations or advances in battery technology (Chen et al. 2015; Nilsson 2011).

However, the hotly debated topic of range stress also features increasingly prominent information systems (IS) research. It has been suggested that appropriate in-vehicle IS can be useful to overcome range-related concerns (e.g., Eisel and Schmidt 2014; Nastjuk and Kolbe 2015). Zhang et al. (2012) present an estimation method to calculate better the remaining range considering various factors, such as road network topology, acceleration and deceleration, wind speed or driving style. Ferreira et al. (2011) introduce a conceptual model for an IS

that supports drivers of EVs through the continuous control of the range and by presenting in time information about charging stations within reach. Based on the results of a driving simulator experiment, Stroemberg et al. (2011) discuss the influence of two different concepts of in-vehicle IS (innovative versus traditional), concluding that the information cluster in EVs needs to be refined. Jung et al. (2015) suggest that an ambiguous range display maintains the driver's trust toward an EV, thus increasing the ability to adapt to remaining range conditions. Moreover, Eisel et al. (2014) determined in a mental simulation experiment that the general provision of range-related information is suitable to mitigate range stress.

In summary, previous research has mainly focused on the improvement of range prediction accuracy, psychological perceptions of range display, the general provision of information to reduce range-related concerns, and the design of certain in-vehicle IS. However, despite the considerable advances in this field, the influence of comprehensive in-vehicle IS on range stress perception in real-world driving tasks, to the best of our knowledge, has not been investigated. There is, therefore, a research gap on the effect of in-vehicle IS on range stress perception. In that regard, Eisel and Schmidt (2014) specify *vehicle monitoring* systems and *geo IS and navigation* systems as main categories of in-vehicle IS in EVs as being suitable to mitigate range stress. While the category of geo IS encompasses systems that inform the driver about road conditions (e.g., traffic), the category of vehicle monitoring includes systems that aim to provide the driver with all relevant information about the status of the vehicle (e.g., remaining range). We aim to investigate the impact of both categories on psychological range stress while also exploring how the in-vehicle IS influenced range stress impacts human behavioral tendencies. Therefore, we elaborate on the following research question:

> RQ: *How do in-vehicle information systems within the two categories (1) vehicle monitoring and (2) geo IS and navigation influence range-related stress perception and thus the attitude toward driving an electric vehicle?*

To approach the research question, we developed a comprehensive research model based on the well-known transactional stress model of Lazarus and Folkman (1984). Furthermore, we relate this model to the attitude toward performing a specific behavior (Ajzen 1991). To evaluate the research model, we conducted experiments in real traffic situations, putting 70 participants in the mindset of EV users. We determined that participants perceived less range stress when provided separately with in-vehicle IS in the category vehicle monitoring and geo IS and navigation compared to the provision of in-vehicle IS of both categories at the same time.

Moreover, the results indicate that the range gauge leads to a higher perception of range stress. Finally, range stress is negatively associated with the willingness to use EVs.

1.2   Theoretical Background and Related Work

1.2.1   The Concept of Stress

The complexity und multidimensionality of the stress concept makes a general and uniform definition difficult and, therefore, should depend on the particular research context (Lazarus 1990; Levine und Scotch 2013). The three main intertwined perspectives that evolved in the history of stress research all emphasize different stress aspects (Bartlett 1998; Cohen et al. 1997; Hobfoll 1989; Levine 2005b).

The biological (response) perspective focuses on the organisms' physiological responses to stressful events from the environment (Cohen et al. 1997). In this context, Selye (1976) defines stress as "the state manifested by a specific syndrome which consists of all the nonspecifically-induced changes within a biologic system." The stereotypical response pattern, called the general adaption syndrome, follows three stages: the alarm reaction, the stage of resistance, and the stage of exhaustion (Selye 1950).

Second, stimulus-based definitions of stress point out the relevance of certain stimuli (stressors) which lead to stress reactions (Bartlett 1998). Researchers suggest different types of stressors, for example, daily hassles (e.g., paper submission deadlines), ambient stressors (global, chronic stressors such as community noise), stressful life events (e.g., divorces, sudden unemployment), or cataclysmic events such as earthquakes or storms (e.g., Baum et al. 1981; Campbell 1983; Lazarus and Cohen 1977).

Finally, within the transaction-based approach, stress is defined as a relationship between an individual and the environment (Cooper et al. 2001; McGrath 1976). One of the most influential models of the transaction-based approach, introduced by Lazarus and Folkman (1984), is referred to as the transactional stress model. In this model, individuals perceive stress when there is an imbalance between demands from the environment and personal coping resources – specifically, when the demand exceeds the individual capabilities and resources to cope with. The stress process is characterized by the interaction of two main cognitive appraisal processes: primary appraisal and secondary appraisal (Lazarus 1966; Lazarus and Folkman 1984).

Within the primary appraisal, individuals interpret the environmental demand for their well-being as either benign-positive, stressful or irrelevant. The differentiation between positive, irrelevant and stressful events is important since only stressful events trigger the stress process. According to Lazarus and Folkman (1987), stressful events are of three types: harm (already experienced loss, e.g., divorce); threat (harm that is anticipated, e.g., anticipated illness); and challenge (anticipated demanding situation that is perceived as manageable when mobilizing personal resources, e.g., imminent examination).

Contemporaneously with the primary appraisal process, individuals evaluate within the secondary appraisal process the resources for coping with stressful appraised events (Lazarus 1990; Lazarus and Folkman 1984). In that regard, the individual assesses the likelihood that a given coping option will help to overcome the stressful situation and that s/he will be able to effectively apply the coping option (Lazarus and Folkman 1984). These expectancies are referred to as *outcome expectation* and *efficacy expectation*. The former describes the conviction that the behavior will lead to an intended outcome. Efficacy expectation refers to the individuals' conviction about the ability to perform the behavior (Bandura 1977). Stress emerges when the personal resources (secondary appraisal) are perceived to be insufficient to overcome a stressful appraised event (primary appraisal). In such a troubled person-environment relationship, individuals use cognitive and behavioral efforts to handle the demands that are appraised as stressful. These coping strategies aim to master, reduce or tolerate the stressed feeling by managing distressing emotions or changing the situation that causes stress (Folkman and Lazarus 1985; Folkman et al. 1986b).

1.2.2 *Range Stress in Electric Vehicles*

Although the range of EVs seems to be sufficient for most people's daily needs, it still constitutes one of the most barriers in the adoption decision (Egbue and Long 2012; Neumann et al. 2010; Pearre et al. 2011). The term *range anxiety* first appeared in the end of 90s and describes EV users' concerns that they might not reach planned destinations due to a discharged battery (Nilsson 2011; Tate et al. 2008).

Furthermore, it results from concern about the charging time and the sparsely available charging infrastructure (Philip and Wiederer 2010; Wynn and Lafleur 2009). In comparison to conventional vehicles, the limited range of EVs constitutes a loss of flexibility requiring drivers to charge several times during trips that exceed the capacity of the battery.

Nilsson (2011) has classified the symptoms of range anxiety into four areas. On a behavioral level, range anxiety is characterized by re-planning activities or avoidance of usage. A study by Carroll and Walsh (2010) shows that users were overly cautious when planning a journey, and adapted their driving style when the state of charge reduced below 50%. Furthermore, Franke et al. (2012b) explain that dealing with the limited range of EVs is characterized by actively avoiding critical range situations, reserving a substantial safety buffer. On an emotional level range anxiety is expressed by changes in the affective state, like concerns, worries or even a fear of not reaching a planned destination. A recent study of Rauh et al. (2015a) revealed that experienced drivers of EVs experience less emotional concerns inexperienced drivers. On a physiological level range anxiety is shown by increased heart rate or sweaty palms. Nilsson (2011) emphasizes that this level has not been confirmed in empirical studies and more research is needed. Finally, within the cognitive level, range anxiety is associated to negative cognitions regarding the range and is expressed more by a concern rather than anxiety or fear (Rauh et al. 2015a). Following this conceptualization, many authors define range anxiety as a certain type of stress (range stress) that is triggered by an individual inability – due to insufficient mobility resources available – to meet specific mobility needs, for example, a timely and relaxed arrival to the target destination (Eisel et al. 2014; Franke et al. 2012b; Franke and Krems 2013a; Nastjuk and Kolbe 2015; Rauh et al. 2015a).

Recent research discusses several approaches to counteract this type of stress. Chen et al. (2015) suggest increasing the number of charging stations to mitigate range-related concerns. Advances in battery technology are regarded as crucial for increasing the range and, hence, reducing the fear of becoming stranded due to a depleted battery (Nilsson 2011; Nykvist and Nilsson 2015). According to Franke et al. (2016b), certain strategies aimed at increasing knowledge about EVs and the related in-vehicle systems, route familiarity, or trust in the range estimation system are useful in reducing range stress. Dellnitz et al. (2014) designed an intelligent cruise control to improve the drivetrain power uptake by considering topographical information, thus aiming to increase the energy efficiency in EVs. Eisel et al. (2014) show in a mental simulation experiment, that the deployment of IS – more specifically, the provision of relevant information about range, energy consumption, or charging locations — are suitable to mitigate the fear of being stranded with a depleted EV battery. Furthermore, Nastjuk and Kolbe (2015) demonstrate that supportive in-vehicle IS can contribute to reducing perceived range stress, but can also lead to stress reactions (technostress). Lundstroem and Bogdan (2012) suggest reshaping the in-vehicle IS based on coping strategies of experienced us-

ers to ease range stress. In that regard, Stroemberg et al. (2011) emphasize that the way in which the information is presented in EVs (traditional vs. innovative display) and the type of information are important, as both influence the driver's perception of the system.

1.2.3 In-Vehicle Information Systems

The car of today has numerous in-vehicle IS with the main purpose of providing different information and functionalities to the driver, including collision warning, vehicle conditions, traffic and weather updates and certain entertainment services (Cao et al. 2010; Pauzié and Manzano 2007). Due to the variety of functionalities provided by in-vehicle IS, Brandt (2013) suggests four different in-vehicle categories.

First, safety and collision avoidance systems are constructed to ensure the safety of the driver, passengers and people outside the vehicle while simultaneously preserving the unique driving experience. Kantowitz and Moyer (1999) list, for example, vehicle location systems, lane departure warning systems or automatic cruise control for systems that support safety for people inside or outside the car. Furthermore, Lee et al. (1999) refer to in-vehicle safety advisory and warning systems that caution the driver of unsafe conditions on the roadway ahead, such as accidents or construction zones.

Second, the category geo IS and navigation encompasses all systems that provide information about road conditions and current traffic. TRANSIT was in the 60s the first U.S. space-based radio navigation satellite navigation system in the world, forming the basis for the later development of GPS (Lachow 1995). Typical systems within this category are navigation systems that provide supportive information about route planning or traffic situation. In-vehicle signing systems support the driver in navigation by transmitting information that is depicted on external roadway signs (Lee et al. 1999).

Third, vehicle monitoring systems encompass technologies that monitor certain functionalities of the vehicle and measure indicators during the process of driving. The range gauge represents a typical device within the category of monitoring systems (Brandt 2013). Finally, all IS that actively communicate with the driver and provide entertainment features are summarized under the category of convenience, communication, and entertainment systems. With the first installed automobile radio in a 1919 custom Cunningham town car, and moreover with the first developed mass production car radio in 1930 by the Galvin Manufacturing Corporation, the era of the automobile as a platform for entertainment had begun (King and Lyytinen

2005). However, besides the radio, further systems such as car-phone, DVD, television, and Bluetooth may make traveling more enjoyable.

The development of in-vehicle IS is continuously evolving. Currently, vehicles employ a number of different sensors that provide the backbone for all next-generation automobile applications, such as vehicle-to-vehicle or vehicle-to-infrastructure communication (Tuohy et al. 2015). Intelligent transport systems use sophisticated road and telecommunication infrastructure to optimize the communication between vehicles and infrastructure and, hence, deliver immense benefits regarding efficient traffic flow, reduced road accidents, and increased sustainability (Nkoro and Vershinin 2014). However, recent research has also emphasized possible risks when a vehicle is connected to an external network, more specifically, vehicle information security and, therefore, the safety of the vehicle may be threatened (Yoshikawa et al. 2015).

1.3   Research Model and Hypotheses Development

The proposed research model relies on the transactional stress model of Lazarus and Folkman (1984) to explore the impact of two in-vehicle IS categories on the respective subdimensions of stress, In addition, it integrates the attitude construct, derived from the well-established theory of planned behavior (Ajzen 1991), to study the influence of range stress on the individuals' tendency to use BEVs. The research model is schematically illustrated in the following Figure C-1.
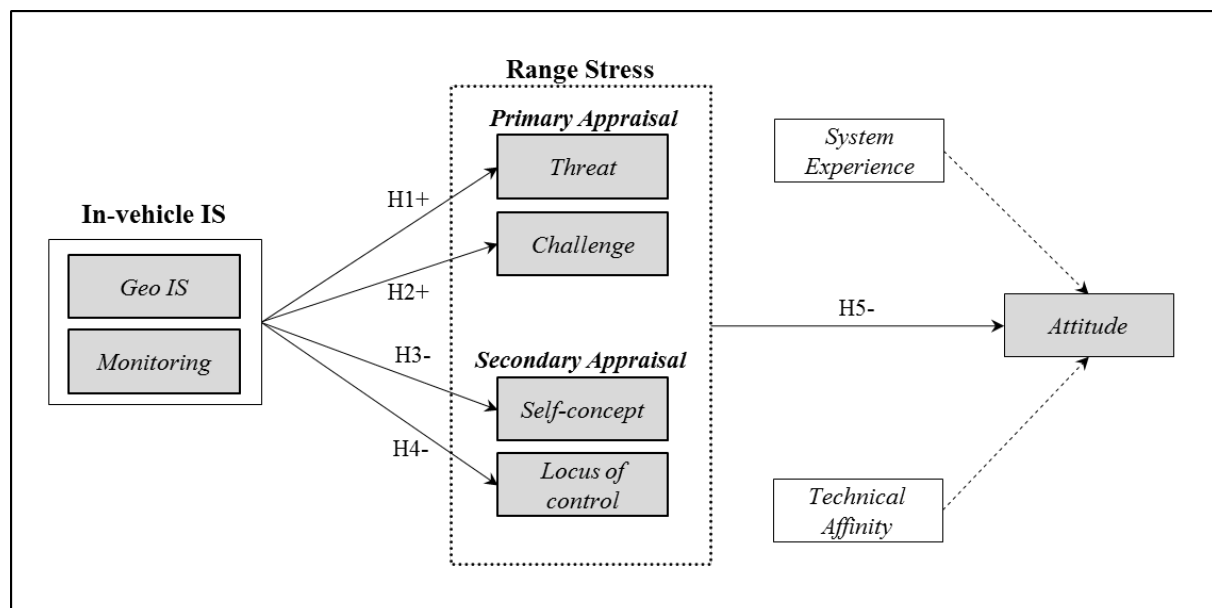
Figure C-1 Research Model

Previous research suggests the in-vehicle IS categories *vehicle monitoring* and *geo IS and navigation* as being suitable for overcoming the fear of becoming stranded due to a depleted battery (Eisel and Schmidt 2014; Nastjuk and Kolbe 2015). According to Brandt (2013), the category of geo IS and navigation encompasses systems that provide the driver with all relevant information on the trip, e.g., the navigation system including displayed locations of charging stations. In contrast, the category of vehicle monitoring includes IS that focus on information about the status of the vehicle. Within this category, the range gauge is considered to be of high importance, particularly with a focus on the limited range in EVs (Stroemberg et al. 2011).

Within the primary appraisal process, individuals evaluate a stressful event as challenging or threatening (we neglect the harm appraisal because it refers to previously experienced loss). In that regard, while challenge appraisals refer to anticipated demands that individuals perceive as manageable when effectively mobilizing coping resources, threat appraisals evolve from anticipated harm. We assume that drivers perceive the critical range situation as more threatening and challenging when providing in-vehicle IS of the category vehicle monitoring instead of the category geo IS.

According to Jerusalem and Schwarzer (1992), the psychological appraisal of an event as threatening or challenging is strongly influenced by the information available about a situation and the degree of uncertainty. Generally, uncertainty can be characterized by a lack of clarity of information and by the inability to exactly assign probabilities to environmental occurrences (Duncan 1972; Lawrence and Lorsch 1976). The range gauge in EVs is considered to be a critical resource of information to assess the driving range of EVs (Wellings et al. 2011).

Nilsson (2011) notes that the accurate and transparent provision of range-related information is crucial for EV users in order to appropriately set the driver's expectation. Franke et al. (2012b) conclude that reliable information about the range may even be more important for EV users than simply enhancing the maximal range.

However, range gauges in EVs appear to be precise, but, in fact, are merely unprecise estimates (Jung et al. 2015). The high variation is caused by, for example, the driving style and external or internal conditions that are not considered in most range displays of current EVs, such as elevation profile, outdoor temperature or use of the vehicle's climate control unit (Pichler and Riener 2015). The fluctuations in the remaining range are often not understood

by the driver and thus may lead to a loss of trust in the system, and, moreover, may even provoke frustration and stress in the driver (Lundstroem 2014; Wellings et al. 2011).

As the monitoring systems, especially the range gauge, permanently provide the range-related information to the driver, we assume that the driver is constantly reminded of the critical range situation. Moreover, due to the volatility of such displays, we argue that the driver's uncertainty about reaching the final destination is enforced and, therefore, a higher threat or challenge occurs. According to Nastjuk and Kolbe (2015), threat or challenge appraisals in critical range situations occur due to an individual's inability to estimate whether s/he can reach the final destination. This kind of uncertainty is enforced, e.g., by anticipated harm due to a missed appointment or the fear of getting stranded in an unfavorable situation, such as at night on an empty road.

In contrast, the category of geo IS typically encompasses systems that provide the driver with information about planned trips and support the driver in reaching them, such as the navigation device (Brandt 2013). According to Eisel et al. (2014), navigation systems help EV drivers reach the planned destination and thus create a less challenging and threatening situation for the driver. Nilsson (2011) emphasizes that the confidence in EV drivers increases with more symbols indicating locations of charging points. As these systems do not highlight the permanent remaining range, we assume that the driver is not constantly reminded to the critical range situation and thus perceives less uncertainty. Accordingly, we summarize our assumptions in the following hypotheses:

> *H1$^+$: Individuals perceive the critical range situation as more threatening when provided with systems of the category vehicle monitoring instead of the category of geo IS and navigation.*

> *H2$^+$: Individuals perceive the critical range situation as more challenging when provided with systems of the category vehicle monitoring instead of the category of geo IS and navigation.*

Contemporaneously with the primary appraisal process, individuals assess their personal coping resources for managing stressful demands in the secondary appraisal process. According to Thoits (1995), two main psychological resources are considered by the individual: self-esteem and locus of control. While self-esteem is closely linked to the self-concept of own abilities that reflects the individual's perceived ability to handle a specific situation (Campbell

1990; Crocker and Major 1998; Stein 1995), locus of control is defined by the individuals perceived degree of being in control over a situation (Rotter 1966).

The self-concept is strongly shaped by the perception of situational factors (Fisher 1996; Nastjuk and Kolbe 2015). Moreover, the self-concept remains unstable in information-rich and uncertain environments and is strengthened in situations in which information consistency dominates (Kienhues and Bromme 2011). Uncertainty can threaten the individual's general sense of coherence, and also poses a risk to one's self-concept (Antonovsky 1990; Babrow et al. 2000). The degree of uncertainty associated with a task is predominantly determined by the complexity that a task involves, the task dynamic, and the heterogeneity of the environment (Rabbie and Lodewijkx 1996). Especially new information that contradicts current beliefs may lead to a reappraisal of the situation, thus creating a higher state of uncertainty and a potential loss of belief in one's own abilities (Brashers 2001; Kruglanski 1989). In a cross-border context, the volatility of the displayed range-related information creates an uncertain environment for the driver and thus constitutes a potential threat to one's self-concept.

Moreover, we assume that monitoring systems within EVs also weaken the perception of being in control of a situation. Generally, the driving task itself is considered to be complex and challenging, as the driver is confronted with uncertainty due to permanently unexpected environmental demands, such as a sudden traffic jam (Osswald et al. 2012). These unpredictable changes make it nearly impossible to estimate the actual remaining range of the EV. In addition to this uncertainty in the driving environment, the fluctuation of the displayed range gauge constitutes an ambiguous situation for the driver and, therefore, empowers the awareness of the critical range situation. Lazarus and Folkman (1984) state that the perception of uncertainty generally increases with a higher awareness of an ambiguous situation. Such perception influences the expectancy of being in control over a situation (Penrod 2001).

Following the same line of argumentation as for the primary appraisal, we assume that individuals are not permanently reminded of the critical range situation when they are only provided with systems of the category of geo IS and navigation. Thus, the awareness of the potential risk for becoming stranded is considerably lower. Modern navigation devices also consider unexpected changes in the traffic (such as a sudden traffic jams) and suggest alternative routes to the final destination. Moreover, these systems warn the driver if the planned destination is not reachable with the remaining battery capacity (Eisel et al. 2014). We, therefore, assume that such features create a more plannable and controlled situation to the driver, thus enhancing the self-concept and the perception of being in control of the situation. Following

this logic, we establish our assumptions regarding the secondary appraisal process in the following manner:

H3⁻: *Individuals perceive themselves to be less self-confident in handling the critical range situation when provided with systems of the category vehicle monitoring instead of the category of geo IS and navigation.*

H4⁻: *Individuals perceive themselves to be less in control over the critical range situation when provided with systems of the category vehicle monitoring instead of the category of geo IS and navigation.*

Finally, we posit that range stress negatively affects one's attitude toward using an EV. The individual's cognitive appraisal of a stressful situation is a determining factor of the attitude construct (Pearson and Thackray 1970). The attitude construct reflects, in general, the individual overall evaluation of performing a specific behavior, encompassing conative, cognitive and affective factors (Ajzen 2005; Ostrom 1969). While the conative dimension captures the tendency to perform a behavior, the cognitive component encompasses knowledge about the behavior. However, the affective component takes on an important role in our study, as it captures the individual's emotions and feelings. According to Lazarus (1993b; 2006), stress arises from negative emotions, such as anger or fear, and, moreover, can be considered as a subset of emotions. Therefore, we assume that the critical range situation is associated with a certain degree of negative emotions, thus unfavorably influencing one's attitude toward using the vehicle.

Previous research has given us indications of this relationship. Eisel et al. (2014), for example, show in a mental simulation experiment that the concern of becoming stranded with an EV is perceived as an acceptance inhibitor of EVs. Djamasbi et al. (2009) found in a study about health care IS a negative relationship between adverse emotional response and user attitude. Furthermore, Nastjuk and Kolbe (2015) revealed a significant negative relationship between stress that results from interaction with IS and the acceptance toward these systems. Kulviwat et al. (2007) explain with their consumer acceptance of technology model that emotional response constitutes a crucial part in explaining the acceptance of consumer goods. We summarize our assumptions in the following hypothesis:

H5⁻: *Range stress negatively influences the attitude toward using an electric vehicle.*

We include technical affinity and system experience (in terms of experience with EVs and the information devices within the vehicles) within our research model because previous research

emphasizes the importance of these aspects when assessing the attitude toward using an EV (Eisel et al. 2014; Franke et al. 2012a; Nastjuk and Kolbe 2015; Nilsson 2011; Rauh et al. 2015a).

1.4 Research Methodology

We performed field experiments (between-subjects design) in real traffic situations with participants driving an EV (*Volkswagen e-up!*). The EV was equipped with an electromotor of 60kW maximum engine power that enables a maximum range of 130km and a maximum speed of 130Km/h (Volkswagen 2016). As part of the experiment, we developed two scenarios in which participants had to drive a predefined route of 93 kilometers, encompassing sections of a city track, a highway, and an Autobahn. For the trip, the vehicle was prepared to display an estimated remaining range of 100 kilometers. We chose the close total distance-remaining range ratio in order to elicit a stressful range situation (Eisel et al. 2014; Franke et al. 2012b; Nastjuk and Kolbe 2015). For the scenarios, the treatment differed in terms of the IS provided within the vehicle. In that regard, IS associated with *geo IS and navigation* and *vehicle monitoring* seem to be most useful for encountering range stress when driving an EV (Eisel and Schmidt 2014; Nastjuk and Kolbe 2015). The control group's *Volkswagen e-up!* was standardly equipped, encompassing all related systems of both in-vehicle IS categories. In subsequent chapters, the group of the category geo IS and navigation is referred to as *geo IS*; vehicle monitoring, to *monitoring*; and the control group to *control*.

1.4.1 Data-collection Procedure and Sampling

The subjects were recruited via announcements at university lectures, direct acquisition, and social network announcements. To obtain a snowball sampling, we requested the initial participants to invite their friends and acquaintances to participate in the experiment (Biernacki and Waldorf 1981). The only necessary pre-condition for participation was the possession of a driver's license. We pre-tested the scenarios and questionnaires by researchers in the field of IS and psychology before conducting the experiment. The pre-test interviews led to minor changes in terms of wording and experiment procedure.

We conducted the experiments at the same time of day to avoid disturbances due to rush hour. Moreover, the experiments were conducted under normal weather conditions. We assigned participants randomly (Bhattacherjee 2012) to the three groups (geo IS, monitoring and control). Altogether, the study drew on a sample of 70 participants ranging from 22-53 years of

age (M = 27.01, SD = 5.61), of which 42.29 percent were women. While 85.71 percent of the participants stated that their highest level of education completed was a university degree, 11.43 percent had obtained a general qualification for university entrance. Moreover, 42.86 percent of the sample stated that they own a car.

1.4.2 Field Experiment Settings

Before starting the experiment, the vehicle was prepared by the experimenter. The vehicle's battery charge was adjusted to provide a displayed driving range of 100 kilometers for each participant. Furthermore, depending on the participant's group affiliation, the vehicle was equipped with the respective information devices. Group 1 (*geo IS*) was provided a navigation system (maps+more), and a smartphone using the application *Chargemap*. This application provides a community-driven list of nearby public and semi-public charging stations for electric vehicle drivers (ChargeMap 2016). Furthermore, to exclude the effect of IS related to the category vehicle monitoring, we hid all related devices that monitor and display range-related information during the driving process (e.g., range gauge, information about the remaining range on the navigation system, consumer energy monitor).

In contrast, group's 2 vehicle (monitoring) was only equipped with the range gauge (analogue and digital) and further systems that monitor and display certain functionalities of the vehicle during the process of driving, such as the consumer energy monitor and the eco-gauge that allows drivers to visually monitor how their driving style impacts energy consumption.

After the vehicle was prepared, the participants received a brief introduction to using the EV. Afterward, participants performed a test drive (10 minutes) to become familiarized with the EV and to decrease arousal due to inexperience with EVs. Subsequently, participants received the task to drive the partly charged EV with an estimated range of 100 kilometers to a railway station 93 kilometers away, where the vehicle would be needed for further testing purposes. Moreover, participants were told that they would be driven back with another vehicle after reaching the final destination.

The participants of group 2 were additionally provided with a physical road map to exclude any issues regarding navigation. The experimenter discussed the route to the destination and ensured that participants understood the designated route to drive. The experimenter then asked the participants to fill out a questionnaire with sociodemographic questions (e.g., age, gender, education) and further general questions concerning their experience with EVs and the IS within the vehicle, affinity for technology, attitude toward using the EV for the desig-

nated route, and current emotional condition. After clarifying all open questions, the experimenter sat down in the rear seat behind the driver to avoid unnatural driving behavior and then asked participants to start the actual driving task. From this moment on, communication between the experimenter and participant was prohibited.

After driving 16 kilometers (approximately 20 minutes of driving, encompassing the city track, the highway, and part of the Autobahn route), participants were asked to pull over and park for an in-between evaluation. Participants were then asked to get out of the vehicle and to fill out a questionnaire about their cognitive assessment of the range situation, attitude toward using the EV, and manipulation check. Participants had to fill out the questionnaire outside the vehicle as the manipulation check included some questions about the provided IS. After filling out the questionnaire, the experiment ended, and participants were debriefed and asked to drive to the starting point. The experiments lasted an average of 90 minutes for each participant, including introduction, test drive, and questionnaire.

1.4.3 Measurement of Constructs

We used the Primary Appraisal Secondary Appraisal (PASA) questionnaire (Gaab 2009; Gaab et al. 2005) to evaluate the perceived range stress situation in our experiment. The PASA questionnaire refers to the transactional stress model of Lazarus and Folkman (1984) and assesses two main cognitive appraisal processes (primary and secondary appraisal), each with two subscales. In that regard, primary appraisal is measured with the scales *threat* (e.g., "I feel uncomfortable with the provided information system."; "I am not worried because I do not feel threatened by the information system.") and *challenge* ("The provided information system is important to me for the trip."; "The provided information system creates a challenge for me.")*; secondary appraisal is assessed with the scales *self-concept of one's abilities* (e.g., "I know how to handle the provided information system."; "I can think of many action alternatives for handling the provided information system.") and *locus of control* (e.g., "I am responsible for handling the provided information system."; "I have strong influence on whether I will be able to handle the provided information system."). The 16-item PASA questionnaire is based on a 6-point Likert scale measuring all respective scales by four items each.

We used five items on a 7-point Likert scale (Ajzen 2002) to measure attitudes toward using the EV for the trip to the railway station (e.g., "Using the battery electric vehicle for the given route is bad vs. good for me."; "Using the battery electric vehicle for the given route is unpleasant vs. pleasant for me."). As previous literature has indicated that attitudes toward using

an EV are influenced by an affinity for technology and system experience (Eisel et al. 2014; Nastjuk and Kolbe 2015; Franke et al. 2012b; Rauh et al. 2015a), we set the controls for this variable. Accordingly, affinity for technology (e.g., "I relate well to technology and machines."; "I am comfortable learning new technology.") was measured by five items on a 7-point Likert scale (Edison and Geissler 2003). System experience was measured by two items in terms of experience with EVs and experience with an in-battery electric vehicle IS on a 7-point Likert scale (e.g., "I have practical experience with battery electric vehicles."; "I have practical experience with the provided information system."), which we adapted from a previous study by Nastjuk and Kolbe (2015). Participants also had to answer certain stimulation checks to test the success of manipulation (Perdue and Summers 1986). In that regard, respondents were asked several questions on a nominal scale ("yes" or "no") concerning the IS in the vehicle, such as "Were you provided with a navigation system for the trip?" and "Were you provided with a digital and analogue range gauge for the trip?" If these questions were answered in the positive, participants were asked on a 7-point Likert scale to what extent the provided systems were useful for overcoming range-related concerns.

1.5 Data Analysis and Results

We used IBM SPSS Statistics 23 (IBM 2015) to check for group differences in the respective subdimensions of stress (H1-H4). Furthermore, we used variance-based-partial least squares structural equation modeling (PLS-SEM; Lohmoeller 1989) to examine the influence of perceived range stress on attitudes (H5). PLS-SEM seemed especially useful as it requires fewer statistical constraints regarding distribution assumptions and sample size (Henseler et al. 2009; Reinartz et al. 2009). Moreover, PLS-SEM enabled us to estimate a model with multiple variables at the same time by maximizing the explained variance of the latent endogenous variables (Barclay et al. 1995; Gefen et al. 2011; Urbach and Ahlemann 2010). To that purpose, we used the software SmartPLS 3 (Ringle et al. 2015). Following the widely adopted two-step approach for data analysis (Anderson and Gerbing 1988), we first evaluated the reliability and validity of the measurement constructs and then tested the structural model.

1.5.1 Measurement Validation

We first checked to see if participants correctly assigned the IS categories to their respective scenarios before starting the analysis. All participants did assign the provided in-vehicle IS to the respective scenarios correctly. Furthermore, all participants rated relatively high on the 7-point Likert scale concerning to what extent the provided systems were useful for overcoming

range-related concerns (M = 5.08). Hence, we assumed that participants perceived the manipulation and therefore considered all responses as suitable for further analysis.

We examined content, convergent, and discriminant validities to evaluate the quality of the reflective constructs. In this regard, content validity is considered as given if the measurements of a construct represent its underlying social construct (Haynes et al. 1995). We derived our constructs and measurements from existing scales of previous studies and well-established theories. Therefore, we argue that content validity is given. Convergent validity refers to the extent to which the measures of a construct are in fact related (Bagozzi and Phillips 1991). To assess convergent validity, we examined individual indicator reliability, composite construct reliability (CR), and average variance extracted (AVE) (Fornell and Larcker 1981). After dropping two items from the challenge scale (factor loadings < .06), all items loaded on their supposed constructs at .06 or higher, indicating acceptable indicator reliability (Chin 1998). Furthermore, while CR exceeds the acceptable limit of .07 (Hulland 1999), all AVEs vary above the suggested lower bound of .05 (Bhattacherjee and Premkumar 2004).

To evaluate discriminant validity (the extent to which the operationalization of a construct differs from other constructs; Bagozzi and Phillips 1991), we assessed in more depth the indicator correlations and AVE (Gefen and Straub 2005). We assume that discriminant validity is given because each item loaded on its assigned construct higher than on other constructs (Chin 1998) and the square root of every AVE is larger than the corresponding construct correlation (Fornell and Larcker 1981). The results are presented in Table C-2.

Table C-2 Factor Loadings, CA, AVE, CR, and Inter-Construct Correlations

	Construct	Loadings	CA	AVE	CR	1	2	3	4	5	6	7
1	Attitude	.891-.948	.955	.848	.965	**.921**						
2	Threat	.654-896	.845	.688	.897	-.703	**.830**					
3	Challenge	.878-.893	.725	.784	.879	-.620	.742	**.886**				
4	Locus of Control	.874-.941	.935	.837	.954	.618	-.675	-.620	**.915**			
5	Self-Concept	.746-.889	.847	.687	.897	.658	-.738	-.683	.745	**.829**		
6	Technical Affinity	.768-.822	.830	.596	.880	-.364	.262	.355	-.292	-.357	**.772**	
7	System Experience	.772-.959	.719	.758	.861	-.320	.293	.242	-.233	-.238	.400	**.871**

AVE: average variance extracted; CA: Cronbach's Alpha; CR: composite reliability; bolded numbers: square root of AVE.

1.5.2 *Hypotheses Testing and Structural Model*

To test the influence of the respective in-vehicle IS on range stress perception and the subdimensions (H1-H4), we decided to check for group differences. Following Gaab (2009), we operationalized range stress by subtracting the mean of the secondary appraisal's subscales (self-concept and locus of control) from the mean of the primary appraisal's subscales (threat and challenge).

To choose the appropriate test for group differences, we first assessed the data for non-normality and homoscedasticity. Both the Kolmogorov-Smirnov test and Shapiro-Wilk W-test showed highly significant results for the constructs challenge ($p = .021/p = .005$), locus of control ($p < .001/p < .001$), self-concept ($p < .001/p = .002$), and range stress ($p = .001/p = .001$). Since these results indicate that our data is non-normally distributed, we used the non-parametric Levene's test to evaluate the homogeneity of variances among groups (Nordstokke et al. 2011). This test showed significant results for the constructs threat ($F = 8.302; p = .001$), locus of control ($F = 5.458; p = .006$), self-concept ($F = 3.660; p = .031$), and range stress ($F = 5.468; p = .006$), thus indicating heteroscedasticity.

Since our data appears to be to a great extent non-normally distributed and heteroscedastic, we decided to apply the Kruskal-Wallis test to evaluate whether there are differences between the groups (McKight and Njab 2010). The groups differed significantly in the constructs threat ($\chi^2 (2) = 44.677; p < .001$), challenge ($\chi^2 (2) = 23.769; p < .001$), locus of control ($\chi^2 (2) = 35.147; p < .001$), self-concept ($\chi^2 (2) = 39.148; p < .001$), and range stress ($\chi^2 (2) = 42.534; p < .001$).

Since the Kruskal-Wallis test reveals significant differences in all constructs, we used the non-parametric Mann-Whitney U test to analyze whether the groups came from the same population in the respective constructs (Nachar 2008). In addition, we calculated the approximate effect size to report the magnitude of the difference between the groups (Coe 2002). To this purpose, we divided the Z-score by the square root of the sample size (Field et al. 2013). Cohen (1992) proposes that effect sizes between .10 and .30 are small to medium, while those between .30 and .50 are medium to large. Due to multiple testing (3 groups), we used a Bonferroni correction to reduce Type I errors (Rice 1989). In that regard, the critical 5 percent level of significance was corrected to 0.017. The results of the Mann-Whitney U test and effect sizes are summarized in Table C-3, Table C-4, and Table C-5.

Table C-3 Group Comparison Between Monitoring and Control

	Monitoring	Control		Mann-Whitney U test			
Constructs	MR	MR	Δ MR	U-statistics	Z-score	Sign.	r
Threat	13.06	35.43	-22.37	1.500	-5.696	<.001	.681
Challenge	16.58	31.03	-14.45	89.500	-3.704	<.001	.443
Locus of control	31.64	12.20	19.44	34.000	-4.955	<.001	.592
Self-concept	31.72	12.10	19.62	32.000	-4.998	<.001	.597
Range Stress	13.54	34.83	-21.29	13.500	-5.409	<.001	.647

SD: standard deviation; Sign.: significance; r: effect size; MR: mean rank

Table C-4 Group Comparison Between Geo IS and Control

	Geo IS	Control		Mann-Whitney U test			
Constructs	MR	MR	Δ MR	U-statistics	Z-score	Sign.	r
Threat	13.00	33.50	-20.50	0.000	-5.733	<.001	.685
Challenge	15.06	32.93	-17.87	51.500	-4.566	<.001	.546
Locus of control	32.48	11.15	21.33	13.000	-5.443	<.001	.651
Self-concept	32.60	11.00	21.60	10.000	-5.498	<.001	.657
Range Stress	13.28	35.15	-21.87	7.000	-5.557	<.001	.664

SD: standard deviation; Sign.: significance; r: effect size; MR: mean rank

Table C-5 Group Comparison Between Geo IS and Monitoring

	Geo IS	Monitoring		Mann-Whitney U test			
Constructs	MR	MR	Δ MR	U-statistics	Z-score	Sign.	r
Threat	21.06	29.94	-8.88	201.500	-2.168	.030	.259
Challenge	22.50	28.50	-6.00	237.500	-1.465	.143	.175
Locus of control	26.32	24.68	1.64	292.000,	-0.401	.688	.048
Self-concept	30.42	20.58	9.84	189.500	-2.400	.016	.287
Range Stress	20.16	30.84	-10.68	179.000	-2.594	.009	.310

SD: standard deviation; Sign.: significance; r: effect size; MR: mean rank

Compared to the control group, the results show that the separate provision of both systems led to a decreased level of range stress perception. In that regard, we could find a significant difference for category monitoring in the primary appraisal subscales, threat (U = 1.500; p < .001) and challenge (U = 89.500; p < .001), and a significant difference in the secondary appraisal subscales, locus of control (U = 34.000; p < .001) and self-concept (U = 32.000; p < .001). Regarding the geo IS category, we could also find significant differences in the scales

for threat (U = 0.000; p < .001), challenge (U = 51.500; p < .001), locus of control (U = 13.000; p < .001), and self-concept (U = 10.000; p < .001). Overall, participants perceived less range stress when separately provided systems of category monitoring (U = 13.500; p < .001) and geo IS (U = 7.000; p < .001).

Concerning the group comparison between geo IS and monitoring, the results revealed a significant difference in the subscale for self-concept (U = 189.500; p = .016) and, adopting a 10 percent significance level (after Bonferroni correction, an actual significance level of p = .033), a significant difference in the threat scale (U = 201.500; p = .030). However, the results show that participants of the geo IS category perceived less range stress (U = 179.000; p = .009).

To evaluate the structural path of the model (H5), the bootstrapping re-sampling procedure was applied with 5000 subsamples (Chin 1998; Hair et al. 2011). The results of the PLS regression are illustrated in Figure C-2.
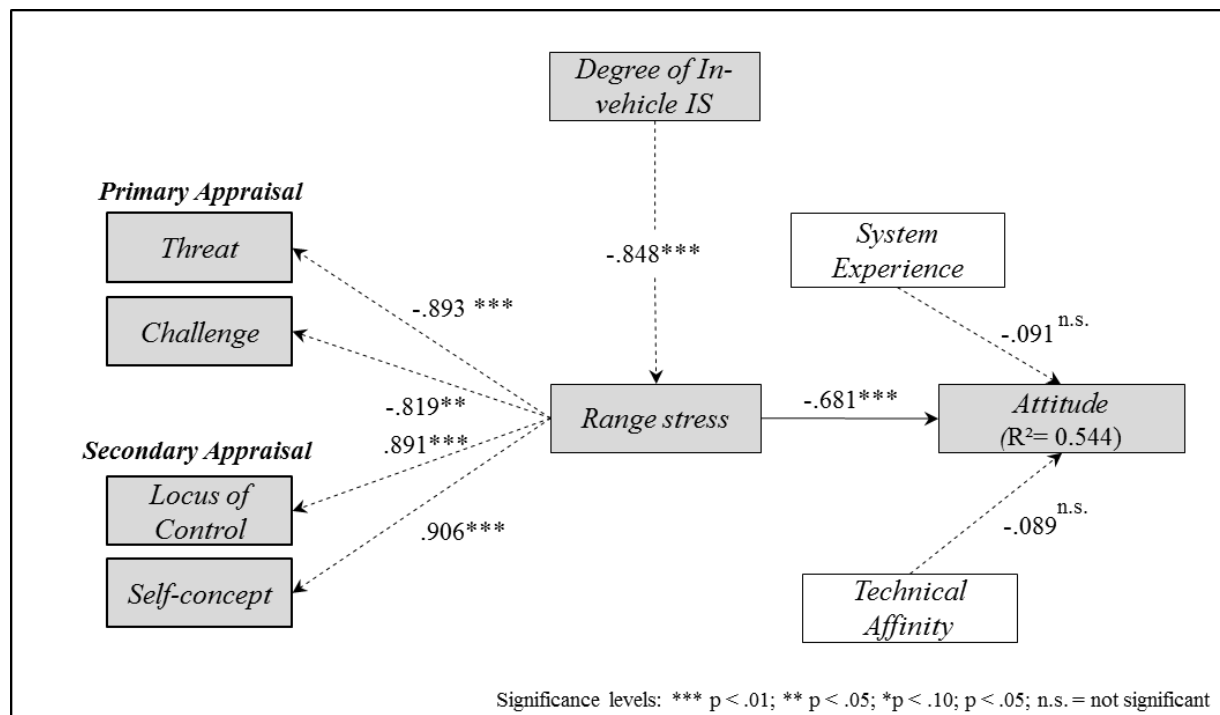
Figure C-2 Path Coefficients of the Structural Model

We applied the *indicator reuse approach* (Lohmoeller 1989; Ringle et al. 2012) to operationalize range stress as a reflective second-order construct with the subdimensions of threat, challenge, locus of control, and self-concept in the structural model. Furthermore, as the control group's vehicle encompasses both in-vehicle IS categories, we integrated the between-subjects factor as a dichotomous variable (degree of in-vehicle IS) with the categories "isolat-

ed in-vehicle IS" (encompassing participants of the group of geo IS and monitoring) and "combined in-vehicle IS" (encompassing participants of the control group). PLS regression analysis reveals a significant negative effect for the degree of in-vehicle IS (b = -.848, p < .01) on perceived range stress. Furthermore, while the analysis could reveal a significant negative effect of perceived range stress (b = -.681, p < .01) on attitudes toward using an EV, system experience (b = -.091, p > .10) and affinity for technology (b = -.089, p > .10) do not seem to have a significant effect on the attitude construct. Overall, the model explains 54.40 percent of the variance explained in the attitudes toward using an EV. According to Chin (1989), this result indicates an above-average explained variance.

1.6   Discussion

First, the results show that individuals perceived less psychological range stress when provided with information systems of the geo IS category compared to the control group. A closer look at the subdimensions of the stress process indicate that, systems of the geo IS category lead to a lower threat and challenge appraisal and to a higher perception of being in control over the critical range situation, as well as an increased perception in one's own competencies to manage the situation. Both primary and secondary appraisal processes are strongly dependent on the information available about a situation and the perceived degree of uncertainty that an individual relates to the situation (Jerusalem and Schwarzer 1992; Monat et al. 1972).

We explain the differences in stress perception by the degree of information accuracy that the respective information systems provide. On the one hand, all related systems in the control group's vehicle (geo IS and vehicle monitoring) provided the driver with relevant information about the critical range situation and therefore should have been able to reduce range related concerns. In this regard, previous research has suggested that the general provision of relevant information regarding the range leads to a better assessment of the critical range situation in comparison to the provision of no information (e.g., Eisel et al. 2014; Nastjuk and Kolbe 2015).

On the other hand, the range gauge as a typical feature within the category of vehicle monitoring is considered to be highly volatile in electric vehicles and thus constitutes an additional source of uncertainty (Jung et al. 2015). Most drivers do not understand which factors do influence the calculation of the remaining range. This makes it nearly impossible to assess the actual range of the electric vehicle, thus leading to uncertainty about whether the destination is reachable within the remaining range or not. Furthermore, the range gauge constitutes one

of the most important resources of information for the driver to assess the driving range of an electric vehicle (Wellings et al. 2011). It is also suggested that reliable and transparent information about the range for drivers of electric vehicles may be even more important to the driver than an increased maximal range (Franke et al. 2012b; Nilsson 2011). Ferreira et al. (2014) state that an accurate range prediction leads to a higher range autonomy and is thus useful to mitigate range stress because the driver is able to better explore the energy capacity storage of the EV.

As participants experienced a highly volatile range gauge due to, for example, variety in acceleration or elevations on the route, we conclude that participants perceived the range display to be unreliable. This is especially important as drivers tend to overestimate the actual range of electric vehicles (Birrell et al. 2014). The resulting loss of trust (e.g., Lundstroem 2014) increases the perceived uncertainty about reaching the final destination within the remaining battery capacity and thus constituting the trip as more challenging and threatening. On a related note, Nastjuk and Kolbe (2015) emphasize that challenge and threat appraisals concerning the critical range situation are potentially provoked by the anticipated disadvantages due to a missing appointment or the concern of getting stranded in an uncomfortable situation (e.g., alone on an empty road).

In contrast, a separate provision of systems from the geo IS category makes the driving task less challenging and threatening as the navigation system decreases uncertainty over, for example, the risk of losing one's way to the final destination. Moreover, the displayed information regarding local charging possibilities enables the individuals to detect alternative actions in critical range situations, thus strengthening their own abilities to realize solutions in case of range problems. In that regard, Nilsson (2011) states that electric vehicle drivers feel more confident when enough charging opportunities are displayed on the navigation system. In addition, drivers equipped with systems of the geo IS category were not permanently confronted with the remaining range, thus creating a lower awareness about the potential critical range situation. While a navigation device helps the driver to locate nearby charging stations and thus contributes to the driver's ability to counteract critical range situations, a range gauge increases the driver's perceived inability to predict the actual remaining range due to the gauge's high volatility, thus not supporting the driver's self-concept of his or her own abilities.

According to Gulian (1989), driver stress occurs in situations in which the driver has only limited control. On a related note, Fuller (2005) states that the more difficult a driving task becomes the more the driver perceives that s/he may lose control over the driving task. Due to proposed alternative navigation options to local charging stations or further points of interests, the perception of being in control over the critical range situation rises. In contrast, if the range display does not provide alternative fallback procedures when it comes to an uncomfortable situation, this triggers, as mentioned above, the driver's awareness about a critical range situation. Moreover, research has found that drivers spend on average 4.3 percent of their time checking the information systems provided within vehicles (Birrell and Fowkes 2014). We assume that drivers spend more time checking the range gauge since they are not familiarized with highly volatile range feedback. This monitoring activity imposes an additional cognitive load on the driver as it relies on valuable resources that the driver needs for the actual driving task (Baumann et al. 2008). This might lead to driver distraction and hence increase the risk of having an accident (Bruyas et al. 2008; Pettitt et al. 2005). However, the experience of such distractions may lead to a perceived loss of control over the situation and thus weaken the locus of control.

Focusing on the differences in stress perception between the control group and the vehicle monitoring group, another intriguing finding in our study was that drivers also perceived more psychological range stress when provided systems from both categories. This was actually surprising as we expected that the additional provision of a navigation device and a display of local charging stations would alleviate range-related concerns.

