

Effects of Video Quality on Perception and Reaction Time in Video-based Remote Train Control

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A large, high-resolution image of the Earth from space occupies the bottom right portion of the slide. It shows a curved horizon with a deep blue atmosphere, white cloud formations, and green landmasses. The text "Knowledge for Tomorrow" is overlaid on this image in a white, serif font.

Knowledge for Tomorrow

Railway Automation and it's Effect on the involved Staff

Subject Rationale

- Railway domain becomes increasingly aware of the central role of **railway automation (ATO)** to
 - increase **transport capacity** for persons and goods
 - while complying with **energy saving** goals on the **mainline**
- From a Human Factors perspective the most interesting part of it are the **fall back layers for automation failure** in intermediate and especially high grades of automation (GoA3-4)
 - In these cases the staff will encounter yet unknown terrain, but remain the decisive element
- In this context of high grades of automation **Remote Train Operation (RTO)** was proposed as a fall-back layer for automated and unstaffed rail vehicles ^[1]



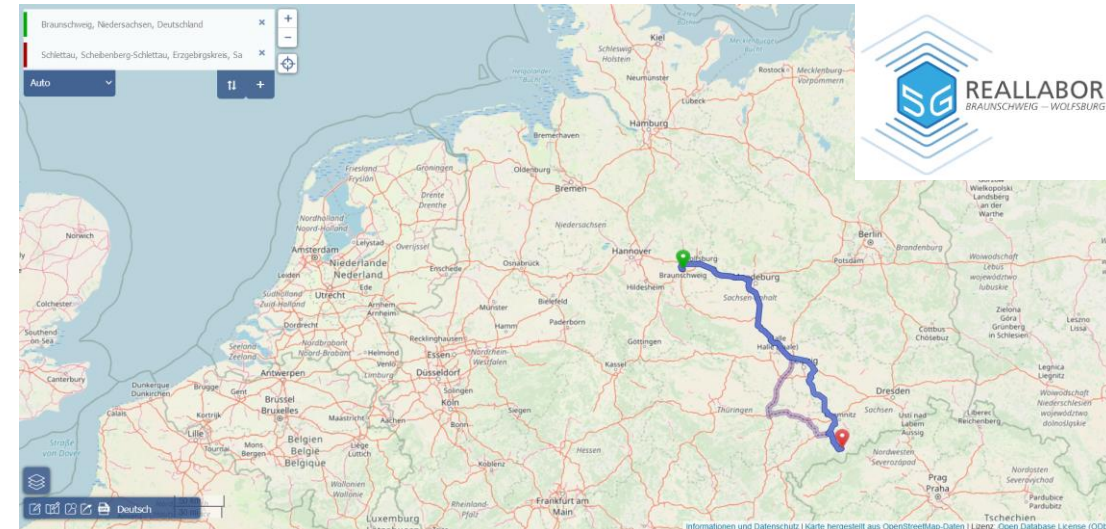
Grade of Automation	Type of train operation	Setting the train in motion	Stopping train	Door closure	Operation in event of Disruption
Grade of Automation 1	ATP with driver	Driver	Driver	Driver	Driver
Grade of Automation 2	ATP + ATO with driver	Automatic	Automatic	Driver	Driver
Grade of Automation 3	Driverless	Automatic	Automatic	Train attendant	Train attendant
Grade of Automation 4	Unattended train operation (UTO)	Automatic	Automatic	Automatic	Automatic

Adapted from: VDE (2015). *Railway applications - Urban guided transport management and command/control systems - Part 1: System principles and fundamental concepts*, IEC 62290-1:2014

Railway Automation and it's Effect on the involved Staff

Some Current Projects

- Project 5GReallabor [2]
 - Goal: Demonstrate RTO via 5G in real-world application
- Thus, remotely controlling a train in Saxony from Brunswick, GER
 - And, we did... (https://www.youtube.com/watch?v=_aG3H2WM4dl)
 - And it worked remarkably well
- Project was focused on technology, safety, regulatory approval and user requirements.
- But our questions on required subsequent video quality and human detection performance largely remained
 - But, correctly perceiving information via video is obviously crucial to RTO!



