Technische Universität Berlin

Photo: Getty Images

Drive2theFuture

Remote driving options as a fallback system for automated trains

Baris Cogan, M.Sc.

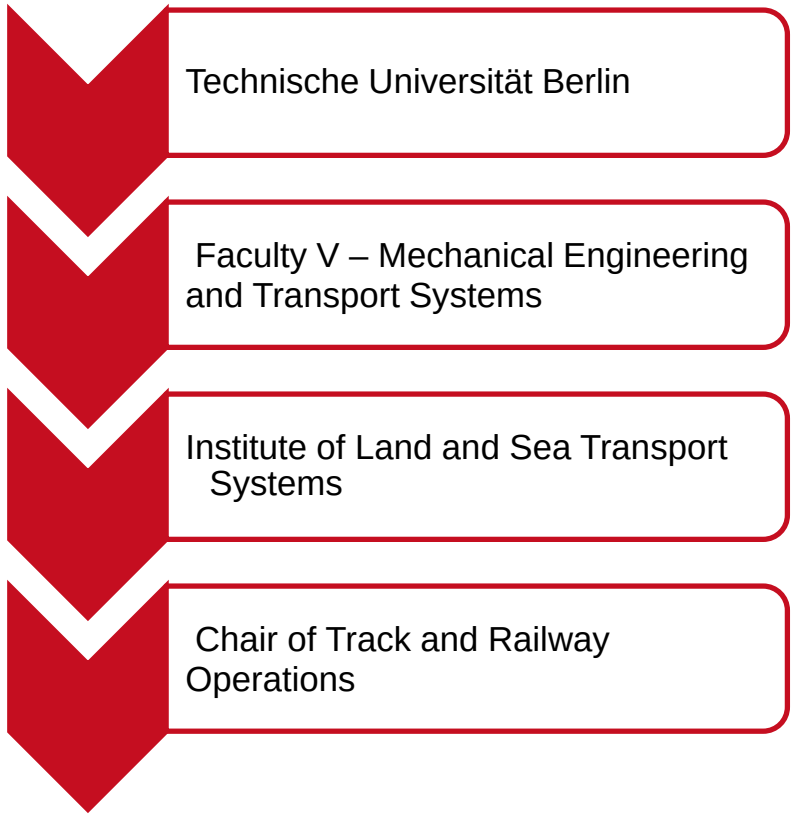
TU Berlin BBI

Acting head of department:

Prof. Dr.-Ing. Birgit Milius

Teaching and research:

