ICTCT Webinar 28 November 2025

How can game theory contribute to understanding road user behaviour?

Torkel Bjørnskau, Institute of Transport Economics

Outline

1. Why game theory?
2. What is it?
3. Why is it useful for us?

This is/was me

- Master in Political Science 1985
- Researcher at TØI january 1986

- Dr. polit 1994:
  Game Theory, Road Traffic and Accidents; A Theory of Road User Interaction.
  TØI report 287/1994. Oslo: Institute of Transport Economics

Outline

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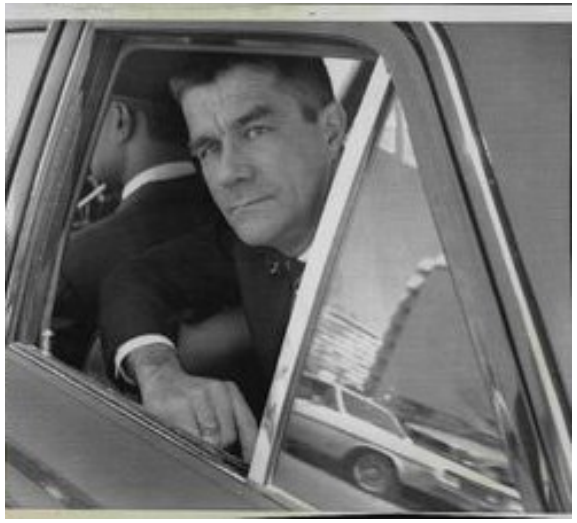
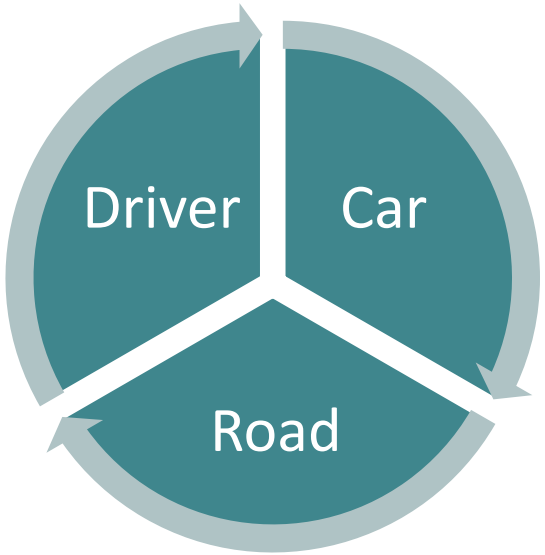
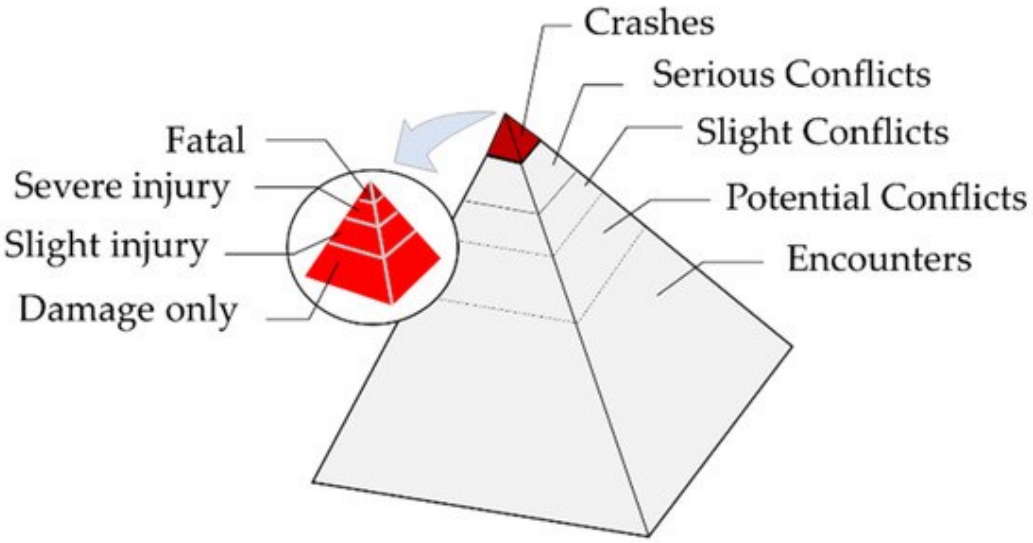
Road safety reserach late 1980s

Traffic engineering: System theory (barriers) + Conflict studies



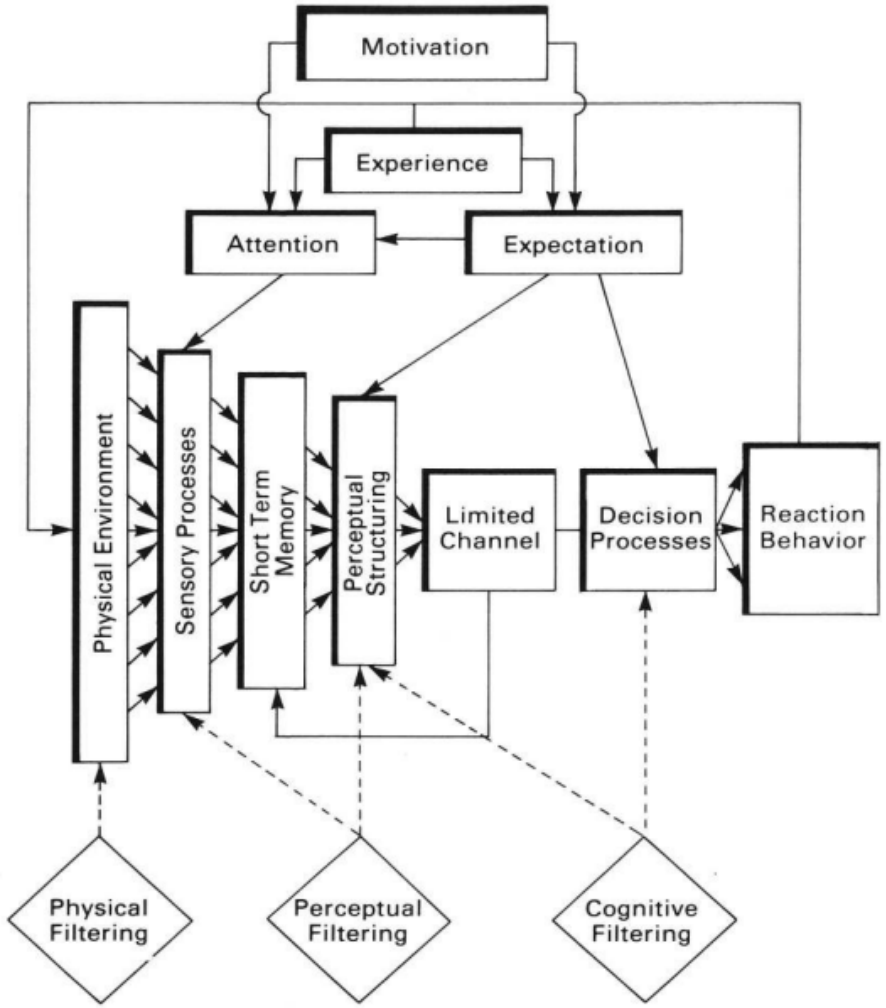




Road safety reserach late 1980s

Traffic psychology: **Cognition/Perception**

- Kåre Rumar (1985)
- John Michon (1985)
- Jens Rasmussen (1983)
- John Groeger (1988)
- Van der Molen & Bötticher (1988)

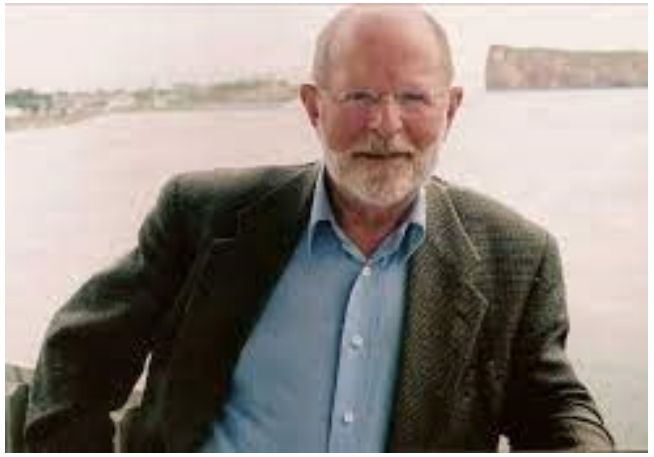


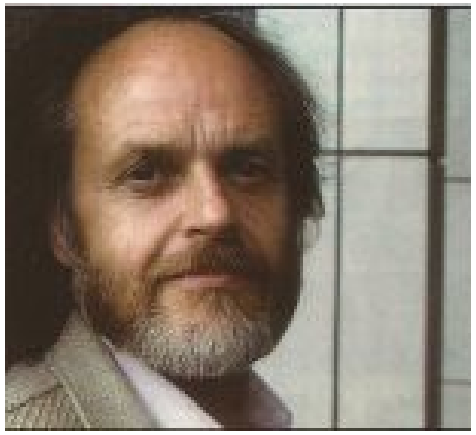
Rumar, K. (1985) The role of perceptual and congnitive filters in observed behavior. In Evans, L. & Schwing (eds.) Human Behaviour and Traffic Safety. Plenum Press.

