What (computational) cognitive science can and should do to combat the climate crisis

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Goal for the talk

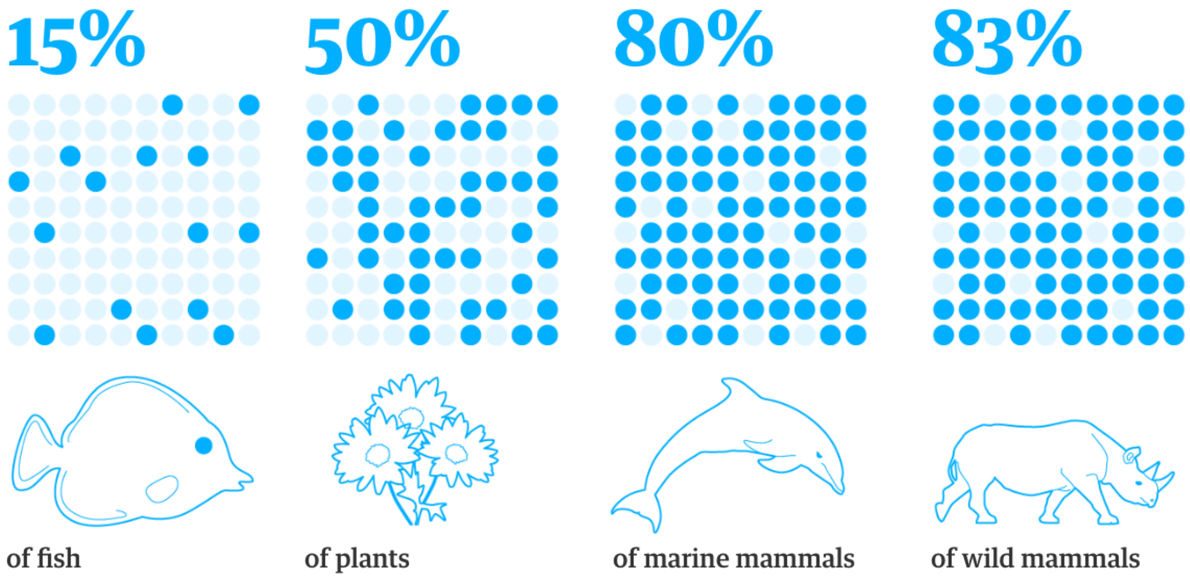
Share my vision for what (computational) cognitive science can do

My current work in this direction

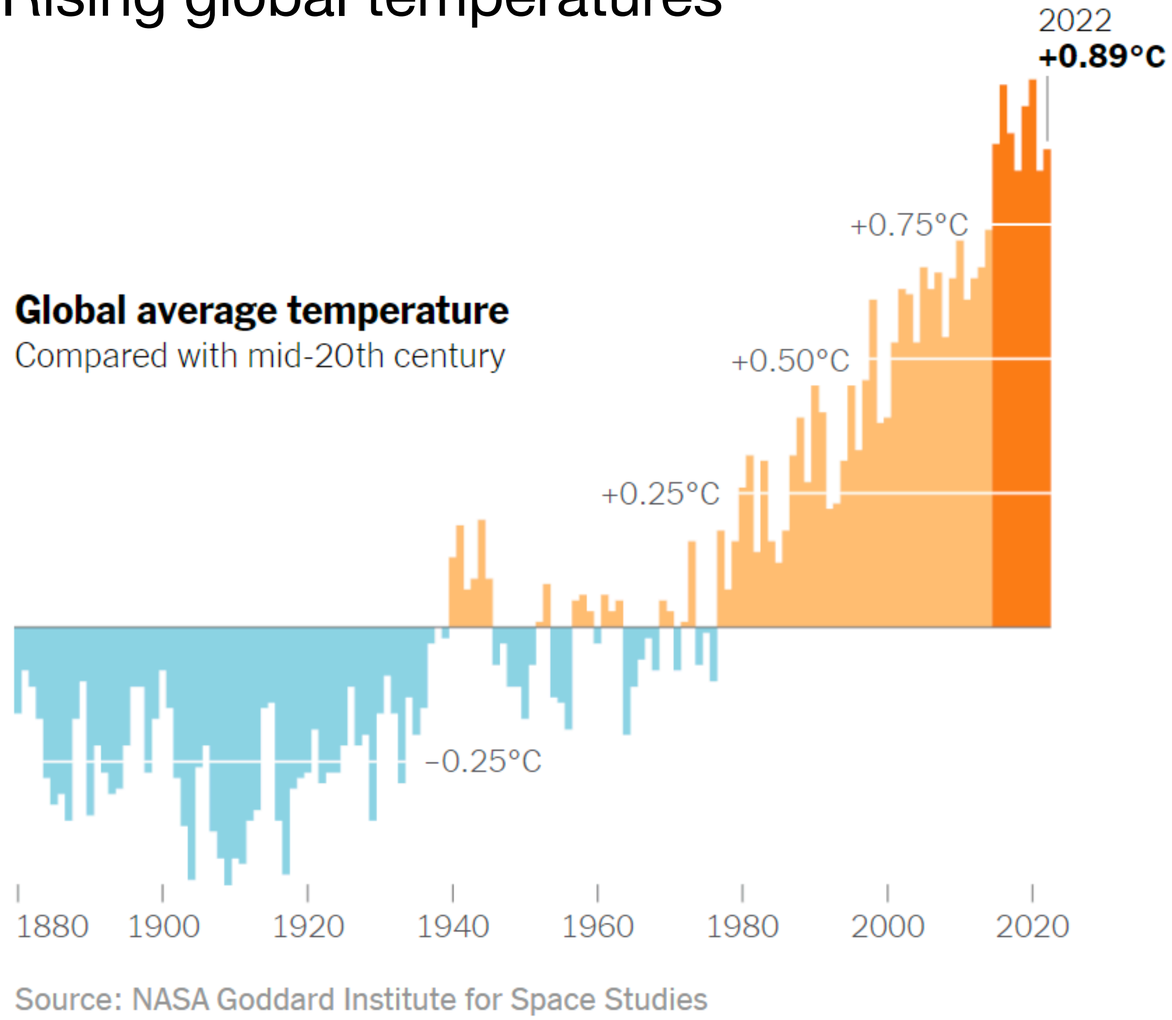
My future plans and vision for the field

(Might skip few technical details and instead focus more on high-level vision)

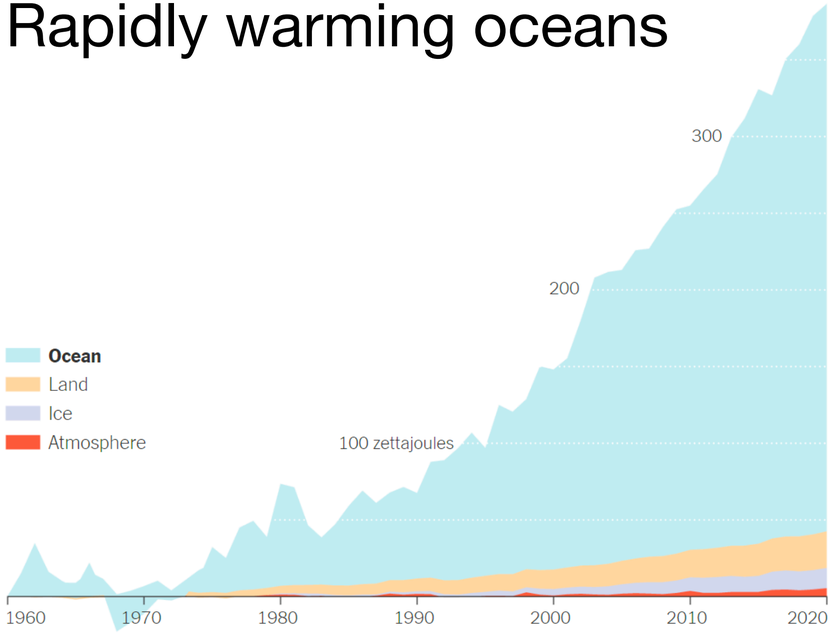
Species lost since rise of human civilization



Rising global temperatures



Rapidly warming oceans

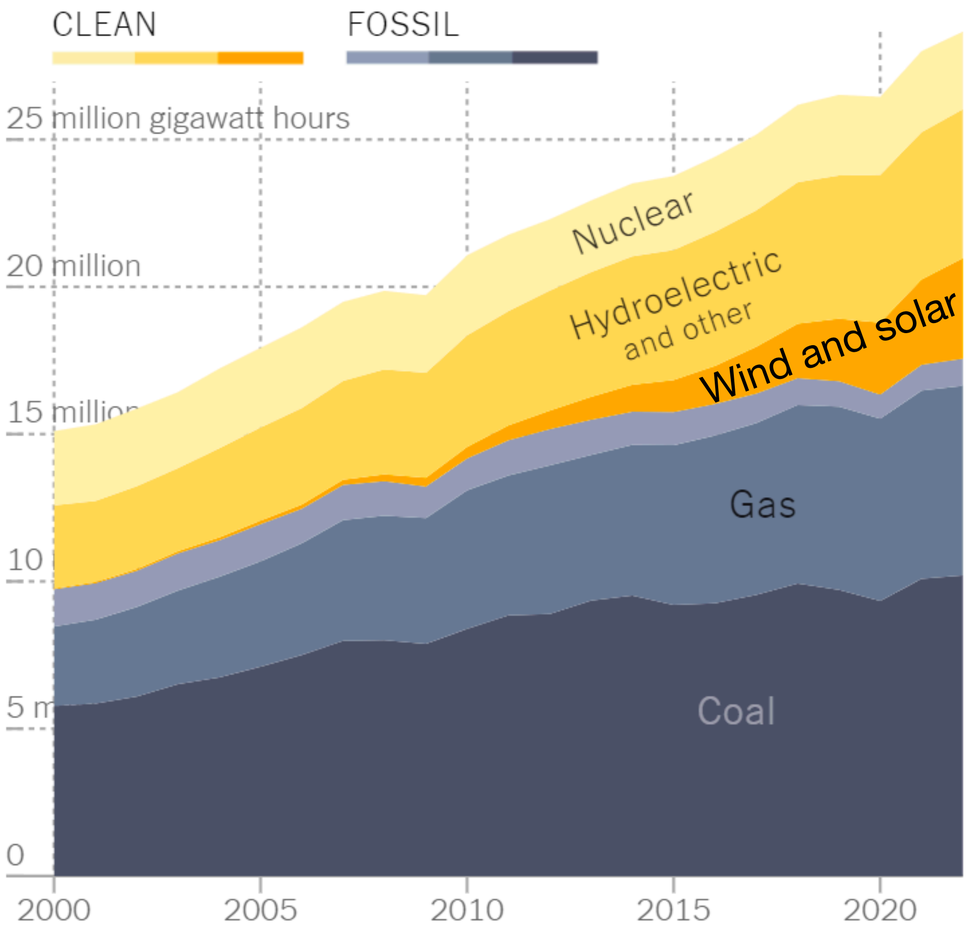


Humanity's footprint on the planet

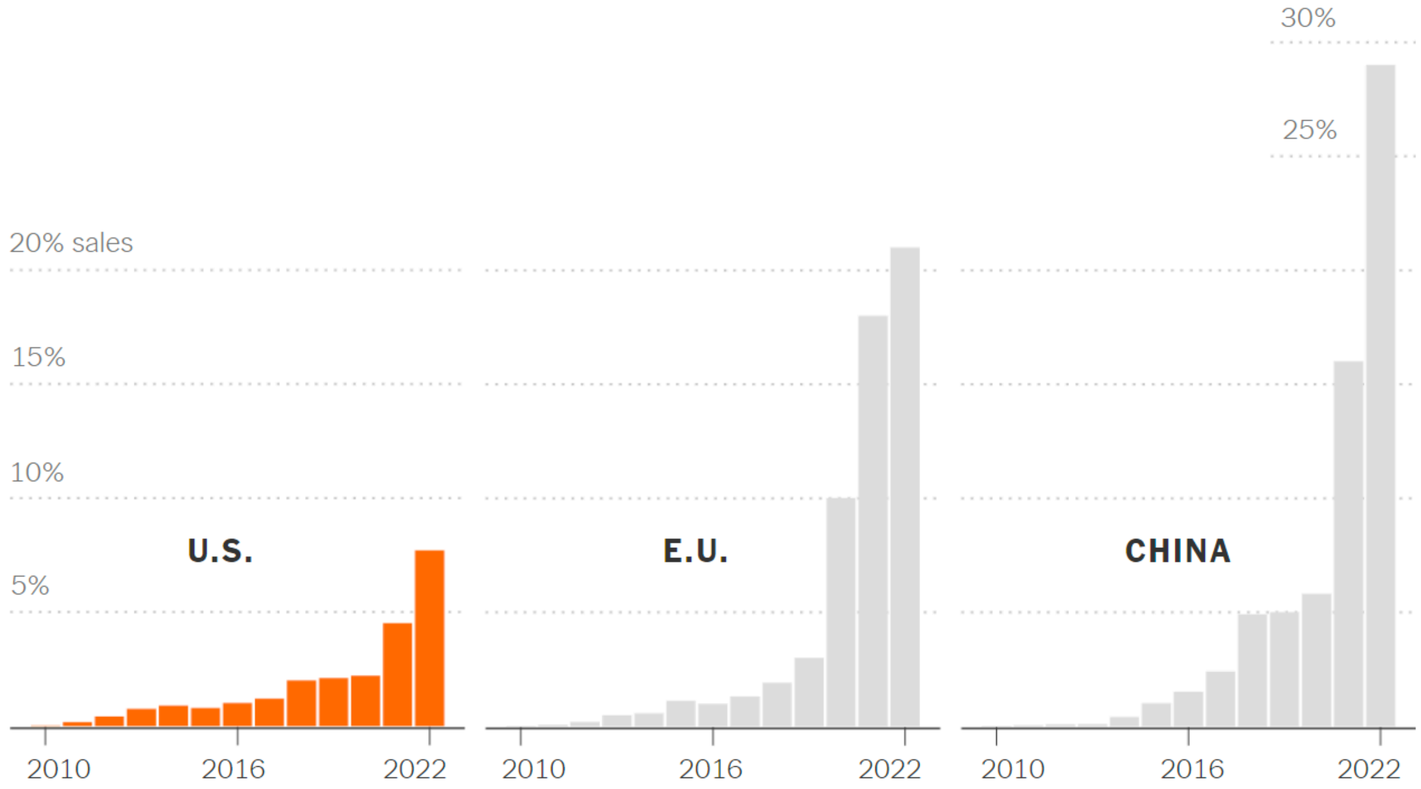
[Wake et al., 2008; Barosky et al., 2011; Ceballos et al., 2017; Ceballos et al., 2020; IPCC 2023]

