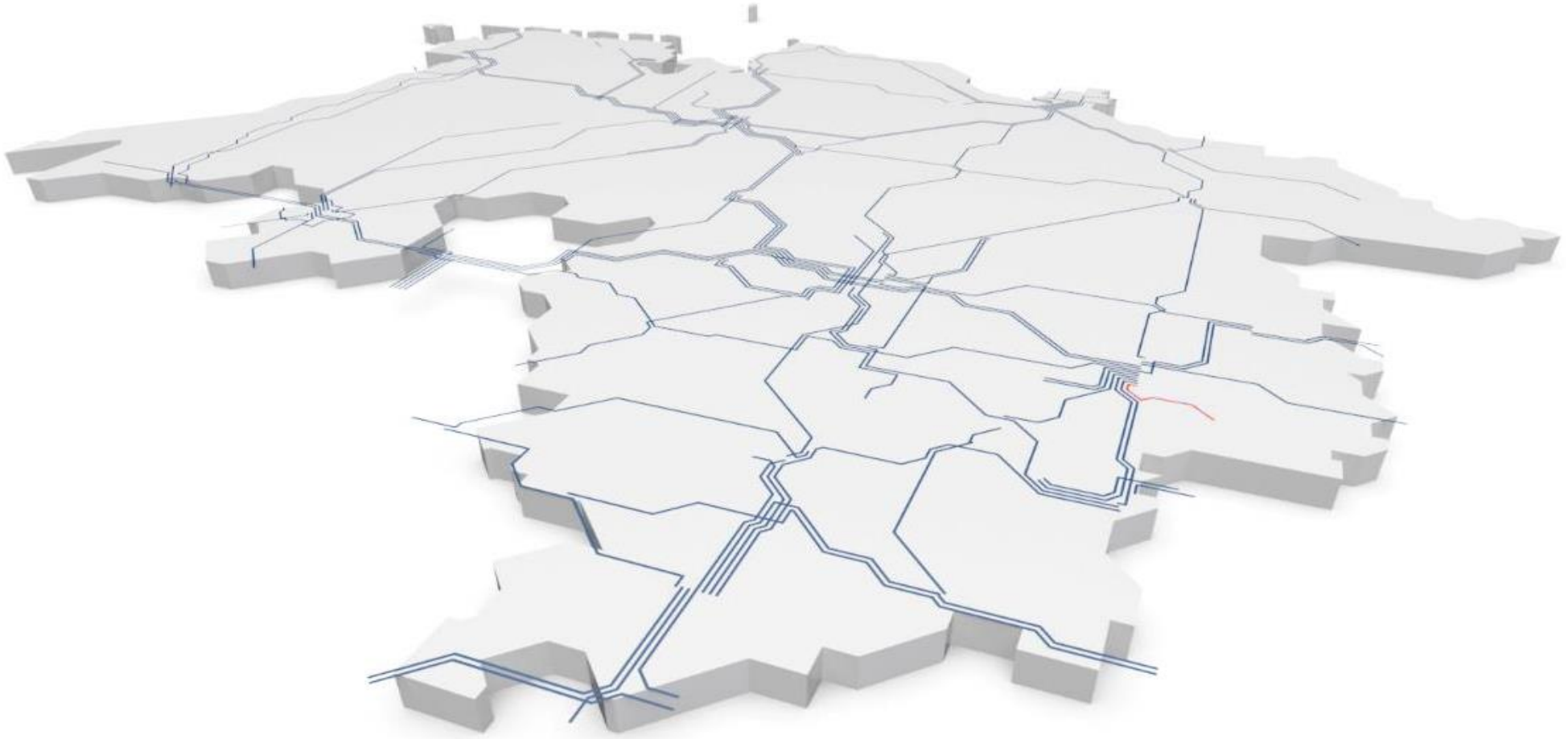

„Train driving by tablet“

Performance and usability testing of a tablet based train remote control

6th German Conference on Rail Human Factors 2025 – 18th/19th January 2025
Justin Adam (TUB) Anja Naumann (DLR)

Finanziert von der Europäischen Union NextGenerationEU

Gefördert durch: Bundesministerium für Wirtschaft und Klimaschutz aufgrund eines Beschlusses des Deutschen Bundestages

What is ARTE?

