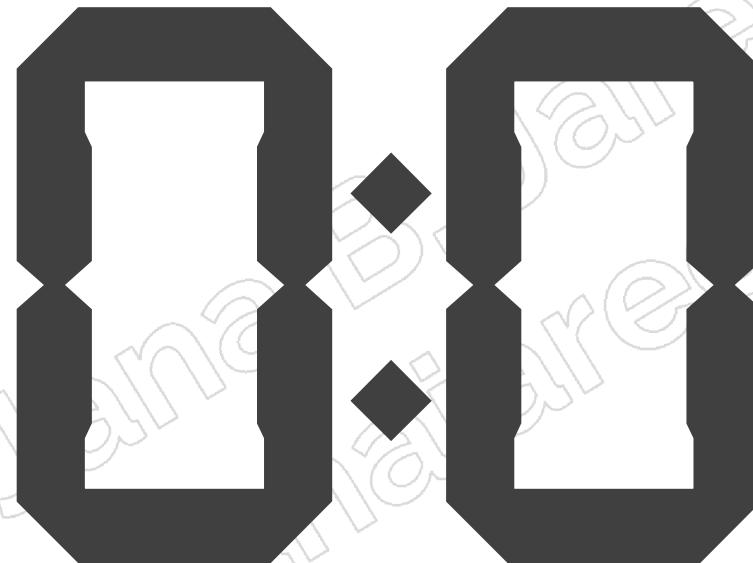

Smartly limited: Exploring how human learning processes (may) outsmart computer optimization

Jana B. Jarecki¹, Jacob Friis Sherson², & the CODER team²

¹ Max Planck Institute for Human Development, Berlin, Germany

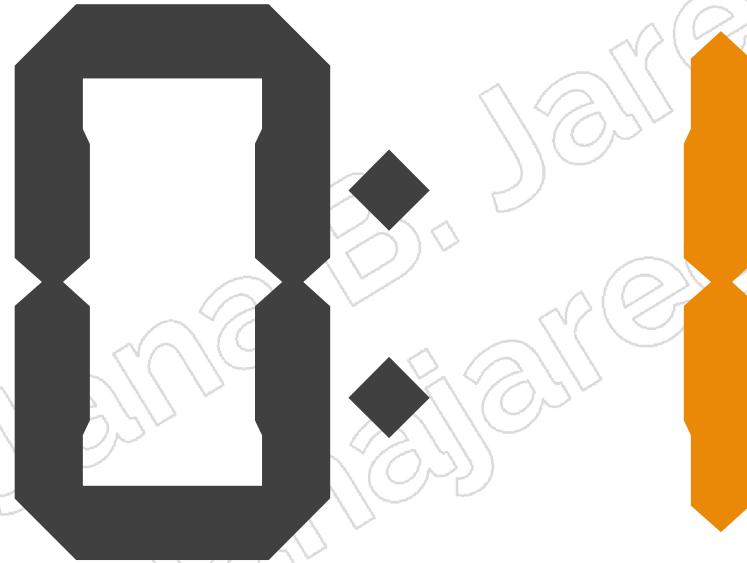
² Department of Physics and Astronomy, Aarhus University, Denmark

Mind vs. Machine

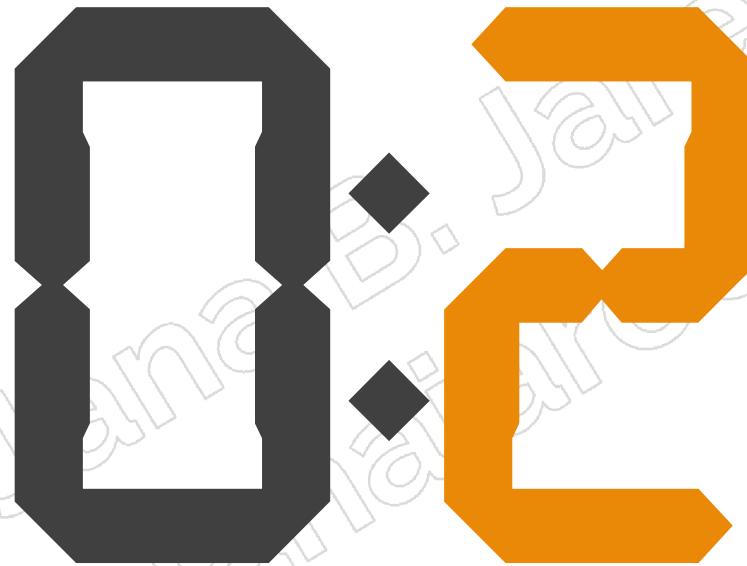


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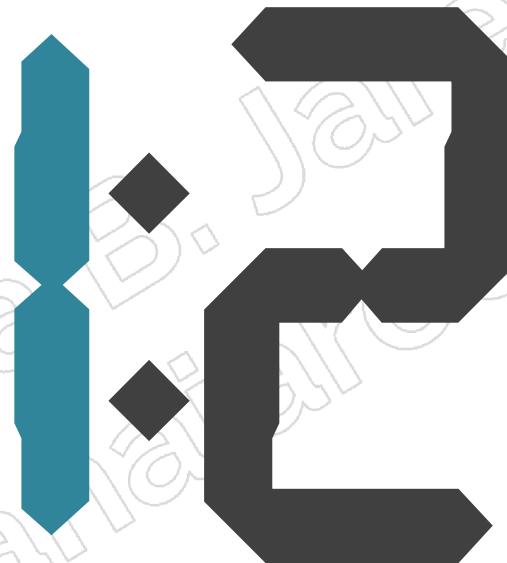
Mind vs. Machine



Mind vs. Machine



Mind vs. Machine

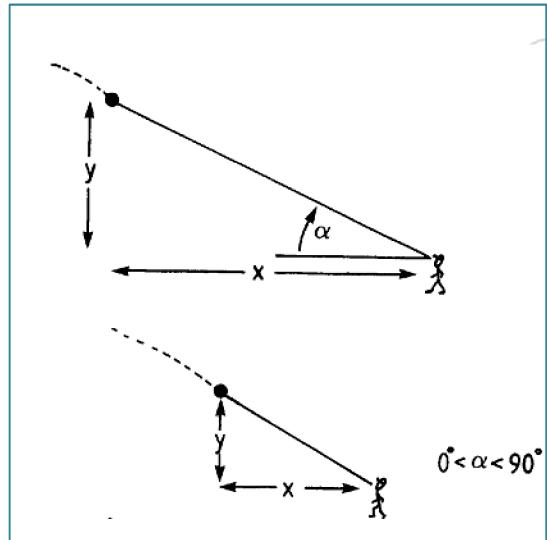
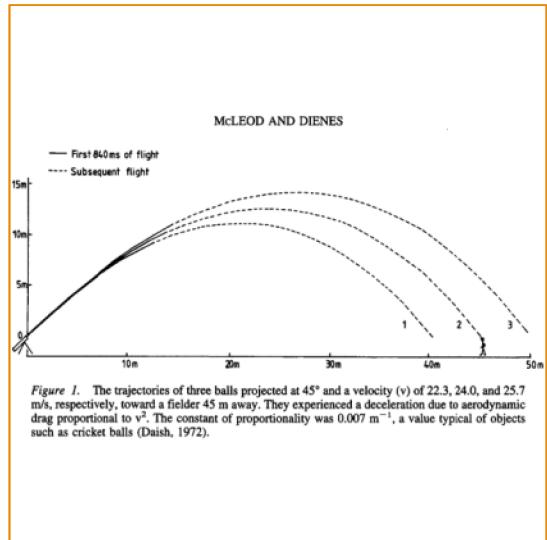