As discussed above, the range gauge is highly volatile, so the driver is not able to predict the actual range of the electric vehicle. Thus, we assume that the participants paid more attention to the range display than to the systems of geo IS. Existing research discusses a widely observed phenomenon in which individuals feel stressed when interacting with information and communication technologies. Referred to as 'technostress', it is defined by Weil and Rosen (1997) as "any negative impact on attitudes, thoughts, behaviors, or body physiology that is caused either directly or indirectly by technology." One main reason why individuals perceive stress from interactions with information and communication technologies is the risk of information overload (Ragu-Nathan et al. 2008). Transferred to our research context, participants of the control group were exposed simultaneously to multiple information streams. According to Hollnagel et al. (2003), a variety of semi- and fully automated systems within the vehicle forces the driver to pay attention to several tasks at the same time and to hence com-

pete with these systems. Meanwhile, interacting with the in-vehicle IS substantially accounts for information overload in the driver as it draws on the same cognitive capacity as the driving task itself (Bach et al. 2009). Regan et al. (2009) point out that redundant information inside the vehicle has the especial potential to distract, confuse, and overload the driver. Translating this statement to fit our context, the volatile information provided by the range gauge was redundant for the driver and thus represented a potential source of confusion, distraction, and overload that might additionally reinforce the perception of range stress.

In summary, our results indicate that participants equipped with systems of the geo IS category perceived less range stress than participants equipped with systems of the vehicle monitoring category. Supporting our assumptions, participants of the vehicle monitoring category rated significantly higher in the stress subscale threat and lower in the subscale self-concept compared to participants of geo IS category. However, we did not find a significant difference in the subscales for challenge and locus of control, but participants overall perceived less range stress when provided with systems from the geo IS category. As discussed earlier, this effect can be explained by the degree of information accuracy that the respective information systems encompass.

Regarding the influence of range stress on the attitude, our findings clearly reflected that perceived range stress led to a decreased propensity of participants to use the electric vehicle for a certain route. We explain this relationship with the affective dimension of the attitude construct. According to Ajzen (2005), the affective component of the attitude construct refers to the individual's emotions and feelings. Stress is considered a subset of emotions as it usually arises from negative emotions such as fear, anger, or anxiety (Lazarus (1993b; 2006). We conclude that the drivers connected the critical range situation with adverse emotions, thus transferring a state of feeling to the affective dimension of the attitude construct. However, although previous research studies suggest that the driver's perception of electric vehicles is dependent on experience and affinity for technology (e.g., Egbue and Long 2012; Jensen et al. 2013; Ploetz et al. 2014), we could not find a significant effect of both factors on the driver's attitude toward using an electric vehicle. One possible explanation could be a low variance within the constructs, e.g., participants had on average a high affinity for technology. Since these aspects were not the focus of our research, we suggest that this relationship be investigated in detail in further studies.

Our study makes several contributions to research and business practices. First, we have proposed a research model that enables researchers to investigate the impact of in-vehicle IS on

perceived range stress and on the attitudes of drivers toward using electric vehicles. Our results show evidence that the provision of too much in-vehicle IS might have counterproductive effects on stress perception. In addition, the results of our study indicate that a range gauge elicits range stress in the driver whereas a navigation device has a calming effect in critical range situations. This is especially important for practitioners as the appropriate provision of information to the driver may decrease range stress perception and thus contribute to a higher dissemination of electric vehicles. In that regard, the attitude construct should be considered as strongly related to intention to perform a specific behavior and the actual behavior (Ajzen 1991; Conner and Armitage 1998). Moreover, driver stress is considered to be one key factor contributing to the risk of accidents (Hollnagel et al. 2003; Horberry et al. 2006; Matthews et al. 1998).

However, the following limitations should be considered when interpreting the results of this study. First, experiments in a natural setting often suffer from a low controllability of external factors, such as the behavior of other traffic participants (Harrison and List 2004). Although we tried to minimize these effects by, for example, conducting the field tests at the same time of day, we suggest that further investigations into the impact of in-vehicle IS on range stress perception use a controlled environment with, for example, driving simulator experiments (e.g., Srinivasan and Jovanis 1997). Moreover, our study was based on a specific scenario, using an electric vehicle with a specific in-vehicle IS. We suggest validating our proposed research model by using different scenarios with different electric vehicles and in-vehicle IS. In addition, the study approaches the research question from a psychological stress perspective. Although the transactional stress model of Lazarus and Folkman (1984) has been applied to explain general IS-related stress (Galluch et al. 2015; Ragu-Nathan et al. 2008) and also served as a foundation to conceptualize range stress and to investigate its relationship to trust in the context of BEVs (Franke et al. 2016b; Rauh et al. 2015a), future research studies should also consider physiological stress measures, such as salivary cortisol levels or skin conductance (Collins et al. 1981; Riedl 2013; Van Eck et al. 1996). In addition, the research relied on the attitude construct, which is considered to be a powerful predictor of intentions and actual behavior (Ajzen, 1991, Ajzen and Madden 1986) and has also been applied to explain BEV-related reactions (Jung et al. 2015). Future research should conduct long-term field experiments to explore the relationship between range stress and actual behavior. The driver's glance behavior may also be studied to investigate which IS category is focused on by the driver (e.g., Smith et al. 2005).

1.7   Conclusion

This study investigates the influence of two main in-vehicle IS categories on perceived range stress in EVs and on the willingness to use such sustainable methods of personal transportation. Thus, we conducted an experiment with 70 participants driving a predefined route with an EV under real traffic conditions. Based on the popular transactional model of Lazarus and Folkman (1984), we developed a comprehensive research model. The results show evidence that that the provision of volatile and too much range-related information leads to an increased range stress appraisal. Moreover, the results show that the attitude toward using EVs decreases when a higher level of range stress is experienced. The study contributes to research and practitioners in the field of human behavior, IS, and EVs.

2   Inaccuracy Versus Volatility – Which is the Lesser Evil?

Table C-6 Fact Sheet of Study No. C2

Title	Inaccuracy Versus Volatility – Which is the Lesser Evil in Battery Electric Vehicles?
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Outlet	Transportation Research Part F: Traffic Psychology and Behaviour
Abstract	Due to the limited range of battery electric vehicles, research has emphasized a frequently observed dimension of driver stress referred to as a concern of becoming stranded due to a depleted battery known as range stress. It has been suggested that the appropriate provision of range-related information through in-vehicle information systems constitutes a promising solution to overcome range stress. However, drivers often struggle to understand the influencing factors of the displayed range in battery electric vehicles and thus lose trust in the range estimation. Building on field experiments in real traffic situations, we aim to investigate the influence of two range gauges typically present in battery electric vehicles, which differ in terms of information accuracy and displayed volatility, on the perception of trust in the estimates, range stress, and acceptance of battery electric vehicles. We found that displaying accurate but volatile range information results in higher perception of range stress, a lower feeling of trust in the range estimate, and lower attitude towards using a battery electric vehicle in comparison to the provision of less accurate but less volatile range information. *Keywords: Battery Electric Vehicles, Range Stress, Trust, In-Vehicle Information Systems.*

2.1   Introduction

2.1.1   Background and Related Work

Given the considerable amount of environmental pollution caused by the transportation sector, battery electric vehicles (BEVs) are considered to be a promising solution to the reduction of carbon emissions by road transport (Capros et al. 2012; McCollum et al. 2014; Thiel et al. 2010). However, the widespread adoption of these vehicles is still low because of the high purchasing costs, the underdeveloped charging infrastructure and the limited driving range (Buehler et al. 2014; Egbue and Long 2012; Wallis and Lane 2013; Zhang et al. 2014).

With regards to the BEVs limited range, research emphasizes on a widely observed phenomenon in which drivers of BEVs experience range stress due to the "continual concern and fear of becoming stranded with a discharged battery in a limited range" (Tate et al. 2008). The phenomenon of range stress can be seen as a specific form of psychological stress caused by the driver's perceived insufficient available range and personal resources to manage a present or an anticipated critical range situation whereby the user experience of the driver might be influenced negatively (Franke et al. 2016a). Following Rauh et al. (2015a), range stress can be expressed on four different levels, as derived from the area of general anxiety and stress. On the cognitive level it can lead to negative thoughts about the range situation, e.g., not reaching the designated destination, while on the emotional level, changes in affect can result in nervousness or fear. Specific behavioral activities, e.g., frequently checking the range displays or finger tapping can occur on the behavioral level, whereas an increased heart rate or respiration is assumed to be caused by increased arousal on the physiological level.

From a psychological point of view, research has proposed a variety of factors suitable to mitigate range-related concerns, for example, knowledge of BEV technology, route familiarity or control beliefs in dealing with technology (Franke et al. 2016b). Franke et al. (2016a) examine personal resilience factors, which may decrease range stress for everyday users of BEV. Besides factors such as range-related personal tolerance, experience with BEVs is also assumed to decrease range stress. Rauh et al. (2015a) arrived to similar results, emphasizing that experience with BEVs decreases range stress.

Despite these psychological factors, another promising solution to overcoming range stress is seen to be in the appropriate delivery of information by in-vehicle information systems. Eisel and Schmidt (2014) propose a conceptual framework to emphasize the value of information systems in order to reduce range-related concerns. In-vehicle information systems of the cate-

gories *vehicle monitoring* and *geo information system and navigation* are proposed to mainly influence the perception of range stress. Vehicle monitoring systems provide the driver all relevant information about the status of the vehicle (e.g., speedometer or range gauge), while the category of geo information system and navigation include, for example, the global positioning system or traffic information system to provide relevant information to the driver on the trip (Brandt 2013).

Based on these categories, Eisel et al. (2014) could show, in a mental simulation experiment, that supportive in-vehicle-information systems (e.g., intelligent navigation device for calculating the most energy-efficient route to the final destination, systems that automatically reserve charging points, or systems that suggest alternative means of transportation in case the BEV is not able to reach the final destination) are generally suited to decrease range stress and thus increase the acceptance of electric vehicles. Nastjuk and Kolbe (2015) arrived at similar results but emphasize, at the same time, the potential danger of advanced in-vehicle information systems, as the interaction with such technologies may elicit stress reactions in drivers of BEVs due to, for example, information overload.

Moreover, research in the area is concerned with improvements regarding range displays in BEVs, as the calculation of the distance to empty is still considered as insufficient (Birrell et al. 2014; Rodgers 2013). The range estimation in BEVs can be considered as an automated system (see also Franke et al. 2015) that "actively selects data, transforms information, makes decisions, or controls processes" (Lee and See 2004). Displayed inaccuracies of automated systems, for example, providing unreliable and fluctuating information, usually adversely affect the trustworthiness and the related usage behavior (Hoff and Bashir 2015; Kantowitz et al. 1997). Sudden displayed range volatilities, up to 20 percent in BEVs, stops the driver from understanding which factors influence the actual remaining range in BEVs and thus might elicit a general low trustworthiness and lower utilized range (Lundstroem 2014; Franke et al. 2015; Wellings et al. 2011). Franke et al. (2016b) showed that trust in digital displayed range information of BEVs and range-related concerns are negatively associated.

It has been suggested that knowing about insufficiencies in automated systems can be useful in increasing the trustworthiness (Cook and Thomas 2005; Dzindolet et al. 2003) and that it is important to provide the user reliable information regarding the probabilities of inaccuracies in automated systems to increase trust and decision quality in certain situations (e.g., Beller et al. 2013; Joslyn and LeClerc 2012; Kay et al. 2016). Moreover, design features, for example,

appearance, ease of use, or transparency, can influence the trust towards these systems (Hoff and Bashir 2015).

In order to improve the understanding of the remaining range, Lundstroem (2014), for example, suggests an alternative display for the remaining range, based on different speed levels, to help the driver understand the correlation between speed and remaining range. Jung et al. (2015) suggest that it is useful to present error-prone range information in BEVs ambiguously. The researchers displayed the range information to the driver in the form of a diffuse color band that varies in width directly with remaining range and showed that it might lead to a general higher trust in BEVs.

Another approach to counteract the inaccurate calculation of the remaining range is the integration of additional information in the range estimation algorithm, for example, temperature, topography, traffic conditions, route optimization or elevation profile (e. g. Neaimeh et al. 2013, Pichler and Riener 2015, Rui and Lukic 2011, Zhang et al. 2012). Rodgers et al. (2013) suggest a multivariate linear regression based model for reducing the failures in the distance to empty calculation. However, such approaches are incapable of ensuring high prediction accuracy in every situation, as even the most promising algorithm cannot account, for example, for the driver's sudden decision to use an alternative route to the final destination (Jung et al. 2015).

2.2 Research Objective

While the provision of range-related information to drivers of BEVs are considered to be useful in overcoming range stress, the inaccurate and volatile range feedback in BEVs negatively affects the driver's confidence in BEVs, which in turn, might reinforce the perception of range stress (Birrell et al. 2014; Liu et al. 2015). As discussed above, previous research in this field mainly focuses on the improvement of range accuracy prediction and on the design of alternative concepts for in-vehicle information systems. It has been shown that in-vehicle information systems, in general, are suited to reduce range-related concerns (Nastjuk and Kolbe 2015); trust in range information positively influences user experience with mobility resources of BEVs in terms of higher usable range (Franke et al. 2015); higher trust in range information displayed by digital remaining range displays are related to lower experienced range stress (Franke et al. 2016b); and higher levels of trust in range estimation systems supports the driver's general resilience against range stress (Franke et al. 2016a).

However, despite the considerable advances in the research fields of trust in BEVs and range stress, little is known about the individual's perception of trust in range displays that are currently available in BEVs, its impact on range stress with particular focus to the psychological subdimensions of the range stress process, and the resulting consequences for the future usage of BEVs. With respect to these research gaps, the study therefore applies an exploratory approach that does not seek to test hypotheses and is commonly used when no or limited knowledge about a phenomenon exists (Aamodt 2012; Pirker 2009). We extend the existing body of knowledge by investigating the interaction between trust in digital and analogue range estimates, range stress, and the acceptance of BEVs. We focus on range displays because they constitute a central instrument in assessing the range in BEVs and thus influence the driving experience to a large degree (Jung et al. 2015). Drivers of BEVs are likely to rely more on the range gauge for estimating the range in comparison to drivers of conventional vehicles (Stroemberg et al. 2011).

To approach the research objective, we conducted experiments in real-traffic situations with 53 participants, using two specific range gauges. We compared two main range displays that are typically present in BEVs. While the digital range gauge displays the remaining range with numbers in terms of Distance to Empty (DtE), the analogue range estimation displays the State of Charge (SoC) by means of a needle. The interdependency between both range displays is for drivers of BEVs not as intuitive as in comparison to the relationship of the remaining driving range and fuel level in conventional vehicles (Stroemberg et al. 2011).

This study points out the importance of accounting for range gauges in BEVs, as we found that drivers of BEVs perceive a lower level of trust in the range estimate, increased level of range stress, and a lower attitude towards using BEVs when provided with accurate but volatile range information in comparison to less accurate but less volatile range information. These results become important especially because an inappropriate provision of range-related information might hinder the transformation of transportation into becoming a low carbon, sustainable one, due to a low acceptance of these vehicles. Concerning this matter, psychological stress is also considered to be a primary culprit in numerous mental and physiological health problems (e.g., Richardson et al. 2012) and, additionally, increases the risk of traffic accidents (Matthews et al. 1998).

2.3   Materials and Methods

We conducted real-traffic field experiments with a between-subjects design to investigate the influence of both range displays on the level of trust, range stress and attitude towards using behavior. We developed two scenarios in which participants had to drive a BEV on a predefined route of 100 kilometers, encompassing sections of a city track, a highway, and a freeway. The BEV used in the experiments was a *Volkswagen e-up!* with an electromotor of 60kW maximum engine power that enables a maximum speed of 130 Km/h (Volkswagen 2016). Additionally, the vehicle's lithium ion battery holds a capacity of 18.7 kWh that provides an average driving range between 120-160 kilometers under normal driving conditions.

For the two scenarios, the treatments differed in terms of the provided range display. While group's 1 vehicle was equipped with a digital range gauge that displays the remaining range with numbers in terms of distance (in kilometers) to empty, group's 2 vehicle encompassed an analogue range estimation that displays the state of charge by means of a needle. Both systems vary in the degree of volatility and displayed information accuracy. The digital range gauge provides precise but volatile range information to the driver, while the analogue range gauge gives a less accurate but low volatile estimate of the remaining range to the driver (see also Birrell et al. 2014; Jung et al. 2015).

2.3.1   Participants

Data was collected between December 2015 and March 2016. Participants were recruited via announcements at university lectures and direct acquisition. To obtain a snowball sampling (Biernacki and Waldorf 1981), we furthermore asked initial participants to invite their circle of acquaintances to take part in the experiments. Participation in the experiment was voluntary, without any financial incentives. The only necessary condition was the possession of a driving license. Overall, the study draws on a sample of 56 participants, of which 3 participants had to be excluded from further analysis due to incomplete questionnaires, technical issues with the vehicle, or wrong traveling directions. Participants' age ranged from 22 to 32 years (M = 25.82; SD = 2.59), of which 33.96 percent were women. Moreover, 43.40 percent of participants own a car while 22.64 percent have direct experience with BEVs. Most participants obtained a university degree or completed the qualification for university admission. Participants were randomly allocated to the two groups by chronological receipt of registration and blocked by sex to avoid high differences in distribution in terms of gender (DtE group: 29 participants of which were 34.48 percent females; SoC group: 24 participants of

which were 33.33 percent females). Furthermore, the two groups differed slightly in terms of age (M_{DtE} = 25.75; SD_{DtE} = 2.66; M_{SoC} = 25.91; SD_{SoC} = 2.56), possession of a car (DtE group: 48.28 percent; SoC group: 37.50 percent), and experience with BEVs (DtE group: 31.03 percent; SoC group: 20.83 percent).

2.3.2 Measurements of Constructs

The Primary Appraisal Secondary Appraisal (PASA) questionnaire (Gaab 2009; Gaab et al. 2005) was used to assess the perceived range stress situation in each scenario. The PASA questionnaire refers to the transactional stress model of Lazarus and Folkman (1984) and characterizes stress by the interaction of two main cognitive appraisal processes (primary and secondary appraisal). Within the primary appraisal process, the PASA questionnaire evaluates a stressful event as either a threat or as a challenge to the individual. Contemporaneous to the primary appraisal process, the PASA questionnaire assesses two main psychological coping resources within the secondary appraisal process (see Crocker and Major 1998; Rotter 1966; Thoits 1995): self-concept of own abilities (beliefs of being able to manage a specific situation) and locus of control (perceived degree of being in control over a situation). The PASA questionnaire measures the four respective subscales of the appraisal processes on a 6-point Likert scale by four items each.

We used the 12-item trust in automated systems scale (Jian et al. 2000) to measure trust towards the respective range displays. The related questionnaire assesses on a 7-point Likert scale with 5 items relating to trust and 7 items relating to the opposite dimension of mistrust. The scale had also been used in the field of electric vehicles by previous studies (e.g., Franke et al. 2016a; Jung et al. 2015). The attitude towards using BEVs was adopted from the well-established theory of planned behavior (Ajzen 1991). We measured the attitude construct by five items on a 7-point Likert scale, as suggested by Ajzen (2002). As a manipulation check, participants were asked several questions on a 7-point Likert scale regarding the correctness of the displayed information, perceived driving behavior due to the displayed range, and usage of the provided range information.

2.3.3 Field Experiment Setting

In the first step, the BEV was prepared by the experimenter before participants reached the designated place for the experiment. The experimenter ensured that the battery of the vehicle was fully loaded. Depending on the participants' group affiliation, the experimenter prepared the dashboard of the vehicle. The dashboard of group 1's (DtE) vehicle was only displaying

the remaining range digitally in kilometers with numbers, while this display was masked for group 2's (SoC) vehicle. Instead, group 2's vehicle displayed the range information by means of state of charge with a needle (similar to the display of the fuel gauge in conventional vehicles). All further in-vehicle information systems (e.g., entertainment system, safety systems, or navigation system) remained equal for both groups.

After the participants arrived to the place of experiment, they received an introduction to using the BEV. The experimenter explained all functionalities of the vehicle with a particular focus on its differences to conventional vehicles (e.g., noiseless driving, strong acceleration, or differentiating displays in the dashboard). Participants then had to perform a test drive (10 minutes) to become familiarized with the vehicle and to avoid irritations because of inexperience with BEVs (e.g., Franke et al. 2016b; Rauh et al. 2015a). After the test drive, participants received a short questionnaire including questions on sociodemographic details (e.g., gender, age, or educational level) and experience with BEVs.

Afterwards, participants received the task of driving the BEV (without being accompanied by the experimenter) for a roundtrip of approximately 100 kilometers. Participants were told that they have to stop at two stations (first stop after approximately 33 kilometers and second stop after approximately 65 kilometers) within the roundtrip to fill out a respective in-between evaluation. The experimenter informed participants that according to the manufacturer (Volkswagen 2016), the vehicle is capable of achieving a range between 120-160 kilometers but the range may also decrease, depending on the style of driving, road conditions, in-vehicle energy consumers, or traffic conditions (e.g., Dellnitz et al. 2014; Neaimeh et al. 2013; Oliva et al. 2013). The close total distance-remaining range ratio was chosen because we intended to create a situation where range stress is likely to occur (Nastjuk and Kolbe 2015; Franke et al. 2012b). The roundtrip and the two stops were displayed by the vehicle's navigation device. Participants were shown where to stop for the in-between evaluations and how to use and interpret the navigation device. The experimenter handed over the two consecutively numbered envelopes with the questionnaires for the first and second evaluation inside and instructed the participants to open the first envelope at the first stop and the second envelope at the second stop. Moreover, participants were provided with a mobile phone in order to call the experimenter after arriving at the stops for the in-between evaluations. After the experimenter clarified all open questions, participants were asked to start the actual driving task.

After arrival at the first stop, participants called the experimenter who told them to fill out the first questionnaire (PASA questionnaire, trust, attitude towards using BEVs) and then to call

the experimenter back. When participants called back, the experimenter notified them of the termination of the experiment. Participants were debriefed and introduced to setting up the navigation device in order to get the shortest route back to the starting point. The experiments lasted an average of 2 hours and 45 minutes, for each participant, including preparation, introduction, test drive, and the driving task.

2.4   Results

To analyze the data, we used the software IBM SPSS Statistics 24. In alignment with previous research in this area (Eisel et al. 2016), we used a statistical significance level of 10 percent in due course of the analysis. Before processing the results, we checked whether participants successfully perceived the intended manipulation. The results of the manipulation check indicated a statistically significant difference with a medium effect size regarding whether participants believed that the displayed range information is displayed correctly (M_{DtE} = 3.93; SD_{DtE} = 1.68; M_{SoC} = 4.78; SD_{SoC} = 1.91; t(51) = -1.702; p = 0.09, d = 0.47) as well as a statistically significant difference with a medium effect size regarding whether participants have adjusted the perceived driving behavior due to the displayed range (M_{DtE} = 4.14; SD_{DtE} = 1.92; M_{SoC} = 2.95; SD_{SoC} = 1.73; t(51) = 2.268; p = 0.03, d = 0.65). Moreover, participants of both groups rated comparatively high on the 7-point Likert scale (M_{DtE} = 5.96; SD_{DtE} = 1.26; M_{SoC} = 5.22; SD_{SoC} = 1.91) regarding the question whether they have actively used the displayed range display for assessing the remaining range. In addition, participants also rated relatively high on the 7-point Likert scale regarding the question whether the remaining range was crucial for accomplishing the driving task (M_{DtE} = 5.44; SD_{DtE} = 2.02; M_{SoC} = 5.30; SD_{SoC} = 2.18). Hence, all participants were considered suitable for further analysis.

In the next step, we calculated Cronbach's Alpha (α) to assess the internal reliability of the scales. All constructs showed acceptable internal reliability with α>.60 (Clark and Watson 1995). To evaluate the influence of both range displays on trust and range stress, we decided to check for group differences. To select an appropriate test for assessing the differences between groups, we first tested the data for normality and homoscedasticity. The Kolmogorov-Smirnov test for non-normality showed statistically significant results for the scales threat, challenge, locus of control, and range stress, thus indicating non-normally distributed data. The scales trust and self-concept are considered to be normally distributed. The Leven's test for homogeneity of variances revealed, with the exception of the trust scale, statistically non-

significant results for all constructs, indicating homoscedasticity. The findings are summarized in the following Table C-7.

Table C-7 Results for Internal Reliability, Distribution, and Homogeneity of Variances

Constructs	Internal Reliability	Distribution (Kolmogorov-Smirnov test)		Homogeneity of Variances (Levene's test)	
	Cronbach's α	K-S Statistics	p-value	F-statistics	p-value
Threat	0.93	0.11	0.08	0.87	0.35
Challenge	0.79	0.13	0.03	0.49	0.48
Locus of control	0.88	0.14	0.01	1.28	0.26
Self-concept	0.90	0.10	0.19	0.04	0.84
Range Stress	0.67	0.14	0.01	0.13	0.72
Trust	0.98	0.08	0.20	4.35	0.04

As most of our constructs appear to be homoscedastic but non-normally distributed, we decided to apply the Mann-Whitney U test to assess the differences between groups. The non-parametric Mann-Whitney U test is especially useful for small sample sizes with non-normal distributed data (Nachar 2008). The results are summarized in the following Table C-8.

Table C-8 Group Comparison Between Both Range Displays

Constructs	DtE	SoC		Mann-Whitney U test			
	MR	MR	Δ MR	U-statistics	Z-score	Sig.	r
Threat	29.03	24.54	4.49	289.00	-1.06	0.15	0.15
Challenge	30.81	22.40	8.41	273.50	-1.98	0.02	0.27
Locus of control	26.52	27.58	-1.06	334.00	-0.25	0.40	0.03
Self-concept	20.48	34.88	-14.40	159.00	-3.39	<0.01	0.47
Range Stress	30.59	22.67	7.92	244.00	-1.86	0.03	0.26
Trust	24.28	30.29	-6.01	269.00	-1.41	0.07	0.19

Sig.: significance; r: effect size; MR: mean rank

The results reveal that participants of group 2 (SoC) perceived statistically significant less range stress compared to participants equipped with the digital (DtE) range display. We could find statistically significant differences in the subscales self-concept and challenge with medium to large effect strengths. However, the results indicate no statistically significant differences and only small strengths of effect in the subscales threat and locus of control. In addition, participants of group 2 trusted the provided range display, in a statistically significant manner, more than participants of group 1.

We ran linear regressions to explore the impact of trust on range stress with respect to the subdimensions of the psychological assessment, and the influence of trust and range stress on the attitude towards using electric vehicles. Before running the regression, we checked for the following assumptions (Berry 1993; Field et al. 2013). First, the analysis of standard residuals indicated that the data contained no outliners (standard residual minimum and maximum were between -3.29 and 3.29). Second, the tests to see if the data met the assumption of collinearity of predictor variables indicated that multicollinearity was not a concern (variance inflation factors were less than 10 for each regression). Third, the results of the Durbin-Watson test revealed that the residual terms are uncorrelated (Durbin-Watson values between 1 and 3). The histogram of the standardized residuals and the P-P plot of standardized residuals indicate normally distributed errors. Finally, the scatterplot of standardized residuals indicate linearity and homogeneity of variance.

The regression analysis revealed a statistically significant negative effect with a medium effect size of trust on range stress ($t(51) = -2.042$, $p = 0.04$, $d = -0.58$). We found a statistically significant positive effect with a medium effect size of trust on the range stress subscale locus of control ($t(51) = 1.981$, $p = 0.05$, $d = 0.56$) but no statistically significant prediction effects on the subscales threat ($t(51) = -1.628$, $p = 0.11$, $d = -0.46$), challenge ($t(51) = -1.071$, $p = 0.28$, $d = -0.30$), and self-concept ($t(51) = 1.362$, $p = 0.17$, $d = 0.38$). In addition, the results revealed a statistically significant negative effect with a large effect size of range stress ($t(51) = -5.578$, $p < 0.01$, $d = -1.59$) and a statistically significant positive effect with a medium effect size of trust ($t(51) = 2.004$, $p = 0.05$, $d = 0.57$) on the attitude towards using an electric vehicle. The results of the regression are summarized in the following Table C-9.

Table C-9 Results of the Regression

	B	SE b	ß	R^2
Trust				
Threat	-.233	.143	-.222	.049
Challenge	-.130	.122	-.148	.022
Locus of control	.254	.128	.267**	.071
Self-concept	.157	.115	.187	.035
Range Stress	-.387	.190	-.275**	.076
Attitude	.239	.119	.270**	.073
Range stress				
Attitude	-.386	.069	-.616***	.379

*$p \le 0.10$; **$p \le 0.05$; ***$p \le 0.01$*

2.5   Discussion

Although the dissemination of BEVs is considered to be crucial to achieving reductions on carbon emissions and local air pollution caused by passenger car transport, their widespread adoption as of now, is still low. One main reason for the low acceptance of BEVs is the limited range and the associated permanent concern of becoming stranded due to a depleted battery. While a promising solution to overcome range stress is seen in the appropriate delivery of range-related information by in-vehicle information systems, drivers often struggle to trust such range information, which in turn, might reinforce the perception of range stress. Thus, the widespread adoption of BEVs might be constrained before it reaches its full potential. We, therefore, experimentally explored the influence of two range gauges that are typically present in BEVs on trust, individual range stress perception, and acceptance of BEVs.

One main finding of the study is that the driver's perception of trust is different in both the range displays studied. Drivers of BEVs trusted the SoC range display more than the digital DtE range gauge. We assume that the difference in trust between both range gauges result from the degree of volatility and information accuracy. Generally, the formation of trust in automated systems such as range estimates is considered a dynamic process that is highly influenced by the provided information about a situation and the associated degree of uncertainty (Hoff and Bashir 2015). Transferred into our research context, the provided information by the DtE range gauge constitutes, on the one hand, an accurate estimate, as it reflects the remaining range in numbers. However, the provided information to the driver, on the other hand, is highly volatile due to the permanent adjustment of the range information with respect to the driver's driving behavior (e.g., due to acceleration or braking), thus transforming the accurate displayed range information into vague range information. The volatile feedback of the range information creates a certain degree of uncertainty for the driver regarding the actual remaining range and thus makes it nearly impossible for the driver to estimate the actual range of the vehicle and leads to a low trust in the gauge. Compared to the DtE range display, the SoC range gauge constitutes a rough remaining range estimate, as it displays the range-related information with a needle in terms of state of charge. However, the information provided by the SoC range display is not subjected to high fluctuations, as the needle does not react swiftly to the driving behavior. Hence, the driver is presented less accurate range information with a low degree of volatility.

The second intriguing finding of the study is that participants perceived less psychological range stress when provided with the SoC range gauge instead with the DtE display. A closer

look at the subdimensions of the stress process indicate that within the primary appraisal process, participants of the DtE group perceived the range situation as more challenging, while within the secondary appraisal process, the perception in one's own competencies to manage the situation (self-concept) was comparatively lower. Generally, both primary and secondary appraisal processes are strongly influenced by the degree of uncertainty that is associated with the provided information (Jerusalem and Schwarzer 1992; Lazarus and Folkman 1984; Monat et al. 1972). Uncertainty is characterized by an individual's inability to forecast an event with a certain degree of accuracy (Milliken 1987). Nastjuk and Kolbe (2015) refer to two main uncertainties that are linked to the limited range in electric vehicles. On the one hand, the general driving task itself constitutes a process that is characterized by many uncertainties due to, for example, sudden traffic changes, thus intensifying the critical range situation, while on the other hand a lack of reliable information provided by in-vehicle information systems reinforces the perceived uncertainty from the driving task. The range gauge constitutes a critical resource of information in estimating the difference between remaining distance and range (Wellings et al. 2011). We therefore assume that the high fluctuation of the digital range gauge leads to an increased uncertainty about reaching the destination with the given range, thus making the smooth arrival at the designated destination more challenging. In addition, the perception of one's own abilities might be weakened due to inconsistent information about a situation (Brashers 2001; Kienhues and Bromme 2011; Kruglanski 1989). With respect to the volatile feedback of the DtE range gauge, participants were confronted with highly inconsistent information that increased uncertainty and thus reduced trust in being able to manage the critical range situation. Such fluctuations may even lead to a certain degree of frustration in drivers of BEVs (Lundstroem 2014). In contrast, due to the lower volatility of the SoC range gauge, participants were less confronted with unreliable information in the first place which resulted in a lower perceived awareness about the potential critical range situation.

Focusing on the relationship between trust and range stress, our results indicate that increased levels of trust in the provided range gauges lead to decreased perceptions of range stress. Considering the subdimensions of the stress process, the negative effect of trust on range stress is mainly explained by the statistically significant positive impact of trust on the perception of being in control over the situation. Previous research suggests that trustworthiness of range information (Franke et al. 2015) and trust in BEVs (Rauh et al. 2015a) is not only crucial for a positive user interaction and experience with mobility resources but also is a resili-

ence factor against range stress (Franke et al. 2016a). Insufficient and unreliable information generally lead to a decreased ability to predict the probability of the outcomes of a certain event (Garner 1962; Lawrence and Lorsch 1967). We assume that it is difficult for the driver to rely on the information provided by the range gauges when trust in these systems is low. The perceived unreliability on the range information creates a situation of uncertainty as to whether the final destination can be reached with the given range, thus reinforcing the perception of range stress. The low trust and the related uncertainty make the driving task more difficult and hence negatively influence the perception of being in control over the situation (Fuller 2005; Hilton 1993; Nastjuk and Kolbe 2015; Penrod 2001). As drivers of BEVs often tend to overestimate the actual remaining range (Birrell et al. 2014), we assume that especially the faster lowering of the actual remaining range compared to the initial expected range leads to the perceived loss of control.

Finally, our results reveal that a lower level of trust in the range gauges and an increased level of range stress negatively influence the attitude of using BEVs. Generally, attitude towards performing a specific behavior is characterized as a three-dimensional construct, including affective, cognitive, and conative responses (Ajzen 2005; Breckler 1984). While the cognitive dimension is related to knowledge, beliefs, or thoughts about performing an action, the conative response reflects the actual tendency to perform a behavior. The affective response includes the individual's emotional state towards performing a behavior. We assume that both range stress and trust influence the affective component of the attitude towards using the BEV for the designated route. Stress is considered to be a subset of emotions, as usually adverse emotions arise from stressful states (Lazarus 1993b). A higher perception of range stress influences the driving experience negatively and thus elicits a negative affective state influencing the attitude to use a BEV in an unfavorable manner (Nastjuk and Kolbe 2015). According to Lee and See (2004), trust itself can be conceptualized as an attitude that is mainly related to the affective dimension and as that which even has the potential to influence actual behavior. The driving task is experienced as more critical if trust in the range estimates is low, thus negatively affecting the attitude of using the BEV. A low trust in the information displayed by the range gauges can also affect the trust (and hence attitude) towards the entire system linked to the range estimate (Lee and See 2004). Lee and Moray (1994) suggest that individuals chose manual control if the anticipated performance during manual control exceeds the trust in automated systems. Drawing from this assumption to suit our context, drivers might not rely on the range gauge but tend to adapt their own knowledge and experience to achieve the target

destination. This feeling of higher responsibility towards reaching the final destination might consequently lead to a higher workload and hence lower attitude towards using the BEV. However, at this point, it should be noted that not only a low level of trust, but also excess trust in automated systems can lead to misuse or disuse (Parasuraman and Riley 1997).

2.6   Limitations, Future Research, and Implications for Research and Practice

There are important implications that can be derived from our results for managerial practice and future research. The results suggest that BEV designers should consider how in-vehicle information systems, especially, range gauges affect driver's subjective perception of trust in the displays and range stress with regards to the underlying psychological appraisal processes, as both were found to influence the attitude towards using BEVs. Particularly, our results emphasize that volatile and unreliable information, as currently presented by digital range displays in BEVs, decrease the user experience. With respect to the volatility of the digital range gauge, it might be counterproductive to employ such displays in BEVs, as drivers are permanently confronted with unreliable information and hence, lose trust in the system and perceive more range stress. On a related note, Rauh et al. (2015a) emphasize that range stress is expressed on a behavioral level by frequently checking the range device. Translating this assumption to our context, the resulting cognitive strain from range stress and the additional monitoring activities captures the driver's limited cognitive resources for the driving process, and might lead to driver distraction, which is strongly linked to safety issues such as traffic accidents (Brooks and Rakotonirainy 2007; Horberry et al. 2006). It is estimated that traffic injuries constitute the eighth leading cause of death worldwide with about 1.24 million people being fatally injured every year globally (Lozano et al. 2013; WHO 2013). To counteract such adverse effects, it may be useful to present more ambiguous range information to the driver, as currently displayed by the analogue range gauge. Moreover, an improved communication of insufficiencies of range gauges, especially with focus on the probabilities of providing inaccurate information by these displays, can lead to an increased level of trust (Cook and Thomas 2005; Dzindolet et al. 2003; Kay et al. 2016), as drivers of BEVs often suffer from a lack of understanding the factors that influence the range estimate (Franke et al. 2015; Lundstroem 2014; Wellings et al. 2011). This becomes especially important because trust in a technological part of a system can be spread to the trust in the system as a whole, and also, may be transferred to trust in the designers of such systems (Hoff and Bashir 2015; Parasuraman and Riley 1997). From a broader perspective, low trust in range gauges may lead not

only to a low trust in vehicles but also may lead to a general low trust in the automobile manufacturer, thus decreasing the manufacturer's reputation. Finally, our results clearly indicate that lower trustworthiness and a resulting higher level of range stress negatively affects the attitude towards the BEV. The attitude towards using BEVs represents an important construct for predicting behavioral intentions and thus actual behavior (Ajzen 1991; Conner and Armitage 1998).

The following limitations should be considered whilst interpreting the results. First, field experiments in a natural setting generally suffer from the influence of external confounding factors, such as traffic behavior of others (Harrison and List 2004). Although we tried to minimize such effects by, for example, conducting the experiment at the same time of day, we suggest to further confirm our results by using controlled environments with, for example, driving simulators (e.g., Roenker et al. 2003). Second, due to the complexity and high time consumption of the study setup, our analysis draws on a sample size of 53 participants, thus not allowing us to generalize the results. We suggest future researchers to variate and extend the sample size to increase the predictive power of our proposed research. Third, the development of trust in in-vehicle information systems and range stress is a complex psychological process that is dependent on many further individual factors. Considering this, participants of our study were on average, young, inexperienced with BEVs, and had a higher degree of education. For example, sociodemographic factors, experience, knowledge, affinity for technology, or personality traits may also affect the perception of trust, range stress and attitude towards using BEVs (e.g., Day and Livingstone 2003; Gallo and Matthews 2003; Hoff and Bashir 2015; Jonsson et al. 2008; Nastjuk and Kolbe 2015; Rauh et al. 2015a). Such aspects certainly need similar attention as well, thus providing important avenues for future research. Fourth, our experiments build up on a specific scenario using the range gauges of a *Volkswagen e-up!*. We thus suggest applying further scenarios (e.g., alternative routes) with different range gauges displaying the state of charge and distance to empty to validate our proposed research. Moreover, we suggest investigating the development of trust perception, range stress, and acceptance over a longer period of time in a long-term field study. Lastly, although we conducted short interviews after the driving task to get a first impression of participant's perceived driving experience, the psychological causes and thoughts that lie behind the results, in detail, are outside the scope of the study. Thus, we suggest applying qualitative research approaches to expand the results of this study to gain deeper insights into the derived results. In addition, future research could focus on the observation of driver's glance behavior

(e.g., Birrell and Fowkes 2014; Smith et al. 2005) to evaluate the degree of utilization of such range devices.

2.7 Conclusion

The objective of this paper was to achieve a broader understanding of the influence of two main range gauges in BEVs referring to the display of state of charge and distance to empty on the perception of trust in the range gauges, perception of range stress, and thus the acceptance of BEVs. Drawing on a sample size of 53 participants, we conducted field experiments in a natural setting demonstrating that accurate but volatile range information as displayed by digital range gauges (DtE) lead to lower levels of trust in the range gauge, higher degree of range stress, and to a decreased attitude towards using BEVs for a certain route, in comparison with analogue range gauges (SoC) displaying less accurate but also less volatile range information. With respect to the limited range of BEVs, our findings point to the importance of appropriate provision of range information to increase the acceptance of BEVs. This becomes even more important, as range prediction algorithms cannot ensure high prediction accuracy in every situation.

D. Synthesis: On the Duality in the Effect of Information Systems on Stress

While the studies presented in Chapters B and C showed that IS can either contribute to the reduction of stress or might increase stress in the individual due to, for example, too much and volatile information, the following section aims at merging both directional effects, pointing out the importance of considering both directional effects at the same time when assessing behavioral outcomes. The study develops and validates a research model to capture both directional effects of IS on the perception of stress and the resulting consequences for behavioral outcomes in the research context of BEVs. The findings reveal that there exists a dual effect of IS on the perception of psychological stress. In this context, IS are useful in reducing range stress, while at the same time, elicit stress in users. Both directional effects are found to influence the attitude towards using BEVs.

1 The Double-Edged Sword of Information Systems

Table D-1 Fact Sheet of Study No D1

Title	On the Duality of Stress in Information Systems Research - The Case of Electric Vehicles
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Outlet	Proceedings of the International Conference on Information Systems (ICIS) 2015 (revised version, prepared for submission to the Journal of the Association for Information Systems)
Abstract	Previous research in the area of information systems (IS), stress, and behavior has emphasized either stress resulting from an inability to cope with information and communication technologies or the potential value of IS to reduce stress in certain situations. In this paper, we merge both emphases: we propose the existence of duality in the effect of IS on stress perceptions – specifically, that the use of IS may increase stress but may simultaneously be useful in overcoming stressful situations. Our results from a mental simulation experiment, using the example of battery electric vehicles (BEVs), reveal a dual effect of IS on stress perception: IS contribute to a reduction of range stress but also elicit what we refer to as technostress. This research highlights the importance of challenging the single viewpoint approach to the IS-stress relationship. *Keywords: Stress, Technostress, Range Stress, In-Vehicle Information Systems, Battery Electric Vehicle, Electric Mobility*

1.1   Introduction

The human brain has an enormous capacity to process information and perform numerous complex tasks simultaneously. Despite this tremendous processing ability, adverse conditions such as cognitive overload may lead to strain and stress (Gaillard 2008), defined by Lazarus and Folkman (1984, p. 19) as "a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being." Within the information systems (IS) community, the concept of stress has garnered popularity in association with the term technostress, which was first described by Brod (1984, p. 16) as "a modern disease of adaptation caused by an inability to cope with new technologies in a healthy manner." The use of IS poses major challenges because it requires continually increasing daily interactions, which may lead to serious negative impacts on psychological and physical health, such as increased blood pressure, depression, or frustration (Ragu-Nathan et al. 2008; Weil and Rosen 1997).

Much research on IS-related stress has focused on the causes, characteristics, and consequences of stress resulting from users interacting with IS in either organizational environments (e.g., Ayyagari et al. 2011; Ragu-Nathan et al. 2008; Riedl et al. 2012) or in private settings, such as with IS-enabled social networking services (Maier et al. 2012; 2014; 2015). Other studies have shown that IS can contribute to managing stress. Al Osman et al. (2014; 2016), for example, proposed the use of IS-enabled biofeedback to mitigate stress. Research has also shown that IS can contribute to reduced stress in other contexts. Hospitals can make use of IS for clinical decision support (Garg et al. 2005); educational institutions can utilize e-learning applications (Lohaus 2010); and in-vehicle IS can aid drivers with functions such as navigation or car maintenance (Eisel et al. 2016).

From these standpoints, IS may be useful for overcoming stressful situations or may induce stress. To the best of our knowledge, no studies simultaneously capture both perspectives. This study aims to shed light on that duality, to ultimately attempt a more precise prediction of stress-related behavioral outcomes. The outcomes could be negative, such as decreased task performance or reduced willingness to use a technology (Maier et al. 2014; Ragu-Nathan et al. 2008; Tarafdar et al. 2015b), or positive in ways that could track stress levels or reduce situation-related uncertainties (Al Osman et al. 2016; Eisel et al. 2014; 2016; Riedl and Léger 2016). We claim that these behavioral outcomes can be better predicted if we consider the simultaneous dual effects of IS on stress. We are, therefore, inspired by the following research question:

RQ: How does the dual nature of IS stress effects direct behavioral outcomes?

Based on the transactional stress model of Lazarus and Folkman (1984), we use the example of battery electric vehicles (BEVs) to develop our research model for three reasons. First, BEVs are becoming an attractive option on the path to achieving climate goals (e.g., Samaras and Meisterling 2008); therefore, the number of people driving them is expected to increase. Second, the automotive industry is undergoing a digital transformation (Gao et al. 2014; McKinsey 2014) which is expected to bring about the installation of more functional IS tools in BEVs (Abdelkafi et al. 2013; Burns 2013; Dijk et al. 2013), and thus make the interaction between driver and in-vehicle IS more complex. Third, the duality of IS stress effects seems to be observable in drivers of BEVs. On one hand, the provision of range-related information through advanced automobile IS appears to be useful for overcoming stressful situations that result from the limited driving range of BEVs (e.g., Eisel et al. 2016; Rauh et al. 2015a). On the other hand, the interaction with in-vehicle IS leads to additional work and an information overload for the driver, thus potentially leading to stress reactions (Bach et al. 2009; Osswald et al. 2012; Pauzié 2008; Ragu-Nathan et al. 2008).

To test the proposed research model, we designed a mental simulation experiment in which 341 participants drove a BEV with different in-vehicle IS configurations (simple versus advanced). Two different scenarios resulted: "simple IS" offered an in-vehicle interface with a low degree of functionality and complexity; the "advanced IS" was characterized by a higher degree of functionality and complexity. The results of our study of BEV interaction clearly support our assumption about the existence of duality in IS stress effects.

In summary, this study makes several contributions. First, we enhance the literature on stress and IS by developing a research model for the role of IS in stress reduction and stress inducement, and we investigate its effect on behavioral tendencies. We emphasize our challenge to previous research that holds a single viewpoint on the IS-stress relation, thus highlighting the importance of considering the ambivalent character of IS (Califf et al. 2015; Lauwers and Giangreco 2016). By doing so, this study extends previous research in the field of stress and IS through a theoretical and practical understanding of the relationship between IS and the respective appraisal processes of stress (Lazarus and Folkman 1984). Second, this research contributes to a better understanding of the positive and negative effects of the digital life (Hess et al. 2014), as observed specifically through the stress caused by increasing digitalization (Brandt 2013; McKinsey 2014; Weng et al. 2016; Xie and Weng 2017). Third, the study reveals a new field of application for technostress research, i.e., user stress from interaction

with in-vehicle IS. Previous technostress research has centered on organizational employees (Riedl et al. 2012), but research on average consumer technostress is also highly important (Maier et al. 2012; 2014; 2015). Thus, this study can be seen as a response to the call for more research on the "broad collection of 'negative' phenomena that are associated with the use of IT [information technology], and that have the potential to infringe on the well-being of individuals, organisations, and societies" (Tarafdar et al. 2015a, p. 161). Finally, in addition to deriving important implications for researchers, this study also supports automotive industry designers and decision makers by finding a balance between providing sufficient information to overcome BEV drivers' range-related concerns and information overload (Neumann and Krems 2016).

1.2   The Dual Effect of IS on Stress Perception

Most studies in the research field of stress and IS have focused on the causes, characteristics, and consequences of stress resulting from interaction with IS and refer this type of stress to the term *technostress* (Ayyagari et al. 2011; Ragu-Nathan et al. 2008; Riedl et al. 2012). In this context, the interaction with IS can have a "negative impact on attitudes, thoughts, behaviors, or body physiology (Weil and Rosen 1997, p.5). Tu et al. (2005), for example, shed light on the influence of computer-related stress on Chinese employees. The authors reveal that an increased level of technostress leads to a loss of productivity and an increasing rate of employee turnover. Ragu-Nathan et al. (2008) examine the influence of technostress on job-related satisfaction criteria, such as commitment to the organization or employee intention to stay. By using survey data from organizational end-users of information and communication technologies, the authors develop and empirically validate measurement instruments for technostress creators (e.g., technology complexity) and technostress inhibitors (e.g., technical support provision). In another instance, Ayyagari et al. (2011) investigate whether specific stressors (e.g., work overload) are related to certain technology characteristics – namely, intrusiveness (e.g., anonymity), usability (e.g., reliability), and dynamism (e.g., velocity of technological change). Tarafdar et al. (2011b) investigate technostress in professional sales. By integrating literature from technostress and social cognitive theory, the authors explore the relationships among technostress, technology self-efficacy, technology-enabled performance, and role stress. In a further study, Tarafdar et al. (2015b) highlight potential mechanisms for counteracting the negative impact of technology on stress. The authors reveal that building technology competence or developing technology self-efficacy and IS literacy enhancement, for example, are useful for inhibiting the negative effect of interaction with technologies. Gal-

luch et al. (2015) investigate the effect of information and communication technology (ICT)-enabled interruptions on perceived stress levels. Based on the transactional stress model of Lazarus and Folkman (1984), the authors reveal, in two laboratory experiments, that various control factors (e.g., timing control, meaning an individual's autonomy to decide when to respond to messages) can influence the relationship between ICT-enabled stressors, stress, and strain. Recent research has also highlighted the prevalence of technostress in the private setting. Maier et al. (2012) identify several networking–specific technostress creators that are determinants of exhaustion by or satisfaction with social networking websites.