Road safety reserach late 1980s

Traffic psychology: **Motivation**

- Gerald Wilde (1982): Target level of risk
- Näätänen & Summala (1976): Zero-risk
- Ray Fuller (1984): Threat avoidance



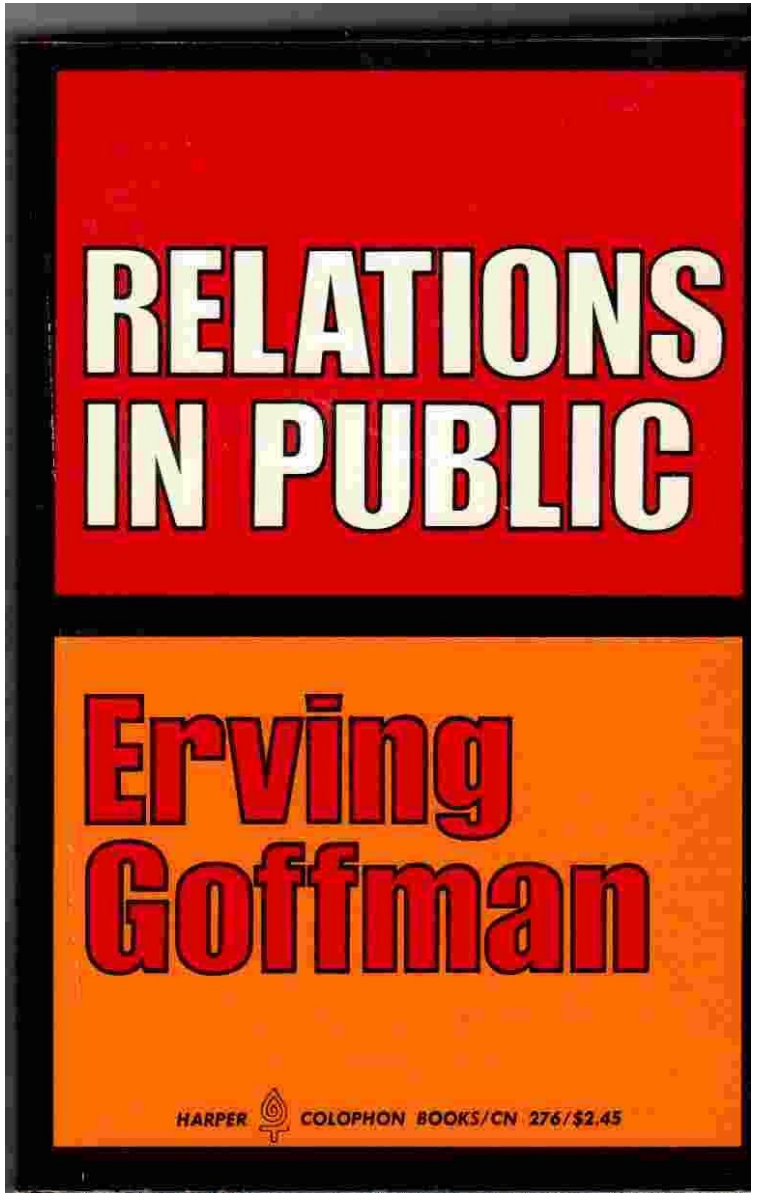


Motivation

«.. his (the driver's) role as an **active creator** of of the traffic situations he is faced with .. has not been given satisfactory notice and, consequently, the **decision-making aspect** of traffic behavior .. has not received research interest in proportion to its importance to road safety».

Näätänen R. & Summala, H. (1976) Road User Behavior and Traffic Accidents (p. 41). North-Holland, Amsterdam-Oxford & American Elsevier, New York.

Motivation but no focus on interaction ..


