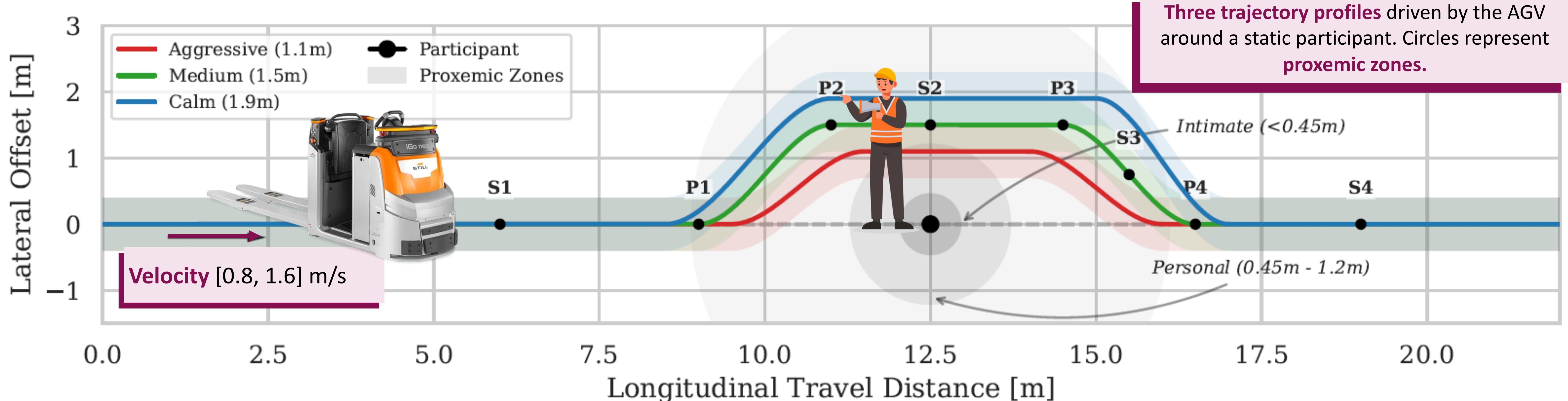


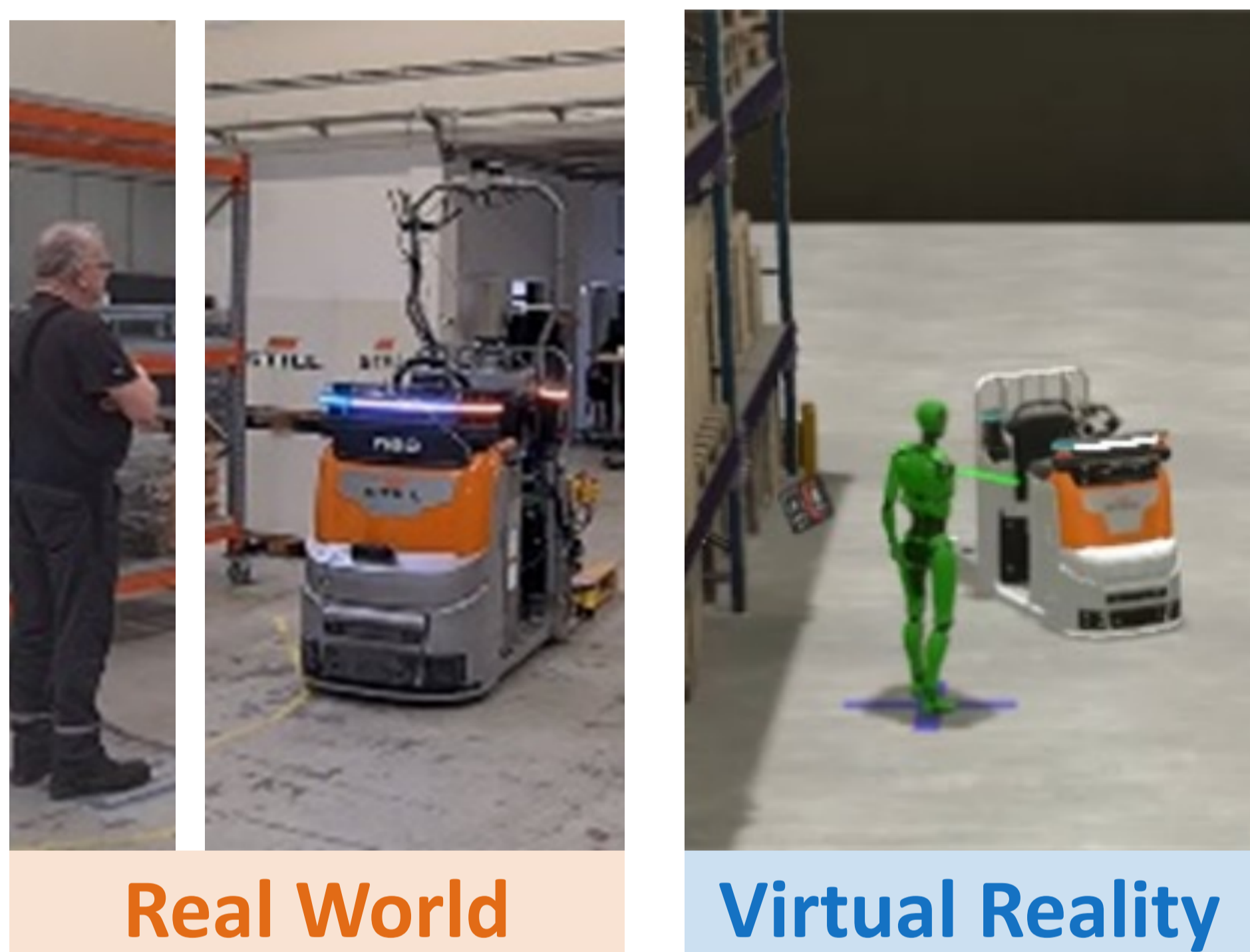
Perceived Safety of Workers in Encounters with Large Industrial AGVs