Conversely, numerous indications in other literature reveal the potential positive impact that IS could have on an individual's perception of stress. Garg et al. (2005), for example, systematically review the effects of computerized clinical decision-support systems on practitioner performance and patient outcomes; the synthesis clearly illustrates the positive impact of these systems on the performance of health professionals by reducing perceived work stress. Lohaus (2010) reports on the development and evaluation of an e-learning, platform-based stress-prevention program for adolescents. The results of the study indicate a significant improvement in self-efficacy and a reduction of stress symptoms for those in the program. Riedl and Léger (2016) outline that psychophysiological methods and tools enable the monitoring of stress-related bodily processes. The researchers suggest that – based on monitored stress levels – stress can be reduced by adjusting IS design elements in real-time. Al Osman et al. (2014) propose a reference model of a *Ubiquitous Biofeedback* system. Based on the proposed reference model, the researchers developed a stress management application that monitors individuals' stress at work, revealing that the system can aid in stress diffusion. In another study, Al Osman et al. (2016) developed a game-related biofeedback system that relies on physiological inputs collected from players through biological sensors to assist players in reducing their stress levels. MacLean et al. (2013), for example, introduced a biofeedback system housed in a wearable butterfly pin which responds to stress in real-time by activating motion of the butterfly's wings to manage stress. Astor et al. (2013) successfully proposed a biofeedback-based NeuroIS tool to develop and enhance emotion-regulation capabilities in financial decision makers.

As outlined above, the relationship between IS and stress is a double-edged sword. While IS can be useful to reduce stress, user interaction with IS can cause stress. Our goal is to study the dual effect of IS on the perception of stress, using drivers of BEVs as a case study. Researchers and practitioners have pointed to a prevalent dimension of driver stress in users of

BEVs, referred to as range stress. Range stress is characterized by a concern about getting stranded due to a depleted battery and mainly results from the limited driving range of BEVs and the underdeveloped charging infrastructure (Dong et al. 2014; Egbue and Long 2012; Eisel and Schmidt 2014; Tate et al. 2008). To counteract this type of stress, users generally demand more IS in and around BEVs as compared to conventional vehicles (Nilsson and Habibovic 2013). Research suggests that presenting additional range-related information to BEV users or adjusting the design of in-vehicle IS are appropriate strategies in mitigating range stress. Ferreira et al. (2011), for example, suggest that IS providing recommendations on nearby charging locations can reduce range stress. In another study, Ferreira et al. (2014) introduced a mobile application that supports the driver in overcoming range-related concerns. The system takes into account information on reachable charging points based on previous driving behavior, electricity market details (e.g., prices), or alternative transportation opportunities (e.g., bike or car sharing). Stroemberg et al. (2011) suggest that the design of in-vehicle IS (i.e., traditionally versus innovatively designed in-vehicle IS) mainly influence the user's driving experience with BEVs. Jung et al. (2015) found that in-vehicle IS displaying the range information ambiguously improves the driving experience in critical range situations. Eisel et al. (2014) demonstrated in a mental simulation experiment that IS are generally useful for the reduction of stress resulting from the limited driving range of BEVs. These findings were confirmed through further study (Eisel et al. 2016) showing, in a field experiment, that psychological and psychophysiological range stress can be reduced by in-vehicle IS. The provision of range-related information through in-vehicle IS – in the categories of *vehicle monitoring* and *geo IS and navigation*, for example, information about energy consumption, charging opportunities, or traffic conditions – were found suitable for reducing range stress in drivers of BEVs. Generally, vehicle-monitoring systems encompass varying IS used to provide the driver with information about the status of the car (e.g., speedometers, fuel gauges, light status), while geo IS and navigation systems inform drivers about road conditions and traffic situations, and encompass technologies such as traffic information systems, or global positioning systems (Brandt 2013).

Opposite the potential benefits these systems offer to reduce stress, the BEV drivers are forced to process an increased amount of information that might lead to driver distraction, stress, and an increased risk of becoming involved in fatal car accidents (Bach et al. 2009; Harms and Patten 2003; Horberry et al. 2006; Matthews et al. 1998; Pereira et al. 2008; Sheridan 2004). The limited mental resources utilized for the primary task of driving compete with

those needed for interaction with in-vehicle IS, thus leading to an additional cognitive load (Ma and Kaber 2005; Osswald et al. 2012). Matthews and Desmond (1995) point out that the relationship between interactions with in-vehicle IS and driver stress is influenced by in-vehicle IS exploiting the limited mental resources needed for the driving task, leading to an overload and stress. The driver's available attentional resources compete with the resources needed for the interaction with in-vehicle IS, which in turn, forces the individual to allocate the mental capacity between the primary task of driving and the secondary task of interacting with in-vehicle IS. These effects are intensified in users of BEVs, as the information displayed by in-vehicle IS is often perceived as confusing, thus acting as a source of frustration, insecurity, and stress (Lundstroem 2014; Stroemberg et al. 2011; Wellings et al. 2011).

1.3   Research Model and Hypotheses Development

Based on the theoretical background discussed in the previous chapter, we derived a research model that aims to capture the dual effect of IS on the perception of stress – specifically, while IS can be useful to overcome stressful situations, the interaction with IS may simultaneously lead to increased stress perception. To do so, we apply Lazarus's transactional stress model (Lazarus and Folkman 1984).

The theoretical assumptions of the transactional stress model are based on two main cognitive processes: primary appraisal and secondary appraisal (Lazarus 1966; Lazarus and Folkman 1984). Within primary appraisal, the individual evaluates an event for his or her well-being as benign-positive, irrelevant, or stressful (Lazarus and Folkman 1984). Events appraised as irrelevant carry no implications for the individual's well-being. The differentiation between relevant and irrelevant is critical because individuals mobilize for action only when necessary. Events are appraised as benign-positive if the individual evaluates an event as positive for his or her well-being, often characterized by positive emotions such as joy, happiness, or exhilaration. Contrastingly, if an event is appraised as stressful, it is seen as either a harm (psychological damage that has already happened, e.g., bereavement), a threat (anticipated danger that has not yet taken place, e.g., anticipated thunderstorm), or challenge (difficult demands people feel confident about overcoming by effectively mobilizing personal resources, e.g., imminent examination). While threat is often related to negative emotions such as anger, fright, or anxiety, challenge may imply emotions such as eagerness or hopefulness (Lazarus 1993a; Lazarus and Folkman 1984). However, a clear distinction between challenge and threat appraisals is

difficult, as challenging situations might result in similar strain as in threatening situations including anxiety, exhaustion, or depression (LePine et al. 2005; Lazarus and Folkman 1984).

In case an event is appraised as stressful, individuals contemporaneously evaluate their resources for coping with this situation in the secondary appraisal – specifically, which solution options are available and applicable for overcoming the stressful event. The two most frequently studied personal coping resources contain two main psychological factors: internal locus of control and self-esteem (Thoits 1995). The former describes and individual's general belief that he or she is in control of a certain event (Rotter 1966). Self-esteem refers to positive attitudes toward oneself (Pearlin and Schooler 1978) and is closely linked to the self-concept that reflects both the perception of how others evaluate the self and the adoption of those others' views (Crocker and Major 1989).

Generally, psychological stress occurs when an individual perceives that their coping resources (secondary appraisal) seem insufficient to handle a situation previously appraised as stressful (primary appraisal).

We assume that IS can affect threat, challenge, locus of control, and self-concept of own abilities appraisals within the transactional stress model by providing information and, thus, either decreasing or increasing stress. Furthermore, we state that stress influences attitudes toward a specific behavior, which, in turn, influences an individual's plan to perform a specified future behavior (Ajzen and Madden 1986). We use the example of BEVs to investigate the dual effects of IS on the perception of stress and its effect on behavioral tendencies. In this context, research has emphasized a particular type of stress in drivers of BEVs, referred to as range stress. Tate et al. (2008) define range stress as the "continual concern and fear of becoming stranded with a discharged battery in a limited range" (p. 158). Range stress usually occurs in a present or anticipated critical range situation in which a misfit between range resource needs (i.e., trip lengths) and available range resources (i.e., displayed driving range) exists (Franke et al. 2016a; 2016b). The provision of relevant and accurate IS information can decrease the uncertainty of reaching the final destination with a BEV and thus reduce range stress by favourably influencing the cognitive appraisal processes (Eisel et al. 2016). However, at the same time, research has warned of the risk of stress caused by an inability to cope with in-vehicle IS in a healthy manner (technostress) due to, for example, IS complexity or information overload (Ragu-Nathan et al. 2008). Since the driving process itself requires high cognitive skills (Young and Regan 2007), the interaction with IS in BEVs poses a further workload on the driver, which, in turn, can adversely influence the cognitive appraisal processes

and hence induce stress (Bach et al. 2009; Horberry et al. 2006; Pereira et al. 2008; Sheridan 2004). The research model is illustrated in Figure D-1 below.
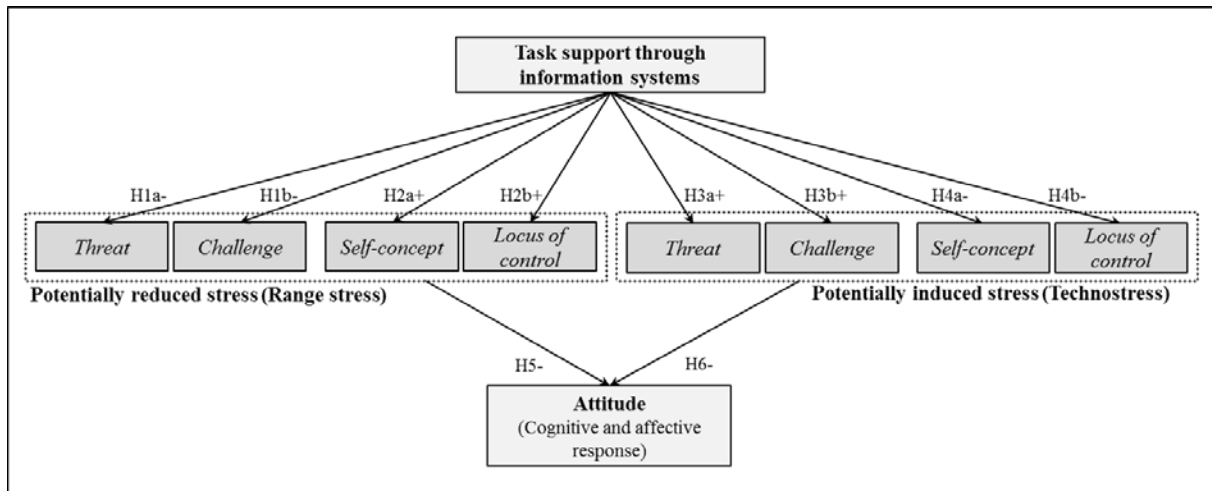

Figure D-1 Proposed Research Model

As discussed in the related work section, advanced in-vehicle IS has the potential to reduce range stress through the provision of range-related information – for example, the location of charging stations, traffic data, or estimated range based on specific data (e.g., weather or altitude). Therefore, in our study we refer to "advanced IS" as in-vehicle systems that provide additional information to the driver about, for example, the location of charging stations, estimated range, or traffic data.

Addressing the primary appraisal process of stress, several authors suggest that the amount of information available determines the perception of uncertainty about a situation and thus influences the individual's appraisal of a situation as threatening or challenging (e.g., Krohne 1997; Lazarus and Folkman 1984; Milliken 1987; Monat et al. 1972). Individuals are more likely to evaluate uncontrollable situations as threatening rather than situations over which they perceive to have control (Lazarus and Folkman 1984). In this context, anticipated future harm or loss might lead to an increased threat appraisal (Jerusalem and Schwarzer 1992). We assume that without relevant information about the distance–range ratio (provided by advanced in-vehicle IS), individuals are unable to estimate whether they will reach the final destination and hence might anticipate future harm or loss. This can be, for example, anticipated personal harm due to missing an important appointment or getting stranded with the BEV in an uncomfortable situation (e.g., at night on a highway). Moreover, according Franke et al. (2016a) and Rauh et al. (2015a), range challenge appraisals are caused by a misfit between range resources (i.e., trip lengths) and needed range resources (i.e., available driving range).

The increased task difficulty due to the additional cognitive workload imposed on the individual in managing the situation makes it more challenging to reach the final destination. In this context, task difficulty is mainly shaped by the "dynamic interface between the demands of the driving task and the capability of the driver" (Fuller 2005, p. 463). We assume that the task of driving a BEV equipped with advanced in-vehicle IS is less difficult, as individuals are provided with relevant information about the trip and hence are not required to invest additional cognitive effort regarding how to reach their destination. The provision of relevant information to the driver through advanced IS leads to a better assessment of the specific demand elicited by the critical distance–range ratio remaining, leading to a decreased task difficulty and thereby less challenge appraisal. Accordingly, we summarize our assumptions in the following pair of hypotheses:

H1a-: Advanced in-vehicle IS lead to lower range-threat appraisals.

H1b-: Advanced in-vehicle IS lead to lower range-challenge appraisals.

As explained earlier, coping options in the secondary appraisal process encompass the subdimensions of self-concept of own abilities as well as locus of control. Kienhues and Bromme (2011) argue that consistent information about a situation fosters the evaluation of one's own abilities and thus empowers individuals to feel capable of solving specific tasks. The degree to which an individual evaluates his or her own capabilities to manage a task is furthermore determined by the uncertainty of the task. In this context, the uncertainty correlates with the probability that an individual is able to foresee an event that, in turn, determines the evaluation of his or her own abilities to handle the respective situation (Babrow et al. 2000; Brashers 2001). Transferred to the context of BEVs, the provision of range-related information enables individuals to detect alternative actions for reaching their destination and hence strengthens their self-conception (Eisel et al. 2014). Moreover, uncertainty also constitutes an important part of an individual's perception of control of events (Hilton 1993). Gulian et al. (1989) point out that on a situational level, stress is induced by specific events over which the driver has only limited control. The more difficult a task becomes, the more the driver loses control over a situation (Fuller 2005). In a cross-border context, the ride in a BEV without advanced in-vehicle IS constitutes a far more difficult task than the ride with appropriate range-related information. Following this line of argumentation, we expect that the provision of information improves BEV drivers' conception of their abilities and locus of control. We establish these assumptions in the following pair of hypotheses:

H2a+: Advanced in-vehicle IS lead to higher range-self-concept appraisals.

H2b+: Advanced in-vehicle IS lead to higher range-locus of control appraisals.

Furthermore, we rely on the concept of technostress and posit that, at the same time, the interaction with IS may cause stress. Generally, the driving process constitutes a complex and challenging task that requires high levels of concentration and may result in driver tension and stress (e.g., Gulian et al. 1989; Hennessy and Wiesenthal 1999). Other stress factors can originate from the use of information and communication systems such as navigation systems or mobile phones while driving (Alm and Nilsson 1995; Schiessl 2007). In addition to primary tasks such as accelerating, braking, or changing gears, interaction with in-vehicle IS constitutes a supplementary demand that can divert the driver's attention from the road and thus exceed his or her information-processing capacity (Harvey et al. 2011). This additional attention demand can lead to distraction from traffic, resulting in an anticipated threat of getting involved in an accident (Bach et al. 2009; Cao et al. 2010; Neale et al. 2005). We assume that individuals might transfer the threat to crash to the interaction with in-vehicle IS. Moreover, the complexity of IS increases with the degree of its provided functionalities. Ragu-Nathan et al. (2008), for example, refer to the increasing complexity of technical capabilities and terminology associated with IS, fostering the uncertainty of how to use the IS in an appropriate manner. Users tend to spend more time and effort in understanding certain aspects of advanced in-vehicle IS in BEVs (Stroemberg et al. 2011). Moreover, the complexity could lead to a greater challenge appraisal in interacting with the in-vehicle IS. Matthews (2002) explains that in-vehicle IS that are complex and difficult to operate may even provoke frustration or hostility, inevitably leading to high stress reactions. Following this logic, we establish the following pair of hypotheses:

H3a+: Advanced in-vehicle IS lead to higher techno-threat appraisals.

H3b+: Advanced in-vehicle IS lead to higher techno-challenge appraisals.

Considering the secondary appraisal process, we assume that with the increasing functionality of in-vehicle IS, individuals are less confident in handling the system and perceive themselves to be less in control of the system. Ragu-Nathan et al. (2008) highlight the potential danger of information overload, as ICT use information from multiple sources, thus creating a flood of information that users are potentially unable to handle. According to Hollnagel et al. (2003), drivers must sometimes compete with semi- and fully automated IS in vehicles, paying attention to several tasks at the same time. Bach et al. (2009) point out that in-vehicle IS are a main culprits in information overload, as interaction with the system relies on the same capacity as the driving task. In this regard, Heylighen (2002) explains that information overload produces

a loss of control over a situation, as the individual's capacity for decision making is limited, thereby rendering individuals unable to consider the optimal option for resolving an associated problem. We also assume that the complexity of the advanced in-vehicle IS not only leads to a perceived loss of control but also affects the drivers' conception of their abilities negatively. The range of functionalities to which an individual is exposed via advanced in-vehicle IS may lead to a certain level of uncertainty about how to use the system and interpret the respective information, which might, in turn, lead to a decrease in self-conception. Following this logic, we summarize our assumption in the following pair of hypotheses:

H4a-: Advanced in-vehicle IS lead to lower techno-self-concept appraisals.

H4b-: Advanced in-vehicle IS lead to lower techno-locus of control appraisals.

In our study, attitude toward behavior plays an important role in predicting behavior. Ajzen (2005, p. 3) defines attitude as "a disposition to respond favorably or unfavorably to an object, person, institution, or event." Separation of the attitude construct into three main classes of responses has been widely adopted among researchers (Ajzen 2005; Breckler 1984; Greenwald 2014). In this classification, the cognitive dimension refers to the individual's knowledge, thoughts, and beliefs about performing a specific behavior; the affective component of attitude involves the individual's feelings and emotions; and the conative (behavioral) response reflects the tendency of actual behavior to occur. This classification is essential for our study because emotions (affective response of attitude) are inextricably linked to the concept of stress (Lazarus 2006; Perrewè and Zellars 1999). Lazarus (1993b) even considers stress to be a subset of emotions, as certain negative emotions, such as anxiety, shame, or anger, arise from stressful situations. Following this logic, emotions (and thus stress) influence attitude toward behavior in the following manner:

H5-: Range stress is negatively associated with attitude toward using a BEV.

H6-: Technostress is negatively associated with attitude toward using a BEV.

1.4   Research Methodology

To assess the proposed hypothesis, we designed and conducted a mental simulation experiment with a between-subjects design, using the example of BEVs. We decided to use a mental experiment for two reasons: first, it is efficient to conduct and, second, prior studies have given us sufficient indication of its applicability and effectiveness in evaluating stress and electric mobility research (Castaño et al. 2008; Eisel et al. 2014; Taylor et al. 1998).

As part of the experiment, we developed two hypothetical scenarios in which participants had to imagine a situation in which they had to drive a BEV. In both scenarios, participants were asked to pick up a friend from a railway station in a city 110 kilometers away. Since the participant's regular vehicle is in the service station, they need to rent a car through a rental car company. The rental car company can provide only a BEV (Volkswagen eGolf) with an estimated remaining driving range of 125 kilometers. The close total-distance-remaining range ratio was chosen to elicit a stressful range situation (Eisel et al. 2014; Franke et al. 2012b). Participants were told that after arrival at the railway station, they had the possibility to use another vehicle from a local car rental company for the return trip. For the two scenarios, the treatment differed in terms of the IS (simple IS vs. advanced IS) provided with the BEV.

In the scenario with simple IS, participants were presented a printed map with a suggested route and a leaflet about the BEV which included information about the energy consumption, estimated driving range when fully charged, maximum driving speed, acceleration, motor capacity, and battery-charging system. The BEV was equipped with simple IS (low degree of functionality) for the trip in terms of a dashboard that included a speedometer, an analogue distance-to-empty display, an ecometer displaying the energy efficiency while driving, and an analogue energy consumption gauge showing the energy usage by internal electric consumers.

In the scenario including advanced in-vehicle IS (high degree of functionality), participants also received the leaflet about the BEV. The BEV was equipped with advanced in-vehicle IS: a dashboard that included a speedometer, a digital remaining driving range display, an ecometer, a digital state-of-charge display, a digital range gauge displaying the distance to the closest charging station, and a digital energy consumption gauge showing the energy usage of internal electric consumers. In addition, a display in the central console of the BEV included an intelligent navigation system able to calculate the optimal (most energy-efficient) route to the final destination and an IS that determined the remaining driving range based on road conditions, weather conditions, driving style, and traffic, thus being able to suggest (under consideration of alternative charging stations) alternative routes when circumstances require. The system can provide information on available charging stations nearby and automatically reserve one of them. Another system displayed the energy consumption of internal devices and the potential driving range savings when switching off the internal consumer. Finally, participants were informed that the vehicle can propose alternative means of transportation to reach the final destination in case the battery was emptied (through the menu button in the central console).

Furthermore, to emphasize the differences between both systems, we distinguished their interface design (see Stroemberg et al. 2011); while the interface of the advanced IS was designed in a more innovative and fresh way (dashboard with digital gauges and a big display within the central console), the simple interface remained rather traditional (dashboard with analogue gauges using needles). The descriptions of both scenarios entailed rich explanations, including pictures of the car's cockpit and information provided by the IS. Each participant was to imagine the respective situation, with the goal of arousing a cognitive evaluation process (Zeimbekis 2011). No restrictions were made on whether participants had to actually use (or ignore) the provided system for the driving task.

1.4.1   *Measurement of Constructs*

To assess the cognitive appraisal processes of the anticipated stress situations, we use the Primary Appraisal Secondary Appraisal (PASA) questionnaire (Gaab 2009; Gaab et al. 2005), which refers to the transactional stress model of Lazarus and Folkman (1984). The related questionnaire assesses the cognitive appraisal processes (primary and secondary appraisal) with two subscales. Primary appraisal is assessed with the scales threat and challenge, while secondary appraisal is evaluated using the scales self-concept of own abilities and locus of control. The 16-item questionnaire uses a 6-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree). The PASA questionnaire has been used in several studies, and its applicability in the context of BEV usage has been proven (e.g., Franke and Krems 2013c; Hammerfald et al. 2006; Rauh et al. 2015a).

Furthermore, attitude toward using the BEV for the trip to the railway station was operationalized on a 7-point Likert scale, which was adopted and adjusted from the theory of planned behavior (Ajzen 2002; Francis et al. 2004). We integrated affinity for technology as well as experience with BEVs and in-vehicle IS in our research model because these factors might have an impact on attitudes toward using the BEV (Eisel et al. 2014; Franke et al. 2012a; Rauh et al. 2015a). Affinity for technology is measured by five items on a 7-point Likert scale, which we adapted in our context from a previous study of Edison and Geissler (2003). Experience related to BEVs and car-related IS are operationalized by one item each on a 7-point Likert scale. The respective measurement items are listed in the Appendix. Respondents were also required to answer certain manipulation checks on a nominal scale ("yes" or "no") to evaluate whether the provided in-vehicle IS was actually perceived, i.e., "Were you provided with a navigation system within the case study?"; "Were you provided with an intelligent route planning systems within the case study?"; "Have you taken into consideration the pro-

vided in-vehicle IS when mentally putting yourself into the situation?" Furthermore, to assess whether participants were able to empathize with the respective scenarios, we asked for responses on a 7-point Likert scale regarding whether they could imagine the respective scenario: "Based on the description of the case study, were you able to mentally put yourself into the situation?"

1.4.2   Data-Collection Procedure and Sampling

Data was collected between October 2014 and January 2015 in Germany. Participants received the scenarios and related questionnaires in paper-based form via drop-off/pick-up methodology (Steele et al. 2001). To obtain a snowball sampling, we requested the initial participants to invite their friends and acquaintances to participate in the study (Biernacki and Waldorf 1981). Participants were assigned alternatingly to both scenarios based on the chronological receipt of registration (see Eisel et al. 2016). Both scenarios were pre-tested by interviewing researchers in the area of IS and stress. The interviews led to minor changes in the wording and length of the scenarios and scales. The first part of the questionnaire included a detailed description of the respective scenario. Afterward, participants were asked to respond to the related constructs. The questionnaire ended with the manipulation check and questions regarding the participant's characteristics. In total, we excluded 15 data sets from the analysis, ending up in a total of 341 completed responses ($n_{simple\ IS} = 176$, $n_{advanced\ IS} = 165$). 12 data sets were excluded due to missing data and implausibility of demographics. In this context, 8 participants didn't answer the questions related to assessment of technostress, range stress, attitude; and 4 participants stated that their age was under 5 years and/or picked the same answer on the Likert scale for each question. 3 data sets were excluded due to a failed manipulation check, i.e., by a wrong assignment of the provided in-vehicle IS to the respective scenario, and/or the inability to empathize with the respective scenario (score lower than 3 on the empathize scale). The average respondent was 32.57 years old ($M_{simple\ IS} = 32.29$, $M_{advanced\ IS} = 32.86$). In the sample, 36.95% (simple IS = 36.36%, advanced IS = 37.58%) stated that their highest level of education completed was high school, 35.19% (simple IS = 34.66%, advanced IS = 35.76%) had a university degree, and 3.81% (simple IS = 4.55%, advanced IS = 3.03%) received a Ph.D. Females made up 42.82% of the sample (simple IS = 43.75% female, advanced IS = 41.82% female), while 53.67% (simple IS = 54.55%, advanced IS = 52.73%) of our sample stated that they owned a car. Participants rated relatively low on the 7-point Likert scale concerning their practical experience with BEVs ($M = 1.94$, $M_{simple\ IS} = 1.97$, $M_{advanced\ IS} = 1.91$). In alignment with previous research, we assume that the sample encompasses

participants particularly interested in BEVs (including potential customers), as participants were not compensated for their participation in the study (Franke et al. 2015b).

1.5   Data Analysis and Results

To analyze the data, we used partial least squares structural equation modeling (PLS-SEM), as implemented in the software SmartPLS 2.0.M3 (Ringle et al. 2005). Following the categorization of Ringle et al. (2012), we decided to operationalize stress as a multidimensional reflective-reflective second-order construct. The conceptualization of a construct as multidimensional is considered appropriate when dimensions of the constructs are distinct, but connected to the higher-level construct through a single theoretical concept (Roy et al. 2012). According to the transactional stress model of Lazarus and Folkman (1984), stress is characterized by its distinctive subdimensions. Although the subdimensions are distinctive, they are considered interrelated, i.e., threat and challenge within the primary appraisal processes and locus of control and self-concept within the secondary appraisal processes (Judge et al. 2002; Lazarus and Folkman 1984). In addition, the respective stress dimensions alone can influence the stress process, thus supporting the conceptualization of stress as reflective (see D'Arcy et al. 2014). On this account, primary appraisal (challenge and threat) and secondary appraisal (locus of control and self-concept) are conceptualized as reflective lower-order constructs of stress. In addition, the items were also operationalized as reflective measures, as they evaluate the same underlying phenomenon in the respective dimensions, have a similar content (and share a common theme within the dimensions), and the deletion of one item does not change the conceptual domain of the underlying construct (Urbach and Ahlemann, 2010). We used the indicator-reuse approach because all lower-order constructs have the same number of indicators (Lohmoeller 1989; Ringle et al. 2012). We used IBM SPSS Statistics 22 to analyze the differences between both groups.

1.5.1   Measurement Validation

In the first step, we checked the survey data for the threat of common method bias as all measures were collected through the same questionnaire. We used Harman's single-factor test to check the presence of common method bias and ran an explorative factor analysis (Podsakoff et al. 2003). The results indicated that no single factor emerged from the factor analysis and that no general factor accounts for the majority of variance among the measures. Therefore, we argue that common method bias is not of great concern to our study. Furthermore, as both stress and attitude are measured by reflective indicators, we examined content, conver-

gent, and discriminant validities to assess the quality of the respective constructs (Hair et al. 2012; Haynes et al. 1995). As discussed above, the items we used follow well-established theories and measures. We therefore argue that content validity is given. Convergent validity can be examined by calculating individual indicator reliability, composite construct reliability (CR), and average variance extracted (AVE), as suggested by Fornell and Larcker (1981). All items loaded on their respective constructs of .60 or higher, which implies an acceptable limit of indicator reliability (Chin 1998). Furthermore, the CR varies above the acceptable limit of .70 (Hulland 1999) and all AVEs also exceed the suggested limit of .50 (Bhattacherjee and Premkumar 2004). Each item loaded on its related construct higher than on other model constructs, indicating that the items represent their assigned construct better than any other construct in the model (Chin 1998). Moreover, we computed the square root of the AVEs. As these square root values are greater than the corresponding construct correlations, we can assume that discriminant validity is given (Fornell and Larcker 1981). The results are summarized in Table D-2.

Table D-2 Factor Loadings, CR, AVE, and Inter-Construct Correlations

Construct	Loadings	AVE	CR	1	2	3	4	5	6	7	8	9	10	11	12
1 Experience EV	n.a.	1.00	1.00	**1.00**											
2 Experience IS	n.a.	1.00	1.00	.504	**1.00**										
3 Range-challenge	.636-.913	.615	.861	-.028	.054	**.784**									
4 Range-locus of control	.847-.914	.782	.935	.045	-.042	-.482	**.884**								
5 Range-self-concept	.791-.847	.667	.889	-.060	-.011	-.458	.437	**.817**							
6 Range-threat	.838-.902	.780	.934	-.045	.068	.804	-.497	-.424	**.883**						
7 Techno-challenge	.633-.897	.611	.860	-.198	-.310	-.345	.322	.063	-.330	**.782**					
8 Techno-locus of control	.749-.886	.712	.908	.188	.230	.173	-.012	-.004	.102	-.417	**.844**				
9 Techno-self-concept	.820-.916	.768	.930	.209	.255	.086	-.067	.121	.034	-.546	.495	**.876**			
10 Techno-threat	.619-.864	.612	.861	-.208	-.179	.081	-.073	-.224	.146	.365	-.346	-.505	**.783**		
11 Technical Affinity	.808-.905	.739	.934	.259	.238	-.032	.061	.091	-.077	-.362	.335	.458	-.378	**.860**	
12 Attitude	.857-.930	.815	.957	.093	-.108	-.504	.467	.324	-.588	.312	-.013	-.058	-.103	.129	**.903**

AVE: average variance extracted; CA: cronbachs alpha; CR: composite reliability; bolded numbers: square root of AVE.

1.6   Hypotheses Testing

To evaluate hypotheses H1a to H4b, we decided to check for group differences. Before selecting an appropriate method for assessing the differences between both groups, we first tested the data for non-normality and homoscedasticity. The test for non-normality shows highly significant results for all variables (Kolmogorov-Smirnov test: $p < .01$; Shapiro-Wilk W-test: $p < .01$), thus indicating non-normally distributed data. Furthermore, the Leven test for as-

sessing the homogeneity of variance among groups shows significant results for the constructs attitude (F = 9.569; p = .002), range-challenge (F = 89.839; p = .000), range-self-concept (F = 5.056; p = .025), and techno-threat (F = 6.619; p = .011), thus indicating heteroscedasticity.

Since our data is non-normally distributed and heteroscedastic, we decided to apply the non-parametric Mann–Whitney U test to analyze whether both groups came from the same population (Nachar 2008). Moreover, to report a measure of strength, we calculated the approximate effect size by dividing the z-score by the square root of the sample size (Field et al. 2013). Effect sizes between .10 and .30 are regarded as small to medium, while those between .30 and .50 are considered medium to large (Cohen 1992). The results of the Mann–Whitney U test are presented in Table D-3.

Table D-3 Results of the Mann-Whitney U Test

	Simple IS		**Advanced IS**		**Mann–Whitney U test**			
	Mean	SD	Mean	SD	Mdn.	Z-score	Sign.	r
Range-threat	3.993	1.354	2.738	1.211	1.255	-8.103	0.000	0.421
Range-challenge	4.653	0.798	3.342	1.401	1.311	-8.778	0.000	0.456
Range-self-concept	3.578	1.230	4.255	1.072	-0.717	-5.367	0.000	0.279
Range-locus of control	3.062	1.334	4.295	1.059	-1.863	-8.306	0.000	0.431
Techno-threat	2.483	1.046	2.491	1.251	-0.008	-0.584	0.559	0.030
Techno-challenge	2.798	1.187	3.944	1.130	-1.146	-8.023	0.000	0.417
Techno-self-concept	4.450	1.248	4.083	1.218	0.367	-2.769	0.006	0.144
Techno-locus of control	4.439	1.173	4.017	1.164	0.422	-3.372	0.001	0.175

SD: standard deviation; Sign.: significance; r: effect size; Mdn.: difference of the mean values

The results demonstrate a significant negative effect of advanced IS on perceived range-threat and range-challenge. Furthermore, the results reveal a positive effect of advanced IS toward the range-related self-concept and locus of control. Regarding the IS-related stress perception, the results imply a significant positive effect of advanced IS on challenge and a significant negative effect of advanced IS on self-concept and locus of control. However, we could not find any significant effect of advanced IS on techno-threat.

Furthermore, to assess hypotheses H5 and H6, we examined the influence of technostress and range stress on attitudes toward using a BEV for a certain route. The bootstrapping re-sampling procedure (Chin 1998) was used to evaluate the structural path of the model. PLS regression analysis revealed a significant negative effect of both range stress and stress resulting from interaction with IS on attitude toward driving a BEV. Furthermore, the results

indicate that experience with BEVs and affinity for technology both have a significant positive effect on attitude. However, experience with car-related IS seems to have a significant negative effect on the attitude toward using a BEV for a certain route. Overall, the model can explain 40.1% of the variance in attitude, indicating an above-average explained variance (Chin 1998). The results of the PLS regression analysis are illustrated in Figure D-2.
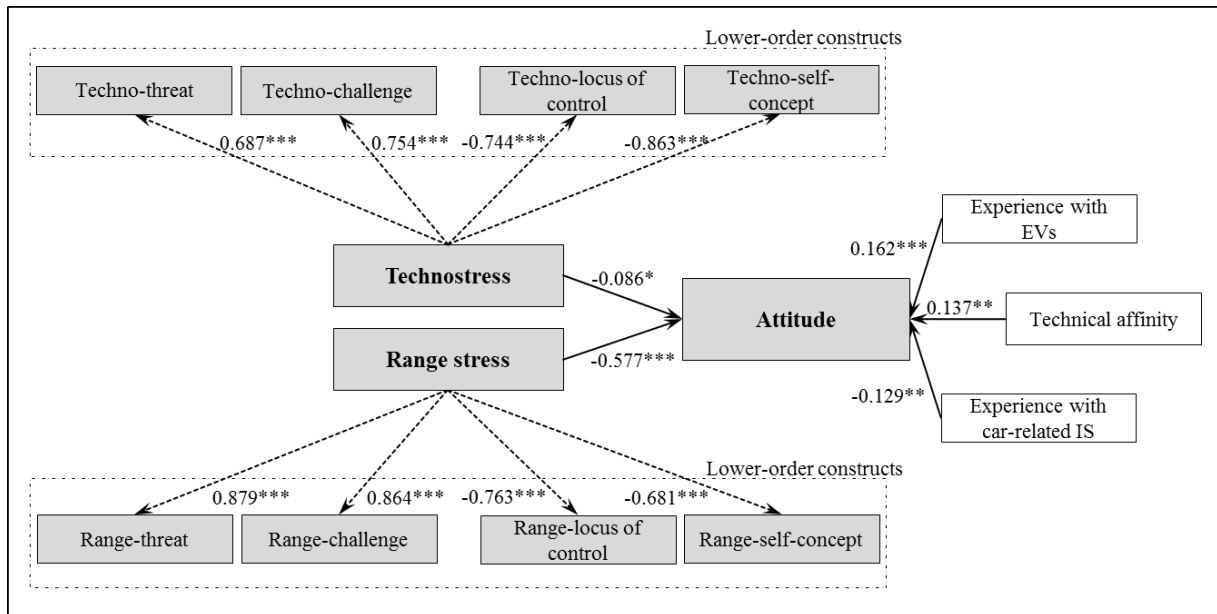

Figure D-2 Coefficients of the Structural Model

1.7   Discussion and Implications

While existing literature in IS research picks up the interdependency of IS and stress and its effect on behavior from a single perspective – either from an adverse, or more recently, a beneficial point of view – we suggest that a research gap exists on the dual effects of IS on stress and thereby on behavioral outcomes. Therefore, we propose and test a research model that integrates both perspectives simultaneously using the example of BEVs. Our results illustrate a duality in the effect of IS on stress. On the one hand, IS are useful for overcoming stressful situations, while, at the same time, the use of IS can cause stress. Moreover, we observed that stress negatively influences the attitude toward performing a specific behavior.

With respect to the beneficial point of view, a closer look at the results indicate that, compared to simple IS, advanced IS led to a statistically lower threat and challenge appraisal, and moreover, to a statistically significant positive effect on the secondary appraisal process subscales of self-concept and locus of control. This difference can be explained by the degree of information available, which determines the perception of uncertainty about a situation and thus influences the appraisal process of stress (Krohne 1997; Monat et al. 1972). With suffi-

cient information about a situation, individuals will able to predict the probability of the out-comes of certain events (Garner 1962; Lawrence and Lorsch 1967), thus making a situation less threatening and challenging. Milliken (1987) differentiates between two important types of uncertainty that can be applied in our research context. One type refers to the uncertainty created through the environment. The provision of relevant information through advanced IS can counter this effect by contributing to better prediction of unexpected environmental changes. Furthermore, Milliken (1987) points out that uncertainty is also related to the ability to predict the consequences of an environmental change for the individual. By providing context-specific information about a situation, advanced IS supports the individual to predict environmental changes, leading to a higher perception of being in control of a situation, and a higher capability of solving specific tasks.

In contrast to the positive effect of IS on perceived stress, we found strong evidence that interaction with advanced IS also leads to technostress. Our results clearly show a significant negative effect of advanced IS on the techno-challenge scale and a negative effect on techno-self-concept and techno-locus of control. Ragu-Nathan et al. (2008) identify multiple factors created by ICTs that may trigger stress. A major factor is that IS leads users to feel dependent on technology as the trend of always being connected with technology increases. Another stress factor is characterized by the increasing complexity of technical capabilities and terminology associated with IS, forcing individuals to spend more time and effort understanding certain aspects of the technology. The interaction with advanced IS may be evaluated by participants as complex, requiring effort to understand how to interpret the information provided and to grasp all functionalities of IS. Moreover, Ragu-Nathan et al. (2008) note that information and communication systems use information from a variety of sources, such as the Internet, subjecting individuals to a flood of information that they are unable to handle efficiently.

Furthermore, our findings reflect that the perception of psychological stress negatively influences the attitude towards performing a specific behavior. This can be explained by the affective component of the attitude construct, which represents an individual's feelings and emotions toward a specific behavior (Ajzen and Fishbein 2005). Because stress is inextricably linked to emotions (Lazarus 1993b), a higher stress level leads to an increased association with negative emotions and thus negatively influences the attitude construct.

Finally, the results indicate that BEV experience and affinity for technology are positively associated with the attitude toward using BEV. With increased BEV experience, drivers im-

prove the perceived fit between available mobility resources and demanded mobility needs, which in turn, leads to increased user experience with BEVs (Rauh et al. 2015a; Franke et al. 2012c). Moreover, individuals with high affinity for technology are generally favorably disposed to electric vehicles (Schuitema et al. 2013; Wesche et al. 2016). However, the significant negative relationship between experience with car-related IS and attitude toward using a BEV is surprising, as we expected that a higher degree of experience would support the processing confidence and lead to a better estimation of the functionality and value of in-vehicle IS. Since this aspect was not the focus of our research, we suggest that this relationship be investigated in detail in further studies.

The paper provides important implications for research in the field of IS and stress as well as for practitioners. In this context, the theoretical and practical usefulness of implementing IS has increasingly shifted from the organizational to the consumer context in recent years, as emphasized by McKenna et al. (2013): "Today, the development and use of IS is changing dramatically. Instead of being developed for (and used by) organizational 'users,' information systems are more and more being developed for consumers. The overriding concern when developing consumer information systems […] changes from that of efficiency and effectiveness to that of facilitating consumers' service encounter and how they experience it" (p. 248). Thus, this study contributes to the evaluation of user experience with particular focus on the relationship between stress and IS. Our research extends previous research in the field of IS and stress, as we found that both, IS-induced stress and IS-reduced stress influence behavioral outcomes, hence breaking from the single viewpoint on the stress-IS relationship (Califf et al. 2015; Lauwers and Giangreco 2016). Our proposed research model allows integration of both perspectives and can be used for further different scenarios apart from BEVs. For example, studies that focus on the effects of technostress on behavioral outcomes in an organizational context (e.g., Ragu-Nathan et al. 2008; Tarafdar et al. 2011a; 2015b) should also consider the useful effect of the implemented system to reduce stress simultaneously for general work stress. Presenting summarized information about the business process can ease decision making and the related stress of, for example, gathering and sorting all information. Considering the dual effect of IS on the perception of stress enables to better predict the related behavioral outcomes and hence creates new implications for the design of these systems. Conversely, researchers who focus on the beneficial effect of IS in reducing stress (e.g., Al Osman et al. 2014; 2016; Garg et al. 2005; Lohaus 2010; Riedl and Léger 2016) should be aware that the interaction with IS could also lead to stress, thus counteracting the intended positive effect of

IS. For example, the butterfly pin biofeedback system discussed by MacLean et al. (2013) revealed that although the system was able to increase driving performance, it also enhanced the level of perceived stress. In a similar vein, a study by Eisel et al. (2016) revealed that IS can be useful to overcome range-related stress but, at the same time, exposure to IS over time led to an increased stress perception in drivers, thus questioning whether IS are completely useful to mitigate stress. In addition, although previous studies of IS and stress, especially in technostress research, rely on the transactional stress model of Lazarus and Folkman (1984) to conceptualize stress, they have not considered in detail the impact of IS on the respective sub-dimensions influencing the stress process (e.g., Galluch et al. 2015; Ragu-Nathan et al. 2008; Tarafdar et al. 2011a). Thus, our study increases the theoretical and practical understanding of the relationship between IS and the respective appraisal processes of stress. Finally, research on technostress has largely focused on the antecedents, consequences, and characteristics of stress related to IS in the organizational context (for a literature review see, for example, Ayyagari et al. 2011 or Riedl et al. 2012). As mentioned above, the practical usefulness of IS has increasingly shifted to the consumer context. Hess et al. (2014) coins this development with the umbrella term digital life, which refers to an increased digitalization through IS in many areas of everyday life. This study contributes to the research stream by introducing a new field of application for technostress, as it revealed that the interaction with IS is not only useful to reduce stress but also can lead to stress perceptions in users of BEVs.

Although our paper has a theoretical focus, we can also gain important insights from our research for practitioners. Our research model demonstrates that the provision of relevant information in an appropriate way may decrease the perceived level of range stress and thereby contribute to a higher dissemination of BEVs. Furthermore, for a successful in-vehicle IS design, practitioners should keep in mind that the interaction with advanced automobile IS can lead to perceived stress and thus influence the attitude toward using a BEV. In this context, various factors may cause stress, such as dependence on technology, IS complexity, or information overload. The variety of functionalities provided by in-vehicle IS could also be harmful to driving safety because they constitute additional attention demands on the driver and can thus lead to distraction from traffic (Cao et al. 2010). In this context, Neale et al. (2005) find in a one-year, large-scale study that over 78 percent of traffic crashes and over 65 percent of near-crashes were caused by secondary task engagements such as interacting with in-vehicle IS. Therefore, the extent of functionalities and the design of in-vehicle IS for BEVs should on the one hand aim to maximize the benefit for the driver (e.g., provide relevant in-

formation in a timely and appropriate way to reduce sources of driver stress such as concerns related to the short range) and on the other hand minimize stress and distraction that result from interacting with in-vehicle IS. Our research model helps practitioners to overcome one of the main challenges in designing in-vehicle IS, since a gap exists between system designers and end users' perceived usefulness of information that should be presented in a vehicle (Kantowitz and Moyer 1999). In the particular usage case of BEVs, the research model enables to balance the dilemma in the in-vehicle IS design, as emphasized by Neumann and Krems (2016): "The challenge will be to provide enough information for the driver to manage the driving task and the limited range issue, but not to overload or frustrate the driver with too many information" (p. 341). By balancing this dilemma, practitioners can improve human-computer interaction – a distinguishing feature influencing vehicle buying and the value of car brands (Lisboa et al. 2016). The negative effect of stress on attitude should be highly relevant to practitioners because the intention to perform a specific behavior is considered to be influenced by the attitude toward behavior, thus determining actual behavior (Ajzen 1991; Ajzen and Madden 1986).

The following limitations should be considered when interpreting the results. First, participant's ages, knowledge about BEVs or in-vehicle IS, and level of education are likely to bias the sample. Considering this, most of the participants were young people with higher educational qualifications. An extension and variation of our sample size could increase the predictive power of our model. Second, our questionnaire was based on a specific scenario in the field of electric mobility. Using a different scenario to evaluate the proposed model might also lead to different results. Third, our results are based on self-report questionnaires that may not be free of certain response distortions (Razavi 2001). Further studies should include additional assessment methods beyond psychometric measures, such as physiological stress responses with the assessment of cortisol in saliva (Kirschbaum and Hellhammer 1994). Finally, mental simulation experiments also suffer from several limitations. First, stated preferences and actions in a hypothetical imagined situation are not identical to actual preferences and actions, as individuals often consider the actions or strategies of other individuals when stating their preferences and actions (Brandts and Charness 2000). Second, mental simulation experiments illustrate only an abstraction of the real world, as certain elements of the real world are not being presented, e.g., physical characteristics of objects (Nersessian 1992). In addition, individuals have only limited cognitive resources, thus restricting their ability to mentally reconstitute the realistic environment (Jones et al. 2011). However, we tried to counteract these

kinds of limitations, testing whether participants were able to put themselves in the respective scenario by including detailed explanations with pictures and simple language in descriptions of the respective scenarios, and by using a first-person viewpoint in the scenarios (Ludwig 2007). With respect to the limitations of mental simulation experiments in general, future research should validate the proposed research model by conducting a field experiment. As we didn't restrict participants on whether they were required to use the provided IS for the driving task within the scenarios, future research could address the relationship between technostress, range stress, and actual use of the provided IS in field experiments. In this context, research has revealed that, for example, technostress leads to a discontinuous usage intention of IS-enabled social networking services (Maier et al. 2015). Future research could also focus on the way IS should be presented in BEVs (e.g., Stroemberg et al. 2011) and which kinds of IS have an impact on different dimensions of driver stress. Apart from electric mobility, the research model could also be applied in further fields of application, such as clinical decision-support systems. The implementation of these systems may contribute to ease the decision-making process of physicians under stress but also may lead to increased stress perception (Chang et al. 2007; Garg et al. 2005; Hakkinen et al. 2003). Finally, the perception of stress is dependent on several personal factors, such as age, gender, or education (Day and Livingstone 2003; Fernandes et al. 2009; Gallo and Matthews 2003; Hall et al. 2006; Michael et al. 2009; Ragu-Nathan et al. 2008). Although these characteristics were similarly distributed between both groups (see chapter Data-Collection Procedure and Sampling), we suggest investigating such differences in future research.

1.8   Conclusion

The objective of this paper was to contribute to a better understanding of the positive and negative consequences resulting from the increased pervasion of IS in the private context (Hess et al. 2014). For this reason, we connected the research stream of technostress with that of IS-induced stress reduction. We suggest that there is a duality in the effect of IS on stress perceptions: IS can contribute to reducing perceived stress in certain situations but can also lead at the same time to stress reactions. Based on the prominent transactional stress model of Lazarus and Folkman (1984), we developed and validated a research model that integrates both perspectives. Through our example of advanced IS use when driving BEVs, we revealed that appropriate in-vehicle IS contribute to reducing range stress while at the same time eliciting stress in drivers of BEVs. Thus, we provide a foundation for further research on the duality in the effect of IS on stress.