RELATIONS
IN PUBLIC
Erving
Goffman
HARPER
COLOPHON BOOKS/CN 276/$2.45

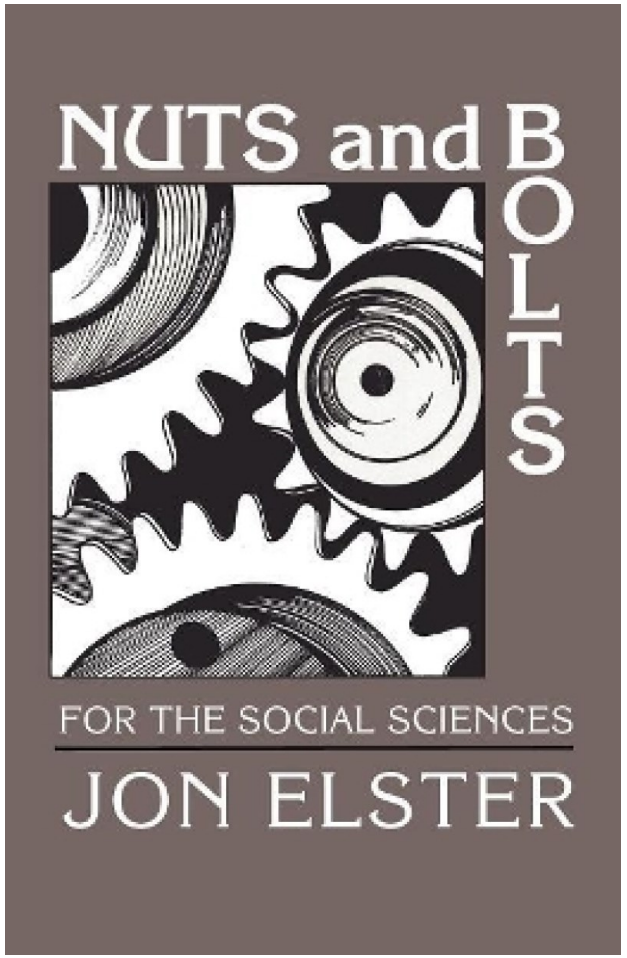
Erving Goffman

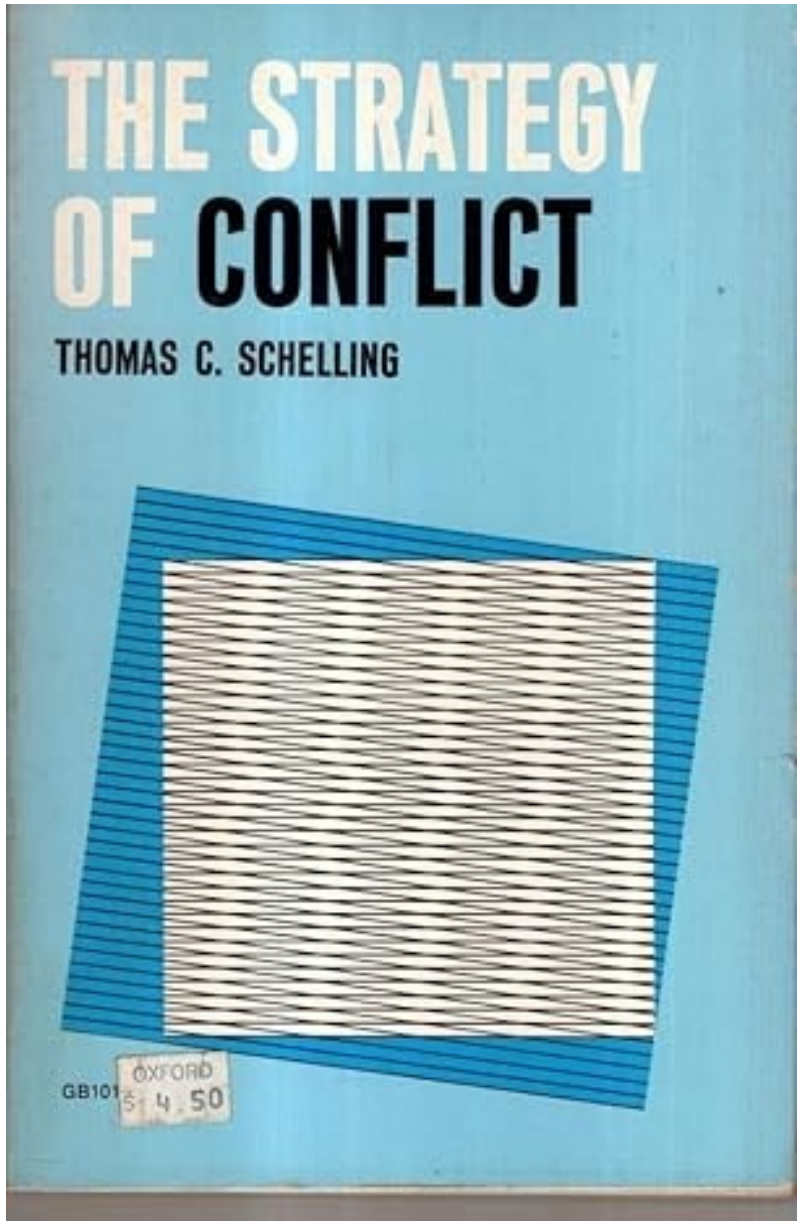
- By not allowing pedestrians to catch his eye, a driver can keep them in a hestiant condition.
- By ostensibly failing to read a course sign that has been pointedly given to him, one driver can force another driver to fall back or accept a «chicken» challenge.
- By «catching» the eye of a driver, another can qesture a request (for example to cut into a line of of cars from a side road, or pull out into the traffic) for which no effective body gesture is available.

Goffman E. (1971). Relations in Public. Microstudies of the Social Order (p. 35). Penguin Books Ltd.

Whe need a tool to model such interaction

"…if one accepts that interaction is the essence of social life, then **game theory** provides solid micro foundations for the study of social structure" (Elster, 1982)




THE STRATEGY
OF CONFLICT
THOMAS C. SCHELLING
OXFORD
GB101
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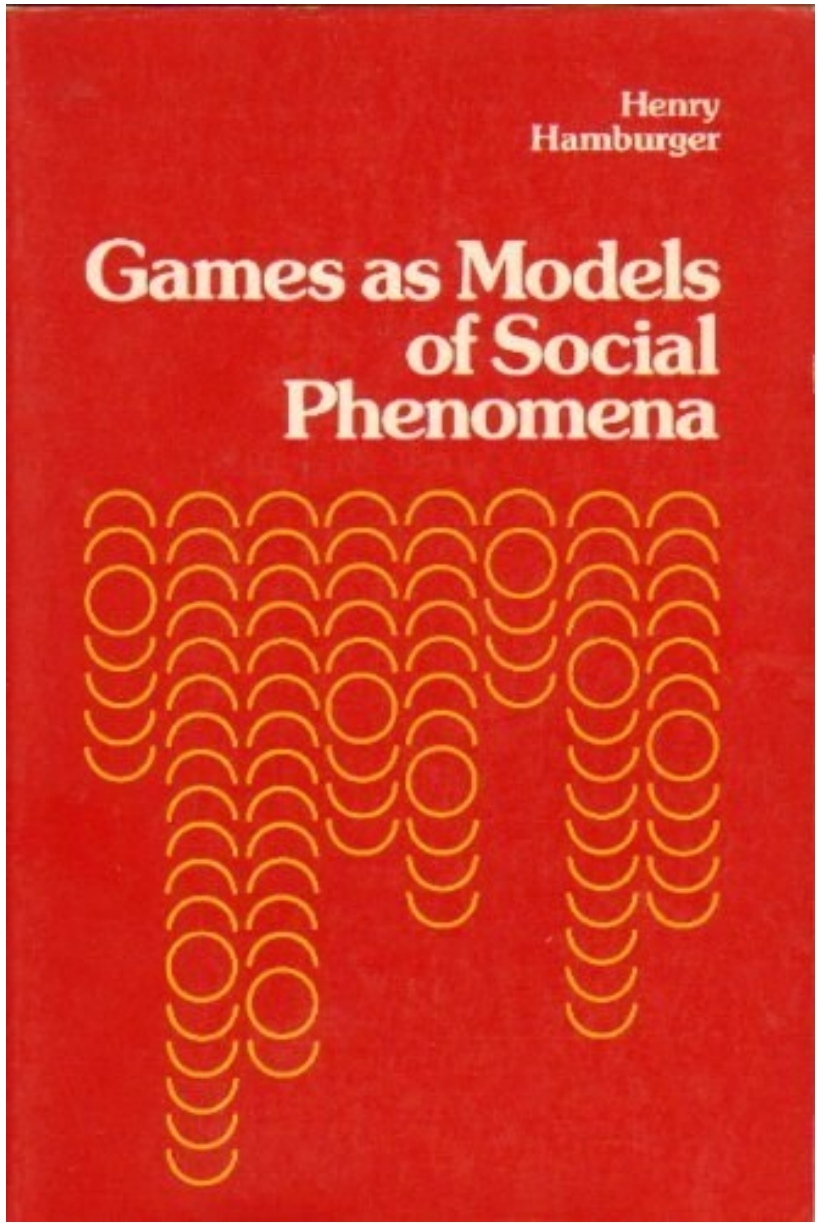
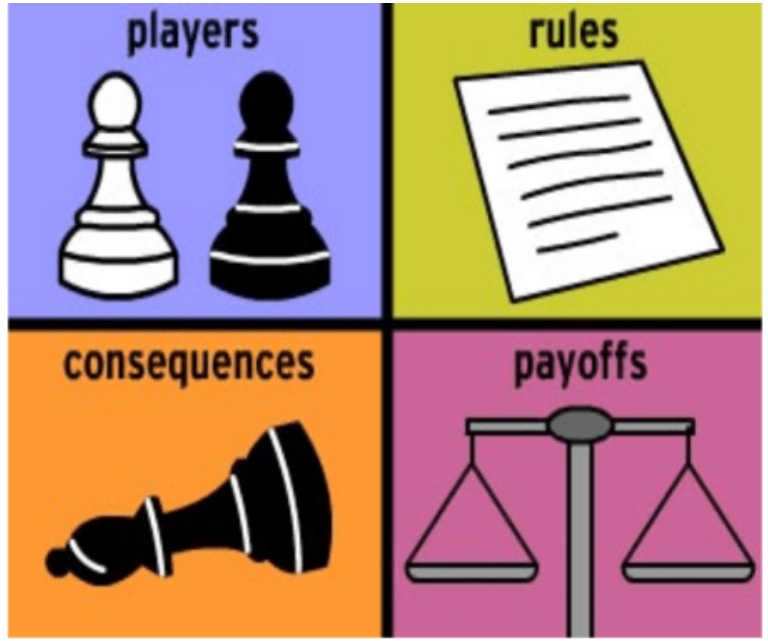

