Defining suitable parameters for safe and effective deployment of a motorcycle Pre-Crash Braking system: findings from field testing and crash simulations

UNIVERSITÀ DEGLI STUDI FIRENZE

Presenter: ***Cosimo Lucci***

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Thomas Lich and Jan Schumacher BOSCH

Claire Naude, Adrien Canu, Christophe Perrin and Thierry Serre Université Gustave Eiffel

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Pioneers project

Objectives:

1. To achieve a deep understanding of the injuries sustained by the riders
2. **To increase the performance of safety systems**
3. To develop better test and assessment methods
4. To increase the awareness and the usage rate of personal protective equipment

Horizon 2020
European Union Funding
for Research & Innovation

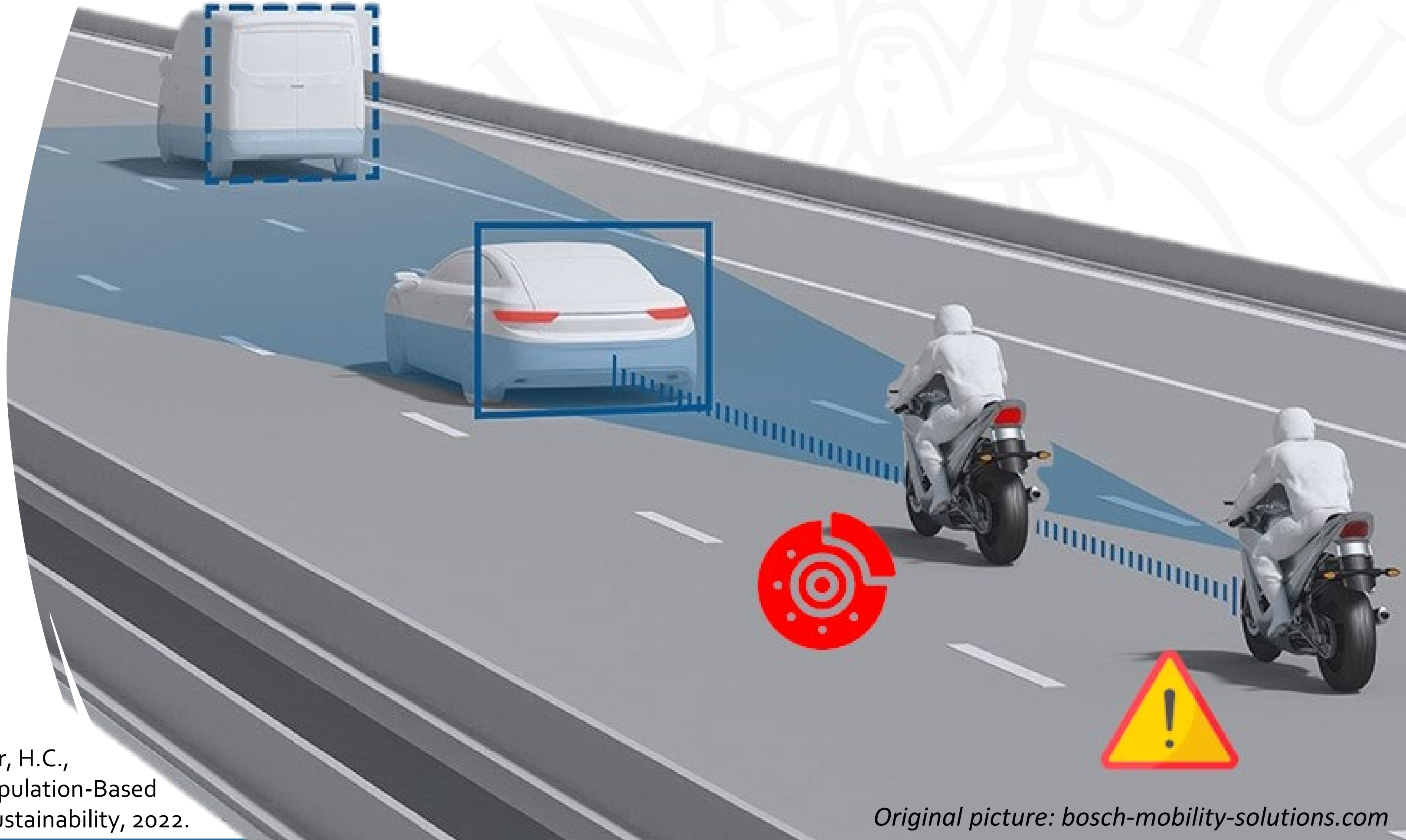
Introduction

Pre-Crash Braking (PCB)

Motorcycle Autonomous Emergency Braking (MAEB)

- Odds of intervention could be **23-50% of motorcycle crashes**

- Main issues related to the **stability** of the vehicle, **controllability** and **acceptability** among end-users



Original picture: bosch-mobility-solutions.com

Terranova, P., Dean, M.E., Lucci, C., Piantini, S., Allen, T.J., Savino, G., Gabler, H.C., Applicability Assessment of Active Safety Systems for Motorcycles Using Population-Based Crash Data : Cross-Country Comparison among Australia , Italy , and USA. Sustainability, 2022.

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Goal

Identify **suitable parameters** of intervention and technical requirements for **safe and effective application of PCB**

PCB working parameters

- PCB deceleration
- PCB fade-in jerk

- Triggering strategy
- Field of view
- Range

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Goal

Identify **suitable parameters** of intervention and technical requirements for **safe and effective application of PCB**

PCB working parameters

Field testing

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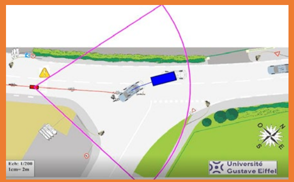
DIEF
DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Crash modeling



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PCB feasibility and acceptability

PCB benefits assessment

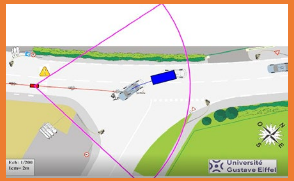
Goal

Identify **suitable parameters** of intervention and technical requirements for **safe and effective application of PCB**

PCB working parameters

Field testing

Crash modeling



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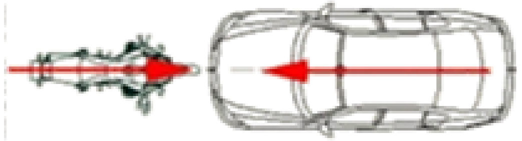
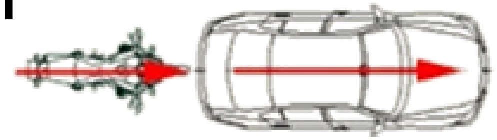
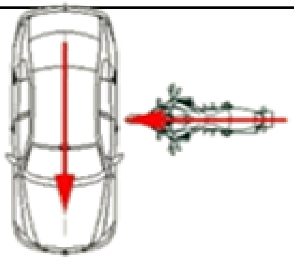
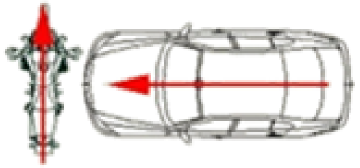
PCB feasibility and acceptability

PCB benefits assessment

Crash data

Crash Configuration	UNIVERSITÀ DEGLI STUDI FIRENZE DIEF DIPARTIMENTO DI INGEGNERIA INDUSTRIALE	Université Gustave Eiffel	Total
Head-on 	5	15	20 (33.3%)
Head-to-rear 	3	2	5 (8.3%)
Head-to-side 	17	7	24 (40.0%)
Sideswipe 	5	6	11 (18.3%)
Total	30	30	60 (100.0%)

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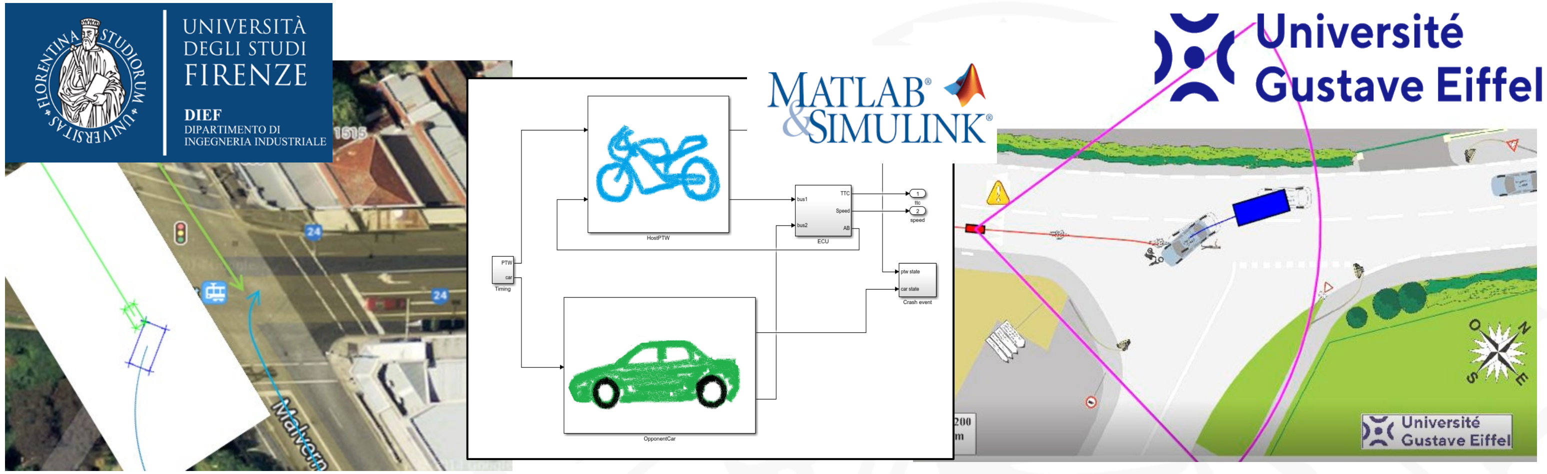
Methods

Crash reconstruction

Trajectories of vehicles prior to the crash reconstructed via numerical 2D simulations