1.9 Appendix

Construct	Items for Technostress	Items for Range Stress
Threat (α=.78/.91)	TT01: I do not feel threatened by the provided information system.*	RT01: I do not feel threatened by the relation of remaining trip distance to available range.*
	TT02: I feel uncomfortable with the provided information system.	RT02: I feel uncomfortable with the relation of remaining trip distance to available range.
	TT03: I am not worried because I do not feel threatened by the information system.*	RT03: I am not worried because I do not feel threatened by the relation of remaining trip distance to available range.*
	TT04: The provided information system scares me.	RT04: The relation of remaining trip distance to available range scares me.
Challenge (α=.79/.81)	TC01: The provided information system is important to me for the trip.	RC01: The relation of remaining trip distance to available range is important to me for the trip.
	TC02: I do not care about the provided information system for the trip.*	RC02: I do not care about the relation of remaining trip distance to available range for the trip.*
	TC03: The provided information system does not constitute a challenge for me.*	RC03: The relation of remaining trip distance to available range does not constitute a challenge for me.*
	TC04: The provided information system creates a challenge for me.	RC04: The relation of remaining trip distance to available range creates a challenge for me.
Self-Concept (α=.90/.83)	TSC01: I know how to handle the provided information system.	RSC01: I know how to handle the relation of remaining trip distance to available range.
	TSC02: I have no idea how to handle the provided information system.*	RSC02: I have no idea how to handle the relation of remaining trip distance to available range.*
	TSC03: I can think of many action alternatives for handling the provided information system.	RSC03: I can think of many action alternatives for handling the relation of remaining trip distance to available range.
	TSC04: I can think of many solutions for handling the provided information system.	RSC04: I can think of many solutions for handling the relation of remaining trip distance to available range.
Locus of Control α=.86/.91)	TLC01: I am responsible for handling the provided information system.	RLC01: I am responsible for handling the relation of remaining trip distance to remaining range.
	TLC02: Through my behavior, I can handle the provided information system.	RLC02: Through my behavior, I can handle the relation of remaining trip distance to available range.
	TLC03: I have strong influence on whether I will be able to handle the provided information system.	RLC03: I have strong influence on whether I will be able to handle the relation of remaining trip distance to available range.
	TLC04: Whether I will be able handle the provided information system will be determined by my effort and personal commitment.	RLC04: Whether I will be able to handle the relation of remaining trip distance to available range will be determined by my effort and personal commitment.
Attitude (α=.94)	Using the battery electric vehicle for the given route is bad vs. good for me.	
	Using the battery electric vehicle for the given route is unpleasant vs. pleasant for me.	
	Using the battery electric vehicle for the given route is worthless vs. useful for me.	
	Using the battery electric vehicle for the given route is harmful vs. beneficial for me.	
	Using the battery electric vehicle for the given route is nonsense vs. sensible for me.	
Technical Affinity (α=.92)	AFT01: I relate well to technology and machines.	
	AFT02: I am comfortable learning new technology.	
	AFT03: Solving a technological problem seems like a fun challenge.	
	AFT04: I find most technology easy to learn.	
	AFT05: I feel as up-to-date on technology as my peers.	
Experience BEVs	I have practical experience with battery electric vehicles.	
Experience In-Vehicle IS	I have practical experience with these types of information systems presented in the case study.	

*Reverse coded items

E. Applying the Knowledge to Sustainable Business Models

While the previous sections mainly focused on BEVs to explain the dual effect of IS on stress and the resulting consequences for behavioral outcomes, the following section goes beyond this usage case, applying the research to mobility-related sustainable business models. This section presents a study that investigates the extent to which IS-enabled sustainable business model designs affect the perception of stress and the behavioral outcomes related to the sustainable mobility service of e-car sharing. IS-supported consumption-based pricing systems influence psychological stress in an unfavorable manner due to, for example, the time pressure imposed on the user and the increased necessity to monitor the driving progress. These effects are found to reduce the willingness to use e-car sharing.

1   Too Much of a Good Thing

Table E-1 Fact Sheet of Study No. E1

Title	Too Much of a Good Thing? An Experimental Investigation of the Impact of Digital Technology-enabled Business Models on Individual Stress and Future Adoption of Sustainable Services
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Outlet	Proceedings of the International Conference on Information Systems (ICIS) 2016
Abstract	The pervasive diffusion of digital technologies affords the development of innovative and sustainable business models. With increased connectivity, options arise for enabling sharing-based services with pay-per-use pricing. Besides the merits that these services gather, e.g., concerning sustainability, flexibility and economics, less is known about the potential adverse impacts on individuals. Thus, we employed an experimental research design to examine how digital technology-enabled business models affect individual stress and perception concerning the future usage of these services. Specifically, we investigated the context of car sharing, a service that has recently been advanced by the use of digital technologies and received increasing adoption rates. The empirical results indicate that digital technology-enabled business model designs significantly influence psychological stress in an unfavorable manner, and hence, negatively affect the willingness to use car sharing. Thus, our investigation points to the importance of accounting for potential dysfunctional societal effects of information systems in sustainability transformation. *Keywords: Stress, Business Model, Sustainability, Digital Technologies, Car Sharing*

1.1   Introduction

Pervasive connectivity has widened the solution space for business model innovation in various areas (Bharadwaj et al. 2013). Emerging digital infrastructures (Tilson et al. 2010) provide the backbone for new services that cater to individuals' personal lives (Yoo 2010). Moreover, these innovative services bear the potential to reduce the negative environmental impacts of conventional alternatives by enabling a better utilization or shared use of resources (Teubner and Flath 2015; Wagner et al. 2014). Recent research has shown that through the use of digital technologies (Bharadwaj et al. 2013), the attractiveness of these sustainable business models can be increased (e.g., Hildebrandt et al. 2015). For instance, an alternative mobility service known as *car sharing* can be leveraged, e.g., through increased reliability and flexibility for users stemming from the advanced connectivity (Hildebrandt et al. 2015). Moreover, with the resulting constant availability of information, actual usage behavior can be tracked and priced, providing much more transparency and optimization potential to providers (Wagner et al. 2014). Thus, as exemplified with this example, by the use of information systems (IS), environmentally sustainable business models can be enhanced for both customers and providers. By doing so, an important contribution to overall sustainability can be made (Boons and Luedeke-Freund 2013; Schaltegger et al. 2012). Consequently, the IS community has started to investigate these business models euphorically (e.g., Teubner and Flath 2015). However, the adverse effects that might result for individuals when these digital technology-enabled potentials are realized in business model designs are less understood.

Characteristic research of these IS-enabled sustainable services has delineated that digital technology usage carries distinct features in business model design known from the digital space. This especially holds true for consumption based pricing (Knote and Blohm 2015). However, constant monitoring and pay-per-use pricing systems may induce individual stress, which in turn, may negatively affect the future willingness to use such innovative sustainable services at all. Hence, if this "dark side" of IS support is not considered appropriately, a negative effect may occur in regards to the further success of sustainable business models, and ultimately, on the sustainable development of society. Recent research has begun reflecting on the potential adverse effects of the digital transformation of business models (Galliers et al. 2015). Loebbecke and Picot (2015), for instance, describe potential negative impacts on employment, e.g., by big data analytics innovations partially rendering human labor and knowledge obsolete. However, there is a lack of understanding regarding the danger of deter-

ring individuals from using sustainable services by digital technology-enabled business model innovations (Veit et al. 2014).

Within the last decade, the IS research community has picked up the topic of sustainability, especially with regard to its environmental dimension (e.g., Chen et al. 2008; Elliot 2011; Jenkin et al. 2011; Melville 2010; Watson et al. 2010). Prior research has demonstrated that, for example, IS-enabled real-time feedback about energy consumption provides a beneficial effect on in-house energy consciousness and conservation behavior (e.g., Allen and Janda 2006; Faruqui et al. 2010; Oltra et al. 2013). Moreover, IS-enabled feedback about the individual's driving behavior is recognized as an effective means to change driving style in favor of environmental impacts (e.g., Dogan et al. 2014; Meschtscherjakov et al. 2009; Tulusan et al. 2012).

Besides general models based on the interaction of IS and environmental sustainable behavior (e.g., Elliot 2011), specific potentials of Green IS with regard to sensemaking and sustainable practicing are described by Seidel et al. (2013). Apart from that, recent research has pointed to the ability of IS in driving sustainable innovation (Van Osch and Avital 2010). Here, the importance in the advancement of alternative, sustainable business models and the role of IS in this regard (Hildebrandt et al. 2015) have been described and examined with reference to special instances (e.g., Teubner and Flath 2015). However, so far, research on the actual impact of IS on sustainability transformations is scarce (Malhotra et al. 2013). Moreover, as Bui and Veit (2015) highlight, prior research has primarily focused on the organizational or business level, thus neglecting the individual level of analysis. Here, e.g., in the case of car sharing, although IS usage enables increased flexible usage of sustainable services for individuals (Hildebrandt et al. 2015), it may set individuals under pressure to save time and money during their trips, thus inducing driver stress. In that regard, researched associated stress caused by an individual's inability to cope with IS in a healthy manner is described by the term technostress (Brod 1984). Weil and Rosen (1997) conceptualize technostress as "any negative impact on attitudes, thoughts, behaviors, or body physiology that is induced either directly or indirectly by technology." Technostress can be experienced, for example, due to increased dependency on technology, information overload, or increased complexity of technology (Ragu-Nathan et al. 2008). Despite the numerous physiological and mental health problems caused by psychological stress, such as heart disease, depression, sleeplessness, or burnout (Avey et al. 2003; Marin et al. 2011; Richardson et al. 2012), driver stress is also considered to be a key factor in increasing the risk of accidents (Matthews et al. 1998). In that regard,

road traffic injuries are the eight leading cause of deaths globally and will become the fifth by 2030 (Lozano et al. 2013; WHO 2008). However, psychological stress might also have a negative impact on the willingness to use innovative and sustainable services in the future. Although the influence of IS on individual stress is interesting in general (see Nastjuk and Kolbe 2015), the impact on sustainable service adoption is of special importance, bearing the ability to counteract the important potentials that IS generally have to offer for sustainability transformation (Chen et al. 2008; Vom Brocke and Seidel 2012; Watson et al. 2010).

In this study, we aim to investigate the impact of digital technology-enabled business model designs for sustainable services on the perception of individual stress and the resulting effect on the willingness to use sustainable services. The study focuses on the digital-technology enabled business model of car sharing. The business model archetype is related to B2C (business to consumer), in which the car sharing operator owns the vehicle and offers roundtrip journeys (Remane et al. 2016). Car sharing represents an instance of modern, sharing-based business models, which generally contributes to a more sustainable transport system because the use of car sharing reduces the vehicle ownership per capita among members, changes mobility patterns in a sustainability favourable manner, and therefore consumes less physical and economic resources that lead to significant enhancements in energy efficiency (Baptista et al. 2014). In this regard, we concentrate on the case of e-car sharing, i.e., car sharing with electric vehicles already identified as, under the right conditions, being more sustainable than car sharing with conventional vehicles and thus bears greater potential to contribute to sustainability transformation (Seidel et al. 2013) in general. We concentrate on dynamic consumption-based pricing systems because they are known to be an important characteristic of digital technology enabled business models for sustainable services (El Sawy and Perreira 2013; Knote and Blohm 2016). Moreover, only the deployment of digital technologies affords highly dynamic usage-based (e.g., per second) pricing systems (King and Lyytinen 2005). Furthermore, pricing systems belong to the business model aspects that affect the customer directly (Osterwalder et al. 2005). Therefore, digital technology-enabled pricing systems are an important snapshot of contemporary digital business model designs, thus offering the possibility to learn about their impact on individual's stress perception. We therefore elaborate on the following research questions:

1.   *How do digital technology-enabled pricing systems influence driver stress in car sharing?*

2.   *How does driver stress induced by digital technology-enabled pricing systems in-*
        fluence the individual's willingness to use car sharing.

To evaluate the proposed research model, we conducted experiments in real traffic situations, putting participants in the mindset of a car sharing user. In that regard, participants were each confronted with different digital-enabled pricing schemes, e.g., charging every half an hour and second-based charging. The results revealed a positive impact of digital technology-enabled pricing systems on psychological stress. Moreover, we found evidence that psychological stress is negatively associated with the willingness to use car sharing. In sum, this study makes several contributions. First, it emphasizes important potential dysfunctional consequences of increased use of IS in digital business model innovation (Fichman et al. 2014). Second, it relates these potential adverse effects to the user acceptance of sustainable services, and thus, shows the negative influences that might result for sustainability transformation. In that regard, the enhanced use of IS in the context of car sharing constitutes a new application field to be added in the research stream of technostress, as previous research has primarily focused on technostress in an organizational environment (Nastjuk and Kolbe 2015; Riedl et al. 2012). As the reach of IS, in recent years, has left the organizational sphere and entered personal lives (Tilson et al. 2010; Yoo 2010), research on the impact of IS must also account for such contexts. Finally, the study points out the importance of experiments in the business model innovation process (Chesbrough 2010), especially when innovating with digital technologies as, by these means, potential negative effects can be detected.

1.2   Theoretical Background and Related Work

1.2.1   *Information Systems and Business Models for Sustainable Services*

Sustainability transformation (Seidel et al. 2013) belongs to the key challenges for contemporary societies and strives at achieving sustainability with respect to its three intertwined dimensions of social, economic, and environmental sustainability (Elkington 1997). Interested in providing contributions to its solution, senior researchers from the IS community have selected this topic at the beginning of this decade, primarily focusing on the environmental dimension (e.g., Melville 2010; Watson et al. 2010). For instance, Watson et al. (2010) conceptually describe the potential of IS for the sustainable transformation of the energy domain. The authors demonstrate how the efficiency of energy systems can be increased by IS that, connected to sensitized objects, coordinate supply and demand. These initial efforts have spurred academic interest in the role of IS for environmental sustainability, referred to as

Green IS (Malhotra et al. 2013). In general, prior works have shown that IS can contribute to environmental sustainability in two ways: (1) monitoring and informing about human behavior and it's environmental consequences, and (2) enabling or enhancing new sustainable practices (Chen et al. 2008; Elliot 2011; Seidel et al. 2013). Both aspects influence human behavior and, in turn, have consequences on the individual, the environment, and society at large (Elliot 2011; Melville 2010).

Drawing on prior related works, Kossahl et al. (2012) derive a taxonomy of sustainable IS research. The authors identify that research targeting IS-enabled opportunities that contribute towards sustainable transformation in non-IS-industries, named Green by IS, can be differentiated according to the respective industrial setting, such as the energy, healthcare or the mobility sector. Due to its massive contributions to overall emissions, the mobility domain has received some attention from the Green IS research community, e.g., in the field of electric mobility (e.g., Brandt et al. 2012). Here research has, for instance, focused on optimizing vehicle routing and scheduling (Groër et al. 2009; Sbihi and Eglese 2010). Hanelt et al. (2015) described that IS in electric vehicles can increase their attractiveness, such as implementing mobile applications, providing more reliability and comfortability in vehicle usage, e.g., by easing charging processes. Besides e-mobility, Green IS research has increasingly drawn from the potentials that arise from the improved connectivity of the vehicles. For instance, Hilpert et al. (2013) develop a Green IS artifact that tracks the greenhouse gas emissions of vehicles and supports knowledge-gathering and decision-making for sustainable business practices. Furthermore, Corbett et al. (2011) investigate the connection between IS and environmental-sustainability measurement principles and suggest that IS in the form of vehicle telematics can contribute to better environmental decision-making.

Recently, the Green IS community has also expanded the focus of IS's potential to contribute to the attractiveness of alternative business models in the mobility sector carrying a lower environmental footprint (e.g., Hildebrandt et al. 2015). Prior studies in business and environmental research have pointed to the particular importance of business model innovation for sustainable development (Boons and Luedeke-Freund 2013; Schaltegger et al. 2012). They bear the potential to deploy eco-friendly technologies in an economical or alternative method of consumption, e.g., by allowing the distribution of resources among several users (Bocken et al. 2014). A central trait of these business models is providing access to resources, rather than ownership, on a pay per use base (Knote and Blohm 2016). Consequently, IS research has begun to deal with these instances. For instance, Teubner and Flath (2015) delineate the

potentials of IS to enhance the economics of ride sharing. An additional example of the potentials of digital technologies for digital business model innovation is car sharing (Fichman et al. 2014). The service is long known (Shaheen et al. 1998), but has recently gained momentum with the help of IS (El Sawy and Perreira 2013; Wagner et al. 2014). For instance, Lee et al. (2011) describe the use of mobile technology in e-car sharing. Hildebrandt et al. (2015) show that the implementation of IS in car sharing operations can attract customers by simplifying the vehicle locating process using smartphones and sensors. In a similar vein, Firnkorn and Mueller (2011) describe that digital technologies provide the necessary real-time information to leverage free-floating car sharing (as opposed to traditional station-based car sharing) business models, thus becoming a more relevant alternative for a wider range of people. El Sawy and Perreira (2013) provide a case study on the business model of Zipcar. The authors delineate that by applying digital technologies, a whole new business model became possible. A central element of digital car sharing, compared to former business models, is the tightening of the temporal pricing scheme permitted by on-board devices and connectivity.

In general, with regard to business models, with the increasing diffusion of digital technologies (Bharadwaj et al. 2013), the role and use of IS have gradually enlarged in the last decades (Merali et al. 2012) and have ultimately reached the interfaces to customers (Osterwalder et al. 2005), thus enabling enhanced value propositions of products as well new pricing systems (e.g., Desyllas and Sako 2013; Matt et al. 2015; Veit et al. 2014). Zolnowski et al. (2011) draw on the case of manufacturing business models, describing that connectivity technology "serves as an enabler for new pricing models like pay-for-performance." Through digital technologies and digital infrastructures (Tilson et al. 2010), it is possible to precisely track, measure, and eventually, price human behavior when using the respective service, e.g., in the case of dynamic insurance pricing (Desyllas and Sako 2013). Although business models comprise various different components (Osterwalder et al. 2005), Bocken et al. (2014) describe the special importance of the pricing systems regarding these "business models for delivering sustainability" stemming from the direct relation to customer behavior. This is illustrated by the case of Xerox's document management systems, which "is based on customer payment per print or copy, which could dis-incentivise printing." Although these features might enhance the economics of the sustainable service for both customer and operator, thus contributing to economic and environmental sustainability, there might emerge severe adverse effects on the individual and the society, thus harming social sustainability (Dyllick and Hockerts 2002).

Literature on both the role of IS on social sustainability as well as on the societal impacts of digital innovations is scarce (Malhotra et al. 2013). With regard to the former, existing works have predominantly focused on describing the role of IS in social reporting issues (e.g., Morhardt 2010). On the other hand, recent research has started reflecting on the potential negative effects of the digital transformation of business models (Galliers et al. 2015; Loebbecke and Picot 2015). However, the negative individual and societal impacts of increasing IS usage, especially in the context of sustainability transformation is particularly unexplored.

1.2.2   The Concept of Stress

Within our study, we conceptualize stress from a transaction-based perspective, as it emphasizes the bilateral relationship between the environment and individuals. In this context, Lazarus and Folkman (1984) propose one of the most influential stress theories by defining stress as "a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being." This definition, on the one hand, considers the specific characteristics of the person taken into account, and on the other hand, considers the property of the event that may trigger the stress reaction. Lazarus and Folkman (1987) emphasize that the transaction-based view considers the environment and the individual not as independent entities but rather as two closely intertwined subsystems. The transaction-based stress model emphasizes three main cognitive appraisal processes: primary appraisal, secondary appraisal, and reappraisal (Lazarus 1966; Lazarus and Folkman 1984). Appraisal is a process in which an individual permanently evaluates the importance of events for their personal well-being (Lazarus 1993a). Within the primary appraisal process, individuals interpret the event as either benign-positive, irrelevant, or stressful for its well-being (Lazarus and Folkman 1984). While as irrelevant appraised events carry no implications for an individual's well-being, benign-positive events occur when the result of an encounter is interpreted as positive for the well-being and are often accompanied by pleasurable emotions such as love, joy, or happiness. This separation is significant, as irrelevant and benign-positive appraisals do not trigger the stress process. Three types of stressful appraised events can be distinguished: (1) threat appraisals (anticipated future harms or losses, e.g., imminent operation), (2) challenge appraisals (challenging situation that is conquerable when efficiently mobilizing personal resources, e.g., paper submission), and (3) harm/loss appraisals (damage or loss has already happened, e.g., the loss of a loved person).

Once an individual appraises an event as stressful, s/he evaluates, within the secondary appraisal process, the coping options available for dealing with the situation. In this complex

psychological process, individuals consider which coping resources are useful to overcome the stressful situation and the likelihood that the coping strategy can be applied effectively. In that regard, the individual's competence, social support, material, and other resources are evaluated to re-establish a balance between the individual and the environment (Jerusalem and Schwarzer 1992). Thoits (1995) refers to two main psychological resources, locus of control and self-esteem, which are evaluated by the individuals in the secondary appraisal process. While the former refers to the individual's belief to be on control over a situation (Rotter 1966), self-esteem is an important concomitant of the self-concept of own abilities that is defined as the perceived ability to manage a specific situation (Crocker and Major 1998).

According to Lazarus's transaction-based view on stress, psychological stress occurs when an individual perceives that the coping resources (secondary appraisal) are insufficient to handle an event appraised as stressful (primary appraisal). In such a case, the individual puts "cognitive and behavioral efforts to master, reduce, or tolerate the internal and/or external demands that are created by the stressful transaction" (Folkman 1984). Finally, in case of environmental perception changes, a reappraisal may occur. In that regard, a situation initially appraised as irrelevant may be evaluated as stressful post processing new information from environment (Lazarus and Folkman 1984).

The transactional-based perspective on stress has also found recognition in the context of driving. In that regard, Gulian et al. (1989) refer to the transaction stress model of Lazarus and Folkman (1984) and define driver stress as a "set of responses associated with the perception and evaluation of driving as being demanding or dangerous relative to the individual's driving capabilities." Fuller (2000; 2005) emphasizes in the task-capability model that a loss of control of the situation arises when the demand of the driving task exceeds the driver's capability. In that regard, drivers compare individual coping resources (driver capability) with the confronted stressors (task demand). The resulting appraised person–environment relationship determines the amount of perceived strain (task difficulty). The person–environment balance can be affected by various dimensions, such as driver aggression, dislike of driving, irritation and frustration connected with the overtaking process, or increased alertness and concentration due to permanent monitoring of other's traffic behavior (Gulian et al. 1989).

However, recent research has also conceptualized the interaction with in-vehicle IS as a further dimension of driver stress (Nastjuk et al. 2015). In that regard, the interaction with in-vehicle systems relies on the driver's limited resources necessary for the evaluation of the current traffic situation, and thus, might lead to driver distraction and stress (e.g., Baumann et

al. 2008; Brooks and Rakotonirainy 2007; Osswald 2012). On a related note, Brandt (2013) emphasizes that the driver interacts with a variety of different in-vehicle information systems, such as convenience, communication, and entertainment systems allowing travelling to be more enjoyable, in addition to, systems that provide information about the current location of the vehicle or traffic conditions (e.g., traffic information systems and global positioning systems), monitoring systems that measure and display the current status of the vehicle, and safety and collision avoidance systems that support the driver to prevent collisions. Driver stress can be expressed in the form of emotional, physiological, and behavioral responses (Gulian et al. 1989; Matthews et al. 1991). While emotional and physiological are characterized by responses, for example, increased anxiety or heart rate, a behavioral response may lead to an adaption of an unsustainable driving behavior due to an aggressive driving style. Despite the variety of health problems associated with stress, aggressive driving behavior is a main culprit of road traffic collisions (e.g., Wickens et al. 2013). According to WHO (2013), approximately 1.24 million people die each year due to road traffic collisions.

1.3   Research Model and Hypotheses Development

In this study, we aim to investigate the impact of digital technology-enabled business model designs on individual stress and future adoption of sustainable services by using the example of car sharing. We assume that an increased level of stress induced by the digital technology-enabled pricing systems negatively affects an individual's decision to use such sustainable services. Our research model is illustrated in Figure E-1 below.
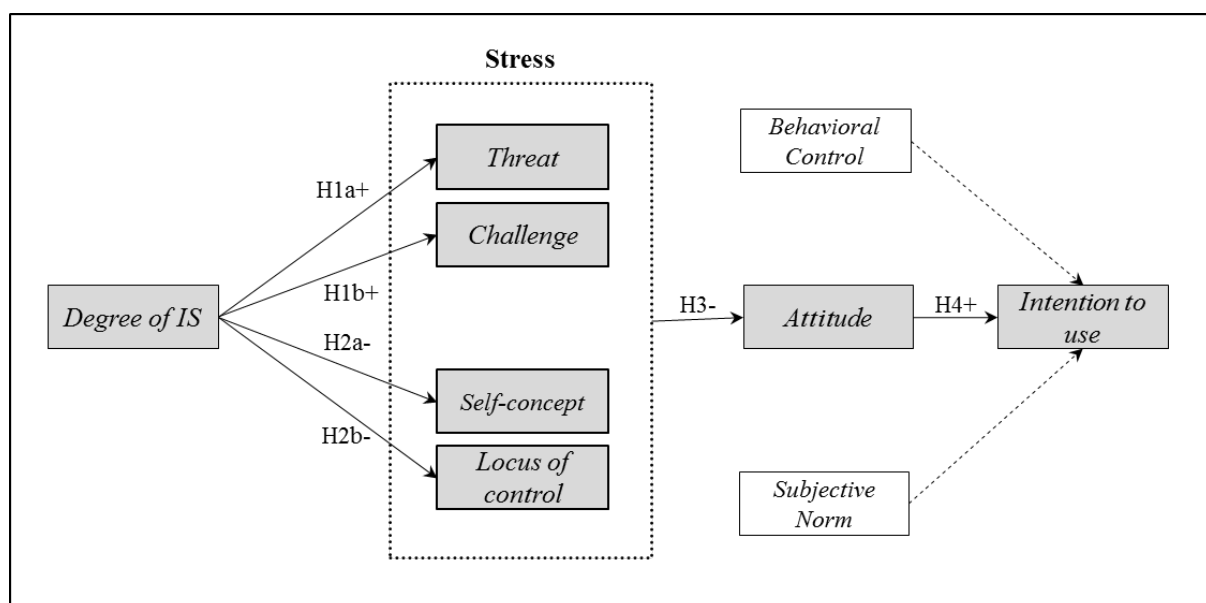

Figure E-1 Research Model

As shown in the research model, we conceptualize stress from a transaction-based perspective by relying on the well-established transactional stress model of Lazarus and Folkman (1984). In addition, the transaction-based stress model overcomes certain limitations of alternative stress explanation approaches and therefore provides a holistic view on the stress process (Krohne 2001; Levine and Ursin 1991). In that regard, stress is triggered by an imbalance between an environmental demand and the individuals coping resources. This imbalance results from the interaction between the primary and secondary cognitive appraisal processes. The respective chosen constructs (challenge, threat, self-concept of own abilities, and locus of control) were chosen because they have been shown to be strong determinants within the primary and secondary appraisal process (Gaab et al. 2009), particularly, in the vehicular context (Eisel et al. 2014; Franke et al. 2016b; Rauh et al. 2015a). We expect that an increased degree of IS deployment (in terms of accuracy of the digital technology-enabled pricing system) acts as a stressor and influences the constructs threat, challenge, self-concept, and locus of control in an unfavorable manner, and hence, lead to an increased stress perception.

Within the primary appraisal process, stressful events are evaluated as either challenging or threatening (we neglect the harm appraisal because it refers to previously experienced loss). In general, opposed to comparably safe environments, such as using a desktop personal computer, the driving task itself constitutes a potentially challenging and threatening situation due to the constantly changing environment (Osswald et al. 2012). The driving task on an operational level (e.g., holding the distance to other traffic participants) comprises various activities and perceptions from second to second. These tasks create a constant time pressure because the driver has only limited time for the decision-making processes (Brouwer et al. 2002). Time pressure is determined by the degree of information that an individual has to process within a given time and may lead to psychological stress and even frustration (Shinar 1998; Zur and Breznitz 1981). The digital technology-enabled pricing system creates a secondary task in addition to the driving process, as it confronts the driver permanently with information about the costs of using the car sharing service that the driver monitors. Therefore, in addition to the time pressure created by the driving task itself, we assume that the permanently displayed information about the duration and costs of using the car sharing service puts the driver even under more time pressure because s/he aims to minimize the costs by, e.g., adjusting the driving style in terms of speeding or overtaking (Adams-Guppy 1995; Katzev 2003; Millard-Ball 2005; Osswald et al. 2012). However, in addition to the primary task of driving, the secondary task of monitoring imposes a cognitive load on the driver, as it captures the driver's

valuable resources necessary for the assessment of the current traffic situation and its development (Baumann et al. 2008). As a consequence, the driver's attention may shift away from driving, which in turn increases the risk of accident (Bruyas et al. 2008; Pettitt et al. 2005). In that regard, the distraction reinforces the driving task as being more challenging or threatening. We establish our assumptions in the following pair of hypotheses:

> *H1a+: Individuals perceive to use the car sharing service as more threatening when digital technology-enabled pricing systems are provided.*

> *H1b$^+$: Individuals perceive to use the car sharing service as more challenging when digital technology-enabled pricing systems are provided.*

Within the secondary appraisal process, individuals evaluate their coping resources to manage the stressful demand. In that regard, two main psychological resources, locus of control and self-concept, are evaluated by the individuals (see Section "The Concept of Stress"). The individual's perception of the self-concept of own abilities is strongly affected by the perception of a situational factor (Fisher 1996) and might be questioned in an uncertain environment (Kienhues and Bromme 2011). Uncertainty is generally associated with the probability to forecast a situation, and influences the perception of own abilities to cope with a situation (Babrow et al. 2000; Brashers 2001). As mentioned above, the driving process itself is described by an environmental uncertainty due to, for example, the rapidly changing traffic situation. Therefore, it is nearly impossible for the driver to estimate the exact time of arrival. We argue that the time pressure created by the digital technology-enabled pricing system empowers the awareness of uncertainty about time of arrival, as an increase in travel time results in increased costs of using the car sharing service. In that regard, time pressure is reinforced with a higher level of awareness about a time-sensitive situation (Wright 1974). Supporting our assumption, a recent study of Nastjuk and Kolbe (2015) suggests that the belief in one's abilities to overcome a critical range situation in electric vehicles increases with a higher degree of environmental uncertainty.

In addition, uncertainty is highly intertwined with the perception of being in control over a situation (Penrod 2001; Whitson and Galinsky 2008). Following the same line of argumentation for the influence of the digital technology-enabled pricing system on the perception of self-concept of own abilities, we posit that uncertainty is reinforced due to a higher awareness, thus leading to a weakened belief to be in control over the situation. Prior IS research also emphasizes the risk of information overload created by information and communication technologies through a flood of information that an individual is not able to handle (Ragu-

Nathan et al. 2008). The pricing system provides an additional source of information that the driver has to interact with, apart from the plethora of information within the vehicle (e.g., Brandt 2013). According to Bach et al. (2009), information systems within the vehicle substantially account for information overload for the driver because it relies on the same cognitive capacity as the task of driving. As a result, the pricing system forces the driver to consider more information than they can effectively process, which strengthens the perception of losing control over a situation (Heylighen 2002; Wurman 2001). Following this logic, we assume that the provision of the digital technology-enabled pricing system influences the appraisal of the driver's abilities and locus of control in the following manner:

> H2a-:   *Individuals perceive their self-concept of own abilities to be weakened regarding the usage of car sharing when digital technology-enabled pricing systems are provided.*

> H2b⁻:   *Individuals perceive their locus of control to be weakened regarding the usage of car sharing when digital technology-enabled pricing systems are provided.*

Furthermore, we draw on the theory of planned behavior (TPB, Ajzen 1991), an intention-based theory that has a superior explanatory of behavior tendencies and actual behavior (Armitage and Conner 2001; Godin and Kok 1996; Krueger et al. 2000; Mathieson 1991; Pavlou and Fygenson 2006). In addition, the theory of planned behavior is open to "further exploration if further important proximal determinants are identified" (Conner and Armitage 1998, p. 1433). In this context, Ajzen 1991) states that the

> "theory of planned behavior is, in principle, open to the inclusion of additional predictors if it can be shown that they capture a significant proportion of the variance in intention or behavior after the theory's current variables have been taken into account" (p. 199).

The respective chosen constructs (attitude, intention, subjective norm, and behavioral control) constitute the main components to predict actual behavior in the theory of planned behavior (Ajzen 1991). The theory of planned behavior is additionally considered to be a suitable framework to explain mobility behavior because it comprises the central predictors (Haustein and Hunecke 2007). The TPB aims to explain the individual behavior by behavioral intentions (the individual's degree of effort to perform a specific behavior), which in turn, is determined by perceived behavioral control, subjective norm, and attitude toward behavior (Ajzen 1991). Subjective norm refers to the evaluation of social pressure from important others about per-

forming the behavior. Perceived behavioral control is defined as "the perceived ease or difficulty of performing the behavior" (Ajzen 1991). Attitude captures an individual's overall assessment of performing a specific behavior and can be classified into three main classes of responses: cognitive, conative, and affective (Ajzen 2005; Breckler 1984; Greenwald 2014). While the cognitive dimension captures the knowledge and perceptions about the intended behavior, the conative dimension refers to the likelihood to perform a specific behavior. However, the affective component reflects an individual's feelings and emotions and takes on an important role in our research context, as stress is considered a subset of emotions and usually arises from negative emotions (Lazarus 1993b; Lazarus 2006; Perrewè and Zellars 1999). According to this relationship, we posit that with an increased level of perceived stress, the attitude toward using car sharing decreases. This assumption is also supported by previous research. In that regard, Eisel et al. (2014) demonstrate, in a mental simulation experiment, that range stress negatively affects the adoption decision of electric vehicles. Nastjuk and Kolbe (2015) arrive to similar dependencies, showing evidence on the duality of stress in IS research that the attitude construct is negatively influenced by the individual stress level. Kulviwat (2007) demonstrate a substantial influence of emotional responses to consumer attitudes. Furthermore, attitude has empirically long been shown to be a predictor of behavioral intentions (Ajzen and Fishbein 1980). Following the theory of planned behavior, we assume that the attitude toward using car sharing is positively linked to the behavioral intention. We summarize our assumptions in the following hypotheses:

> $H3^-$: *Psychological stress negatively influences the attitude toward using car sharing.*

> $H4^+$: *The attitude toward using car sharing is positively associated with behavioral intention.*

1.4   Research Methodology

To test how digital technology-enabled pricing systems affect stress and perception concerning the future usage of car sharing, we performed field experiments in real traffic situations with a between-subjects design. As part of the experiment, we developed two scenarios in which participants had to drive an electric vehicle on a predefined city track of 10 km. The electric vehicle used for the experiment was a *Volkswagen e-up!* equipped with an electromotor of 60 kW maximum engine power and a maximum speed of 130 km/h. Moreover, the vehicle's lithium-ion battery holds a capacity of 18.7 kWh, which enables a driving range of

between 120 and 160 km under normal driving conditions (Volkswagen 2016). For the two scenarios, the treatment differed in terms of the accuracy of the pricing system.

1.4.1 Data-collection Procedure and Sampling

Altogether, the study draws on a sample of 69 participants. We used different recruitment streams such as social networks, announcement in lectures, and direct acquisition. To obtain a snowball effect, we also asked initial participants to invite their circle of acquaintances to participate in the experiment (Biernacki and Waldorf 1981). The possession of a driving license was the only necessary condition for participation. Each participant was randomly assigned to one of the groups (Bhattacherjee 2012). Before conducting the experiment, the scenarios were pre-tested by researchers in the field of IS and psychology. The pre-tests led to minor changes in terms of wording and design of the scenarios. Experiments were conducted at the same time of the day (afternoon) to avoid potential effects of, for example, darkness or rush hour. Furthermore, the experiments were not conducted under extreme weather conditions. Participants' age ranged from 20 to 39 years (Mean = 25.79, SD = 3.17), of which 44.9 percent were woman. Moreover, while most participants completed the qualification for university admission or obtained a university degree (84.06 percent), 44.93 percent lived in a household without a personal vehicle. An average participant spent around 28.81 min commuting per weekday for a distance of 13.36 km. Assessed on a 7-point Likert scale, the direct experience among participants with e-car sharing was relatively low (Mean = 2.26, SD = 1.99).

1.4.2 Field Experiment Setting

Before starting the experiment, the vehicle was prepared by the experimenter. In that regard, the experimenter ensured that the battery capacity for each participant was not lower than 75% (approximately remaining driving range of 90 km) in order to avoid range anxiety – stress that results from a concern of getting stranded due to a depleted battery (Nastjuk and Kolbe 2015; Rauh et al. 2015a; Tate et al. 2008). Furthermore, depending on participants' group affiliation, the vehicle was prepared with the respective digital technology-enabled pricing system. In that regard, while group 1 (24 participants) was charged every half an hour a fixed amount of 7.29 EURO, group 2 (23 participants) was charged 0.0041 EURO per second. To avoid cost disadvantages within groups, the extrapolated price of the second-based pricing was set as equal to the pricing system based on every half an hour. The chosen charging prices were close to the usual prices of local car sharing companies.

The respective pricing information was displayed to the driver *via* a self-developed application installed on a smartphone that was mounted on the vehicle's center console prior to the driving task. The application displayed the costs of using the car sharing services based on the trip duration (hours, minutes, and seconds) in real time. The vehicle used by the control group (22 participants) was not equipped with a digital technology-enabled pricing system. Instead, participants of the control group were informed in advance that their ride would be charged following the classical car sharing combined pricing scheme based on kilometers driven and hours used. Furthermore, all participants were provided with a navigation system (maps+more) to ensure that they actually drive the designated route.

After preparing the vehicle, participants were briefed about using the electric vehicle (e.g., using and interpreting the in-vehicle information systems). Subsequently, participants performed a test drive to get used to the practical handling of the electric vehicle and to avoid cognitive arousal due to inexperience with driving an electric vehicle (Rauh et al. 2015a). Participants then received the driving task in paper-based form to read. Participants were instructed that they are customers of a local car sharing company and have rented the provided *Volkswagen e-up!* for a maximum duration of 30 min to drive a designated route of 10 km, which lasts about 21 min depending on traffic and driving style. The route was divided into three tracks. While track 1 contained high and middle volume of traffic with a speed limit of 50 km/h, track 2 was a reduced-traffic area with speed limits of 30 km/h. Track 3 was dominated by a low traffic volume and speed limits up to 70 km/h. Furthermore, the instruction included an explanation of the charging system for the vehicle usage. Participants were provided with a fictive budget of 10 EURO, of which they had to pay the car sharing service. When exceeding the rental time of 30 min, a fine of 5 EURO was subtracted from the provided budget. In order to increase external validity of the experimental design, i.e., to design the situational context as realistically as possible, especially regarding the rational to minimize the personal costs of car sharing usage, we introduced a monetary incentive within the experiment. In each group, the participant with the highest residual fictive budget received 50 EURO. If this condition applied to more than one person, we drew lots. The experimenter asked participants to repeat the given instruction in their own words, in order to ensure that all participants had understood the task. The experimenter sat down in the rear seat after clarifying all open questions. From this moment on, the communication between the driver and the experimenter was prohibited in order to avoid any distraction. After completing the city track, participants received the questionnaires and were debriefed.

1.4.3   Measurement of Constructs

To evaluate the perceived psychological stress for the respective driving task, we used the widely recognized Primary Appraisal Secondary Appraisal (PASA) questionnaire (Gaab 2009; Gaab et al. 2005), which refers to the transactional stress model of Lazarus and Folkman (1984). The related questionnaire assesses the two main cognitive appraisals (primary and secondary) with two subscales. While the primary appraisal measures the perceived demand with the scales *threat* (e.g., "I do not feel threatened by the situation"; "I find this situation very unpleasant.") and *challenge* (e.g., "The situation is not a challenge for me."; "I do not care about this situation.") the secondary appraisal assesses the coping resources with scales *self-concept of own abilities* (e.g., "In this situation I know what I can do."; "In this situation I can think of lots of action alternatives.") and *locus of control* (e.g., "I can best protect myself against failure in this situation through my behavior."; "I am able to determine a great deal of what happens in this situation myself."). The questionnaire measures each construct with four items on a 6-point Likert scale, ranging from 1 (strongly disagree) to 6 (strongly agree). Attitude toward behavior, subjective norm (perceived social pressure to engage in an action), perceived behavioral control (perception of ability to perform a certain behavior), and behavioral intention were derived from the well-established theory of planned behavior (Ajzen 1991). For measuring these constructs, we followed the manual for constructing questionnaires based on the theory of planned behavior proposed by Francis et al. (2004). In that regard, attitude toward using the e-car sharing service was measured on a 7-point Likert scale with four items (e.g., "Using the e-car sharing service is: good vs. bad; pleasant vs. unpleasant"). While subjective norm (e.g., "Most people who are important to me think that I should use e-car sharing."; "It is expected of me that I use e-car sharing.") and perceived behavioral control (e.g. "The decision to use e-car sharing is beyond my control."; "Whether I use e-car sharing is up to me.") were operationalized by four items each, intention to use the e-car sharing service (e.g., "I expect to use e-car sharing in the future."; I intend to use e-car sharing in the future.") was assessed with three items on a 7-point Likert scale.

The between-subjects factor (degree of IS) was measured using an ordinal scale, with 1 corresponding to the control group, 2 referring to the group charged a fixed amount every half an hour, and 3 relating to the group charged every second. In order to ensure that participants perceived the stimuli, we asked whether they were provided with a digital technology-enabled pricing system, and if they said yes, whether they were charged for the e-car sharing service every half an hour a fixed amount or per second. Furthermore, participants had to respond to

some questions on a 7-point Likert scale concerning the influence of the pricing systems on their driving behavior (e.g., "Did you feel pressured to drive faster due to the displayed costs?" or "Did the pricing system put you under pressure while driving?").

1.5 Data Analysis and Results

To test our proposed research model, we relied on variance-based partial least squares structural equation modeling (PLS-SEM; Lohmoeller 1989) using the software SmartPLS 3 (Ringle et al. 2015). We decided to apply variance-based model estimation because PLS-SEM requires fewer statistical constraints, for example, the assumption of normally distributed data or requirements regarding sample size (Henseler et al. 2009; Reinartz et al. 2009). We additionally used IBM SPSS Statistics 23 (IBM 2015) to assess the group differences in the respective subdimensions of stress. We followed the widely adopted two-step modelling approach for data analysis (Anderson and Gerbing 1988). We first assessed the measurement model to ensure reliability and validity of the constructs. Afterwards, we tested the structural model.

1.5.1 Validation of the Measurements

Before starting the analysis, we checked whether participants correctly assigned the provided digital technology-enabled pricing system (second-based and half an hour-based) to the respective scenario. All participants were able to correctly assign the system to their allotted scenario. Furthermore, participants rated relatively high on the 7-point Likert scale concerning whether they felt forced to drive faster due to the displayed costs (group1: M = 5.25; group2: M = 5.04), whether they felt stressed due to the provided digital technology-enabled pricing system (group1: M = 5.42; group2: M = 5.17), and whether the digital technology-enabled pricing system put them under pressure while driving (group1: M = 5.33; group2: M = 5.26). Hence, we assume that participants perceived the intended manipulation, and therefore, consider all responses suitable for further analysis.

To assess the quality of the reflective constructs, we examined content, convergent, and discriminant validities. Content validity describes the degree to which a measure represents every element of the underlying social construct (Haynes et al. 1995). We argue that content validity is given as our constructs and measures follow established theories and existing scales.

Convergent validity is defined as the degree to which multiple items of the underlying construct correspond with one another (Bagozzi and Phillips 1991). According to Fornell and

Larcker (1981), convergent validity can be assessed by calculating individual indicator relia-bility, composite construct reliability (CR), and average variance extracted (AVE). Due to low factor loadings, we dropped two items from the challenge and self-concept scale. Afterwards, all items loaded on their own construct at .60 or higher, which indicates an acceptable reliabil-ity of the indicators (Chin 1998; Hulland 1999). Furthermore, the CR varied between .851 and 1.000, above the acceptable limit of .07 (Hulland 1999). All AVEs exceeded the suggested lower bound of .50 (Bhattacherjee and Premkumar 2004).

Discriminant validity refers to the extent to which the measures of a construct are empirically distinct from the measures of other constructs in the same model (Bagozzi and Phillips 1991). The square roots of the AVEs are greater than the corresponding construct correlations, indi-cating discriminant validity (Fornell and Larcker 1981). Finally, each item loaded on its re-spective construct higher than on the other constructs in the model, confirming that the measures represent their assigned construct better than any other construct (Chin 1998). The results of the validity assessment are presented in Table E-2.

Table E-2 Factor Loadings, CA, AVE, CR, and Inter-Construct Correlations

	Construct	Loadings	CA	AVE	CR	1	2	3	4	5	6	7	8	9
1	Attitude	.676-.824	.653	.591	.862	**.769**								
2	Intention	.631-.964	.811	.739	.891	.504	**.859**							
3	Behavioral Control	.682-.941	.856	.613	.862	.218	.396	**.783**						
4	Subjective Norm	.751-.905	.863	.711	.907	.450	.587	.183	**.843**					
5	Threat	.693-.928	.840	.680	.894	-.134	-.022	.126	-.059	**.824**				
6	Challenge	.853-.868	.649	.740	.851	.-159	.102	.124	.023	.337	**.860**			
7	Locus of Control	.770-.868	.866	.715	.909	.142	-.017	-.036	.149	-.554	-.315	**.845**		
8	Self-Concept	.713-.875	.741	.663	.854	.446	.301	.220	.239	-.293	.220	.449	**.814**	
9	Degree of IS	1.000	1.000	1.000	1.000	-.192	.090	.032	.005	.376	.408	-.443	-.436	**1.000**

AVE: average variance extracted; CA: Cronbach's Alpha; CR: composite reliability; bolded numbers: square root of AVE.

1.5.2   Hypotheses Testing

We decided to check for group differences in order to assess the effect of digital technology-enabled pricing systems on the stress construct and on the subdimensions' threat, challenge, self-concept, and locus of control (H1a-H2b). Following Gaab (2009), we computed the stress construct by subtracting the mean of the secondary appraisal's subscales from that of the pri-mary appraisal's subscales. Before selecting an appropriate method for assessing the group

differences, we tested in the first step the data for non-normality. The Kolmogorov–Smirnov test and Shapiro–Wilk test showed highly significant results for the construct threat ($p <$ $.001/p < .001$), self-concept ($p = .032/p = .034$), locus of control ($p < .001/p < .001$), and stress ($p = .008/p = .003$), thus indicating non-normal distributed data. Therefore, we used the nonparametric Leven test in the second step for assessing the homogeneity of variances among groups (Nordstokke et al. 2011). The test reveals significant results for the construct threat ($F = 5.544$; $p = .006$) and non-significant results for the construct challenge ($F = 0.001$; $p = .999$), self-concept ($F = 1.589$; $p = .212$), locus of control ($F = 0.409$; $p = .667$), and stress ($F = 0.446$; $p = .642$).

Since our data are, to a great extent, homoscedastic but non-normally distributed, we decided to apply the Kruskall–Wallis test to assess whether there are differences between the three groups (McKight and Njab 2010). The groups differed statistically significantly in the construct threat (χ^2 (2) $= 9.316$; $p = .009$), challenge (χ^2 (2) $= 13.182$; $p = .001$), self-concept (χ^2 (2) $= 18.004$; $p = .001$), locus of control (χ^2 (2) $= 14.523$; $p = .001$), and stress (χ^2 (2) $= 29.705$; $p < .001$). To investigate post-hoc the group-specific differences within each construct, we applied the nonparametric Mann-Whitney U test (Nachar 2008). Furthermore, the approximated effect size (r) was calculated by dividing the z-score by the square root of the sample size (Field et al. 2013). Following Cohen (1992), effect sizes between .10 and .30 were considered small to medium, whereas those between .30 and .50 were regarded as medium to large. A Bonferroni correction was used to reduce Type I errors due to multiple testing (Rice 1989). In that regard, the critical 5 percent level of significance was corrected to 0.0125. The results of the Mann-Whitney U test and the effect sizes are presented in Table E-3, Table E-4, Table E-5, and Table E-6.