Progress on climate action **not nearly enough**

Increase in cleaner energy

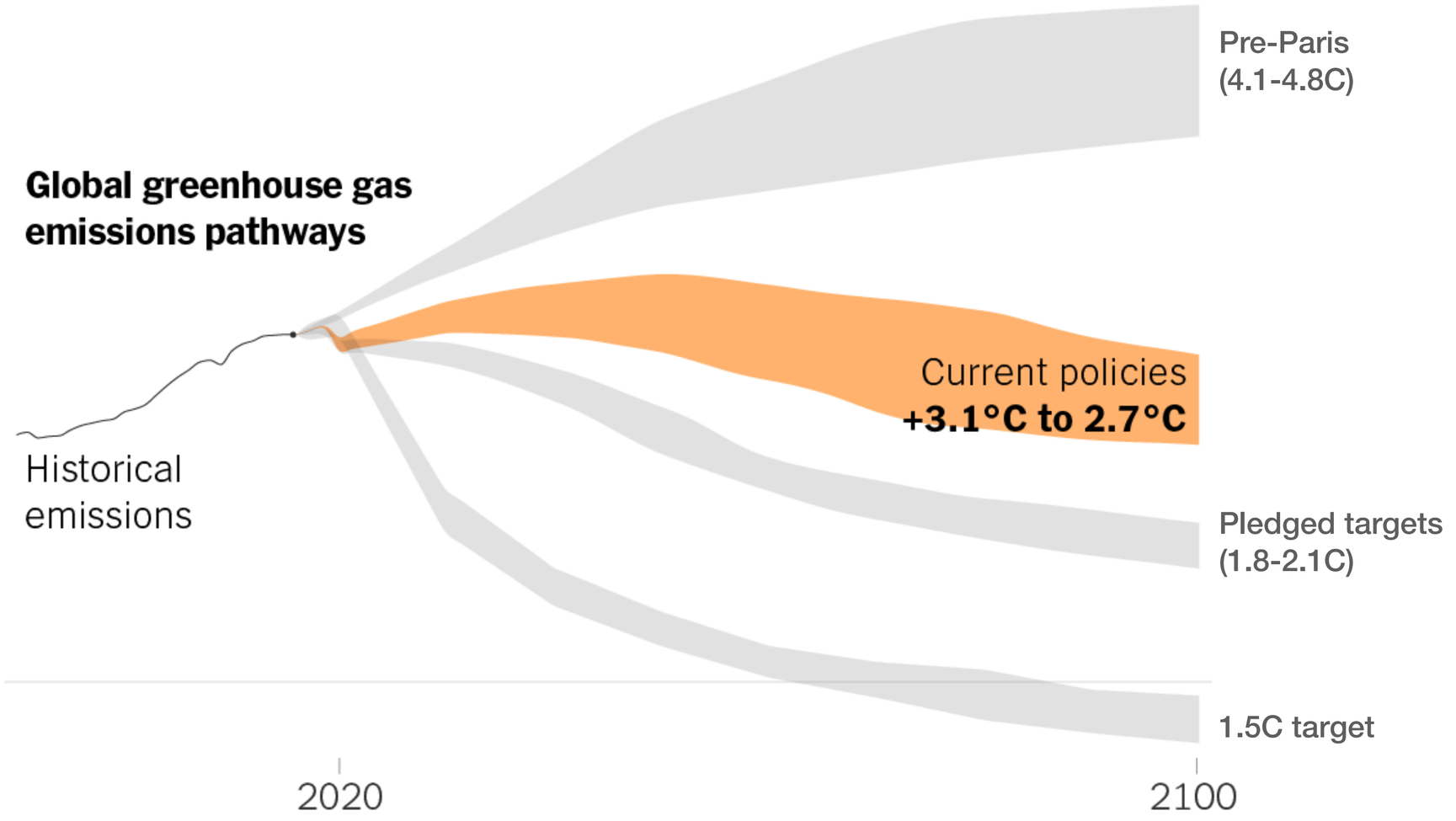


Electrification of personal vehicles



Source: International Energy Agency · Note: Sales share of battery electric vehicles excludes plug-in hybrids, electric trucks and buses and other vehicles. · By The New York Times

Progress on climate action **not nearly enough**



Oct. 25, 2021 | Source: Climate Action Tracker

Climate change is fundamentally an issue of ***human behavior***

What cognitive science can do to help in **future**

Cognitive underpinnings of **environmentally-damaging** behaviors

Why climate change doesn't feel like a big **problem**

What cognitive science can do to help in the **short run**

Motivate **individuals** to be more sustainable

Help efforts aiming to bring **systemic** changes

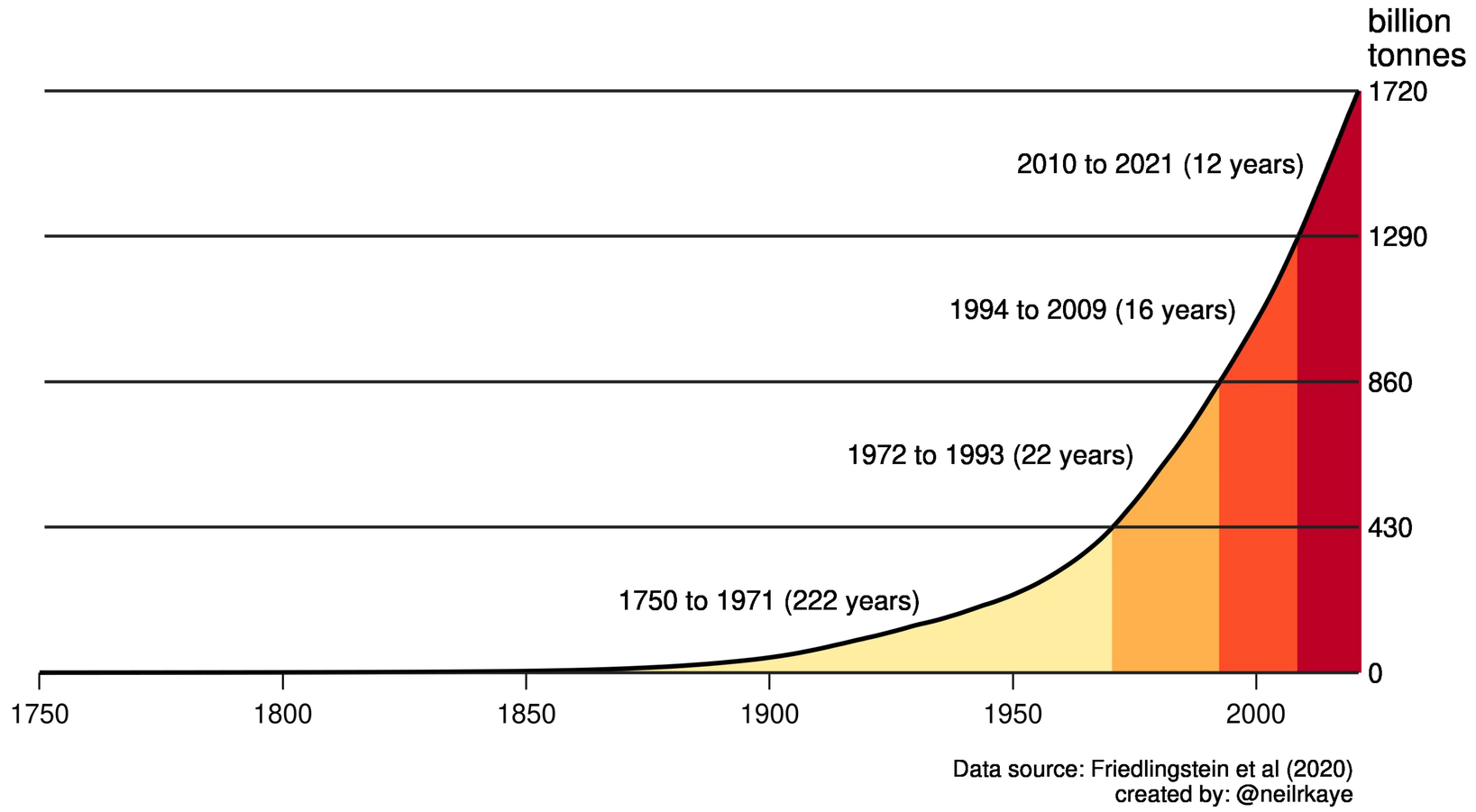
Part 1

What cognitive science can do to help in future

1. Understand overconsumption and habituation

Climate change is fueled by **overconsumption**

Exponential growth in emissions!



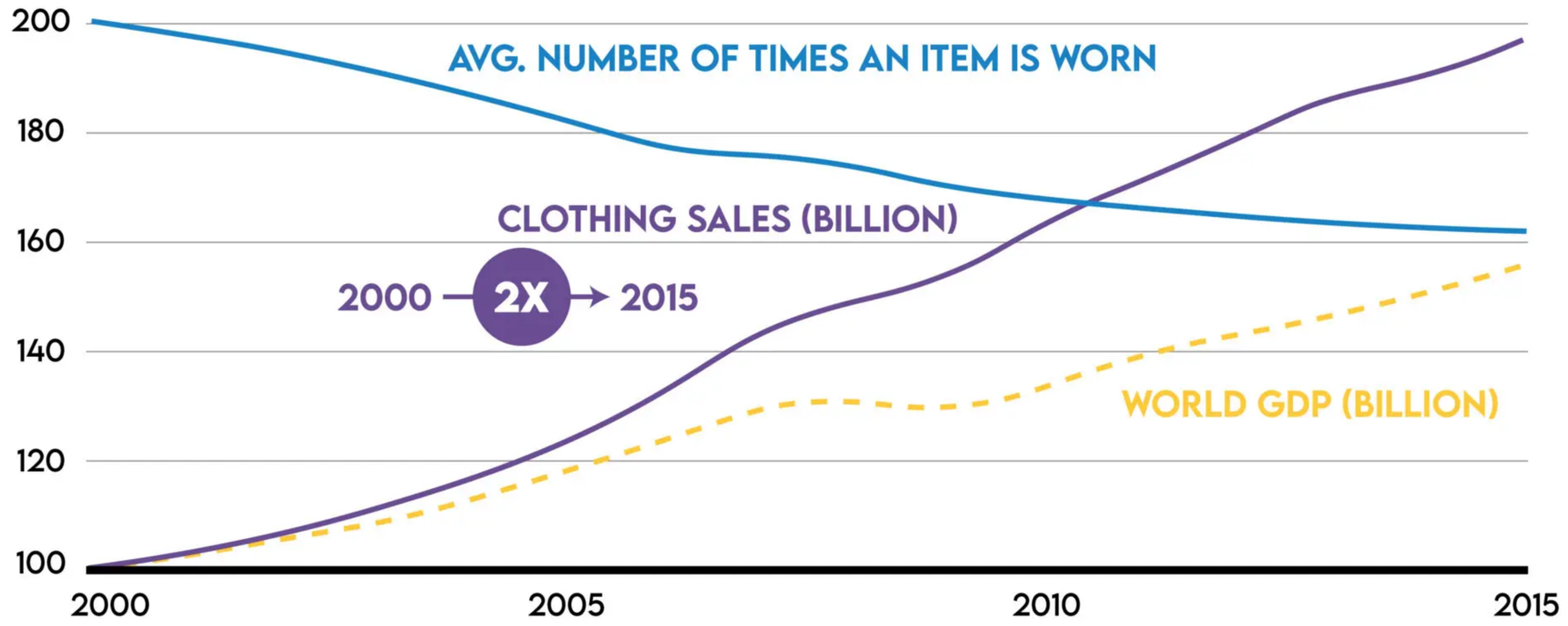
Data source: Friedlingstein et al (2020)
created by: @neilrkaye

Climate change is fueled by **overconsumption**

Half the fossil fuels and many other resources ever used by humans have been consumed in ***just the past 30 years!***

[Steffen et al., 2015; Rees, 2018]

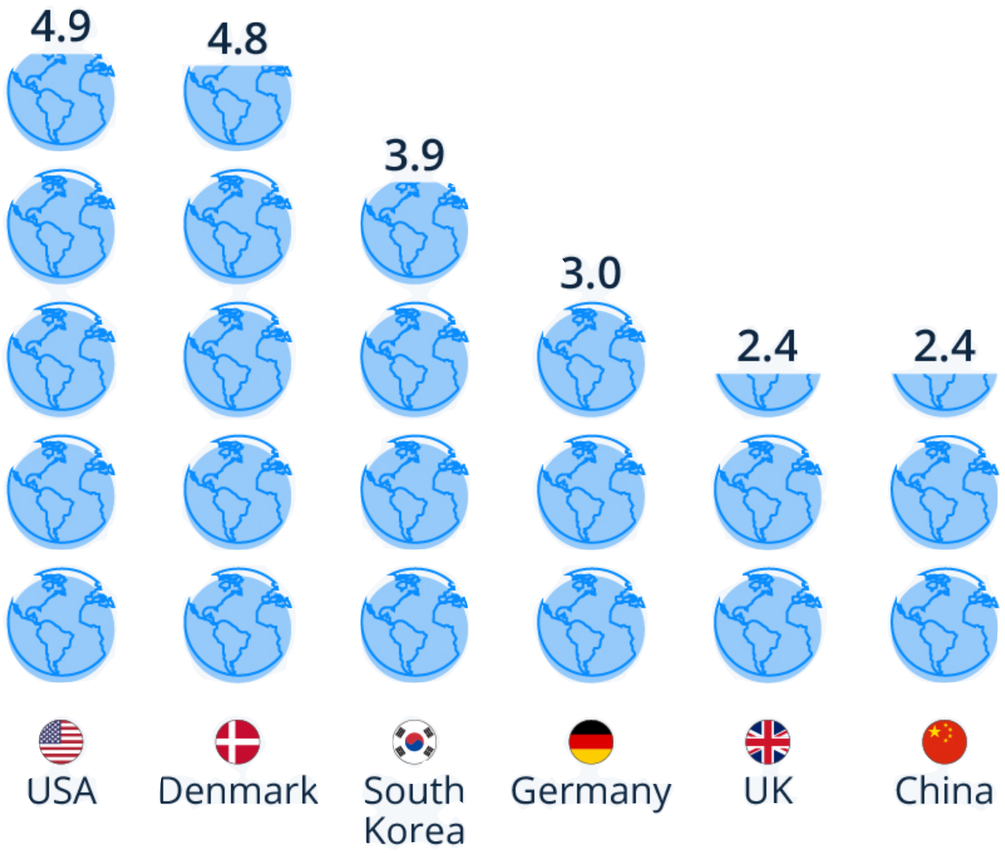
Growth of **clothing sales** and decline in **clothing utilization** since 2000



SOURCE: ELLEN MACARTHUR FOUNDATION
GRAPHIC BY: CRYSTAL FANG

Consumption has grown **exponentially..** but the planet has not

Number of earths/its resources needed if the world's population lived like the following countries:



Selected countries. Calculated based on 2022 data estimates
Source: Global Footprint Network