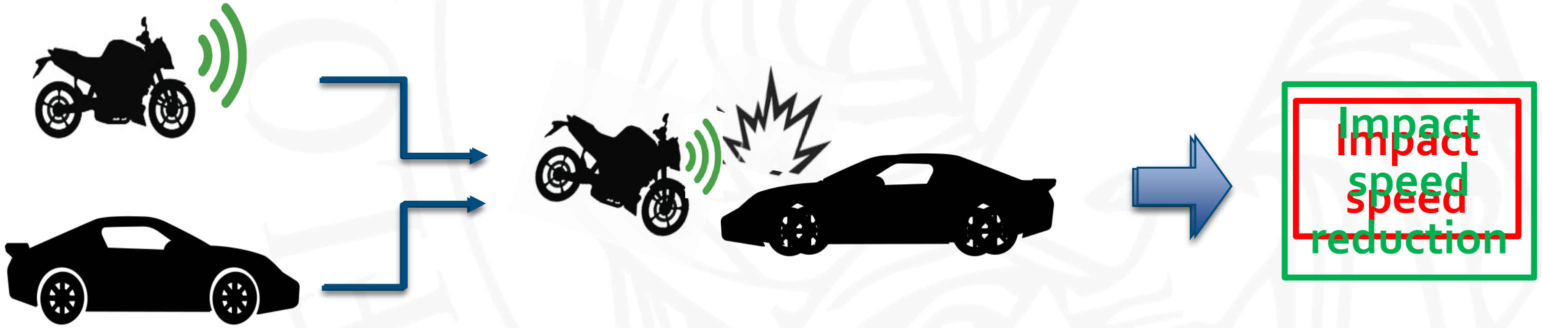


Parameter	Range	Incremental step
Triggering strategy	[conservative, standard, progressive]	-
Deceleration	[3 m/s^2 -7 m/s^2]	2 m/s^2
Fade-in Jerk	[15 m/s^3 -25 m/s^3]	-
Field of View	+/- [10° - 70°]	15°
Range	[30 m - 90 m]	15 m

Crash simulations

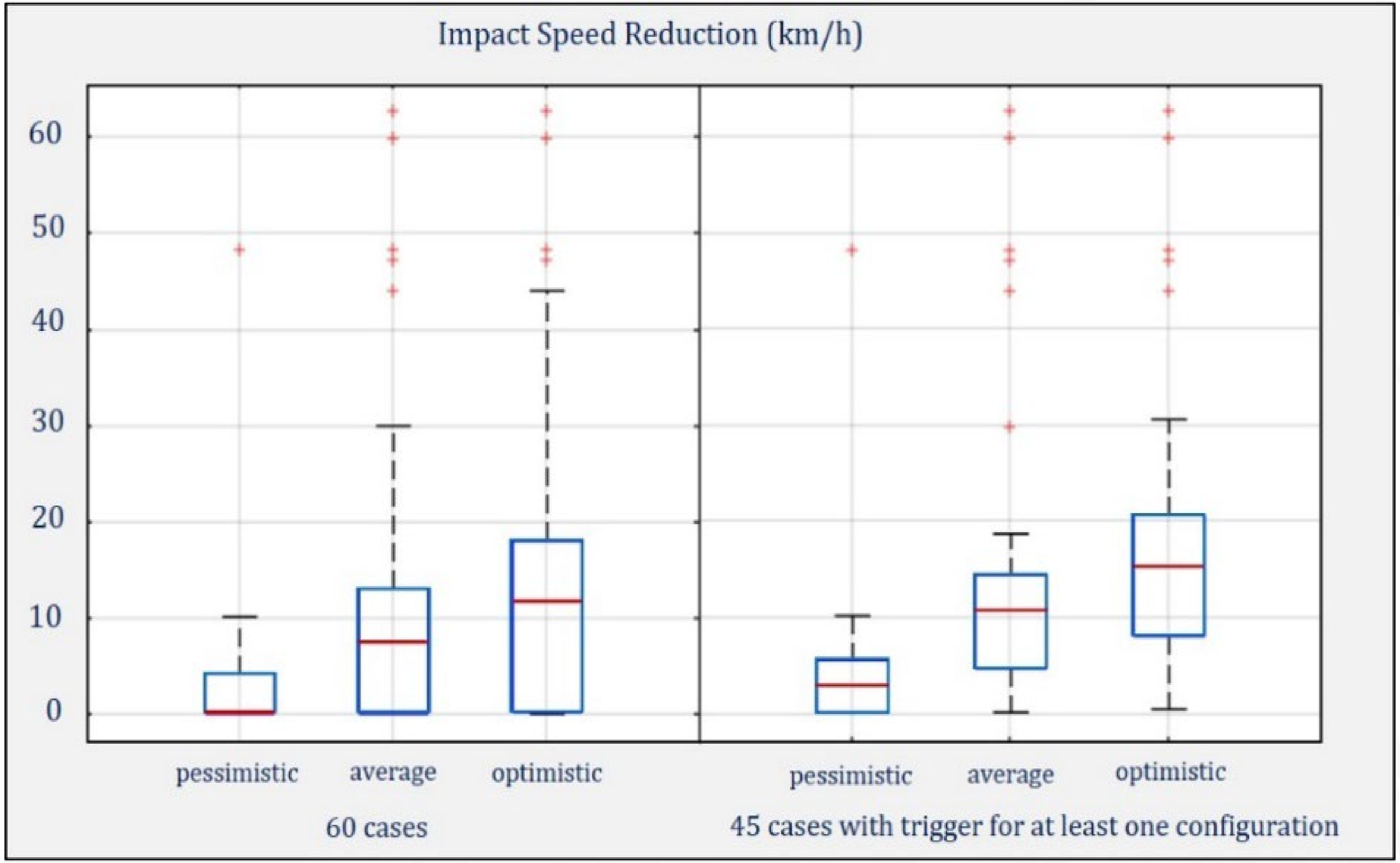
- ➢ Triggering of MAEB at **inevitable collision** state
- ➢ Employing different **PCB working parameters**

PCB Benefits Estimation



Results – PCB Impact Speed Reduction

- 45/60 cases with active PCB
- 3 realistic configuration tested:
  - **Pessimistic**: mean impact speed reduction of **2.8** km/h
  - **Average**: mean impact speed reduction of **10.7** km/h
  - **Optimistic**: mean impact speed reduction of **15.1** km/h



Goal

Identify **suitable parameters** of intervention and technical requirements for **safe and effective application of PCB**

PCB working parameters

Field testing

Crash modeling

PCB feasibility and acceptability

PCB benefits assessment

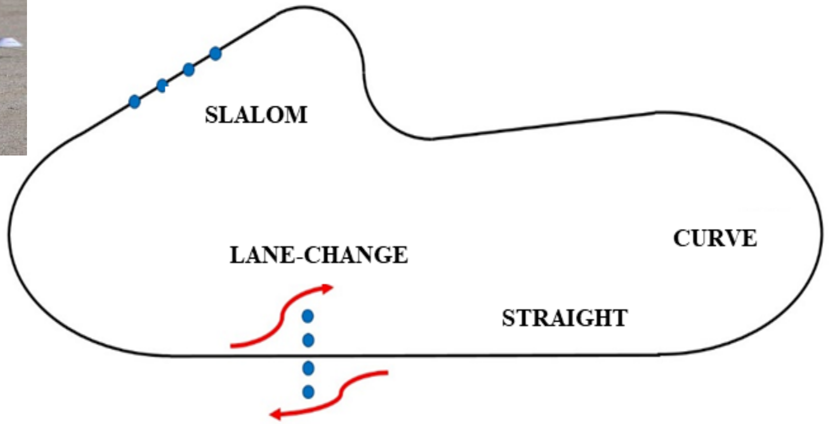
Field Tests

Stratified sampling: 51 participants, common riders

Piaggio MP3

- 10 days of test - 20 participants
- Two maneuvers
- PCB nominal **deceleration**: 0.3 & 0.5 g
- PCB nominal **fade-in jerk**: 1.5 g/s & 0.5 g/5

→ Approx **400 AB interventions**



Ducati Multistrada 1260s

- 14 days of test - 31 participants
- Four maneuvers
- PCB nominal **deceleration**: 0.3 & 0.5 g
- PCB nominal **fade-in jerk**: 1.5 g/s

→ Approx **600 AB interventions**

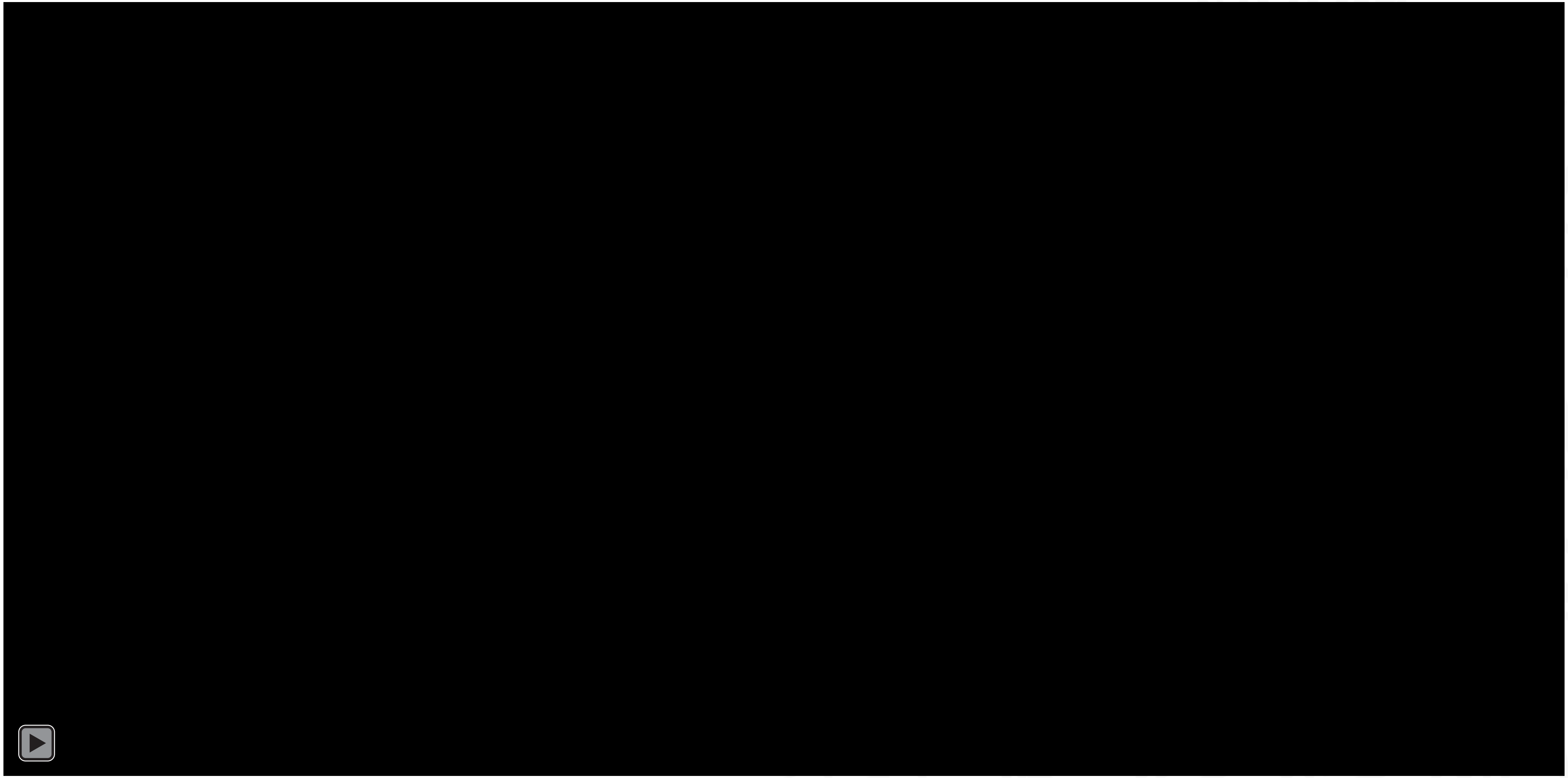
Ethical approval *by the Ethics Committee of the University of Florence - (Written opinion N. 46, 20/03/2019)*