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Summary: We implement a collision avoidance maneuver of a large industrial AGV around a standing person and measure perceived safety in VR and in real life



Experimental Design



AGV iGo neo OPX **Velocity** [0.8, 1.6] m/s
Stack ROS2 + RPP + eHMI **VR** HTC XR Elite+Unity

- The AGV is equipped with an external Human-Machine interface (LED strips and a speaker)
- The encounter is replicated in VR using realistic driving sounds and a shaded 3D model of the AGV
- After experiencing the three trajectory profiles, participants could define their own preferred version in VR by moving the projected keypoints

Measuring Perceived Safety

Continuous Trigger
Pressure-sensitive VR controller samples perceived risk as $T(s) \in [0,1]$ during the encounter

Questionnaires
Safety assessment per trajectory profile.
One final questionnaire after all trials.
Post trial interviews.

Trigger press metrics

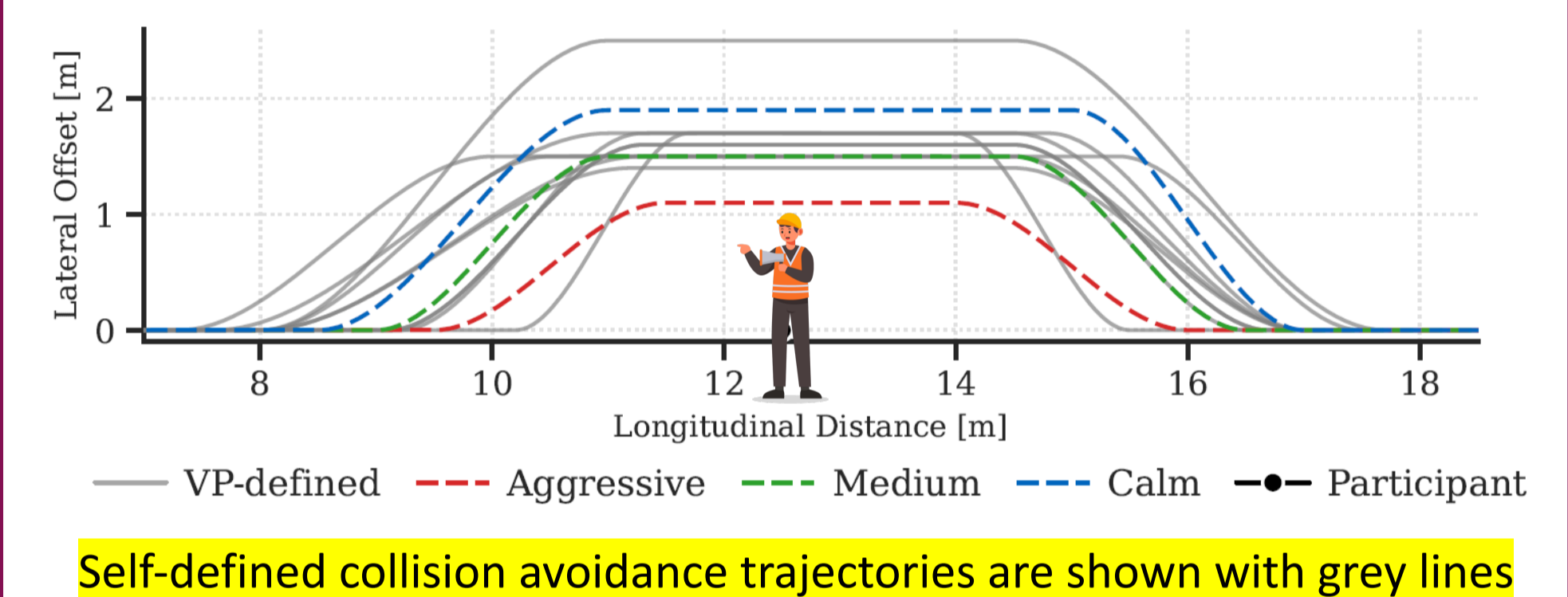
- Trigger rate time engaged
- $AUC = \int T(s) ds$ cumulative threat over AGV path
- t_{total} total time the trigger was pressed