Railway Automation and it's Effect on the involved Staff

Some Current Projects

- Project ATO-Cargo [3]
 - Goal: Demonstrate ATO and RTO on the BETUWE (NL) line in regular traffic in the freight domain
- This challenge is taken on together by DLR, operating companies and suppliers.
- DLR is responsible for defining user requirements, ensuring Human Factors conform system design and final workplace evaluation during a one-year test trial in 2025
- Also in this context, we even more so need to specify **requirements concerning video quality**



Railway Automation and it's Effect on the involved Staff

Literature on Human Video Perception in Relation to Video Quality

- Problem has recently (2019) been identified in the literature [4], but has not been adresssed systematically in the railway context
- There is limited general literature from end-consumer domain available on
 - Bitrate:
 - Positive effect of bitrate on quality acceptability [5]
 - Stalling has more adverse effects on Quality of Experience (QoE), if bitrate is higher [6]
 - Frame Rate:
 - Higher frame rate was not linked to participant information assimilation, but increased user enjoyment [7]
 - Quality of experience... e.g. [5]
- There is a gap in the literature that needed to be filled



Effects of Video Quality on Perception and Reaction Time

Research question

- Series of consecutive studies set up to answer the research question:
 - What effects framerate and bitrate exert on perception accuracy and response times in a choice-reaction time setting resembling information acquisition from video footage in remote train operation.
- Preliminary hypothesis
 - Higher bitrate and frame rate were hypothesized to go along with higher response accuracy and lower response times
- At this moment, two initial exploratory studies have taken place
 - the first in our lab
 - the second online via SociSurvey



Effects of Video Quality on Perception and Reaction Time

Methodology Employed in both Exploratory Studies

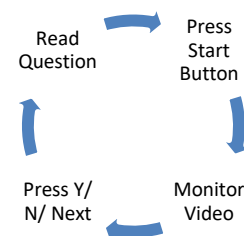
- Sample
 - N1= 19/ N2= 12
 - Gender (37% Male; 63% Female)/ Age (M=42,47; SD= 19,3)
 - German Speaking, Novizes
- Within Subject Design
- Independent Variables
 - Bitrate
 - 3 levels: 1/ 6/ 24 (HD) Mbps
 - Frames per Second (FPS)
 - 3 levels: 5/ 15/ 25 FPS
 - Stimulus Type
 - 2 levels: Light Signal/ Distance Marker
 - Congruency Question/Stimulus
 - 2 levels: Congruent/ Incongruent ->Plausibility check only