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Mind vs. Machine



Catching a ball Take-the-best Naive Bayes

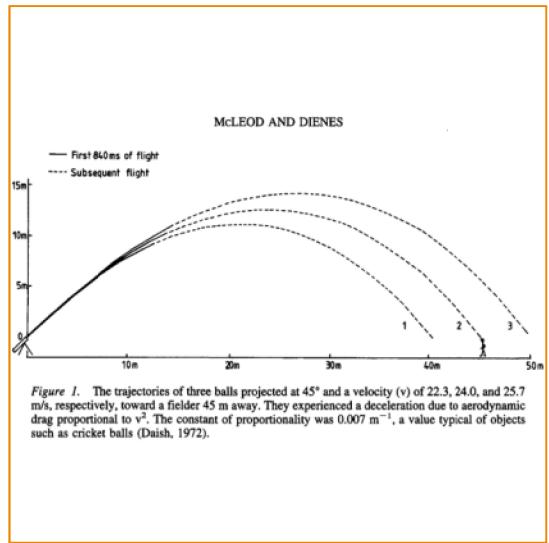


Catching a ball

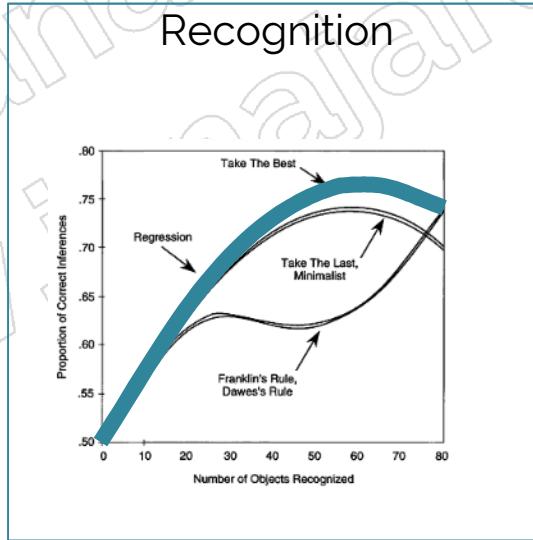
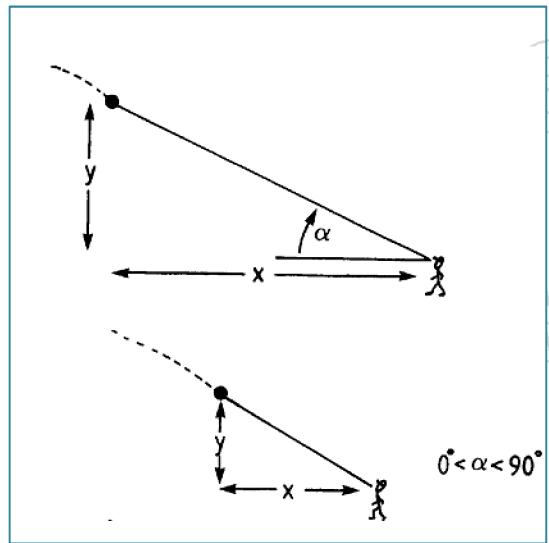
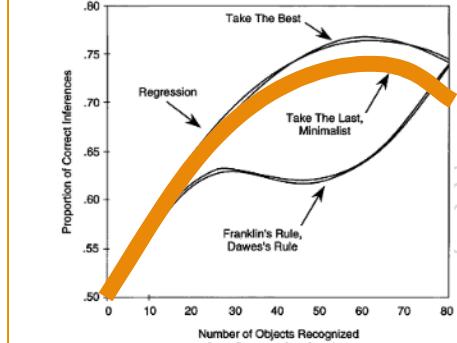
Inferences



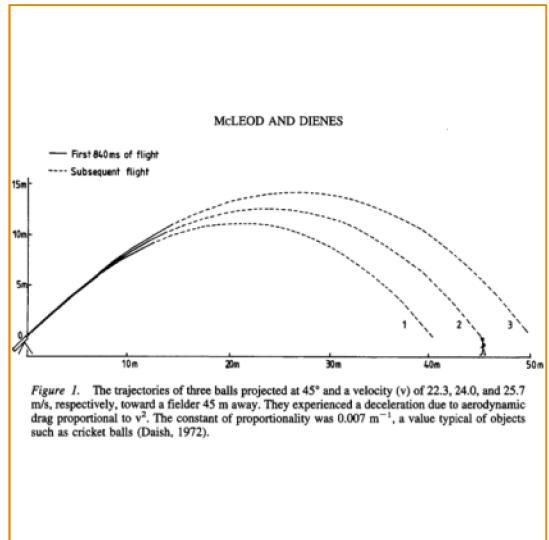
Classification



capital, soccer, university, ...

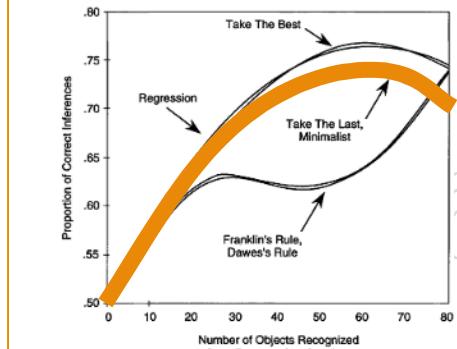


Catching a ball

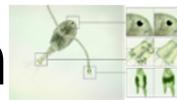


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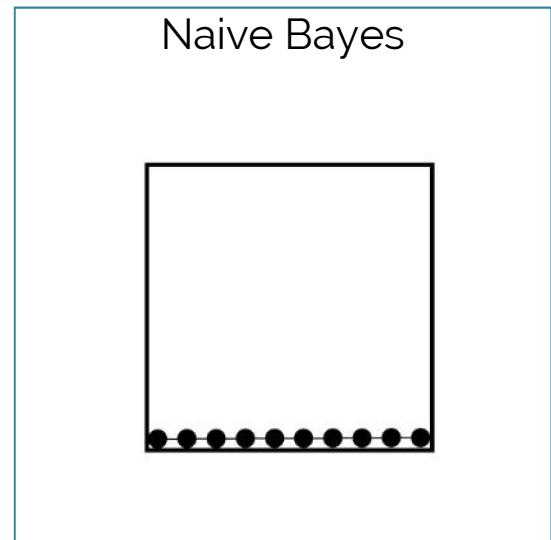
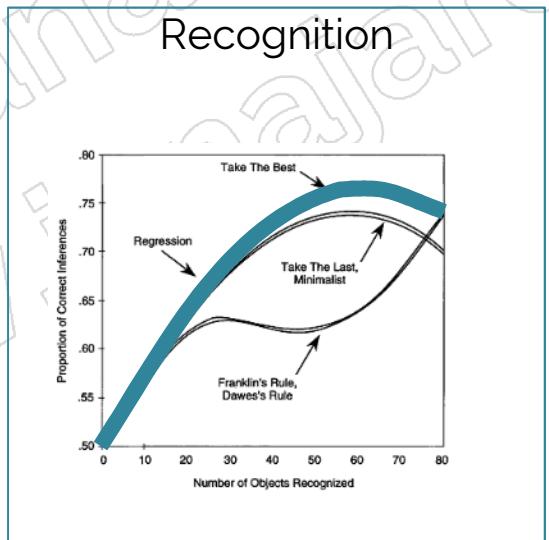
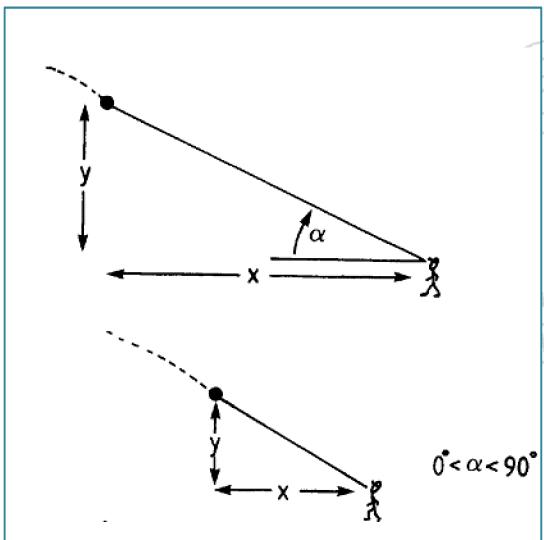
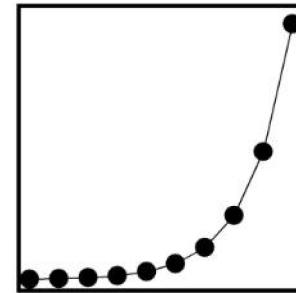
capital, soccer, university, ...