To address environmental issues, it is important to understand overconsumption

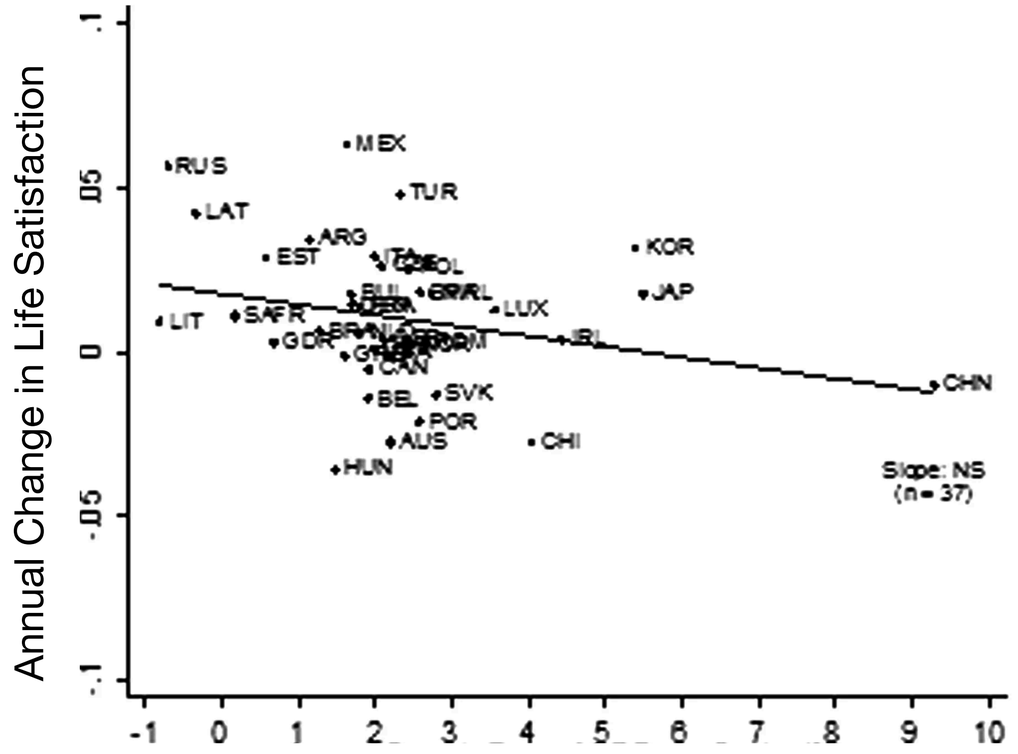
Why are we consuming so much?

To live the “good life”…?

To increase happiness and well-being?

Is increased consumption increasing happiness?

Over long-term, happiness does not increase as a country's income rises



[Easterlin, 1974; Diener & Diener, 2002; Easterlin et al, 2010]

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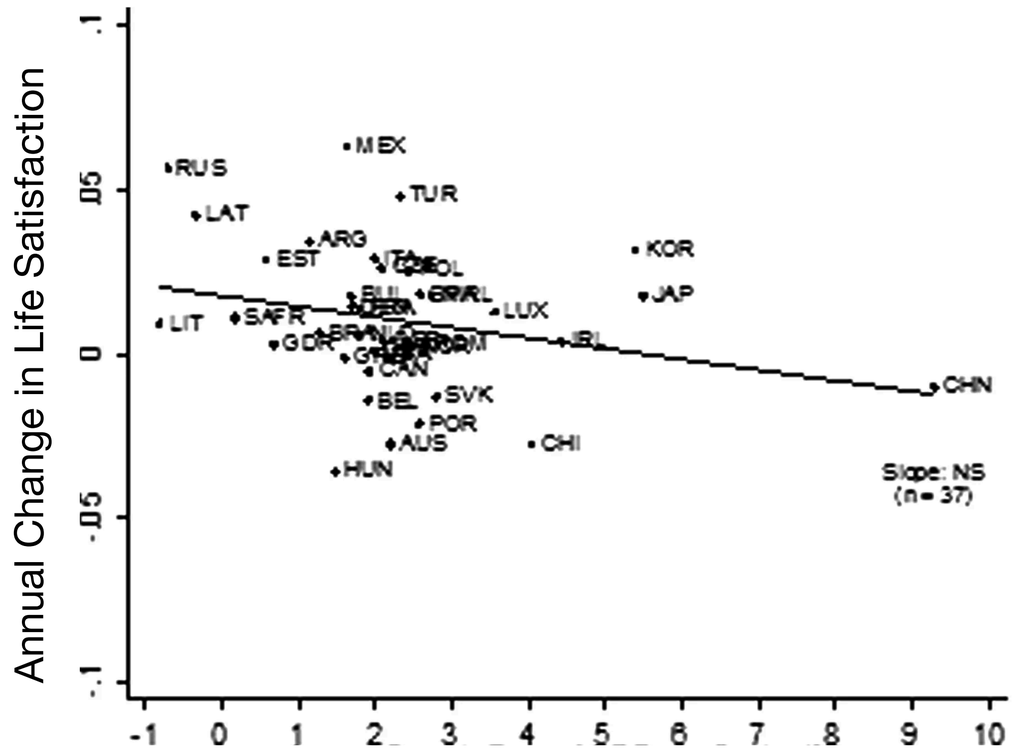


[Easterlin, 1974; Diener & Diener, 2002; Easterlin et al, 2010]

Material purchases don't necessarily increase happiness

[Gilovich & Kumar 2015; Kumar et al., 2020]

Materialistic people are less happy

[Chancellor & Lyubomirsky, 2011; Wang et al., 2017]

Happiness depends on two tragic relativities

Habituation

Brickman, 1978

Brickman et al., 1978

Frederick & Loewenstein 1999

Clark et al., 2008

Comparisons

Veenhoven, 1991

Luttmer, 2005

Ball & Chernova, 2008

Herrmann et al., 2019

Happiness depends on two tragic relativities

Habituation + **Comparisons**

..can lead to a vicious cycle of never-ending wants and desires

[Lyubomirsky & Ross, 1997; Chancellor & Lyubomirsky, 2011; Knight & Gunatilaka, 2012]

Happiness depends on two tragic relativities

Habituation + **Comparisons**

…can result in depression, materialism, and overconsumption

[Lyubomirsky & Ross, 1997; Chancellor & Lyubomirsky, 2011; Knight & Gunatilaka, 2012]

My work

This talk

How habituation and comparisons influence an individual agents' behavior

Dubey, Griffiths, & Dayan (2022). *PLOS Computational Biology*

Future directions

How agents should manage multiple needs

Dulberg, Dubey, Berwain, & Cohen (2023). *PNAS*

How multiple agents can solve a resource consumption problem in the face of habituation and comparisons

Future directions

Research question

Why do we habituate and compare?

Dubey, Griffiths, & Dayan (2022). *PLOS Computational Biology*

These relative features might have offered evolutionary advantages

[Nesse, 1990; Buss, 2000; Nesse 2004; Kovac, 2012; Euba, 2021]

Habituation and comparisons might be optimal in presence of uncertainty, noise, or costly computation

[Rayo & Becker 2007; Rangel & Clithero 2012; Palminteri & Lebreton, 2021; Hunter & Daw, 2021]

We analyze the costs and benefits of these features by adopting the framework of Reinforcement Learning

Habituation and comparisons could have been favored due to the ***learning*** advantages they confer

Dubey, Griffiths, & Dayan (2022). *PLOS Computational Biology*

Study: Why do we habituate and compare?

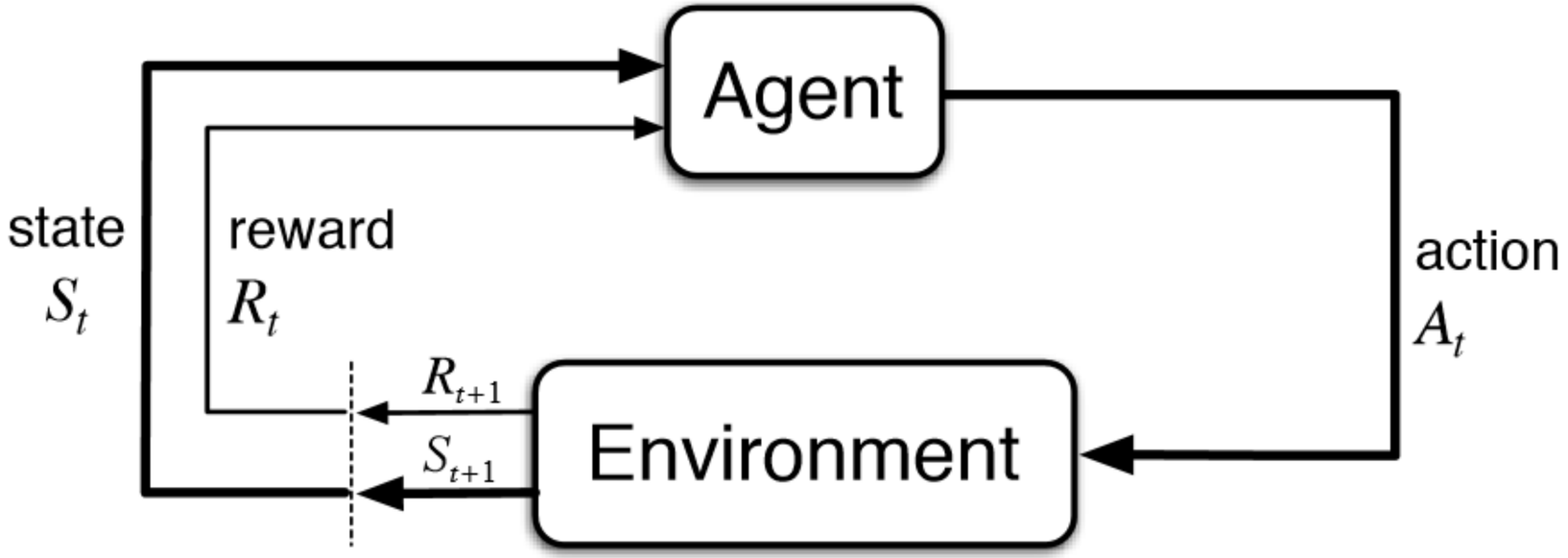
A reinforcement learning perspective on habituation and comparisons

Dubey, Griffiths, & Dayan (2022). *PLOS Computational Biology*

- Background
- Methods
- Results

Reinforcement Learning

Describes how an agent learns to interact with an environment through *feedback*



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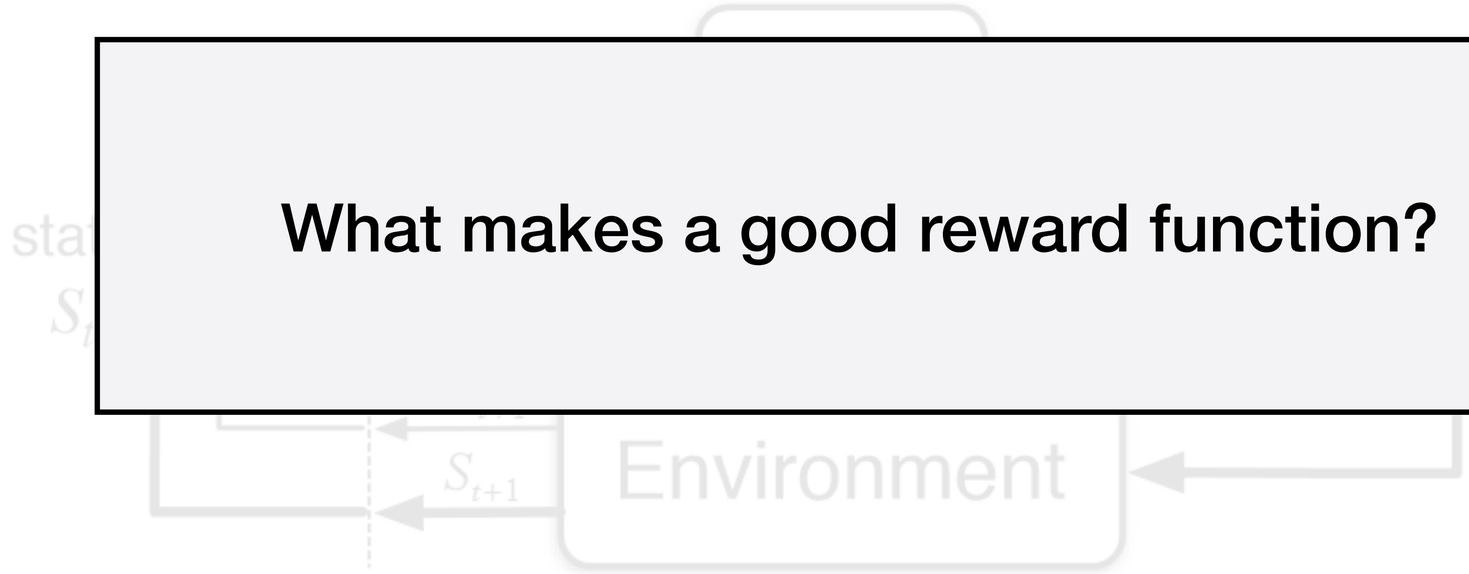
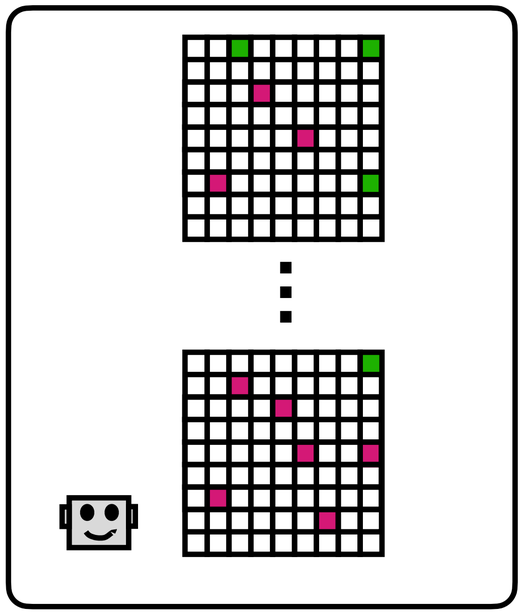


What makes a good reward function?

