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# Design and Evaluation of a Supervisory Control Lab System for Automation Research

- A Theoretical and Empirical Contribution to the Discussion on Function Allocation -

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"You can discover more about a person
in an hour of *play* than
in a year of conversation."

Plato (428 - 348 B.C.)

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# unaware & loaded vs. troubleshooter?

see Ironies of Automation (Bainbridge, 1983)

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# BEHIND THE CURTAIN: DEVELOPERS‘ MIND -> AUTOMATION

- human operators and automation cooperate, but:
  How should functions between both be allocated?
- complementary approach only if both the human operator and the „*developer behind* “ are known regarding their potentials

- any automation restricted to resources of developers (1)
- intelligence not in the machine but developers‘ minds (2)

- not human vs. machine but human vs. human, but:
  How can operator and developer be compared **empirically**?
- ATEO project = endeavour to such an empirical approach (3)

(1) Bainbridge (1983); (2) Norman (2007); (3) Wandke & Nachtwei (2008)

# BUILD THE PLAYGROUND AND GET TO KNOW THE OPERATOR

- Empirical common ground: ***one and the same process*** should be supervised and controlled by human **operators versus developers** through their very **own means**

- For the **human operator** these means are supervision and control of processes **via a *master display*** (window to the process).

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# Question regarding a first-of-a-kind system

Prerequisite:

- If operators‘ and developers‘ potentials should be compared, fairness is of essence: **both need near-optimum** external resources.

Question:

- **Does the master display in ATEO serve as such a near-optimum resource for the human operator?**

Goal:

- Operators‘ behavior can be attributed to human potentials and not to master display usability problems.