Classification



Full Bayesian Approach



Smartly limited:
simple algorithms need not be inferior to
complex algorithms



Janusz B. Jarecki
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Reasons for smart limitations

1. Uncertainty vs. risk
2. Computationally complex vs. simple
3. Prediction error variance vs. bias

Reasons for smart limitations

1. Uncertainty vs. risk
 - | Outcomes and distributions unknown vs. known
 - | E.g., catching a ball
2. Computationally complex vs. simple
3. Prediction error variance vs. bias

Reasons for smart limitations

1. Uncertainty vs. risk

Outcomes and distributions unknown vs. known

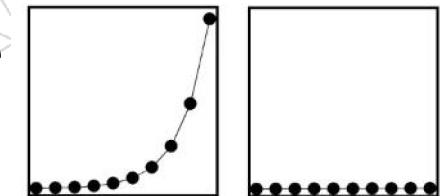
E.g., catching a ball

2. Computationally **complex** vs. simple

„NP hard“: **exponential** increase in time

E.g., classification

3. Prediction error variance vs. bias



Reasons for smart limitations

1. Uncertainty vs. risk
 - | Outcomes and distributions unknown vs. known
 - | E.g., catching a ball
2. Computational complex vs. simple
 - | „NP hard“: exponential increase in time
 - | E.g., classification
3. Prediction error **variance** vs. bias
 - | E.g., city-size inference

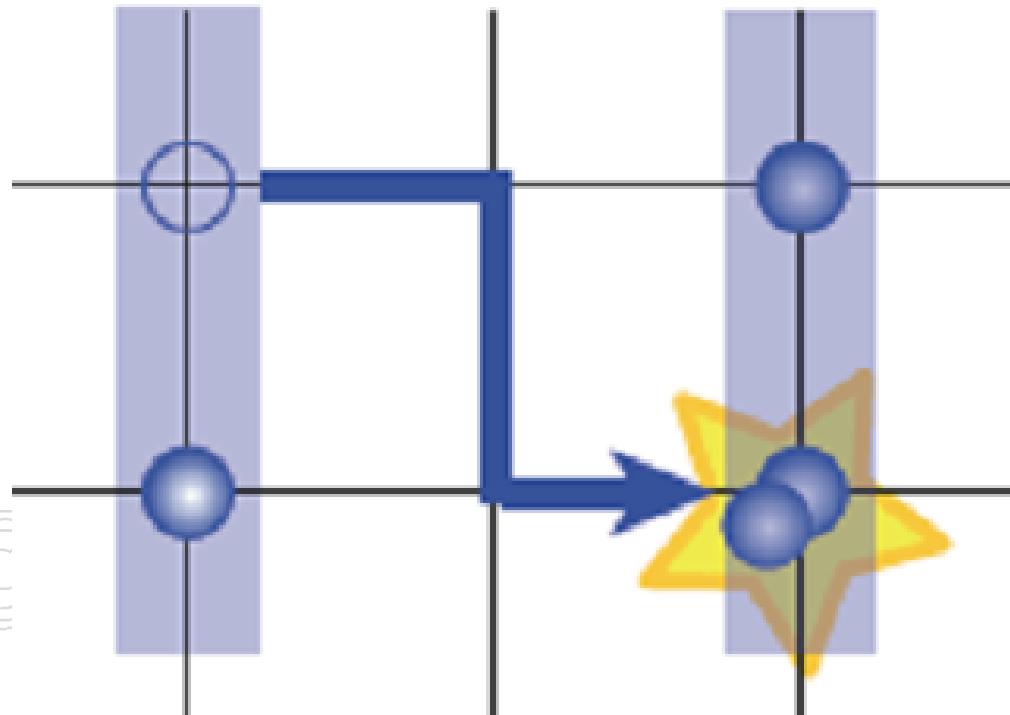
„Ignorance is bliss“ in cases of
Uncertainty
Complexity
Prediction



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Quantum Physics problem

| Problem: Moving an atom from A to B

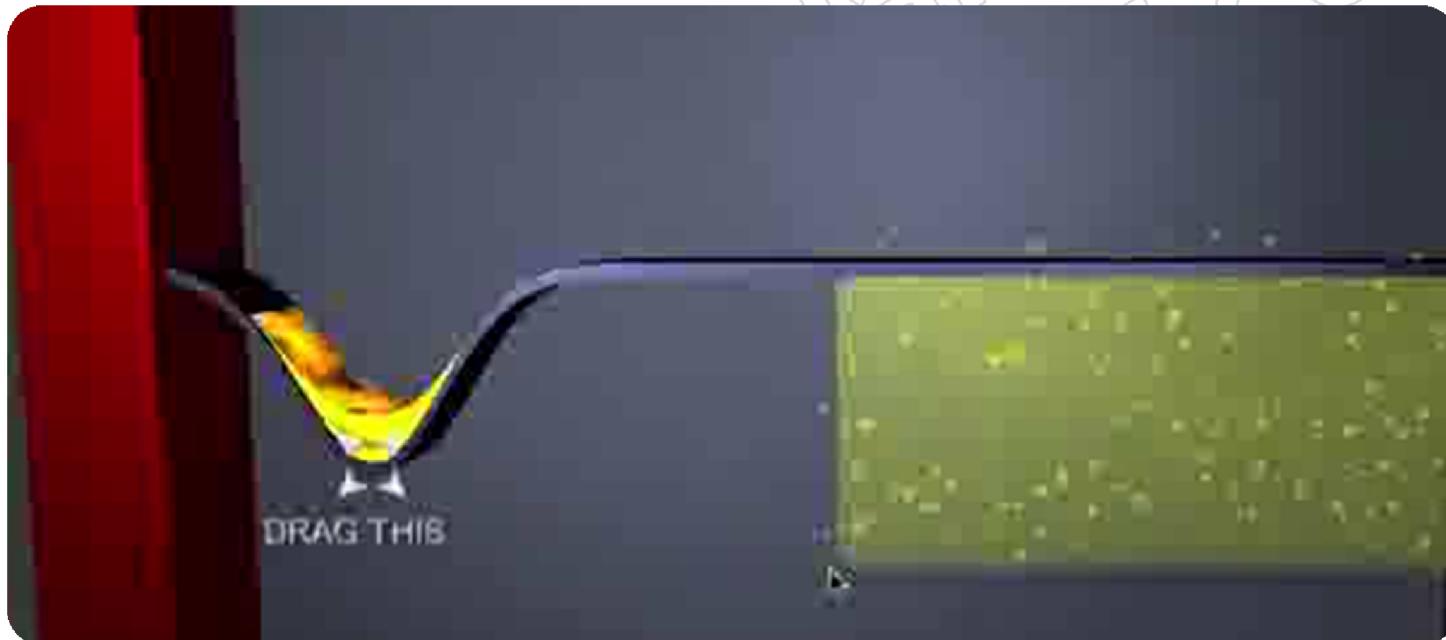


Quantum Physics problem

| Problem: Moving an atom from A to B

| Atom's state is a probability distribution

| When moving the distribution changes



1. Uncertainty vs. risk

- | Outcomes and distributions unknown vs. known

- | Possible movement paths unknown

2. Computationally complex vs. simple

- | Analytical solution impossible

- | Exhaustive numerical optimization impossible

3. Prediction error variance vs. bias

- | Best solution unknown

- | Fitting (instead of prediction) impossible

Moving atoms in quantum physics
falls into the domain where smart limitations
should work



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The game

Level 1

Level 2

Level 3

Level 4

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Welcome to Quantum Minds!

[Next >](#)

Your main goal is to prove your mastery of quantum mechanics in level four.

The first three levels will introduce you to the basics of moving a simulated atom.

Each level must be completed 3 consecutive times to prove your success was not just based on luck.

By level four you will be ready for the real challenge!

Got it! ↗

For educational use only

Getting users to play

- Danish press releases
- US articles
- German press releases
- Blog posts
- Facebook
- Twitter



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How do users play the game?

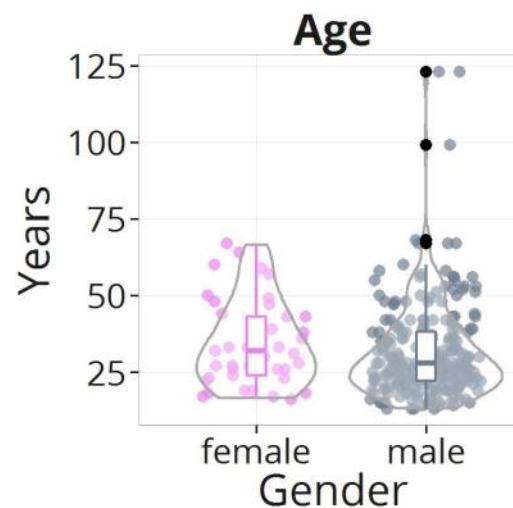
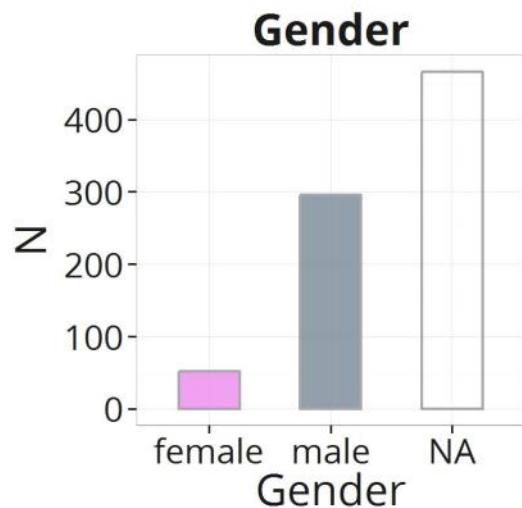
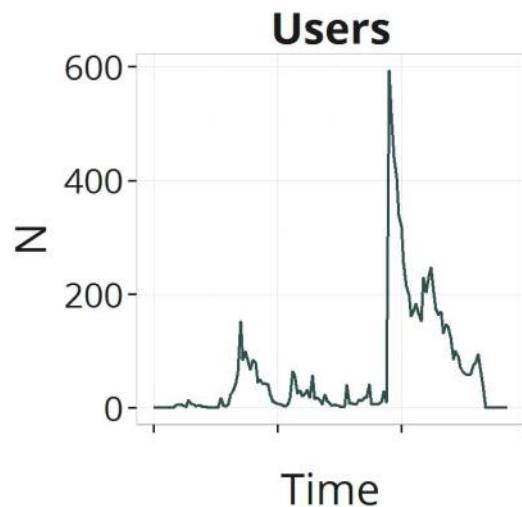
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Total number of players