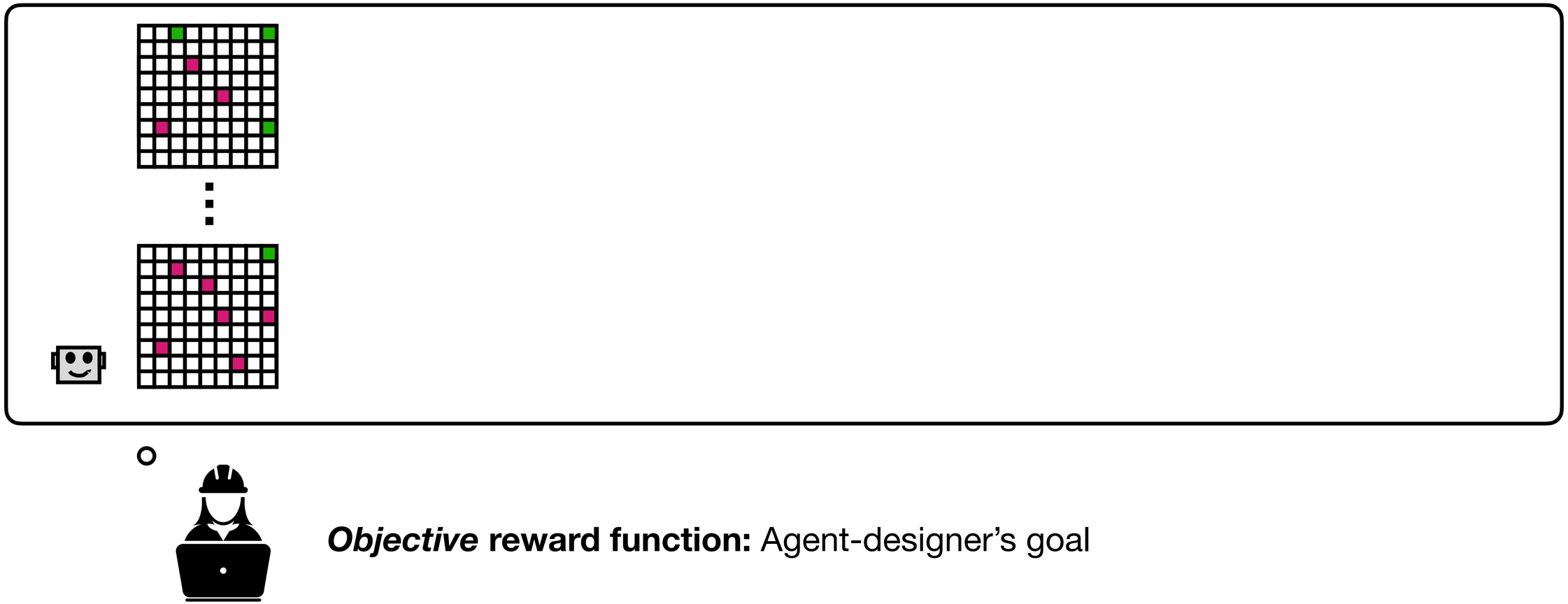


What reward function should
I provide to the agent?

Reward design

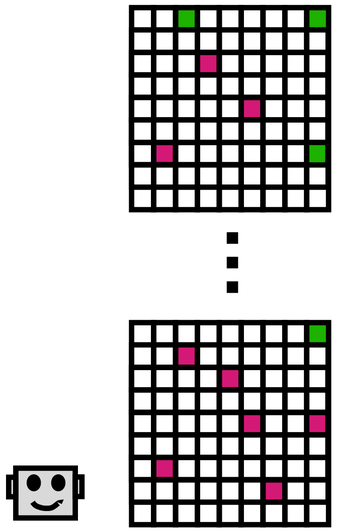
[Ng et al., 1999; Singh et al., 2010; Sorg et al., 2018]

Optimal Reward Framework [Singh et. al., 2010]

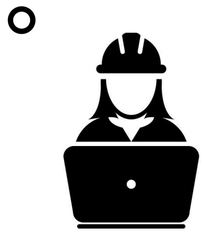


***Objective* reward function:** Agent-designer's goal

Optimal Reward Framework [Singh et. al., 2010]



Challenge: Learning from objective rewards alone is very hard



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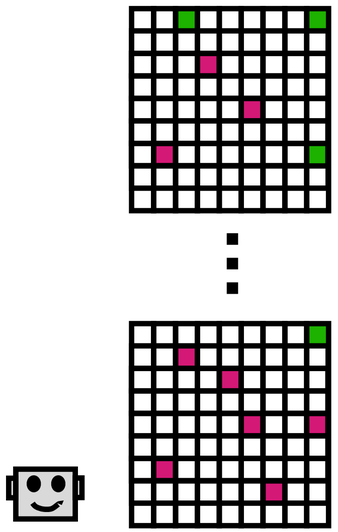
What should the subjective reward function be in the agent's computation?



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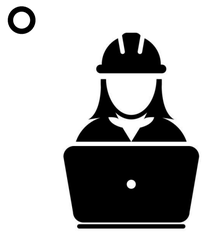
***Subjective* reward function:** Agent's reward, provides useful feedback



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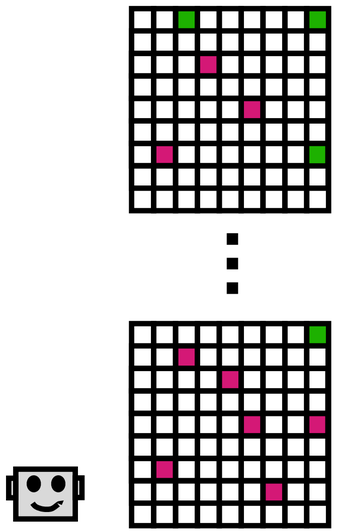
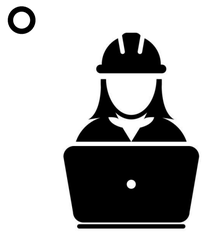


Challenge: Learning from objective rewards alone is very hard

***Subjective* reward function:** Agent's reward, provides useful feedback

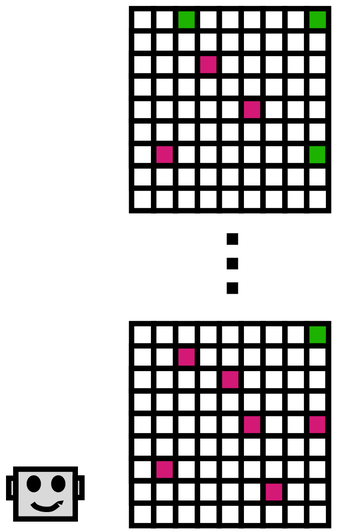
***Optimal reward*:** Subjective reward that bests achieves the designer's objective



***Objective* reward function:** Agent-designer's goal

Habituation and comparisons as useful reward signals

Environments with $w_2 \neq 0$ and $w_3 \neq 0$ can provide insights!



Each possible ***subjective*** reward function takes the form:

$f = w_1 \,.\, \text{Objective} + w_2 \,.\, \text{Habituate} + w_3 \,.\, \text{Compare}$

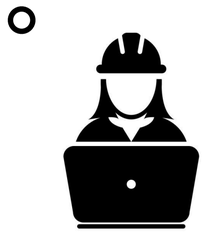
Objective $= r_t$

Habituate $= r_t - Q(s_t, a_t)$

Compare $= r_t$ – aspiration

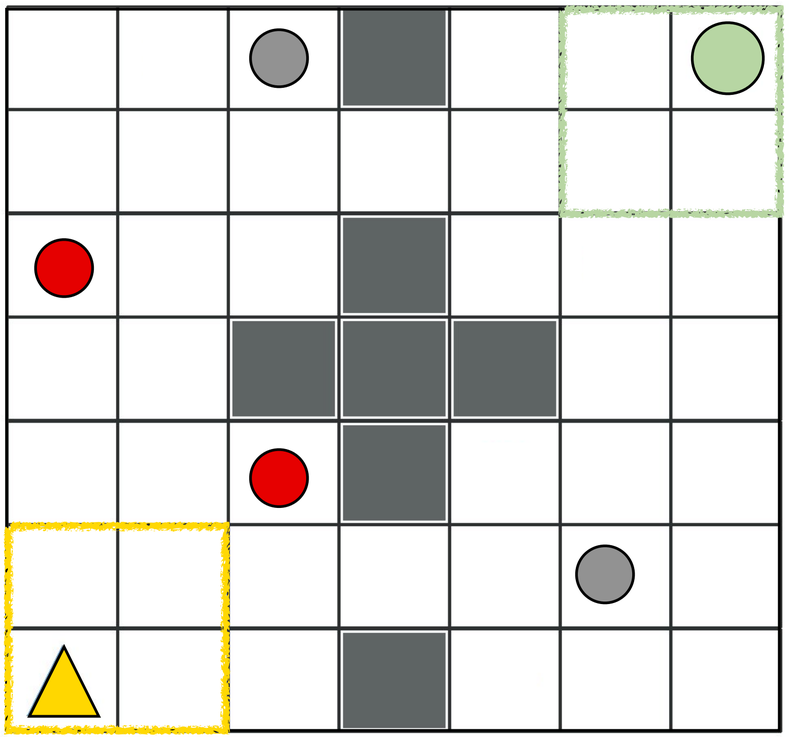
Derive optimal reward by performing dense grid search over w_i [0 to 1; 0.1]

Also searched aspiration, ϵ, and α



Designer's objective: maximize expected return $J_t = \sum_{t=t}^{T} r_t$

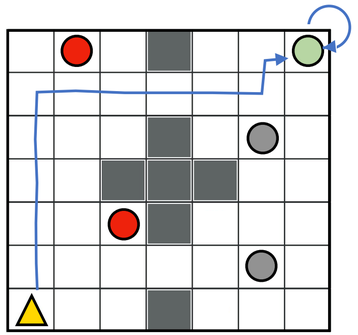
[Baggio & Papyrakis, 2014; Palminteri et al., 2015; Rutledge et al., 2016]



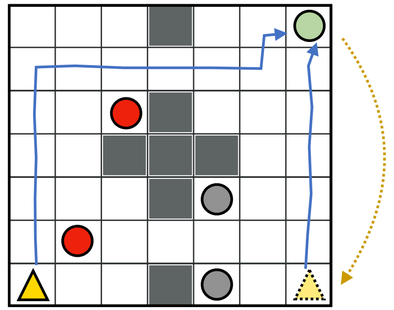
Learning agent
Food state
Poison state
Sinkhole state

The agent can choose five actions:
Up, Down, Right, Left, and Stay

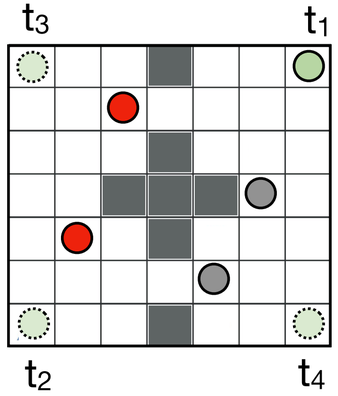
One-time learning



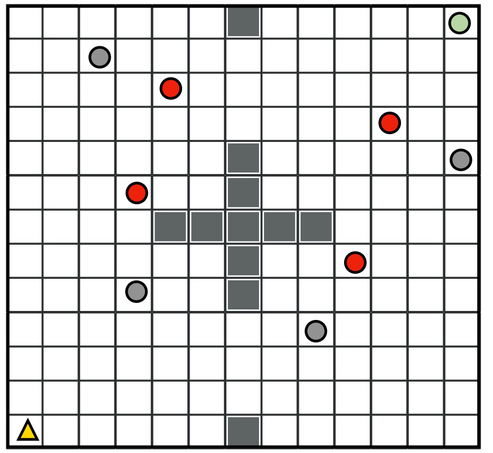
Lifetime learning



Non-stationary



Sparse



Study: Why do we habituate and compare?

A reinforcement learning perspective on habituation and comparisons

Dubey, Griffiths, & Dayan (2022). *PLOS Computational Biology*

- Background
- Methods
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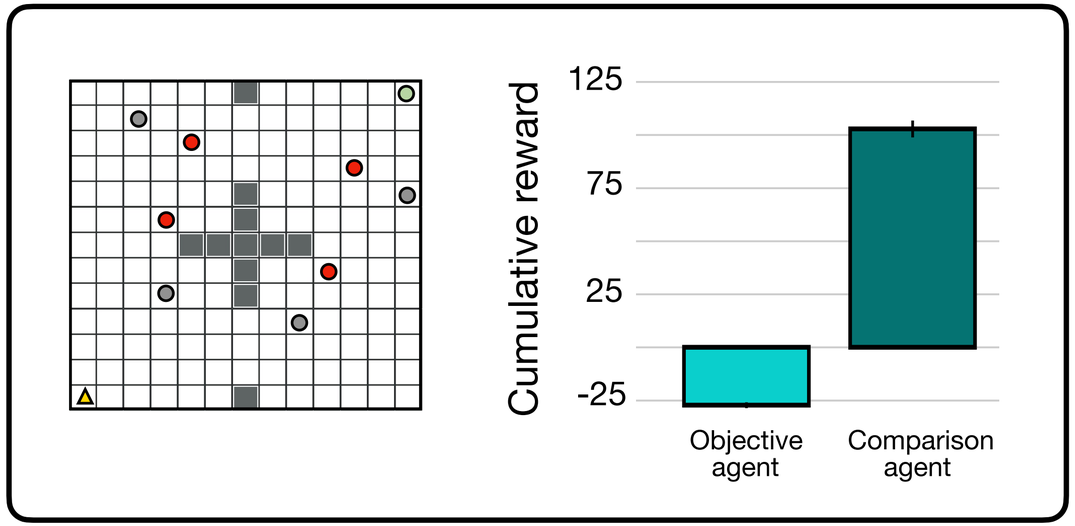
Finding 1:

Comparisons significantly speed learning in all environments

Sparse environments



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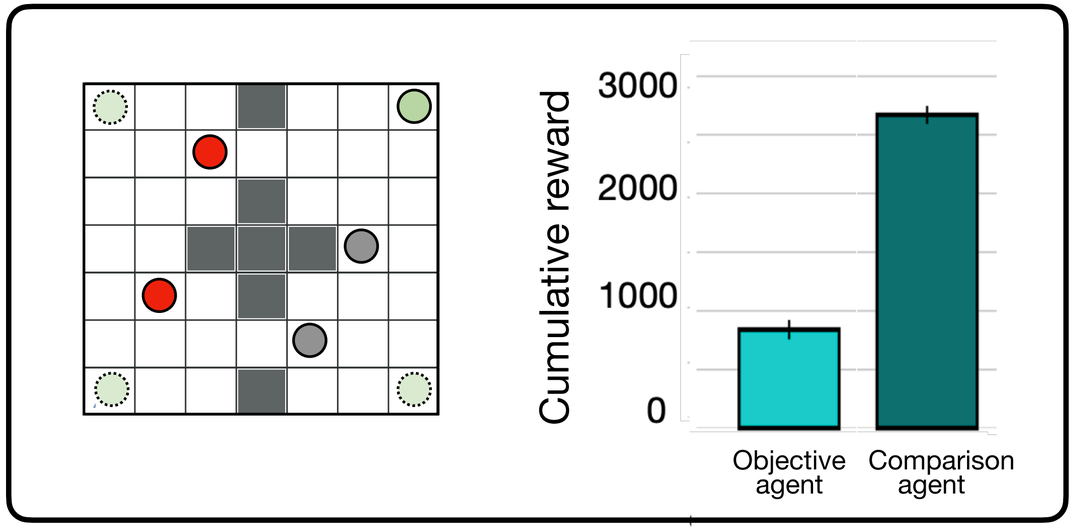
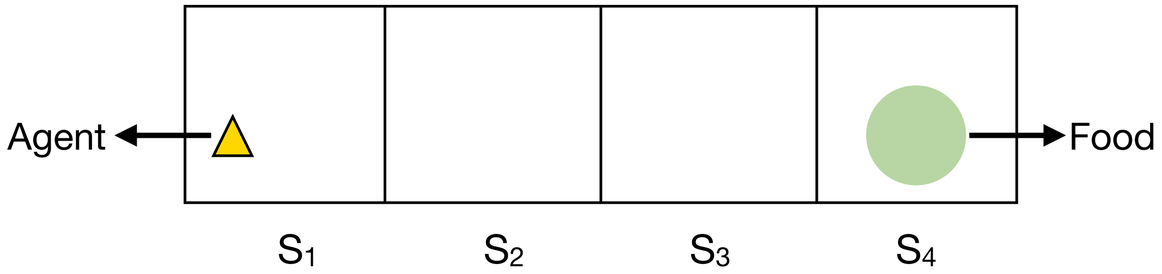
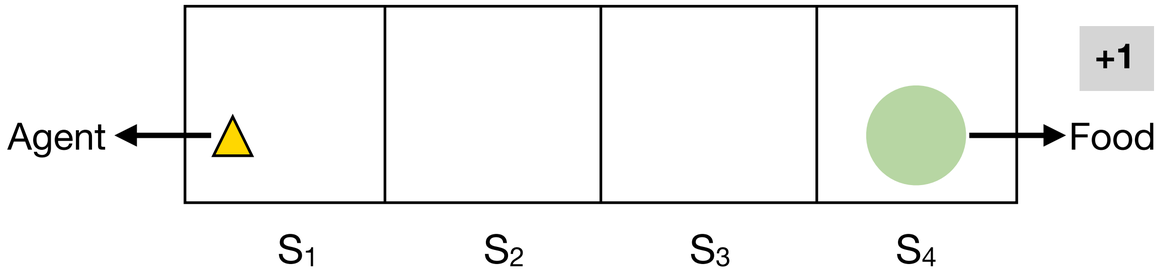