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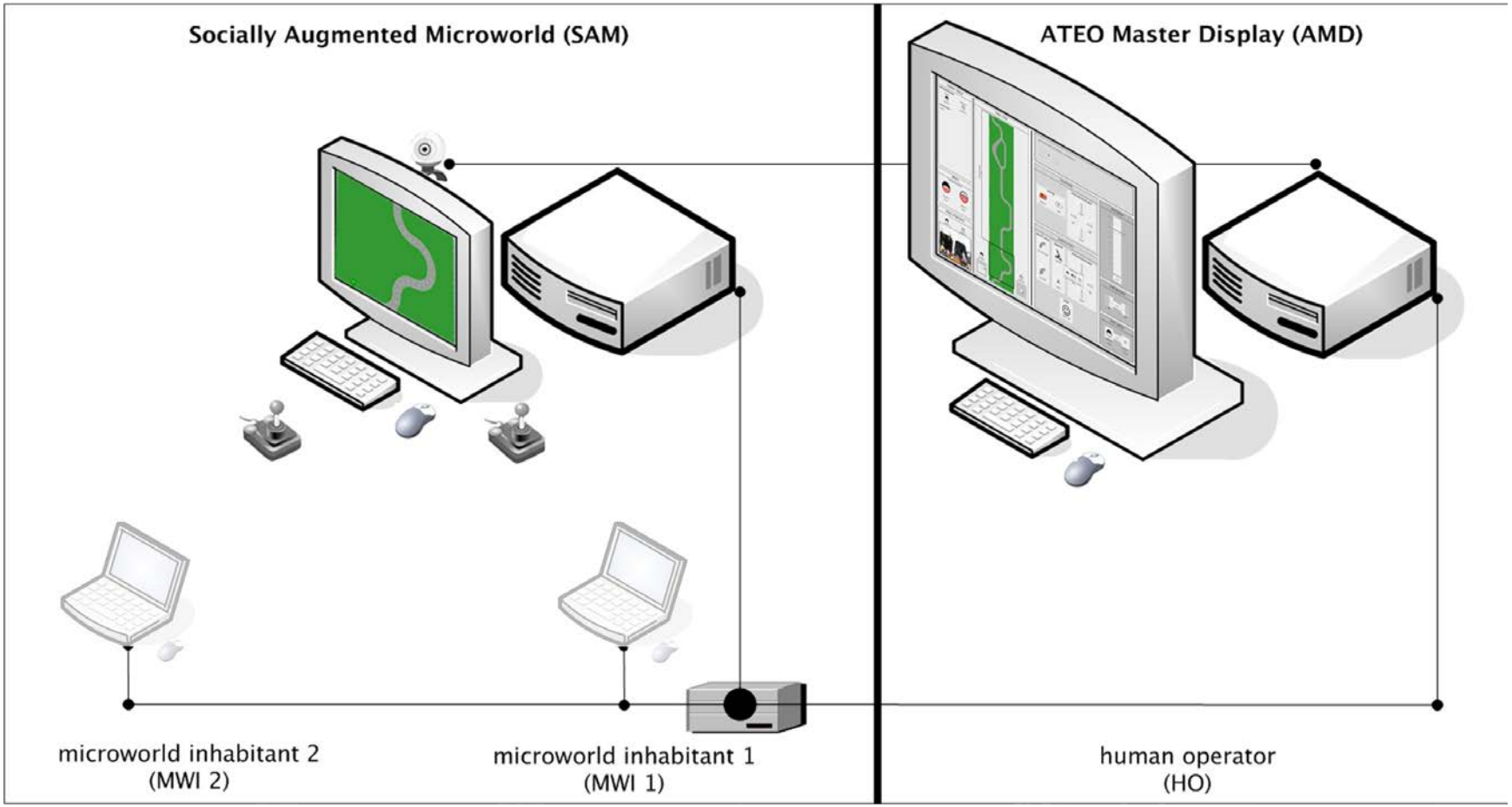
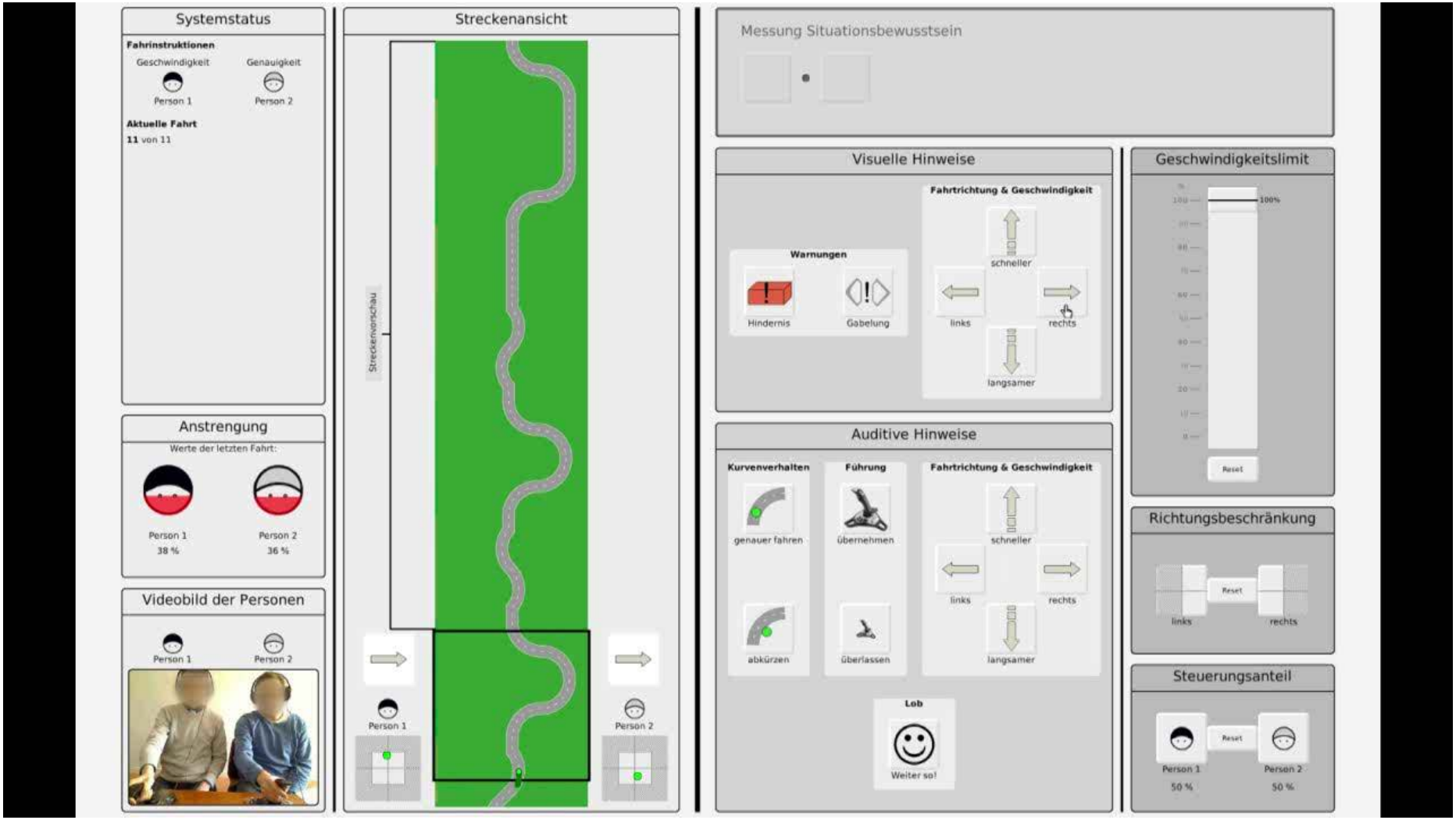
# ATEO Lab System (ALS): SAM + AMD