812

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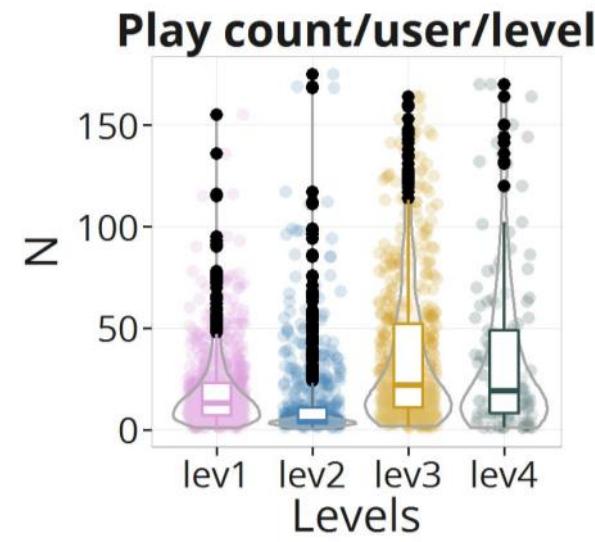
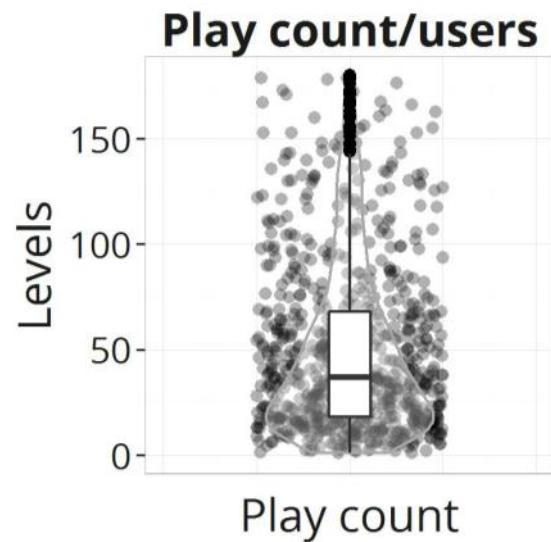
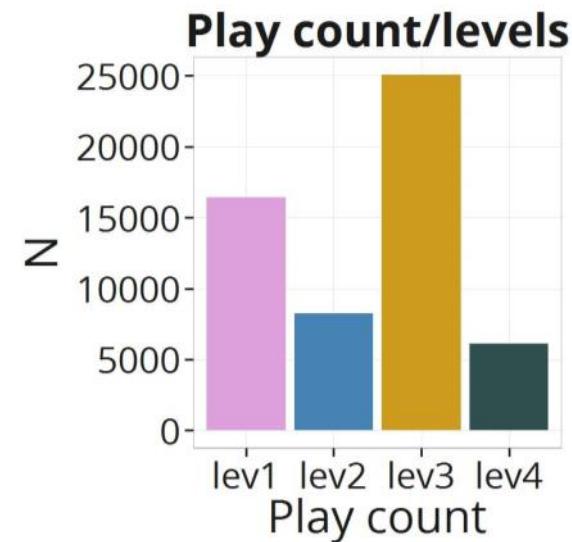
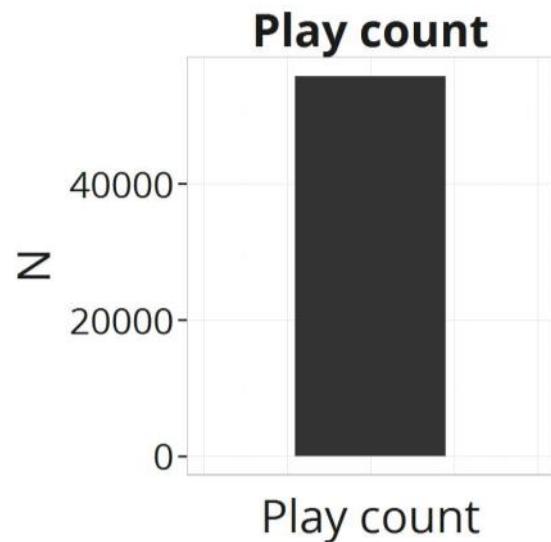
20-24 demographics



Total number of plays

56 870

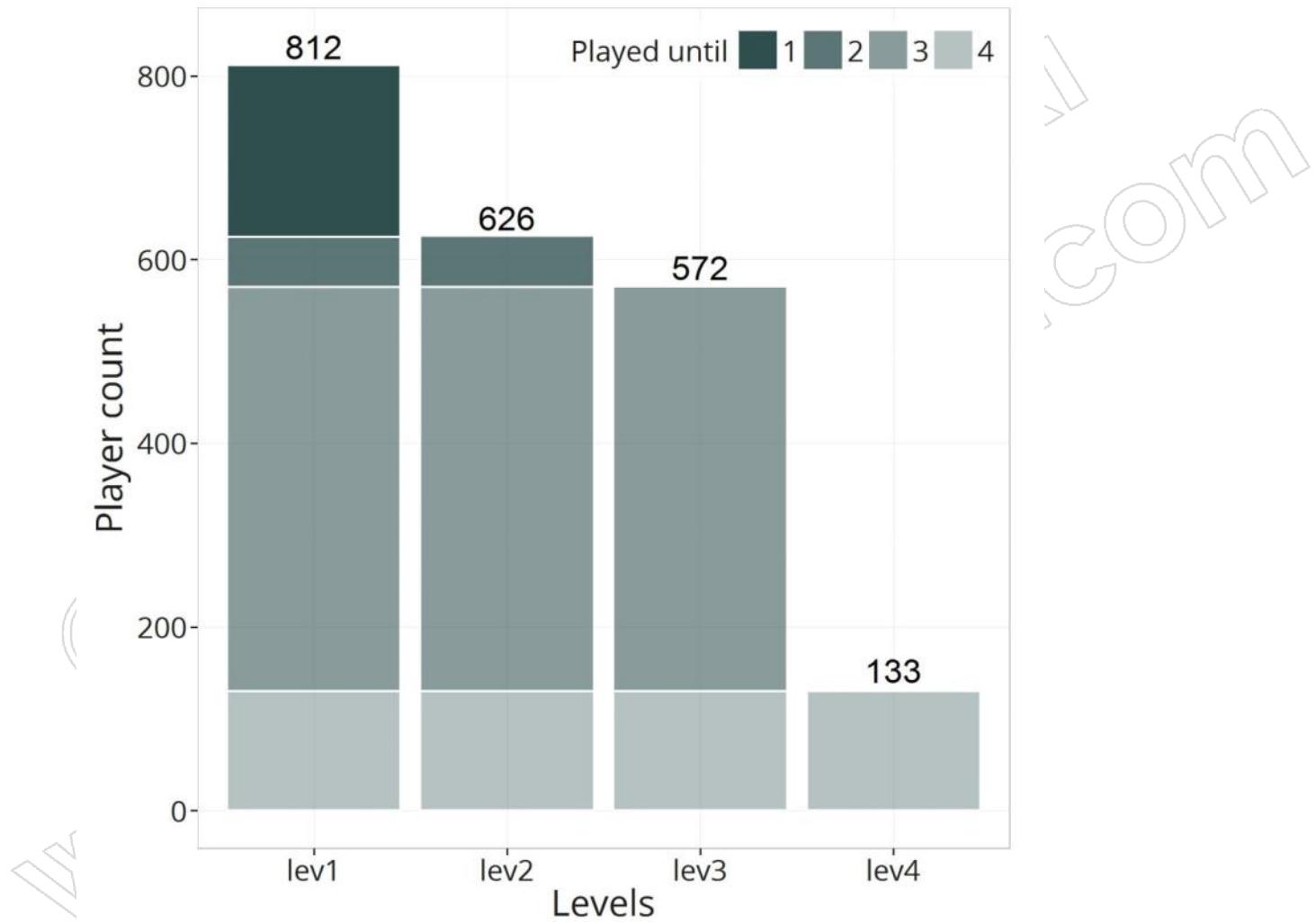
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Total number of players reaching level 4