- Infrastructure
- Operation
- Strategies

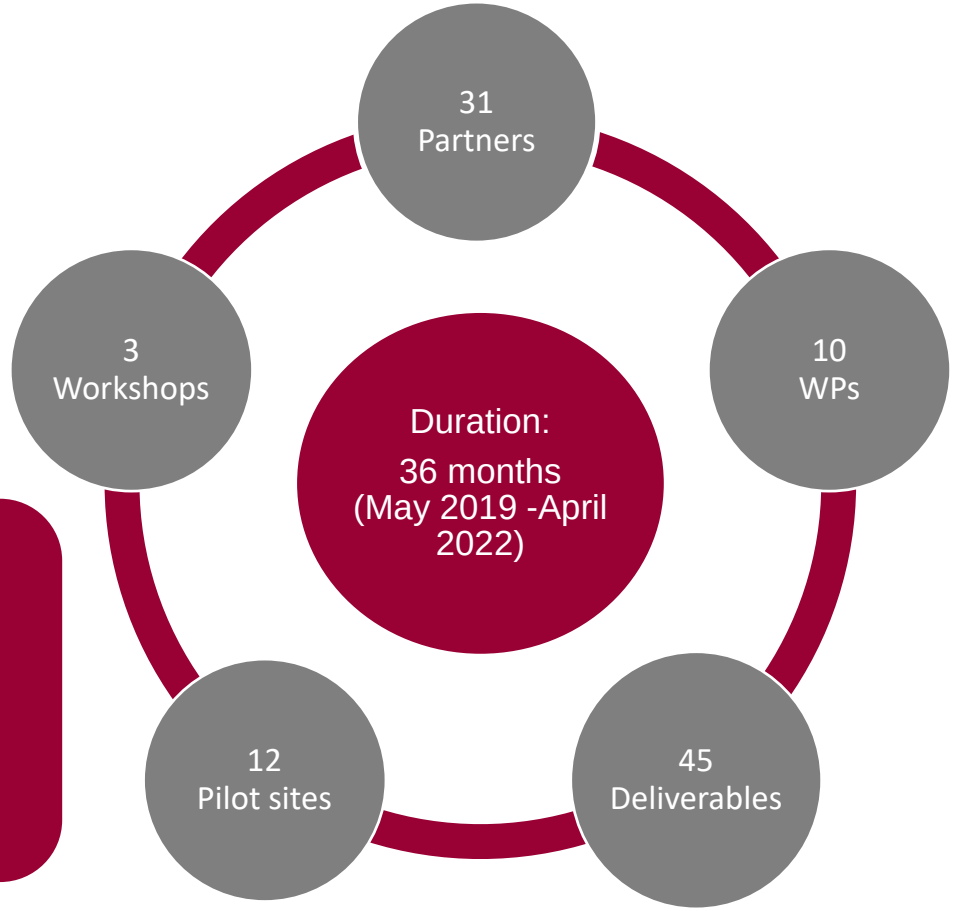


BACKGROUND

Drive2theFuture

All transport modes:

Road, Rail, Maritime, Air



To prepare “drivers”, passengers and vehicle operators of the future to accept and use connected, cooperative and automated transport modes and the industry of these technologies to understand and meet their needs and wants.

The train operator in a GoA3/4 environment

Typical workstation today

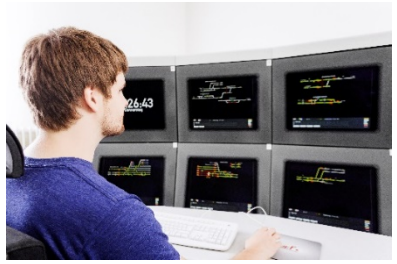


Image source: *Berlin Partner/M.Wüstenhagen and Getty Images*

- Conventional main line operation
- Manual/partial automation (GoA 0 – GoA 2)

Future workstation

Image source: *Pixabay*

- High Grade of Automation (GoA 3 – GoA 4)
- Additional tasks (i.e. remote supervision)

Aims of the pilot:

Designing and testing a new remote workstation as a fall-back system in case of automation failures in a realistic environment

- Learning lessons from existing GoA3/4 metro systems
- Identifying needs and requirements of future operators
- Testing simplistic solutions for a future workstation

METHODOLOGY

Pilot Study: Design Concept

- Benchmarking good practices (existing systems such as Nuremberg U-Bahn or research prototypes)
- Determining use cases
- Priori risk assesment: identifying potential issues and shortcomings
- Internal meetings-workshops

Vehicle & function	Feedback to user	Transition of control	HMI Elements	HMI design
RAIL				
RA-2: emergency remote control (Autonomous Mode) 5a	▪ **System mode:** automated mode, take over request ▪ **System status:** connected ▪ **Environment:** real-time front camera view ▪ **Route:** position, timetable etc.	1. Visual and auditory signal on the display for SBOs to take over 2. As soon as operator confirms manual takeover, real-time front-camera view on monitor turned on	▪ Display for outside front view of the train (track and signals) ▪ Signaller's monitors for related information such as position, timetable etc. ▪ Icons: system mode and state ▪ Cab controller: throttles and buttons for speed ▪ adjustment, start-stop, speed display  [37]	▪ rail driver device or generic look-alike cab interieur to steer and operate the train ▪ Red, flashing icon: Takeover request ▪ Green icon: connected ▪ Black icon: automated mode  [37]
U-Bahn Nuremberg: Project RUBIN (Autonomous Mode) 5b	▪ **System status:** ○ early alarm to control center in case of emergency ○ emergency call from passengers: video surveillance and speaking connection to control center ○ past events memory: footage 10 seconds before incident occurred ▪ **Environment:** automatic appearance of interrupted track section on control center screen	▪ daily test runs still operated by normal drivers ▪ manual control on train possible with emergency steering	▪ Displays for video surveillance and position tracking of trains ▪ Speaking connection from train to control center  [38]	▪ Schematic presentation of trains on separate "multivisionboards" (in real time) with different colors ▪ Emergency steering in the passenger compartment

