Validation of a VR cycling simulation in terms of perceived criticality and experience of presence

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Theory

- **Traffic conflicts** are defined as a "situation from which it can be reasonably inferred that two or more **road users** are intending to occupy the **same region of space** at the **same time** in the near future" [1]
- **Proximity** of vehicles passing cyclists constitutes a key parameter to **cyclists' perceived safety** [2]
- How can automated vehicles **interact safely and comfortably** with cyclists in traffic conflicts?
- **VR cycling simulation** provides a safe and standardized environment for investigating **cyclists' perception of traffic conflicts** and their perceived criticality
- **However:** Examination of simulation validity to ensure the generalizability of results [3]

Aim:
- Development of a virtual reality (VR) cycling simulation
- Investigation of the simulation **validity**:
  - **Perceived criticality** in traffic conflicts
  - **Experience of presence**

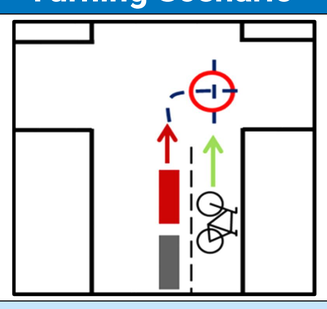
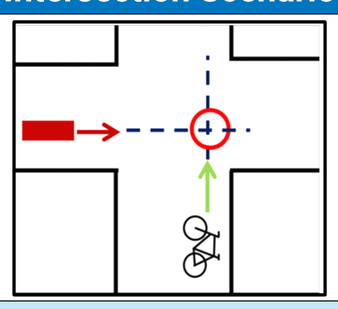
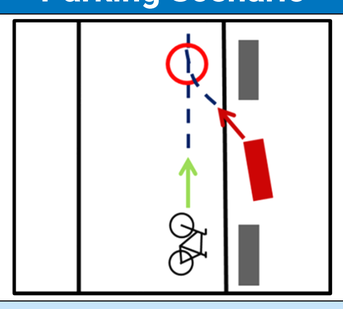
Online Study

Experimental design: 3 (conflict scenarios) x **4** (levels of potential of critical outcome) **within-subjects design**

Levels of potential of critical outcome

- Initial attempted post encroachment time (**IAPT**): **Timespan** between the **leaving of the first** and **arrival of the second road user** at a (theoretical) conflict point, if **no speed or trajectory adjustments** are initiated by the road users [4]
- **4 Levels** of potential of critical outcome:
  High potential (IAPT = 1s), medium potential (IAPT = 2s), low potential (IAPT = 3s), no potential (baseline)

Conflict scenarios

Turning Scenario	Intersection Scenario	Parking Scenario
		

Procedure:
- **Beginning:** Demographics, cycling experience, sensation-seeking [5], affinity for technology [6]
- **Trials:** Each conflict scenario with each level was presented *twice* with subsequent questionnaire on perceived risk [scale ranges from 1 ~ *harmless* to 8 ~ *non acceptable*, see 7]
- **Ending:** Experience of presence within VR simulation [8]

VR Cycling Simulation

- Based on open source project **Westdrive X LoopAR** [9]
- **Simulation** was **modified** to provide a **naturalistic impression of a bike ride**, including the cyclist's perspective when sitting on a bike as well as the moving bicycle wheel, the handlebar and the cyclist's hands in the foreground

SCAN TO SEE EXAMPLE VIDEOS

Results

Sample characteristics:

Participants
N = 35 (23 woman), *M*= 23.3 years old
Sensation Seeking Scale*
M = 2.96 (*SD* = 0.74)
Affinity for Technology Interaction**
M = 3.28 (*SD* = 0.83)

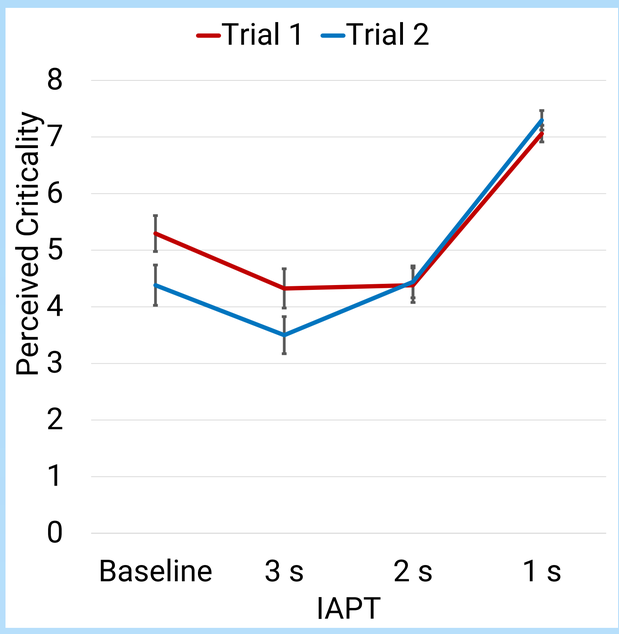
Igroup Presence Questionnaire***

Subscales	*M*	*SD*
Experienced Realism	3.35	0.74
Spatial Presence	3.01	0.52
Involvement	3.34	0.77
General Presence	3.17	1.46