133 of 812

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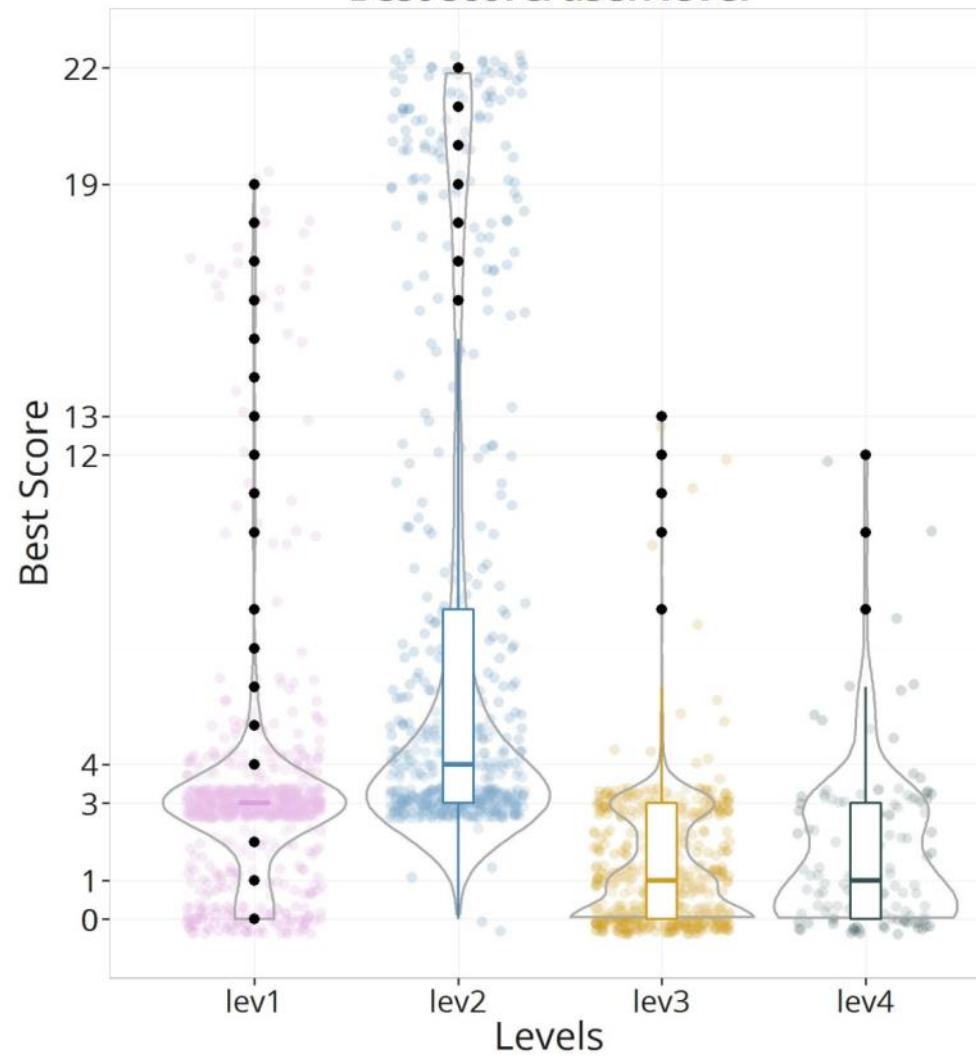


Consecutive successes in level 4

12 (min 3)

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Best score/user/level



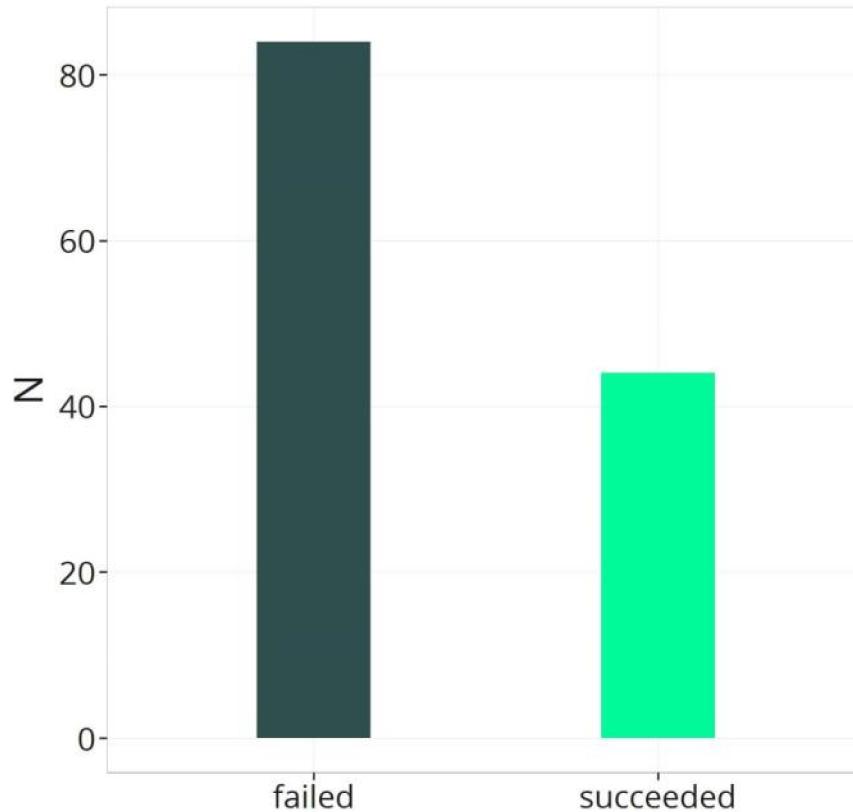
Number of players succeeding in level 4

44 (of 133)

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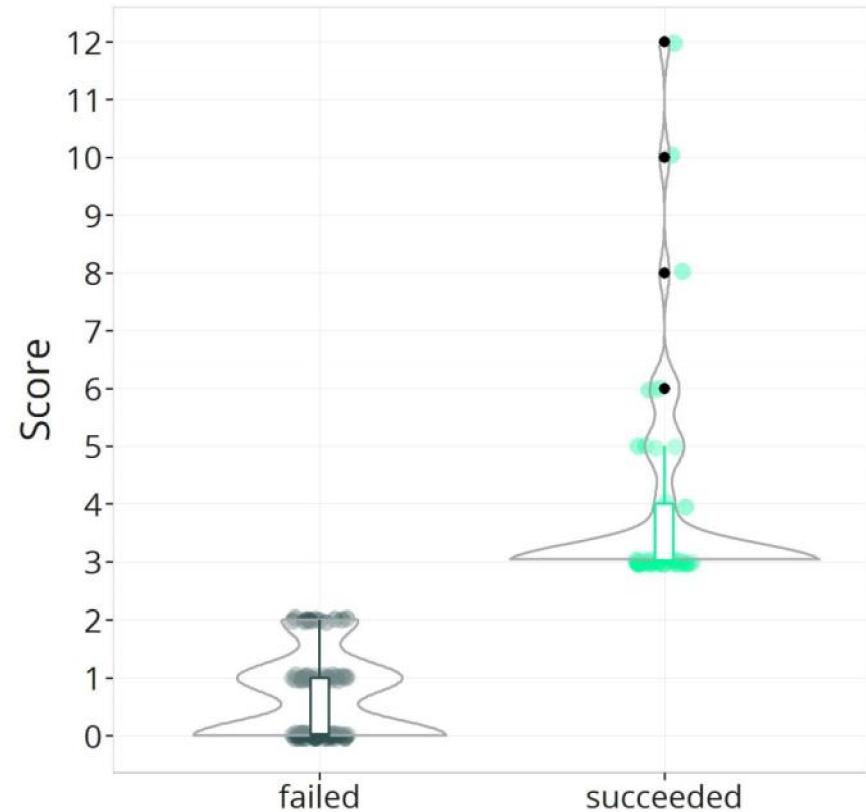
Level 4 performance