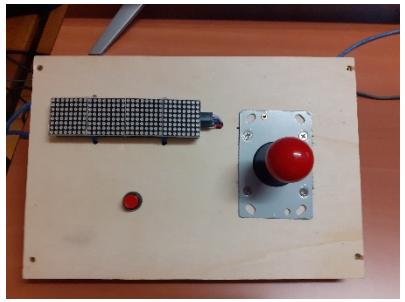
Pilot Study: Iterative User Testing

The remote driver

- An operator in a remote controlling center normally supervises the routine automated operation. The operator intervenes only in cases of disruption

Test set-up

- Real-time front view of the track ahead (SimMetro)
- Route: Berlin S-Bahn
- Steering devices
  - RailDriver (RD)
  - Joystick (JS)
- Information displays
  - Traction and brakeforce
  - Route map
  - Visual SiFa warning on LED display



JS

RD

Pilot Study: Test Scenario

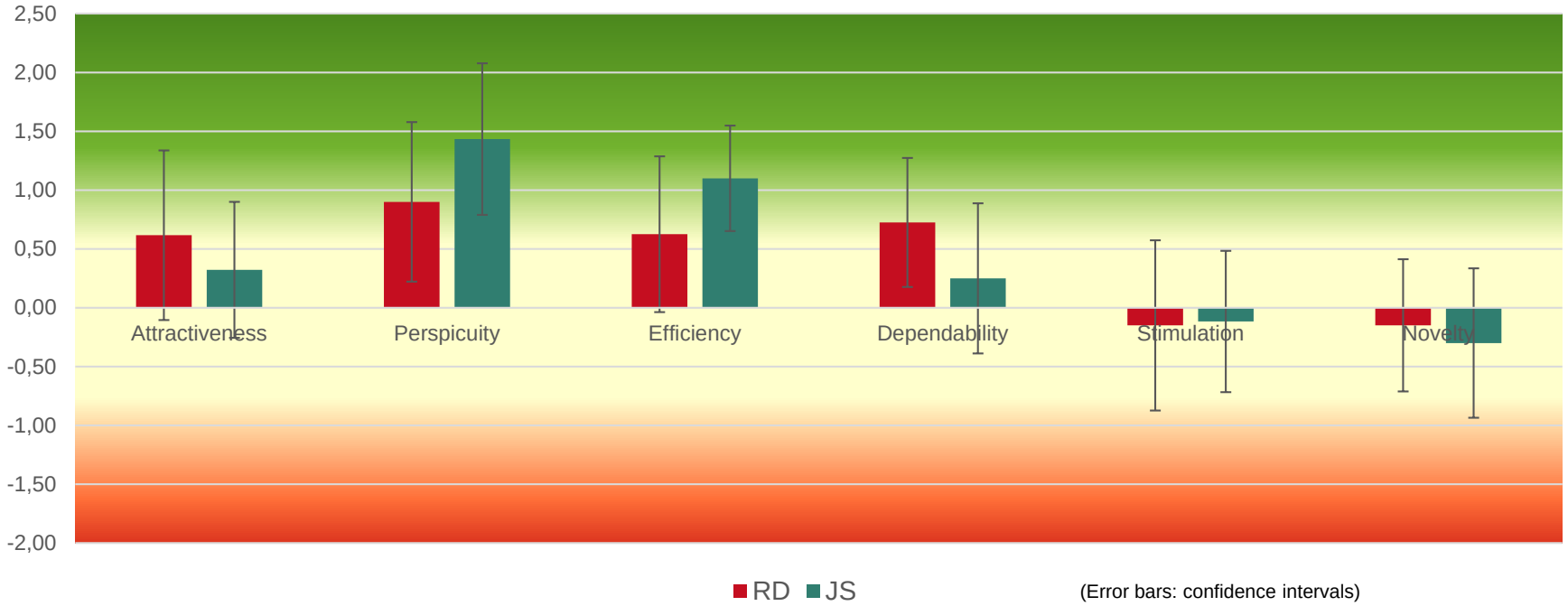
- **The tasks:**
  - Taking the manual control of the train. (Departure, on-sight driving and stop at the arrival station)
  - Driving the train until the predetermined location (approx. 9 km)
  - Attending to the deadman`s switch (button)
  - The allowed speed of 40 km/h throughout the ride
  - One ride with each controller; RailDriver (RD) and Joystick (JS)
- **The user groups:**
  - 12 students of the TUB railway department
  - Two user groups: RD and JS
- **The aims:**
  - Evaluating the user acceptance, user experience and mental workload of the train operator
  - Improving the HMI based on the user feedback and observations