- Joined Research Project:
  - Alstom (Transport & Signalling)
  - German Aerospace Center (DLR)
  - Technische Universität Berlin (TUB)
- Funding:
  - Federal Ministry for Economic Affairs and Climat Action (BMWK)
  - Federal Governmant of Lower Saxony
- Research Scope:
  - GoA 3/4 Operation under state of the art signalling
  - Operational / Technical Analysis
  - Development and Testing of
    - Automatic Train Operation (ATO)
    - Obstacle Detection System (ODS)
    - Signal Detection System (SDS)
    - Remote Train Operation (RTO)
  - Planning for future GoA 3/4 Operation

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Researching Remote Train Operation at ARTE

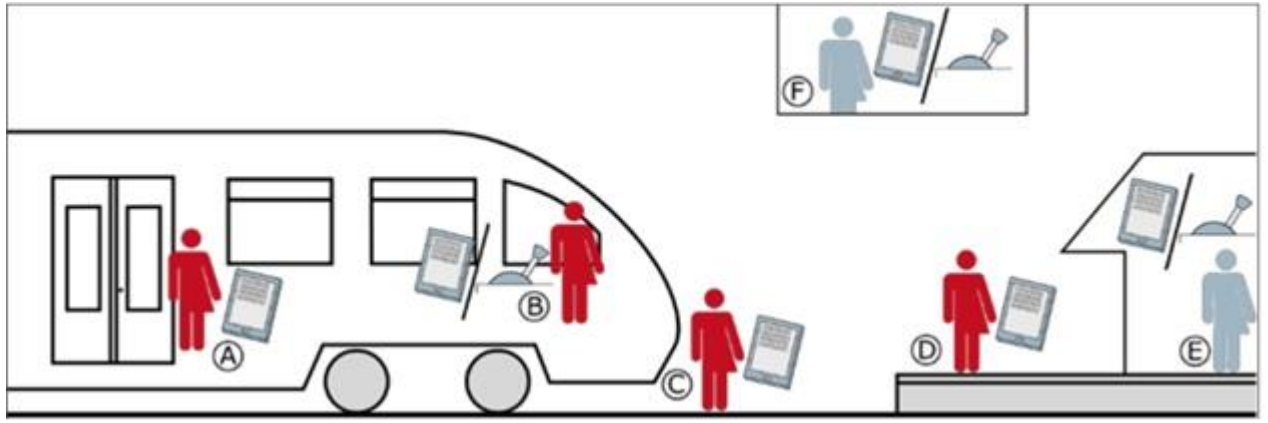
Research Scope

- Operational Settings, Rules, Surroundings
- Development of new job profiles:
  - Remote Operator
  - Train Attendant Plus
- Development and Testing of a tablet based Remote Train Control
  - Remote Operation by future Remote Operators and Train Attendants
  - Operation from within, nearby the train or from control room
  - Wideangle and Tele Videostreams from the cab
  - Operation by touch control on the tablet

Why choose a tablet for remote control?

Mobile Control Solution for different situations

- ARTE aims at full ATO Operation
  - RTO is fallback or maintenance mode only (seldom use)
- “classic” fully equipped control room remote operation workplace already developed
  - Unsuitable for operation within or nearby the train
- Movability and Flexibility – variety of use cases
  - Operation on/at the train
  - Operation from the control room
  - Shunting
  - Maintenance / Depot Service



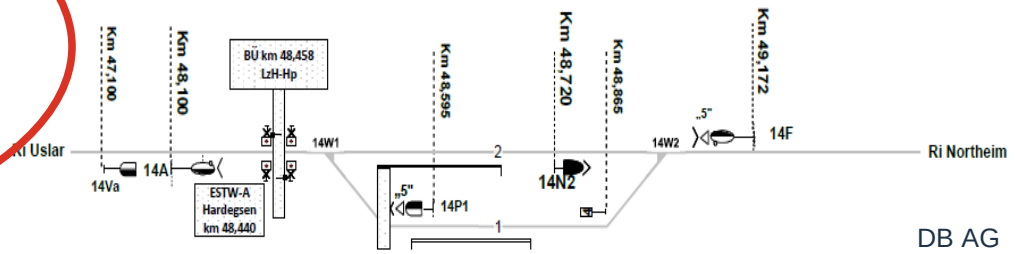
Adebahr, Milius, Naumann (2023) Flexible Arbeitsumgebungen für die ATO-Rückfallebene, EI (1/23).