Simple 4-state env



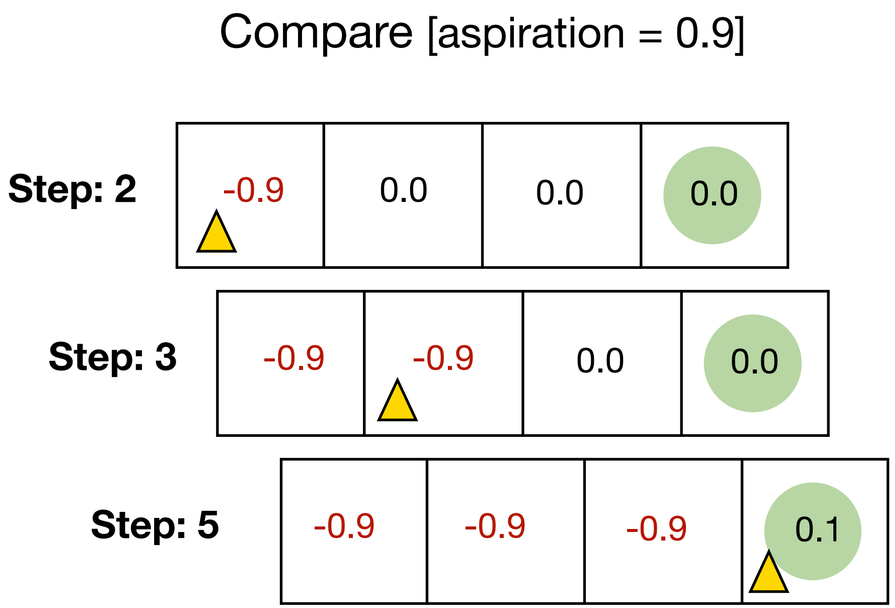
Objective: Get to the food state as quickly as possible

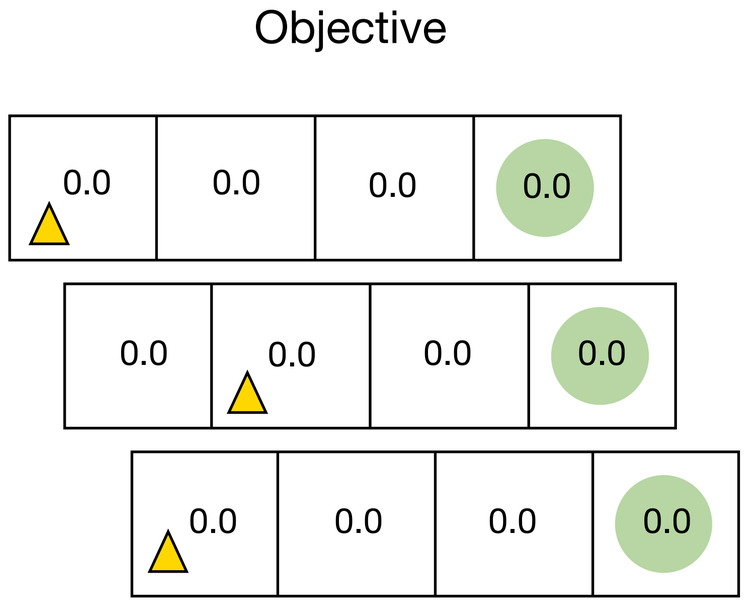
Simple 4-state env



Objective: Get to the food state as quickly as possible

Comparison provides an ***exploration*** incentive





Note: number in grid represents value of state

Disclaimer: Comparisons aren’t the only way to encourage exploration

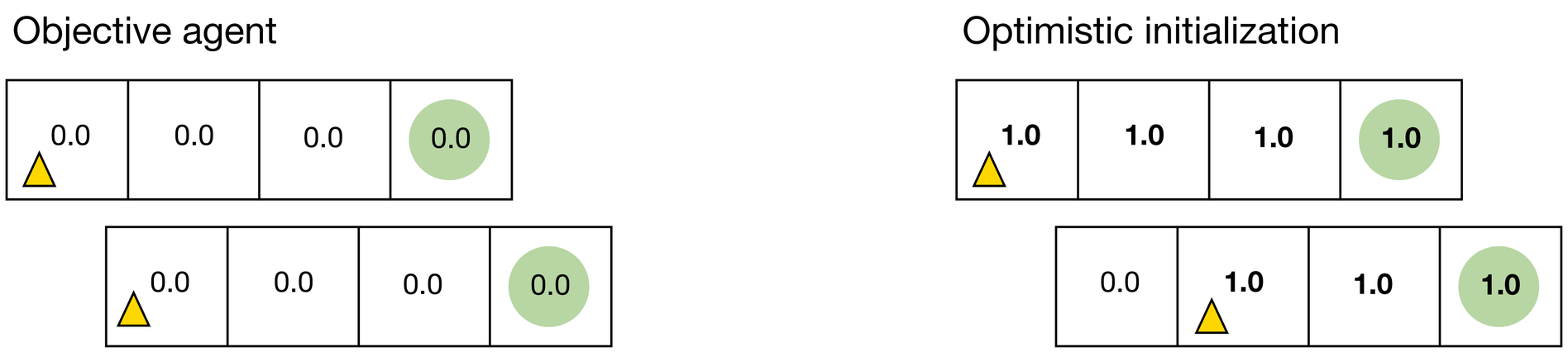
Finding 2:

Exploration induced by comparisons is more efficient than exploration induced by optimistic initialization

Comparisons encourage exploration by inducing ***pessimism***

Alternative: Encourage exploration via ***optimistic*** initialization

[Sutton 1991; Dayan & Sejnowski, 1996]

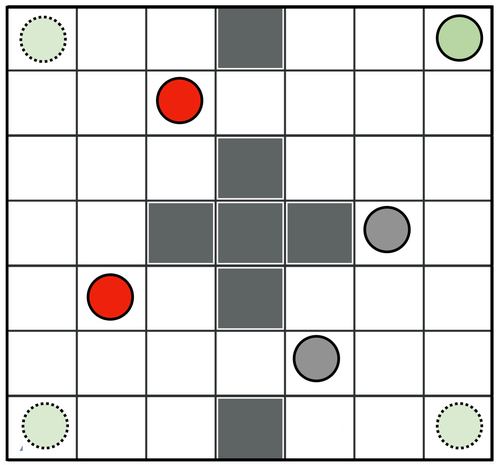


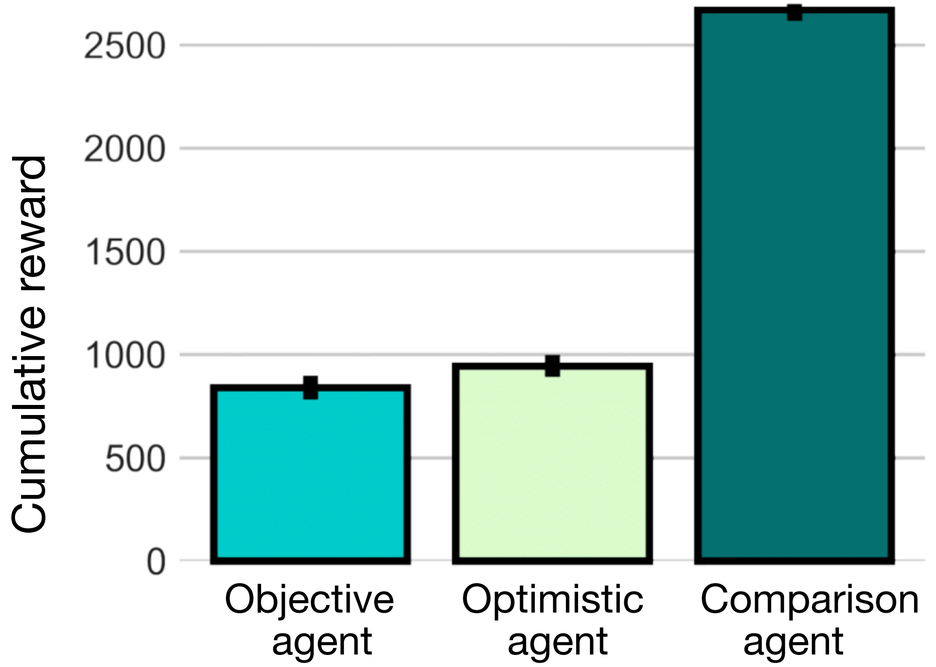
Optimism vs. pessimism

Comparison agents perform better than optimistic agents in non-stationary settings

Optimistic initialization is temporary; comparisons are forever

Non-stationary environments



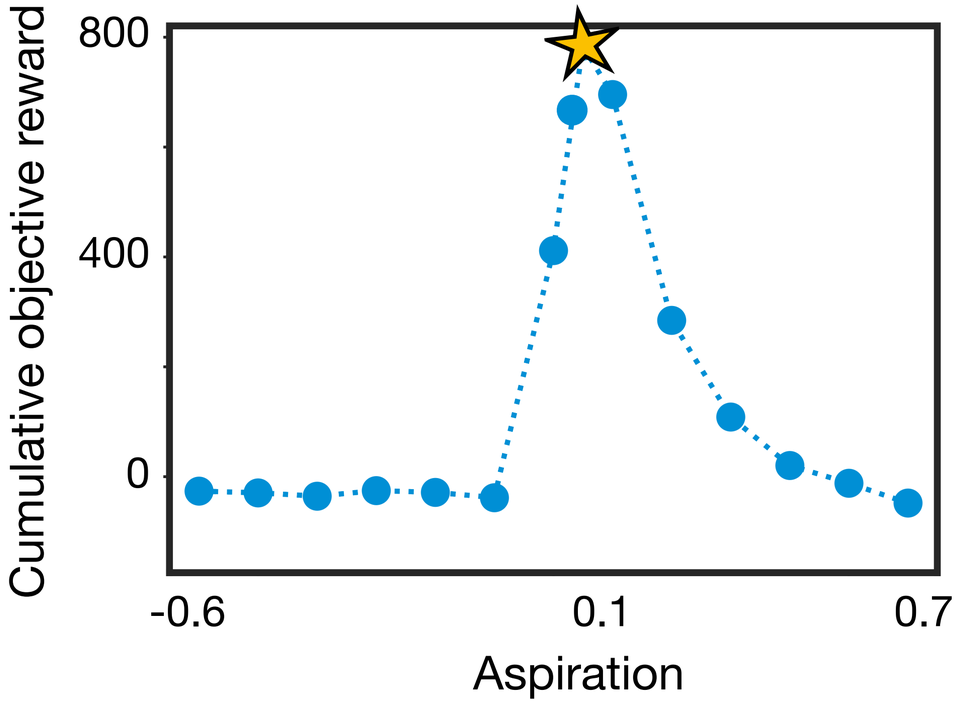


Finding 3:

When and why comparisons become ***maladaptive***

Maladaptive comparisons

Comparisons are only useful when aspiration is set properly!