Evaluation

- User experience:
  - UX Questionnaire
- Persuasive and affective HMI:
  - Persuasiveness scale (based on a 7-point scale adapted from Thomas et. al, 2019)
  - Quality, effectiveness, capability
- Measuring the emotion:
  - Self-assessment manikins (based on a 5-point scale Bradley and Lang, 1994)
  - Valence, arousal, dominance
- Mental workload:
  - Self-assessment workload scale (NASA-TLX by Hart and Staveland, 1988)
- Preference ratings of design elements:
  - HMI Questionnaire (-2 to +2 scale)
  - Monitor, control elements etc.
- General user feedbacks and expert observations

RESULTS

User Experience (UX)

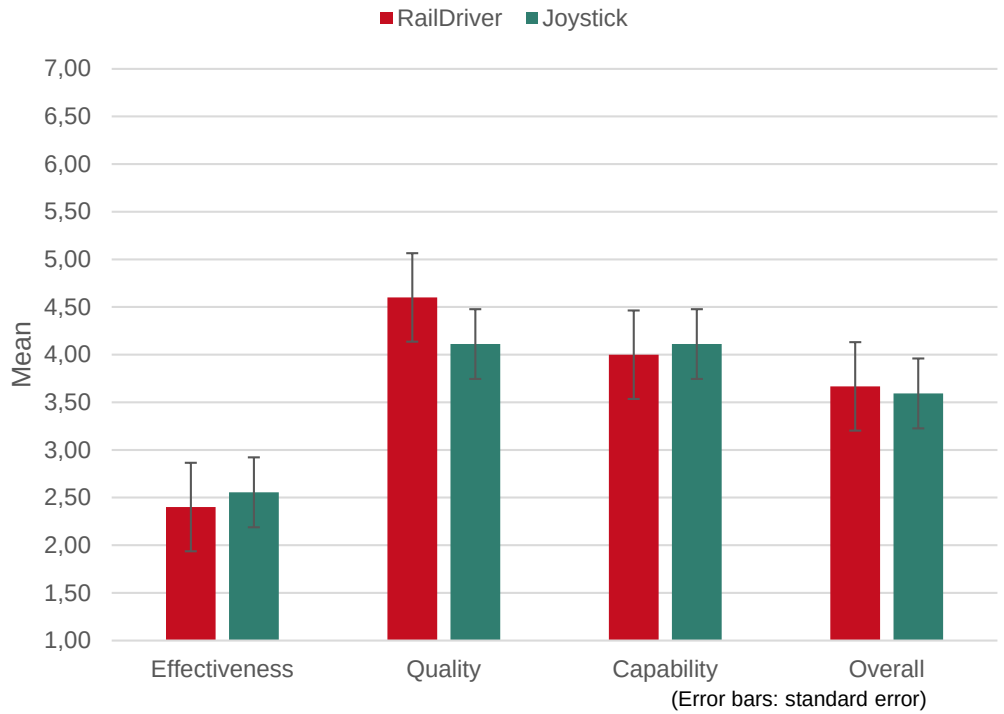


(Error bars: confidence intervals)