Effects of Video Quality on Perception and Reaction Time

Methodology Employed in both Exploratory Studies

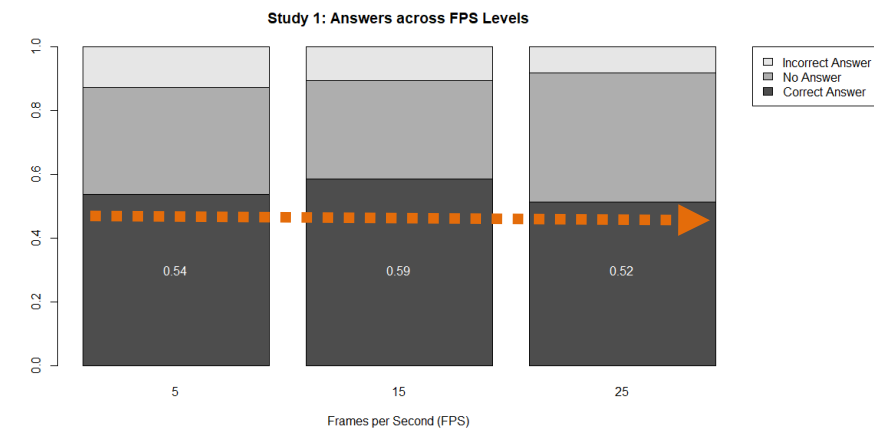
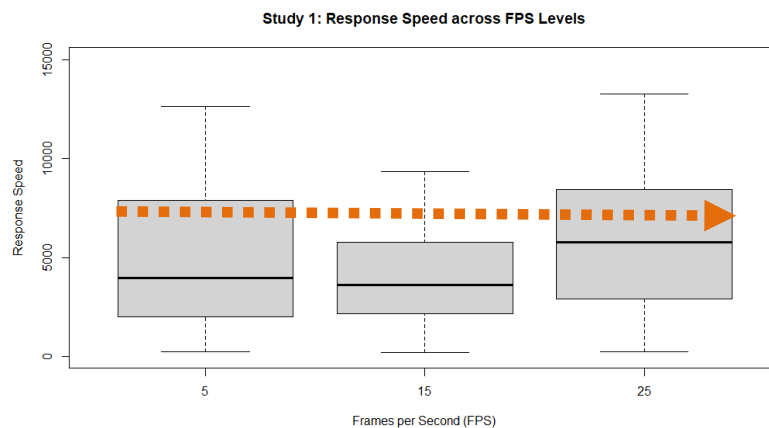
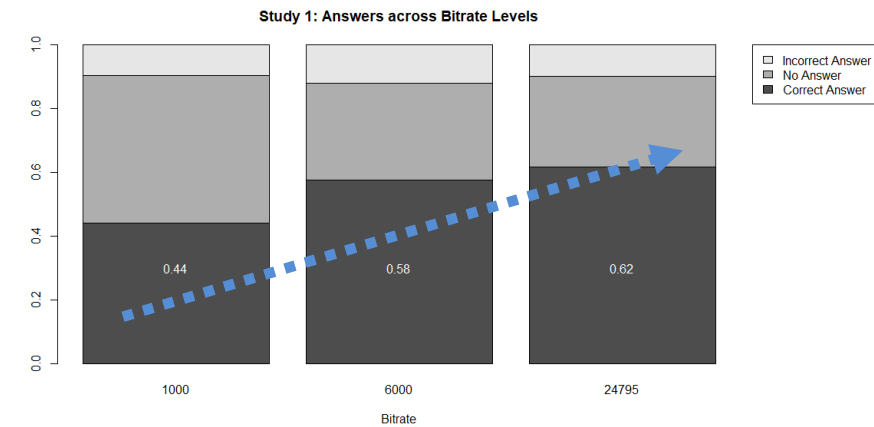
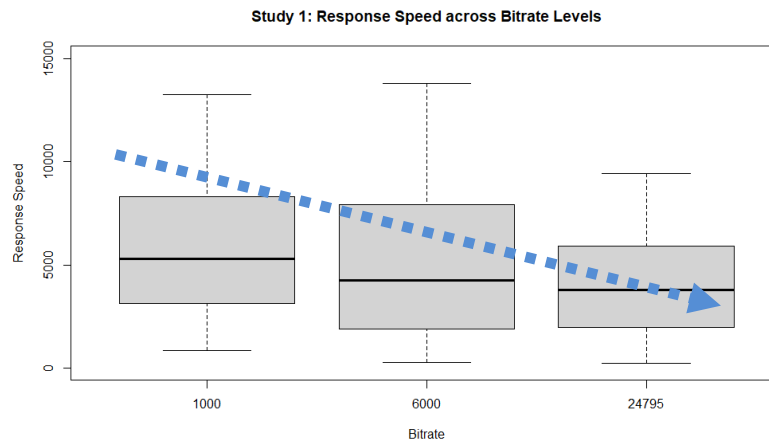
- Dependent Measures
 - Response Accuracy
 - Right/ Wrong/ No Answer
 - Response Speed
 - Time from stimulus onset in video to button press
- Procedure
 - Participants were presented with a computer-based series of 36 videos - varying in quality, stimulus type and congruency - and were asked to respond to a question concerning each video
 - „Is the next relevant signal green/red?“
 - „Does the next relevant distance marker read XYZ?“
 - Randomized order of video presentation