Testing within ARTE

- 1. Testing on Model railway
  - Relatively easy Setup
  - Room for various Settings, Tests
  - Only remote operation from control room
- 2. Testing on Alstom Test Track
  - Remote Operation from all working positions
  - Test Track fully available at 8 hour
  - Short Track (1.200m), no Signals
- 3. Testing on public infrastructure
  - Highly realistic
  - Long Distance Driving
  - Fully Signalling
  - Available at limited and short periods only
  - Northeim – Bodenfelde line

DLR

DLR



DB AG

Evaluation einer Zugfernsteuerung mit Tablet im Modellbahnaufbau
https://elib.dlr.de/201328/1/EI_ARTE_Naumann_etal_12_23.pdf

Entwicklung und Realerprobung einer Steuerung über Tablet für Remote Train Control
https://srss.bbi-berlin.com/pages/programm.php

RTO-Erprobung im Spannungsfeld zwischen Testmethodik und Safety
https://eurailpress-archiv.de/SingleView.aspx?show=11063471

Test 3 on public infrastructure

Goals and Methods

Research Goals

- Driving Performance
  - Driving at an exact speed
  - Stopping at an exact point
  - Detection and Reaction to Signals
- Usability of Tablet Remote Control
  - Size of Control and Video
  - Information displayed
- Learnability of tablet functions

Methods

- Pre-test questionnaire
  - Knowledge, Experience, Attitudes on Technology, Remote Control, Rail Operation
  - Self Assessment of expected Performance
- Instructor questionnaire
  - Observing Speed and Operations
  - Observing Usage of Tablet (working positions, view/glance behauvior)
  - Noting Questions, Comments etc.
- Post-test questionnaire
  - Control, Informations, Video, Experience
  - Usability (SUS), Acceptance (van der Laan), Experience (UEQ)
  - Simulator Sickness
- Post-test interview

Test 3 on public infrastructure

Test Design and Procedures

- Information
  - Only Participants with valid medical testing (G25)
  - Only Participants from jobs within rail sector (drivers, attendants, etc.)
  - Written Information on Operational Procedures and Remote Control Manual
  - 1 hour online information lecture on testing procedure and safety
- Introduction
  - Participants picked-up at Northeim station
  - Repeated Information on test procedure
  - Consent, Pre-test questionnaire
- Driving task
  - 1st run from cab, direct view on track possible
  - 2nd run from passenger area, no direct view on track, within train
  - Start at standstill, end at standstill
- Post-test questionnaire and interview