Guttmans Lambda2 (λ-2) scale relaibilty test		
Dimension	**λ-2 (JS)**	**λ-2 (RD)**
Attractiveness	0,93	0,93
Perspicuity	0,76	0,70
Efficiency	0,68	0,66
Dependability	0,77	0,78
Stimulation	0,83	0,85
Novelty	0,83	0,7

- Higher pragmatic quality (task related) compared to hedonic quality (non-task related) for both RD and JS (significant only for JS)
- No significant difference between RD and JS (p>0.05)

Persuasive and affective HMI



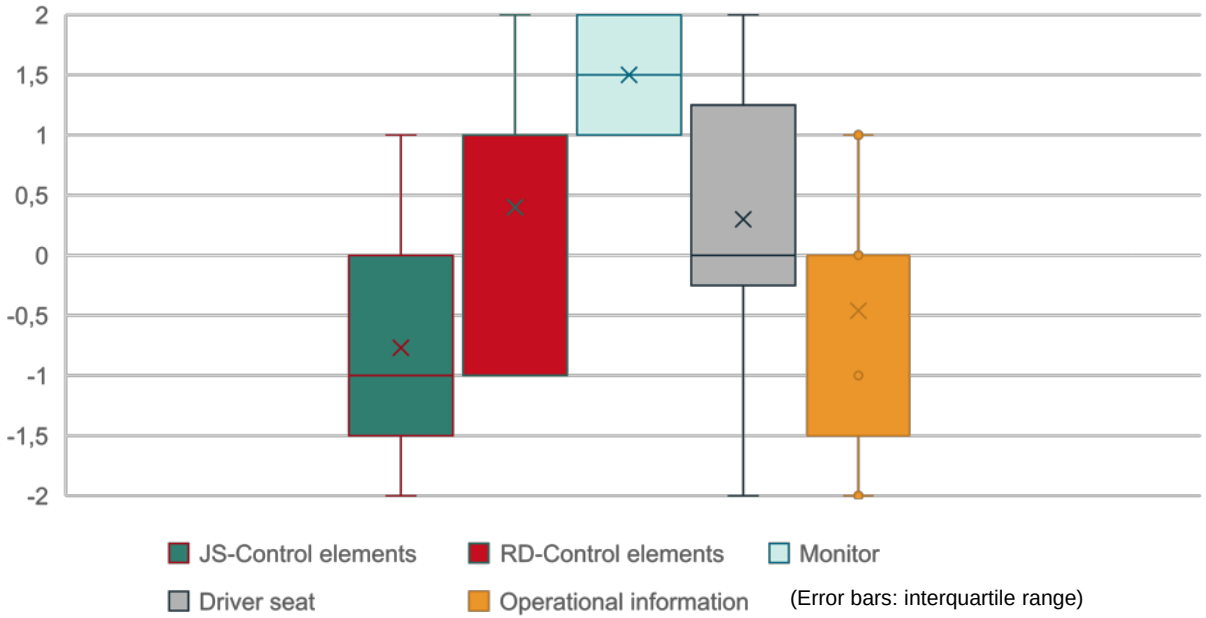
(Error bars: standard error)

Factors	Scale Items
Effectiveness	After viewing this system, I will make changes in my attitude towards automated technology.
Quality	This system is trustworthy.
Capability	This system has the potential to influence user behavior.
7-point Likert scale (Strongly disagree-strongly agree)	

(Adapted from Thomas et. al, 2019)

- The difference is not significant between RD and JS for each scale factors
- One way MANOVA showed no significant effect of different HMI systems on the factors