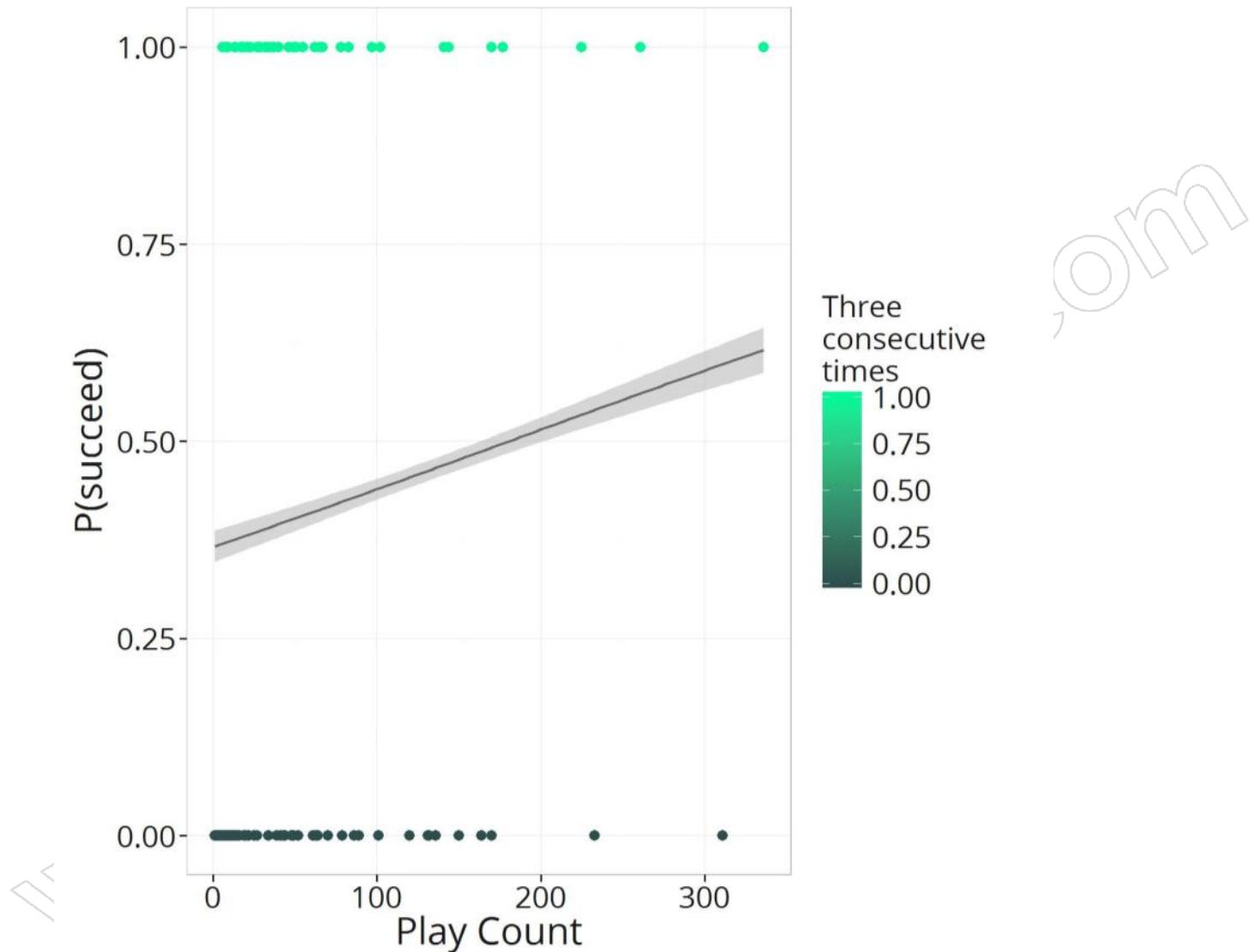
Three consecutive times failed succeeded