Participants
N=10 participants, professional assembly staff at STILL GmbH in Hamburg, 50% aged 20–49 y., 50% aged ≥ 50 y.

Profile	Modality	Trigger rate [%]	AUC	t_{total} [s]
Aggressive	Real	75	2.0 ± 2.0	3.8 ± 3.7
	VR	90	3.5 ± 3.3	6.4 ± 4.8
Medium	Real	50	0.7 ± 1.3	1.1 ± 2.3
	VR	40	0.6 ± 1.7	1.8 ± 3.4
Calm	Real	20	0.7 ± 2.0	0.9 ± 2.5
	VR	30	0.9 ± 2.0	2.4 ± 4.7

Results

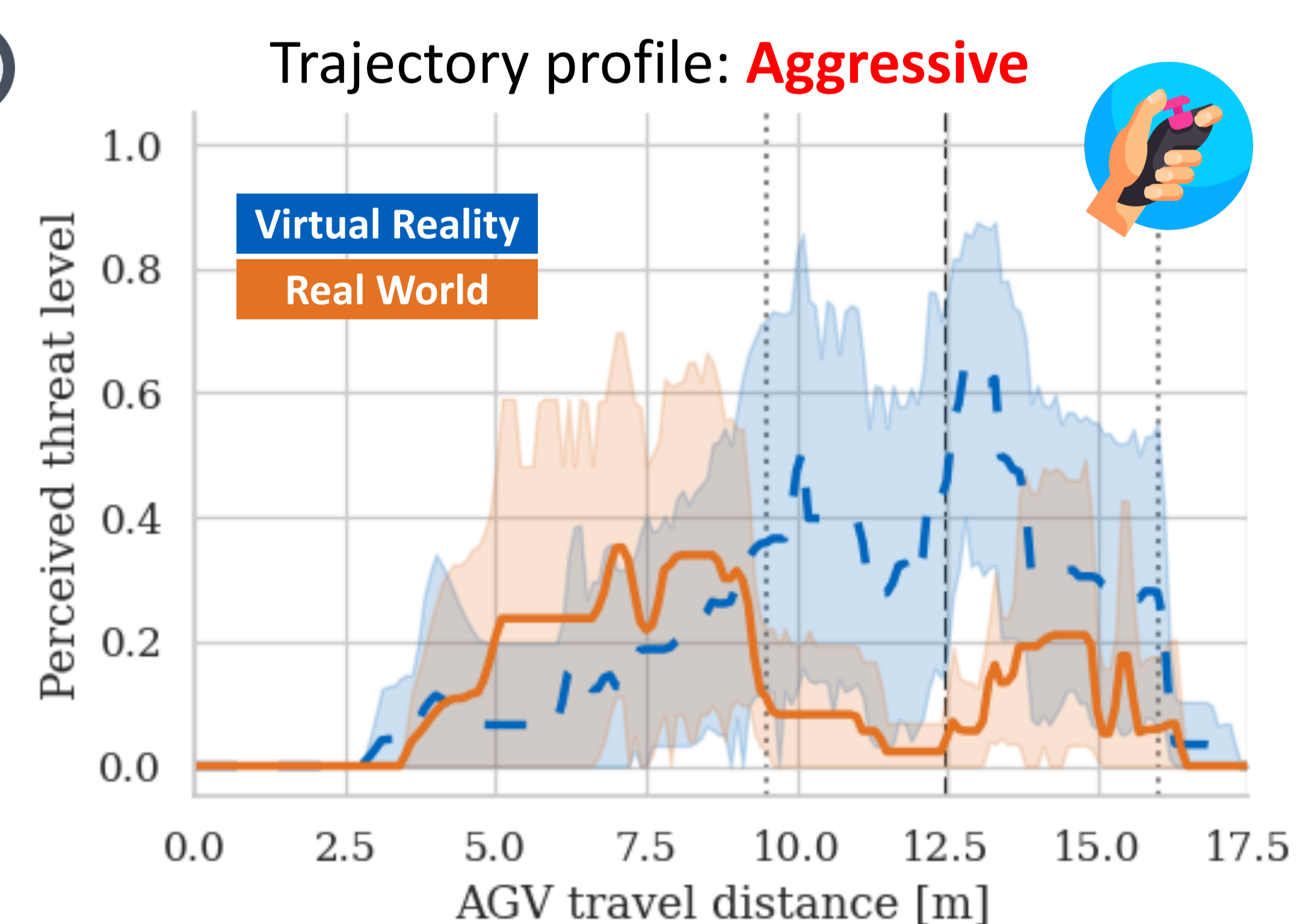
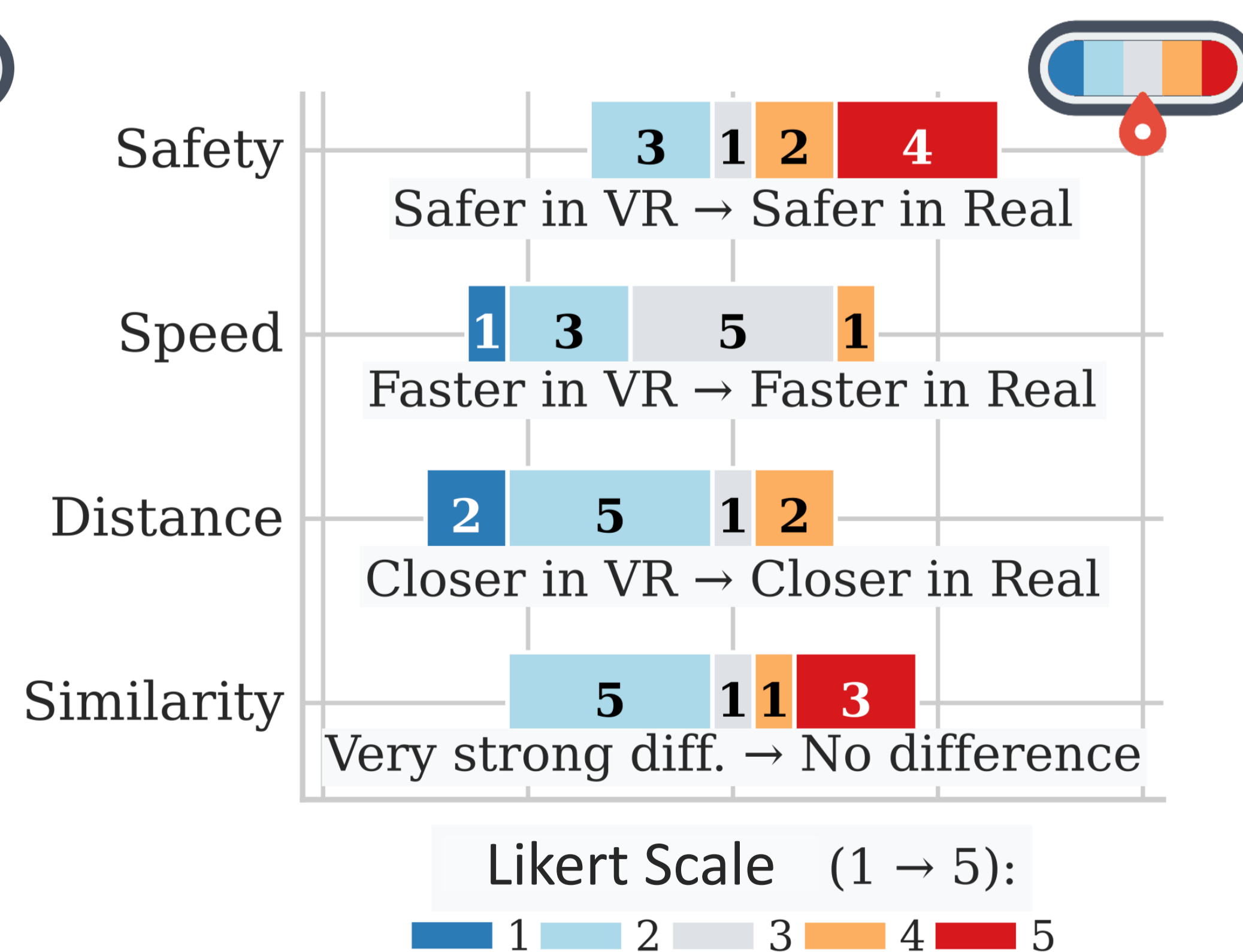
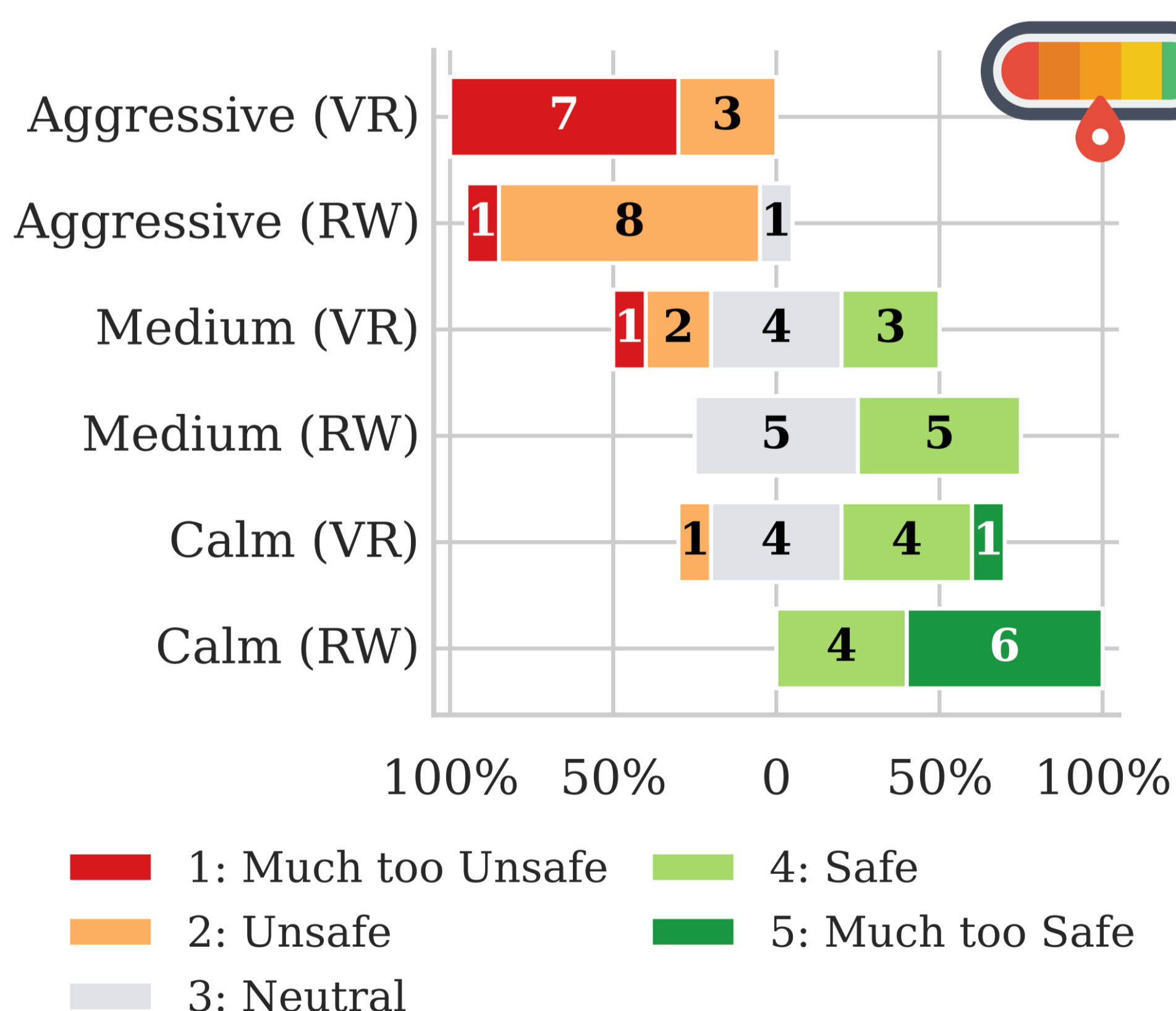
Preferred lateral passing distance
1.5 – 2m



Lateral Offsets of self-defined trajectory profiles match the **medium** trajectory profile

Longitudinal Onsets of self-defined trajectory profiles match the **calm** trajectory profile

- Both in VR and real-life, participants pressed the trigger most actively in the **aggressive** profile
- All trigger press metrics decrease in the **medium** and **calm** profiles
- Participants felt slightly less safe in VR



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