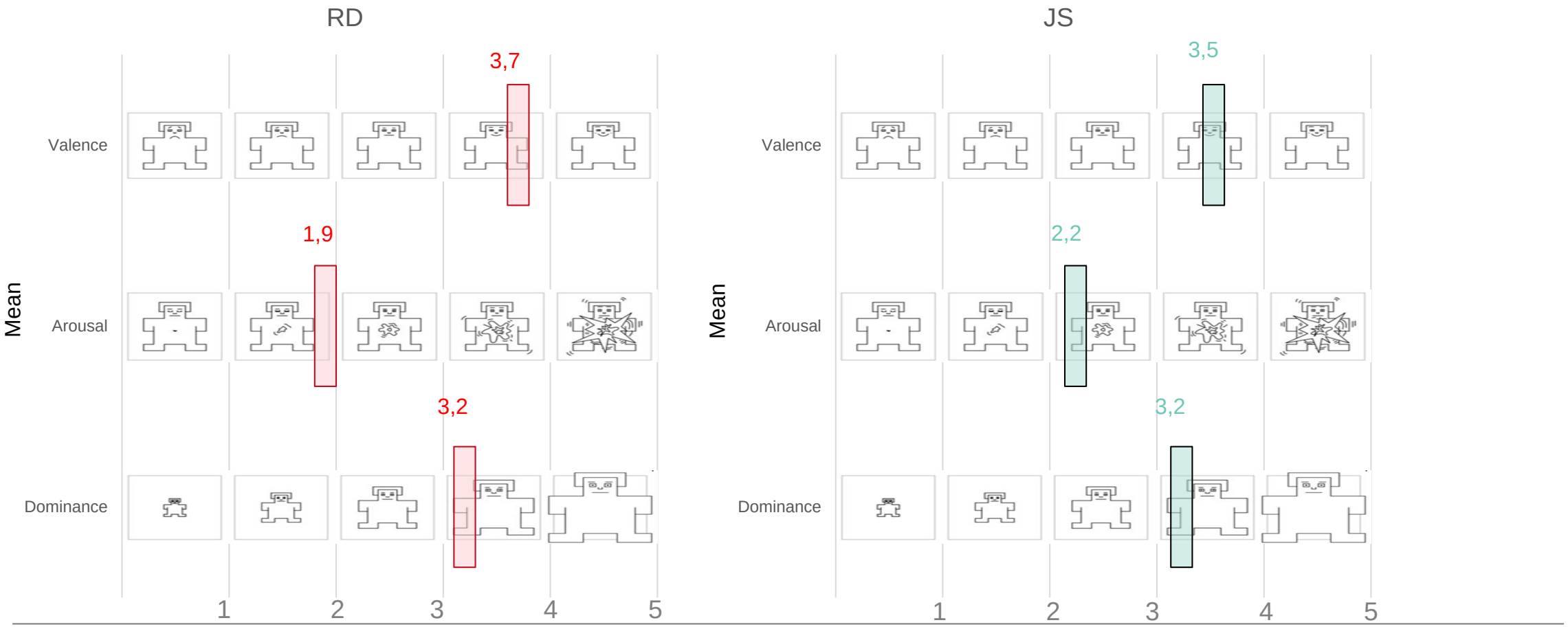
Design Elements and Additional Functionalities