Compared to the control group, the results indicate that both digital technology-enabled pricing systems led to an increased stress perception while driving (Table E-3 and Table E-4). In that regard, we could find a significant positive effect of the fixed-based price charging system (group 1) on the primary appraisal dimension challenge ($U = 133.5$; $p = .004$) and a negative effect on the secondary appraisal dimension's self-concept ($U = 87.0$; $p < .001$) and locus of control ($U = 140.0$; $p = .006$). Overall, the charging system led to an increased level of perceived stress ($U = 71.0$; $p < .001$). Regarding the second-based pricing system (group 2), the analysis revealed a significant positive impact of the system on the scales threat ($U = 134.0$; $p = .004$) and challenge ($U = 108.5$; $p = .001$), and a significant negative effect on the subscales self-concept ($U = 103.0$; $p = .001$) and locus of control ($U = 96.0$; $p < .001$). Overall, the sec-

ond-based pricing system led to a significantly increased level of stress perception (U = 37.5; p < .001). The results of the group comparison between both digital technology-enabled pricing systems (Table E-5) indicated no significant differences in stress and its subscales. Taking into consideration the impact of digital technology-enabled pricing systems in general (groups 1 and 2) on the subdimensions of stress, the results (Table E-6) clearly showed a significant positive effect on threat (U = 320.0; p = .007) and challenge (U = 242.0; p < .001), and a significant negative impact on self-concept (U = 190.0; p < .001) and locus of control (U = 236.0; p < .001). In that regard, participants perceived more stress when providing a digital technology-enabled pricing system (U = 108.5; p < .001).

Table E-3 Group Comparison Fixed-based Pricing

	Group 1	**Control group**		**Mann-Whitney U test**			
Constructs	MR	MR	Δ MR	U-statistics	Z-score	Sign.	r
Threat	26.75	19.95	6.80	186.0	-1.906	.057	0.229
Challenge	28.94	17.57	12.37	133.5	-2.888	.004	0.348
Self-concept	16.13	31.55	-15.42	87.0	-3.926	.000	0.473
Locus of control	18.33	29.14	-10.81	140.0	-2.760	.006	0.332
Stress	31.54	14.73	16.81	71.0	-4.259	.000	0.513

SD: standard deviation; Sign.: significance; r: effect size; MR: mean rank

Table E-4 Group Comparison Second-based Pricing

	Group 2	**Control group**		**Mann-Whitney U test**			
Constructs	MR	MR	Δ MR	U-statistics	Z-score	Sign.	r
Threat	28.17	17.59	10.58	134.0	-2.911	.004	0.350
Challenge	29.28	16.43	12.85	108.5	-3.300	.001	0.397
Self-concept	16.48	29.82	-13.34	103.0	-3.429	.001	0.413
Locus of control	16.17	30.14	-13.97	96.0	-3.604	.000	0.434
Stress	32.37	13.20	19.17	37.5	-4.903	.000	0.590

SD: standard deviation; Sign.: significance; r: effect size; MR: mean rank

Table E-5 Group Comparison between the Digital Technology-enabled Pricing Systems

	Group 1	Group 2		Mann-Whitney U test			
Constructs	MR	MR	Δ MR	U-statistics	Z-score	Sign.	r
Threat	21.21	26.91	-5.70	209.0	-1.483	.138	0.179
Challenge	22.40	25.67	-3.27	237.5	-0.825	.410	0.099
Self-concept	23.71	24.30	-0.59	269.0	-0.150	.881	0.018
Locus of control	26.21	21.70	4.51	223.0	-1.143	.253	0.138
Stress	20.69	27.46	-6.77	196.5	-1.696	.090	0.204

SD: standard deviation; Sign.: significance; r: effect size; MR: mean rank

Table E-6 Group Comparison between Classic and Digital Technology-enabled Pricing

	Group 1+2	Control group		Mann-Whitney U test			
Constructs	MR	MR	Δ MR	U-statistics	Z-score	Sign.	r
Threat	39.19	26.05	13.14	320.0	-2.715	.007	0.327
Challenge	40.85	22.50	18.35	242.0	-3.561	.000	0.429
Self-concept	28.04	49.86	-21.82	190.0	-4.236	.000	0.510
Locus of control	29.02	47.77	-18.75	236.0	-3.659	.000	0.441
Stress	43.69	16.43	27.26	108.5	-5.271	.000	0.635

SD: standard deviation; Sign.: significance; r: effect size; MR: mean rank

Furthermore, to assess hypotheses H3 and H4, we examined the influence of stress on attitude and intention to use the service of car sharing. Using the indicator reuse approach, we operationalized stress as a reflective-reflective second-order construct with the four subdimensions of stress as lower-order constructs (Lohmoeller 1989; Ringle et al. 2012). To evaluate the structural path of the model, the bootstrapping re-sampling procedure was applied with 5000 subsamples (Chin 1998; Hair et al. 2011). An overview of the structural model estimations can be found in Figure E-2.

PLS regression analysis revealed a significant positive effect of the degree of IS used (b = .549, p < .01) on perceived stress and a negative significant impact of stress on the attitude toward using the car sharing service (b = -.288, p < .05). Considering the relationship between attitude and intention, the results indicated that attitude is a significant predictor (b = .264, p < .05) for the intention to use the car sharing service. Furthermore, subjective norm (b = .418, p < .01) and behavioral control (b = .257, p < .01) were found to be a significant predictor for intention. Overall, the model can explain 45.0% variance in intention to use car sharing, indicating an above-average explained variance (Chin 1998).
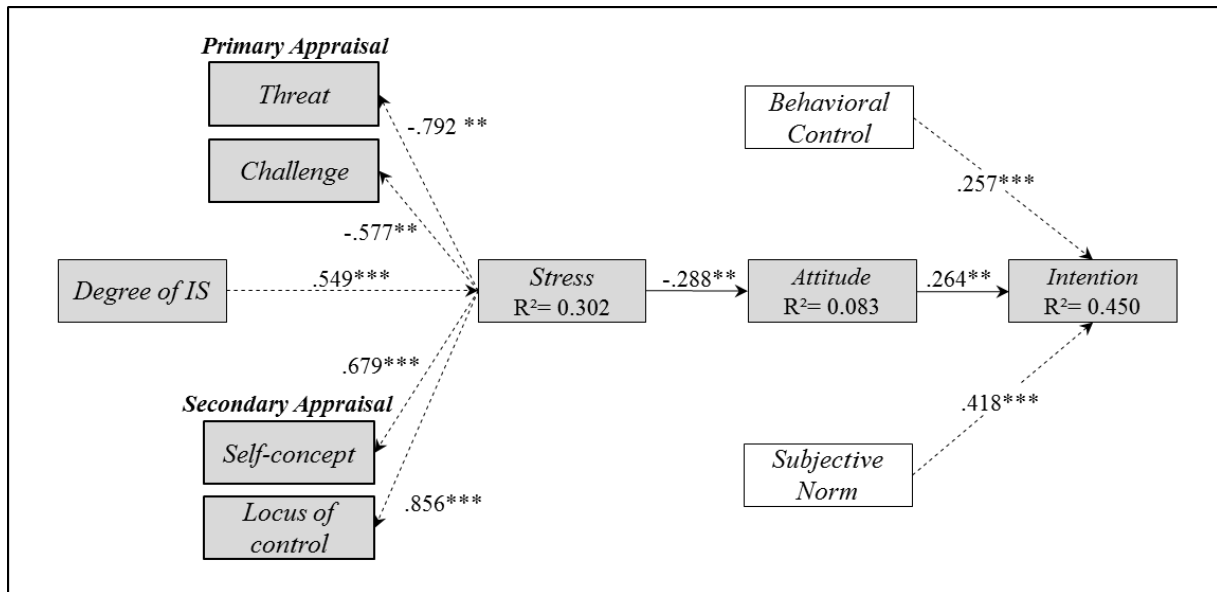
Figure E-2 Path Coefficients of the Structural Model

1.6 Discussion

The increased connectivity, which stems from the diffusion of digital technologies in an increasing number of areas of life (Yoo 2010) together with the rising coverage of general digital infrastructures (Tilson et al. 2010), has been credited to enable and improve sustainable business models (e.g., Chen et al. 2008). By an increased availability of real-time information, the viability of such business models is heightening (Teubner and Flath 2015), e.g., by increasing the flexibility of their use as well as the increased control and monitoring potentials for suppliers (e.g., Hildebrandt et al. 2015). Thus, digital technologies can contribute to the sustainable development of modern societies, a potential selected by recent Green IS research (Malhotra et al. 2013). However, besides these potentials, the consequences of digital business model innovation for sustainable services on the individual must be considered (Elliot 2011). By their affordances, digital technologies might further contribute to the heightening turbulence and frantic pace in our society. In a time of rising cases of stress-related disorders, digitally enabled business model designs that overstrain individuals might have a significant impact on the willingness of these individuals to use the services in the future. Thus, the sustainability transformation afforded by IS might be constrained before it actually reaches its full potential.

In this study, we experimentally investigated the impact of digital technology-enabled pricing systems, an important characteristic of digital business model designs for sustainable services (e.g., Hildebrandt et al. 2015), in the context of car sharing on individual stress and on the

factors that determine future adoption of such services. Our results clearly indicated that a higher level of IS application results in an increased stress appraisal. A closer look at the primary appraisal processes of the transactional stress model indicates that participants perceive the car sharing usage as more threatening and challenging when provided with digital technology-enabled pricing systems. Furthermore, considering the secondary appraisal processes, the digital technology-enabled pricing systems led to a decreased evaluation of the situation as controllable, and moreover, reinforced participants feel less confident in managing the given task. These differences can, to some extent, be explained by the time pressure that the pricing system creates due to a permanent display of the travel time and costs. In that regard, time pressure impairs the driving task because it leads to cognitive strains that distract an individual (Keinan et al. 1999). Moreover, the provided pricing systems induce an increased pressure to monitor the driving progress, which in turn, consumes the limited mental resources needed for effective task performance (Baumeister et al. 1998; Karau and Kelly 1992; Kelly et al. 1997). This is especially important because contemporary automobiles are considered complex mobile computers equipped with a number of interactive systems, such as navigation system, range gauge, or speedometer (Brandt 2013; Krum et al. 2008). The interaction with this wide range of in-vehicle IS constitutes additional tasks that compete with the primary task of driving, which may lead to stress reactions (Hollnagel et al. 2003; Horberry et al. 2006; Matthews et al. 1998; Osswald et al. 2012; Schmidt et al. 2010). In that regard, the provided pricing systems constitute an additional information resource along with the existing in-vehicle information systems. According to Bach et al. (2009), the interaction with in-vehicle IS is a main source of information overload because it relies on the same capacity as that of the driving task. This overload also produces a perceived loss of control over a situation, as the capacity for decision-making is limited, thus inhibiting the individual to consider the optimal solution for handling a given task (Heylighen 2002).

Within the IS community, the cognitive strain related to the interaction with information and communication technologies is summarized under the term *technostress,* defining "a modern disease of adaptation caused by an inability to cope with new technologies in a healthy manner" (Brod 1984). Ragu-Nathan et al. (2008) state that one major stress factor created by information and communication technologies is caused by the increasing continual exposure to technologies, thus leading individuals to perceive to be dependent on technologies. Transferred to our scenario, participants may perceive that their style of driving is partly dependent on the provided pricing system, as they were permanently exposed to the displayed infor-

mation in terms of costs of using the car sharing service and trip duration. This is in line with the findings of Nastjuk and Kolbe (2015), showing in a mental simulation experiment that participants experience technostress due to the driver's perception of being permanently connected with in-electric vehicle IS. Moreover, it is difficult for participants to determine the actual duration of travel. Consequently, the final costs for using the car sharing service, as, for example, traffic jams, construction zones, and further related uncertainty factors might influence the actual journey time. Such uncertainty is correlated with the individual's ability to forecast an event, which in turn, affects the individual's competence to manage a specific demand (Babrow et al. 2000; Brashers 2001).

However, the test for group differences revealed no significant differences in stress perception between both digitally enabled pricing systems. This result is surprising, as we expected that the second-based pricing system increases the awareness about the time-sensitive situation more than the half an hour-based pricing system. Nevertheless, as both pricing systems permanently displayed the costs of using car sharing services based on the trip duration, we assume that participants of both groups were exposed to a nearly equal time pressure, and thus, both scenarios show a comparable extent of stress. Moreover, our findings reflect that perceived stress led to a decreased propensity of the test persons to further use sustainable services. In that regard, we found that stress negatively influences attitude — a significant predictor of the intention to use car sharing. This relationship can be proved by the affective dimension of the attitude construct, as it reflects the individual's emotions — a concept that is inextricably linked to stress (Ajzen 2005; Lazarus 1993b). Following Nastjuk and Kolbe (2015), IS-induced stress is accompanied by negative emotions; therefore, this stress negatively influences the attitude toward behavior. Participants seemed to reflect the digital technology-enabled pricing systems on the attitude, and thus, on the intention to use car sharing. In line with the theory of planned behavior (Ajzen 1991), we also found perceived behavioral control and subjective norm to be important predictors of the intention to use car sharing.

As personal mobility accounts for a large part of the contribution to environmental degradation and car sharing, in general, represents a more sustainable form of flexible individual transport (Wagner et al. 2014), the results indicate how opportunities for sustainability transformation can actually be reduced by higher levels of IS support. Transferred to a higher level of abstraction, our findings thus point to a dangerous yet less-discussed adverse effect of digital technology-enabled business model innovation for sustainable service adoption. Precise pricing, e.g., in a tight temporal pricing scheme, an important characteristic of modern digital

technology-enabled business models for sustainable services (Knote and Blohm 2016), may increase cognitive loads, in turn inducing stress. Although generally problematic, this effect might even hinder the future adoption of these sustainable services, leading to regression with regard to sustainability transformation. A majority of sustainability IS research so far has dealt with the question of conceptualizing as well as analyzing the relationship between IS and sustainable practices, while research on the design and actual impact of these systems is scarce (Malhotra et al. 2013). Moreover, sustainability IS research on the individual as a unit of analysis is missing (Bui and Veit 2015). Our study contributes to both these fields by, first, empirically delineating a multi-level negative impact: individuals experience increased stress levels induced by IS-supported pricing systems, which were found to negatively influence the factors influencing individual adoption behavior. By this relationship, the negative impact on the individual is elevated, as with lower adoption of sustainable services, lower environmental benefits can be gained, and progress toward sustainability transformation slows down. Second, these insights provide important aspects to consider in the design of Green IS and the services building upon them. Here the provision of more amount of as well as more frequent information and advanced monitoring of usage behavior and usage-based pricing represent design options that are enabled by IS. However, although certainly beneficial in general, the degree of their implementation needs to be handled with care as adverse effects on human behavior might emerge. To date, research on the design of green IS (e.g., Hilpert et al. 2013) has focused on the respective functionality, but rather neglected the importance of individual factors. Recent studies have described that we are witnessing a changing nature of IT (El Sawy 2003), where it is increasingly fused with everyday life (Yoo 2010). However, besides the potentials for digital innovation (Fichman et al. 2014; Yoo et al. 2010) that emerge from this development, it needs to be considered that this fusion demands more attention to the human factors in designing IS artifacts.

With these insights, we contribute to the literature on business model innovation (Chesbrough and Rosenbloom 2002) as well as digital innovation (Fichman et al. 2014). In particular, our findings reveal that conducting field experiments is an important means to uncover the potential adverse effects on human behavior, which in turn, might hinder the actual adoption of the respective innovation. Thus, our results underscore the importance of conducting experiments for business model innovation, as described by Chesbrough (2010) and Sosna et al. (2010), especially when digital technologies are deployed. Therefore, our study points to a profound issue in sustainable IS research. While the new possibilities in business model innovation that

result from progresses in digital technology diffusion might increase the economics of sustainable business models (e.g., Wagner et al. 2014), thus creating options to transform our economies toward more environmentally friendly ways of doing business and consumption (Chen et al. 2008), the third pillar of sustainability, the social dimension, must not be forgotten (Elliot 2011). Apart from that, when related to the *Conceptual Model of the Intended Impact of Fundamentally Changed Human Behavior on the Environment* by Elliot (2011), our research highlights the importance of a less-discussed relationship in sustainable IS research. While prior research demonstrates how IS can provide monitoring functionalities, the impact of this IS-enabled monitoring and feedback generation via continuous display of real-time information on individual well-being is less understood. We address this perspective with our research but call for further investigations on this subject.

Moreover, further social costs emerging as increasing stress levels lead to more cases of stress-related disorders (e.g., burn-out and depression). These aspects point to the importance of employing a more sound perspective in sustainable IS research comprising economic, social, and environmental factors, as neglecting one dimension will automatically harm the others. Thus, our research contributes to recent calls to investigate the individual and societal impacts of digital transformation and related business model innovation (Loebbecke and Picot 2015).

There are important implications that can be derived from our results for managerial practice. Most importantly, we provide insights for managers in design, product or business model innovation management in regards to two specific aspects. First, experts from this audience might be questioning about using the potentials of increased connectivity to implement new or adapted business models with highly precise pricing systems. However, our results show that these potentials, appearing interesting in the economic reasoning, may have significant downturns in terms of customer acceptance as a result of the stress they impose on the individual. Higher levels of stress, induced by IS, are not only unhealthy for an individual but generally also burdens societies. In our research context of personal mobility, driver stress is related to safety issues such as accidents, and thus, injuries and deaths (Kontogiannis 2006; Matthews et al. 1998). In that regard, road traffic injuries are the eighth leading cause of death globally with approximately 1.24 million people dying each year on the world's roads (Lozano et al. 2013; WHO 2013). To counteract these adverse effects, the general display of pricing information could be less fine-grained and only provide more detailed information if demanded. As stress is an individual phenomenon, innovators may also offer customizable displays

allowing customers to adapt to the level or frequency of information they feel comfortable with. Second, we show that experimental testing may be applied to identify the optimal amount and frequency of information provision and thus contribute to risk reduction in innovation, and important consideration before taking huge investments as they can be conducted with relatively small samples and yield robust results. Moreover, the insights are regularly more realistic in comparison to many other means of market research, e.g., surveys or laboratory experiments. Finally, conducting field experiments is a beneficial method to integrate the customer in the innovation process, which may result in a superior customer orientation within the business model innovation.

1.7   Limitations

The following limitations should be considered when interpreting the results of this study. Generally, field experiments in natural settings suffer from a low controllability of external factors (Harrison and List 2004). Shifting to our scenario, we could not control for certain factors that influence an individual's driving behavior and stress perception, such as traffic jams or behavior of other traffic participants. Moreover, stress perception is strongly dependent on personal factors, such as education, age, gender, driving experience, experience with e-car sharing, or affinity for technology (e.g., Burke and Mikkelsen 2005; Fernandes et al. 2009; Gallo and Matthews 2003; Nastjuk et al. 2015). In that regard, participants that are younger are probably more price sensitive and technologically educated than the general population. Furthermore, the sample in this study is relatively unexperienced with e-car sharing. However, typical early adopters of sustainable services, such as car sharing, are tendentially represented by young and educated population (Hampshire and Gaites 2011). Therefore, our results make meaningful contribution to the adoption of these services. Nevertheless, the results draw on a small sample size of 69 participants, which does not allow our results to be generalized. A variation and extension of the small sample size could increase the predictive power of the proposed research model. In addition, our results are based on a specific scenario within a European country, limiting its generalizability. To confirm the proposed research model, the influence of digital technology-enabled business models on individual stress and perception with regards to the future usage of these services should be investigated with further scenarios. Finally, there are certainly more digital technology-enabled business model design aspects beyond the pricing system. We selected this treatment due to its direct relation to customer behavior and its status as a representative characteristic of digital business models for sustainable services (e.g., Bocken et al. 2014; Knote and Blohm 2016). However, other aspects cer-

tainly need similar attention as well, thus providing important avenues for future research. In this regard, further digital technology-enabled car sharing business model characteristics such as automated vehicle access technologies (Remane et al. 2016) should be focused by future research. Apart from that, it is notable to mention the arising interest to also compare our results to car sharing with conventional combustion engine vehicles. It appears that our results would also apply for that case. However, as we intended to investigate the impact on the acceptance of sustainable services, we opted for using e-car sharing since it demonstrates, under the right conditions, to produce less environmental degradation than car sharing with conventional vehicles and thus represents an overall greater potential contribution to sustainable transformation. However, testing our results in comparison to conventional car sharing settings has been noted as an interesting aspect to assess in future research.

1.8   Conclusion

Digital technologies afford business models for the efficient, flexible and reliable use of sustainable services, e.g., car sharing. While prior research has investigated these positive influences of IS in this regard (e.g., Hildebrandt et al. 2015), this study set out to examine the negative individual impacts that might result from specific digitalized business model design options. To do so, we developed a research model that relates the popular transactional stress model of Lazarus and Folkman (1984) to the well-established theory of planned behavior (Ajzen 1991). To evaluate the proposed research model, we conducted experiments in real traffic situations, putting 69 participants in the mindset of car sharing users. The results indicated that the deployment of digital technology-enabled pricing systems in car sharing influences the cognitive appraisal processes in an unfavorable manner, and hence, lead to an increased stress perception. Moreover, the results revealed that an increased level of stress negatively affects the individual's decision to use car sharing in the future. With our findings, we point to a dangerous side effect of increasing IS-usage in business models and the potential negative impacts on sustainability transformation in general. Thus, we provide a foundation for further research on the societal impacts of digital technology-enabled business models.

F. Contributions

The interaction with IS leads to effects that are dual in nature. While IS can contribute to reducing stress in certain situations, the interaction with IS also poses the risk of inducing stress in the individual. With respect to this dual effect, the thesis had two overarching goals: First, it aimed to increase the understanding of both directional effects of IS with on stress perception. Second, it intended to clarify the consequences of this dual effect on behavioral outcomes. Using the example of BEVs, this thesis focused on two underlying research questions that are approached with five aligned studies. This part first recapitulates the findings of each conducted study (F.1) with a particular focus on the derived research questions (A.1.2). Afterwards, it presents the major contributions for research and practitioners (F.2). Finally, this thesis ends with remarks on limitations and avenues for further research (F.3).

1   Findings

This chapter presents the core findings of the five studies with respect to the derived research questions. In alignment with the structure of the thesis, it first presents the findings regarding the beneficial effects of IS with respect to the perception of stress (F.1.1), followed by the findings regarding the adverse effects of IS (F.1.2). It then concludes with a synthesis that integrates the findings on a higher level, emphasizing the dual effect of IS on the perception of stress and the resulting consequences for behavioral outcomes (F.1.3). This chapter ends by presenting findings on the relationship between IS, stress, and behavioral outcomes in the context of mobility-related sustainable business models (F.1.4).

1.1   Findings Regarding the Bright Side of Information Systems

The first part of the thesis aimed at exploring the degree to which IS are suitable to reduce the level of perceived stress using the example of BEVs. Previous research in the field of IS and stress has mainly focused on the dark side of IS (Tarafdar et al. 2015a), in particular, on individual stress that results from the interaction with IS in an organizational setting (Ayyagari et al. 2011; Ragu-Nathan et al. 2008; Riedl et al. 2012). One study was conducted to investigate the opposite effect, in other words, the beneficial effect of IS with respect to the perception of stress and its consequences for behavioral outcomes.

Based on the transactional stress model of Lazarus and Folkman (1984) and the theory of planned behavior (Ajzen 1991), study B1 presented a first conceptual model which evaluates how IS can be used to reduce the level of perceived psychological stress. In addition to using psychometrical evaluation methods, study B1 used psychophysiological measurements (skin conductance) to assess the perception of stress, thus responding to the necessity for more research using biological measurements when assessing the relationship between IS and stress (Riedl et al. 2012), especially in the context of range stress (Nilsson 2011).

The results of the psychometric evaluation indicates that appropriate IS generally are useful to mitigate stress that results from the concern of becoming stranded due to a depleted battery. With respect to the primary appraisal process, participants perceived the given driving task as less threatening and challenging when provided with certain range-related in-vehicle IS. The results revealed no statistically significant effect of IS on the secondary appraisal process (locus of control and self-concept of own abilities). Although both psychological coping resources can be influenced in the short run by the degree of uncertainty, which, in turn, is de-

termined by the available degree of information (Babrow et al. 2000; Brashers 2001; Kienhues and Bromme 2011), they are also considered to be relatively stable over time (Asendorpf et al. 2002; Bowsher and Keep 1995). In addition, the study provides evidence that stress is negatively linked to the attitude towards performing a specific behavior. Transferred to the research context of BEVs, the findings showed that a higher level of perceived range stress results in a lower attitude towards using a BEV for a given route. Generally, the concept of stress is closely interrelated with emotional responses (Lazarus 1993a; 1993b; 2006), which reflect to a certain degree the affective component of the attitude construct (Ajzen 2005; Breckler 1984; Greenwald 2014). Thus, a higher degree of perceived stress is mainly associated with negative emotions, which, in turn, negatively influence the attitude towards performing a specific behavior.

The results of the psychophysiological measurement led to three main insights. First, the given driving task was perceived as initially more stressful (reflected by higher skin conductance values) when IS (especially the navigation device) were missing. The presence of IS made participants feeling more comfortable, as the IS provided context-related information about the trip, e.g., charging stations nearby. This effect is reflected by the second finding, revealing that the individual's average stress level was lower for the driving task when equipped with IS. Finally, the results showed that the average slope for skin conductance was higher when individuals were provided with a higher degree of IS, thus indicating a faster increase in stress perception. As in the experimental design the difference between both groups were solely based on the provided IS, it can be concluded that this disparity in slope origins from the interaction with IS. This finding raises the question of whether IS are fully suitable to reduce stress in specific situations, as there exists an opposite effect referred to as stress that results from, for example, information overload (Ragu-Nathan et al. 2008). It can be concluded that psycho-physiological measurement methods constitute a useful extension to psychometrical evaluation methods because they enable the observation of the temporal progression of stress over time. However, such evaluation methods measure all types of stress, thus making it difficult to filter the intended type of stress. Table F-1 presents the title of the study and the core contributions.

Table F-1 Findings of Study B1

Findings of Study B1

Title	Understanding the Influence of In-Vehicle Information Systems on Range Stress – Insights from an Electric Vehicle Field Experiment
Core contributions	Conceptual model that enables to investigate the relationship between IS, stress, and behavioral outcomes. Evidence on the potential value of appropriate IS to reduce stress, which in turn, increases the attitude towards performing a behavior in the specific context of BEVs. Revealing that in addition to psychometrical evaluation methods, psychophysiological measurements constitute a suitable methodological extension to assess the effect of IS on the perception of stress.

1.2 Findings Regarding the Dark Side of Information Systems

While study B1 provides evidence that IS are generally suitable to reduce range stress in BEVs, the interaction with technologies demand high individual mental skills that might induce stress reactions (Ayyagari et al. 2011). The results of the psychophysiological measurement in study B1 indicated a faster increase in stress perception due to the provision of IS, which raised the question whether IS are fulsome able to reduce stress in the respective research context. Hence two studies were conducted to investigate this effect in more detail.

In study B1, IS were assessed as a bunch, neglecting a classification in BEV-related IS categories (Brandt 2013). Study C1, therefore, set out to explore in detail the effect of two in-battery electric vehicle IS categories, namely vehicle monitoring systems and geo IS and navigation systems on the perception of stress and the resulting willingness to use BEVs. Both categories have been suggested to be useful in reducing range-related concerns (Eisel and Schmidt 2014).

The results of the conducted field experiments in real traffic situations showed that the provision of too much context-related information through IS led to a higher range stress perception. In comparison to the separate provision of IS within the categories vehicle monitoring and geo IS and navigation, the given situation was perceived more challenging and threatening when provided with systems of both categories. In addition, the results indicated a lower perception of having control over the critical range situation, as well as a decreased perception of the individual's abilities to manage the given task. These findings were surprising because it was assumed that range stress is negatively correlated with the degree of available range-related information. Generally, the limited mental resources needed for the driving task are additionally exploited through the interaction with in-vehicle IS, thus overloading the individ-

ual more when a higher degree of IS is provided (Bach et al. 2009; Ma and Kaber 2005). This stressful overload induced by the provided in-vehicle IS was likely to be transferred to the critical range situation, thus increasing the perception of range stress.

Focusing on the differences in stress perception between both categories, it could be shown that the interaction with IS of the vehicle monitoring category was perceived as more stressful (mainly influenced by a higher threat appraisal and lower appraisal of the self-concept of own abilities) compared to IS in the category of geo IS and navigation. The range gauge as a typical feature within the category of vehicle monitoring is considered to be highly volatile (Jung et al. 2015), which in turn, creates a source of uncertainty because it makes difficult for the individual to assess the actual driving range of the vehicle. In contrast, the navigation display as a typical feature within the category of geo IS and navigation decreases the degree of uncertainty because it provides comparably less volatile information, for example, by displaying local charging opportunities nearby. Such information strengthens the own abilities to realize solutions in case of range problems and makes the driving task less threatening (e.g., by reducing the risk of getting stranded alone on an empty road).

In alignment with the previous conducted study B1, it was revealed that a higher level of range stress led to a lower acceptance, i.e., lower attitude towards using a BEV. Table F-2 presents the title of the study and the core contributions.

Table F-2 Findings of Study C1

Findings of Study C1	
Title	Less is Sometimes More – The Impact of In-Vehicle Information Systems on Perceived Range Stress
Core contributions	Revealing that the provision of too much information provided by IS has a counterproductive effect on stress perception. The range gauge elicits range stress whereas a navigation device has a calming effect in critical range situations. A higher degree of range stress results in a lower attitude towards using BEVs.

As study C1 has shown that the category of vehicle monitoring, which is mainly represented by the range gauge, appears to be counterproductive in reducing range stress, the following study, C2, put the range gauge in focus of its investigation, thus providing a more in-depth analysis of the interaction between IS, stress, and behavioral outcomes. The range gauge is considered to be highly volatile and unreliable, which has increasingly raised the question whether users can trust these devices (Franke et al. 2015; Lundstroem 2014; Wellings et al.

2011). Thus, study C2 took the concept of trust into consideration when investigating the relationship between IS, stress and behavioral outcomes. By doing so, two range gauges that are typical present in BEVs were in focus of the study. Both devices differed in terms of the accuracy of the information provided and the displayed volatility.

First, the findings of the conducted field experiments in real traffic situations showed that accurate but highly volatile range information (conceptualized by a digital range gauge that displayed the remaining range with numbers in terms of distance to empty) was perceived as less trustworthy compared to less accurate but also less volatile range information (represented by an analogue range gauge that displayed the state of charge by means of a needle). The formation of trust is generally considered as a dynamic process which is influenced by the degree of uncertainty associated with the provided information (Hoff and Bashir 2015). Although the range device displaying the remaining driving range with numbers is more accurate, the comparably high degree of volatility of the displayed information created uncertainty regarding the actual remaining driving range, thus transforming the range device to a "guess-o-meter" (Lundstroem 2014). The permanent fluctuating adjustment of the remaining driving range due to, for example, driving behavior or topographical characteristics (Bolovinou et al. 2014; Pichler and Riener 2015) put the driver into a situation in which it is nearly impossible to estimate the actual driving range, thus decreasing the trust into the range device. This effect is diminished by the range device displaying the remaining driving range in terms of state of charge, as the needle is not subjected to such high fluctuations due to a less swiftly reaction to the driving behavior.

Second, the provision of accurate but highly volatile range information through the distance to empty range gauge led to a higher perception of range stress in comparison to the less accurate but less volatile state of charge range gauge. This could be mainly explained by statistically significant differences in the subscales: self-concept of own abilities and challenge. As explained previously, the degree of uncertainty associated with the provided information mainly influences both primary and secondary appraisals (Jerusalem and Schwarzer 1992; Lazarus and Folkman 1984). The range gauge constitutes the main source of information for assessing the driving range (Wellings et al. 2011). High fluctuations in the displayed driving range information increase the degree of uncertainty, which in turn, creates a more challenging situation in terms of smoothly arriving at the target destination. In addition, the inconsistent information (Brashers 2001; Kienhues and Bromme 2011; Kruglanski 1989) provided by the digital range gauge weakens the perceived ability to handle the given driving task. In

contrast, the low fluctuation of information of the analogue range gauge makes the critical range situation for the user not obvious in the first moment, thus leading to a lower perception of range stress. These results were also reflected by the relationship between trust and range stress. The findings revealed that trust in the range device was negatively associated with range stress. A higher level of trust generally supports the resilience against range stress (Franke et al. 2016a). Unreliable range information leads to uncertainty, which – as explained above – reinforces the perception of range stress. As the driving range is often overestimate (Birrell et al. 2014), an increased lowering of the actual range (compared to the expected remaining driving range) results in a lower perceived control over the situation.

Finally, the results revealed that a lower level of trust and – in alignment with the results of the previous conducted studies (B1 and C1) – a higher level of range stress led to lower attitude towards using BEVs. A higher level of range stress negatively influences the affective component (Ajzen 2005) of the attitude construct by associating negative emotions with the stressful situation (Lazarus 1993a). The concept of trust itself reflects an attitude that is mainly shaped by the affective dimension (Lee and See 2004). Thus, a low trust in the range estimate is transformed to an uncomfortable driving experience, which is reflected by a negative attitude towards using BEVs. Table F-3 illustrates the title of the study and the core contributions.

Table F-3 Findings of Study C2

Findings of Study C2	
Title	Inaccuracy Versus Volatility – Which is the Lesser Evil in Battery Electric Vehicles?
Core contributions	Revealing that the provision of accurate but volatile range information as displayed by a digital (distance to empty) range gauge results in a decreased feeling of trust in the range estimate, a higher perception of range stress, and a lower attitude towards using BEVs in comparison to the provision of less accurate but less volatile range information as presented by the analogue (state of charge) range gauge. Trust is negatively related to range stress and positively related to attitude. Range stress is negatively related to the attitude towards using BEVs.

In summary, both studies provided evidence that IS not only provide benefits in terms of reducing stress but also lead to stress perception. With respect to research question two (RQ2), which aims at investigating the effect of IS-related stress on the attitude towards performing a specific behavior, both conducted studies could show that a higher degree of perceived stress led to a lower attitude regarding the usage of BEVs.

1.3 Synthesis: On the Duality in the Effect of Information Systems on Stress

While the findings of study B1 showed that IS generally can be useful to mitigate stress in the context of sustainable mobility, studies C1 and C2 revealed that the provision of too much and unreliable information through in-vehicle IS might lead to an increased range stress perception. This increase in range stress is likely to be caused by a transfer of stress resulting from the interaction with the in-vehicle IS. The thesis aimed at capturing both effects of IS on the perception of stress, emphasizing the importance of considering both directions at the same time when assessing behavioral outcomes. Study D1 was conducted to capture both perspectives on the IS-stress relationship, thus breaking off the single point of view by emphasizing its ambivalent role (Califf et al. 2015; Lauwers and Giangreco 2016). In addition, study D1 aimed at investigating the implications of this dual effect on the attitude towards using BEVs.

The findings of the mental simulation experiment showed that a dual effect of IS on the perception of stress exists. Using the example of driving a BEV in a critical range situation, two scenarios were developed within study D1 that differed in the degree of IS provided (simple and straightforward IS vs. advanced and complex IS). The results revealed that the provision of context-related advanced IS (reflecting a high degree of IS pervasion) was useful to reduce stress that results from the limited range in BEVs. Compared to the provision of simple IS (reflecting a low pervasion of IS), the given situation was perceived as less threatening and challenging. Moreover, the results indicated a higher perception of being in control over the critical range situation, as well as an increased perception of abilities to manage the given task due to the provision of advanced IS. As explained above, the difference results mainly from the degree of information available and the perception of uncertainty about the situation, which mainly influence the appraisal processes of stress (Krohne 1997; Lazarus and Folkman 1984; Milliken 1987; Monat et al. 1972). The provision of sufficient and context-related information through advanced IS reduces the degree of uncertainty, which favorably affects the stress process.

In contrast, the interaction with advanced IS was perceived at the same time as more stressful compared with the simple IS (due to the subdimensions of challenge, self-concept, and locus of control). The higher degree of information provided by the advanced IS forces the individual to process more information which imposes an additional cognitive load (Baumann et al. 2008), thus making the driving task more challenging. The resulting driver distraction due to the increased workload (Bach et al. 2009; Horberry et al. 2006; Sheridan 2004) results in a

loss of control over the driving task, which, in turn, weakens the locus of control. In addition, the increased complexity of technical capabilities and terminology associated with advanced IS increases the perception of stress (Ragu-Nathan et al. 2008), as the user is forced to spend more time and effort in understanding all aspects of the provided technology in order to utilize all relevant functionalities. Especially the information presented by IS in BEVs differentiates due to the electric propulsion from that one in conventional vehicles, which often confuses the driver and leads to a certain degree of uncertainty (Stroemberg et al. 2011).

With regards to the stress-attitude relationship, the results confirmed the previous findings of studies B1, C1, C2, showing that a higher level of both, IS-induced and range stress lead to a lower attitude towards using a BEV. In summary, the study emphasized the importance of considering the dual effect of IS on stress because it enables a more precise prediction of IS-influenced behavioral outcomes in specific fields of applications. On the one hand, IS enables to reduce stress, which in turn, increases the attitude towards performing a specific behavior. On the other hand, the interaction with IS might lead to stress at the same time, which in turn, negatively affects the attitude towards performing a specific behavior. Table F-4 presents the title of the study and the core contributions.

Table F-4 Findings of Study D1

Findings of Study D1	
Title	On the Duality of Stress in Information Systems Research – The Case of Electric Vehicles
Core contributions	Research model that enables the investigation of the dual effect of IS on stress and its consequences for behavioral outcomes. Showing that advanced and complex IS are able to reduce range stress, while at the same time, the interaction with these systems induce stress. Both, range stress and IS-related stress negatively influence the attitude towards using a BEV.

The insights from studies B1, C1, and C2 laid the foundation for investigating the duality in the effect of IS on stress perception, which was finally captured in study D1. Based on all findings generated within the four conducted studies, a conceptual framework has been developed, depicting an integrated view on the IS-stress-behavioral outcomes relationship on two levels. On the overarching level, the framework relates the findings to a general relationship between IS, stress, and attitude, while on a subordinated level, the framework applies the findings to the specific research context of BEVs. Figure F-1 presents the developed framework.
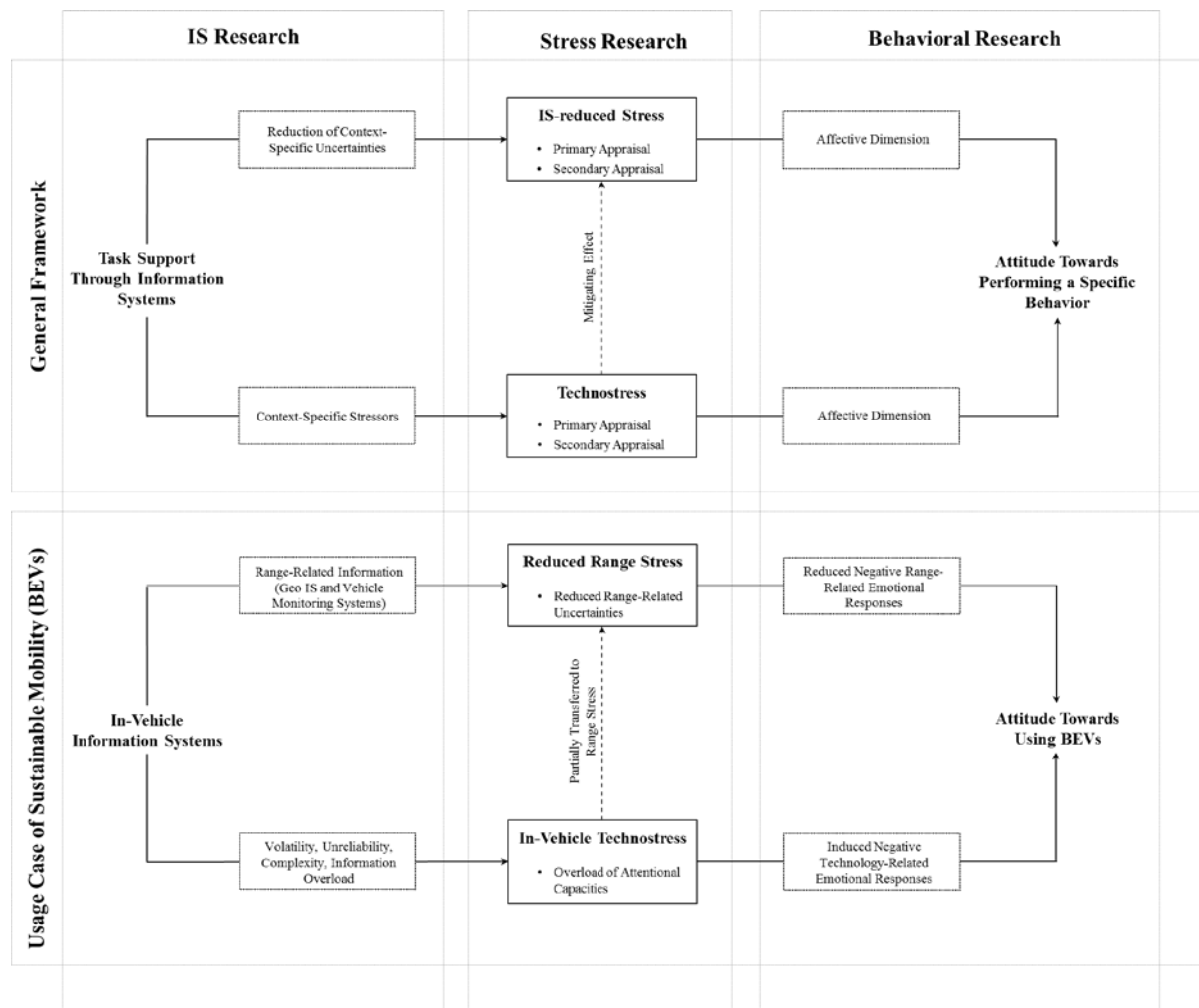
Figure F-1 Integrated Findings of the Research

As illustrated, IS generally lead to effects that are dual in nature. While bearing the potential to reduce stress in specific situations, the interaction with IS might lead to stress reactions. Both directional effects influence behavioral outcomes.

In this context, IS can reduce the related uncertainties about a specific situation (i.e., environmental changes and their consequences (Milliken 1987)), which are considered to be a powerful stressor (Monat et al. 1972; Zakowski 1995). By providing timely and relevant context-related information about a situation through IS, the information gap associated with a situation can be closed, thus enabling a better prediction of the outcome of certain events (Garner 1962; Lawrence and Lorsch 1967).

In contrast, the interaction with IS may induce stress at the same time, mainly caused by certain context-specific stressors. In the organizational context, for example, the increased workload for users imposed by IS, the feeling of permanently being connected through IS, the complexity associated with IS, or the pressure regarding being up to date with new technolog-

ical developments constitute powerful stressors (Ragu-Nathen et al. 2008; Tarafdar et al. 2007; Tu et al. 2005). In the private usage context, e.g., IS-supported social networks, the feeling of giving too much social support or the increasing invasion of social network sites in private life might lead to stress perceptions in the user (Maier et al. 2012; 2014). Technology-related stress can mitigate the potential value of IS in reducing stress (IS-reduced stress), as stress related to a specific situation can be transferred to other situational contexts (Liu and Ali 2008). Both IS-reduced and IS-induced stress influence the attitude towards performing a specific behavior because the resulting emotional response (Lazarus 1993a; 1993b; 2006) influence the affective component (Ajzen 2005; Breckler 1984; Greenwald 2014) of the attitude construct.

In the particular research context of BEVs, systems within the category of vehicle monitoring and geo IS and navigation (Brandt 2013) seem to be especially useful for reducing range stress. In this regard, advanced traveler IS provide drivers with important information about current traffic situations and available charging stations reachable within the given charge, enabling better trip planning and energy usage. This makes the given driving task less stressful, as the uncertainty regarding whether an intended destination can be reached is reduced. Thus, the emotional responses of concern, worry, or nervousness associated with range stress (Nilsson 2011; Rauh et al. 2015a) can be reduced, which in turn positively influences the attitude towards using BEVs.

In contrast, as explained above, the interaction with in-vehicle IS might lead to stress reactions in the user. In the particular context of BEVs, highly volatile, inconsistent, and unreliable range information displayed by, for example, the digital range gauge in BEVs (Lundstroem 2014; Franke et al. 2015; Wellings et al. 2011), as well as the complexity of IS in BEVs due to the increased digitalization in the automobile (Yoo 2010), especially in and around BEVs (Abdelkafi et al. 2013; Dijk et al. 2013) additionally exploit the limiting mental resources needed for the driving task (Bach et al. 2009; Hollnagel et al. 2003; Pereira et al. 2008). Such effects, in turn, lead to an overload of attentional capacities in the driver (Ma and Kaber 2005; Matthews 1995). The resulting IS-induced stress can mitigate the positive effects that in-vehicle IS have on range stress, as the individual might transfer this type of stress to range stress. Finally, as explained above, the negative associated emotional response reduces the desire of using BEVs for a certain route.

1.4   Outlook: Applying the Research to Sustainable Mobility-Related Business Models

The previous conducted studies set their focus on the usage case of driving a BEV in a critical range situation to explore the effect of IS on stress and its consequences for behavioral outcomes. BEVs promise considerable environmental benefits (Tang et al. 2013) and are therefore increasingly integrated in mobility-related sustainable business models, such as e-car sharing (Seign and Bogenberger 2012). While IS can contribute to the efficiency of e-car sharing (Hildebrandt et al. 2015), an inappropriate deployment of IS can lead to stress perception and therefore negatively impact the future adoption of such services and thus BEVs in general. Study E1 therefore investigated the impact of different IS-enabled dynamic consumption-based pricing systems (King and Lyytinen 2005) on the perception of stress and the resulting effects on the willingness towards using e-car sharing. The study focused on these particular pricing systems because they constitute an important component of IS-enabled business models for sustainable services (El Sawy and Perreira 2013; Hildebrandt et al. 2015; Knote and Blohm 2016) which affect the user directly (Osterwalder et al. 2005).

The findings of the conducted field experiments in real traffic situations showed that the deployment of IS-enabled pricing systems, i.e., charging every half an hour and second-based charging, led to a higher perception of psychological stress in the user, mainly explained by higher evaluations of the situation as threatening and challenging and by a decreased assessment of the situation as controllable (locus of control) as well as by reduced perceptions of confidence with respect to managing the task (self-concept of own abilities). While IS-enabled pricing systems increased the price transparency for the user by enabling a more precise pricing, the deployed systems created a time pressure due to permanently displaying the travel time and costs, which, in turn, led to cognitive strains (Keinan et al. 1999) that potentially distract the user. The additional increased pressure to monitor the price development consumes limited mental resources needed for performing the driving task (Baumeister et al. 1998; Karau and Kelly 1992; Kelly et al. 1997), which leads to an information overload and higher stress perceptions (Bach et al. 2009; Hollnagel et al. 2003; Horberry et al. 2006; Matthews et al. 1998; Osswald et al. 2012; Schmidt et al. 2010). In addition, the final costs for using the e-car sharing service is difficult to assess in advance for the user, as, for example, traffic or further factors cannot be influenced by the user. As discussed above, the resulting degree of uncertainty reduces the ability to forecast events (Babrow et al. 2000; Brashers 2001), which in turn, influences the appraisal processes of stress in an unfavorable manner.

Finally, in alignment with the findings of the previous conducted studies, study E1 revealed that stress is negatively associated with the attitude towards using the e-car sharing service, which in turn, appeared to be a significant predictor of the intention to use car sharing. Table F-5 illustrates the title of the study and the core contributions.

Table F-5 Findings of Study E1

Findings of Study E1	
Title	Too Much of a Good Thing? An Experimental Investigation of the Impact of Digital Technology-enabled Business Models on Individual Stress and Future Adoption of Sustainable Services
Core contributions	Assessment of the impact of IS-enabled business model designs on individual stress and perception concerning the future usage of related service. Pointing on the importance of accounting for potential dysfunctional societal effects of IS the context of sustainable business models by revealing that a higher degree of IS deployment in terms of IS-enabled pricing systems increases the perception of psychological stress in the user. Showing that a higher level of psychological stress negatively influences the attitude and thus intention towards using e-car sharing.

In summary, study E1 demonstrated that the initial developed and validated conceptual research model can be applied in further sustainable research contexts, apart from driving BEVs in critical range situations. The results highlighted the adverse effect of IS on behavioral outcomes related to services of sustainable business models, showing how opportunities for sustainable transformation created by IS (Hildebrandt et al. 2015; Wagner et al. 2014) can be diminished by higher levels of IS support.

2   Implications

Using the example of BEVs, this thesis has delineated the relationship between IS, stress, and behavioral outcomes. Established theories were combined, extended, and empirically validated to explore the dual effect of IS on the perception of stress and its consequences on behavioral outcomes. Based on the findings presented in the previous chapter, the following chapter discusses the general implications of this thesis for research and practitioners.