Tests Protocol

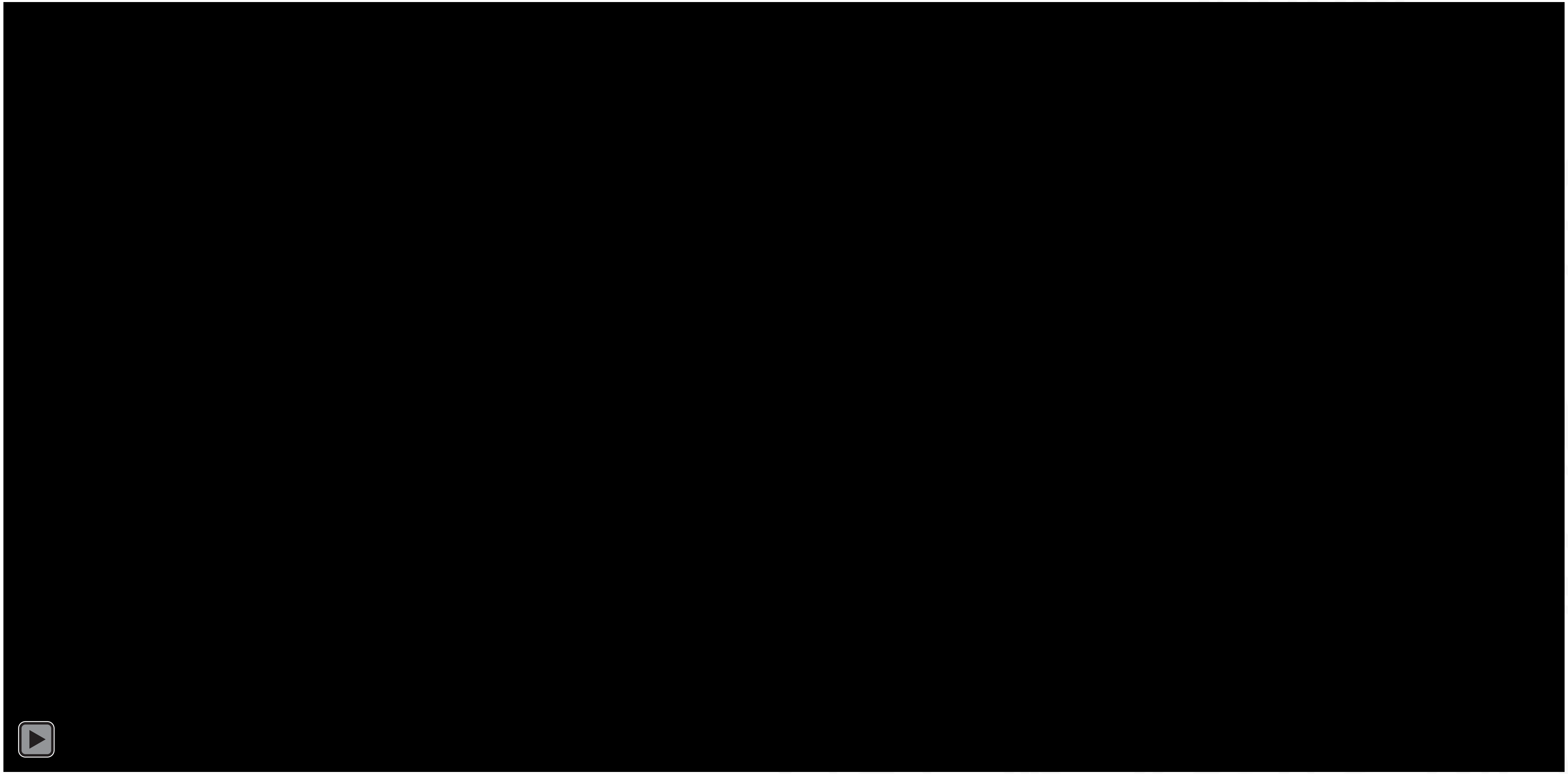
1. **Preparation** of the participant
2. **Warm-up** and familiarization with the test-track and the test-vehicle
3. Identification of the **participant's skills**: manual braking
4. **Familiarization with the Automatic Braking (AB) system**: AB declared activation in straight line
5. **Test sessions**: rider performing manoeuvres around the test-track with AB undeclared pseudo-random activations
6. Final questionnaire and brief interview

Lucci C, Marra M, Huertas-Leyva P, Baldanzini N, Savino G. **Investigating the feasibility of Motorcycle Autonomous Emergency Braking (MAEB): design criteria for new experiments to field test automatic braking.** MethodsX, 2021.

Straight lane



Avoidance manoeuvre



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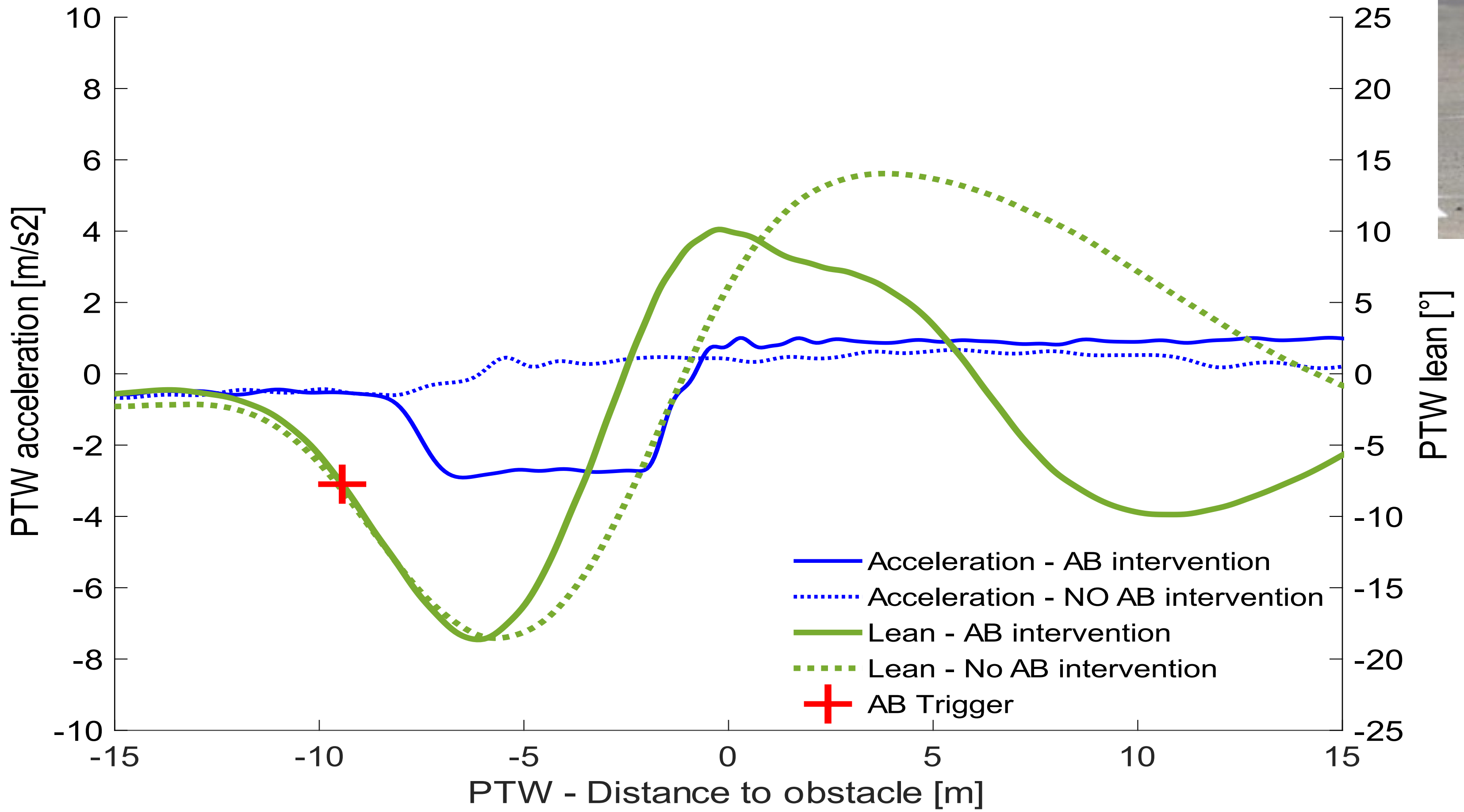
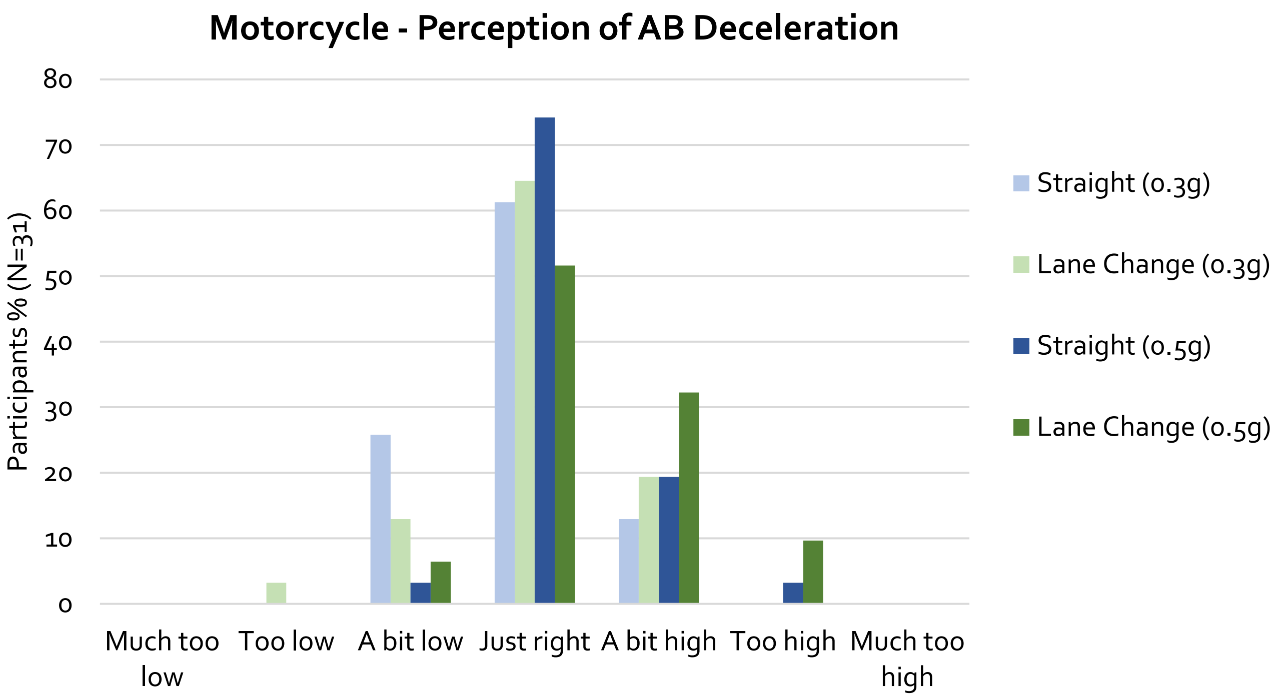
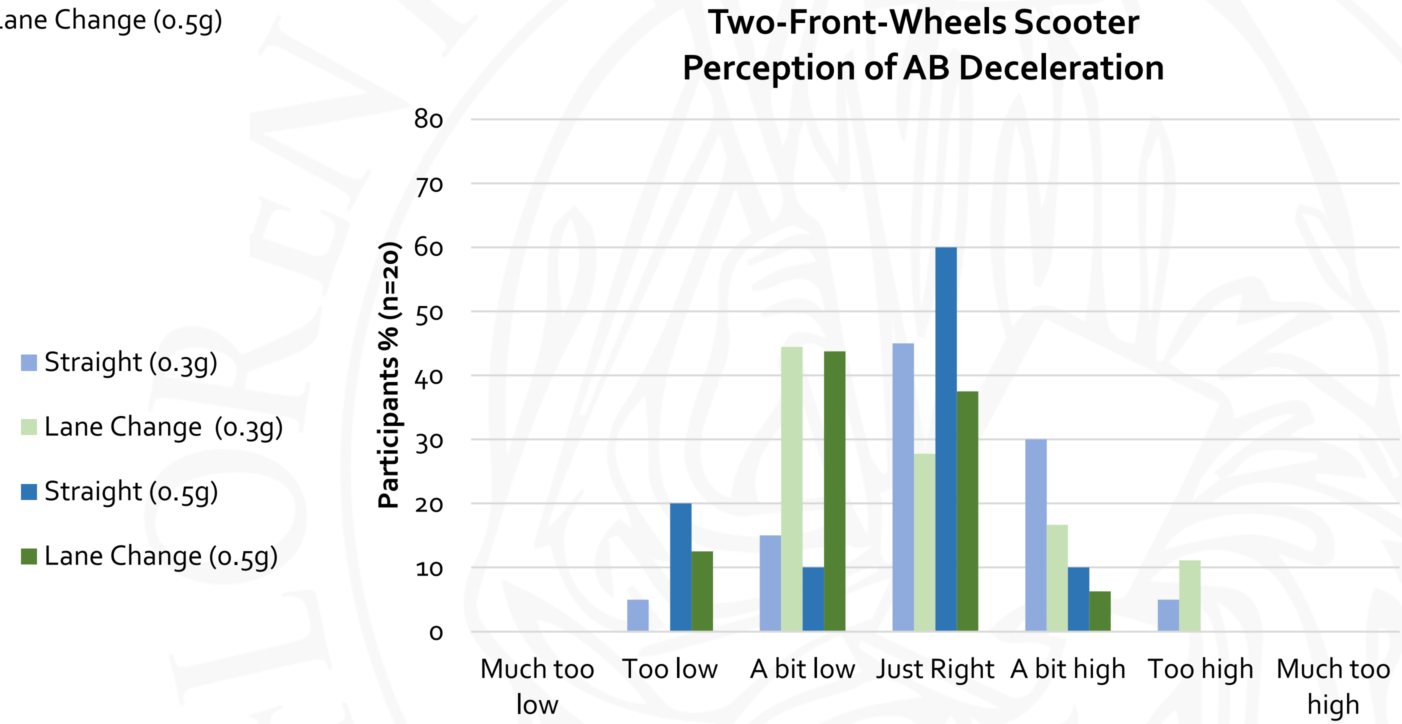
Test results – Avoidance manoeuvre