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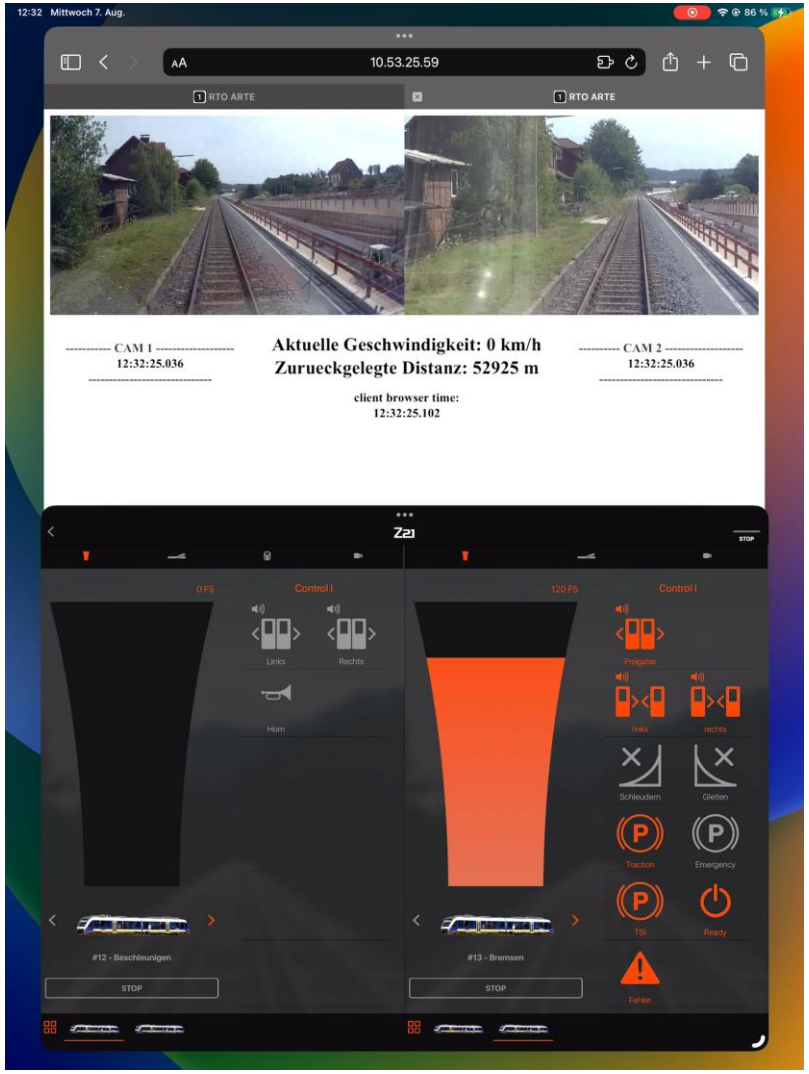
Test 3 on public infrastructure

Start of trial – Video presentation

- Non intrusive remote screen capture
- Maximum Speed 40 km/h
- Different viewing angles
  - Left side: Wideangle
  - Right side: Televiewv
  - Note perception of Speed
  - Note visibility of Signs / Signals / objects near and far