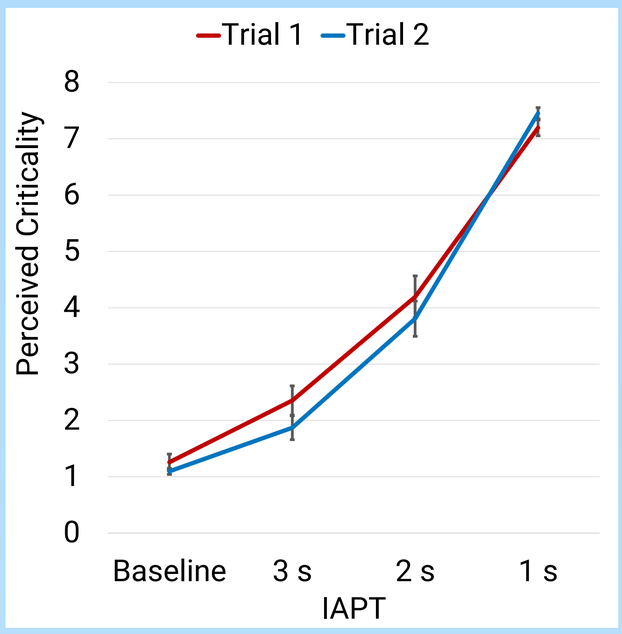
Scale ranges:
* 1 '*strongly disagree*' to 5 '*strongly agree*'
** *1'completely disagree*' to 5 '*completely agree*'
*** 0 (disagreement) to 6 (agreement) (transformed)

Perceived Criticality:

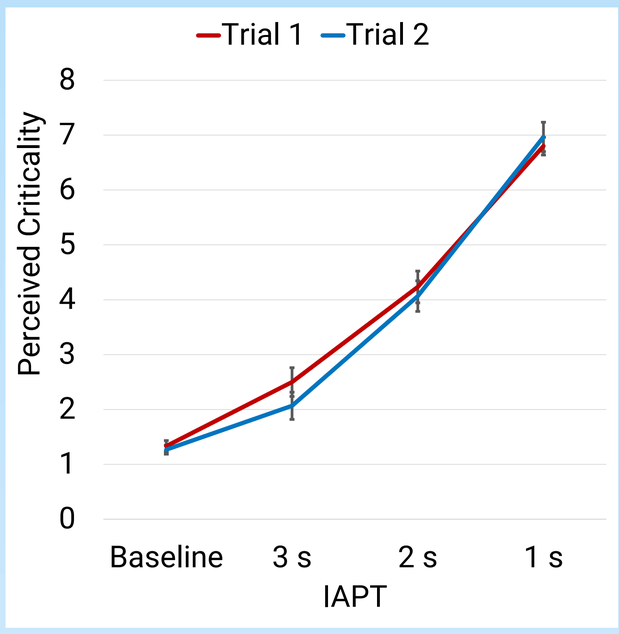
Turning Scenario:
$F(2.05, 67.65) = 57.41$, $p < .001$,
$\eta_p^2 = .635$ (Greenhouse-Geisser correction)



Intersection Scenario:
$F(2.14,64.14) = 325.71$, $p < .001$,
$\eta_p^2 = .916$ (Greenhouse-Geisser correction)



Parking Scenario:
$F(3, 87) = 262.49$, $p < .001$, $\eta_p^2 = .901$



Pairwise comparisons of IAPT-levels within each scenario:
Turning Scenario: all $p < .005$, except of IAPT=2s and IAPT=3s ($p = .838$)
Intersection Scenario: all $p < .001$
Parking Scenario: all $p < .005$

Pairwise comparisons of trial 1 and trial 2 within each scenario:
Turning Scenario:
$F(1, 33) = 6.29$, $p = .017$, $\eta_p^2 = .160$
Intersection Scenario:
$F(1, 30) = 1.80$, $p = .019$, $\eta_p^2 = .057$
Parking Scenario:
$F(1, 29) = 1.16$, $p = .290$, $\eta_p^2 = .038$

Discussion

- The results for the intersection and parking scenario were in line with assumptions: **Shorter IAPT were related to higher perceived criticality**
- There was **no significant difference** in perceived criticality for the **turning scenario** between IAPT = **2s** and IAPT = **3s**
- **Overall**, the **turning scenario** was perceived as **more critical** compared to the parking and intersection scenario
- **Acceptable results** for **experience of presence** → Potential improvements in a laboratory with VR headset

The presented VR cycling simulation seems to provide a useful tool for investigating traffic conflicts with different levels of criticality between automated vehicles and cyclists.

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