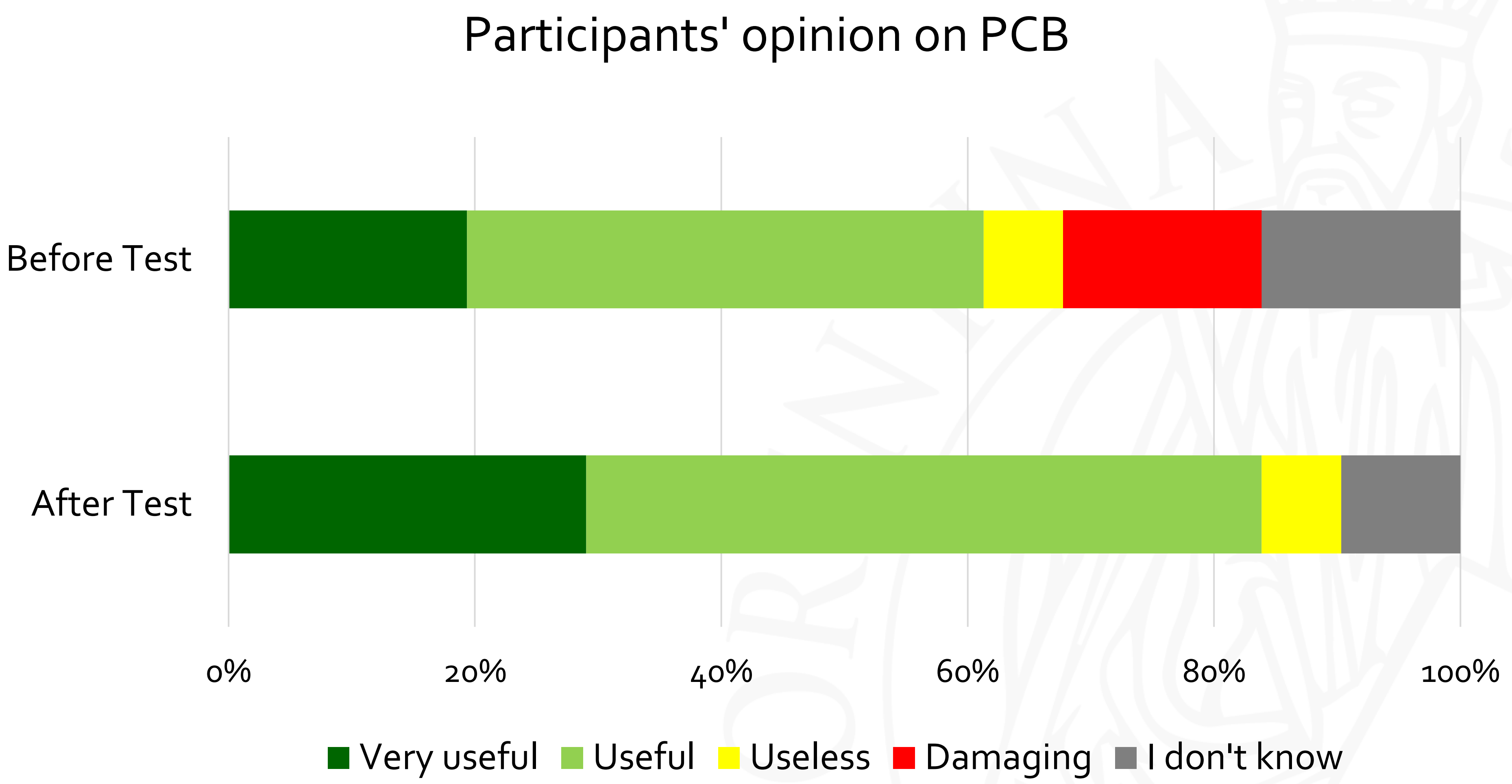
Lucci C, Baldanzini N, Savino G. **Field testing the applicability of motorcycle autonomous emergency braking (MAEB) during pre-crash avoidance manoeuvre**. Traffic Injury Prevention, 2021.

Test results – PCB deceleration





Test results – PCB acceptability

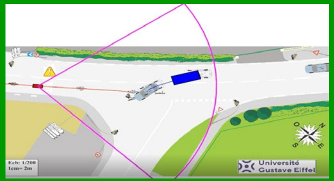


Lucci C, Baldanzini N, Savino G. **Does Motorcycle Autonomous Emergency Braking (MAEB) mitigate rider injuries and fatalities? Design of effective working parameters and field test validation of their acceptability.** Transportation Research part C: Emerging Technologies, 2022

Conclusions – Importance of PCB parameters

Field testing

Crash modeling



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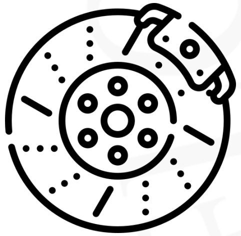
PCB **safely applicable** not only in straight-line

- *Lean angle up to 25 °*
- *During manoeuvres (e.g., swerve before crash)*

High levels of PCB intervention feasible

- *Deceleration up to* ***0.5 g***
- *Fade-in jerk up to* ***2 g/s***



Obstacle recognition parameters

- *Standard & Progressive triggering effective*
- *Field of view ≥ 80° required*

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Thank you for your attention !