# ATEO Master Display (AMD) version 1.28



# USABILITY ENGINEERING METHODS RELATED TO AMD

1 model on operators' potentials and deficiencies (Nachtwei, 2010)

2 model on performance shaping factors (PSF) (Gérard et al., 2011)

3 review of supervisory control design guidelines (industrial, aviation setting)

4 interviews with field operators based on PSF (to infer design problems)

5 hierarchical task analysis for ATEO Master Display (Hildebrandt et al., 2010)

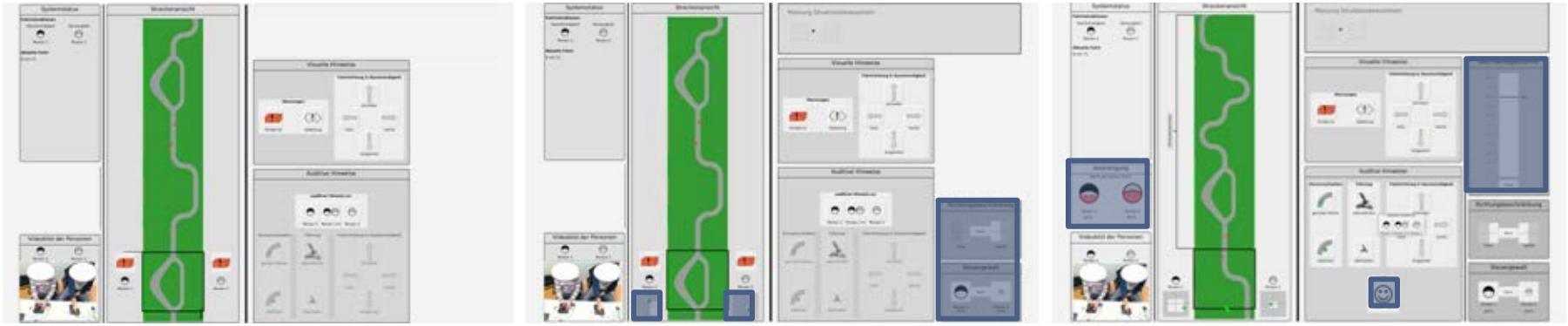
6 evolutionary prototyping in interdisciplinary group (17 iterations based on 1-5)

7 heuristic evaluation based on task analysis results (with two expert teams)

8 evolutionary prototyping in interdisciplinary group (7 iterations based on 1-7)