2.1   Major Contributions to the Research Community

The thesis sets out in the first step some major implications primary for the transportation science community, particularly, in the field of electric mobility. The developed research model has been validated by using the example of driving a BEV. In this context, the outlined work provides a research model that enables relevant stakeholders in the field of transportation science to explore two main phenomena that can be observed in drivers of BEVs. First, the derived research model enables the investigation of the influence of in-vehicle IS on the perception of stress that results from the limited driving range in BEVs (Rauh et al. 2015a; Tate et al. 2008). Although previous research has suggested that the influence of IS generally might be useful to reduce range stress (Eisel and Schmidt 2014; Rauh et al. 2015b) by, for example, integrating additional information in in-vehicle IS (Ferreira et al. 2011; 2014) or by adjusting the design of the respective range-related systems (Jung et al. 2015; Lundstroem 2014; Stroemberg et al. 2011), the actual perception of range stress with particular focus on the stress appraisal processes have not been investigated in detail. Second, the increased digitalization in the automotive industry (Gao et al. 2014; Mc Kinsey 2014) leads to an expected increase of IS in BEVs (Abdelkafi et al. 2013; Burns 2013; Dijk et al. 2013). The limited cognitive resources for interacting with in-vehicle IS compete with that one needed for performing the complex task of driving (Fuller 2005; Hollnagel et al. 2003; Ma and Kaber 2005), which, in turn, might lead to driver distraction and stress (Bach et al. 2009; Horberry et al. 2006; Matthews et al. 1998; Osswald et al. 2012; Schmidt et al. 2010). Thus, the provided research model enables relevant stakeholders to find a balance between providing sufficient information to the driver to reduce range-related concerns while not overloading and frustrating the driver (Neumann and Krems 2015). With particular focus on this dilemma, the thesis outlines the importance of using biological measurements. Such measures make it possible to investigate the development of stress over time, and hence are necessary when investigating

the phenomenon of range stress (Nilsson 2011; Rauh et al. 2015a) as well as stress that results from the interaction with IS (Riedl et al. 2012).

With regards to the findings of study E.1, this thesis contributes to mobility-related business model research by emphasizing the potential dysfunctional societal consequences of increased IS use. While the viability of business models can be enlarged by, for example, an increased accessibility of real-time information (Amey et al. 2011; Teubner and Flath 2015) or the possibility to track, control, and monitor the related services (Hildebrandt et al. 2015), an inappropriate application of IS can negatively influence willingness to use the related services. Moreover, research in the field of business models has mostly centered on an organizational level, thus neglecting the actual impact on the individual (Bui and Veit 2015; Elliot 2011; Malhotra et al. 2013). Against this background, this thesis contributes to the call for more research on the individual and societal impacts of digitalization-driven business models (Loebbecke and Picot 2015), especially with respect to the importance of applying an experimental research design when exploring such effects (Chesbrough 2010; Sosna et al. 2010).

Although the thesis' focus is on stress perception in the context of BEVs, it also provides some insights to the IS community, particularly, to the IS research stream of human-computer interaction (Banker and Kauffmann 2004). Within this research subdomain, much recent work has been dedicated to the dark side of IS (Tarafdar et al. 2015a), in particular, to stress that results from interaction with IS due to, for example, information overload or IS complexity (Ayyagari et al. 2011; Galluch et al. 2015; Ragu-Nathan et al. 2008; Riedl et al. 2012; Tarafdar et al. 2017). Although previous studies have shown that IS can be useful in reducing stress in a variety of usage contexts (e.g., Al-Osman et al. 2014; Garg et al. 2005; Lohaus et al. 2010; Rauh et al. 2015a), recent IS research has stressed the importance to consider the relationship between IS and the psychological stress appraisal processes (Tarafdar et al. 2017). Tarafdar et al. (2017) summarize this research gap as follows:

> "While techno-stressors and aspects of the technology environment have been examined, studies have not looked at primary or secondary appraisal, that is, the influencers of the relationship between environmental conditions and techno-stressors" (p. 8).

This thesis revealed that IS in the usage context of BEVs have the ability to influence the appraisal processes of stress in a favorable manner by providing timely and relevant information, which in turn, has been shown to positively affect behavioral outcomes. Hence, the research on hand sheds light on an as yet understudied perspective on the IS-stress-behavior relationship.

In addition, this research revealed that the provision of too much and unreliable information through in-vehicle IS increases stress perception in the user and thus negatively influences the attitude towards using BEV. Much research in this field has focused on the relationship between the interaction with in-vehicle IS and driver distraction (Kircher 2007; Lee et al. 2014; Ranney 2008; Young et al. 2007). This thesis extends the knowledge in this field because it provides first insights into the effect of in-vehicle IS on the respective appraisal processes of psychological stress.

In addition, previous technostress research is rather centered in the organizational setting (Riedl et al. 2012), although the private usage context becomes increasingly important for this research stream (Maier et al. 2012; 2014; 2015b). This trend is additionally reinforced by the tendency that IS are more being developed for and used by consumers (McKenna et al. 2013). In this context, Hess et al. (2014) summarizes this trend with the umbrella term *digital life*, which "denotes a private life that is strongly affected by the use of digital technologies" (p. 247). With its research focus on BEVs, this thesis introduced a new field of application for technostress research and responds to the call for more research on the

> "broad collection of 'negative' phenomena that are associated with the use of IT, and that have the potential to infringe the well-being of individuals, organisations and societies" (Tarafdar et al. 2015a, p. 161).

Another intriguing implication of this thesis is that a simultaneous consideration of the dual effect of IS on stress in terms of the potential value of IS in reducing stress and the risk of such systems to induce stress at the same time enables a more precise predicting of behavioral outcomes. Hence, this study contribute to a better understanding of the role of IS in stress perception and address the gap of its ambivalent role on behavioral outcomes (Califf et al. 2015; Lauwers and Giangreco 2016). In this context, research has shown that IS-induced stress results in behaviorally negative outcomes, such as exhaustion from using a technology, reduced task performance, or reduced tendency of using a technology (Maier et al. 2014; Tarafdar et al. 2011a; 2015b), while at the same time, such unfavorable behavioral outcomes can be mitigated when IS reduces context-related stress (Eisel et al. 2014). Thus, research in the field of IS and stress could include this dual effect to generate further insights into behavioral outcomes. Studies, that, for example, focus on the potential value of IS in reducing stress (e.g., Al Osman et al. 2014; 2016; Astor et al. 2013; Eisel et al. 2014; Garg et al. 2005) should also be aware that the interaction with these systems can lead to stress at the same time. In this context, MacLean et al. (2013) developed an early-stress warning biofeedback system called

MoodWings that is supposed to support the user in performing better during a stressful driving task. Although the system was able to significantly increase driving safety, it led to higher experienced levels of physiologically and self-perceived stress. The consideration of a dual effect of IS on stress in the design and development of such systems makes it possible to fully exploit the associated system benefits. In contrast, research that points on the potential danger resulting from the interaction with IS (Ayyagari et al. 2011; Maier et al. 2014; Ragu-Nathan et al. 2008; Riedl 2013; Tarafdar et al. 2007; 2010; 2015b) also benefit from the insights of this research. While, for example, increased IS complexity, associated feeling of permanently being connected with IS, or information overload constitute powerful stressors that lead to adverse behavioral outcomes (Ragu-Nathan et al. 2008), such systems are also able to reduce stress-related uncertainties in the user by providing context-specific information. Considering this dual effect allows for a more precise prediction of IS-influenced behavioral outcomes in specific fields of applications.

Finally, by validating the importance of the stress construct in predicting attitudes, this thesis extends behavioral research models that apply the attitude construct to predict behavior, such as the theory of reasoned action (Ajzen and Fishbein 1980) or the theory of planned behavior (Ajzen 1991). Moreover, as the attitude construct plays a major role in acceptance research (Venkatesh et al. 2003), the findings of this thesis contribute to this specific IS research stream. In this context, the importance of integrating affective components in acceptance research has been emphasized within the IS community (e.g., Brown et al. 2004; Djamasbi et al. 2009; Kulviwat et al. 2007), since traditional research has focused rather on cognition than on affect (Furneaux and Nevo 2008; Zhang and Li 2005). In this context, Kulviwat et al. (2007) emphasize:

> "Although a few studies have included a limited form of affect, integrating a comprehensive representation of affect with cognition in a model has yet to occur" (p. 1060).

With regards to this gap, recent studies on technology acceptance have begun to highlight the importance of considering affective components, i.e., fun or pleasure, when investigating the individual's perception of a technology (Venkatesh et al. 2012). However, although stress can influence the individuals decision to accept a technology (Maier et al. 2015), there is a lack of understanding regarding the effect of stress on the attitude towards performing a behavior.

2.2 Major Contributions to Practice

Due to the thesis' focus on BEVs as a usage case to explain the dual effect of IS on stress and the resulting consequences for behavioral outcomes, it sets out important contributions for designers and decision makers in the automotive industry.

Considering the fact that the transportation sector mainly contributes to the emission of greenhouse gas (European Commission 2016), BEVs are regarded to be an important sustainable means of transportation with a great potential for reducing environmental pollution (Thomas 2009). However, the market success of these vehicles is still low (Lieven et al. 2011; Zhang et al. 2014), as the limited driving range of approximately 150 kilometers (Perujo and Ciuffo 2010) and the underdeveloped charging infrastructure (Dong et al. 2014) leads to driver stress that is related to the concern of not reaching a planned destination due to a depleted battery (Tate et al. 2008). First, the findings of the thesis revealed that the provision of information through IS generally influences the perception range stress, thus emphasizing the importance of an appropriate IS design. With respect to the variety of functionalities that in-vehicle IS offer to drivers (Brandt 2013), the thesis identify two range-related in-vehicle IS categories, namely, vehicle monitoring and geo IS as mainly influencing the driving range perception, and hence should be object of interest for designers of in-vehicle IS when approaching the range problem. While the category of vehicle monitoring relates to technologies that monitor specific functionalities of the vehicle, such as the range gauge, the category of geo IS and navigation includes all systems that provide information about the road conditions, e.g., navigation systems (Brandt 2013). Comparing both categories, the findings of the thesis indicated that the navigation system is perceived as especially beneficial for overcoming range stress, as it enables the driver to better plan the route to the final destination, thus reducing uncertainty related to the situation. In this context, navigation devices should display a list of nearby public and semi-public charging stations and suggest alternative routes in case of critical range situations by considering alternative charging options and automatically reserving possibilities to increase user experience. In contrast, the thesis revealed that the range gauge as a typical feature of the category of vehicle monitoring increases the perception of range stress in the driver, thus questioning whether the deployment of range gauges in its current appearance in BEVs are useful. The range gauge constitutes an additional source of uncertainty, as it displays the information in a highly volatile manner (Jung et al. 2015). Current range estimates do not appropriately incorporate individual factors in the distance to empty estimation, such as changing driving behavior, elevation profile, traffic condition, or weather

(Ferreira et al. 2012; Neaimeh et al. 2013; Pichler and Riener 2015; Rui and Lukic 2011). The resulting imprecision of such devices are reflected by sudden changes in the displayed range of up to 20 percent (Lundstroem 2014), which in turn, increases the perception of range stress, and moreover reduces the degree of trustworthiness in the range information. As a consequence, decision makers should be careful in integrating range devices that display the range information accurate but highly volatile (e.g., through a digital range display) before either the driving range of BEVs can – cost-effectively – be increased to that of conventional vehicles and/or the problem of the insufficient charging infrastructure (Dong et al. 2014) and long charging duration (Kumar and Jain 2014) can be solved. In order to bridge these constraints, the range information should be displayed more inaccurate but with a low degree of volatility, as it is presented by the state of charge display by means of a needle.

It could be shown that the provision of accurate but highly volatile range information additionally leads to a low level of trust perception in the range estimate. This is especially important, as trust in part of a system can be transferred to trust in the whole system (Hoff and Bashir 2015; Parasuraman and Riley 1997). The management of car manufacturers should be aware that a low trust in, for example, the range gauge might result in a low trust in the vehicle and the related car manufacturer brand, thus endangering the reputation of the car manufacturer. This potential risk of losing trust can be reduced by ensuring that deficiencies related to these IS are sufficiently communicated to users of BEVs (Cook and Thomas 2005; Dzindolet et al. 2003; Kay et al. 2016).

In addition, besides the influencing character of the design of certain range-related IS in BEVs on the perception of range stress, the general provision of too much and complex information to drivers can result to a perception of another type of stress that is referred to as technostress. The vehicle of today has already become a computer platform with an open interface for integrating more devices and services (Koscher et al. 2010; Yoo et al. 2010), which in turn, increases the opportunities to include a variety of intelligent concepts into the vehicle, such as car-to-infrastructure communication or the Internet of Things (Brandt 2013; Vermesan and Friess 2014; Weng et al. 2016; Xie and Wang 2017). Practitioners should keep in mind that exposure to IS might lead to stress perception, which – besides the general negative effect on the individual's well-being and health (Avey et al. 2003; Marin et al. 2011; Richardson et al. 2012) – poses a risk in becoming involved in accidents (Kontogiannis 2006; Matthews et al. 1998).

In summary, the trend of increasingly integrating IS in and around BEVs (Abdelkafi et al. 2013; Burns 2013; Dijk et al. 2013), is a double-edged sword. While the appropriate provision of relevant and timely information through IS can contribute to reduce range stress, it might lead at the same to stress perception. The overall findings of the conducted studies show that a higher level of range stress and technostress negatively influence behavioral outcomes in terms of a lower attitude towards using BEVs. Practitioners profit from these findings, as the attitude is a significant predictor of behavioral intentions and thus actual behavior (Ajzen 1991; 2005; Ajzen and Madden 1986). The proposed and validated research model enables practitioners to better understand and balance the dual effect of IS on the perception of stress, thus improving the human-computer interaction as a main distinctive feature influencing car purchases and the value of automobile brands (Lisboa et al. 2016). In this context, the thesis addresses a fundamental difficulty, as emphasized by Kantowitz and Moyer (1999):

> "Although the designer is most often human, human-centered design does not imply that the system designer is a satisfactory surrogate for the end user. Information that the designer finds useful and interesting may not matter to the driver, and so should not be presented (p. 4).

The findings of the thesis are not only limited to the context of BEVs and can be useful for practitioners in further fields of application in which user experience is directly impacted by IS. In this context, the thesis showed that practitioners involved in digital business model management, particularly, with focus on designing sustainable services, profit from the findings of the research. While IS serve as an enabler of sustainable business models by, for example, an increased access of information in real-time (Amey et al. 2011; Teubner and Flath 2015) or enhanced monitoring opportunities (Hildebrandt et al. 2015), practitioners should consider the actual impact of business model characteristics on individuals. By investigating the instance of e-car sharing as a typical representative of a modern sustainable business model (Kley et al. 2011), the findings of the thesis clearly point on the potential dysfunctional consequences in terms of psychological stress that might result from an increased IS application. IS afford the integration of certain characteristics of business models that affect the customer directly, such as precise pricing through consumption-based pricing systems (Kind and Lyytinen 2005; Osterwalder et al. 2005). The potentials of IS in successfully designing sustainable business models with highly precise pricing schemes can be limited as users tend to react highly sensitively to pricing information in terms of psychological stress, which in turn, results in a decline of user acceptance. Here, practitioners should apply experimental testing

to customize business model services, to reduce risk factors for the successfully design of business model services before investing large sums of money.

Finally, the findings of the thesis add also value to practitioners in further areas in which human-computer interaction shapes the user experience with technologies. Decision support systems, for example, that collect, store, process data are applied in business to support the decision making-process and hence are increasingly implemented in organizations (Al-Mamary et al. 2014; Grabski et al. 2011). In this context, the effectiveness of the decision-making process is strongly dependent upon the information being available (Saaty 1990). Keller and Staelin (1987) outline that the decision effectiveness is adversely affected by increases in quantity of information made available. While the provision of information through decision-support systems unlock the potential to reduce work-related stress by easing the access to information, these systems are able to produce more information more quickly and hence can lead to an information overload, stress, reduced decision quality, and loss of job satisfaction (Gul and Chia, 1994; Jones 1997; Speier et al. 1999; Ragu-Nathan et al. 2008; Tarafdar et al. 2011a). Hence, the research on hand supports practitioners in the design of decision-support systems to the fully exploit their potential.

3   Concluding Remarks

Using the example of BEVs, this cumulative thesis aimed at understanding how IS influence the perception of stress and what consequences this effect has on behavioral outcomes. To achieve this aim, two research questions were developed and approached with five studies applying an experimental research design. The findings revealed that IS lead to consequences that are dual in nature. IS can be useful for overcoming stressful situations and, at the same time, pose the risk of inducing stress. Both directional effects influence behavioral outcomes, thus providing fruitful insights for research and practitioners.

One study in Chapter B provided insights in the positive effect of IS on the perception of stress and its consequences for behavioral outcomes. A conceptual model was developed that enables to investigate the relationship between IS, stress, and behavior. The results showed that the general provision of timely and relevant information through IS is suitable to reduce stress that origins from the limited range in BEVs, thus positively influencing the attitude towards using BEVs. As the findings of Chapter B gave also indication that stress might result from the interaction with IS, Chapter C aimed at exploring this effect in more detail. To do so, two studies investigated the opposite effect of IS on the perception of stress. It could be

shown that the inappropriate provision of information through IS might increase the perception of stress in the user. In the specific case of BEVs, the results indicated that especially accurate but highly volatile range information and too much information increased the perception of stress, which in turn, negatively influenced the willingness to use BEVs. In summary, the findings revealed that there exists a dual effect of IS on the perception of stress – IS can either reduce or induce stress. To capture both perspectives simultaneously, one study in Chapter D put emphasis on the importance of integrating both perspectives, showing that both IS-induced and IS-reduced stress influence behavioral tendencies. Finally, one study in Chapter E expanded the research focus to a broader context of sustainability by emphasizing the importance of considering the actual impact of IS on individuals in the design of sustainable business models. It has been shown that IS-enabled pricing schemes – an important characteristic of sustainable business models – influence the stress perception in users of car sharing. In alignment with the previous findings, a higher level of stress hampers the willingness to use e-car sharing.

3.1   Limitations

While this thesis derived important implications for research and practitioners, there are also some limitations that must be considered when interpreting the results. Overall, this thesis understands itself as a first step into the exploration of the dual effect of IS on the perception of stress and its consequences on behavioral outcomes. In this regard, the results of the study have limited generalizability because they rely on a specific context of application, i.e., BEVs.

With exception of study D1, field experiments in natural setting were conducted to test the proposed research models. Field experiments carried out in natural settings generally suffer from a low influenceability of external factors, such as behavior of other traffic participants (Harrison and List 2004). Although the experiments were conducted at the same time of day to minimize external confounding factors, it was not possible to control for all traffic-related influences, for example, risky overtaking maneuvers. In this context, the stress appraisal processes might be influenced by such confounding factors (Gulian et al. 1989), thus biasing the results. Moreover, compared to online-based surveys, the general set-up of field experiments were notably more complex and higher in time consumption, thus resulting in a lower sample size. Hence, some findings (e.g., non-significant outcomes) may be a result of the small sample size.

Another concern that might bear a threat for the generalization of the findings results from the composition of the sample. Participants of the conducted studies were German speaking individuals, thus limiting the generalizability of the findings to this specific population (Lee and Baskerville 2003). The stress process is mainly affected by sociodemographic factors, previous experience, technical affinity, or personal traits (e.g., Burke and Mikkelsen 2005; Day and Livingstone 2003; Fernandes et al. 2009; Gallo and Matthews 2003; Lazarus and Folkman 1987; Ragu-Nathan et al. 2008). Most participants in the respective studies had a higher level of education and were younger than the average German citizen. Although young and educated people generally reflect potential customers of sustainable means of transportation (Franke et al. 2016; Hampshire and Gaites 2011), an extension and variation of the sample could support the validity of the generated findings.

In addition, the conducted studies relied on specific scenarios, using a BEV with specific in-vehicle IS. For instance, a *Volkswagen e-up!* was used to investigate the impact of IS on the perception of stress in studies B1; C1, C2, and E1. Thus, the respective stress appraisals are based on a certain in-vehicle IS design and functionality. Compared to other electric vehicles, such as the *Tesla Model S* (Tesla 2017), the in-vehicle IS of the *Volkswagen e-up!* provide a low range of functionalities, thus limiting the results to similar equipped BEVs. Nevertheless, the results can still be considered as important, as the main focus of the thesis was to capture the duality in the effect of IS on stress and the consequences for behavioral outcomes rather than on BEVs. In addition, this limitation was tackled by study D1, which relied on advanced in-vehicle IS with high range of functionalities to capture the impact of IS on stress and behavioral outcomes.

There is another limitation concerning the set-up of the experiment. Due to insurance reasons, the experimenter was present during the driving tasks in studies B1, C1, and E1 (an exceptional permission was given for study C2). The presence of the experimenter might have biased the results to a certain degree. However, to minimize such experimenter effects (Kintz et al. 1965), the experimenter sat in the driver side rear seat. Communication between the experimenter and the driver was not allowed during the driving task to avoid additional disturbance in the driver's natural driving behavior. Moreover, short interviews were conducted with participants after the driving task to get an impression of participant's perceived stress experience.

Another limitation refers explicitly to study D1 which relied on mental simulation experiments to test the proposed research model. In general, actual preferences must not necessarily

match those of hypothetical imagined situations because mental simulation experiments are only capable to reflect an abstraction of the real world, and in addition, participants have limited cognitive resources to mentally reconstruct the intended realistic situation (Brandts and Charness 2000; Jones et al. 2011; Nersessian 1992). To minimize this limitation, participants were tested on their ability to mentally put themselves in the respective scenarios. In addition, pictures with a detailed explanation of the scenarios using a first-person viewpoint were included to stimulate participant's imagination capacity (Ludwig 2007).

Aside from the limitations mentioned above, most results rely on self-report questionnaires that pose the risk of response distortions (Razavi 2001). In the specific research context, question-based questionnaires reflect the perception of psychological stress at specific point in time. For instance, participants of studies B1, C1, C2, and E1 received the questionnaire directly after completing the driving task. As a consequence, likely the most recent impressions was predominant, which in turn, might bias the results. As discussed in study B1, a frequent provision of questionnaires throughout the experiment could alleviate such effects. However, this might lead to another shortcoming in terms of affecting the procedure of the experiment. In addition, study B1 has shown that physiological stress measures (Collins et al. 1981; Riedl 2013; Van Eck et al. 1996) are a useful extension to questionnaire-based assessment methods for stress, as the temporal progression of stress can be tracked. At this point, it should be noted that the physiological stress measure used in study B1 does not allow to explicitly draw conclusion on range stress, as it measures all types of stress.

Finally, the studies primarily conceptualized psychological stress as a negative experience by relying on the transactional stress model of Lazarus and Folkman (1984). Research differentiates in this context between two types of stress, eustress and distress (Selye 1976; 1979). While eustress refers to beneficial stress in terms of positive feelings that results from the experience of positive events (e.g., an engagement), distress is associated with negative feelings and unhealthy bodily states. Focusing on the appraisal processes of the transactional stress model (Lazarus and Folkman 1984), challenge appraisals can also be accompanied by positive emotions, such as excitement, eagerness, or confidence (Lazarus 1993a; Folkman 2008). Hence, the evaluation of a critical range situation in BEVs does not imply necessarily a negative experience. However, the findings also revealed significant differences in the threat appraisal scale, thus indicating that the respective scenarios were linked to a negative experience (Lazarus and Folkman 1984). In addition, participants reported in the short interviews that

were conducted after the driving task that the given scenarios were rather associated with unpleasant negative feelings than with positive stress.

3.2 Avenues for Further Research

Against the backdrop of the findings and the derived limitations, the thesis provides potential pathways for future research.

First, as discussed above, the findings of studies B1; C1, C2, and E1 are based on specific scenarios, using a *Volkswagen e-up!* with specific in-vehicle IS. The proposed research should be investigated more in detail by using a variety of scenarios with different vehicles and in-vehicle IS (e.g., scenarios with a higher degree of digitalization in and around the vehicle). This might result in new insights regarding the relationship between IS, the appraisal processes of stress, and behavioral patterns.

Second, the duration of the treatments within the experiments were relatively short, which does not allow us to make any conclusions as to whether the assumed relationships between IS, stress, and behavioral outcomes is a transient effect or stable over time. The investigation of such effects could raise new opportunities for future research. Here, long-term field studies could be applied to shed light on such effects (Buehler et al. 2014). Moreover, using establishing controlled environments for the experiments by, for example, using driving simulators (Roenker et al. 2003; Srinivasan and Jovanis 1997) might be useful to counteract the above discussed limitations regarding the experimenter effect and external confounding factors (e.g., traffic behavior).

Third, as the sample represents a German speaking population, it would be useful to expand the research to other cultural backgrounds. Generally, the stress appraisal processes are influenced by several cultural practices, such as religion or puberty rites (Spradley and Phillips 1972). In this context, extending the research to the Asian region could be of particular interest. China, for example, is considered to be the dominant sales market for automobiles, thus shaping the speed and direction of the digitalization trend in the automotive industry (Gao et al. 2014). Moreover, the perception of stress differs between Western and Asian countries (Tu et al. 2005).

Fourth, this thesis mainly follows the behavioral science paradigm, using existing real-world IS for the validation and development of theories to explain behavior (Hevner et al. 2004). In alignment with the design science research paradigm, which focuses on creating IS artifacts

(Kuechler and Vaishnavi 2008), future research could focus on the design and evaluation of innovative in-vehicle IS to optimize the user experience with particular focus on stress perception and behavioral outcomes. In this context, research has shown that the design of IS in BEVs mainly influences the user's stress perception (Jung et al. 2015; Lundstroem 2014).

In addition, as shown by study B1, the application of physiological stress measures should additionally be applied to further shed light on the biological reactions to stressful encounters. Riedl et al. (2012) summarize that most studies in the field of technostress use questionnaire-based approaches and highlight the importance of using physiological stress measures:

> "Conscious stress perceptions of humans, measured by means of questionnaires […] hardly correlate with the typically unconscious elevations of stress hormones, in particular cortisol increases" (p. 62).

The importance of using physiological stress measures has also been emphasized in the research context of range stress in BEVs (Nilsson 2011). Apart from these measures, the observation of driver's glance behavior (Birrell and Fowkes 2014; Smith et al. 2005; Tivesten and Dozza 2014) should be studied in future research to investigate which provided information of the IS is actually focused by the user.

After accomplishing the respective driving tasks in studies B1, C1, C2, and E1, short informal interviews were conducted with participants to obtain an impression about the driving experience. Nevertheless, the psychological trains of thought and the explicit reasons for causing psychological stress are outside the scope of this thesis. Here, qualitative research approaches could provide detailed insights on the psychological processes that lie behind the results. At this point, an investigation of the respective technostress creators and inhibitors (Ragu-Nathan et al. 2008) is of great interest. Appendix A presents the preliminary results of a research in progress that aims at identifying relevant technostress creators and inhibitors in the vehicular context and their effects on psychological and behavioral outcomes.

Finally, the transactional model of Lazarus and Folkman (1984) served as a main theoretical lens for explaining the perception of stress throughout all the studies. Other appraisal-related theories, such as the cognitive-load theory (Sweller 1988; 1989) could provide further fruitful insights in the proposed research. The cognitive load theory "is concerned with the manner in which cognitive resources are focused and used during learning and problem solving" (Chandler and Sweller 1991, p. 294), thus providing potential solution approaches for presenting the information through IS without overloading the user's cognitive resources. With respect to the

measurement of behavioral outcomes, the conducted studies relied on the attitude construct as a main predictor of behavioral intentions and actual behavior (Ajzen 1991; Ajzen and Madden 1986). In addition, the attitude construct represents a main component in acceptance research, which in turn, mainly relies on behavioral theories (Venkatesh et al. 2003; Williams et al. 2009). In this context, the thesis focused on the initial acceptance towards using IS. Future research could shift the focus on continual usage behavior (Maier et al. 2015), as the theoretical foundations between acceptance and continual usage decisions differ (Bhattacherjee and Lin 2014; Karahanna et al. 1999).

References

Aamodt, M. G. 2015. Industrial/organizational psychology: An applied approach, Sydney: Cengage Learning.

Abdelkafi, N., Makhotin, S., and Posselt, T. 2013. "Business model innovations for electric mobility—what can be learned from existing business model patterns?," International Journal of Innovation Management (17:1), pp. 1-41.

Acello, R. 1997. "Getting into gear with the vehicle of the future," San Diego Business Journal (18:35), p. 15.

Adams-Guppy, J. R., and Guppy, A. 1995. "Speeding in relation to perceptions of risk, utility and driving style by British company car drivers," Ergonomics (38:12), pp. 2525-2535.

Ahmed, M. U., Begum, S., Funk, P., Xiong, N., and von Scheele, B. 2011. „A multi-module case-based biofeedback system for stress treatment," Artificial Intelligence in Medicine (51:2), pp. 107-115.

AIS (The American Institute of Stress) 2017. "America's #1 Health Problem," (available at https://www.stress.org/americas-1-health-problem/).

Ajzen, I. 1991. "The Theory of Planned Behavior," Organizational Behavior and Human Decision Processes (50:2), pp. 179-211.

Ajzen, I. 2002. "Constructing a TpB Questionnaire: Conceptual and Methodological Considerations," Working Paper, University of Massachusetts, Amherst.

Ajzen, I. 2005. "Attitudes, Personality and Behavior," New York: Mc-Graw Hill International.

Ajzen, I., and Fishbein, M. 1980. "Understanding Attitudes and Predicting Social Behavior," Englewood Cliffs: Prentice-Hall.

Ajzen, I., and Fishbein, M. 2005. "The influence of attitudes on behavior," in Handbook of Attitudes and Attitude Change: Basic Principles, D. Albarracin, B. T. Johnson and M. P. Zanna (eds.), Mahwah: Erlbaum, pp. 173-221.

Ajzen, I., and Madden, T. J. 1986. "Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control," Journal of Experimental Social Psychology (22:5), pp. 453-474.

Al Osman, H., Dong, H., & El Saddik, A. 2016. "Ubiquitous biofeedback serious game for stress management," IEEE Access (4), pp. 1274-1286.

Al Osman, H., Eid, M., & El Saddik, A. 2014. "U-biofeedback: a multimedia-based reference model for ubiquitous biofeedback systems," Multimedia Tools and Applications (72:3), pp. 3143-3168.

Allanson, J. 2002. "Electrophysiologically interactive computer systems," Computer (35:3), pp. 60-65.

Allen, D., and Janda, K. 2006. "The effects of household characteristics and energy use consciousness on the effectiveness of real-time energy use feedback: a pilot study," in Proceedings of the American Council for an Energy-Efficient Economy, pp. 1-12.

Alm, H., and Nilsson, L. 1995. "The effects of a mobile telephone task on driver behaviour in a car following situation," Accident Analysis & Prevention (27:5), pp. 707-715.

Al-Mamary, Y. H., Shamsuddin, A., and Aziati, N. 2014. "Factors affecting successful adoption of management information systems in organizations towards enhancing organizational performance," American Journal of Systems and Software (2:5), pp. 121-126.

Amey, A., J. Attanucci, and R. Mishalani 2011. "Real-time ridesharing. Transportation Research Record," Journal of the Transportation Research Board (2217:1), pp. 103–110.

Anderson, J. C., and Gerbing, D. W. 1988. "Structural Equation Modeling in Practice: A Review and Recommended Two-Step Approach," Psychological Bulletin (103:3), pp. 411-423.

Antonovsky, A. 1990. "Personality and Health: Testing the Sense of Coherence Model," in Personality and Disease, H. S. Friedman (eds.), New York: Wiley, pp. 155-177.

Armitage, C. J., and Conner, M. 2001. "Efficacy of the Theory of Planned Behaviour: A meta-analytic review," British Journal of Social Psychology (40:4), pp. 471-499.

Asendorpf, J. B., Banse, R., and Muecke, D. 2002. "Double dissociation between implicit and explicit personality self-concept: the case of shy behavior," Journal of Personality and Social Psychology (83:2), pp. 380-393.

Astor, P. J., Adam, M. T., Jerčić, P., Schaaff, K., and Weinhardt, C. 2013. „Integrating biosignals into information systems: A NeuroIS tool for improving emotion regulation," Journal of Management Information Systems (30:3), pp. 247-278.

Au, N., Ngai, E. W., and Cheng, T. E. 2002. "A critical review of end-user information system satisfaction research and a new research framework," Omega – The International Journal of Management Science (30:6), pp. 451-478.

Avey, H., Matheny, K. B., Robbins, A., and Jacobson, T. A. 2003. "Health Care Providers' Training, Perceptions, and Practices Regarding Stress and Health Outcomes," Journal of the National Medical Association (95:9), pp. 833-845.

Ayyagari, R., Grover, V., and Purvis, R 2011. "Technostress: Technological Antecedents and Implications," MIS Quarterly (35:4), pp. 831-858.

Babrow, A. S., Hines, S. C., and Kasch, C. R. 2000. „Managing Uncertainty in Illness Explanation: An Application of Problematic Integration Theory," in Explaining Illness: Research, Theory, and Strategies, B. Whaley (eds.), Hillsdale: Erlbaum, pp. 41–67.

Bach, K. M., Jæger, M. G., Skov, M. B., and Thomassen, N. G. 2009. "Interacting with In-Vehicle Systems: Understanding, Measuring, and Evaluating Attention," in Proceedings

of the 23rd British HCI Group Annual Conference on People and Computers: Celebrating People and Technology, Cambridge, UK, pp. 453-462.

Bagozzi, R. P., Yi, Y., and Phillips, L. W. 1991. "Assessing Construct Validity in Organizational Research," Administrative Science Quarterly (36:3), pp. 421-458.

Bandura, A. 1977. "Self-efficacy: Toward a Unifying Theory of Behavioral Change," Psychological Review (84:2), pp. 191-215.

Banker, R. D., and Kauffman, R. J., 2004. "50th anniversary article: The evolution of research on information systems: A fiftieth-year survey of the literature in management science," Management Science (50:3), pp. 281-298.

Baptista, P., Melo, S., and Rolim, C. 2014. "Energy, environmental and mobility impacts of car-sharing systems. Empirical results from Lisbon," Procedia-Social and Behavioral Sciences (111), pp. 28-37.

Barclay, D. C., Higgins, C., and Thompson, R. 1995. "The Partial Least Squares Approach to Causal Modeling: Personal Computer Adoption and Use as an Illustration," Technology Studies (2:2), pp. 285-308.

Bartlett, D. 1998. "Stress: Perspectives and Processes," in Health Psychology, S. Payne and S. Horn (eds.), London: McGraw-Hill, pp. 1-173.

Baum, A., Singer, J. E., and Baum, C. S. 1981. "Stress and the Environment," Journal of Social Issues (37:1), pp. 4-35.

Baumann, M. R., Petzoldt, T., Groenewoud, C., Hogema, J., and Krems, J. F. 2008. "The Effect of Cognitive Tasks on Predicting Events in Traffic," in Proceedings of the European Conference on Human Centred Design for Intelligent Transport Systems, Lyon, France, pp. 3-11.

Baumeister, R. F., Bratslavsky, E., Muraven, M., and Tice, D. M. 1998. "Ego depletion: is the active self a limited resource?," Journal of Personality and Social Psychology (74:5), p. 1252.

Beller, J., Heesen, M., and Vollrath, M. 2013. "Improving the driver–automation interaction an approach using automation uncertainty," Human Factors: The Journal of the Human Factors and Ergonomics Society (55:6), pp. 1130-1141.

Berry, W. D. 1993. "Understanding regression assumptions," Newbury Park, CA: Sage.

Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., and Venkatraman, N. 2013. "Digital Business Strategy: Toward a Next Generation of Insights," MIS Quarterly (37:2), pp. 471–482.

Bharati, P., and Chaudhury, A. 2004. "An empirical investigation of decision-making satisfaction in web-based decision support systems," Decision support systems (37:2), pp. 187-197.

Bhattacherjee, A. 2012. "Social Science Research: Principles, Methods, and Practices," University of South Florida: Open Access Textbooks.

Bhattacherjee, A., and Lin, C. P. 2015. "A unified model of IT continuance: three complementary perspectives and crossover effects," European Journal of Information Systems (24:4), pp. 364-373.

Bhattacherjee, A., and Premkumar, G. 2004. "Understanding changes in belief and attitude toward information technology usage: A theoretical model and longitudinal test," MIS Quarterly (28:2), pp. 351-370.

Biernacki, P., Waldorf, D. 1981. "Snowball Sampling: Problems and Techniques of Chain Referral Sampling," Sociological Methods & Research (32:1), pp. 148–170.

Birrell, S. A., and Fowkes, M. 2014. "Glance Behaviours When Using In-Vehicle Smart Driving Aid: A Real-World, On-Road Driving Study," Transportation Research Part F (22), pp. 113-125.

Birrell, S. A., McGordon, A., and Jennings, P. A. 2014. "Defining the Accuracy of Real-World Range Estimations of an Electric Vehicle," in Proceedings of the 17th International IEEE Conference on Intelligent Transportation Systems (ITSC), Qingdao, China, pp. 2590-2595.

Blascovich, J., and Mendes, W. B. 2000. "Challenge and threat appraisals: The role of affective cues," in Feeling and thinking: The role of affect in social cognition, J. P. Forgas (eds.), New York: Cambridge University Press, pp. 59–82.

Bocken, N. M. P., Short, S. W., Rana, P., and Evans, S. 2014. "A literature and practice review to develop sustainable business model archetypes," Journal of Cleaner Production (65), pp. 42-56.

Bohus, B., Koolhaas, J. M., Nyakas, C., Steffens, A. B., Fokkema, D. S., and Scheurink, A. J. W. 1987. "Physiology of Stress: a Behavioral View," in Biology of Stress in Farm Animals: An Integrative Approach, Wiepkema, P.R., Van Adrichen, P.W.M., (eds.), Netherlands: Springer, pp. 57-70.

Bolovinou, A., Bakas, I., Amditis, A., Mastrandrea, F., and Vinciotti, W., 2014. "Online Prediction of an Electric Vehicle Remaining Range based on Regression Analysis," IEEE International Electric Vehicle Conference (IEEE-IEVC), Florence, Italy, pp. 1-8.

Boons, F., and Luedeke-Freund, F. 2013: "Business Models for Sustainable Innovation: State of the Art and Steps Towards a Research Agenda," Journal of Cleaner Production (45), pp. 9-19.

Booth, P. 2014. "An Introduction to Human-Computer Interaction," New York: Psychology Press.

Bosworth, K., Gustafson, D. H., and Hawkins, R. P. 1994. "The BARN system: Use and impact of adolescent health promotion via computer," Computers in Human Behavior (10:4), pp. 467-482.

Boudreau, M. C., Gefen, D., and Straub, D. W. 2001. "Validation in information systems research: a state-of-the-art assessment," MIS Quarterly (25:1), pp. 1-16.

Bowsher, J. E., and Keep, D. 1995. "Toward an understanding of three control constructs: personal control, self-efficacy, and hardiness," Issues in Mental Health Nursing (16:1), pp. 33-50.

Brandt, T. 2013. "Information Systems in Automobiles –Past, Present, and Future Uses," in Proceedings of the 19th Americas Conference on Information Systems, Chicago, IL, pp. 1-10.

Brandt, T., Feuerriegel, S., and Neumann, D. 2012. „Road to 2020: IS-Supported Business Models for Electric Mobility and Electrical Energy Markets," in Proceedings of the International Conference on Information Systems (ICIS), Orlando, FL, pp. 1-10.

Brandts, J., & Charness, G. 2000. "Hot vs. cold: Sequential responses and preference stability in experimental games," Experimental Economics (2:3), pp. 227-238.

Brashers, D. E. 2001. "Communication and Uncertainty Management," Journal of Communication (51:3), pp. 477-497.

Breckler, S. J. 1984. "Empirical validation of affect, behavior, and cognition as distinct components of attitude," Journal of personality and social psychology (47:6), pp.1191-1205.

Brod, C. 1984. "Technostress: The Human Cost of the Computer Revolution," Boston: Addison-Wesley.

Brooks, C., and Rakotonirainy, A. 2007. "In-vehicle technologies, Advanced Driver Assistance Systems and driver distraction: Research challenges," in Distracted Driving, I. J. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter, and J. D. Irwin (eds.), Sydney, Australia, pp. 471-486.

Brouwer, W. H., Withaar, F. K., Tant, M. L., and van Zomeren, A. H. 2002. "Attention and Driving in Traumatic Brain Injury: A Question of Coping with Time-Pressure," The Journal of Head Trauma Rehabilitation (17:1), pp. 1-15.

Brown, S. A., Fuller, R. M., and Vician, C. 2004. "Who's afraid of the virtual world? Anxiety and computer-mediated communication," Journal of the Association for Information Systems (5:2), p. 2.

Brown, J. L., Vanable, P. A., Carey, M. P., and Elin, L. 2011. "Computerized stress management training for HIV+ women: a pilot intervention study" AIDS Care (23:12), pp. 1525-1532.

Brownley, K. A., Hurwitz, B. E., and Schneiderman, N. 2000. "Cardiovascular Psychophysiology," in Handbook of Psychophysiology, J. T. Cacioppo, L. G. Tassinary, and G. G. Berntson (eds.), 2nd Edition, Cambridge: Cambridge Univ. Press, pp. 224–264.

Bruyas, M. P., Brusque, C., Auriault, A., Tattegrain, H., Aillerie, I., and Duraz, M. 2008. "Impairment of Lane Change Performance Due to Distraction: Effect of Experimental Contexts," in Proceedings of European Conference on Human Centred Design for Intelligent Transport Systems, Lyon, France, pp. 89-100.

Buehler, F., Neumann, S., Cocron, P., Franke, T., and Krems, J. F. 2010. "Usage patterns of electric vehicles: a reliable indicator of acceptance? Findings from a German field study," Proceedings of the 90th annual meeting of the transportation research Board, pp. 1-13.

Buehler, F., Cocron, P., Neumann, I., Franke, T., and Krems, J. F. 2014. "Is EV experience related to EV acceptance? Results from a German field study," Transportation Research Part F: traffic psychology and behaviour (25:34), pp. 34-49.

Bui, A. and Veit, D. 2015. "The Effects of Gamification on Driver Behavior: An Example from a Free Float Carsharing Service," in Proceedings of 23rd European Conference on Information Systems (ECIS), Research-in-Progress Papers, Muenster, Germany, pp. 1-14.

Burchfield, S. R. 1979. "The Stress Response: A New Perspective," Psychosomatic Medicine (41:8), pp. 661-672.

Burke, A. F. 2007. "Batteries and ultracapacitors for electric, hybrid, and fuel cell vehicles," Proceedings of the IEEE (95:4), pp. 806-820.

Burke, R. J., and Mikkelsen, A. 2005. "Gender issues in policing: do they matter?," Women in Management Review (20:2), pp. 133-143.

Burns, L.D. 2013. "A vision of our transport future," Nature (479), pp. 181–182.

Califf, C., Sarker, S., Sarker, S., and Fitzgerald, C. 2015. "The Bright and Dark Sides of Technostress: An Empirical Study of Healthcare Workers," in Proceedings of the International Conference on Information Systems, Fort Worth, Texas, pp. 1-13.

Campbell, J. M. 1983. "Ambient Stressors," Environment and Behavior (15:3), pp. 355-380.

Campbell, J. D. 1990. "Self-Esteem and Clarity of the Self-Concept," Journal of Personality and Social Psychology (59:3), pp. 538-549.

Cao, Y., Van Der Sluis, F., Theune, M., and Nijholt, A. 2010. "Evaluating Informative Auditory and Tactile Cues for In-Vehicle Information Systems," in Proceedings of the 2nd International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Pittsburgh, PA, pp. 102-109.

Capros, R., Tasios, N., De Vita, A., Mantzos, L., and Paroussos, L. 2012. "Transformations of the energy system in the context of the decarbonisation of the EU economy in the time horizon to 2050," Energy Strategy Reviews (1:2), pp. 85–96.

Carroll, S., and Walsh, C. 2010. "The Smart Move Trial: Description and Initial Results," London, UK: Cenex.

Castaño, R., Sujan, M., Kacker, M., and Sujan, H. 2008. "Managing Consumer Uncertainty in the Adoption of New Products: Temporal Distance and Mental Simulation," Journal of Marketing Research (45:3), pp. 320-336.

Chan, C. C. 2007. "The state of the art of electric, hybrid, and fuel cell vehicles," Proceedings of the IEEE (95:4), pp. 704-718.

Chan, C. C., and Wong, Y. S. 2004. "Electric vehicles charge forward," Power and Energy Magazine, IEEE (2:6), pp. 24-33.

Chandler, P., and Sweller, J. 1991. "Cognitive Load Theory and the Format of Instruction," Cognition and Instruction (8:4), pp. 293-332.

Chang, I. C., Hwang, H. G., Hung, W. F., and Li, Y. C. 2007. "Physicians' acceptance of pharmacokinetics-based clinical decision support systems," Expert Systems with Applications (33:2), pp. 296-303.

Chargemap 2015. "Find a Charging Station for Your Electric Vehicle - About Us," (available at: https://chargemap.com/infos/chargemap).

Chen, A.J., Boudreau, M.-C. and Watson, R. 2008. "Information Systems and Ecological Sustainability," Journal of Systems and Information Technology (10:3), pp. 189-201.

Chen, T. D., Wang, Y., and Kockelman, K. M. 2015. "Where Are the Electric Vehicles? A Spatial Model for Vehicle-Choice Count Data," Journal of Transport Geography (43), pp. 181-188.

Chesbrough, H. 2010. "Business Model Innovation: Opportunities and Barriers", Long Range Planning (43:2), pp. 354–363.

Chesbrough, H., and Rosenbloom, R. S. 2002. "The Role of the Business Model in Capturing Value from Innovation: Evidence from Xerox Corporation's Technology Spin-Off Companies", Industrial and Corporate Change (11:3), pp. 529–555.

Chin, W. W. 1998. "The partial least squares approach to structural equation modeling," Modern methods for business research (295:2), pp. 295-336.

Clark, L. A., and Watson, D. 1995. "Constructing validity: Basic issues in objective scale development," Psychological assessment (7:3), pp. 309-319.

Coe, R. 2002. "It's the Effect Size Stupid: What Effect Size is and Why it is Important," in Annual Conference of the British Educational Research Association, University of Exeter, UK, pp. 1-18.

Cohen, J. 1992. "A Power Primer." Psychological Bulletin (112:1), pp. 155-159.

Cohen, S., Kessler, R. C., and Gordon, L. U. 1997. "Strategies for Measuring Stress in Studies of Psychiatric and Physical Disorders." in Measuring stress: A guide for health and social scientists, Cohen, S., Kessler, R. C., Gordon, L. U. (eds.), Oxford: Oxford University Press, pp. 3-26.

Collins, G. A., Cohen, M. J., Naliboff, B. D., and Schandler, S. L. 1981. "Comparative Analysis of Paraspinal and Frontalis EMG, Heart Rate and Skin Conductance in Chronic Low Back Pain Patients and Normals to Various Postures and Stress," Scandinavian Journal of Rehabilitation Medicine (14:1), pp. 39-46.

Conner, M.,and Armitage, C. J. 1998. "Extending the Theory of Planned Behavior: A Review and Avenues for Further Research," Journal of Applied Social Psychology (28:15), pp. 1429-1464.

Cook K. A., Thomas J. J. (eds.) 2005. "Illuminating the Path - The Research and Development Agenda for Visual Analytics," in IEEE Computer Society, Los Alamitos, CA, USA.

Cooper, C. L., Dewe, P. J., and O'Driscoll, M. P. 2001. "Organizational stress: A review and critique of theory, research, and applications," New York: Sage.

Corbett, J., Webster, J., Boudreau, M.-C., and Watson, R. 2011. "Defining the Role for Information Systems in Environmental Sustainability Measurement," Sprouts: Working Papers on Information Systems (11:2), pp. 1-9.

Crocker, J., and Major, B. 1989. "Social Stigma and Self-Esteem: The Self-Protective Properties of Stigma," Psychological Review (96:4), pp. 608-630.

Davis, F. D. 1989. "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology", MIS Quarterly (13:3), pp. 319-340.

Dawson, M. E., Schell, A. M., and Filion, D. L. 2000. "The Electrodermal System," In Handbook of Psychophysiology, J. T. Cacioppo, L. G. Tassinary, and G. G. Berntson (eds.), 2nd Edition, Cambridge: Cambridge Univ. Press, pp. 200–223.

Dawson, M. E., Schell, A. M., and Filion, D. L. 2007. "The electrodermal system," in Handbook of Psychophysiology, J. T. Cacioppo, L. G. Tassinary, and G. G. Berntson (eds.), 3rd Edition, New York: Cambridge University Press, pp. 159-181.

Day, A. L., and Livingstone, H. A. 2003. "Gender differences in perceptions of stressors and utilization of social support among university students," Canadian Journal of Behavioural Science (35:2), pp. 73-83.