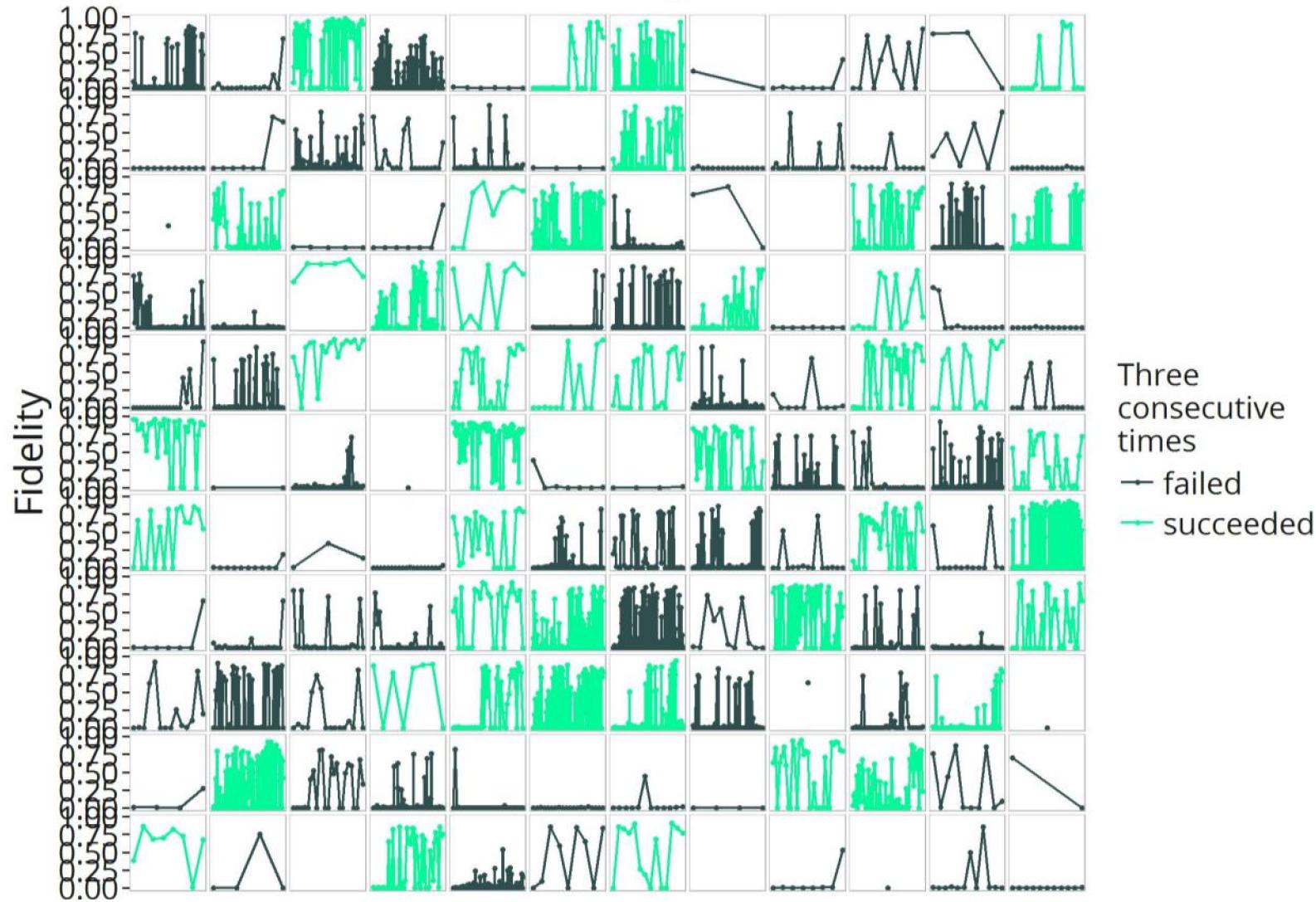
Level 4 scores

Three consecutive times failed succeeded





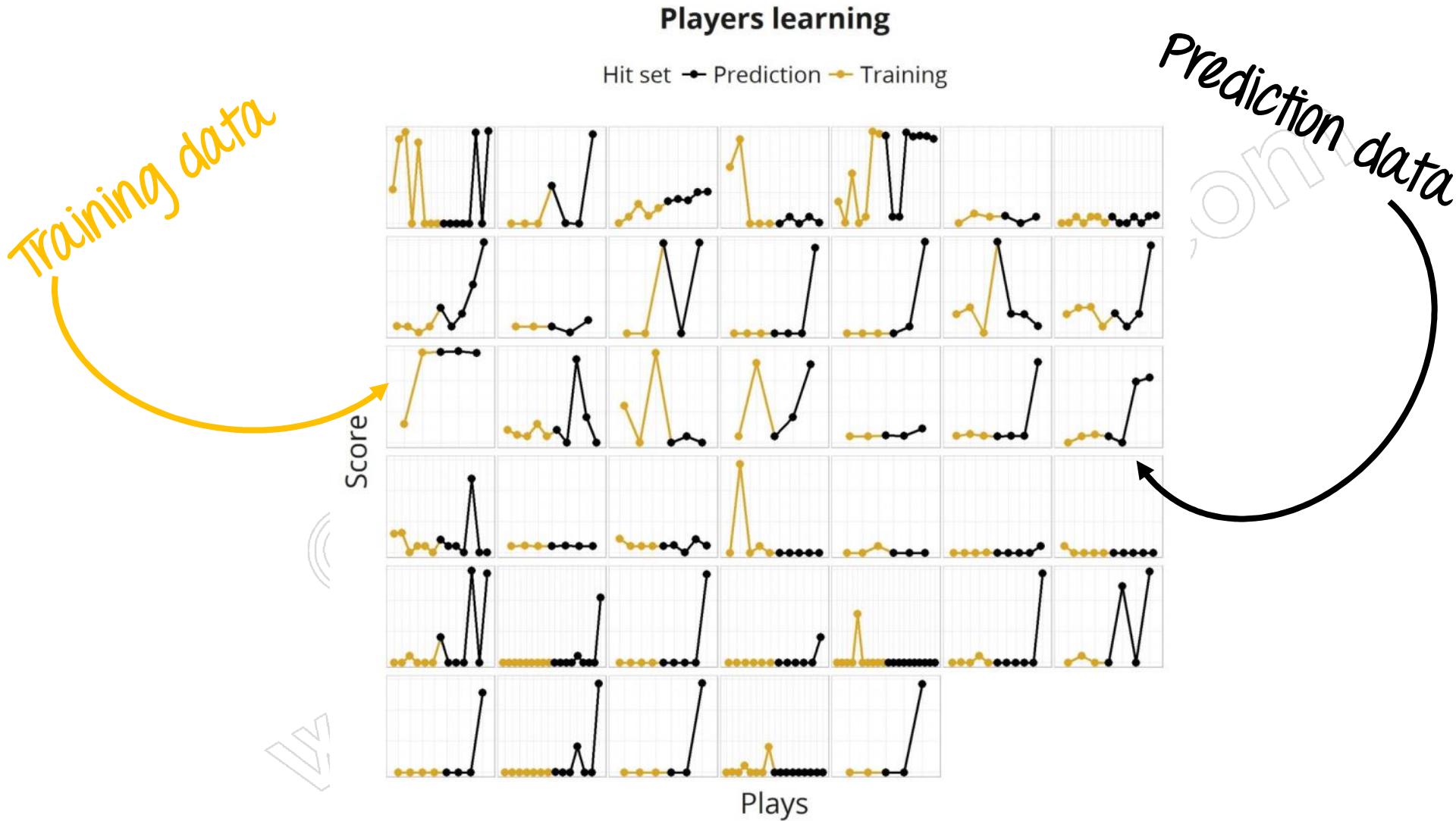
Level 4 learning curves



Summary up to now

- | In tasks where
 - | analytical optimization is **impossible**, and
 - | exhaustive numerical optimization is computationally **infeasible**,
 - | e.g., changing the position of atoms in quantum physics,
- | human cognition can perform
 - | despite a **lack of experience** in these tasks
 - | with as few as **2 learning trials**
 - | **multiple times** in a row.

Outlook into the future



Training data

if humans

Predict from early learning strategies
succeeds in solving a quantum physics
challenge.

Prediction data



Training data

Use path analysis methods from geoscience and biology, to predict from early learning strategies if humans succeeds in solving a quantum physics challenge.