Henry
Hamburger
Games as Models
of Social
Phenomena

Outline

1. Why game theory?
2. **What is it?**
3. Why is it useful for us?

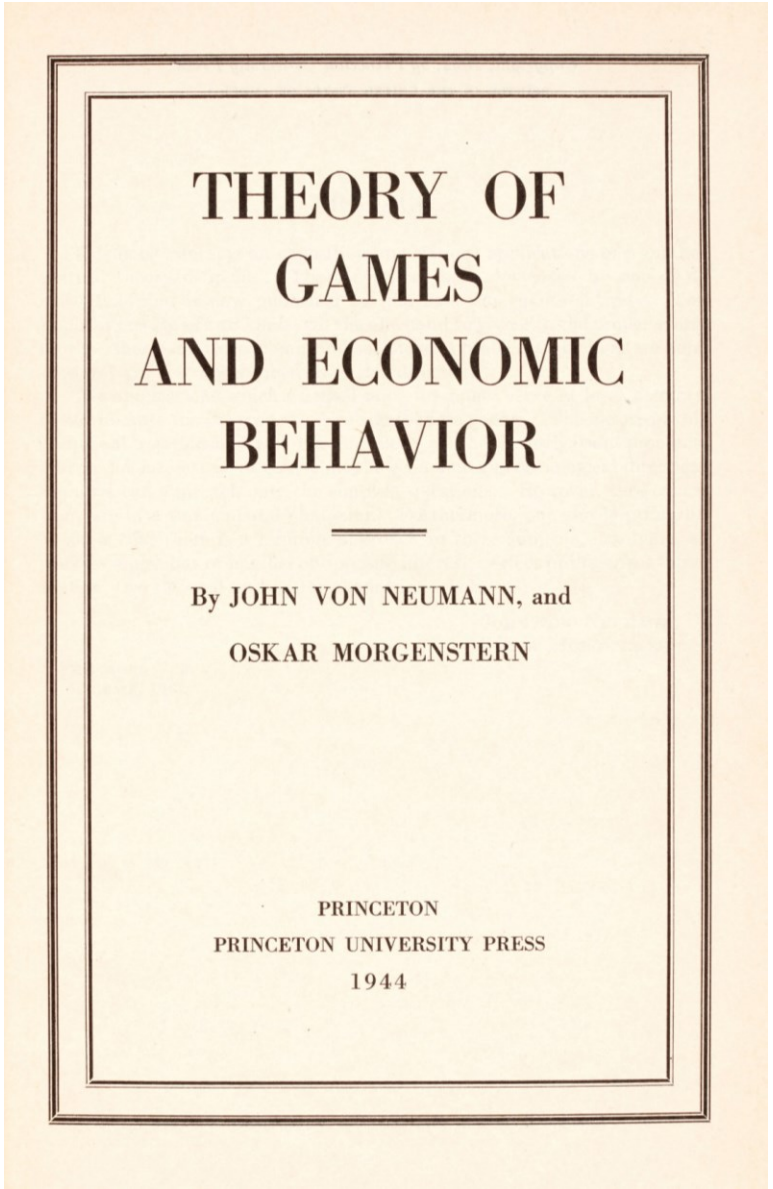
What is game theory?

- A game is a situation where **two or more** decision-makers (players) interact and the **outcome** for each depends both on their own choices and the choices of others.
- Each player has a **set of possible actions** (strategies) they can choose from.
- Players try to **maximise benefit or minimise loss**.
- Because everyone's outcome depends on everyone else's decisions, players must act upon **beliefs** about what others will do.
- Game theory studies how people behave in such interactive situations, predicting when they **cooperate**, when they **compete**, and how **stable patterns of behaviour (equilibria)** can emerge.



Traditional game theory

- Formal mathematical study of interaction between two or more players
- Perfect rationality
- Complete information
- Solutions can be deduced
- Example: Chess


THEORY OF GAMES AND ECONOMIC BEHAVIOR

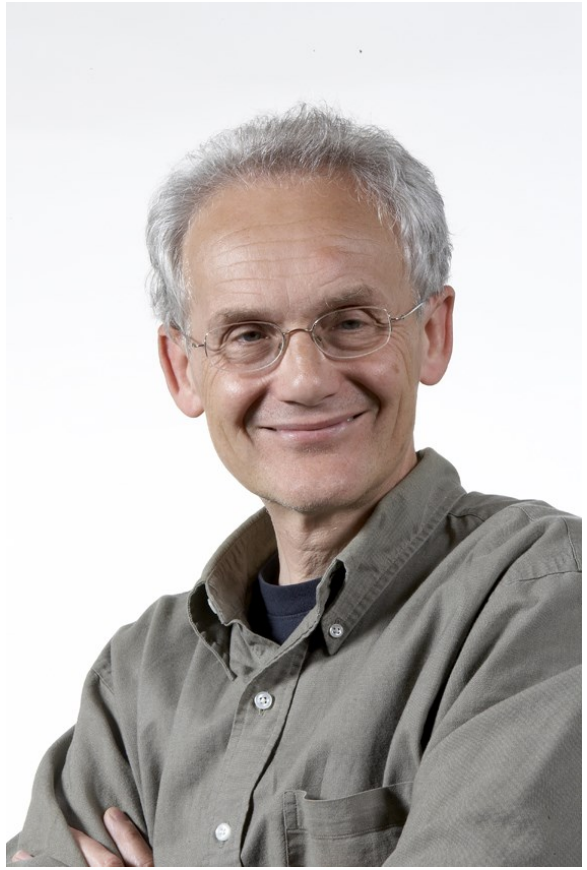
By JOHN VON NEUMANN, and OSKAR MORGENSTERN

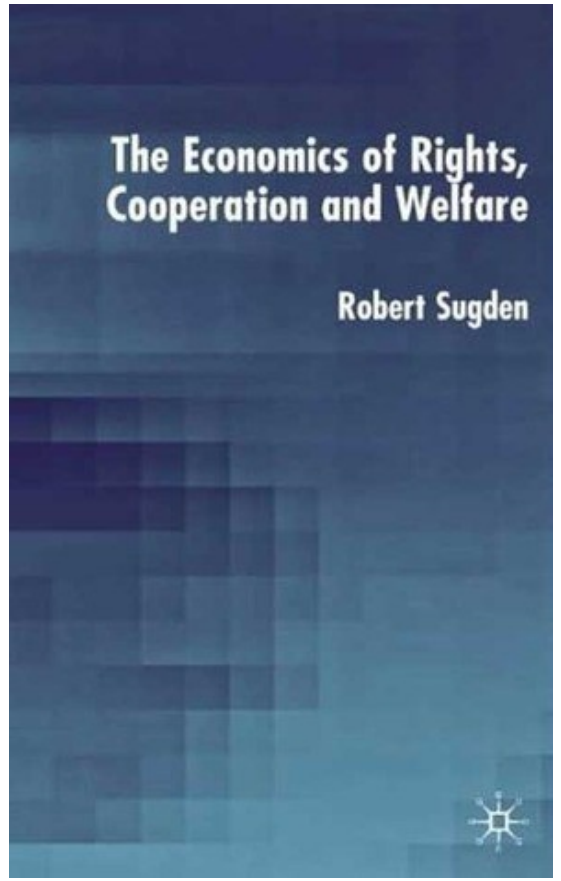
PRINCETON
PRINCETON UNIVERSITY PRESS
1944

Modern dynamic/behavioural game theory

- «If I am to explain these phenomena (social conventions) as the product of game-playing behaviour, **I need a theory of how peple actually play games**. Any assumptions I make about behaviour must be ones that most human beings act on .. in almost all places and times.

- I can make no use of a concept of rationality that is so sophisticated that ordinary people do not act on unless it has been carefully explained to them»





Sugden, R. (1986). The Economics of Rights, Co-operation and Welfare (p. 16). Basil Blackwell