D'Arcy, J., Herath, T., & Shoss, M. K. 2014. "Understanding employee responses to stressful information security requirements: a coping perspective," Journal of Management Information Systems (31:2), pp. 285-318.

Dellnitz, M., Eckstein, J., Flaßkamp, K., Friedel, P., Horenkamp, C., Koehler, U., Ober-Bloebaum, S., Peitz, S., and Tiemeyer, S. 2014. "Development of an Intelligent Cruise Control Using Optimal Control Methods," Procedia Technology (15), pp. 285-294.

Deloitte 2010. "Gaining traction. A customer view of electric vehicle mass adoption in the U.S. automotive Market," (available at http://www.deloitte.com.br/publicacoes/2007/MFG.Gaining_Traction_customer_view_of_electric_vehicle_mass_adoption.pdf).

Desyllas, P., and Sako, M. 2013. "Profiting from business model innovation: Evidence from Pay-As-You-Drive auto insurance," Research Policy (42:1), pp. 101-116.

Dijk, M., Orsato, R. J., and Kemp, R. 2013. "The emergence of an electric mobility trajectory," Energy Policy (52), pp. 135-145.

Dimitropoulos, A., Rietveld, P., and van Ommeren, J. N. 2011. "Consumer valuation of driving range: A meta-analysis (No. 11-133/3)," Tinbergen Institute Discussion Paper, pp. 1-35.

Djamasbi, S., Fruhling, A. L., and Loiacono, E. 2009. "The influence of affect, attitude and usefulness in the acceptance of telemedicine systems," Journal of Information Technology Theory and Application (JITTA) (10:1), pp. 1-38.

Dogan, E., Bolderdijk, J. W., and Steg, L. 2014. "Making small numbers count: environmental and financial feedback in promoting eco-driving behaviours," Journal of Consumer Policy (37:3), pp. 413-422.

Dong, J., Liu, C., and Lin, Z. 2014. "Charging infrastructure planning for promoting battery electric vehicles: An activity-based approach using multiday travel data," Transportation Research Part C: Emerging Technologies (38), pp. 44-55.

Downey, H. K., and Slocum, J. W. 1975. "Uncertainty: Measures, research and sources of variation," Administrative Science Quarterly (18:3), pp. 562-577.

Duhachek, A. 2005. "Coping: A Multidimensional, Hierarchical Framework of Responses to Stressful Consumption Episodes," Journal of Consumer Research (32:1), pp. 41-53.

Duke, M., Andrews, D., and Anderson, T. 2009. "The feasibility of long range battery electric cars in New Zealand," Energy Policy (37:9), pp. 3455-3462.

Duncan, R. B. 1972. "Characteristics of Organizational Environments and Perceived Environmental Uncertainty," Administrative Science Quarterly (17:3), pp. 313-327.

Dyllick, T., and Hockerts, K. 2002. "Beyond the Business Case for Corporate Sustainability," Business Strategy and the Environment (141), pp. 130-141.

Dzindolet, M. T., Peterson, S. A., Pomranky, R. A., Pierce, L. G., and Beck, H. P. 2003. "The role of trust in automation reliance," International Journal of Human–Computer Studies (58:6), pp. 697–718.

Edison, S. W., and Geissler, G. L. 2003. "Measuring attitudes towards general technology: Antecedents, hypotheses and scale development," Journal of Targeting, Measurement and Analysis for Marketing (12:2), pp. 137–156.

Egbue, O., and Long, S. 2012. "Barriers to Widespread Adoption of Electric Vehicles: An Analysis of Consumer Attitudes and Perceptions," Energy Policy (48), pp. 717–729.

Eisel, M., Nastjuk, I., and Kolbe, L.M. 2016. "Understanding the influence of in-vehicle information systems on range stress - Insights from an electric vehicle field experiment," Transportation Research Part F (43), pp. 199-211.

Eisel, M., and Schmidt J. 2014. "The Value of IS for Increasing the Acceptance of Electric Vehicles - The Case of Range Anxiety," in: Tagungsband Multikonferenz Wirtschaftsinformatik, Paderborn, pp. 882-894.

Eisel, M., Schmidt, J., Nastjuk, I., Ebermann, C., and Kolbe, L. 2014. "Can Information Systems Reduce Stress? The Impact of Information Systems on Perceived Stress and Attitude," in Proceedings of the International Conference on Information Systems, M. D. Mayers and D. Straub (eds.), Auckland, NZ, pp. 1-16.

El Sawy, O. A. 2003. "The IS Core IX: The 3 Faces of IS identity: connection, immersion, and fusion," Communications of the Association for Information Systems, (12:1), pp. 588-598.

El Sawy, O. A., and Pereira, F. 2013. Business modelling in the dynamic digital space: An ecosystem approach. Los Angeles: Springer.Elkington, J. 1998. Cannibals with Forks: The Triple Bottom Line of 21st Century Business, Stoney Creek: New Society Publishers.

Elliot, S. 2011. "Transdisciplinary Perspectives on Environmental Sustainability: A Resource Base and Framework for IT-enabled Business Transformation," MIS Quarterly (35:1), pp. 197-236.

Elliot, G. R., and Eisdorfer, C. 1982. Stress and Human Health:Analysis and Implication of research, New York: Springer.

European Commission. 2016. "Road transport: Reducing CO2 emissions from vehicles," (available at: https://ec.europa.eu/clima/policies/transport/vehicles_en).

European Environmental Agency. 2017. "CO2 emissions from cars and vans: all larger manufacturers met their 2015 targets," (available at: https://www.eea.europa.eu/highlights/co2-emissions-from-cars-and).

Evans, G.W., and Cohen, S., 1987. "Environmental Stress," in Handbook of Environmental Psychology, D. Stokols and I.Altman, New York, Chichester, Brisbane, Toronto, Singapore: John Wiley and Sons, pp. 571-610.

Eysenck, M. W. 2000. "Psychology: A Student's Handbook," London: Taylor & Francis.

Faruqui, A., Sergici, S., and Sharif, A. 2010. "The impact of informational feedback on energy consumption—A survey of the experimental evidence," Energy (35:4), pp. 1598-1608.

Fernandes, C. F. V., Kumar, S., and Nandakumar, M. 2009. "Gender Differences in Stress among Bank Officers of Private and Public Sectors," The IUP Journal of Organizational Behaviour, pp. 1-7.

Ferreira, J., Pereira, P., Filipe, P., and Afonso, J. 2011. "Recommender System for Drivers of Electric Vehicles," in Proceedings of the 3rd International Conference on Electronics Computer Technology, Kanyakumari, India, pp. 244-248.

Ferreira, J. C., Monteiro, V., and Afonso, J. L., 2012. "Data Mining Approach for Range Prediction of Electric Vehicle," Conference on Future Automotive Technology – Focus Electromobility, Munich, Germany, pp. 1-15.

Ferreira, J., Monteiro, V., and Afonso, J. 2014. "Vehicle-to-Anything Application (V2Anything App) for Electric Vehicles," IEEE Transactions on Industrial Informatics (10 :3), pp. 1927-1937.

Fichman, R. G., Dos Santos, B. L., and Zheng, Z. (E.) 2014. "Digital Innovation as a Fundamental and Powerful Concept in the Information Systems Curriculum," MIS Quarterly (38: 2), pp.329-353.

Field, A. 2009. "Discovering statistics using SPSS" London: Sage.

Field, A., Miles, J., and Field, Z. 2013. Discovering Statistics Using IBM SPSS Statistics, London: Sage.

Fink, G. 2016. "Stress, Definitions, Mechanisms, and Effects Outline: Lessons from Anxiety," in Handbook of Stress – Stress: Concepts, Cognition, Emotion, and Behavior, G. Fink (editor), Volume 1, Cambridge: Academic Press, pp. 3-11.

Fisher, C. 1996. "The Impact of Perceived Environmental Uncertainty and Individual Differences on Management Information Requirements: A Research Note," Accounting, Organizations and Society (21:4), pp. 361-369.

Folkman, S. 1984. "Personal Control and Stress and Coping Processes: A Theoretical Analysis," Journal of Personality and Social Psychology (46:4), pp. 839-852.

Folkman, S. 2008. "The case for positive emotions in the stress process," Anxiety, stress, and coping, (21:1), pp. 3-14.

Folkman, S., and Lazarus, R. S. 1980. "An analysis of coping in a middle-aged community sample," Journal of health and social behavior (21:3), pp. 219-239.

Folkman, S., and Lazarus, R. S. 1985. "If It Changes It Must Be a Process: A Study of Emotion and Coping During Three Stages of a College Examination," Journal of Personality and Social Psychology (48:1), pp. 150-170.

Folkman, S., Lazarus, R. S., Gruen, R. J., and DeLongis, A. 1986a. "Appraisal, coping, health status, and psychological symptoms," Journal of personality and social psychology (50:3), pp. 571-579.

Folkman, S., Lazarus, R. S., Dunkel-Schetter, C., DeLongis, A., and Gruen, R. J. 1986b. "Dynamics of a Stressful Encounter: Cognitive Appraisal, Coping, and Encounter Outcomes," Journal of Personality and Social (50:5), pp. 992-1003.

Fornell, C., Larcker, D. F. 1981. "Evaluating structural equations with unobservable variables and measurement error," Journal of Marketing Research (18), pp. 39-50.

Francis, J. J., Eccles, M. P., Johnston, M., Walker, A., Grimshaw, J., Foy, R., Kaner, E. F. S., Smith, L., and Bonetti, D. 2004. Constructing questionnaires based on the theory of planned behaviour. A manual for health services researchers, Newcastle upon Tyne, UK: Centre for Health Services Research, University of Newcastle upon Tyne, pp. 1-42.

Franke, T., Buehler, F., Cocron, P., Neumann, I., and Krems, J.F. 2012a. "Enhancing sustainability of electric vehicles: A field study approach to understanding user acceptance and behavior," in Advances in Traffic Psychology, M. Sullman and L. Dorn (eds.), Farnham, UK, Ashgate.

Franke, T., Cocron, P., Buehler, F., Neumann, I., & Krems, J.F. 2012c. „Adapting to the range of an electric vehicle – the relation of experience to subjectively available mobility resources," Proceedings of the European Conference on Human Centred Design for Intelligent Transport Systems, Valencia: Spain, pp. 95-103.

Franke, T., and Krems, J. F. 2013a. "Interacting with limited mobility resources: Psychological range levels in electric vehicle use," Transportation Research Part A: Policy and Practice, 48, pp. 109-122.

Franke, T., and Krems, J. F. 2013b. "What drives range preferences in electric vehicle users?," Transport Policy (30), pp. 56–62.

Franke, T., and Krems, J. F. 2013c. „Understanding charging behaviour of electric vehicle users," Transportation Research Part F: Traffic Psychology and Behaviour (21), pp. 75-89.

Franke, T., Neumann, I., Buehler, F., Cocron, P., and Krems, J. F. 2012b. "Experiencing range in an electric vehicle - understanding psychological barriers," in: Applied Psychology: An International Review (61:3), pp. 368-391.

Franke, T., Rauh, N., Guenther, M., Trantow, M., and Krems, J. F. 2016a. "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), pp. 13-26.

Franke, T., Rauh. N., Krems J. F. 2016b. "Individual differences in BEV drivers' range stress during first encounter of a critical range situation," Applied Ergonomics (57), pp. 28-35.

Franke, T., Trantow, M., Guenther, M., Krems, J. F., Zott, V., and Keinath, A. 2015. "Advancing electric vehicle range displays for enhanced user experience: the relevance of trust and adaptability," in Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications ACM, Nottingham, United Kingdom, pp. 249-256.

Fuller, R. 2000. "The task-capability interface model of the driving process," Recherche-Transports-Sécurité (66), pp. 47-57.

Fuller, R. 2005. "Towards a General Theory of Driver Behaviour," Accident Analysis & Prevention (37:3), pp. 461-472.

Furneaux, B., and Nevo, D. 2008. "Beyond Cognitions: A Call for Greater Consideration of Emotion in Information Systems Decision Theories," in Proceedings of the 41st Annual Hawaii International Conference on System Sciences, Waikoloa, HI, USA, pp. 1-8.

Gaab, J. 2009. "PASA-Primary Appraisal Secondary Appraisal – Ein Fragebogen zur Erfassung von situationsbezogenen kognitiven Bewertungen," in: Verhaltenstherapie (19:2), pp. 114–115.

Gaab, J., Rohleder, N., Nater, U. M., and Ehlert, U. 2005. "Psychological Determinants of the Cortisol Stress Response: The Role of Anticipatory Cognitive Appraisal," Psychoneuroendocrinology (30:6), pp. 599-610.

Gaillard, A. W. K. 2008. "Concentration, stress and performance," in Performance under stress, P. A. Hancock and J. L. Szalma (eds.), Aldershot: Ashgate, pp. 59–75.

Galliers, R., Newell, S., Shanks, G., Topi, H. 2015. "Call for papers for the special issue: the challenges and opportunities of 'datification'; Strategic impacts of 'big' (and 'small') and real time data – for society and for organizational decision makers," The Journal of Strategic Information Systems (24:2), pp. II–III.

Gallo, L. C., and Matthews, K. A. 2003. "Understanding the association between socioeconomic status and physical health: do negative emotions play a role?," Psychological Bulletin (129:1), pp. 10-51.

Galluch, P. S., Grover, V., and Thatcher, J. B. 2015. "Interrupting the Workplace: Examining Stressors in an Information Technology Context," Journal of the Association for Information Systems (16:1), pp. 1-47.

Gao, P., Hensley, R., and Zielke, A. 2014. A road map to the future for the auto industry. McKinsey Quarterly, pp. 1-11.

Garbarino, M., Lai, M., Bender, D., Picard, R. W., and Tognetti, S. 2014. "Empatica E3—A wearable wireless multi-sensor device for real-time computerized biofeedback and data acquisition," in Proceedings of the International Conference on Wireless Mobile Communication and Healthcare (Mobihealth), Athens, Greece, pp. 39-42.

Garg, A. X., Adhikari, N. K., McDonald, H., Rosas-Arellano, M. P., Devereaux, P. J., Beyene, J., Justina, S., and Haynes, R. B. 2005. "Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review," The Journal of the American Medical Association (293:10), pp. 1223-1238.

Garner, W. 1962. Uncertainty and structure as psychological concepts, New York: Wiley.

Gavanski, I., and Wells, G. L. 1989. "Counterfactual processing of normal and exceptional events," Journal of Experimental Social Psychology (25:4), pp. 314-325.

Gefen, D., Rigdon, E. E., Straub, D. 2011. "An Update and Extension to SEM Guidelines for Administrative and Social Science Research," MIS Quarterly (35:2), pp. iii-xiv.

Gefen, D., and Straub, D. W. 2005. "A Practical Guide to Factorial Validity Using PLS-Graph: Tutorial and Annotated Example," Communications of the AIS (16:5), pp. 91-109.

Gerber, A. S., and Green, D. P. 2012. "Field Experiments: Design, Analysis, and Interpretation," New York: W.W. Norton.

Gifford, W. E., Bobbitt, H. R., and Slocum, J. W. 1979. "Message characteristics and perceptions of uncertainty by organizational decision makers," Academy of Management Journal (22:3), pp. 458-481.

Godin, G., and Kok, G. 1996. "The theory of planned behavior: a review of its applications to health-related behaviors," American Journal of Health Promotion (11:2), pp. 87-98.

Goodhue, D. L., and Thompson, R. L. 1995. "Task-technology fit and individual performance," MIS Quarterly, 213-236.

Goud, R., de Keizer, N. F., ter Riet, G., Wyatt, J. C., Hasman, A., Hellemans, I. M., and Peek, N. 2009. "Effect of guideline based computerised decision support on decision making of multidisciplinary teams: cluster randomised trial in cardiac rehabilitation," Bmj (338), pp. 1-9.

Grabski, S. V., Leech, S. A., and Schmidt, P. J. 2011. „A review of ERP research: A future agenda for accounting information systems," Journal of information systems (25:1), pp. 37-78.

Grandey, A. A. 2000. "Emotion regulation in the workplace: A new way to conceptualize emotional labor," Journal of Occupational Health Psychology 5(1), pp. 95–110.

Greenwald, A.G. 2014. „Why are Attitudes Important." in Attitude structure and function, A.R. Pratkanis, S.J. Breckler, A.G. Greenwald (eds.), Psychology Press. New York: United States, pp. 429-440.

Gregor, S. 2006. "The Nature of Theory in Information Systems," MIS Quarterly (30:3), pp. 611-642.

Gregor, S., and Hevner, A. R. 2013. "Positioning and presenting design science research for maximum impact," MIS Quarterly (37:2), pp. 337-355.

Groër, C., Golden, B., and Wasil, E. 2009. "The Consistent Vehicle Routing Problem," Manufacturing & Service Operations Management (11:4), 2009, pp. 630-643.

Gul, F.A. and Chia, Y.M., 1994. "The effects of management accounting systems, perceived environmental uncertainty and decentralization on managerial performance: a test of three-way interaction. Accounting," Organizations and Society (19:4-5), pp. 413-426.

Gulian, E., Matthews, G., Glendon, A. I., Davies, D. R., and Debney, L. M. 1989. "Dimensions of Driver Stress," Ergonomics (32:6), pp. 585-602.

Hair, J. F., Ringle, C. M., and Sarstedt, M. 2011. "PLS-SEM: indeed a silver bullet." Journal of Marketing Theory and Practice (19 :2), pp. 139–151.

Hair, J. F., Sarstedt, M., Ringle, C. M., and Mena, J. A. 2012. "An assessment of the use of partial least squares structural equation modeling in marketing research," Journal of the Academy of Marketing Science (40:3), pp. 414-433.

Hakkinen, H., Turunen, P., and Spil, T. 2003. "Information in health care process-evaluation toolkit development," in Proceedings of the 36th Annual Hawaii International Conference on System Sciences, Big Island, HI, R.H. Sprague (eds.), pp. 1-7.

Hall, N. C., Chipperfield, J. G., Perry, R. P., Ruthig, J. C., and Goetz, T. 2006. "Primary and secondary control in academic development: gender-specific implications for stress and health in college students," Anxiety, stress, and coping (19:2), pp. 189-210.

Hammerfald, K., Eberle, C., Grau, M., Kinsperger, A., Zimmermann, A., Ehlert, U., and Gaab, J. 2006. „Persistent effects of cognitive-behavioral stress management on cortisol responses to acute stress in healthy subjects—a randomized controlled trial," Psychoneuroendocrinology (31:3), pp. 333-339.

Hampshire, R., and Gaites, C. 2011. "Peer-to-peer carsharing: Market Analysis and Potential Growth," Transportation Research Record: Journal of the Transportation Research Board (2217), pp. 119-126.

Hanelt, A., Nastjuk, I., Kruep, H., Eisel, M., Ebermann, C., Brauer, B., Piccinini, E., Hildebrandt, B. and and Kolbe, L. M. (2015), "Disruption on the Way? The Role of Mobile Applications for Electric Vehicle Diffusion", in Proceedings of the 12th International Conference on Wirtschaftsinformatik, Osnabrueck.

Harms, L., and Patten, C. 2003. "Peripheral detection as a measure of driver distraction. A study of memory-based versus system-based navigation in a built-up area," Transportation Research Part F: Traffic Psychology and Behaviour (6:1), pp. 23-36.

Harrison, G. W., and List, J. A. 2004. "Field Experiments," Journal of Economic Literature (42:4), pp. 1009-1055.

Harvey, C., Stanton, N. A., Pickering, C. A., McDonald, M., and Zheng, P. 2011. "In-vehicle information systems to meet the needs of drivers," Intl. Journal of Human–Computer Interaction, (27:6), pp. 505-522.

Hassard, J., Teoh, K., Cox, T., Dewe, P., Cosmar, M., Gruendler, R., Flemming, D., Cosemans, B., and Van den Broek, K. 2014. "Calculating the cost of work-related stress and psychosocial risks - a literature review," Publications Office of the European Union: European Agency for Safety and Health at Work, pp. 1-41.

Haustein, S., and Hunecke, M. 2007. "Reduced Use of Environmentally Friendly Modes of Transportation Caused by Perceived Mobility Necessities: An Extension of the Theory of Planned Behavior1," Journal of Applied Social Psychology (37:8), pp. 1856-1883.

Haynes, S. N., Richard, D., and Kubany, E. S. 1995. "Content Validity in Psychological Assessment: A Functional Approach to Concepts and Methods," Psychological Assessment (7:3), pp. 238-247.

Hennessy, D. A., and Wiesenthal, D. L. 1999. "Traffic Congestion, Driver Stress, and Driver Aggression," Aggressive Behavior (25:6), pp. 409-423.

Henseler, J., Ringle, C. M., and Sinkovics, R. R. 2009. "The Use of Partial Least Squares Path Modeling in International Marketing," Advances in International Marketing (20:1), pp. 277-319.

Hess, T., Legner, C., Esswein, W., Maaß, W., Matt, C., Oesterle, H., Schlieter, H., Richter, P., and Zarnekow, R. 2014. "Digital Life as a Topic of Business and Information Systems Engineering?," Business & Information Systems Engineering (6:4), p. 247.

Hevner, A., and Chatterjee, S. 2010. "Design Research in Information Systems," New York: Springer Publishing.

Hevner, A. R; March, S. T., Park, J., and Ram, S. 2004. "Design science in information systems research," MIS Quarterly (28:1), pp. 75-105.

Heylighen, F. 2002. "Complexity and Information Overload in Society: Why Increasing Efficiency Leads to Decreasing Control," Draft Paper for The Information Society, pp. 1-19 (available online at http://pespmc1.vub.ac.be/papers/info-overload.pdf; retrieved September 08, 2015).

Hidrue, M. K., Parsons, G. R., Kempton, W., and Gardner, M. P. 2011. "Willingness to pay for electric vehicles and their attributes," Resource and Energy Economics (33:3), pp. 686-705.

Hildebrandt, B., Hanelt, A., Piccinini, E., Kolbe, L., and Nierobisch, T. 2015. "The Value of IS in Business Model Innovation for Sustainable Mobility Services - The Case of Car-sharing," in Wirtschaftsinformatik Proceedings 2015, pp. 1008-1022.

Hilpert, D. W. I. H., Kranz, J., and Schumann, M. 2013. "Leveraging Green IS in logistics," Business & Information Systems Engineering (5:5), pp. 315-325.

Hilton, B. A. 1993. "The Uncertainty Stress Scale: its development and psychometric properties," The Canadian Journal of Nursing Research, (26:3), pp. 15-30.

Hirschheim, R. 1985. "Information systems epistemology: An historical perspective," Research methods in information systems, pp. 13-35.

Hobfoll, S. E. 1989. "Conservation of Resources: A New Attempt at Conceptualizing Stress," American Psychologist (44:3), pp. 513-524.

Hoff, K. A., and Bashir, M. 2015. "Trust in automation integrating empirical evidence on factors that influence trust," Human Factors: The Journal of the Human Factors and Ergonomics Society (57:3), pp. 407-434.

Hollnagel, E., Nåbo, A., and Lau, I. 2003. "A Systemic Model for Driver-In-Control," in Second International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Iowa City, IA, pp. 86-91.

Horberry, T., Anderson, J., Regan, M. A., Triggs, T. J., and Brown, J. 2006. "Driver Distraction: The Effects of Concurrent In-Vehicle Tasks, Road Environment Complexity and Age on Driving Performance," Accident Analysis & Prevention (38:1), pp. 185-191.

House, J. S. 1974. "Occupational stress and coronary heart disease: A review and theoretical integration," Journal of Health and Social Behavior, pp. 12-27.

Hulland, J. 1999. "Use of Partial Least Squares (PLS) in Strategic Management Research: A Review of Four Recent Studies," Strategic Management Journal (20:2), pp. 195-204.

Hunt, D. L., Haynes, R. B., Hanna, S. E., and Smith, K. 1998. "Effects of computer-based clinical decision support systems on physician performance and patient outcomes: a systematic review," Jama (280:15), pp. 1339-1346.

IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, New York: IBM Corp.

ICCT. 2013. "The International Council on Clean Transportation: European Vehicle Market Statistics,   (available at: http://www.theicct.org/sites/default/files/publications/EU_vehiclemarket_pocket-book_2013_Web.pdf).

Jenkin, T., Webster, J. and McShane, L. 2011. "An Agenda for 'Green' Information Technology and Systems Research," Information and Organization (21:1), pp. 17-40.

Jensen, A. F., Cherchi, E., and Mabit, S. L. 2013. "On the Stability of Preferences and Attitudes Before and After Experiencing an Electric Vehicle," Transportation Research Part D: Transport and Environment (25), pp. 24-32.

Jerusalem, M., and Schwarzer, R. 1989. "Anxiety and self-concept as antecedents of stress and coping: A longitudinal study with German and Turkish adolescents," Personality and Individual Differences (10:7), pp. 785-792.

Jerusalem, M., and Schwarzer, R. 1992. "Self-Efficacy as a Resource Factor in Stress Appraisal Processes," in Self-Efficacy: Thought Control of Action, R. Schwarzer (eds.), London: Routledge, pp. 195-213.

Jian J.-Y., Bisantz A. M., Drury C. G. 2000. Foundations for an Empirically Determined Scale of Trust in Automated Systems. International Journal of Cognitive Ergonomics (4:1), 53–71.

Jones, B. 1997. "Dying for information?," Management Review (86:7), p. 9.

Jones, N., Ross, H., Lynam, T., Perez, P., and Leitch, A. 2011. "Mental models: an interdisciplinary synthesis of theory and methods," Ecology and Society (16:1), pp. 1-15.

Jonsson, I. M., Harris, H., and Nass, C. 2008. "How accurate must an in-car information system be?: consequences of accurate and inaccurate information in cars," in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems ACM, pp. 1665-1674.

Joslyn, S. L., and LeClerc, J. E. 2012. Uncertainty forecasts improve weather-related decisions and attenuate the effects of forecast error. Journal of experimental psychology: applied, 18(1), 126-140.

Judge, T. A., Erez, A., Bono, J. E., & Thoresen, C. J. 2002. "Are measures of self-esteem, neuroticism, locus of control, and generalized self-efficacy indicators of a common core construct?," Journal of Personality and Social Psychology (83:3), pp. 693-710.

Jung, M. F., Sirkin, D., Guer, T. M., and Steinert, M. 2015. "Displayed Uncertainty Improves Driving Experience and Behavior: The Case of Range Anxiety in an Electric Car," in Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, Seoul, Republic of Korea, pp. 2201-2210.

Kantowitz, B. H., Hanowski, R. J., and Kantowitz, S. C. 1997. "Driver acceptance of unreliable traffic information in familiar and unfamiliar settings," Human Factors: The Journal of the Human Factors and Ergonomics Society (39:2), pp. 164-176.

Kantowitz, B. H., and Moyer, M. J. 1999. "Integration of Driver In-Vehicle ITS Information," in Proceedings of Intelligent Transportation Society of America (ITSA) 9th Annual Meeting and Exposition, Washington, DC, pp. 1-9.

Karahanna, E., Straub, D. W., and Chervany, N. L. 1999. "Information technology adoption across time: a cross-sectional comparison of pre-adoption and post-adoption beliefs," MIS Quarterly (23:2), pp. 183-213.

Karau, S. J., and Kelly, J. R. 1992. "The Effects of Time Scarcity and Time Abundance on Group Performance Quality and Interaction Process," Journal of Experimental Social Psychology (28:6), pp. 542-571.

Katzev, R. 2003. "Car sharing: A new approach to urban transportation problems," Analyses of Social Issues and Public Policy (3:1), pp. 65-86.

Kay, M., Kola, T., Hullman, J. R., and Munson, S. A. (2016). "When (ish) is My Bus? User-centered Visualizations of Uncertainty in Everyday, Mobile Predictive Systems.," in Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, San Jose, CA, New York, USA., pp. 5092-5103.

Keinan, G., Friedland, N., Kahneman, D., and Roth, D. 1999. "The Effect of Stress on the Suppression of Erroneous Competing Responses," Anxiety, Stress & Coping (12:4), pp. 455-476.

Keller, K. L., and Staelin, R. 1987. „Effects of quality and quantity of information on decision effectiveness," Journal of Consumer Research, pp. 200-213.

Kelly, J. R., Jackson, J. W., and Hutson-Comeaux, S. L. 1997. "The Effects of Time Pressure and Task Differences on Influence Modes and Accuracy in Decision-Making Groups," Personality and Social Psychology Bulletin (23:1), pp. 10-22.

Kienhues, D., and Bromme, R. 2011. "Beliefs About Abilities and Epistemic Beliefs: Aspects of Cognitive Flexibility in Information-Rich Environments," in Links Between Beliefs and Cognitive Flexibility, J. Elen, E. Stahl, R. Bromme, G. Clarebout (eds.), Luxemburg: Springer Science & Business Media, pp. 105-124.

King, J., and Lyytinen, K. 2005. "Automotive Informatics: Information Technology and Enterprise Transformation in the Automobile Industry," in Transforming Enterprise: The Economic and Social Implications of Information Technology, W. Dutton, B. Kahin, R. O'Callaghan and A. Wycoff (eds.), MIT Press, pp. 283-312.

Kintz, B. L., Delprato, D. J., Mettee, D. R., Persons, C. E., and Schappe, R. H. 1965. "The Experimenter Effect," Psychological Bulletin (63:4), pp. 223-232.

Kircher, K. 2007. "Driver distraction: a review of the literature," VTI, Linköping: Sweden, pp. 1-58.

Kirschbaum, C., and Hellhammer, D. H. 1994. „Salivary cortisol in psychoneuroendocrine research: recent developments and applications," Psychoneuroendocrinology (19:4), pp. 313-333.

Klauer, S.G., Dingus, T.A., Neale, V.L., Sudweeks, J. D., and Ramsey, D.J. 2006. "The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data," National Highway Traffic Safety Administration (eds.) DOT HS 810 594: Virginia Tech Transportation Institute.

Kley, F., Lerch, C., and Dallinger, D. 2011. "New business models for electric cars—A holistic approach," Energy Policy (39:6), pp. 3392-3403.

Knote, R. and Blohm, I. 2016. "Deconstructing the Sharing Economy: On the relevance for IS research," in Proccedings of Multikonferenz Wirtschaftsinformatik (MKWI), Illmenau, Germany, pp. 45-54.

Kobasa, S. C., Maddi, S. R., and Kahn, S. 1982. "Hardiness and health: a prospective study," Journal of Personality and Social Psychology (42:1), pp. 168-177.

Kolb, D. G. 2008. "Exploring the metaphor of connectivity: Attributes, dimensions and duality," Organization Studies (29:1), pp. 127-144.

Kondo, Y., Kato, H., Ando, R., Suzuki, T., and Karakama, Y., 2013. "To What Extent Can Speed Management Alleviate the Range Anxiety of EV?," in International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium (EVS27), Barcelona, Spain, pp. 1-8.

Kontogiannis, T. 2006. "Patterns of driver stress and coping strategies in a Greek sample and their relationship to aberrant behaviors and traffic accidents," Accident Analysis & Prevention (38:5), pp. 913-924.

Kossahl, J., Busse, S. and Kolbe, L.M. 2012. "The Evolvement of Energy Informatics in the Information Systems Community: A Literature Analysis and Research Agenda," in ECIS 2012 Proceedings, Barcelona, pp. 1-13.

Krohne, H. W. 1997. "Stress und Stressbewaeltigung," in: Gesundheitspsychologie, R. Schwarzer (eds.), pp. 267-283.

Krohne, H. W. 2001. "Stress and coping theories," in The international encyclopedia of the social and behavioral sciences, Smelser, N.J., Baltes, P.B. (eds.), Amsterdam: Elsevier, pp. 15163-15170.

Krueger, N. F., Reilly, M. D., and Carsrud, A. L. 2000. "Competing Models of Entrepreneurial Intentions," Journal of Business Venturing (15:5), pp. 411-432.

Kruglanski, A. W. 1989. Lay Epistemics and Human Knowledge: Cognitive and Motivational Bases, New York: Plenum.

Krum, D. M., Faenger, J., Lathrop, B., Sison, J. A., and Lien, A. 2008. "All roads lead to CHI: interaction in the automobile," in Extended Abstracts Proceedings of the 2008 Conference on Human Factors in Computing Systems, Florence, Italy, pp. 2387-2390.

Kuechler, B., and Vaishnavi, V. 2008. "On theory development in design science research: anatomy of a research project," European Journal of Information Systems (17:5), pp. 489-504.

Kulviwat, S., Bruner, G. C., Kumar, A., Nasco, S. A., and Clark, T. 2007. "Toward a Unified Theory of Consumer Acceptance Technology," Psychology & Marketing (24:12), pp. 1059–1084.

Kumar, L., and Jain, S. 2014. "Electric propulsion system for electric vehicular technology: A review," Renewable and Sustainable Energy Reviews (29), pp. 924-940.

Lachow, I. 1995. "The GPS Dilemma: Balancing Military Risks and Economic Benefits", in International Security, The MIT Press, (20:1), pp. 126-148.

Ladewig, J. 1987. "Endocrine Aspects of Stress: Evaluation of Stress Reactions in Farm Animals," in Biology of Stress in Farm Animals: An Integrative Approach, P.R. Wiepkema, P.W.M van Adrichen (eds.), Netherlands: Springer, pp. 13-25.

Lauwers, M., and Giangreco, A. 2016. "Technostress and IT Exploration in Healthcare," in Proceedings of the International Conference on Information Systems, Dublin, Irland, pp. 1-10.

Lawrence, P. R., and Lorsch, J. W. 1967. "Differentiation and Integration in Complex Organizations," Administrative Science Quarterly (12:1), pp. 1-47.

Lazarus, R.S., 1966. Psychological Stress and the Coping Process, New York: McGraw-Hill.

Lazarus, R. S. 1990. "Theory-Based Stress Measurement," Psychological Inquiry (1:1), pp. 3-13.

Lazarus, R. S. 1993a. "From psychological stress to the emotions: A history of changing outlooks," Annual Review of Psychology (44:1), pp. 1-22.

Lazarus, R.S. 1993b. "Why We Should Think of Stress as a Subset of Emotion," in Handbook of Stress: Theoretical and Clinical Aspects, L. Goldberger and S. Breznitz (eds.), New York: Free Press, pp. 21-39.

Lazarus, R. S. 1999. "Stress and Emotion: A New Synthesis," New York: Springer.

Lazarus, R. S. 2006. Stress and Emotion: A New Synthesis, New York: Springer.

Lazarus, R. S., and Folkman, S. 1984. "Stress, appraisal, and coping," New York: Springer.

Lazarus, R. S., and Cohen, J. B. 1977. "Environmental Stress," in Human Behavior and Environment, I. Altmann and J. F. Wohlwill (eds.), New York: Plenum Press, pp. 89-127.

Lazarus, R. S., and Folkman, S. 1987. "Transactional theory and research on emotions and coping," European Journal of Personality (1), pp. 141-169.

Leahy, A., Clayman, C., Mason, I., Lloyd, G., and Epstein, O. 1998. "Computerised biofeedback games: a new method for teaching stress management and its use in irritable bowel syndrome," Journal of the Royal College of Physicians of London (32:6), pp. 552-556.

Lee, A. S. 1991. "Integrating positivist and interpretive approaches to organizational research," Organization science (2:4), pp. 342-365.

Lee, A. S., and Baskerville, R. L. 2003. "Generalizing Generalizability in Information Systems Research," Information Systems Research, (14:3), pp. 221-243.

Lee, J. D., Gore, B. F., and Campbell, J. L. 1999. "Display Alternatives for In-Vehicle Warning and Sign Information: Message Style, Location, and Modality," Transportation Human Factors (1:4), pp. 347-375.

Lee, B., Lee, Y. J. N., Park, S., Kim, H., Lee, S., and Kim, J. 2014. "Driver's Distraction and Understandability (EOU) Change due to the Level of Abstractness and Modality of GPS Navigation Information during Driving," Procedia Computer Science (39), pp. 115-122.

Lee, J. D., and Moray, N. 1994. "Trust, self-confidence, and operators' adaptation to automation," International Journal of Human-Computer Studies, (40:1), pp. 153-184.

Lee, J., Nah, J., Park, Y., and Sugumaran, V. 2011. "Electric Car Sharing Service Using Mobile Technology," in Proceedings of the International Conference on Information Resources Management (CONF-IRM), Seoul, South Korea, pp. 1-8.

Lee, J. D., and See, K. A. 2004. "Trust in automation: Designing for appropriate reliance," Human Factors (46:1), pp. 50–80.

Lei, C. F., and Ngai, E. W. T. 2014. "The Double-Edged Nature of Technostress on Work Performance: A Research Model and Research Agenda," in Proceedings of the International Conference on Information Systems, Auckland, New Zealand, pp. 1-18.

Lèon, H.G.B., Peñalvo, F.J.G., and Rodriguez-Conde, M.J. 2008. "Construction of Assessments with Double Adaptation Processes," in: Innovative Techniques in Instruction Technology, E-learning, E-assessment and Education, M. Iskander (ed.), Springer Science & Business Media, Luxembourg, pp. 156-160.

LePine, J. A., Podsakoff, N. P., and LePine, M. A. 2005. "A meta-analytic test of the challenge stressor–hindrance stressor framework: An explanation for inconsistent relationships among stressors and performance," Academy of Management Journal (48:5), pp. 764-775.

Levine, S. 2005a. "Developmental determinants of sensitivity and resistance to stress," Psychoneuroendocrinology (30), pp. 939-946.

Levine, S. 2005b. "Stress: An Historical Perspective," Techniques in the Behavioral and Neural Sciences (15), pp. 3-23.

Levine, S., and Scotch, N. A. 2013. "Perspective on Stress," in Social Stress, S. Levine and N. A. Scotch (eds.), New Brunswick, New Jersey, pp. 279-290.

Levine, S., and Ursin, H. 1991. "What is stress?" in Stress: Neurobiology and neuroendocrinology, M. R. Brown, G. F. Koob, & C. Rivier (eds.), New York: Marcel Dekker, pp. 3-21.

Lieven, T., Muehlmeier, S., Henkel, S., and Waller, J. F. 2011. "Who will buy electric cars? An empirical study in Germany," Transportation Research Part D: Transport and Environment, (16:3), pp. 236-243.

Lisboa, I. C., Vieira, J., Mouta, S., Machado, S., Ribeiro, N., Silva, E., and Pereira, A. F. 2016. "An MCDM approach to the selection of novel technologies for innovative in-vehicle information systems," International Journal of Decision Support System Technology (8:1), pp. 43-55.

Liu, W. M., and Ali, S. R. 2008. "Social class and classism: Understanding the psychological impact of poverty and inequality," in Handbook of Counseling Psychology, S. D. Brown, and R. W. Lent (eds.), John Wiley & Sons, pp. 159-175.

Liu, H., Hu, J., and Rauterberg, M. 2009. „Software architecture support for biofeedback based in-flight music systems," in Proceedings of the International Conference on Computer Science and Information Technology, Bejing, China, pp. 580-584.

Liu, G., Ouyang, M., Lu, L., and Li, J. 2015. "Remaining driving range estimation for electric vehicles based on an advanced battery residual energy model," in 28th International Electric Vehicle Symposium and Exhibition, Goyang, Korea, pp. 1-5.

Lockhart, R. 1967. "Interrelations between amplitude, latency, rise time and the edelberg recovery measure of the galvanic skin response," Psychophysiology (9:4), pp. 437-442.

Loebbecke, C. and Picot, A. 2015. "Reflections on Societal and Business Model Transformation Arising From Digitization and Big Data Analytics: A Research Agenda", Journal of Strategic Information Systems (24), pp. 149–157.

Loehmann, S., Landau, M., Koerber, M., and Butz, A. 2014. "Heartbeat: Experience the Pulse of an Electric Vehicle," in Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications ACM, Seattle, WA, USA, pp. 1-10.

Lohmoeller, J.-B. 1989. Latent Variable Path Modeling with Partial Least Squares, Heidelberg: Physica.

Lohaus, A., 2010 "Stress prevention in adolescence : evaluation of a multimodal training approach," Journal of Public Health (19:4), pp. 385-388.

Lohaus, A., and Beyer, A. 2006. "Stressbewaeltigung im Jugendalter- Ein Trainingsprogramm," Hogrefe, Goettingen.

Lozano, R. and Murray, C. J. L. 2013. "Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010," The Lancet (380:9859), pp. 2095-2128.

Luedeke-Freund, F. 2010. "Towards a Conceptual Framework of 'Business Models for Sustainability," in Knowledge collaboration & learning for sustainable innovation, R. Wever, J. Quist, A. Tukker, J. Woudstra, F. Boons, and N. Beute (eds.), Netherlands: Delft.

Lundstroem, A. 2014. "Differentiated Driving Range: Exploring a Solution to the Problems with the Guess-O-Meter in Electric Cars," in Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Seattle, WA, pp. 1-8.

Lundstroem, A., and Bogdan, C. 2012. "COPE1 – Incorporating Coping Strategies into the Electric Vehicle Information System," in Adjunct Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Portsmouth, NH, pp. 113-115.

Lykken, D. T., and Venables, P. H. 1971. "Direct Measurement of Skin Conductance: A Proposal for Standardization," Psychophysiology (8:5), pp. 656-672.

Lyon, B. L. 2000. "Stress, coping, and health," in Handbook of stress, coping and health: Implications for nursing research, theory, and practice, V. H. Rice (eds.), 2nd Edition, London: Sage, pp. 3-23.

Ma, R., and Kaber, D. B. 2005. "Situation awareness and workload in driving while using adaptive cruise control and a cell phone," International Journal of Industrial Ergonomics, (35:10), pp. 939-953.

MacLean, D., Roseway, A., & Czerwinski, M. 2013. "MoodWings: a wearable biofeedback device for real-time stress intervention," in Proceedings of the 6th International Conference on Pervasive Technologies Related to Assistive Environments, Island of Rhodes: Greece, pp. 1-8.

Maddi, S. R. 2006. "Hardiness: The courage to grow from stresses," The Journal of Positive Psychology (1:3), pp. 160-168.

Maier, C., Laumer, S., and Eckhardt, A. 2011. "Technology Adoption by Elderly People – An Empirical Analysis of Adopters and Non-Adopters of Social Networking Sites," in Proceedings of the 10th International Conference on Wirtschaftsinformatik, Zurich, Switzerland, pp. 901-911.

Maier, C., Laumer, S., Eckhardt, A., and Weitzel, T., 2012. "Online Social Networks as a Source and Symbol of Stress: An Empirical Analysis," in Proceedings of the International Conference on Information Systems (ICIS), Orlando (FL).

Maier, C., Laumer, S., Eckhardt, A., and Weitzel, T. 2014. "Giving too much social support: social overload on social networking sites," European Journal of Information Systems (24:5), pp. 447-464.

Maier, C., Laumer, S., Weinert, C., and Weitzel, T. 2015. "The effects of technostress and switching stress on discontinued use of social networking services: a study of Facebook use," Information Systems Journal (25:3), pp. 275-308.

Mayo Clinic 2017. "Biofeedback," available at https://www.mayoclinic.org/tests-procedures/biofeedback/about/pac-20384664).

Malhotra, A., Melville, N. and Watson, R. 2013. "Spurring Impactful Research on Information Systems for Environmental Sustainability," MIS Quarterly (37:4), pp. 1265-1274.

March, S. T., and Smith, G. F. 1995. "Design and natural science research on information technology," Decision support systems (15.4), pp. 251-266.

Marin, M. F., Lord, C., Andrews, J., Juster, R. P., Sindi, S., Arsenault-Lapierre, G., Fiocco, A. J., and Lupien, S. J. 2011. "Chronic Stress, Cognitive Functioning and Mental Health," Neurobiology of Learning and Memory (96:4), pp. 583-595.

Masjosthusmann, C., Koehler, U., Decius, N., and Bueker, U. 2012. "A vehicle energy management system for a battery electric vehicle," in Vehicle Power and Propulsion Conference (VPPC) IEEE, Seoul, South Korea, pp. 339-344.

Mason, J. W. 1975. "A historical view of the stress field," Journal of human stress (1:2), pp. 22-36.

Matano, R. A., Futa, K. T., Wanat, S. F., Mussman, L. M., and Leung, C. W. 2000. "The Employee Stress and Alcohol Project: the development of a computer-based alcohol abuse prevention program for employees," The Journal of Behavioral Health Services and Research (27:2), pp. 152-165.

Mathieson, K. 1991. "Predicting User Intentions: Comparing the Technology Acceptance Model with the Theory of Planned Behavior," Information Systems Research (2:3), pp. 173-191.

Matt, C., Hess, T., and Benlian, A. 2015. "Digital Transformation Strategies," Business & Information Systems Engineering (57:5), pp. 339-343.

Matthews, G. 2002. "Towards a transactional ergonomics for driver stress and fatigue," Theoretical Issues in Ergonomics Science (3:2), pp. 195-211.

Matthews, G., and Desmond, P. A. 1995. "Stress as a factor in the design of in-car driving enhancement systems," Le Travail Humain: A Bilingual and Multi-Disciplinary Journal in Human Factors (58:2), pp. 109-129.

Matthews, G., Dorn, L., and Glendon, A. I. 1991. "Personality Correlates of Driver Stress," Personality and Individual Differences (12:6), pp. 535-549.

Matthews, G., Dorn, L., Hoyes, T. W., Davies, D. R., Glendon, A. I., and Taylor, R. G. 1998. "Driver Stress and Performance on a Driving Simulator," Human Factors: The Journal of the Human Factors and Ergonomics Society (40:1), pp. 136-149.

McCallie, M. S., Blum, C. M., and Hood, C. J. 2006. "Progressive muscle relaxation," Journal of Human Behavior in the Social Environment (13:3), pp. 51-66.

McCollum, D., Krey, V., Kolp, P., Nagai, Y., and Riahi, K. 2014. "Transport electrification: A key element for energy system transformation and climate stabilization," Climatic Change (123:3-4), pp. 651–664.

McGrath, J., 1976. "Stress and Behavior in Organizations," in Handbook of Industrial and Organizational Psychology, M. D. Dunnette (eds.), Chicago: Rand-McNally, pp. 1351-1395.

McKenna, B., Tuunanen, T., and Gardner, L. 2013. "Consumers' adoption of information services," Information & Management (50), pp. 248–257.

McKight, P. E., and Najab, J. 2010. "Kruskal-Wallis Test," in Corsini Encyclopedia of Psychology (Vol. 4), I. B. Weiner and W. E. Craighead, New York: John Wiley & Sons.

McKinsey 2014. "Connected car, automotive value chain unbound: Advanced Industries," (available at: https://www.mckinsey.de/files/mck_connected_car_report.pdf).

Melville, N. P. 2010. "Information systems innovation for environmental sustainability," MIS Quarterly (34:1), pp. 1-21.

Merali, Y., Papadopoulos, T., and Nadkarni, T. 2012. "Information Systems Strategy: Past, Present, Future?," The Journal of Strategic Information Systems (21:2), pp. 125-153.

Meschtscherjakov, A., Wilfinger, D., Scherndl, T., and Tscheligi, M. 2009. "Acceptance of future persuasive in-car interfaces towards a more economic driving behaviour," in Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Essen, Germany, pp. 81-88.

Michael, G., Anastasios, S., Helen, K., Catherine, K., and Christine, K. 2009. "Gender differences in experiencing occupational stress: the role of age, education and marital status," Stress and Health (25:5), pp. 397-404.

Millard-Ball, G. Murray, J. Ter Schure, C. Fox, and Burkhardt, J. 2005. "TCRP report 108: Car-sharing: Where and how it succeeds," Transp. Res. Board Nat. Acad., Washington, DC.

Milliken J. F. 1987. "Three Types of Perceived Uncertainty About the Environment: State, Effect, and Response Uncertainty," Academy of Management Review (12:1), pp. 133-143.

Monat, A., Averill, J. R., and Lazarus, R. S. 1972. "Anticipatory Stress and Coping Reactions Under Various Conditions of Uncertainty," Journal of Personality and Social Psychology (24:2), pp. 237-253.

Moons, I., and Pelsmacker, P. 2015. "The role of emotions for the usage intention of the electric car: longitudinal perspective in the Belgian context," in Proceedings of the 11th International Marketing Trends Conference (2:1), Paris, France, pp.7-15.

Morton C., Schuitema G., and Anable J. 2011. "Electric Vehicles: Will Consumers Get Charged Up?," in Universities's Transport Study Group Conference January 2011, Open University, Milton Keynes, pp. 1-13.

Myers, M. D. 1997. "Qualitative research in information systems," Management Information Systems Quarterly (21:2), pp. 241-242 (MISQ Discovery, archival version, pp. 1-18, available at http://www.qual.auckland.ac.nz/).