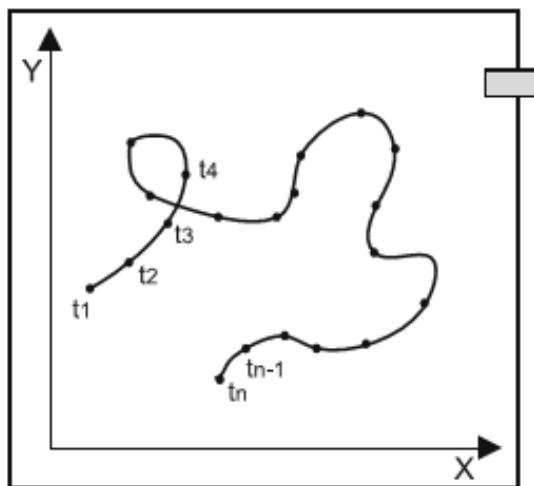
Prediction data



Path analysis methods from geoscience and biology



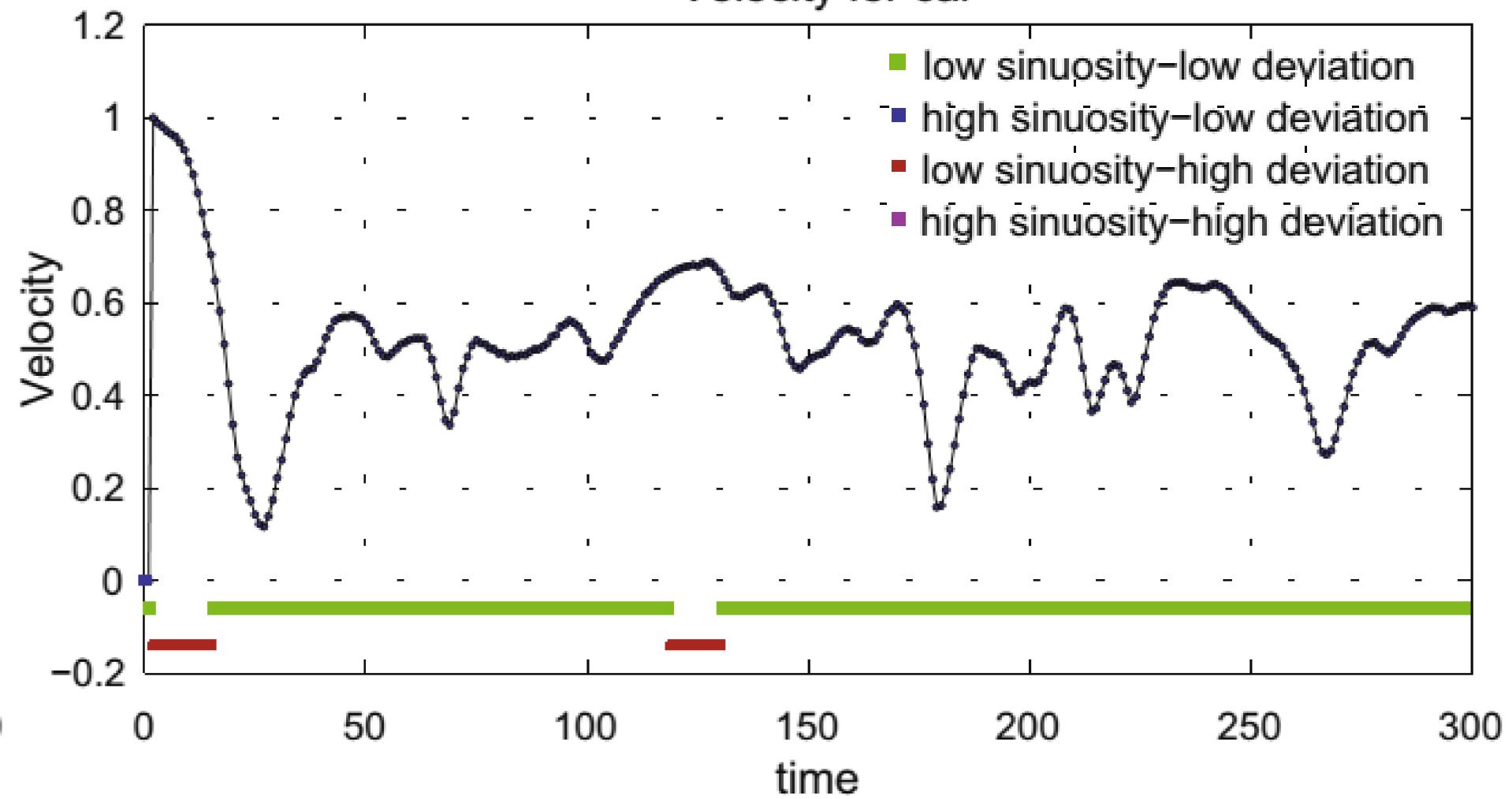
Movement path



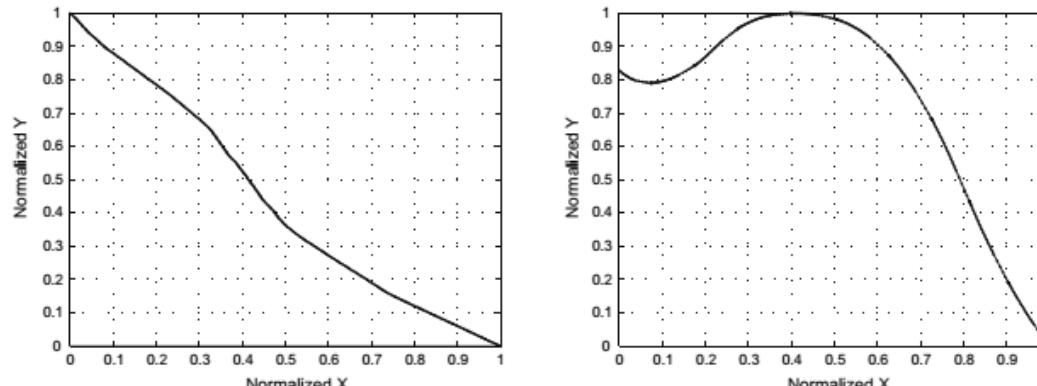
Path properties

- Speed
- Acceleration
- Turning angle
- Displacement
- Path length
- Straightness

Velocity for car

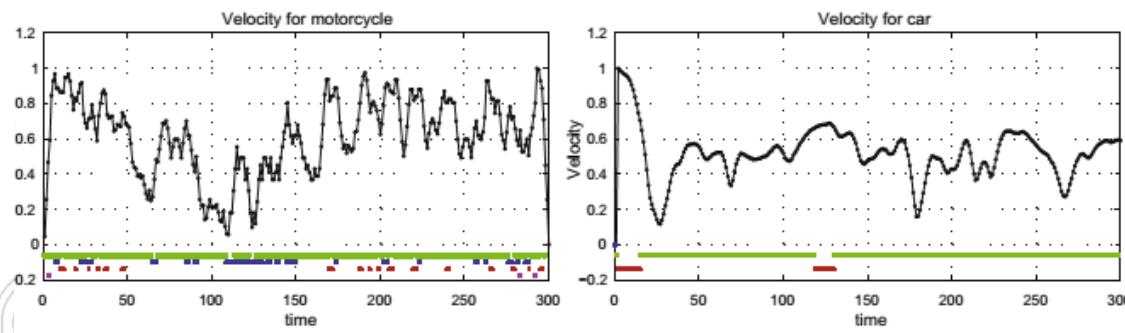


Normalized path



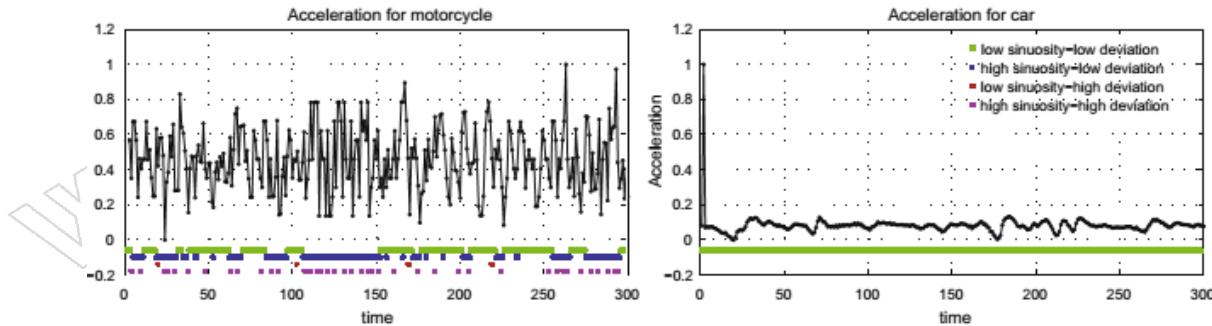
(a) Normalized sample trajectory (300 fixes) of motorcycle (on the left) and car (on the right)

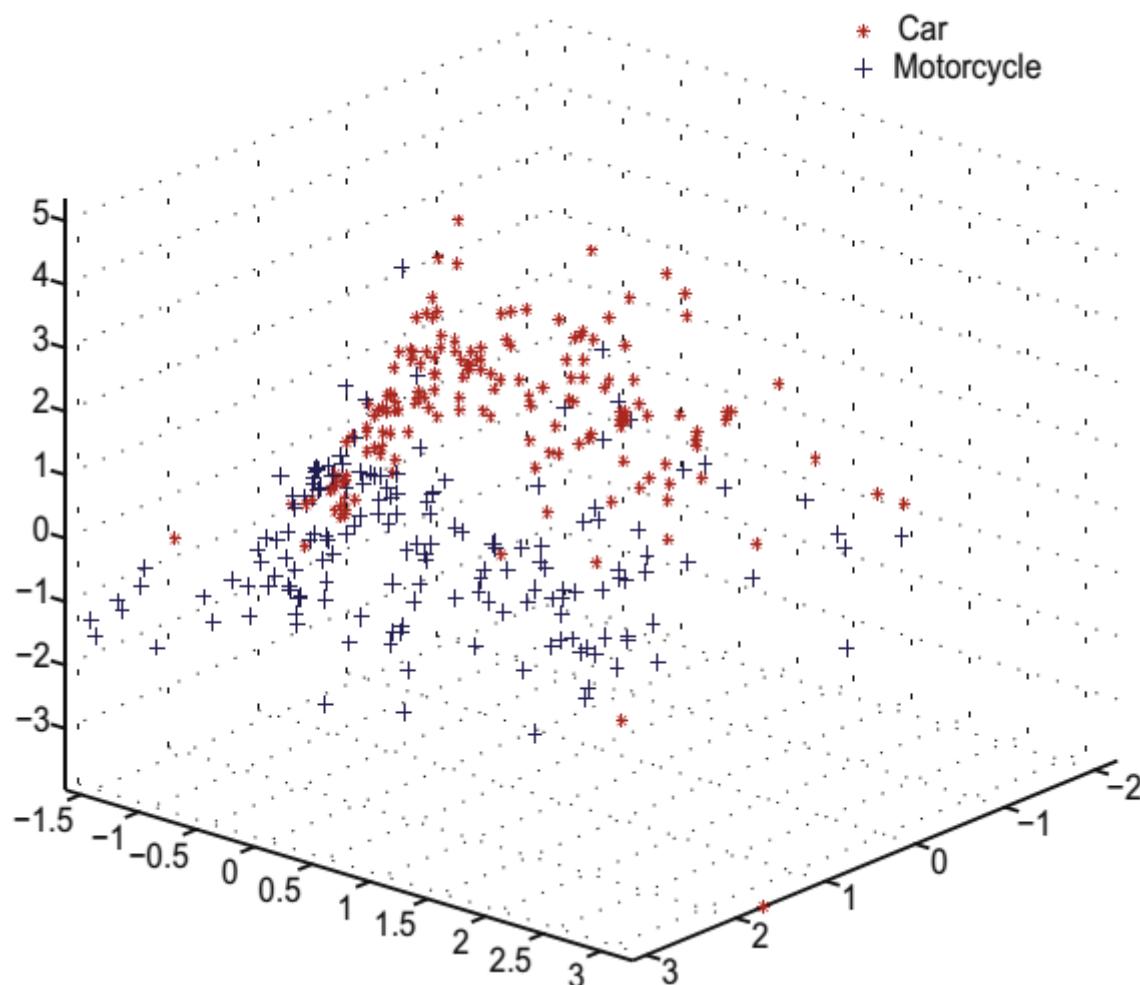
Velocity



(b) Normalized and decomposed velocity profiles for the sample trajectories of motorcycle (on the left) and car (on the right)

Acceleration





- Dodge, S., Weibel, R. & Forootan, E. (2009) Revealing the physics of movement: comparing the similarity of movement characteristics of different types of moving objects. *Computers, Environment and Urban Systems* 33:419–34. doi:10.1016/j.compenvurbsys.2009.07.008
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- McLeod, P. & Dienes, Z. (1996) Do fielders know where to go to catch the ball or only how to get there? *Journal of Experimental Psychology: Human Perception and Performance* 22:531–43. doi:10.1037//0096-1523.22.3.531
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