Video Screen Recording by TU Berlin
unavailable in pdf version

Results

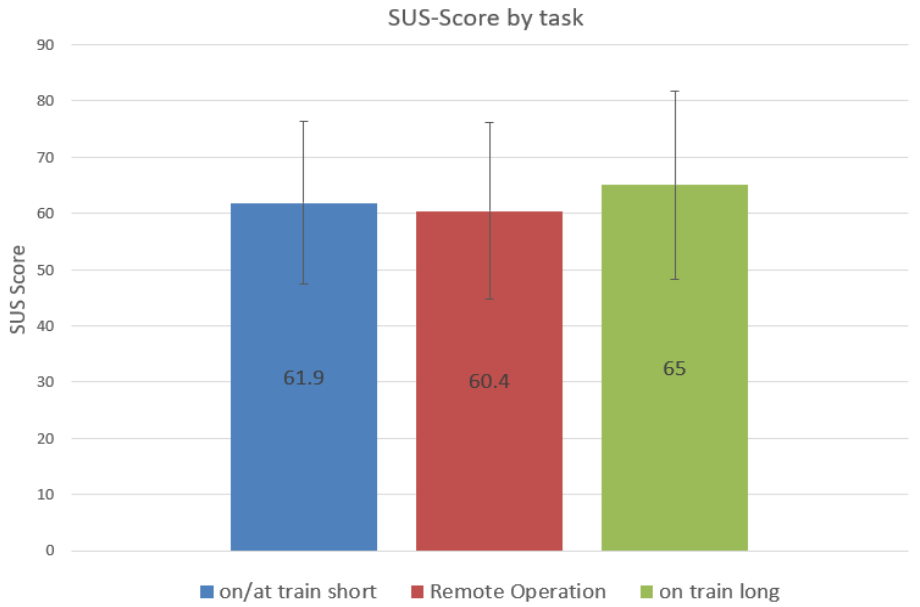
Participants

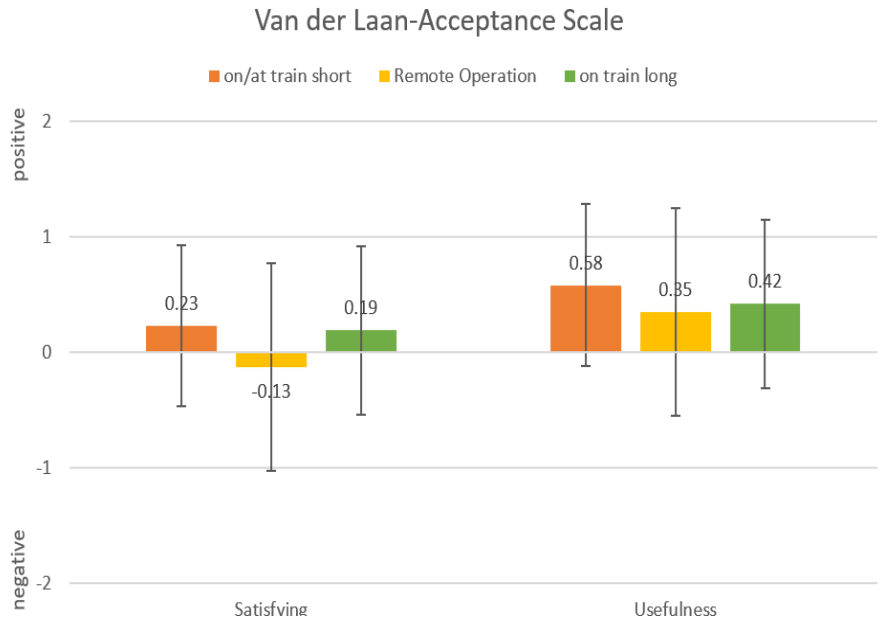
- *n*=10
- age (years) *M*=34.9
- 8x train driver, 2x train attendants
- Job experience (years) *M*=12 (*SD*=9 high deviation!)
- TeiSEL affinity towards technology: above average population (voluntary participation)
- Self Rated Knowledge
  - Northeim-Bodenfelde line 5x little/non (only pre information), 4x little, 1x average
  - specific train (LINT41) 6x non, 2x little, 1x average, 1x good
  - Railway Operation (Scale 1-7) *M*=5.3, *SD*=1.5
  - Train Driving (Scale 1-7) *M*=5.0, *SD*=1.79 (train attendants rated lower than train drivers)
  - Remote Control (Railway, Drones etc.) 5x Yes, 5x No
- Self Rated Multi-Tasking ability (Scale 1-7) *M*=5.5, *SD*=1.0
- Expected Driving Task Performance: (Scale 1-7) *M* =4.5, *SD*=0.8

Results

Usabilty, Acceptance, User Experience

- System Usability Score - SUS
  - average to good usability
- Van der Lan Score - VDL
  - System is viewed as useful
  - System needs improvement for acceptance
- Interview:
  - Driving experience is comparable
  - Concept of remote driving is remarked positively
  - Observing of camera and control rated as exhausting





Results

Driving Performance

- Self rated performance better than expected
  - Recognition of Signals: Cab *M=4.1 SD= 2.3* *passenger area* *M=3.9 SD=2.0*
  - Correct Speed: Cab *M=5.1 SD= 1.6* *passenger area* *M=5.2 SD=1.2*
  - Stopping at correct position: Cab *M=5.7 SD= 1.9* *passenger area* *M=5.9 SD=1.0*
- Considerate driving
  - Acceleration: 2x slow/safe, 14x average, 4x strong/fast
  - 12x exact speed within +/- 5km/h
  - 8x exact speed seldomly too slow (below -5 km/h)
  - Adaption to gradiant needed → participants found sweet spot of power
  - Rather thougtful and safe behauvior observed
- Exact Stopping at staions
  - 16 trials with deviation below +/- 5m
  - 4 trials with deviation above +/- 5m
  - Results in line with earlier findings on Alstom test track (average +/- 4m)

Results

Ergonomics and Gaze / View Behauviour

- Ergonomics
  - Hold by both hands, control by thumb
  - Hold by one hand, control by index finger
- Tablet often lent against objects
  - Interview: tablet rated as too heavy
- Gaze / View Behauvior:
  - Participants used outside view (both positions) (11 of 20)
  - Looked on their fingers during control operation (13 of 20)
- Motion sickness
  - 1 of 10 persons → important future criteria