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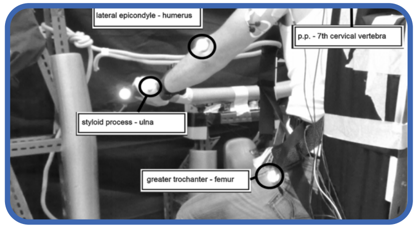
Literature review



Analysis of the stability of PTW riders in autonomous braking scenarios

I. Symeonidis et al. – 2012

PISa Project (Powered-two-wheelers Integrated Safety)

G. Savino et al. – 2012

ABRAM Project (Autonomous BRAking for Motorcycles)

G. Savino et al. – 2016

Limits of Autonomous Emergency Brake Systems for Powered Two-Wheelers – an Expert Study

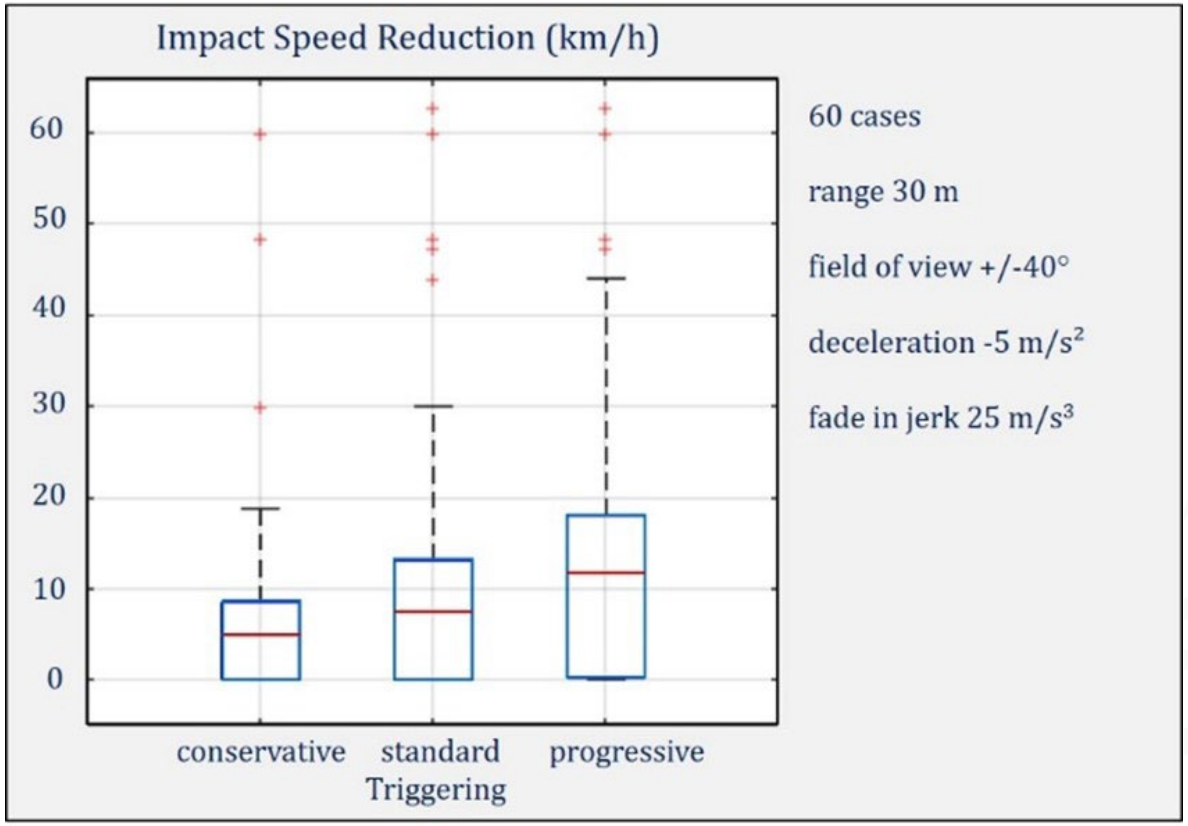
N. Merkel et al. – 2018

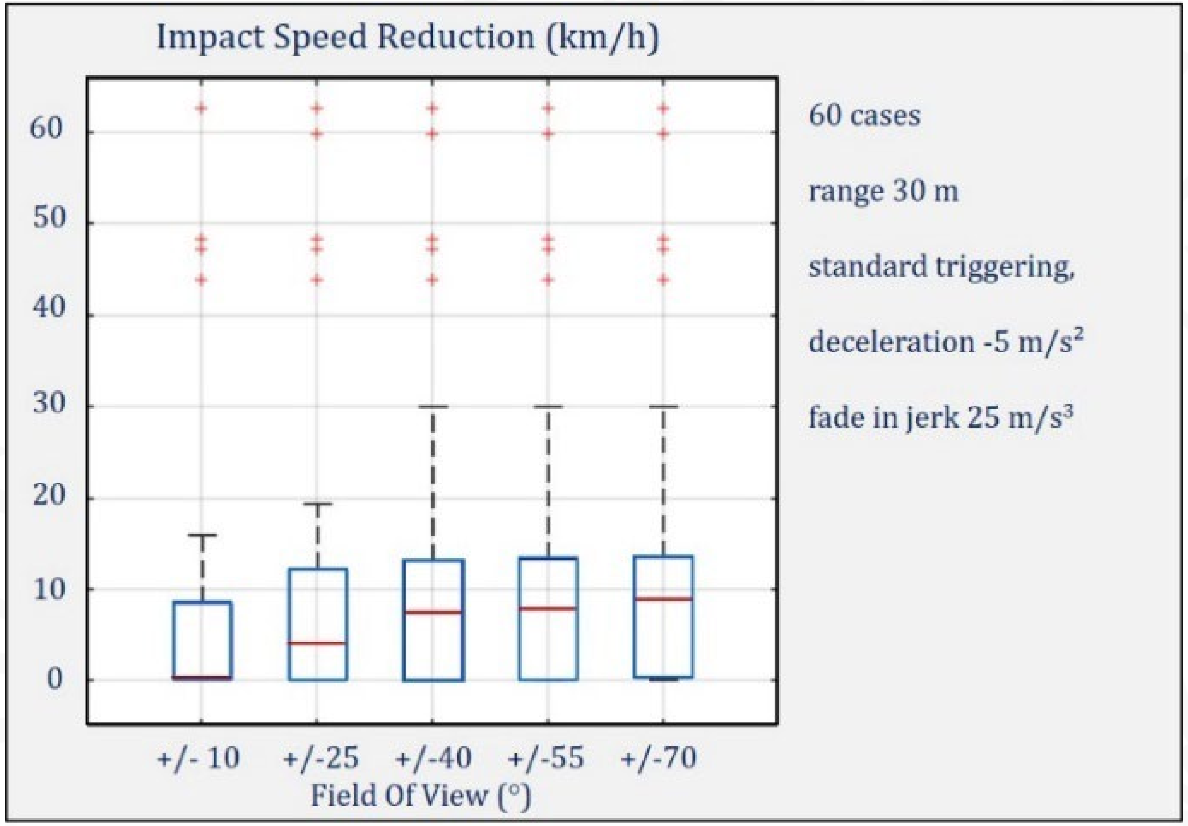
Literature review

Safety Sistem	Category 1 (not relevant)			Category 2 (possible)			Category 3 (probably)			Category 4 (definitely)		
	Prato	USA	Victoria	Prato	USA	Victoria	Prato	USA	Victoria	Prato	USA	Victoria
ABS	8,8%	15,4%	7,1%	13,0%	54,3%	49,3%	3,5%	3,1%	2,3%	74,7%	27,2%	40,6%
MAEB	21,4%	32,8%	52,1%	27,0%	47,5%	24,3%	41,1%	8,1%	17,3%	10,5%	11,6%	5,7%
Collision warning	19,6%	32,7%	41,6%	3,9%	37,4%	14,1%	36,5%	8,7%	20,5%	40,0%	21,2%	23,1%
Curve warning	90,9%	58,2%	79,1%	4,6%	32,2%	4,4%	0%	0%	0%	4,6%	9,6%	15,8%
Curve assist	70,2%	72,0%	43,5%	22,8%	14,7%	36,6%	2,5%	3,4%	3,2%	4,6%	9,9%	16,1%

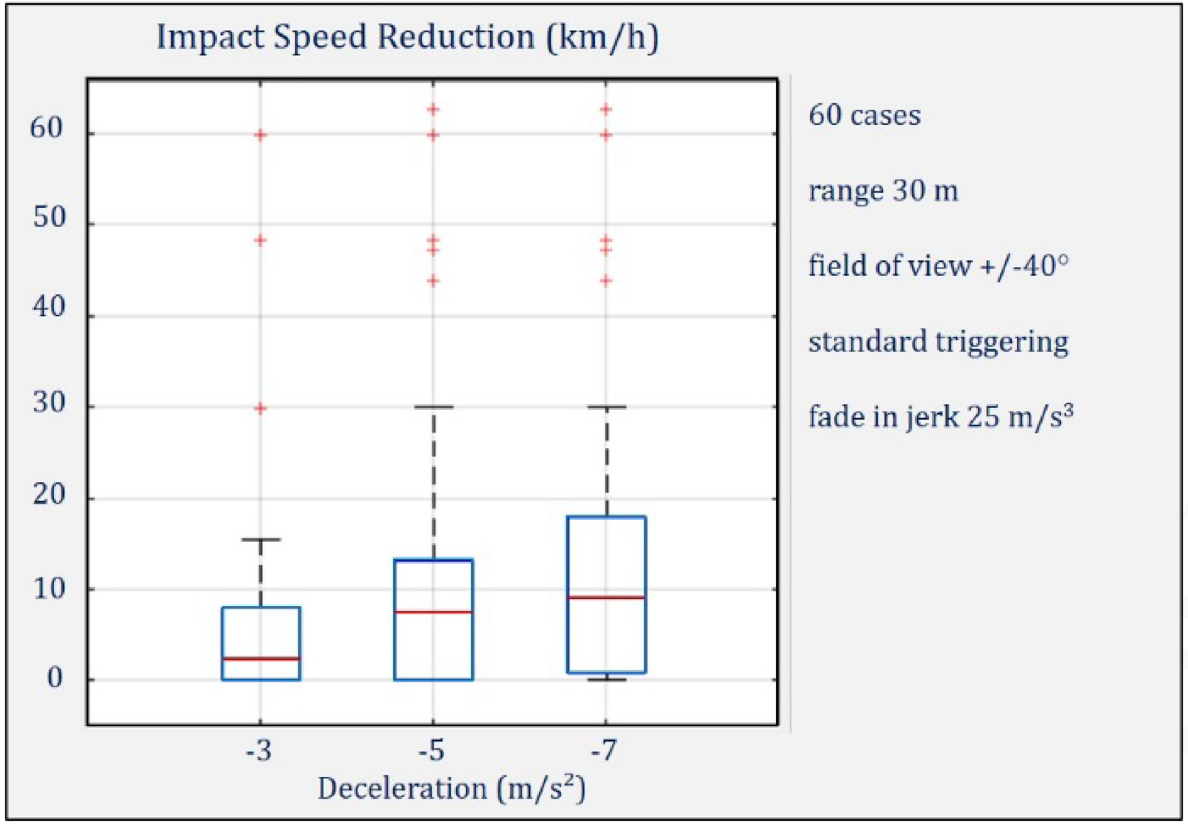
*P. Terranova, M. Dean, H. C. Gabler, S. Piantini, and G. Savino, "**Active safety systems for motorcycles where are we A novel transnational comparison of applicability in the Australian, American and Italian fleets**" in AAAM Student Symposium, 2020, pp. 2018–2020*