Effects of Video Quality on Perception and Reaction Time

Results on Response Accuracy and Speed in Study 1

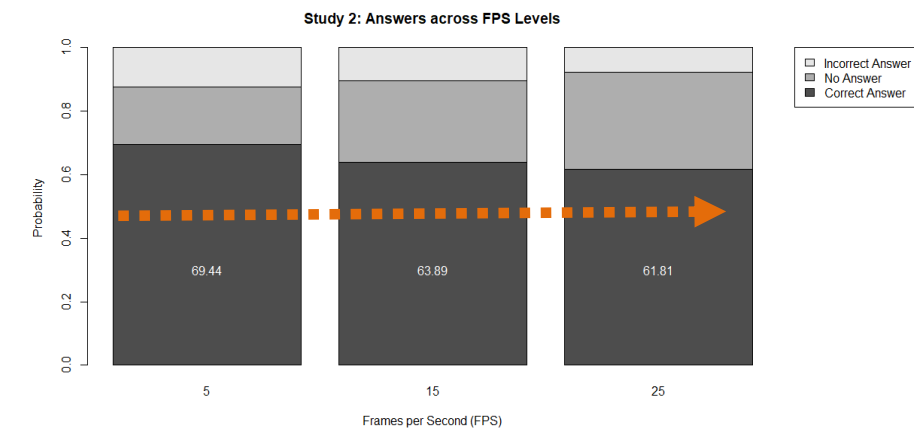
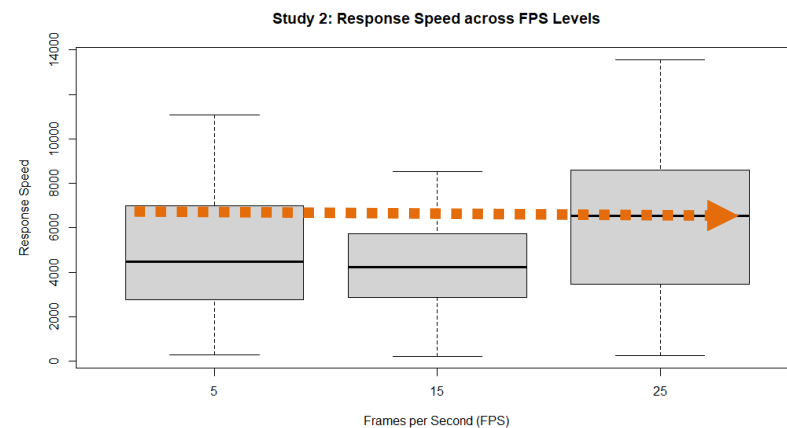
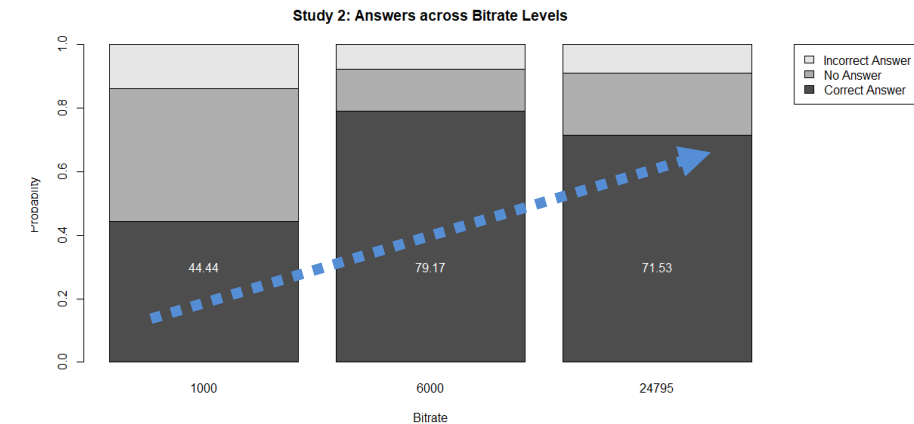
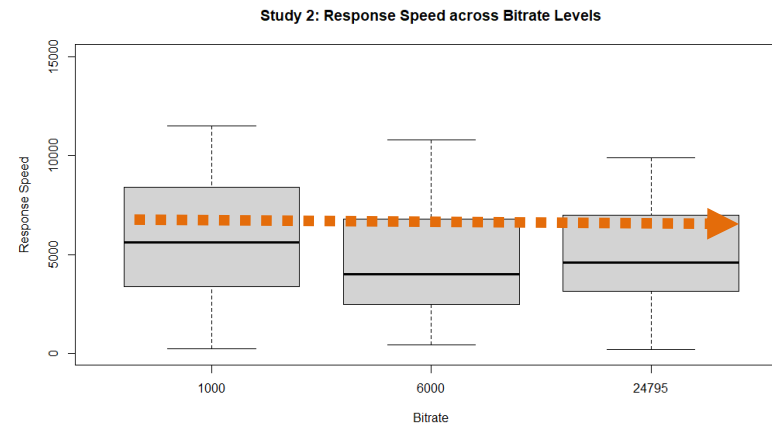
- Bitrate:
 - Tendency to go along with higher response accuracy
 - Additionally, tendency to go along with faster response times
- Frame Rate (FPS):
 - No tendency visible by descriptive exploration
- Generally low correct answers due to novice sample?
- Interestingly, bitrate levels are by no means equidistant,
 - data does not indicate linear relation