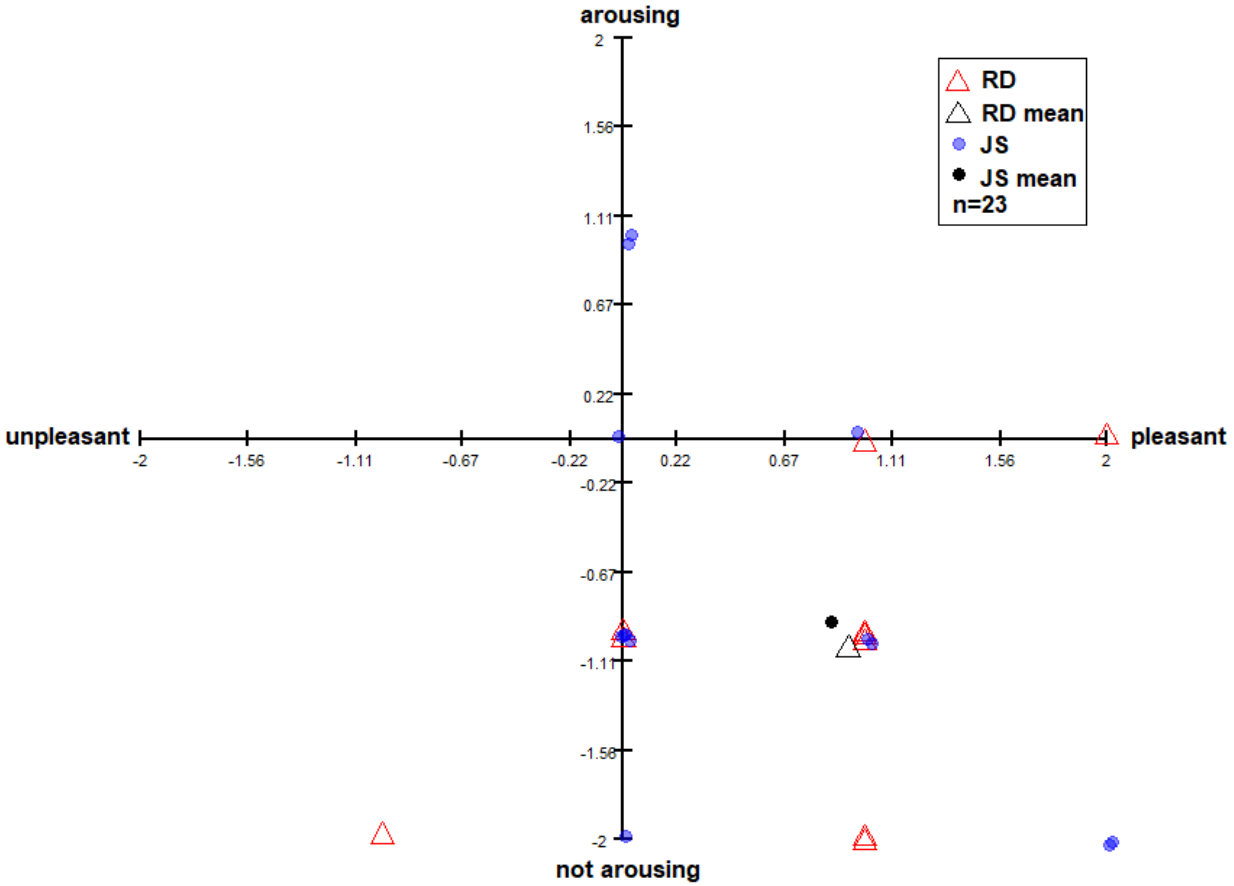
Additional functionality recommendations	Frequency
SiFa Sound	5
Speedometer on the front-view monitor	4
EBuLA	3
Sound from the train location	2

