Electric vehicle user behavior and policy implications
What can we learn from field studies?

Thomas Franke
Technische Universität Chemnitz
Cognitive & Engineering Psychology

E-Mobility research at TU Chemnitz

- **Focus**: the **user perspective** on EVs
  - User experience & user behavior
  - Implications for EV design & policy
- Conducted **BEV field trials** since 2008
  - MINI E Berlin 1.0 & 2.0 , BMW ActiveE Berlin, …
  - Methodology for international MINI E field trials (US, UK, France,…)
- **Topics** under investigation: the BEV user & ….
  - Range, eco-driving, HMI design, apps for multimodal mobility, safety, acoustics, regenerative braking, acceptance, charging, V2G, W2V, ….
- **Methods** (Cocron et al., 2011; Franke et al., 2014a)
  - Field trials & field experiments, data logging, diaries…
  - Focus groups, interviews, questionnaires, ….
  - Usability tests, expert evaluation, …

Cocron, P., Bühler, F., Neumann, I., Franke, T., Krems, J.F., Schwalm, M., & Keinath, A. (2011). Methods of evaluating electric vehicles from a user's perspective - the MINI E field trial in Berlin. *IET Intelligent Transport Systems*, *5*(2), 127-133.
Franke, T., Günther, M., Trantow, M., Krems, J.F., Vilimek, R., & Keinath, A. (2014a). Examining user-range interaction in battery electric vehicles - a field study approach. In T. Ahram, W. Karwowski, & T. Marek (Eds.) *Proceedings of … AHFE 2014, Krakow, Poland.*

Barriers to widespread EV adoption

- Attitude–behavior gap
  - Attitudes towards EVs: generally very positive
  - Purchase intentions: generally relatively low

- Barriers? (e.g., Bühler et al., 2014a)
  - "I cannot charge at home." ➔ charging infrastructure development
  - "EVs are too expensive." ➔ policy & mass market
  - "Can I really cope with the limited range?"

- Limited range as a challenge for widespread acceptance of EVs
  - Larger batteries are not the ultimate solution
    - Ecological footprint of battery production

- Better understand user-range interaction
  - Can users adapt to limited range?

Bühler, F., Cocron, P., Neumann, I., Franke, T., & Krems, J. F. (2014a). Is EV experience related to EV acceptance? Results from a German field study. *Transportation Research Part F: Traffic Psychology, 25*, 85-90.

EV field trials – data basis

MINI E Berlin 1.0 & 2.0 field trials (2008-2011)

- *N* = 110 private users, 6 months BEV use
  – (>100 fleet users, >40 carsharing users)
- Urban mobility (⌀ 38 km/day)
- BEV: MINI E, around 160 km range

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BMW ActiveE Leipzig – long-distance commuter field trial (2012-2015)

- *N* = 75 private users, 3 months BEV use
- Commuter mobility (⌀ 94 km/day)
- BEV: BMW ActiveE, around 130-160 km range
- *Preliminary data (max. N = 60)*

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Stadtwerke Leipzig

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

schaufenster elektromobilität

Eine Initiative der Bundesregierung

BAYERN – SACHSEN ELEKTROMOBILITÄT VERBINDET

Longitudinal research designs:

- **T0**: before EV experience, **T1**: with EV experience

Can user adapt to limited range?

- **Drivers adapt to EV range…**
  - Increase in comfortable range & perceived fit of mobility resources vs. needs (Franke et al., 2012b; Franke et al., 2014b)
- **How long does it take?**
  - Urban mobility profile (⌀ 38 km/day): ≈ 2400 km (62 car usage days) (Pichelmann et al., 2013)
  - Commuter mobility (⌀ 94 km/day): comfortable range stable after >6 weeks usage (Franke et al., 2014b)
- However: Adaptation does **not** come **automatically** (without effort)
  - Users who **+** actively explore and exhaust range = **+** improvement in comfortable range (Franke et al., 2012b)
  - Users who **+** actively try to understand range dynamics = **+** increase in range prediction skills (Franke et al., 2014a)
- **Implications:**
  - Practical experience is crucial for EV acceptance & resolving perceived range barrier
  - Potential to increase speed & effectiveness of adaptation ➔ gamification