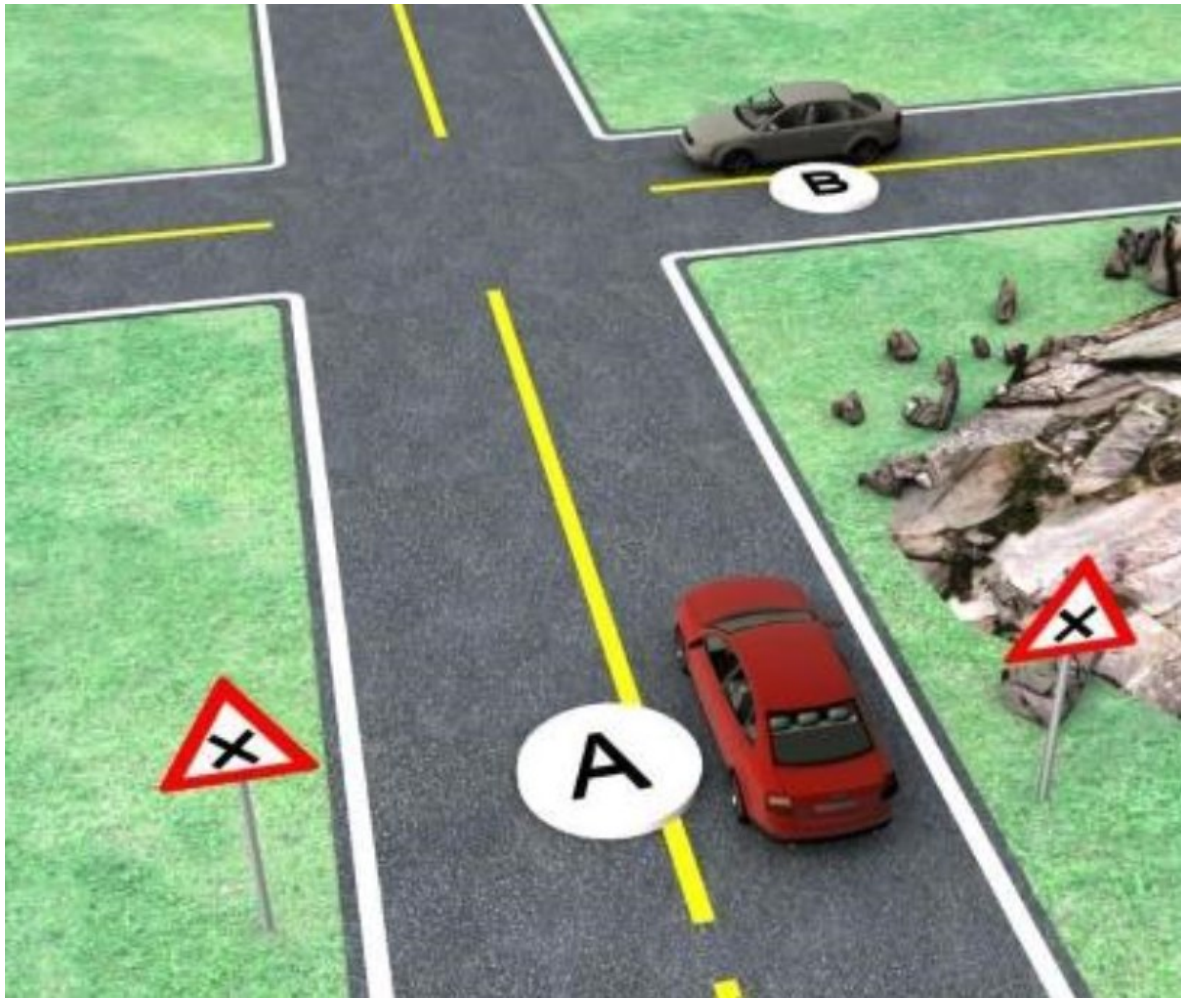
Outline

1. Why game theory?
2. What is it?
3. **Why is it useful for us?**

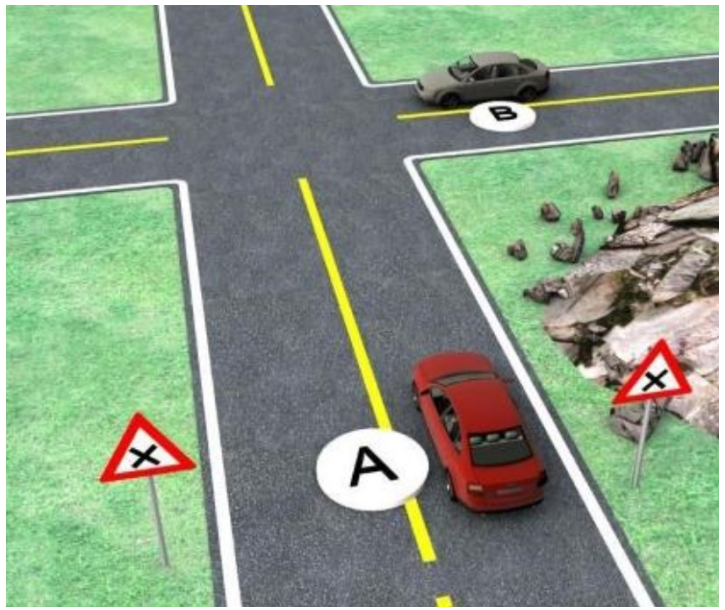
Game theory can help us understand road user behaviour

1. The collapse of the right-hand give-way rule
2. The counter-rule behaviour of cyclists at zebra crossings
3. The interactions of AVs and normal road users
4. The convention of dipping headlights

LEADER – the basic crossroads game

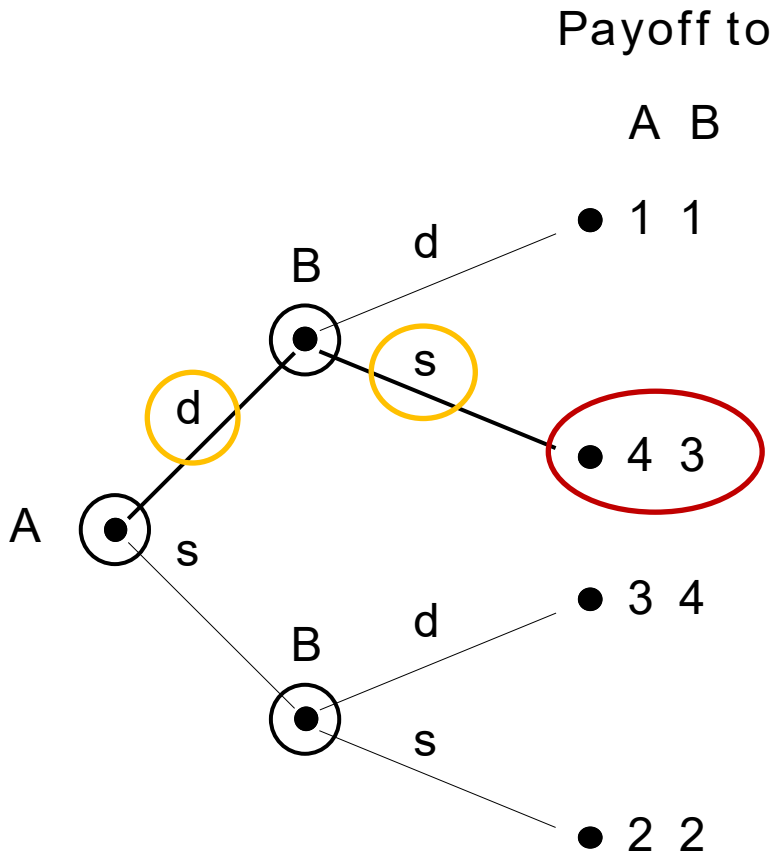


LEADER – the basic crossroads game



B

A	Drive	Stop
Drive	1, 1	3, 4
Stop	4, 3	2, 2



1. The Collapse of The Right-Hand Rule

The priority rules in Norway

- 1912: Right-hand rule + Signal with horn (speed limit 35 km/h, but max 12 km/h at intersections)

- «.. The practice has incorporated itself that one now stops and waits for all traffic from the right if one in the slightest way bothers or inhibits this.»
  (Motorliv no. 7/1934; 143)

Signalling

«The chauffeurs often shot like rockets across streets and intersections without the slightest reduction in speed, limiting themselves only to giving one or more blasts of the horn.»

Police officer Gunnar Eilifsen, Motortidende no. 5, 1933.

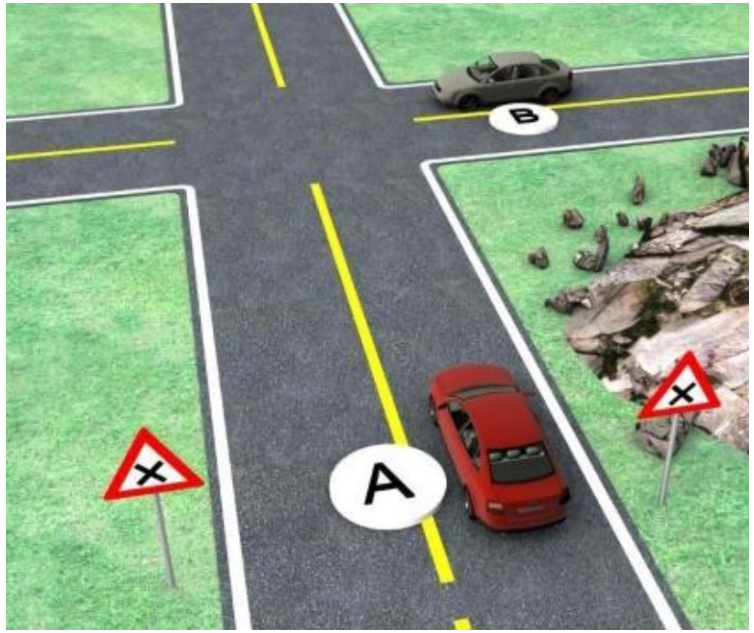
The priority rules in Norway

- 1935: Speed limit increased from 45 km/h to 60 km/h

- « .. Most countries are now in the process of arranging systems for yielding for traffic from larger roads, legalizing a sort of a pre-established practice.»
  (Road Director Axel Rønning, Motortidende no. 14/1937).