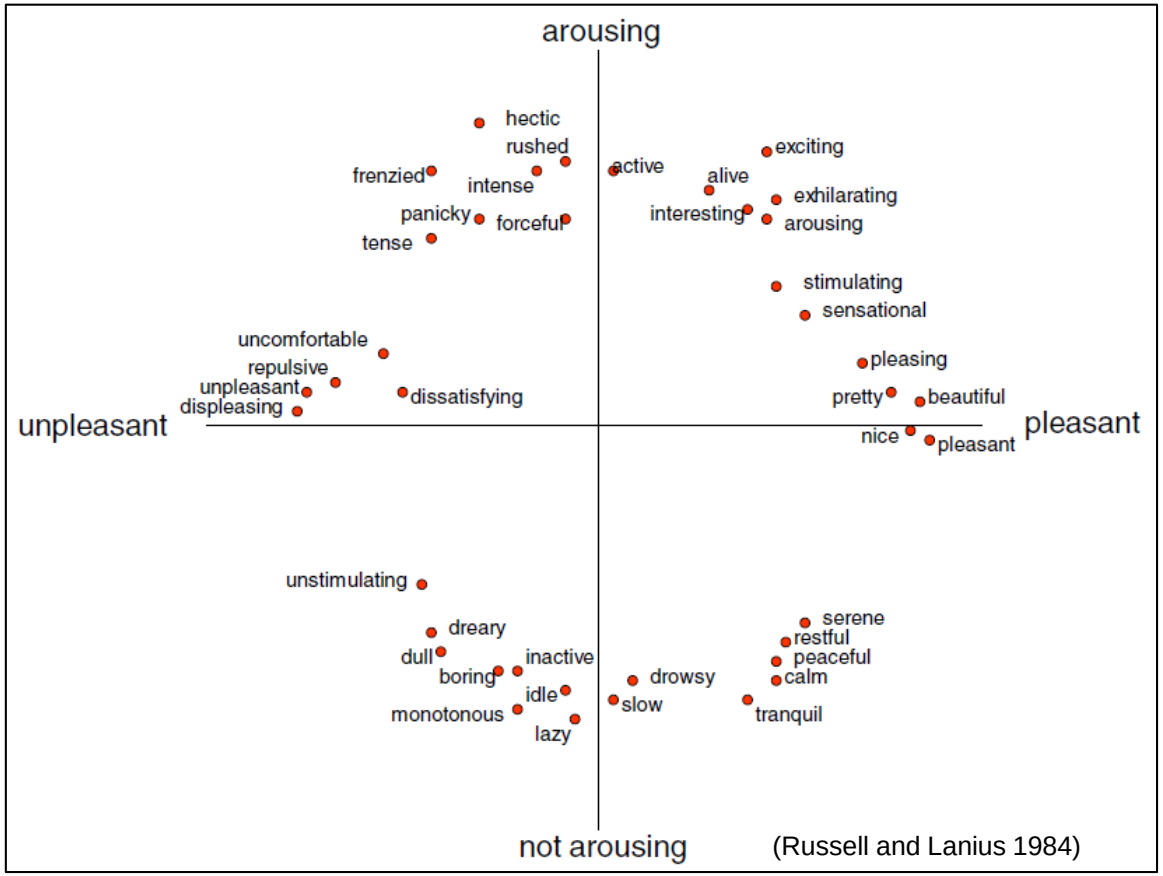
- Lower mean for JS-control elements (joystick and buttons) compared to RD (alfa=0.05, p<0.01, t=2.67)
- Ratings of JS-control elements differed significiantly from zero (alfa=0.05, p<0.01)
- Operational information is rated the lowest (p<0.05)

Self Assessment Manikin (5-point scale)



Measuring emotion: Arousal and pleasure as indicators of affect





(Russell and Lanius 1984)

Mental Workload (NASA-TLX)

NASA-TLX (unweighted)	Mean	Standard Deviation
RD	36,6	13,7
JS	41,8	15,6

- Low workload levels for both RD and JS during on-sight driving(significant compared to mean=50)
- No significant difference of workload between RD and JS (alfa=0.05, t=-0.12, p>0.05)

CONCLUSION

Main Findings

- Positive feedback on the overall system as a fallback solution
  - High task-related quality
  - The HMI elicits positive emotions regarding pleasure and dominance, but low arousal levels (not an immersing work environment)
- Low subjective workload for both RD and JS
  - Parallel with the low arousal findings
  - No significant difference between the rides with two different controllers
- No significant difference between RD and JS in terms of user experience, workload and HMI persusasiveness
  - Flexibility of hardware choice in future implementations
  - The RailDriver controller is preferred over Joystick based on the user preference ratings
- Subjects require/desire more operational information

Future steps

- Next pilot phase: user tests with train drivers and signallers
- Collecting objective performance measures
- Implementing additional functionalities (i.e. monitoring the routine operation, communication etc.) and other information sources (i.e. real time location on the route display)
- Impact of training on the user experience and performance

Poll

A short questionnaire of 4 questions to gather your opinions on:

- Use cases for remote driving
- User (operator) acceptance of the remote driving
- Tasks of the remote driver
- Training requirements of the remote driver

THANK YOU FOR YOUR ATTENTION!

Survey on the acceptance of automated vehicles:

http://www.drive2thefuture.eu/2020/01/28/welcome-to-our-survey/