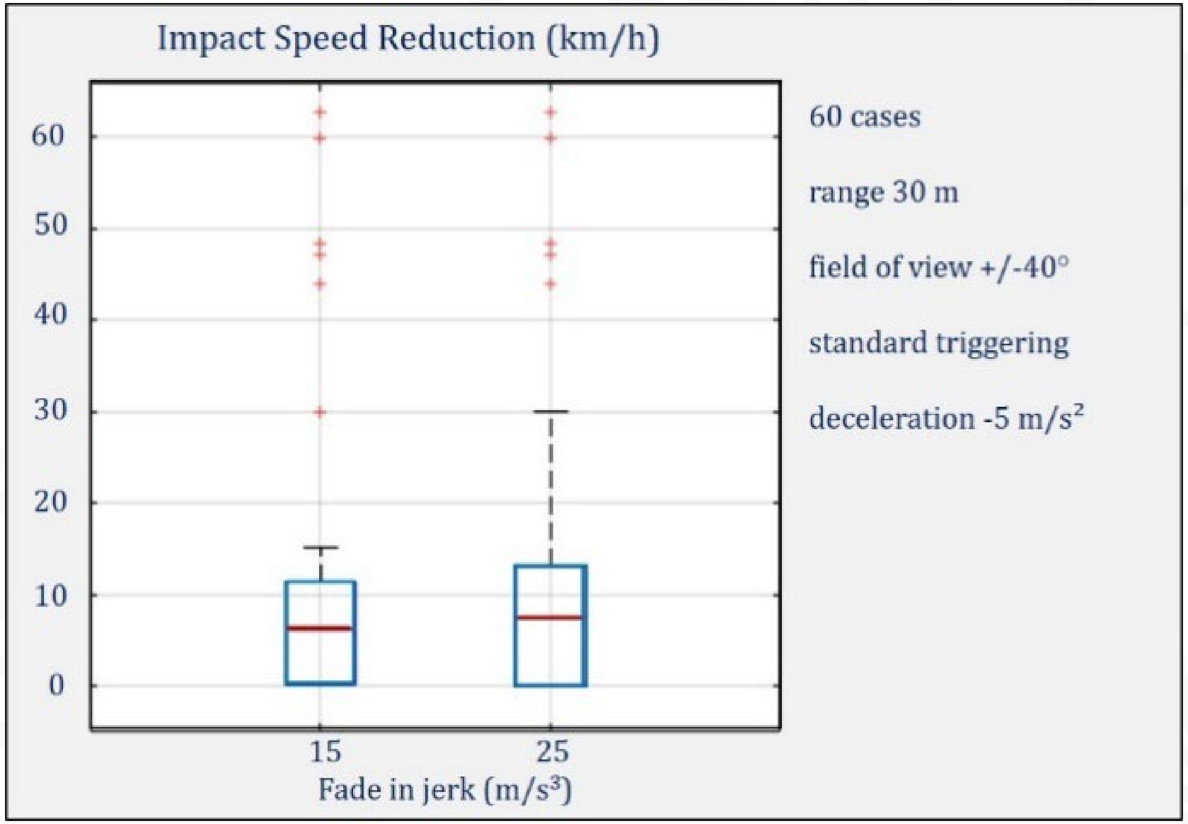
Results – PCB Triggering & Field of view





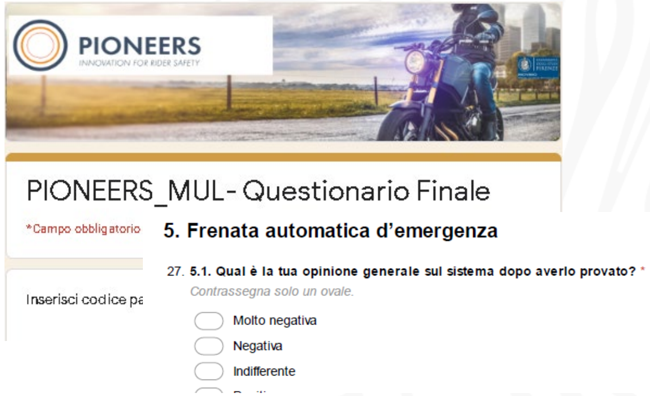
Results – PCB Deceleration & Fade-in jerk



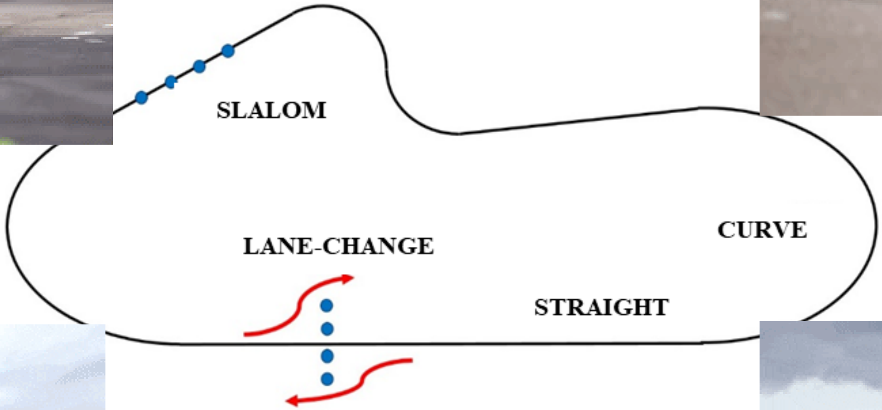


Equipment and instrumentation

- Vehicle data
- Rider IMU sensor
- Action cameras
- Questionnaires
- Full protective equipment and airbag jacket
- Outriggers