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Results

Video

- Video Size
  - All participants found Video too small
  - 60% found it too small to give sufficient situational overview
  - 50% mentioned difficulties in reading signals
  - All participants found tablet size to be good
- Preference for Angle of view: 60% Tele, 30% None, 10% Wide
  - Tele was preferred for: realistic feeling of speed, more details, reading signals
- Video Quality (rated by school ratings from 1-6)
  - Colour Contrast: 3.8
  - Brightness Contrast: 2.8
  - Sharpness: 2.4
  - Brightness: 2.3
  - Non-laggy Video: 3.0
  - Non-pixelated Video: 3.1

Results

Design, Information, Interview Data

- Layout:
  - Combine acceleration and deceleration
  - Acceleration and Deceleration on each side with video and controls in the middle
- Enlarge Video, Improve Colour Contrast:
  - Idea: Allow for changing camera views
- Integrate status symbols of train controls
  - Brake status
  - Large Speedometer
- Include track side info
- Combine Tablet with haptic controllers
  - The idea of using a tablet was regarded well / not questioned

Iteration of remote control

HTML based layout

- Large speedometer
- Buttons round
- Status signs square
- One control lever
- Video stream:
  - Larger Video
  - High Latency indicator

Resumé

- ARTE project proved possibility of driving a train by tablet control
- A mobile device including Video and Controls is a possible future solution
- Further research of Video and Control Layout