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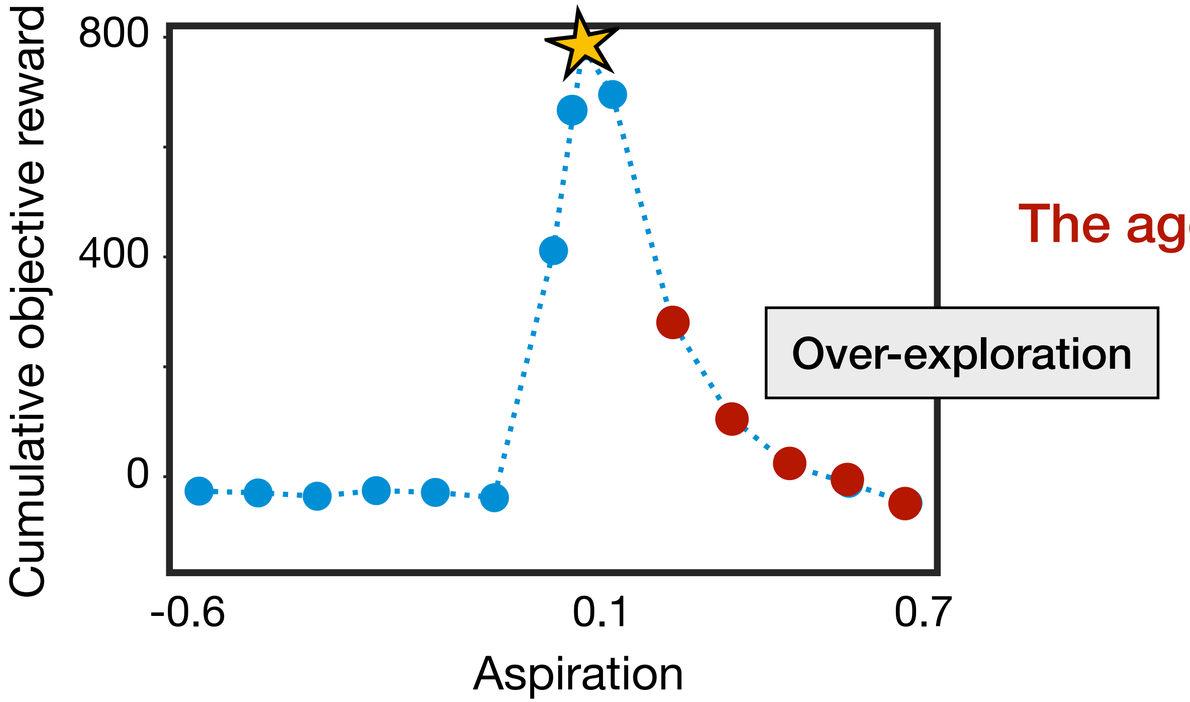
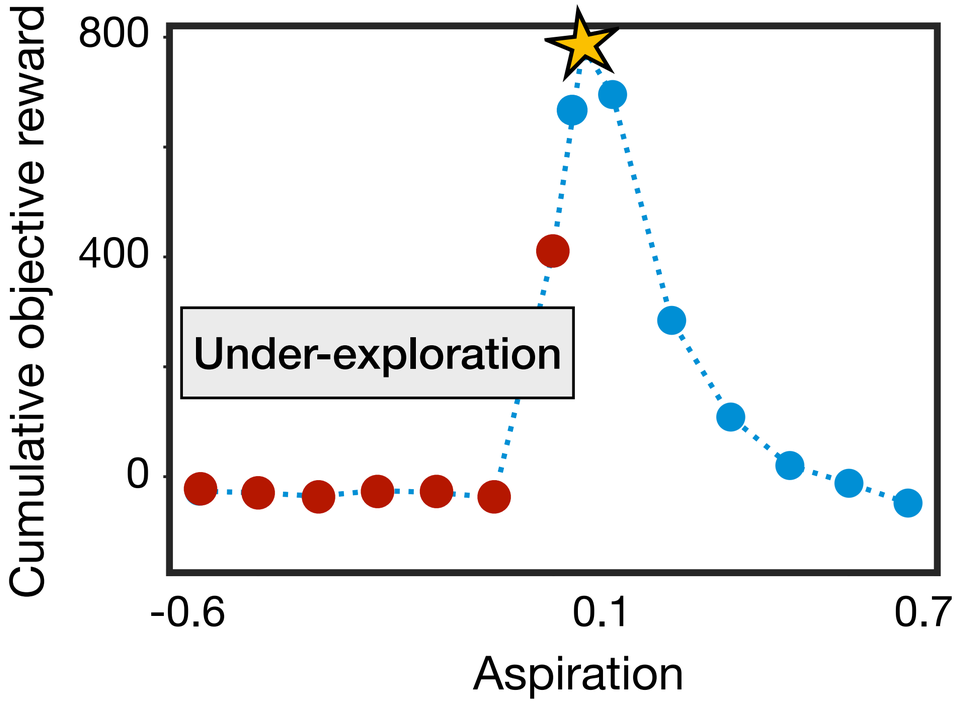


The agent is never satisfied with anything in the world!

Maladaptive comparisons

Comparisons are only useful when aspiration is set properly!



The agent is satisfied too easily!

Maladaptive comparisons

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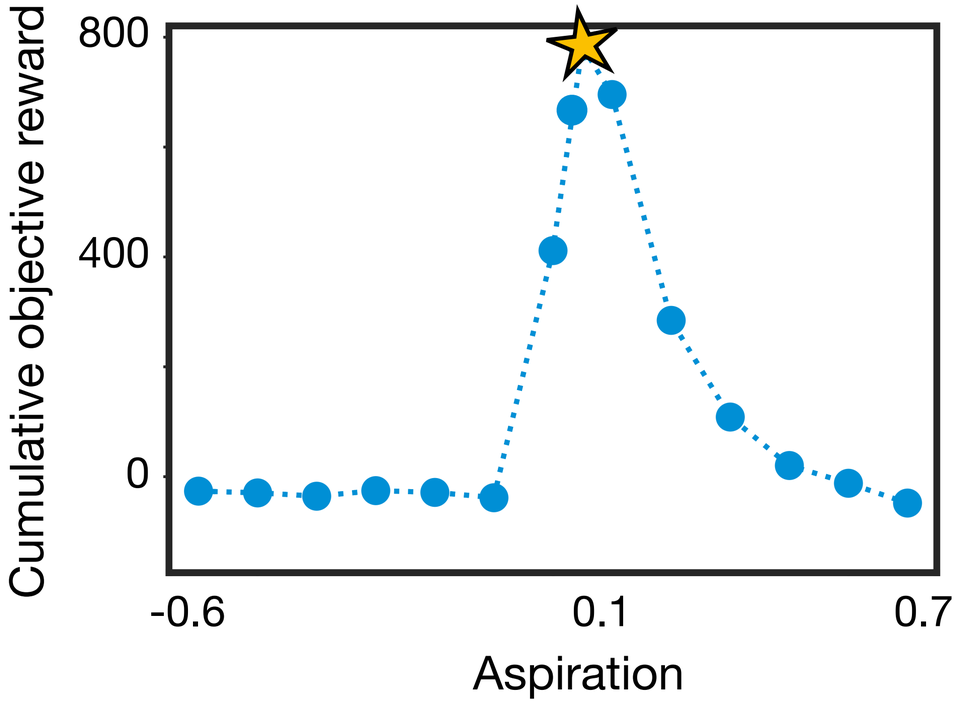
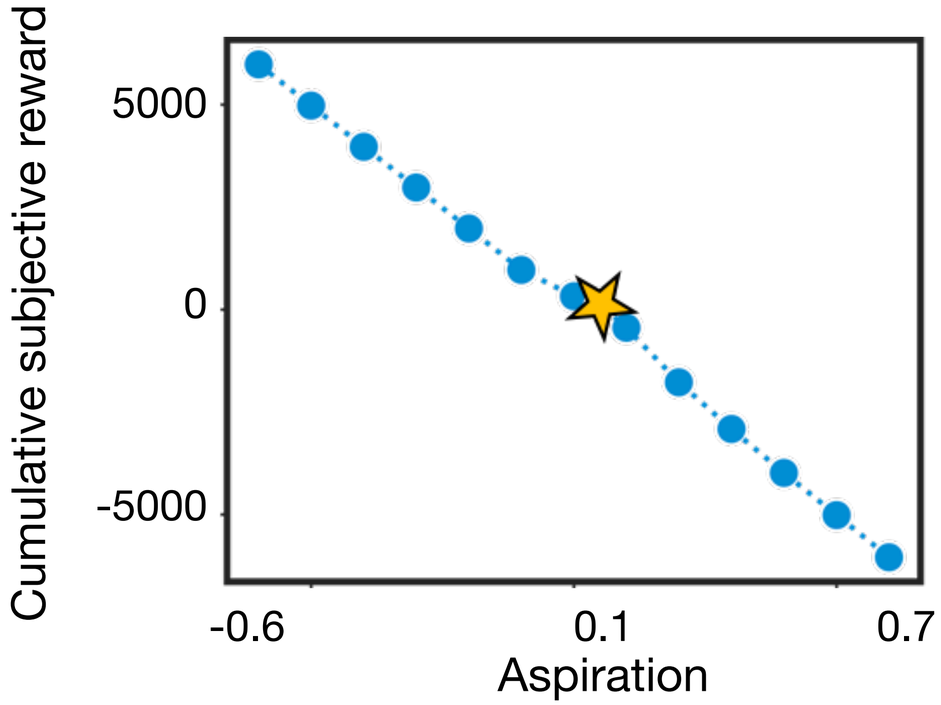


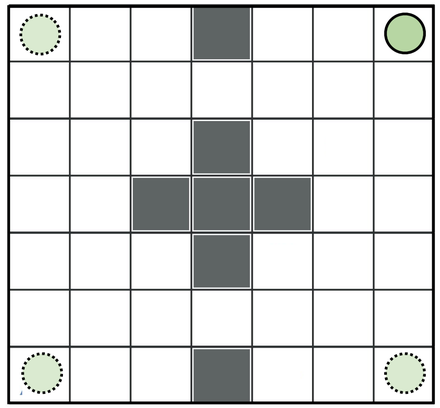
Trade-off between objective and subjective reward

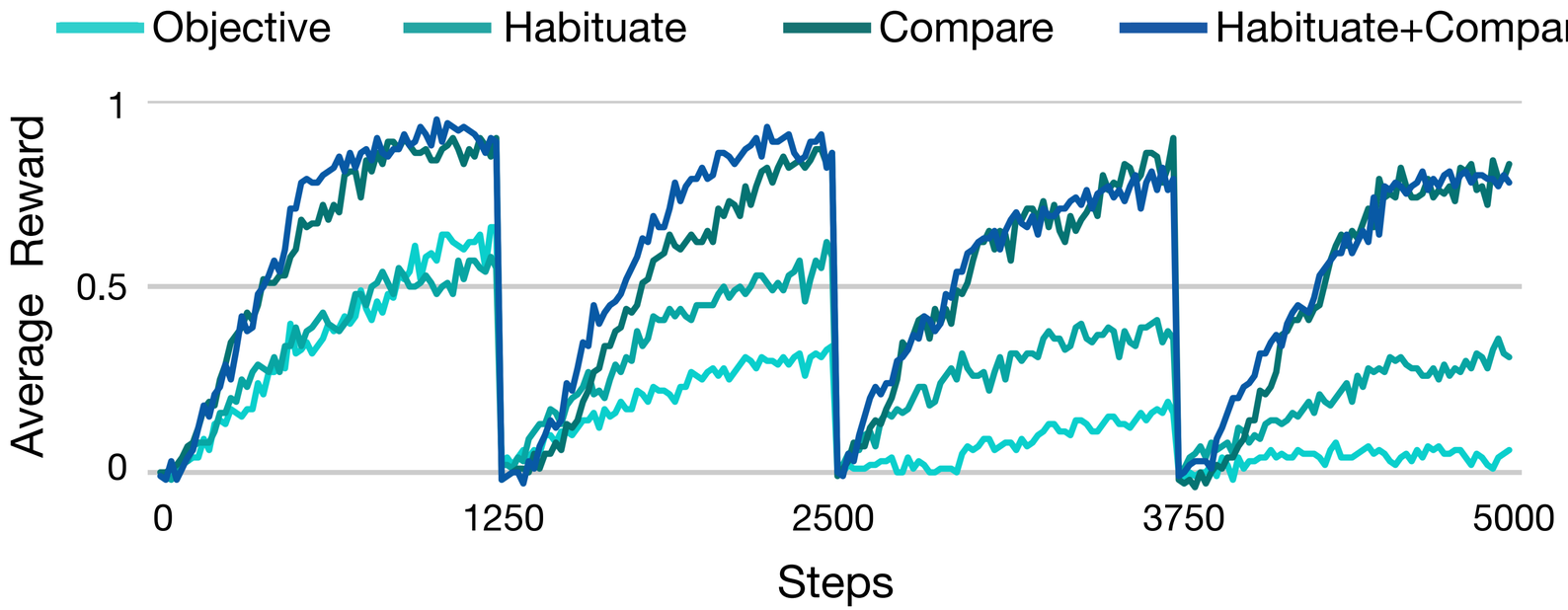


Finding 4:

When and why habituation helps an agent

Habituation improves learning in *non-stationary* environments





Study: Why do we habituate and compare?

A reinforcement learning perspective on habituation and comparisons

Dubey, Griffiths, & Dayan (2022). *PLOS Computational Biology*

- Background
- Methods
- Results
- Takeaways

When and why do habituation and comparisons help us?

These presumable “flaws” play an important role in promoting adaptive behavior

They facilitate learning when rewards are infrequent and help adapt to environmental changes

When do they become maladaptive?

They can quickly become maladaptive in many modern-day situations, where we are constantly bombarded with new luxuries

Implications

From a computational viewpoint, it might be ***optimal*** to design agents that always want more

Computational perspective: Overconsumption might be a deeply rooted bias

Requires fundamental investigation on how to manage these biases of the human mind

What cognitive science can do to help in future

1. Understand overconsumption and habituation

Future directions

Computational underpinnings of overconsumption
(aka how to be happy with less)

People are willing to pay more for “rare” products [Snyder,1992; Stephens et al.,2007]

Research question: Why do we cherish rare rewards?

We don’t appreciate things when they are widely available [Rothenhoefer et al., 2021]

Research question: Why does abundance cause value-depreciation?

What cognitive science can do to help in future

1. Understand overconsumption and habituation

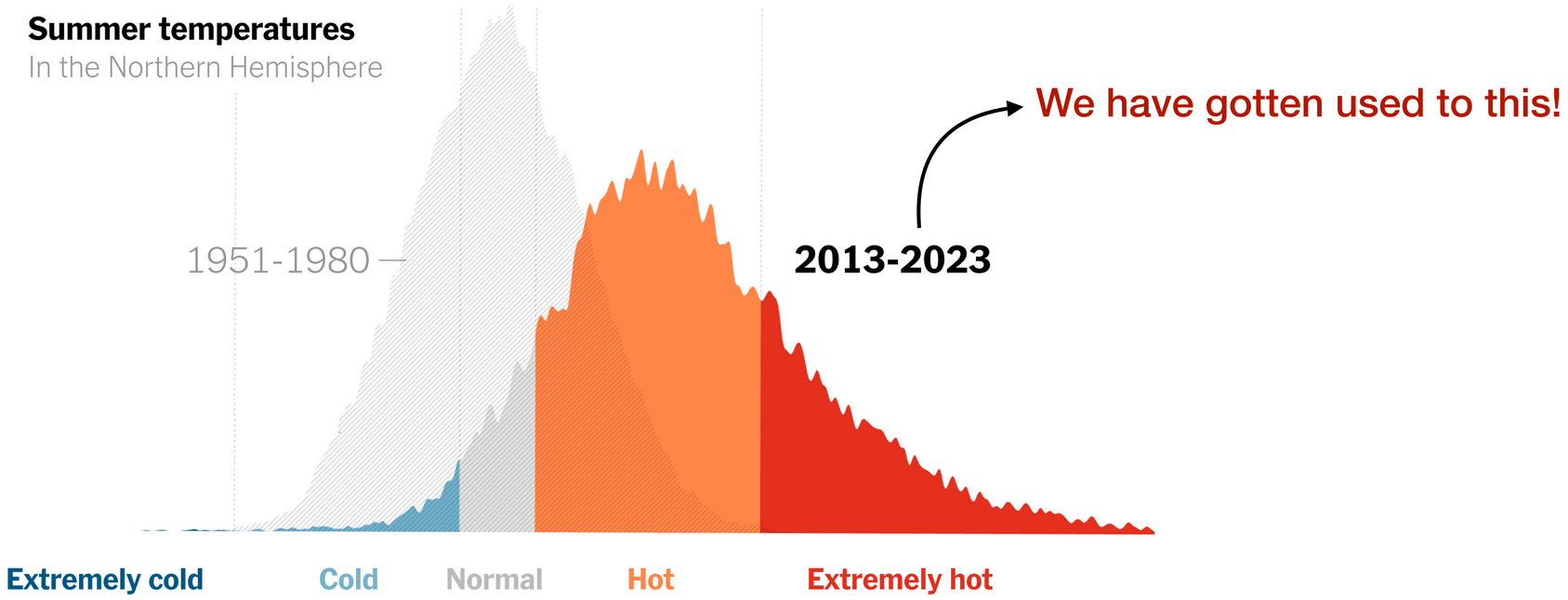
2. Understand habituation to worsening events

Previously: How people adapt and get used to **good** things

Dubey, Griffiths, & Dayan (2022). *PLOS Computational Biology*

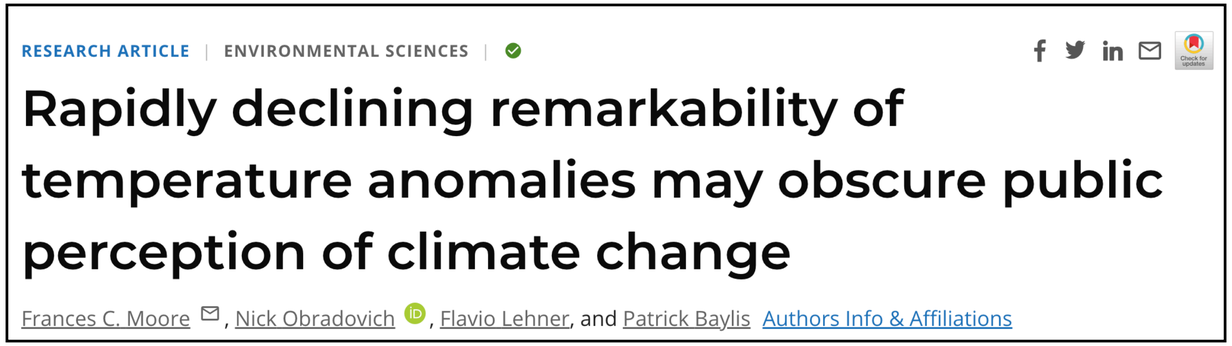
.. But people also adapt to **bad** events

Especially problematic in the context of climate change!