Dynamics in the cross-roads game

- 1912: Right-hand rule + signal with horn (speed limit 35 km/h, but max 12 km/h at intersections)
- During the 1930's speed limits increased from 45 to 60 km/h on major roads
- B drivers discovered that A drivers, on larger roads, often were unable to stop ("brinkmanship")
- A convention to yield to traffic from the larger road developed (formalised as the "Gentleman's rule")
- The convention was formalised by give-way rules and priority signs



2. The Zebra Crossing Game

The traffic rules

Before 1998:

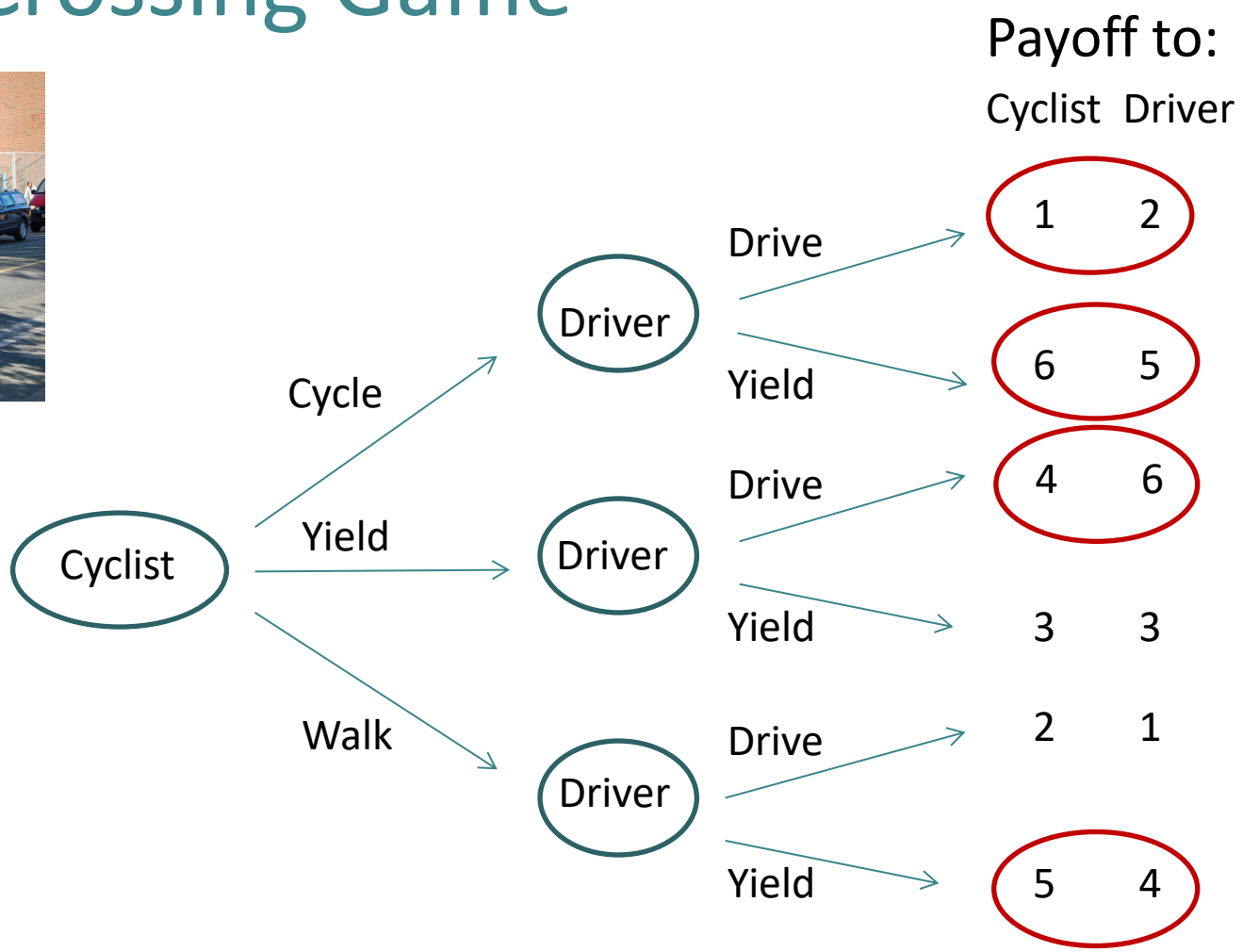
The right-hand rule + vehicles turning must give way to those going straight

After 1998:

Cyclists entering or crossing the street from a pavement or cycle lane has to yield to traffic in the street

➡ Cyclists who cycle over zebra crossings must yield to the cars.
But, cars must yield to pedestrians at zebra crossings