Effects of Video Quality on Perception and Reaction Time

Results on Response Accuracy and Speed in Study 2

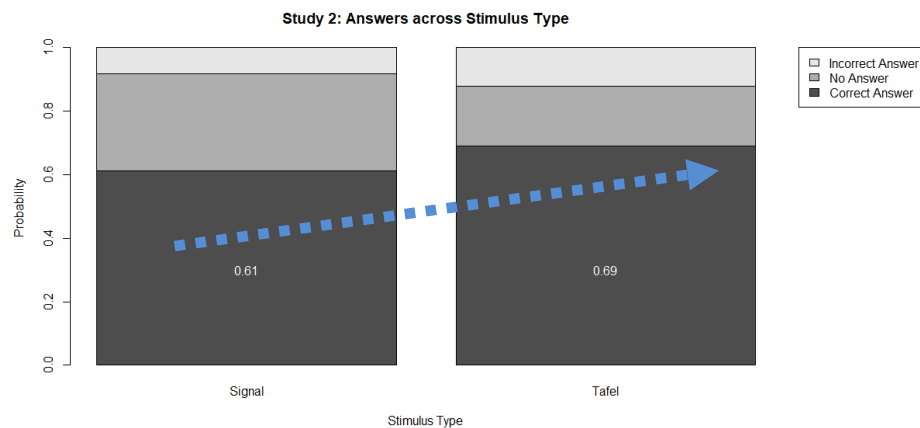
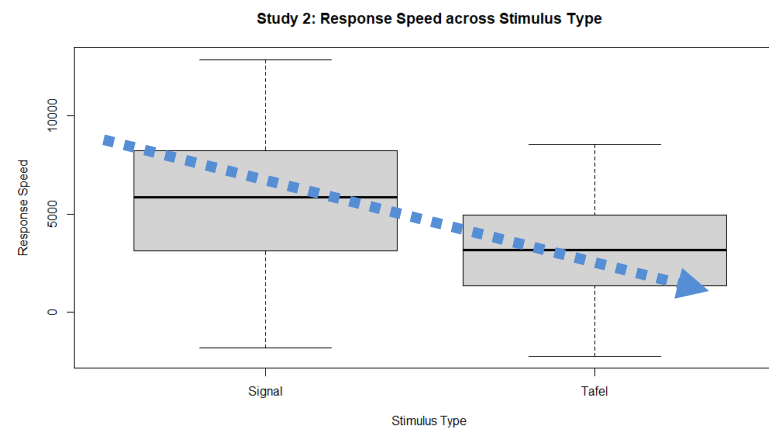
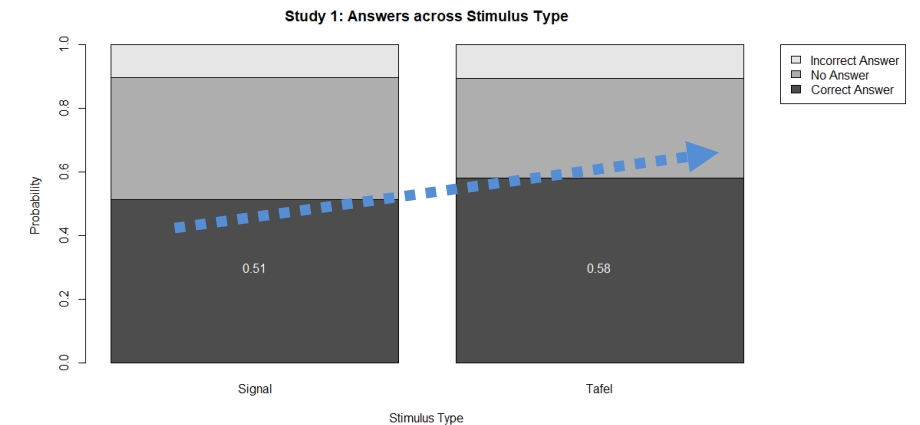
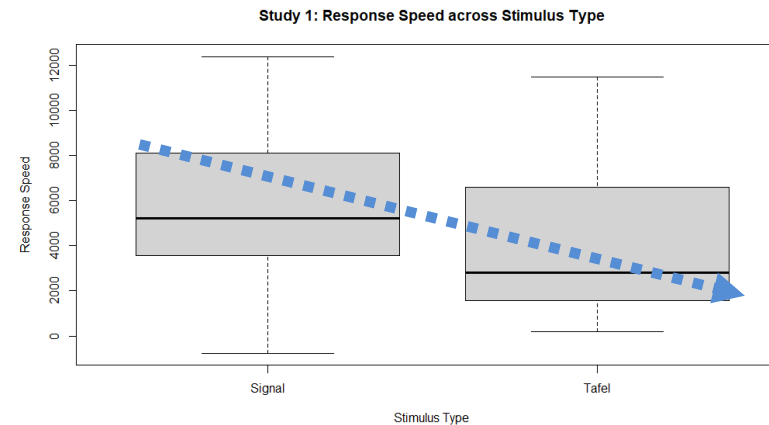
- Bitrate:
 - Tendency to go along with higher response accuracy
- Frame Rate (FPS):
 - No tendency visible by descriptive exploration
- Data from study 2 shows some consistency with results from Study 1