The “Boiling Frog” effect

Humans get used to extreme weather disturbingly fast



RESEARCH ARTICLE | ENVIRONMENTAL SCIENCES |

Rapidly declining remarkability of temperature anomalies may obscure public perception of climate change

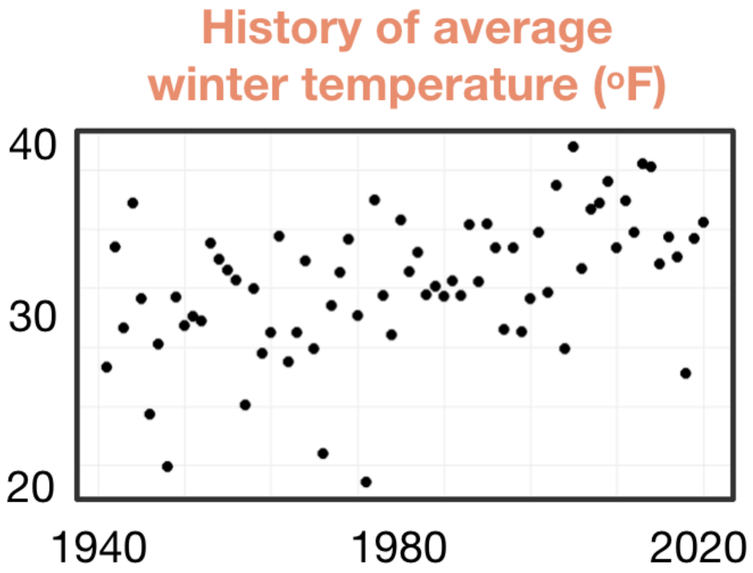
Frances C. Moore, Nick Obradovich, Flavio Lehner, and Patrick Baylis Authors Info & Affiliations

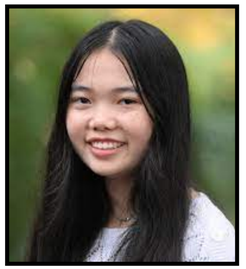
CLIMATE POLITICS SCIENCE

Wildfire smoke reminded people about climate change. How soon will they forget?

Extreme weather and climate-linked disasters don’t always lead to changes in public opinion.

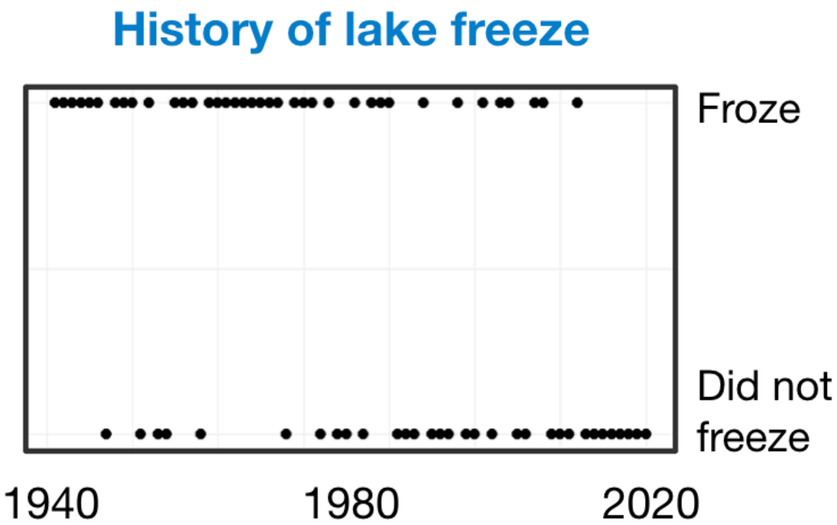
Understanding and countering the boiling frog effect





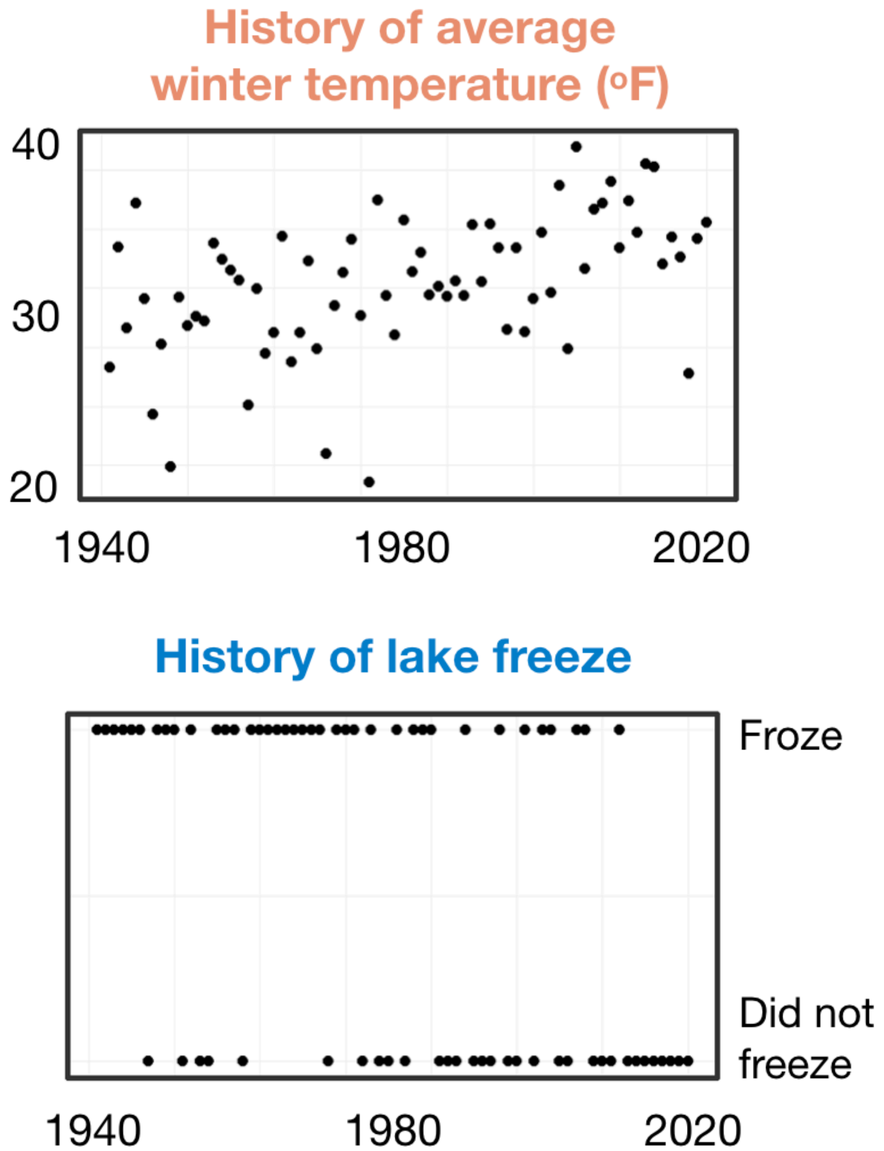
Student lead
Grace Liu

Both graphs have the **same** correlation

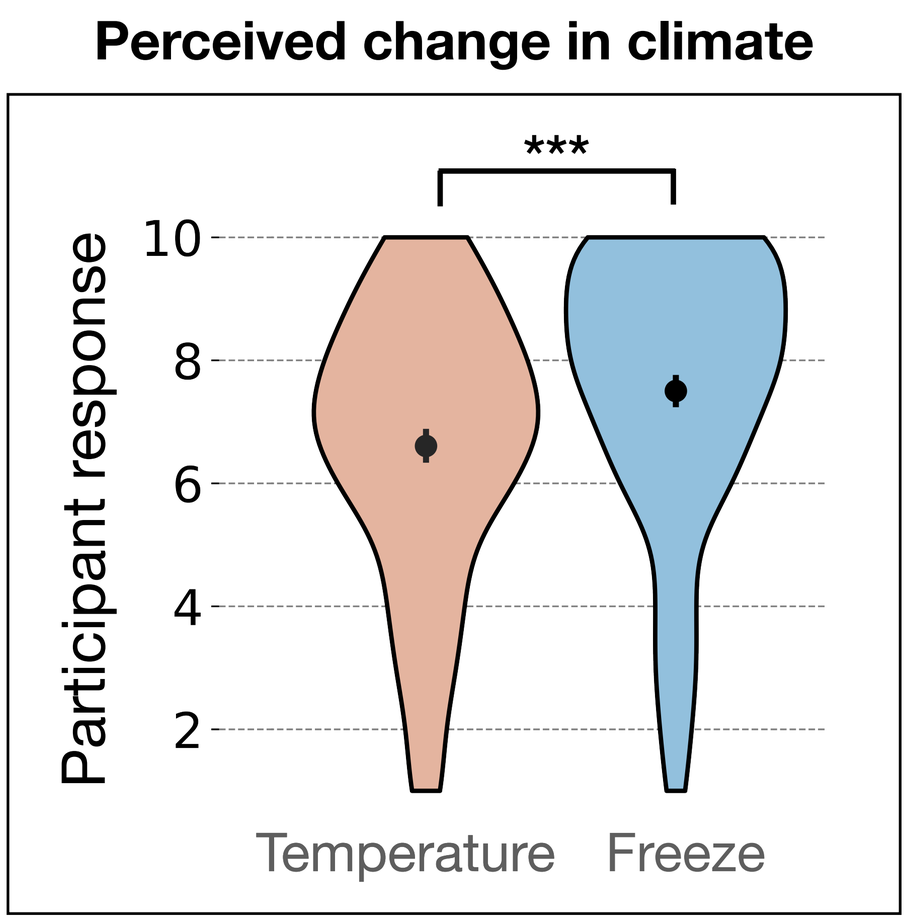


Liu, Snell, Griffiths, & **Dubey** (under review)

Understanding and countering the boiling frog effect

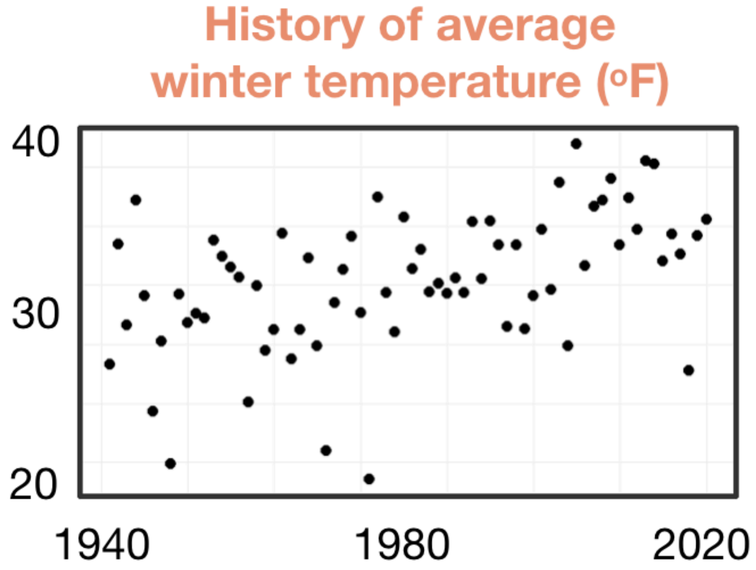


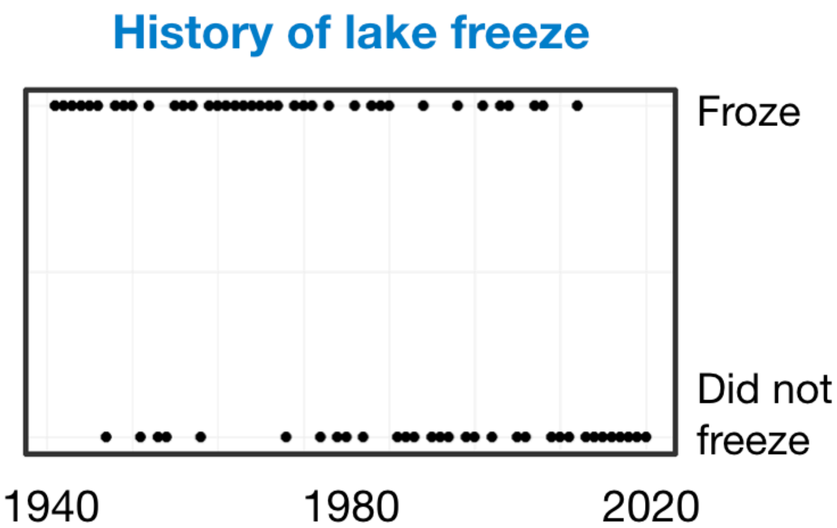
Study 1, *N* = 799



Liu, Snell, Griffiths, & **Dubey** (under review)

Understanding and countering the boiling frog effect





Both graphs have no underlying changepoint

Liu, Snell, Griffiths, & **Dubey** (under review)