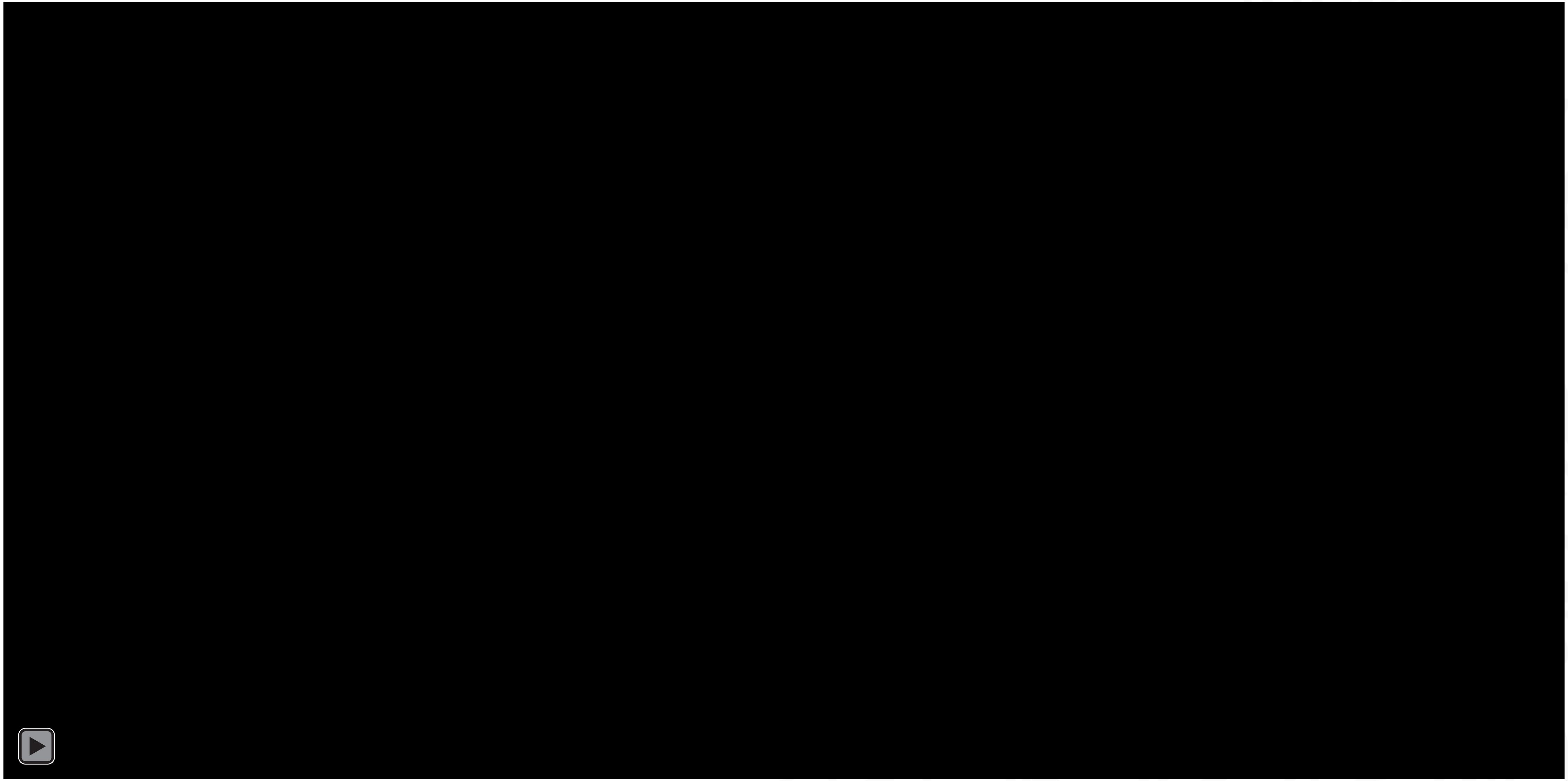
Test protocol



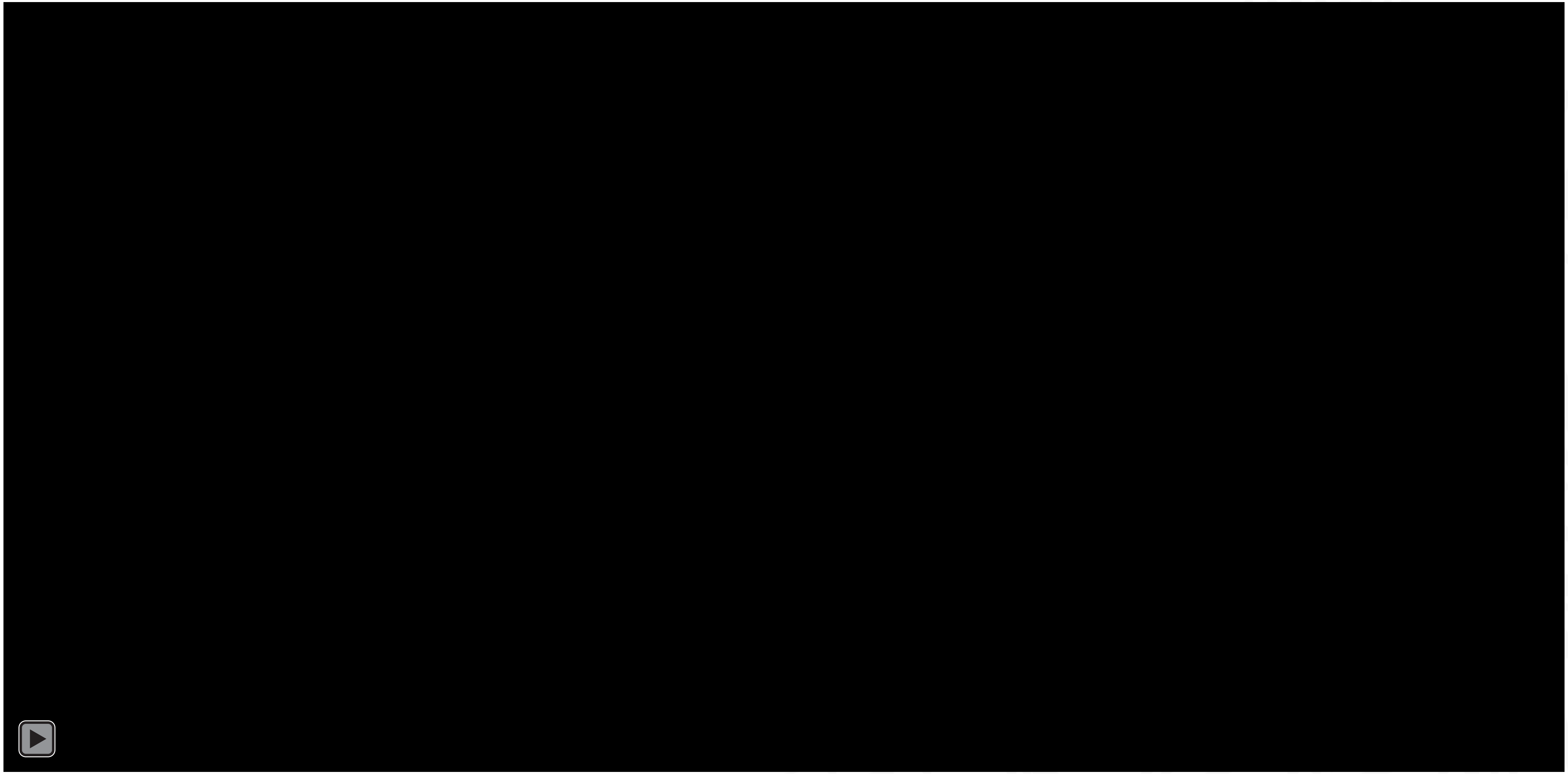
Field tests results

Test Vehicle	Participants	Manoeuvre	Nominal deceleration [m/s²]	N° of PCB activations	Initial Speed [km/h]		Event duration [s]		Deceleration [m/s²]		Fade-in jerk [m/s³]	
					Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ducati Multistrada	31	Straight-line	3	63	47.6	4.7	1.07	0.03	2.9	0.3	15.0	4.0
		Lane change		65	41. 7	6.0	1.05	0.11	3.0	0.4	12.6	4.1
		Straight-line	5	63	49.1	4.7	1.14	0.03	4.7	0.4	20.2	3.9
		Lane change		65	41.5	5.4	1.05	0.20	4.8	0.4	19.6	7.3
Piaggio MP3	20	Straight-line	3	42	40.7	3.8	0.97	0.12	3.1	0.3	15.3	3.4
		Lane change		34	38.8	3.2	0.96	0.13	3.6	0.3	17.2	3.9
		Straight-line	5	40	41.1	4.7	1.00	0.00	4.7	0.4	18.9	3.2
		Lane change		33	39.4	3.3	0.93	0.19	5.2	0.5	20.5	4.4