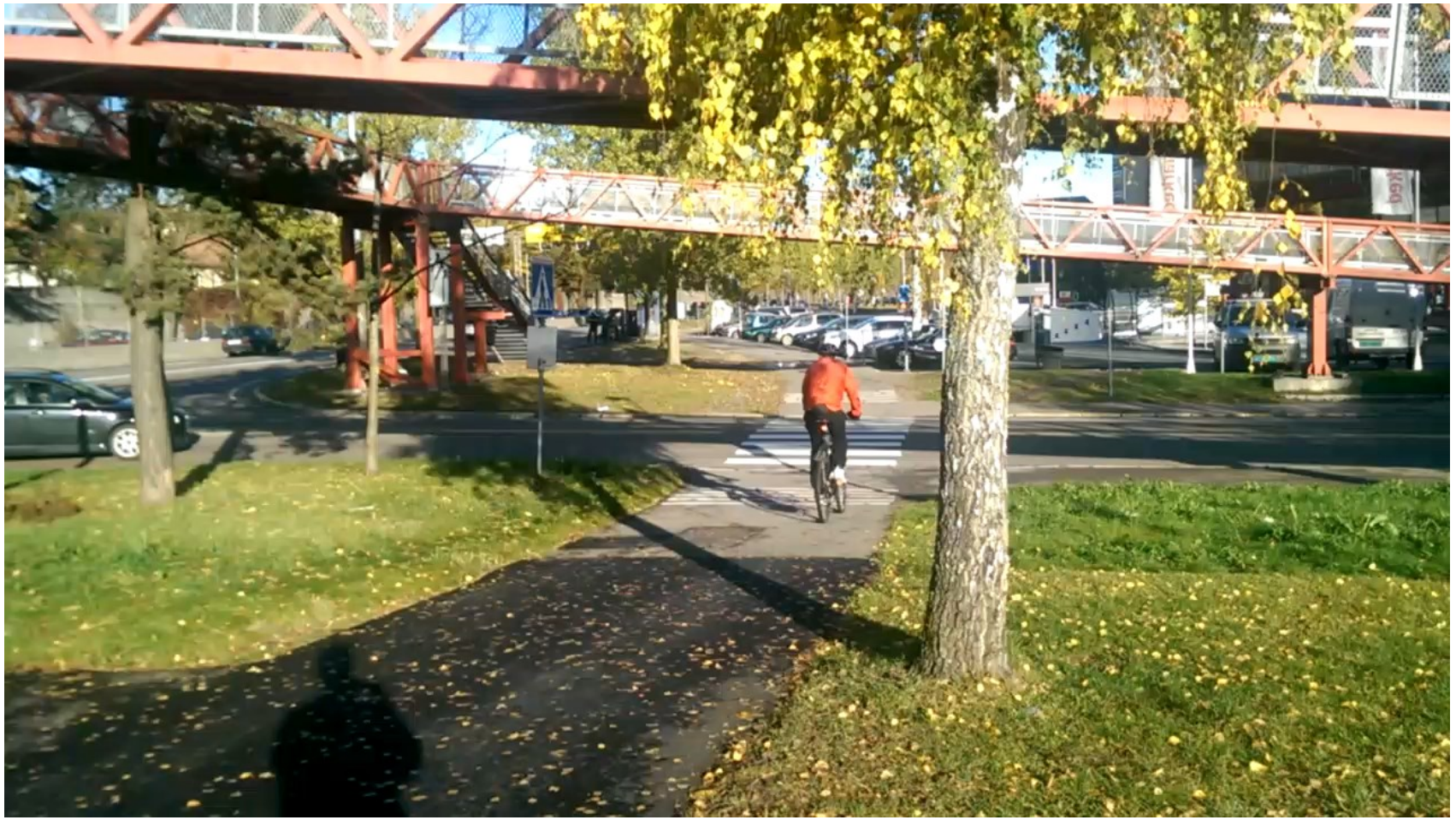
The Zebra Crossing Game



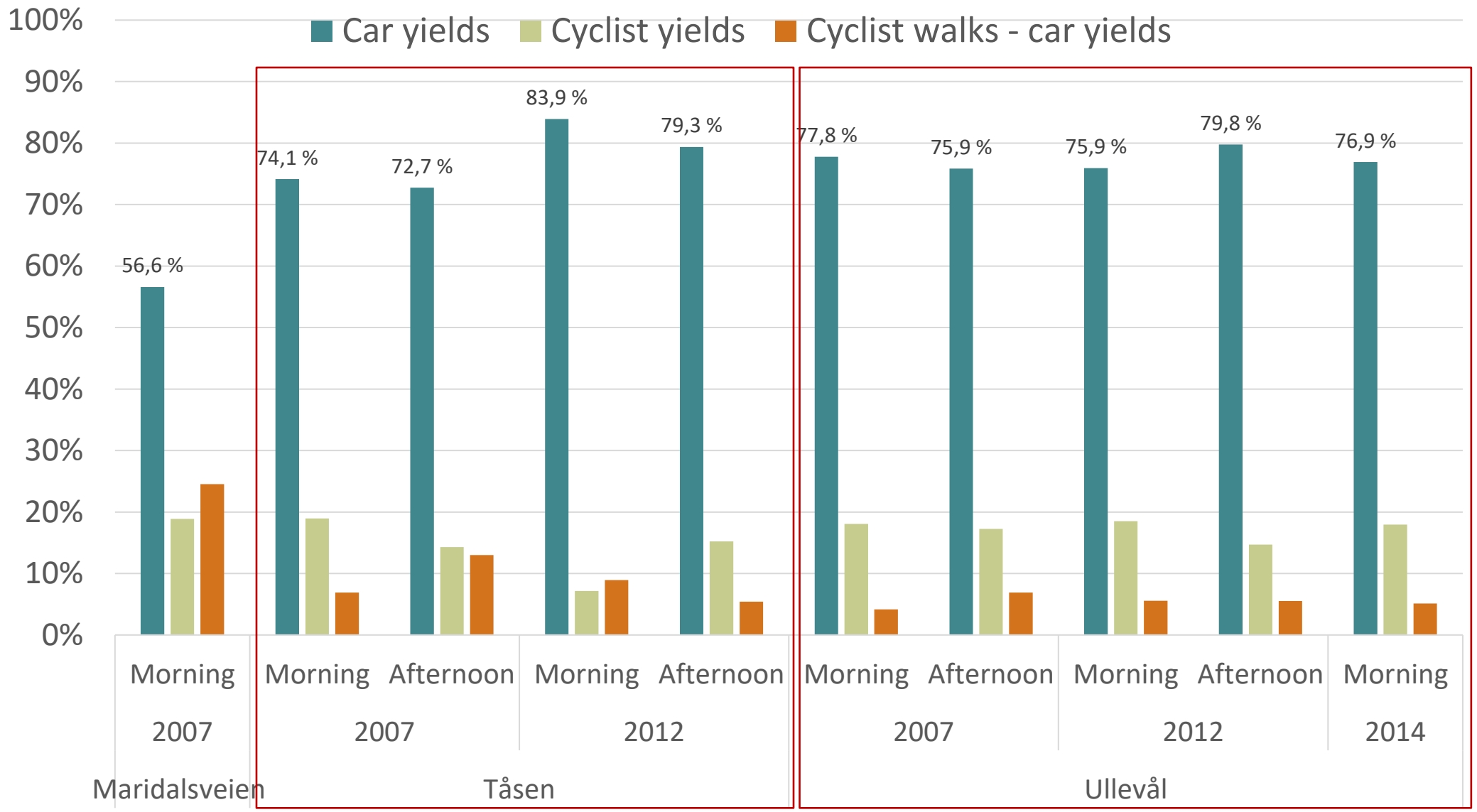
Pay offs in ordinal values: 6 > 5 > 4 > 3 > 2 > 1

At Tåsen

At Ullevål



The Zebra Crossing Game: Registrations in Oslo

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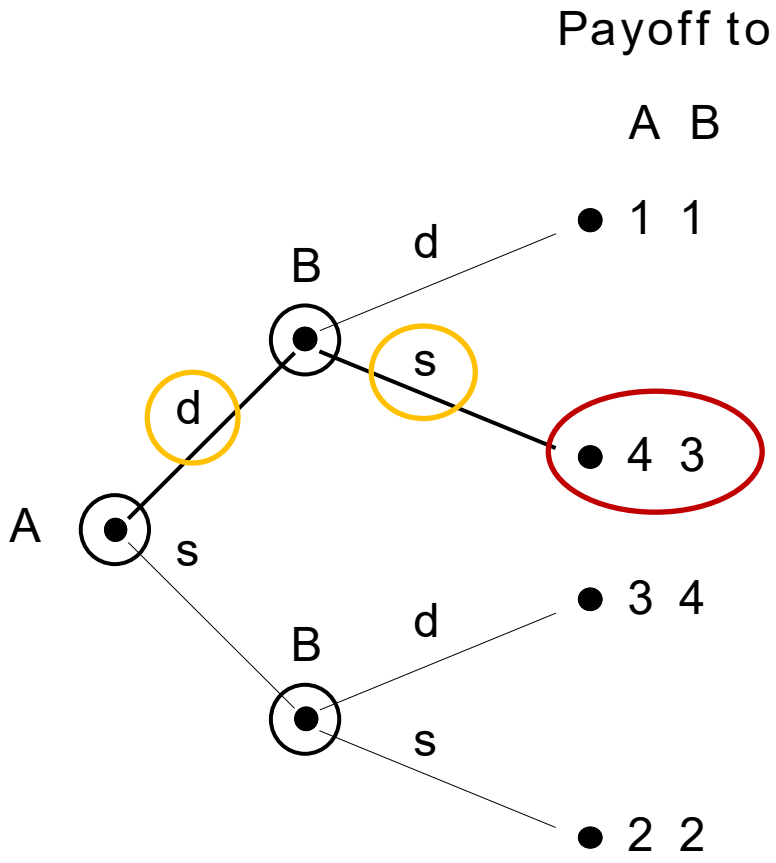
Conclusion – The Zebra Crossing Game

- Car drivers yield to cyclists – as they do to pedestrians
- Active negotiations – eye contact
- The solution is in line with the game theoretic model
- A convention or norm has been established – contrary to the rules
- Not much conflict

3. Interactions of AVs and normal road users



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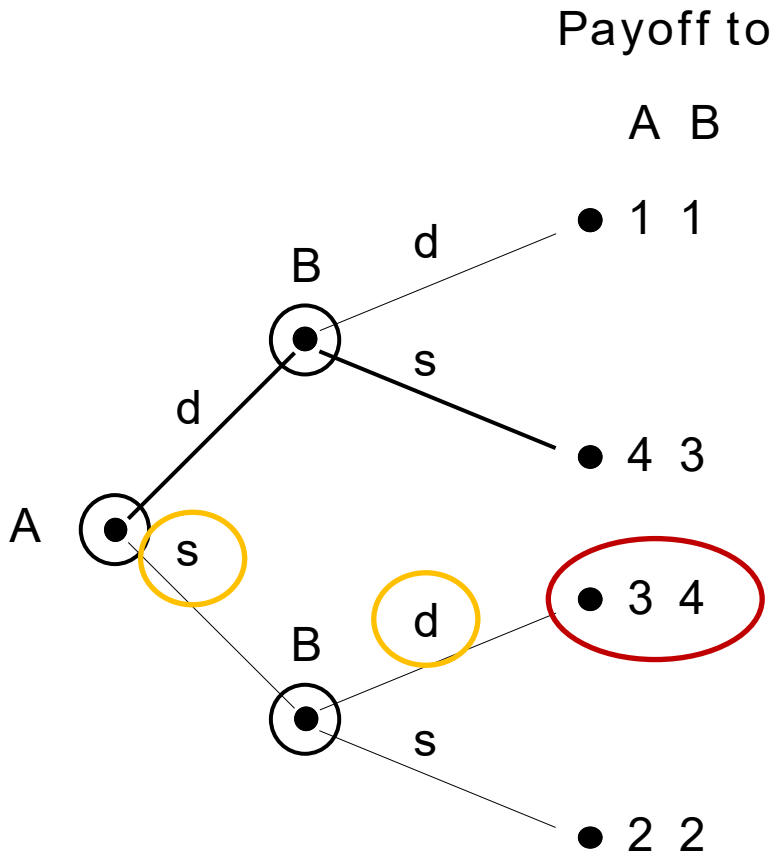
3. Interactions of AVs and normal road users



B

A	Drive	Stop
Drive	1, 1	3, 4
Stop	4, 3	2, 2

Journal of Planning Education and Research

Pedestrians, Autonomous Vehicles, and Cities

Adam Millard-Ball

First Published October 27, 2016 | Research Article | Check for updates
https://doi.org/10.1177/0739456X16675674

Bjørnskau, T., Aasvik, O., De Ceunynck, T., Fyhri, A., Hagenzieker, M., Johnsson, C., & Laureshyn, A. (2023). **"Game over" for autonomous shuttles in mixed traffic?** Results from field surveys among pedestrians and cyclists on how they interact with autonomous shuttles in real-life traffic in Norway. *Transportation Research Interdisciplinary Perspectives*, *18*, 100781.