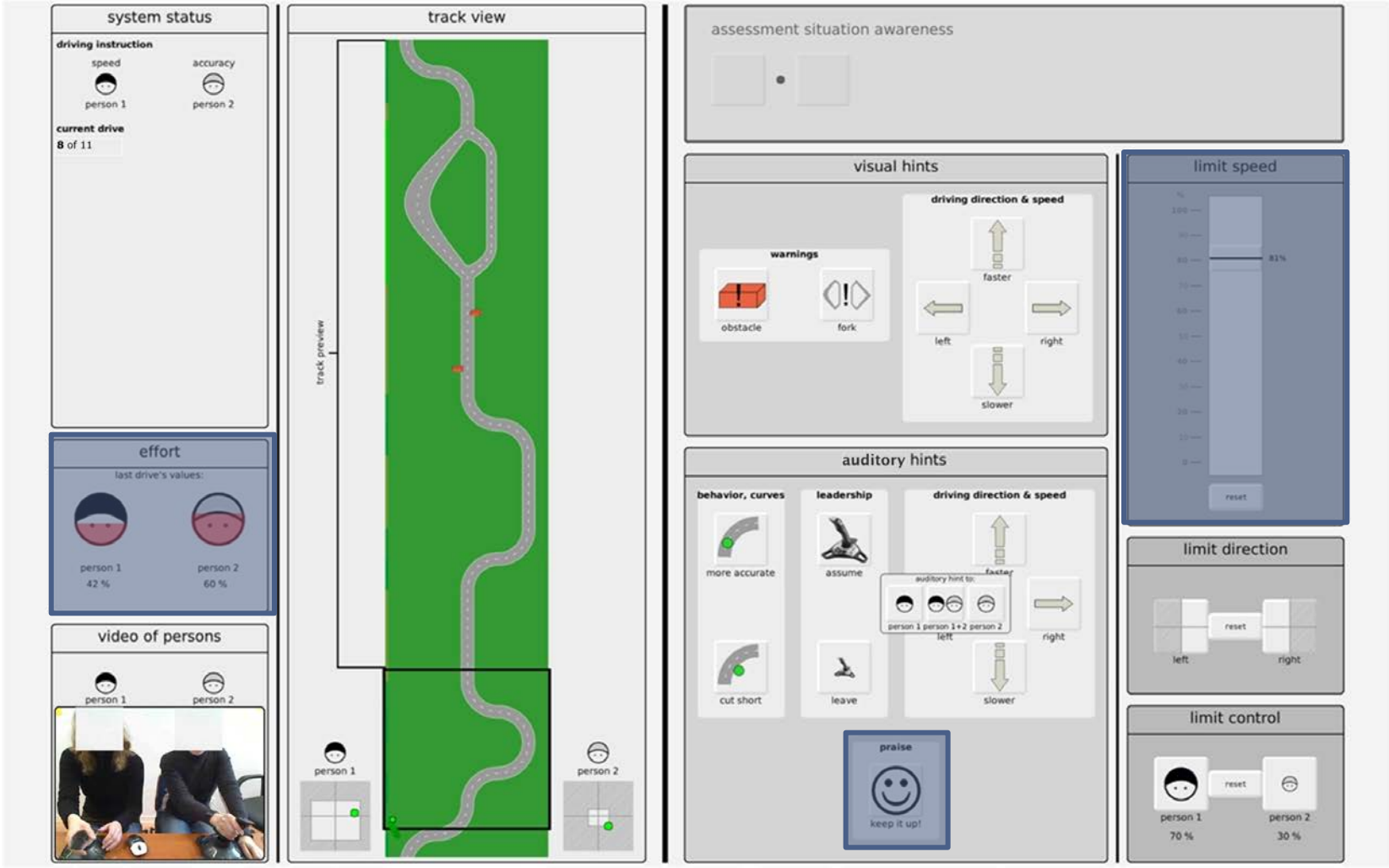
**Enough? Now the testing…**

# USABILITY TESTING METHODS RELATED TO AMD



- three AMD versions v1.26 – 1.28: extension of input and output
- naive participants trained as human operators and MWI
- 77 human operators and 2x77=154 MWI in between design
  - Human operators: 47% men, 18 to 46 years, *M*=28.59, *SD*=6.56
  - MWI participants: 47% men, 18 to 64 years, *M*=26.86, *SD*=6.82
  - Exclusion criteria: left-handedness, students of psychology, having received psychological/psychiatric treatment, red-green blindness or having participated in tracking studies

# EXPERIMENTAL COMPARISON OF TWO AMD-VERSIONS



# Experimental Procedure and dependent variables

- Experimental procedure (from operator‘s perspective):
  - AMD training (theory, practice concerning SAM and AMD): 85 min
  - AMD operation (four trials with questionnaire in between): 31 min
  - Post-assessment and evaluation (questionnaires, interview): 34 min

- Five different main **dependent variables:**
  - ***performance*** (index of human operator and team related indicators of safety and efficiency),
  - ***wear out*** (effort of the “subsystem” microworld inhabitant team in SAM, discretely measured after each trial),
  - ***mental workload*** and ***situation awareness*** of human operators
  - and ***perceived usability*** regarding the AMD