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Franke, T., Cocron, P., Bühler, F., Neumann, I., & Krems, J.F. (2012b). Adapting to the range of an electric vehicle: …. In … *Proceed. of HCD-ITS 2012.*
Franke, T., Günther, M., Trantow, M., Krems, J.F., Vilimek, R., & Keinath, A. (2014a). Examining user-range interaction …. In … *Proceed. of AHFE 2014.*
Franke, T., Günther, M., Trantow, M., Rauh, N., & Krems, J.F. (2014b). The range comfort zone of electric vehicle …. In … *Proceed. of HCD-ITS 2014.*
Pichelmann, S., Franke, T., & Krems, J. F. (2013). The Timeframe of Adaptation to Electric Vehicle Range. In … *LNCS 8005*.

Do users experience range anxiety?

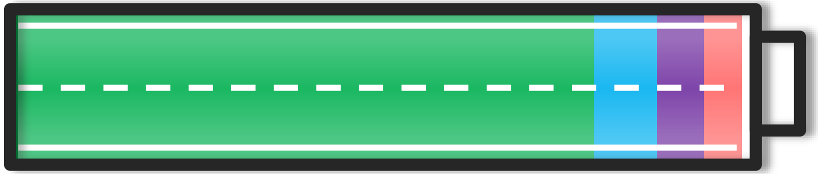
After adaptation phase (T1):

- Relatively high **range satisfaction:** most users experience range as sufficient
  - Urban mobility (⌀ 38 km/day): ≈ 90% (Franke et al., 2012a; Franke & Krems, 2013a)
  - Long distance commuters (⌀ 94 km/day): ≈ 79%
- Stressful range situations (**range anxiety**) occur **seldom**
  - Urban: ≈ 1 stressful range situation per month (Franke et al., 2012a; Franke & Krems, 2013a)
  - Commuters: ≈ 2.4 stressful range situations per month (Franke et al., 2014a)
- Users avoid range stress ➔ **range comfort zone**
- **Implications:**
  - Range anxiety not adequate to characterize everyday range experience
  - Comfortable range better accounts for user experience and behavior
    - □Relevant **benchmark variable** to optimize electric mobility systems

Franke, T., Neumann, I., Bühler, F., Cocron, P., & Krems, J.F. (2012a). Experiencing range in an electric vehicle …. *Applied Psychology, 61*(3), 368-391.
Franke, T., & Krems, J.F. (2013a). Interacting with limited mobility resources … . *Transportation Research Part A: Policy and Practice, 48,* 109-122.
Franke, T., Günther, M., Trantow, M., Krems, J.F., Vilimek, R., & Keinath, A. (2014a). Examining user-range interaction in battery electric vehicles – a field study approach. In T. Ahram, W. Karwowski, & T. Marek (Eds.) *Proceedings of AHFE 2014, Krakow, Poland.*

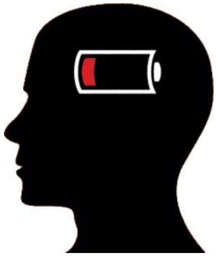
Which factors lead to a higher comfortable range?

- Technical | competent | performant | comfortable range



- + Comfortable Range = + range satisfaction (Franke & Krems, 2013a)

- Higher usable range if… (Franke et al. 2012a; Franke & Krems, 2013a)
  - Users can subjectively control & predict range resources
  - Prior knowledge & daily range practice
  - Certain personality characteristics



Implications:

- Increase controllability of range resources – range elasticity & safety options
- Reliability of range estimation & recharging opportunities – trust is important

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What is the optimal range? (Franke & Krems, 2013c)

- Range preferences (RP) decrease with experience
- RP > average daily distance
- RP ≈ maximum daily distance in typical week
- Objective range needs predict RP at T1 (not T0)