Data from the pilot with AV shuttles in Ski 2021

Cars did not give way to the shuttle (8 situations)

Some recent support (Nordhoff, Hagenzieker et al. 2025):

Data from 4 cities in the US

- *It is very easy to cut them off. They will stop. If you need to merge, you're like, Oh, there's a robot car, I can definitely merge in front of that robot car', or if you're a pedestrian and you're like, They're going to stop for me because they see you, they see you coming.'"* (P016)
- *„It has gotten really fun to play with them. If you try to bluff them, you can make them stop or clinch. You'd see one coming along and you wait until the last second and step off the curve. That's enough to stop them. The human drivers are going to dominate them."* (P025)

Nordhoff, S., Hagenzieker, M., Lee, Y. M., Wilbrink, M., Merat, N., & Oehl, M. (2025). "It's just another car driving"– Perceptions of US residents interacting with driverless automated vehicles on public roads. *Transportation Research Part F: Traffic Psychology and Behaviour*, *111*, 188-210.

4. The Dipping Headlights Game

The dipping headlights game as a Prisoner's Dilemma

B

A	Low lights	Full lights
Low lights	3, 3	4, 1
Full lights	1, 4	2, 2

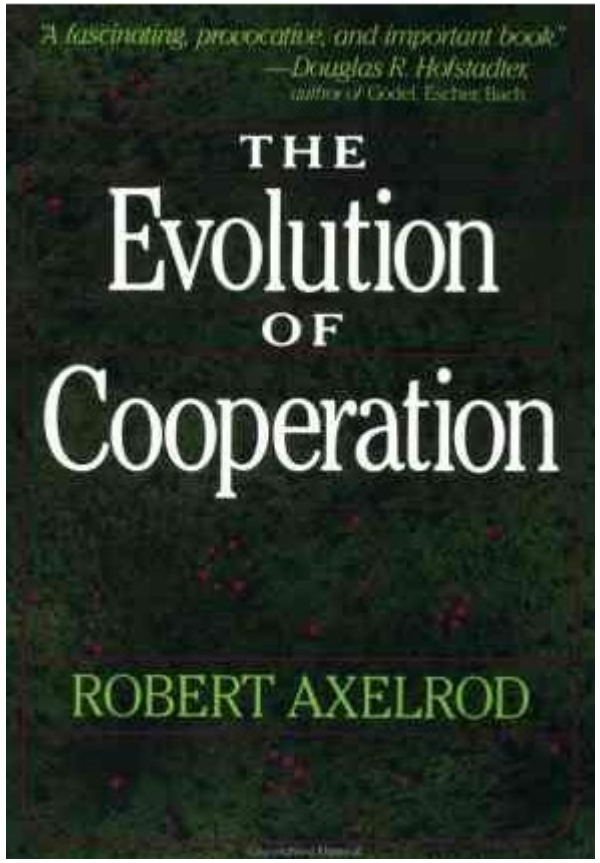
Driver education text books

Veien til førerkortet (The Road to a Driver's Licence) 1976:
"It has been common practice to switch to dipped headlights when an oncoming car does so. You should not follow this habit, however, because many drivers tend to switch far too early, while the vehicles are still a long distance apart."

The exact same wording appeared in the 1995 edition of the same book.

-> So thousands of new drivers have entered the traffic, with this knowledge, but nothing has changed?

Hole G., Borch K. & Torsmyr K. (1976). Veien til førerkortet. Autoriserte trafikkskolers landsforbund.
Borch K., Moe, D., Nermark, J. & Torsmyr K. (1995). Veien til førerkortet. Autoriserte trafikkskolers landsforbund.


"A fascinating, provocative, and important book"
—Douglas R. Hofstadter
author of Gödel, Escher, Bach
THE
Evolution
OF
Cooperation
ROBERT AXELROD

Empirical (survey) results

- The driver education tries to teach drivers to use full lights more than what is normal.
- These attempts **have not succeeded** because the novice drivers entering the driver population constitute a small minority of drivers.
- Hence, they are **sanctioned by flashing head lights** on the roads and adjust their behavior to normal practice.
- If a large numbers of novice drivers had entered the population at the same time, the established **cooperation** in the dipping head-lights game **might unravel**.

Bjørnskau, T. (2018). Dipping Headlights: An Iterated Prisoner's Dilemma or Assurance Game. In *Game Theory-Applications in Logistics and Economy*. IntechOpen.

Recent publications/further reading

Rune Elvik: A review of game-theoretic models of road user behaviour:

1. A general model of behavioural adaptation.
2. Choice of vehicle size as a Prisoners' dilemma game.
3. Speed choice as a co-ordination game.
4. Speed compliance as a game between drivers and the police.
5. Merging into traffic from an acceleration lane as a mixed-strategy game.
6. Choice of level of attention in following situations as an evolutionary game.
7. Choice of departure time to avoid congestion as variant of a Prisoners' dilemma game.
8. Interaction between cyclists crossing the road and car drivers.
9. Dipping headlights at night well ahead of the point when glare becomes noticeable.
10. Choice of evasive action in a situation when cars are on collision course

Elvik, R, (2014). *A review of game-theoretic models of road user behaviour*. Accident Analysis and Prevention, 62, 388-396

Recent publications

Camara, F. et al. (2018). *Empirical game theory of pedestrian interaction for autonomous vehicles.* In: Proceedings of Measuring Behavior 2018, pp. 238–244.
Camara, F. et al. (2021). *Evaluating pedestrian interaction preferences with a game theory–based AV controller.* Transportation Research Part F, 80, 147–163.
Wu, W. et al. (2019). *Game theory modeling for vehicle–pedestrian interactions and simulation based on cellular automata.* International Journal of Modern Physics C, 30(4), 1950025.
Tang, T. et al. (2020). *Understanding the Interaction between Cyclists' Traffic Violations and Enforcement Strategies: An Evolutionary Game-Theoretic Analysis.* Int. J. Environ. Res. Public Health, 17(22), 8457.
Kalantari, A. H. et al. (2023). *Driver–Pedestrian Interactions at Unsignalized Crossings Are Not in Line With the Nash Equilibrium.* IEEE Access, 11, 110708–110721.
Amini, R. E. et al. (2024). *A game-theoretic approach for modelling pedestrian–vehicle interactions.* Accident Analysis & Prevention, 205, 107536.
Soni, R. (2024). *Game theoretic interactions between pedestrians and automated vehicles.* PhD thesis, University of Lincoln.
Mohammadi, A. et al. (2025). *Cyclists' interactions with professional and non-professional drivers: Observations and game theoretic models.* Transportation Research Part F, 112, 48–62.
Arafat, M. E. et al. (2025). *A game theoretical model to examine pedestrian behaviour and safety on unsignalised slip lanes using AI-based video analytics.* Accident Analysis & Prevention, 217, 108034.
Adamova, V. et al. (2025). *Game Theory-Based Risk Assessment of the Use of Autonomous Cars in Urban Areas.* Mathematics, 13(4), 553.
Michieli, U. & Badia, L. (2018). *Game Theoretic Analysis of Road User Safety Scenarios Involving Autonomous Vehicles.* Proc. IEEE PIMRC.

Summing up

Patterns of behaviour (culture/conventions) develop through interaction:

- The give-way rule for traffic from the right-hand side collapsed (in most countries)
- Car drivers give way to cyclists at zebra crossings
- AVs will meet severe challenges in mixed traffic because they are “committed to” stop
- Novice drivers act according to normal behaviour when dipping the headlights in the dark – not according to what they have been taught

Tough brinkmanship!

Thank you for your attention!

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