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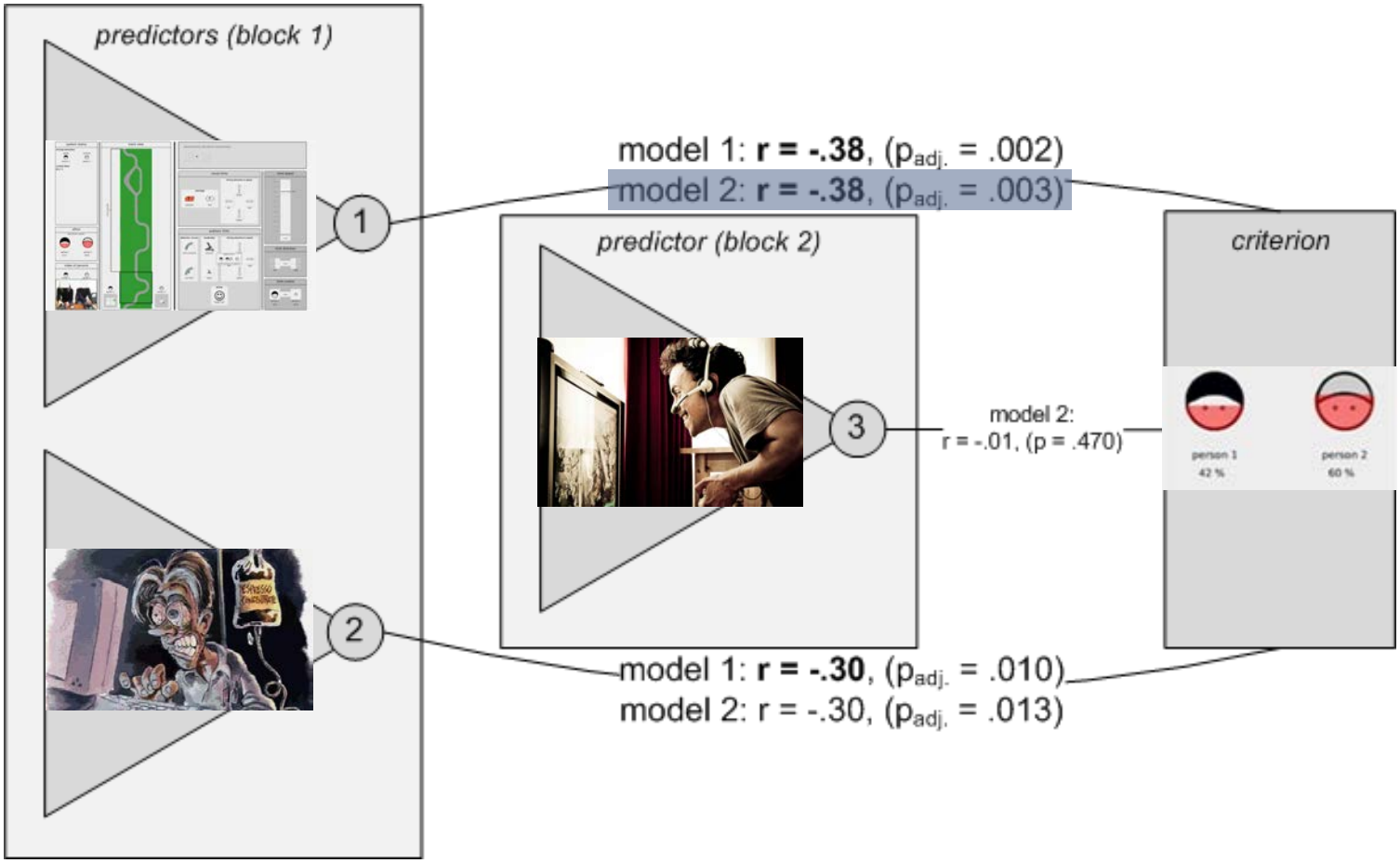
# RESULTS RELATED TO DESIGN & EVALUATION OF THE AMD

- *Research question: How near are we to the optimum design?*

- hypotheses → results: **latest AMD vs. prior AMD version**:
  - higher performance → no significant difference
  - lower wear out (load MWI) → yes
  - higher mental workload → no significant difference
  - higher situation awareness → no for global, yes for local
  - higher perceived usability → no for global, yes for local

# INTERFACE EXTENSION HELPS TO DECREASE MWI WEAR OUT




wear out in AMD v1.27: $M$ = 60.46, $SD$ = 12.99
wear out in AMD v1.28: $M$ = 51.01, $SD$ = 12.29

$N$=49: $F$ (1, 45) = 7.908 for $R^2$ in model 2
$R^2$ = .26 ($R^2_{adj}$ = .17 ($p$ < .01) model 1; $\Delta R^2$ = .00 ($p$ < .01)

annotation: results with one outlier exluded, forced entry of predictors within block 1, one-tailed part correlations