Effects of Video Quality on Perception and Reaction Time

Results on Stimulus Type across Studies

- Stimulus Type:
 - Distance marker (German: „Tafel“)
 - Light signal
- Data consistently suggests
 - that distance markers may be **more correctly** and **faster** identified than light signals
- Stimulus Type matters!



Effects of Video Quality on Perception and Reaction Time

Preliminary Conclusions in this Current Line of Research

- In the data gathered,
 - **Bitrate** seems to have a **more direct effect** on both measures than frame rate (in line with literature [5]) on dependent variables
 - Interestingly, assessed **bitrate levels were not equidistant** and indicated a non linear relation with a limited incremental benefit of additional bitrate above a certain rate
 - We did not observe effects of frame rate on both measures using simple descriptive means
 - **Frame rate** might exert effects on more **subjective measures** (QoE_[7,6], long term viewing_[5] acceptability), which were not covered in this research so far
- Methodological conclusion for next study:
 - Research questions:
 - Clearly define **lower bound cut-off** on bitrate (introduce equidistant bitrate scale)
 - Include other **stimulus types** and characteristics (size, contrast etc.)
 - Method:
 - Clean design to target one independent variable and employ **between subject design** to increase internal validity
 - Analyses:
 - Introduce significance testing as sample sizes increase and model definitions mature



References

- [1] Brandenburger, N. (2021). Remote Control of Automation: Workload, Fatigue, and Performance in Unattended Railway Operation, Dissertation, Technical University Brunswick, GER
- [2] <https://verkehrsforschung.dlr.de/de/projekte/5g-reallabor>
- [3] <https://verkehrsforschung.dlr.de/de/projekte/projekt-ato-cargo-erprobung-automatisierter-gueterzuege>
- [4] Masson, E., Richard, P., Garcia-Guillen, S., & Adell, G. M. (2019). TC-rail: Railways remote driving. In *Proc. 12th World Congr. Railway Res.* (pp. 1-7).
- [5] Saving Bitrate vs. Pleasing Users: Where is the BreakEven Point in Mobile Video Quality, Wei Song, Dian W. Tjondronegoro, Michael Docherty, 2011
- [6] Anwar, M.S., Wang, J., Ullah, A. *et al.* Measuring quality of experience for 360-degree videos in virtual reality. *Sci. China Inf. Sci.* **63**, 202301 (2020). <https://doi.org/10.1007/s11432-019-2734-y>
- [7] Gulliver, S., & Ghinea, G. (2004). Stars in Their Eyes: What Eye-Tracking Reveals About Multimedia Perceptual Quality. IEEE. 06, 2004