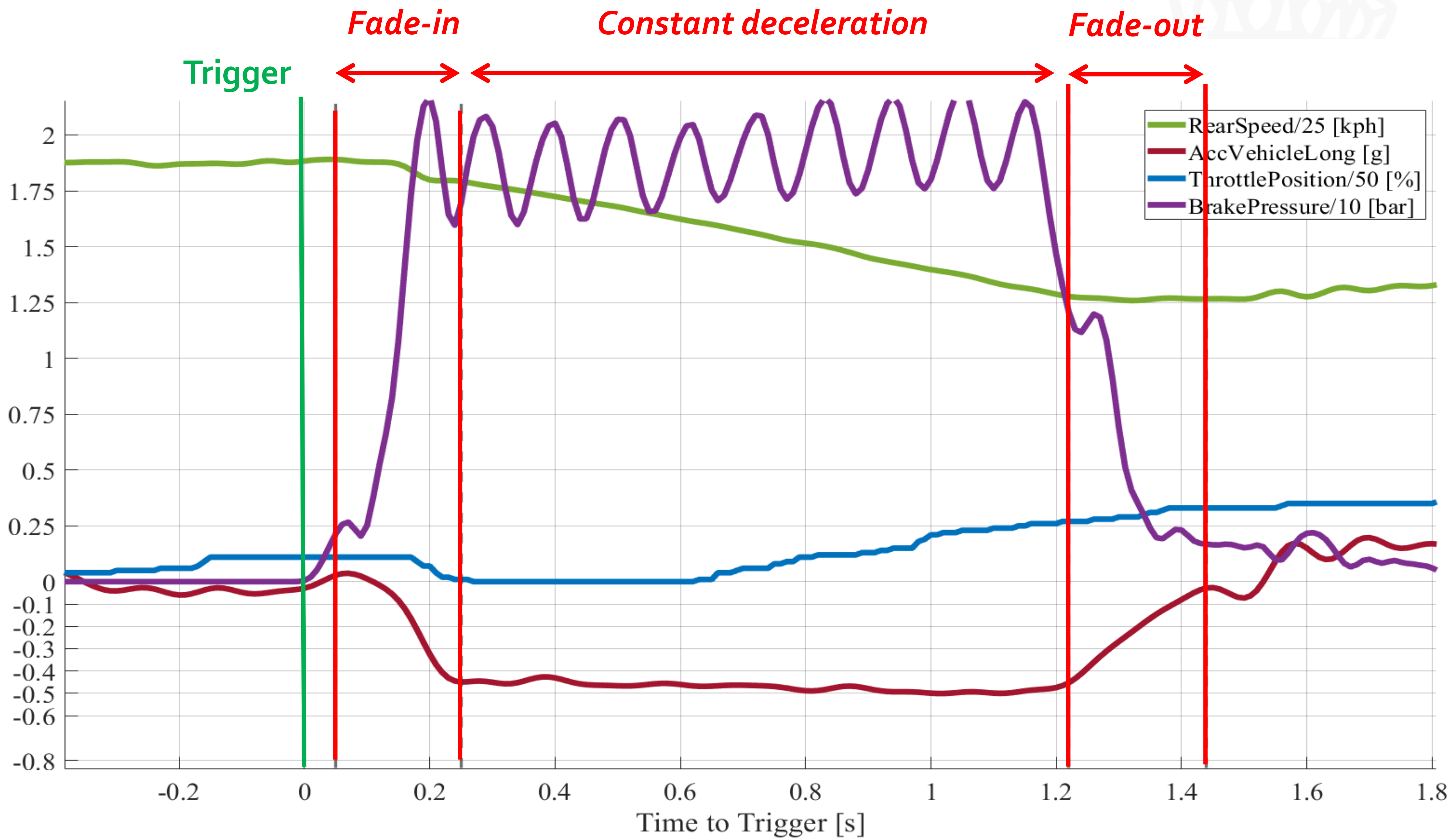
Slalom



Curve

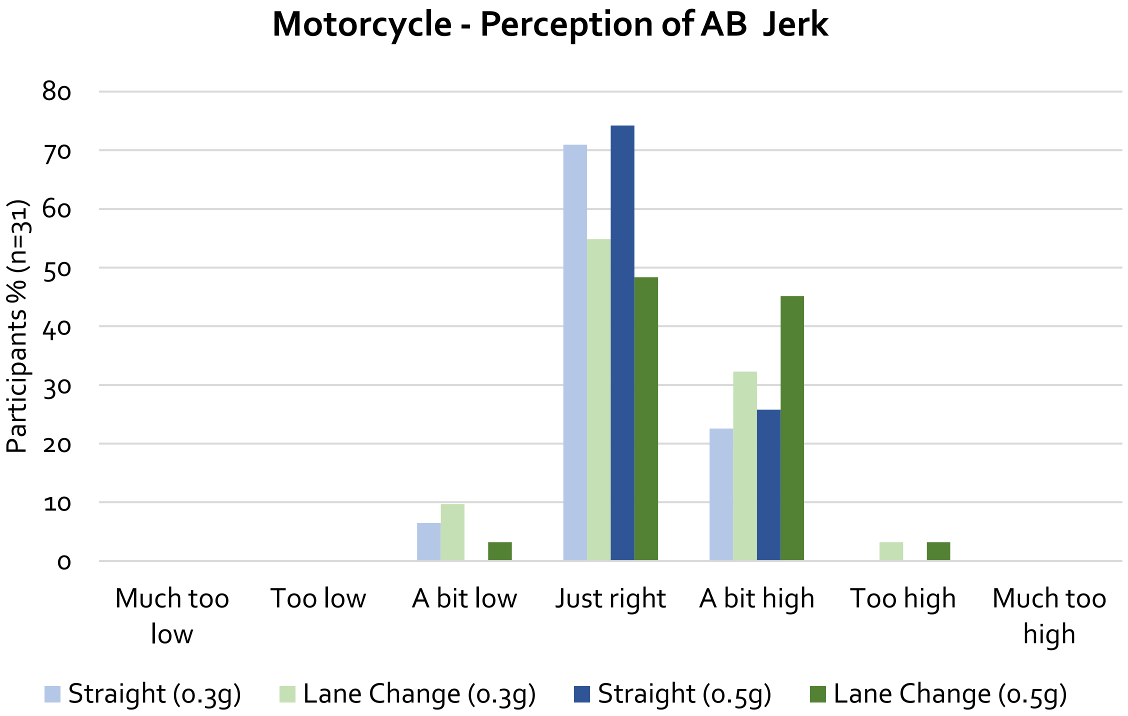


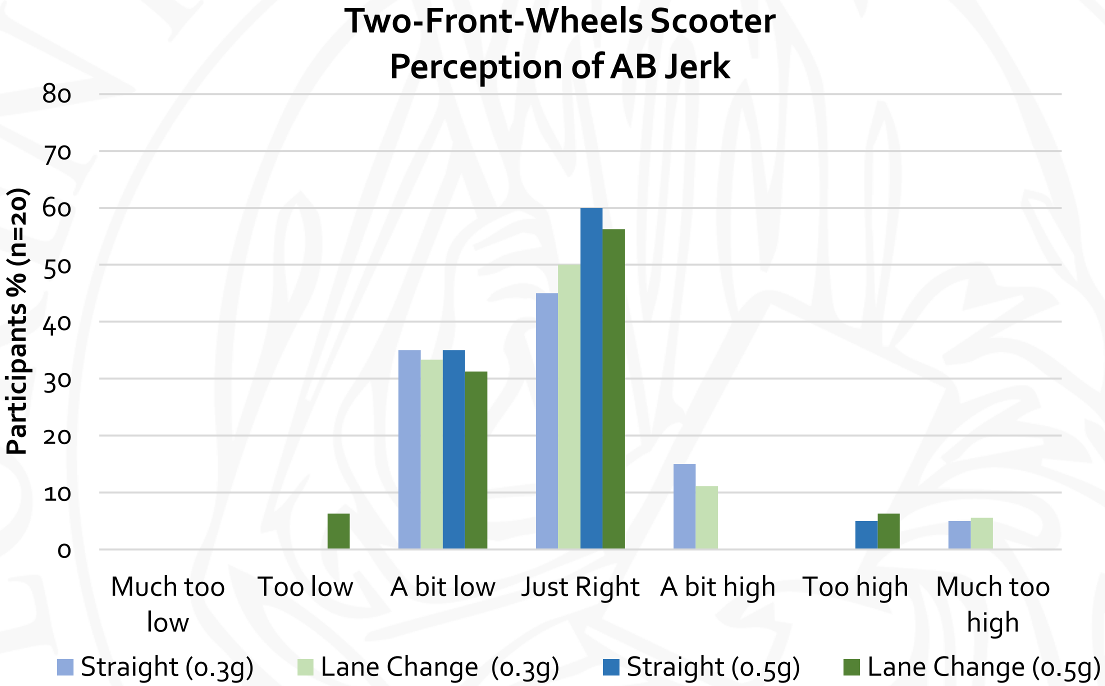
Curve



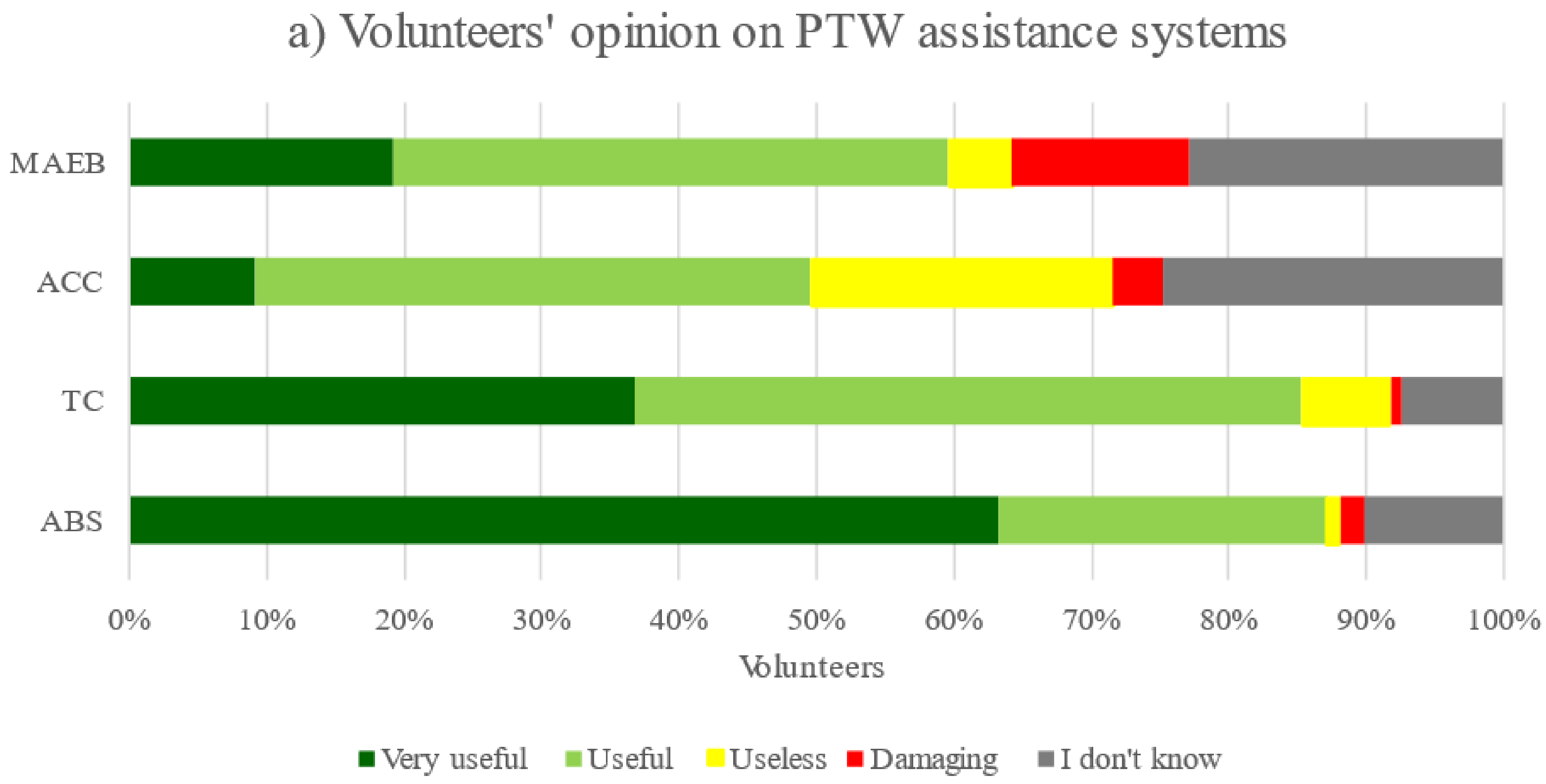
Fade-in
Constant deceleration
Fade-out
Trigger
RearSpeed/25 [kph]
AccVehicleLong [g]
ThrottlePosition/50 [%]
BrakePressure/10 [bar]
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.8
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Time to Trigger [s]

Test results – PCB Fade-in jerk





Test Results



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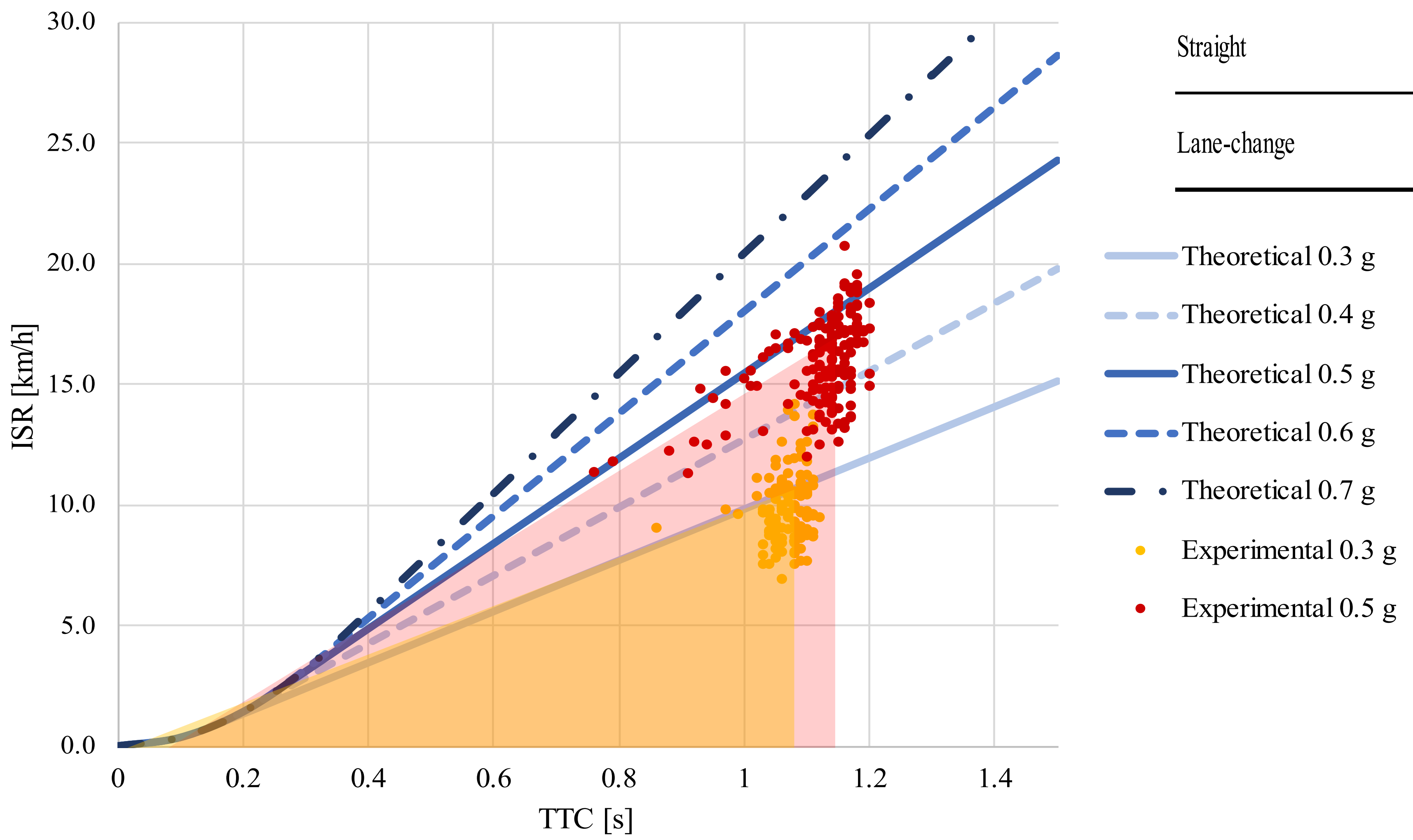
Test Results



Manoeuvre	Nominal Deceleration [g]	TTC [s]		ISR [km/h]	
		Mean	SD	Mean	SD
Straight	0.3	1.07	0.027	9.9	1.65
	0.5	1.14	0.031	16.1	1.81
Lane-change	0.3	1.07	0.037	10.1	1.31
	0.5	1.08	0.098	15.5	1.80

Test Results