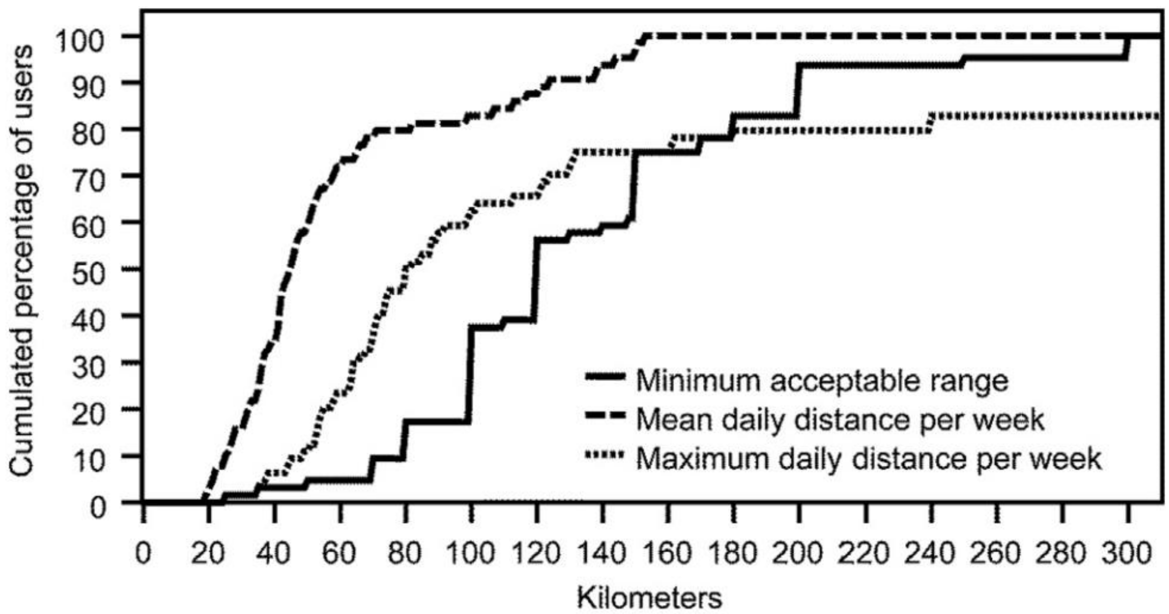

Fig. 1. Cumulative distributions of M_{7D} and Max_{7D} and T1 minimum acceptable range ($N=64$).

Implications:

- Potential customers with EV experience do not request exaggerated range setups
- “Simulate” experience? Mobility logging & informative feedback
  – Yet: quality of simulation & feedback very important (trust)

Franke, T., & Krems, J. F. (2013c). What drives range preferences in electric vehicle users? *Transport Policy, 30,* 56-62.

Does it also work without charging at home?

- **Matched samples** from MINI E Berlin studies, N = 36 (Bühler et al., 2014b)
  - Matched according to charging needs (daily distance), age, gender, ...
  - **Home chargers** (HC): home-based charging station
  - **Public chargers** (PC): no charging opportunity at home, > 85% public charging, public charging station in walking distance of home/work
- **Results:**
  - Charging frequency: **HC** = 3.4 events/week *versus* **PC** = 2.0 events/week
  - After adaptation no significant differences in…
    - … perception of EVs (both positive), perceived usefulness & satisfaction
    - … willingness to recommend & purchase intentions
- **Implication:**
  - Electric mobility also feasible with only public charging

Can we easily get green energy into batteries?

Renewable (green) energy as **prerequisite** for sustainable electric mobility

- When is energy "green"? – Excess energy from renewable sources (e.g., wind-to-vehicle, W2V)

Does this come automatically? (Franke & Krems, 2013b)

- MINI E Berlin 1.0: W2V system shifted energy input to "green windows"
- Users develop different charging routines ("**charging styles**")
  - Charging when necessary vs. charging when opportunity
  - Charging style is related to W2V efficiency
- **Incentive mechanism necessary** for +W2V efficiency
  - Gamification (money is not the only way)
- Project: Managed Charging V3.0
  - Field test of incentive mechanisms for intelligent charging

Franke, T., & Krems, J. F. (2013b). Understanding charging behaviour of electric vehicle users. *Transportation Research Part F: Traffic Psychology and Behaviour, 21*, 75-89.