# EXAMPLE: SITUATION AWARENESS REGARDING WEAR OUT

- no global increase in situation awareness, but:

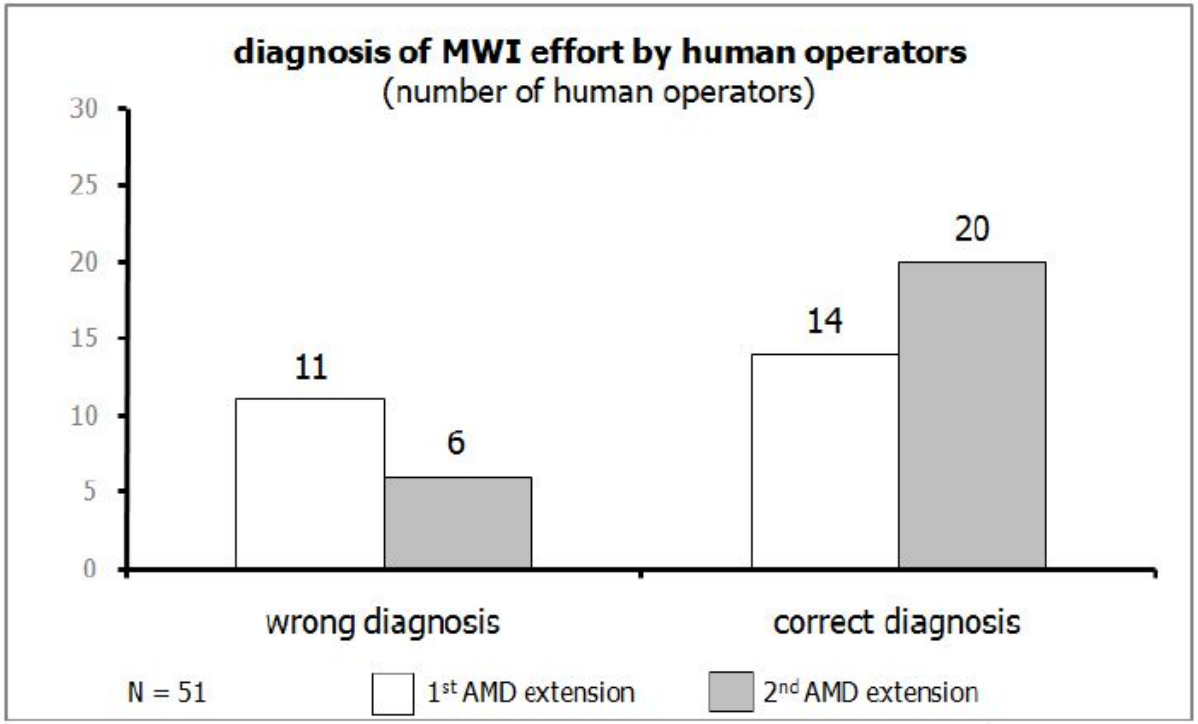



Figure 4: Correct MWI effort diagnosis by interface without (1st extension) vs. with (2nd extension) effort display

$\chi^2(1) = 2.51$, $p = .06$ (one-tailed), odds ratio = 2.62

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# LIMITATIONS REGARDING METHODS AND RESULTS

- rather **generic manipulation** instead of step-by-step testing of each element in the AMD

- **aggregation of convergent variables** in criteria: difficult to interpret versus reduced error variance and no alpha-inflation due to multiple testings

- **design is a flexible and opportunistic act** [1] –>
  What would AMD‘s kin look like?

[1] Simon (1995)

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# TAKE HOME MESSAGES

- ATEO Master Display (**AMD**) **important resource** of operators, but not the only one (e.g. effects of emotional stability)
- AMD design - like any **design - not final**, but: suffices to investigate operators‘ potentials and deficiencies
- usability **evaluation**: no fishing for effects but validation of usability **engineering**
- **preliminary work for function allocation:** operator and automation not isolation but as joint cognitive system (1)

(1) Roth, Bennett & Woods (1987)

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# Please anticipate: the future of ATEO

- supervisory competence (**eye tracking**) and operators‘ behavior evaluated by thesis of M. Stade in detail
- **cooperative automation** based on insights from ATEO 2.0 will be studied until 2013
- **behavior-based personality** diagnostics [(1)] possible since setting not as restricted as other experiments

[(1)] Furr (2009)

Thank you for your attention.

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*to be continued…*

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