Nachar, N. 2008. "The Mann-Whitney U: A Test for Assessing Whether Two Independent Samples Come from the Same Distribution," Tutorials in Quantitative Methods for Psychology (4:1), pp. 13-20.

Nacke, L. E., Kalyn, M., Lough, C., and Mandryk, R. L. 2011. "Biofeedback game design: using direct and indirect physiological control to enhance game interaction," in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 103-112.

Nastjuk, I., and Kolbe, L. M. 2015. "On the Duality of Stress in Information Systems Research - The Case of Electric Vehicles," in Proceedings of the International Conference on Information Systems (ICIS), Fort Worth, Texas, pp. 1-22.

Nastjuk, I., Trang, S., Kolbe, L. M. 2015. "The Influence of Sociodemographic and Technology-Associated Factors on Stress from Human Interaction with Electric Vehicle Information Systems," in 21st Americas Conference on Information Systems (AMCIS), Puerto Rico, pp. 1-14.

Neaimeh, M., Hill, G. A., Huebner, Y., and Blythe, P. T. 2013. "Routing systems to extend the driving range of electric vehicles," IET Intelligent Transport Systems (7:3), pp. 327-336.

Neale, V. L., Dingus, T. A., Klauer, S. G., Sudweeks, J., and Goodman, M. 2005. "An overview of the 100-car naturalistic study and findings," National Highway Traffic Safety Administration, (Paper nr. 05-0400), pp. 1-10.

Nersessian, N. J. 1992. "In the theoretician's laboratory: Thought experimenting as mental modeling," in Proceedings of the Biennial Meeting of the Philosophy of Science Association (2), pp. 291-301.

Neubauer, J., and Wood, E. 2014. "The impact of range anxiety and home, workplace, and public charging infrastructure on simulated battery electric vehicle lifetime utility," Journal of power sources (257), pp. 12-20.

Neumann, I., Cocron, P., Franke, T., and Krems, J. F. 2010. "Electric Vehicles as a Solution for Green Driving in the Future? A field Study Examining the User Acceptance of Electric Vehicles," in Proceedings of the European Conference on Human Interface Design for Intelligent Transport Systems, Berlin, Germany, pp. 445-453.

Neumann, I., and Krems, J. F. 2016. "Battery electric vehicles–implications for the driver interface," Ergonomics (59:3), pp. 331-343.

Nilsson, M. 2011. "Electric Vehicle: The Phenomenon of Range Anxiety," (available at http://www.elvire.eu/IMG/pdf/The_phenomenon_of_range_anxiety_ELVIRE.pdf).

Nilsson, M., and Habibovic, A. 2013. "Identifying EV drivers' needs for information communication technology to ease the EV charging process," in Proceedings of the International Conference on Automotive User Interfaces and Interactive Vehicular Applications 2013, Eindhoven, Netherlands, pp. 13-16.

Nkoro, A. B., and Vershinin, Y. A. 2014. "Current and Future Trends in Applications of Intelligent Transport Systems on Cars and Infrastructure," in Proceedings of the 17th International Conference on Intelligent Transportation Systems, Qingdao, China, pp. 514-519.

Nordstokke, D. W., Zumbo, B. D., Cairns, S. L., and Saklofske, D. H. 2011. "The Operating Characteristics of the Nonparametric Levene Test for Equal Variances with Assessment and Evaluation Data," Practical Assessment, Research & Evaluation (16:5), pp. 1-8.

Novaco, R. W., Stokols, D., Campbell, J., and Stokols, J. 1979. "Transportation, Stress, and Community Psychology," American Journal of Community Psychology (7:4), pp. 361-380.

Nykvist, B., and Nilsson, M. 2015. "Rapidly Falling Costs of Battery Packs for Electric Vehicles," Nature Climate Change (5:4), pp. 329-332.

Oliva, J. A., Weihrauch, C., and Bertram, T. 2013. "A Model-Based Approach for Predicting the Remaining Driving Range in Electric Vehicles," in Annual Conference of the Prognostics and Health Management Society (4), New Orleans, USA, pp. 438-448.

Oltra, C., Boso, A., Espluga, J., and Prades, A. 2013. "A qualitative study of users' engagement with real-time feedback from in-house energy consumption displays," Energy Policy (61), pp. 788-792.

Orlikowski, W. J., and Baroudi, J. J. 1991. "Studying information technology in organizations: Research approaches and assumptions," Information systems research (2:1), pp. 1-28.

Orlikowski, W. J., and Iacono, C. S. 2001. "Research commentary: Desperately seeking the "IT" in IT research—A call to theorizing the IT artifact," Information systems research (12:2), pp. 121-134.

Osch, W. van, and Avital, M. 2010. "From Green IT to Sustainable Innovation," in AMCIS 2010 Proceedings. Paper 490.

Osswald, S., Wurhofer, D., Troesterer, S., Beck, E., and Tscheligi, M. 2012. "Predicting Information Technology Usage in the Car: Towards a Car Technology Acceptance Model," in Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Portsmouth, NH, pp. 51-58.

Osterwalder, A., Pigneur, Y., and Tucci, C.L. 2005. "Clarifying Business Models: Origins, Present, and Future of the Concept," Communications of the Association for Information (16), pp. 1-25.

Ostrom, T. M. 1969. "The Relationship Between the Affective, Behavioral and Cognitive Components of Attitude," Journal of Experimental Social Psychology (5:1), pp. 12-30.

Owusu-Ansah, S., Azasoo, J. Q., and Adu, I. N. 2016. "Understanding the effects of technostress on the performance of banking staff," International Journal of Business Continuity and Risk Management (6:3), pp. 222-237.

Parasuraman R., and Riley V. 1997. "Humans and Automation: Use, Misuse, Disuse, Abuse," Human Factors: The Journal of the Human Factors and Ergonomics Society (39:2), pp. 230–253.

Pasaoglu, G., Fiorello, D., Martino, A., Zani, L., Zubaryeva, A., and 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:C), pp. 51-59.

Pauzié, A., and Manzano, J. 2007. "Evaluation of Driver Mental Workload Facing New In-Vehicle Information and Communication Technology," in Proceedings of the 20th Enhanced Safety of Vehicles Conference (ESV20), Lyon, France, (10), pp. 1-10.

Pavlou, P. A., and Fygenson, M. 2006. "Understanding and Predicting Electronic Commerce Adoption: An Extension of the Theory of Planned Behavior," MIS Quarterly (30:1), pp. 115-143.

Pearlin, L. I., and Schooler, C. 1978. "The structure of coping," Journal of Health and Social Behavior (19) pp. 2-21.

Pearre, N. S., Kempton, W., Guensler, R. L., and Elango, V. V. 2011. "Electric Vehicles: How much Range is Required for a Day's Driving?," Transportation Research Part C: Emerging Technologies, 19(6), 1171-1184.

Pearson, D. W., and Thackray, R. I. 1970. "Consistency of Performance Change and Autonomic Response as a Function of Expressed Attitude Toward a Specific Stress Situation," Psychophysiology (6:5), pp. 561-568.

Penrod, J. 2001. "Refinement of the Concept of Uncertainty," Journal of Advanced Nursing (34:2), pp. 238-245.

Perdue, B. C., and Summers, J. O. 1986. "Checking the Success of Manipulations in Marketing Experiments," Journal of Marketing Research (23:4), pp. 317-326.

Pereira, M., Hamama, H., Bruyas, M. P., and Simoes, A. 2008. "Effect of additional tasks in driving performance: Comparison among three groups of drivers," in Proceedings of the European Conference on Human Centred Design for Intelligent Transport Systems, Lyon, France, pp. 239-252.

Perrewé, P. L. and Zellars, K. L. 1999. "An examination of attributions and emotions in the transactional approach to the organizational stress process," Journal of Organizational Behavior (20:5), pp. 739-752.

Perujo, A., and Ciuffo, B. 2010. "The introduction of electric vehicles in the private fleet: Potential impact on the electric supply system and on the environment. A case study for the Province of Milan, Italy," Energy Policy (38:8), pp. 4549-4561.

Pettitt, M., Burnett, G. E., and Stevens, A. 2005. "Defining Driver Distraction," in Proceedings of the 12th World Congress on Intelligent Transport Systems, San Francisco, CA, pp. 1-12.

Philip, A., and Wiederer, R. 2010. "Policy Opinions for Electric Vehicle Charging Infrastructure in C40cities," Technical Report, Harvard Kennedy School, pp. 1-94.

Pichler, B., and Riener, A. 2015. "Evaluation of Historical Electric Vehicle (EV) Driving Data to Suggest Improvements in Driving Efficiency," in Adjunct Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Nottingham, UK, pp. 130-135.

Pirker, C. 2009. Statistical Noise or Valuable Information - The Role of Extreme Cases in Marketing Research, Wiesbaden: Gabler.

Ploetz, P., Schneider, U., Globisch, J., and Duetschke, E. 2014. "Who Will Buy Electric Vehicles? Identifying Early Adopters in Germany," Transportation Research Part A: Policy and Practice (67), pp. 96-109.

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., and Podsakoff, N. P. 2003. "Common method biases in behavioral research: a critical review of the literature and recommended remedies." Journal of Applied Psychology (88:5), pp. 879-903.

Prusak, O. 2007. "Relationships among Locus of Control, Perceived Self-Efficacy, and Medication Adherence in Members of Double-Troble in Recovery or Dual Recovery Anonymus Self-Help Groups," Capella University, Minneapolis, Minnesota.

Rabbie, J. M. and Lodewijkx, H. F. M. 1996. "A Behavioral Interaction Model: Toward an Integrative Theoretical Framework for Studying Intra- and Intergroup Dynamics," in Understanding Group Behavior, E. H. Witte and J. H. Davis (eds.), Psychology Press, pp. 255-294.

Ragu-Nathan, T. S., Tarafdar, M., Ragu-Nathan, B. S., and Tu, Q. 2008. "The consequences of technostress for end users in organizations: Conceptual development and empirical validation," Information Systems Research, (19:4), pp. 417-433.

Ranney, T. A. 2008. "Driver Distraction: A Review of the Current State of Knowledge," National Highway Traffic Safety Admin., Technical Report, pp. i-28

Ranney, T. A., Mazzae, E., Garrott, R., and Goodman, M. J. 2000. "NHTSA Driver Distraction Research: Past, present, and future," National Highway Traffic Safety Administration, pp. 1-11.

Rauh, N., Franke, T., and Krems, J. F. 2015a. "Understanding the impact of electric vehicle driving experience on range anxiety," Human Factors: The Journal of the Human Factors and Ergonomics Society (57:1), pp. 177-187.

Rauh, N., Franke, T., and Krems, J. F. 2015b. "User experience with electric vehicles while driving in a critical range situation–a qualitative approach," IET Intelligent Transport Systems (9:7), pp. 734-739.

Ravichandran, T. and Lertwongsatien, C. 2005. "Effect of information systems resources and capabilities on firm performance: A resource-based perspective," Journal of management information systems (21:4), pp. 237-276.

Razavi, T. 2001. "Self-Report Measures: An Overview of Concerns and Limitations of Questionnaire Use in Occupational Stress Research," in Working Paper from University of Southampton – Department of Accounting and Management Sciences, (Paper 01-175), Southampton, pp. 1-23.

Regan, M. A., Victor, T. W., Lee, J. D., and Young, K. L. 2009. "Driver Distraction Injury Prevention Countermeasures—Part 3: Vehicle, Technology, and Road Design," in Driver Distraction. Theory, Effects, and Mitigation, M. A. Regan, J. D. Lee and K. L. Young (eds.), New York: Taylor and Francis Group, pp. 579-601.

Reinartz, W. J., Haenlein, M., and Henseler, J. 2009. "An Empirical Comparison of the Efficacy of Covariance-Based and Variance-Based SEM," International Journal of Market Research (26:4), pp. 332–344.

Remane, G., Hanelt, A., Tesch, J. F., Nickerson, R. C., and Kolbe, L. M. 2016. "A taxonomy of carsharing business models," in Proceedings of the International Conference on Information Systems (ICIS 2016), Dublin, Ireland, pp. 1-19.

Rezvani, Z., Jansson, J., and Bodin, J. 2015. "Advances in consumer electric vehicle adoption research: A review and research agenda," Transportation research part D: transport and environment (34), pp. 122-136.

Rice, W. R. 1989. "Analyzing Tables of Statistical Tests," Evolution (43:1), pp. 223-225.

Rice, V.H. 2000. "Theories of stress and relationship to health, in Handbook of stress, coping, and health: Implication for nursing. Research, theory, and practice, V H. Rice (eds.), London: Sage Publications, pp. 22-42.

Richardson, S., Shaffer, J. A., Falzon, L., Krupka, D., Davidson, K. W., and Edmondson, D. 2012. "Meta-analysis of Perceived Stress and its Association with Incident Coronary Heart Disease," The American Journal of Cardiology (110:12), pp. 1711-1716.

Riedl, R. 2013. "On the Biology of Technostress: Literature Review and Research Agenda," ACM SIGMIS Database (44:1), pp. 18–55.

Riedl, R., Kindermann, H., Auinger, A., and Javor, A. 2012. "Technostress from a Neurobiological Perspective." Business & Information Systems Engineering (4:2), pp. 61-69.

Riedl, R., Léger, P. M. 2016. „Fundamentals of NeuroIS – Information Systems and the Brain," Berlin Heidelberg: Springer.

Ringle, C. M., Sarstedt, M., and Straub, D. 2012. "A Critical Look at the Use of PLS-SEM in MIS Quarterly," MIS Quarterly (36:1), iii-8.

Ringle, C. M., Wende, S., and Becker, J. 2015. "SmartPLS 3," Boenningstedt, Germany, (available at: http://www.smartpls.de).

Ringle, C. M., Wende, S., and Will, A. 2005. "SmartPLS (Release 2.0 (beta))," University of Hamburg, Germany, (available at: http://www.smartpls.de).

Roberts, J. 2000. "From know-how to show-how? Questioning the role of information and communication technologies in knowledge transfer," Technology Analysis & Strategic Management (12:4), pp. 429-443.

Rodgers L. P. 2013. "Electric Vehicle Design, Racing and Distance to Empty Algorithms," Dissertation, Cambridge, MA, USA, (available at: http://hdl.handle.net/1721.1/81705).

Rodgers L., Wilhelm E., and Frey D. 2013. "Conventional and novel methods for estimating an electric vehicle's "distance to empty," in Proceedings of the ASME 2013 International Conference on Advanced Vehicle Technologies, Portland, USA.

Roenker, D. L., Cissell, G. M., Ball, K. K., Wadley, V. G., and Edwards, J. D. 2003. "Speed-of-processing and driving simulator training result in improved driving performance," Human Factors: The Journal of the Human Factors and Ergonomics Society (45:2), pp. 218-233.

Roshanov, P. S., Misra, S., Gerstein, H. C., Garg, A. X., Sebaldt, R. J., Mackay, J. A., Weise-Kelly, L., Navarro, T., Wilczynski, N.L., and Haynes, R. B. 2011. "Computerized clinical decision support systems for chronic disease management: a decision-maker-researcher partnership systematic review," Implementation Science (6:92), pp. 1-16.

Rotter, J. B. 1966. "Generalized Expectancies for Internal Versus External Control of Reinforcement," Psychological Monographs: General and Applied (80:1), pp. 1-27.

Roy, S., Tarafdar, M., Ragu-Nathan, T. S., & Erica, M. 2012. "The Effect of Misspecification of Reflective and Formative Constructs in Operations and Manufacturing Management Research," Electronic Journal of Business Research Methods (10:1), pp. 34-52.

Rui W., Lukic S. M. 2011. "Review of driving conditions prediction and driving style recognition based control algorithms for hybrid electric vehicles," in: IEEE Vehicle Power and Propulsion Conference (VPPC), Chicago, IL, USA.

Saadé, R. G., and Kira, D. 2006. "The Emotional State of Technology Acceptance," in: Issues in Informing Science & Information Technology (3), pp. 529-539.

Saaty, T. L. 1990. "Decision making for leaders: the analytic hierarchy process for decisions in a complex world," University of Pittsburgh, RWS publications.

Sakhdari, B., and Azad, N. L. 2015. "An optimal energy management system for battery electric vehicles," IFAC-PapersOnLine (48:15), pp. 86-92.

Salanova, M., Llorens, S., and Cifre, E. 2013. "The dark side of technologies: technostress among users of information and communication technologies," International Journal of Psychology (48:3), pp. 422-436.

Salvucci, D. D., and Liu, A. 2002. "The time course of a lane change: Driver control and eye-movement behavior," Transportation Research Part F (5:2), pp. 123-132.

Samaras, C. and Meisterling, K. 2008. "Life cycle assessment of greenhouse gas emissions from plug-in hybrid vehicles: implications for policy," Environmental science & technology (42:9), pp. 3170-3176.

Sbihi, A., and Eglese, R.W. 2010. "Combinatorial Optimization and Green Logistics," Annals of Operations Research (175:1), pp. 159-175.

Schaltegger, S., Luedeke-Freund, F., and Hansen, E. G. 2012. "Business Cases for Sustainability: The Role of Business Model Innovation for Corporate Sustainability," International Journal of Innovation and Sustainable Development (6:2), pp. 95-119.

Schiessl, C. 2007. "Stress and strain while driving," in Young Researchers Seminar - European Conference of Transport Research Institutes, Brno: Czech Republic, pp. 1-11.

Schmidt, A., Dey, A. K., Kun, A. L., and Spiessl, W. 2010. "Automotive user interfaces: human computer interaction in the car," in Proceedings of the 28th International Conference on Human Factors in Computing, Atlanta, GA, pp. 3177-3180.

Schuitema, G., Anable, J., Skippon, S., and Kinnear, N. 2013. "The role of instrumental, hedonic and symbolic attributes in the intention to adopt electric vehicles," Transportation Research Part A: Policy and Practice (48), pp. 39-49.

Seidel, S., Recker, J., and vom Brocke, J. 2013. "Sensemaking and Sustainable Practicing: Functional Affordances of Information Systems in Green Transformations," MIS Quarterly (37:4), pp. 1275-1299.

Seign, R., and Bogenberger, K. 2012. „Prescriptions for the successful diffusion of carsharing with electric vehicles," in Proceedings of the Conference on Future Automotive Technology, Muenchen, Germany, pp. 1-8.

Selye, H. 1946. "The General Adaptation Syndrome and the Diseases of Adaptation," The Journal of Clinical Endocrinology & Metabolism (6:2), pp. 117-230.

Selye, H. 1949. "The General Adaption Syndrome and the Diseases of Adoption," The Journal of Clinical Endocrinology (6:2), pp. 117-230.

Selye, H. 1950. "The Physiology and Pathology of Exposure to Stress," Montreal: Acta.

Selye, H. 1959. "Perspectives in stress research," Perspectives in biology and medicine (2:4), pp. 403-416.

Selye, H. 1976. "Stress Without Distress," Philadelphia, PA: Lippincott.

Selye, H., 1979. "The Stress of My Life: A Scientist's Memoirs," New York: Van Nostrand Reinhold.

Shaheen, S.A., Sperling, D., and Wagner, C. 1998. "Carsharing in Europe and North America: Past, Present, and Future," Transportation Quarterly (52:3), pp. 35-52.

Sharma, R., Manzie, C., Bessede, M., Crawford, R. H., and Brear, M. J. 2013. "Conventional, hybrid and electric vehicles for Australian driving conditions. Part 2: Life cycle CO_2-e emissions," Transportation Research Part C: Emerging Technologies (28), pp. 63-73.

Shavelson, R. J., Hubner, J. J., and Stanton, G. C. 1976. "Self-Concept: Validation of Construct Interpretations," Review of Educational Research (46:3), pp. 407-441.

Sheridan, T. B. 2004. "Driver distraction from a control theory perspective," Human Factors: The Journal of the Human Factors and Ergonomics Society (46:4), pp. 587-599.

Shim, J. P., Warkentin, M., Courtney, J. F., Power, D. J., Sharda, R., and Carlsson, C. 2002. "Past, present, and future of decision support technology," Decision support systems (33:2), pp. 111-126.

Shinar, D. 1998. "Aggressive driving: the contribution of the drivers and the situation," Transportation Research Part F: Traffic Psychology and Behaviour, (1:2), pp. 137-160.

Skippon, S., and 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: Transport and Environment (16:7), pp. 525-531.

Smith, D., Chang, J., Glassco, R., Foley, J., and Cohen, D. 2005. "Methodology for Capturing Driver Eye Glance Behavior During In-Vehicle Secondary Tasks," Transportation Research Record: Journal of the Transportation Research Board (1937), pp. 61-65.

Soscia, I. 2007. "Gratitude, delight, or guilt: The role of consumers' emotions in predicting postconsumption behaviors," Psychology & Marketing (24:10), pp. 871–894.

Sosna, M., Trevinyo-Rodríguez, R. N., and Velamuri, S. R. 2010. "Business model innovation through trial-and-error learning: The Naturhouse case," Long range planning (43:2), pp. 383-407.

Speier, C., Valacich, J. S., and Vessey, I. 1999. "The influence of task interruption on individual decision making: An information overload perspective," Decision Sciences (30:2), pp. 337-360.

Spradley, J. P., and Phillips, M. 1972. "Culture and Stress: A Quantitative Analysis," American Anthropologist (74.3), pp. 518-529.

Srinivasan, R., and Jovanis, P. P. 1997. "Effect of In-Vehicle Route Guidance Systems on Driver Workload and Choice of Vehicle Speed: Findings from a Driving Simulator Experiment," in Ergonomics and Safety of Intelligent Driver Interfaces, Y. Ian Noy (eds.), CRC Press, pp. 97-114.

Steele, J., Bourke, L., Luloff, A. E., Liao, P. S., Theodori, G. L., and Krannich, R. S. 2001. "The drop-off/pick-up method for household survey research," Community Development (32:2), pp. 238-250.

Stein, K. F. 1995. "Schema Model of the Self-Concept," Image: The Journal of Nursing Scholarship (27:3), pp. 187-193.

Stroemberg, H., Andersson, P., Almgren, S., Ericsson, J., Karlsson, M. and Nåbo, A. 2011. "Driver Interfaces for Electric Vehicles," in Proceedings of the 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Salzburg, Austria, pp. 177-184.

Stutts, J.C., Reinfurt, D.W., Staplin, L., Rodgman, E.A. 2001. „The role driver distraction in traffic crashes. Report Prepared for AAA Foundation for Traffic Safety, Washington DC, USA, pp. 1-64.

Sweller, J. 1988. "Cognitive load during problem solving: Effects on learning," Cognitive Science (12:2), pp. 257-285.

Sweller, J. 1989. "Cognitive technology: Some procedures for facilitating learning and problem solving in mathematics and science," Journal of Educational Psychology (81:4), pp. 457-466.

Tams, S., Hill, K., de Guinea, A. O., Thatcher, J., and Grover, V. 2014. "NeuroIS-alternative or complement to existing methods? Illustrating the holistic effects of neuroscience and self-reported data in the context of technostress research," Journal of the Association for Information Systems (15), pp. 723-753.

Tang, B. J., Wu, X. F., and Zhang X., 2013. „Modeling the CO_2 emissions and energy saved from new energy vehicles based on the logistic-curve," Energy Policy (57), pp. 30-35.

Tarafdar, M., Cooper, C. L., and Stich, J. F. 2017. „The technostress trifecta-techno eustress, techno distress and design: Theoretical directions and an agenda for research," Information Systems Journal, pp. 1-37.

Tarafdar, M., Tu, Q., Ragu-Nathan, B. S., and Ragu-Nathan, T. S. 2007. "The impact of technostress on role stress and productivity," Journal of Management Information Systems, (24:1), pp. 301-328.

Tarafdar, M., Gupta, A., and Turel, O., 2015a. "Special issue on 'dark side of information technology use': an introduction and a framework for research," Information Systems Journal, (25:2), pp.161-170.

Tarafdar M, Pullins E., and Ragu-Nathan TS, 2011b. "Examining impacts of technostress on the professional salesperson's performance," in: Proceedings of the 17th Americas Conference on Information Systems, B. Rajagopalan, and P. Goes (eds.), Detroit, MI, pp. 1–13.

Tarafdar, M., Pullins, E. B., and Ragu-Nathan, T. S. 2015b. "Technostress: negative effect on performance and possible mitigations," Information Systems Journal (25:2), pp. 103-132.

Tarafdar, M., Tu, Q., and Ragu-Nathan, T. S. 2010. "Impact of technostress on end-user satisfaction and performance," Journal of Management Information Systems (27:3), pp. 303-334.

Tarafdar, M., Tu, Q., Ragu-Nathan, T.S., and Ragu-Nathan, B.S. 2011a. "Crossing to the dark side: examining creators, outcomes, and inhibitors of technostress," Communications of the ACM (54:9), pp. 113-120.

Tate, E. D., Harpster, M. O., and Savagian, P. J. 2008. "The Electrification of the Automobile: From Conventional Hybrid, to Plug-in Hybrids, to Extended-Range Electric Vehicles," SAE International Journal of Passanger Cars –Electronic and Electrical Systems (1:1), pp. 156-166.

Taylor, S. E., Pham, L. B., Rivkin, I. D. and Armor, D. A. 1998. "Harnessing the imagination-mental simulation, self-regulation, and coping," American psychologist (53:4), pp. 429-439.

Tesla   2017.   "Support: Model   S   Specifications,"   (available   at: https://www.tesla.com/support/model-s-specifications?redirect=no).

Teubner, T., and Flath, C. M. 2015. "The economics of multi-hop ride sharing," Business & Information Systems Engineering (57:5), pp. 311-324.

Thiel C., Perujo A., and Mercier A. 2010. "Cost and CO2 aspects of future vehicle options in Europe under new energy policy scenarios," Energy Policy (38:11), pp. 7142–7151.

Thoits, P. A. 1995. "Stress, Coping, and Social Support Processes: Where are We? What Next?," Journal of Health and Social Behavior (35), pp. 53-79.

Thomas, C. S. 2009. "Transportation options in a carbon-constrained world: Hybrids, plug-in hybrids, biofuels, fuel cell electric vehicles, and battery electric vehicles," International Journal of Hydrogen Energy (34:23), pp. 9279-9296.

Tielert, T., Killat, M., Hartenstein, H., Luz, R., Hausberger, S., and Benz, T. 2010. "The impact of traffic-light-to-vehicle communication on fuel consumption and emissions," In Internet of Things (IOT), Tokyo, Japan, pp. 1-8.

Tilson, D., Lyytinen, K. and Sørensen, C. 2010. "Research Commentary-digital Infrastructures: the Missing IS Research Agenda", Information Systems Research (21:4), pp. 748–759.

Tivesten, E., and Dozza, M. 2014. "Driving context and visual-manual phone tasks influence glance behavior in naturalistic driving," Transportation Research Part F (26), pp. 258-272.

Tu, Q., Wang, K., and Shu, Q. 2005. "Computer-related technostress in China," in: Communications of the ACM (48:4), pp. 77-81.

Tulusan, J., Staake, T., and Fleisch, E. 2012. "Providing eco-driving feedback to corporate car drivers: what impact does a smartphone application have on their fuel efficiency?," in Proceedings of the 2012 ACM conference on ubiquitous computing, Pittsburgh, USA, pp. 212-215.

Tuohy, S., Glavin, M., Hughes, C., Jones, E., Trivedi, M., and Kilmartin, L. 2015. "Intra-Vehicle Networks: A Review," IEEE Transactions on Intelligent Transportation Systems (16:2), pp. 534-545.

Turrentine, T., Garas, D., Lentz, A., and Woodjack, J. 2011. "The UC Davis MINI E Consumer Study," Institute of Transportation Studies, University of California, Davis, USA.

Urbach, N., and Ahlemann, F. 2010. "Structural Equation Modeling in Information Systems Research Using Partial Least Squares," Journal of Information Technology Theory and Application (11:2), pp. 5-40.

Van Eck, M., Berkhof, H., Nicolson, N., and Sulon, J. 1996. "The Effects of Perceived Stress, Traits, Mood States, and Stressful Daily Events on Salivary Cortisol," Psychosomatic Medicine (58:5), pp. 447-458.

Veit, D., Clemons, E., Benlian, A., Buxmann, P., Hess, T., Spann, M., Kundisch, D., Leimeister, J. M., and Loos, P. 2014. "Business Models - An Information Systems Research Agenda," Business & Information Systems Engineering (6:1), pp. 45-53.

Velcu-Laitinen, O., and Yigitbasioglu, O. M. 2012. "The use of dashboards in performance management: Evidence from sales managers," The International Journal of Digital Accounting Research (12:18), pp. 39-58.

Venkatesh, V., Morris, M. G., Davis, G. B., and Davis, F. D. 2003. "User acceptance of information technology: Toward a unified view," MIS Quarterly (27:3), pp. 425-478.

Venkatesh, V., Thong, J. Y., and Xu, X. 2012. "Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology," MIS Quarterly (36:1), pp. 157-178

Vermesan, O., and Friess, P. 2014. "Internet of Things – From Research and Innovation to Market Deployment," Aalborg: River Publishers.

Vitaliano, P. P., Scanlan, J. M., Zhang, J., Savage, M. V., Hirsch, I. B., and Siegler, I. C. 2002. "A path model of chronic stress, the metabolic syndrome, and coronary heart disease," Psychosomatic medicine (64:3), pp. 418-435.

Volkswagen AG 2015. "e-up! - Technische Daten des Wagens – Reichweite," (available at: http://www.volkswagen.de/de/models/up/varianten.s9_trimlevel_detail.suffix.html/e-up~2Fe-up.html#/tab=1bae3a9b847aaf26d6dd239d0475be8f).

Volkswagen AG 2016. "e-up! - Technische Daten des Wagens - Reichweite," (available at: http://www.volkswagen.de/de/models/up/varianten.s9_trimlevel_detail.suffix.html/e-up~2Fe-up.html#/tab=1bae3a9b847aaf26d6dd239d0475be8f).

Vom Brocke, J. and Seidel, S. 2012. "Environmental Sustainability in Design Science Research: Direct and Indirect Effects of Design Artifacts Design Science Research in Information Systems", in Advances in Theory and Practice, K. Peffers, M. Rothenberger and B. Kuechler (eds.), Berlin/Heidelberg: Springer, pp. 294-308.

Wagner, S., Brandt, T., Kleinknecht, M., and Neumann, D. 2014. "In Free-Float: How Decision Analytics Paves the Way for the Carsharing Revolution", in Proceedings of the International Conference on Information Systems (ICIS), Auckland, New Zealand, pp. 1-17.

Wallis N., and Lane B., 2013. "Electric vehicles: Improving consumer information to encourage adoption," European Council for Energy Efficient Economy, Tech. Rep. (4:514-13), pp. 1-14.

Walsh, C., Carroll, S., Eastlake, A., and Blythe, P., 2010. "Electric Vehicle Driving Style and Duty Variation Performance Study," University of Sheffield, UK, (available at: http://www.cenex.co.uk/wp-content/uploads/2014/02/Electric-vehicle-driver-and-duty-variation-performance-study.pdf).

Watson, R. T., Boudreau, M.-C. and Chen, A. J. 2010. "Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS Community", MIS Quarterly (34:1), pp. 23–38.

Watson D., Clark L. A., and Tellegen A. 1988. "Development and Validation of Brief Measures of Positive and Negative Affect: The PANAS Scales," Journal of Personality and Social Psychology (54:6), p. 1063.

Weikl, S., and Bogenberger, K. 2012. "Relocation Strategies and Algorithms for free-floating Car Sharing Systems," IEEE Intelligent Transportation Systems Magazine (5:4), pp. 100-111.

Weil, M. M., and Rosen, L. D. 1997. "Technostress: Coping with Technology @Work @Home @Play," New York: John Wiley & Sons.

Weindelt, B. 2016. "Digital Transformation of Industries: Automotive Industry," World Economic Forum, White Paper (in collaboration with Accenture), pp. 1-29.

Weinert, C., Maier, C., and Laumer, S. 2015. "Why are teleworkers stressed? An empirical analysis of the causes of telework-enabled stress," in Proceedings der 12. Internationalen Tagung Wirtschaftsinformatik (WI 2015), O. Thomas and F. Teuteberg (eds.), Osnabrueck, Deutschland, pp. 1407-1421.

Wellings, T., Binnersley, J., Robertson, D., and Khan, T. 2011. "Human Machine Interfaces in Low Carbon Vehicles: Market Trends and User Issues," in Low Carbon Vehicle Technology Project, Document No. HMI 2.1, University of Warwick, pp. 1-42.

Weng, F., Angkititrakul, P., Shriberg, E. E., Heck, L., Peters, S., and Hansen, J. H. (2016). "Conversational In-Vehicle Dialog Systems: The past, present, and future," IEEE Signal Processing Magazine (33:6), pp. 49-60.

Wesche, J. P., Ploetz, P., and Duetschke, E. 2016. „How to trigger mass market adoption of electric vehicles? Factors predicting interest in electric vehicles in Germany," Working Paper Sustainability and Innovation, (No. S07-2016). pp. 1-19.

Wheaton, B., 1999. "Social Stress," in Handbook of the Sociology of Mental Health, C. S. Aneshensel and Jo C. Phelan (eds.), New York: Springer Science & Business Media, pp. 277-300.

Whitson, J. A., and Galinsky, A. D. 2008. "Lacking control increases illusory pattern perception", Science (322:5898), pp. 115-117.

WHO (World Health Organization) 2008. "The Global Burden of Disease: 2004 Update," Geneva, Switzerland.

WHO (World Health Organization) 2013. "Global status report on road safety 2013: supporting a decade of action," Geneva, Switzerland.

Wickens, C. M., Mann, R. E., and Wiesenthal, D. L. 2013. "Addressing Driver Aggression Contributions From Psychological Science," Current Directions in Psychological Science (22:5), pp. 386-391.

Williams, M. D., Dwivedi, Y. K., Lal, B., and Schwarz, A. 2009. "Contemporary trends and issues in IT adoption and diffusion research," Journal of Information Technology (24:1), pp. 1-10.

Wright, P. 1974. "The Harassed Decision Maker: Time Pressures, Distractions, and the Use of Evidence," Journal of Applied Psychology (59:5), pp. 555-561.

Wunderlich, P., Kranz, J. and Veit, D. 2013. "Beyond carrot-and-stick: How values and endogenous motivations affect residential Green IS adoption," in Proceedings of the International Conference on Information Systems (ICIS), Milano, Italy, pp. 1-19.

Wurman, R. A. 2001. "Information Anxiety 2," New York: New Riders Publishers.

Wynn, T., and Lafleur, S. 2009. "A Free Market Perspective on Electric Vehicles," Portland, OR: Cascade Policy Institute.

Xie, X. F., and Wang, Z. J. 2017. "Integrated In-Vehicle Decision Support System for Driving at Signalized Intersections: A Prototype of Smart IoT in Transportation," Transportation Research Board, 96th Annual Meeting, Washington, DC, USA.

Yoo, Y. 2010. "Computing in Everyday Life: A Call For Research on Experimental Computing," MIS Quarterly (34:2), pp. 213-231.

Yoo, Y., Henfridsson, O., and Lyytinen, K. (2010). "Research commentary—the new organizing logic of digital innovation: an agenda for information systems research," Information systems research (21:4), 724-735.

Yoshikawa, M., Sugioka, K., Nozaki, Y., and Asahi, K. 2015. "Secure In-Vehicle Systems Against Trojan Attacks," in Proceedings of the 14th International Conference on Computer and Information Science (ICIS), Las Vegas, NV, pp. 29-33.

Young, K. and Regan, M. 2007. "Driver Distraction: A Review of the Literature," in Distracted Driving, I.J. Faulks, M. Regan, M. Stevenson, J. Brown, A. Porter and J.D. Irwin (eds.), NSW: Australasian College of Road Safety, pp. 379-405.

Yu, B., Hu, J., and Feijs, L. (2014). "Design and evaluation of an ambient lighting interface of HRV biofeedback system in home setting," in Proceedings of the International Conference on Ubiquitous Computing and Ambient Intelligence, Belfast, Northern Irland, pp. 88-91.

Zakowski, S. 1995. "The effects of stressor predictability of lymphocyte proliferation in humans," Psychology and Health (10:5), pp. 409–425.

Zeimbekis, J. 2011. "Thought experiments and mental simulations," in: Thought Experiments in Methodological and Historical Contexts, K. Ierodiakonou, and S. Roux (eds.), Brill.

Zhang, P. 2007. "Roles of Attitudes in Initial and Continued ICT Use: A Longitudinal Study," Americas Conference on Information Systems (AMCIS) 2007.

Zhang, P., and Li, N. 2005. "The importance of affective quality," Communications of the ACM (48:9), pp. 105-108.

Zhang, X., Rao, R., Xie, J., and Liang, Y. 2014. "The Current Dilemma and Future Path of China's Electric Vehicles," Sustainability (6:3), pp. 1567-1593.

Zhang, Y., Wang, W., Kobayashi, Y., and Shirai, K. 2012. "Remaining Driving Range Estimation of Electric Vehicle," in Proceedings of the 2012 IEEE International Electric Vehicle Conference (IEVC), Greenville, SC, pp. 1-7.

Zolnowski, A., Schmitt, A. K., and Boehmann, T. 2011. "Understanding the impact of remote service technology on service business models in manufacturing: from improving after-sales services to building service ecosystems," ECIS 2011 Proceedings, Paper 109.

Zur, H. B., and Breznitz, S. J. 1981. "The Effect of Time Pressure on Risky Choice Behavior", Acta Psychologica (47:2), pp. 89-104.

Appendix

Appendix A. Preliminary results of a study in progress on technostress creators in the vehicular context

Authors	Nastjuk, I., Marrone, M.
Title	Information Systems Drive me Mad! – An Investigation of Technostress Creators and Inhibitors on Psychological and Behavioral Outcomes in the Vehicular Context
Target Outlet	Journal of the Association for Information Systems
Research Question	What are the techno-stressors and techno-inhibitors in the vehicular context and how do these influence psychological and behavioral outcomes?
Methodological Approach	Mixed-method approach (qualitative and quantitative survey)
Proposed Technostress Creators	**Techno-Invasion:** situations in which in-vehicle IS become an integral part of everyday life due to, for example, individual's extended reachability or feeling of being permanently connected (adapted from Maier et al. 2012; Ragu-Nathan et al. 2008; Tarafdar et al. 2011a) **Techno-Overload:** situations in which individuals face an increased workload caused by the in-vehicle IS, due to information overload or multitasking (adapted from Ayyagari et al. 2011, Ragu-Nathan et al. 2008; Tarafdar et al. 2011a). **Techno-Complexity:** situations, in which individuals may become frustrated with the number of features provided by the in-vehicle IS, as well as how to use the features (adapted from Ayyagari et al. 2011, Maier et al. 2012; Ragu-Nathan et al. 2008; Tarafdar et al. 2011a). **Invasion of privacy:** situations in which individuals perceive the individual's privacy is being compromised due to in-vehicle IS (adapted from Ayyagari et al. 2011). **Techno-Uncertainty:** situations, where continuing changes and upgrades in in-vehicle IS do not give individuals a chance to develop a base of experience for the use of in-vehicle IS, thus their existing knowledge becomes rapidly obsolete (adapted from Ayyagari et al. 2011, Maier et al. 2012; Ragu-Nathan et al. 2008; Tarafdar et al. 2011a).
Proposed Technostress Inhibitors	**Driver Support Network:** mechanisms that are related to individuals' support in reducing effects from technostress by addressing users' in-vehicle IS problems relating (adapted from Ragu-Nathan et al. 2008; Tarafdar et al. 2011a). **Hardiness:** Refers to a pattern of strategies and attitudes that increase the individual's resistance to stressful conditions by turning stressful events into opportunities (adapted from Kobasa et al. 1982; Maddi 2006).
Proposed Psychological and Behavioral Outcomes	**Techno-Exhaustion:** individual's aversive, potentially harmful and unconscious psychological strain as a result of feeling tired related to the usage of in-vehicle IS (adapted from Maier et al. 2014). **Driving Exhaustion:** individual's aversive, potentially harmful and unconscious psychological strain as a result of feeling tired related to the driving activity (adapted from Maier et al. 2014). **In-vehicle IS Satisfaction:** individual's overall affective and cognitive evaluation of the pleasurable level of consumption-related fulfillment experienced with the in-vehicle IS (adapted from Au et al. 2002; Maier et al. 2014). **Vehicle Satisfaction:** individual's overall affective and cognitive evaluation of the pleasurable level of consumption-related fulfillment experienced with the vehicle (adapted from Au et al. 2002; Maier et al. 2014). **In-vehicle IS-Driving Fit:** the degree to which in-vehicle IS provide features and support that fit the requirements of the driving task (adapted from Goodhue and Thompson 1995).

Appendix B. Overview of the authors' contribution in the studies included in this thesis

No	Title	Description of each authors' contributions
B1	Understanding the Influence of In-Vehicle Information Systems on Range Stress – Insights from an Electric Vehicle Field Experiment	Research idea and study design were mainly developed by Ilja Nastjuk and Matthias Eisel. Data analyses were carried out by Ilja Nastjuk and Matthias Eisel. Data collection was mainly conducted by Ilja Nastjuk, Matthias Eisel, and supported by Mohamed Arabi (as part of his master thesis that was supervised by Ilja Nastjuk, Matthias Eisel, and Lutz M. Kolbe). The article was written by Ilja Nastjuk in collaboration with Matthias Eisel. Lutz M. Kolbe supervised and guided the paper.
C1	Less is Sometimes More – The Impact of In-Vehicle Information Systems on Perceived Range Stress	Research idea and study design were mainly developed by Ilja Nastjuk. Data collection was mainly conducted by Ilja Nastjuk and supported by Björge Full (as part of his master thesis that was supervised by Ilja Nastjuk and Lutz M. Kolbe). Data analyses were conducted by Ilja Nastjuk. The article was written by Ilja Nastjuk. Mauricio Marrone and Lutz M. Kolbe supervised and guided the paper.
C2	Inaccuracy Versus Volatility – Which is the Lesser Evil in Battery Electric Vehicles?	Research idea, study design, and data collection were mainly developed and conducted by Ilja Nastjuk and assisted by Johannes Werner (as part of his master thesis that was supervised by Ilja Nastjuk and Lutz M. Kolbe). Data analyses were conducted by Ilja Nastjuk. The article was mainly written by Ilja Nastjuk. The theoretical background was partly written by Johannes Werner. Mauricio Marrone and Lutz M. Kolbe supervised and guided the paper.
D1	On the Duality of Stress in Information Systems Research – The Case of Electric Vehicles	Research idea and study design were mainly developed by Ilja Nastjuk. Data collection and data analysis were conducted by Ilja Nastjuk. The article was written by Ilja Nastjuk. Mauricio Marrone and Lutz M. Kolbe supervised and guided the paper.
E1	Too Much of a Good Thing? An Experimental Investigation of the Impact of Digital Technology-enabled Business Models on Individual Stress and Future Adoption of Sustainable Services	Research idea and study design were mainly developed by Ilja Nastjuk and Andre Hanelt. Data analysis was conducted by Ilja Nastjuk. Data collection was mainly conducted by Ilja Nastjuk and assisted by Thomas Hagen Hilbrig (as part of his master thesis that was supervised by Ilja Nastjuk, Andre Hanelt, and Lutz M. Kolbe). The article was mainly written by Ilja Nastjuk and Andre Hanelt. Lutz M. Kolbe supervised and guided the paper.

Appendix C. Overview of author's published and submitted double blind reviewed articles as of June 2018

Authors	Publication
Nastjuk, I., Marrone, M., Herrenkind, B., Kolbe, L.M.	What Drives the Acceptance of Autonomous Driving? Future Directions and Policy Recommendations, Transportation Research Part A: Policy and Practice (submitted, 2nd round of revisions).
Nastjuk, I., Werner, J., Marrone, M., Kolbe, L.M.	Inaccuracy Versus Volatility – Which is the Lesser Evil in Battery Electric Vehicles?, Transportation Research Part F: Traffic Psychology and Behaviour (submitted, 2nd round of revisions).
Brendel, A.B., Lichtenberg, S., Brauer, B., **Nastjuk, I.**, Kolbe, L.M.	Improving Electric Vehicle Utilization in Car Sharing – A Simulation of an E-Car Sharing Vehicle Utilization Management Systems, Transportation Research Part D: Transport and Environment, 2018.
Brendel, A.B., Lichtenberg, S., **Nastjuk, I.**, Kolbe, L.M.	Adapting Car sharing Vehicle Relocation Strategies for Shared Autonomous Electric Vehicle Services, 2017, Proceedings of the International Conference on Information Systems (ICIS 2017), Seoul, South Korea, pp. 1-24.
Eisel, M., **Nastjuk, I**., Kolbe, L.M.	Understanding the influence of in-vehicle information systems on range stress - Insights from an electric vehicle field experiment, 2016, Transportation Research Part F: Traffic Psychology and Behaviour (43), pp. 199-211.
Nastjuk, I., Hanelt, A., Kolbe, L.M.	Too Much of a Good Thing? An Experimental Investigation of the Impact of Digital Technology-enabled Business Models on Individual Stress and Future Adoption of Sustainable Services, 2016, Proceedings of the International Conference on Information Systems (ICIS 2016), Dublin, Ireland, pp. 1-24.
Nastjuk, I., Marrone, M., Kolbe, L.M.	Less is Sometimes More? The Impact of In-Vehicle Information Systems on Perceived Range Stress, 2016, Proceedings of the International Conference on Information Systems (ICIS 2016), Dublin, Ireland, pp. 1-22.
Nastjuk, I., Kolbe, L.M.	On the Duality of Stress in Information Systems Research - The Case of Electric Vehicles, 2015, Proceedings of the International Conference on Information Systems (ICIS 2015), Fort Worth, Texas, pp. 1-22.
Nastjuk, I., Trang, S., Kolbe, L.M.	The Influence of Sociodemographic and Technology-Associated Factors on Stress from Human Interaction with Electric Vehicle Information Systems, 2015, Proceedings of the Americas Conference on Information Systems (AMCIS 2015) Puerto Rico, pp. 1-14.
Hanelt, A., **Nastjuk, I.**, Krüp, H., Eisel, M., Ebermann, C., Brauer, B., Piccinini, E., Hildebrandt, B., Kolbe, L.M	Disruption on the Way? The Role of Mobile Applications for Electric Vehicle Diffusion, 2015, Proceedings of the International Conference on Wirtschaftsinformatik (WI 2015), Osnabrück, Germany, pp. 1023-1037.
Eisel, M., Schmidt, J., **Nastjuk, I.**, Ebermann, C., Kolbe, L.M.	Can Information Systems Reduce Stress? The Impact of Information Systems on Perceived Stress and Attitude, 2014, Proceedings of the International Conference on Information Systems (ICIS 2014), Auckland, New Zealand, pp. 1-16.

Appendix D. Curriculum Vitae (Abstract)

PERSONAL INFORMATION

Name	Ilja Nastjuk
Date of Birth	06.11.1987
Place of Birth	Kamenez Podolskij, Ukraine
Nationality	German

ACADEMIC QUALIFICATION

2016 - 2018	Doctor of Philosophy in Accounting and Corporate Governance (granted scholarship), Faculty of Business and Economics, Macquarie University, Sydney, Australia
2014 – 2017	Doctor of Philosophy in Management Information Systems, Faculty of Economic Sciences, Georg-August-Universität Göttingen, Göttingen, Germany
2012 – 2013	Semester abroad (granted scholarship), School of Business of Nanjing University, Nanjing, China
2011 – 2014	Master of Science (M. Sc.) in Management, Georg-August-Universität Göttingen, Göttingen, Germany
2007 – 2010	Bachelor of Science (B. Sc.) in Business Studies, Martin-Luther-University Halle-Wittenberg, Halle (Saale), Germany

PROFESSIONAL QUALIFICATION

Since 2018	Lecturer, Faculty of Business and Economics, Macquarie University, Sydney, Australia
Since 2017	Tutor, Faculty of Business and Economics, Macquarie University, Sydney, Australia
2016	Lecturer, Verwaltungs- und Wirtschaftsakademie Göttingen (VWA), Göttingen, Germany
Since 2014	Research associate, Chair of Information Management (Sustainable Mobility Research Group), Georg-August-University of Göttingen, Göttingen, Germany
2013 – 2014	Graduate assistant, Chair of Information Management (Sustainable Mobility Research Group), Georg-August-University of Göttingen, Göttingen, Germany
2013	Internship, Department of Finance and Controlling, Continental Tyre PJ Malaysia Sdn. Bhd., Kuala Lumpur, Malaysia
2010 – 2011	Associate Director, Economic Development Department, Industry Petrobeton (Heidelberg Cement Group), St. Petersburg, Russia
2009	Internship, Department of Sales and Marketing, KKM Knape/Kirchner Moskau, Moscow, Russia