Summing up

- **E-Mobility** already **works** in its current stage of development
- However: **psychological barriers** have to be addressed
- Perceived range barrier can be overcome by **practice** in dealing with range
  - However: support of adaptation process ➔ gamification
  - Maybe helpful: simulation of EV mobility
- Available **safety options** can increase controllability of range = + comfortable range
  - Reliability is crucial – e.g. public charging with reservation
- **Battery development**: reduce vehicle price or increase battery range?
  - Users can adapt to limited range ➔ rather reduce vehicles costs
  - High variance in preferences & mobility needs ➔ different battery sizes
- **Environmental benefit** of EVs is strongly dependent on the **user factor** (Franke et al., 2012c)

Franke, T., Bühler, F., Cocron, P., Neumann, I., & Krems, J.F. (2012c). Enhancing sustainability of electric vehicles: A field study approach to understanding user acceptance and behavior. In Sullman, M., Dorn. L. (Eds.). *Advances in Traffic Psychology* (p. 295-306). Farnham, UK: Ashgate.

Thanks a lot for your attention!

Contact: **thomas.franke@psychologie.tu-chemnitz.de**

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References

Bühler, F., Cocron, P., Neumann, I., Franke, T., & Krems, J. F. (2014a). Is EV experience related to EV acceptance? Results from a German field study. *Transportation Research Part F: Traffic Psychology, 25*, 85-90.

Bühler, F., Franke, T., Schleinitz, K., Cocron, P., Neumann, I., Ischebeck, M., & Krems, J. F. (2014b). Driving an EV with no opportunity to charge at home - is this acceptable?, In: D. de Waard, K. Brookhuis, …, & A. Toffetti (Eds.), *Proceedings of the Human Factors and Ergonomics Society Europe Chapter 2013 Annual Conference.*

Cocron, P., Bühler, F., Neumann, I., Franke, T., Krems, J.F., Schwalm, M., & Keinath, A. (2011). Methods of evaluating electric vehicles from a user's perspective - the MINI E field trial in Berlin. *IET Intelligent Transport Systems*, *5*(2), 127-133.

Franke, T., Neumann, I., Bühler, F., Cocron, P., & Krems, J.F. (2012a). Experiencing range in an electric vehicle - understanding psychological barriers. *Applied Psychology: An International Review, 61*(3), 368-391.

Franke, T., Cocron, P., Bühler, F., Neumann, I., & Krems, J.F. (2012b). Adapting to the range of an electric vehicle: the relation of experience to subjectively available mobility resources. In Valero Mora, P., Pace, J.F., Mendoza, L. (Eds.). *Proceedings of the European Conference on Human Centred Design for Intelligent Transport Systems 2012, Valencia, Spain*. Lyon, France: Humanist Publications.

Franke, T., Bühler, F., Cocron, P., Neumann, I., & Krems, J.F. (2012c). Enhancing sustainability of electric vehicles: A field study approach to understanding user acceptance and behavior. In Sullman, M., Dorn. L. (Eds.). *Advances in Traffic Psychology* (p. 295-306). Farnham, UK: Ashgate.

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Franke, T., Günther, M., Trantow, M., Krems, J.F., Vilimek, R., & Keinath, A. (2014a). Examining user-range interaction in battery electric vehicles - a field study approach. In T. Ahram, W. Karwowski, & T. Marek (Eds.) *Proceedings of the 5th international conference on applied human factors and ergonomics AHFE 2014, Krakow, Poland.*

Franke, T., Günther, M., Trantow, M., Rauh, N., & Krems, J.F. (2014b). The range comfort zone of electric vehicle users – concept and assessment. In Risser, R., Pauzié, A., Mendoza, L. (Eds.), *Proceedings of the European Conference on Human Centred Design for Intelligent Transport Systems 2014, Vienna, Austria.* Lyon, France: Humanist Publications.

Pichelmann, S., Franke, T., & Krems, J. F. (2013). The Timeframe of Adaptation to Electric Vehicle Range. In M. Kurosu (Ed.). *Human-Computer Interaction. Applications and Services, LNCS 8005* (pp. 612-620). Berlin, Germany: Springer.