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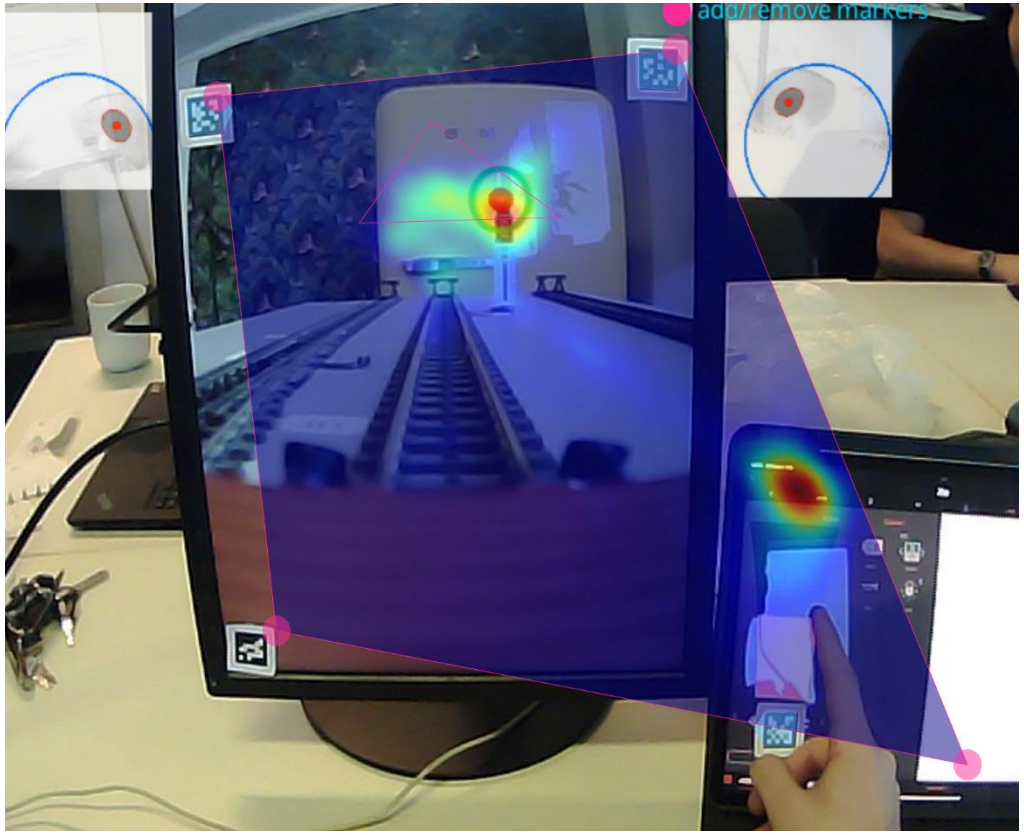
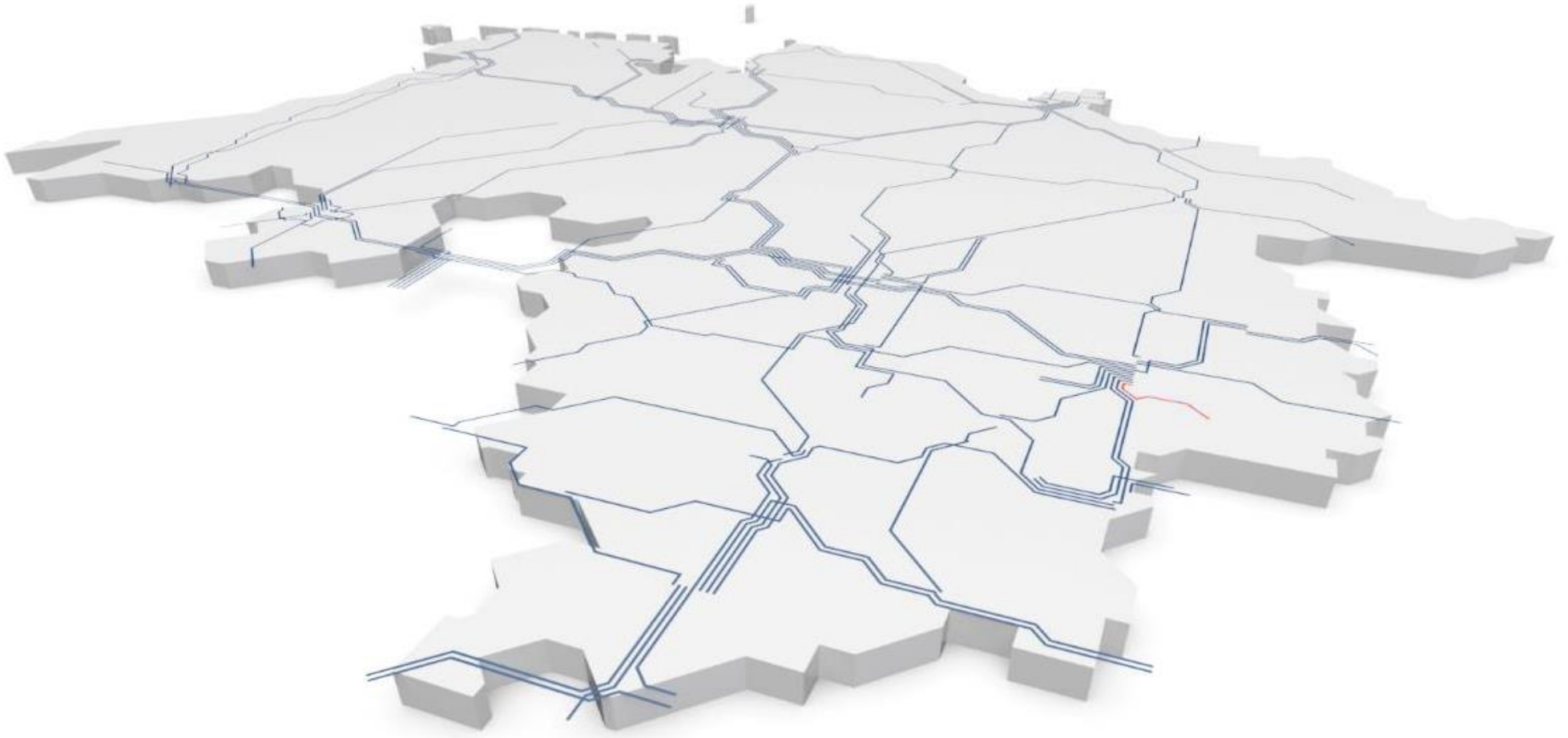
Further Discussion

Missing Haptic on Tablet Interfaces

- Do users need a haptic lever for tasks with competing areas of visual attention?
  - Tablet vs. real world
- Can a versatile and cost efficient tablet replace a proprietary control with levers and switches?





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