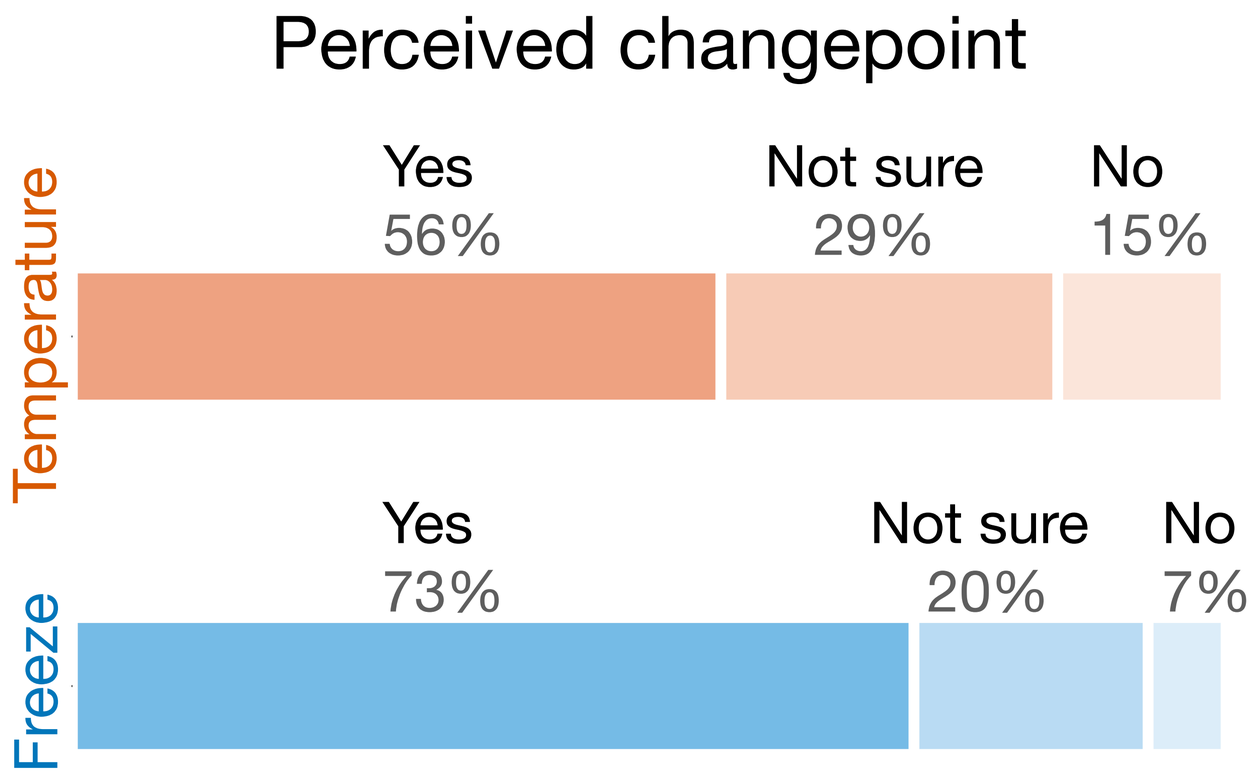
Understanding and countering the boiling frog effect

Study 2 (*N* = 398)

Do participants perceive a changepoint in the data?

Liu, Snell, Griffiths, & **Dubey** (under review)

An illusion of changepoint in binary data



Liu, Snell, Griffiths, & **Dubey** (under review)

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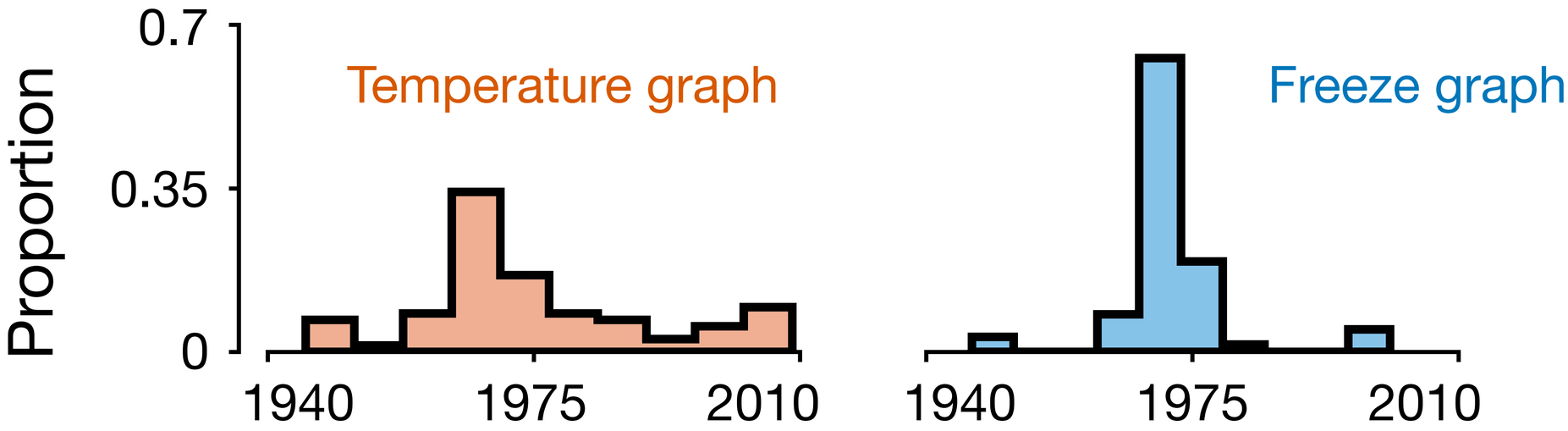
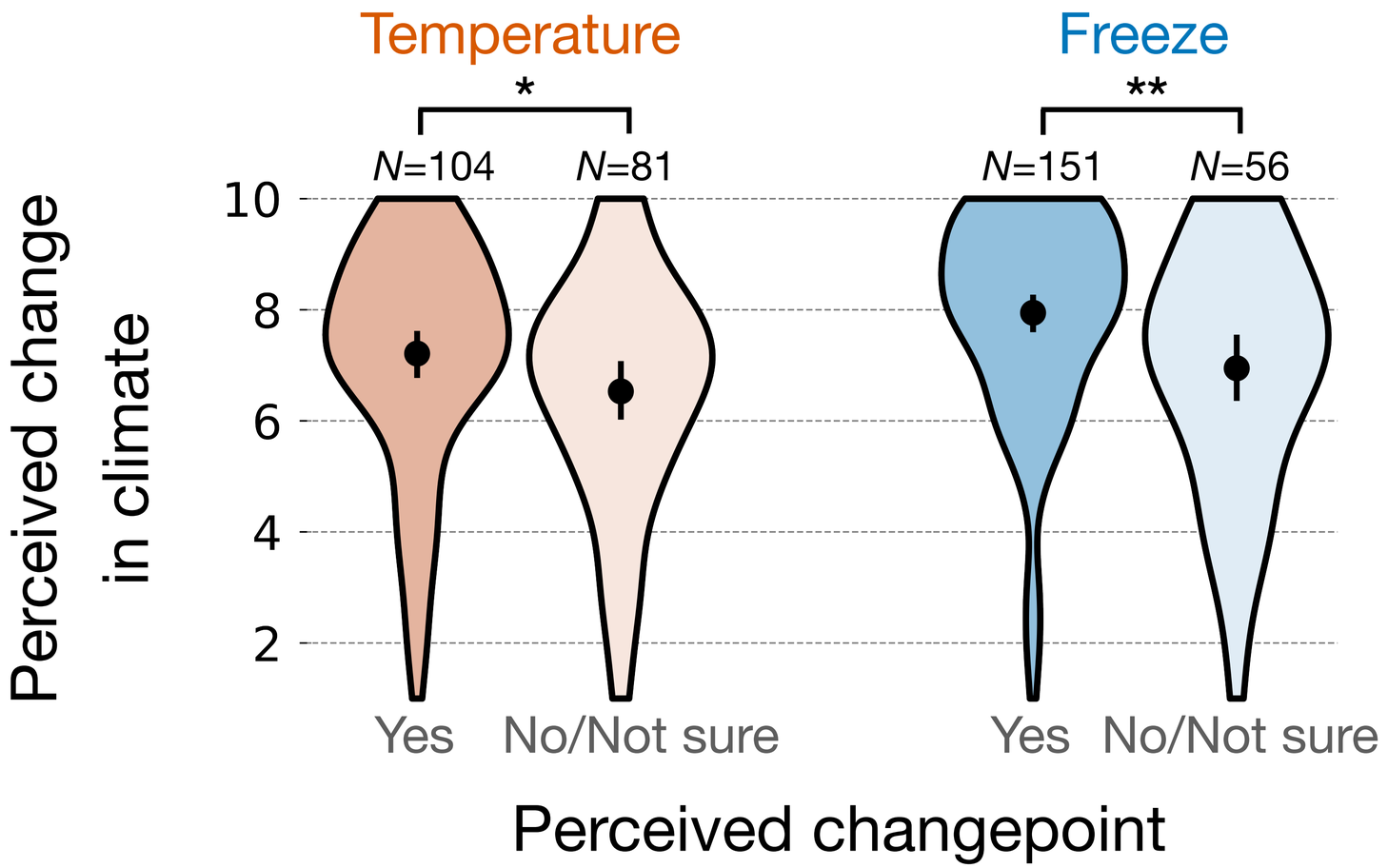


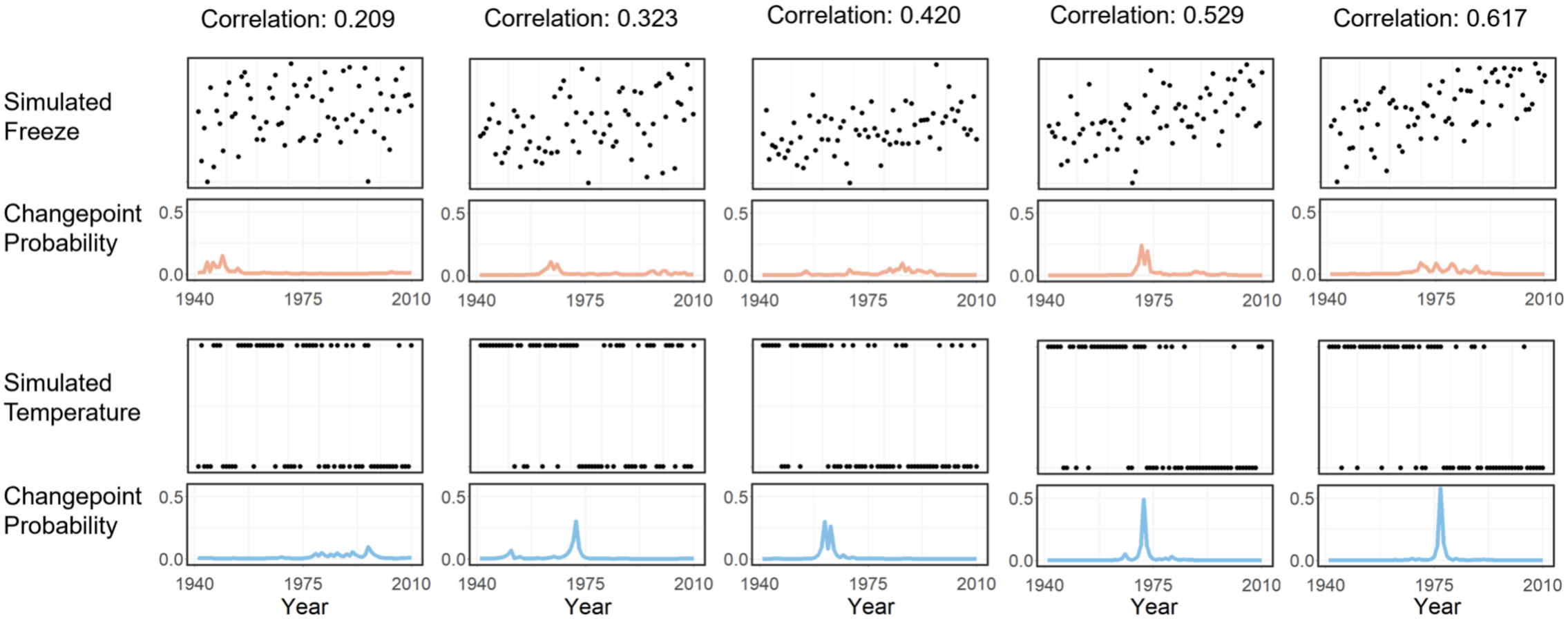
Liu, Snell, Griffiths, & **Dubey** (under review)

Changepoint influences climate perception



Liu, Snell, Griffiths, & **Dubey** (under review)

An optimal changepoint model explains the illusion



Liu, Snell, Griffiths, & **Dubey** (under review)

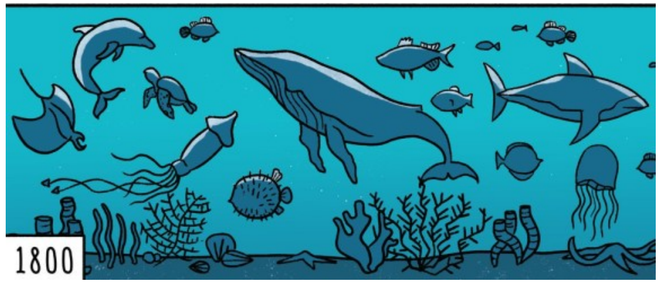
What cognitive science can do to help in future

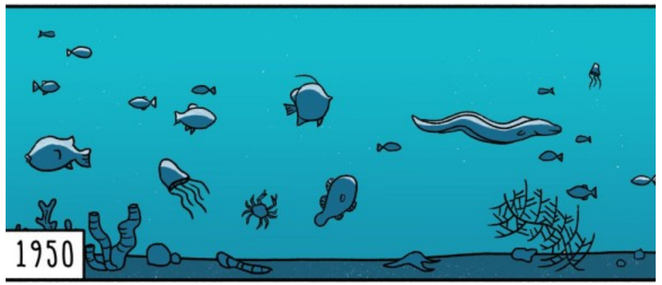
1. Understand overconsumption and habituation

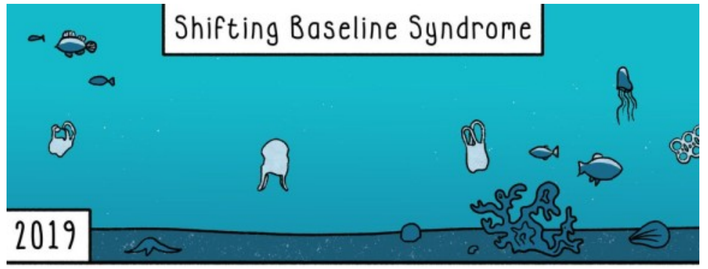
2. Understand habituation to worsening events

Future directions

Shifting baseline syndrome (aka boiling frog among generations)







What cognitive science can do to help in future

1. Understand overconsumption and habituation

2. Understand habituation to worsening events

3. Understand imagination in the context of climate change

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.

.

Part 2

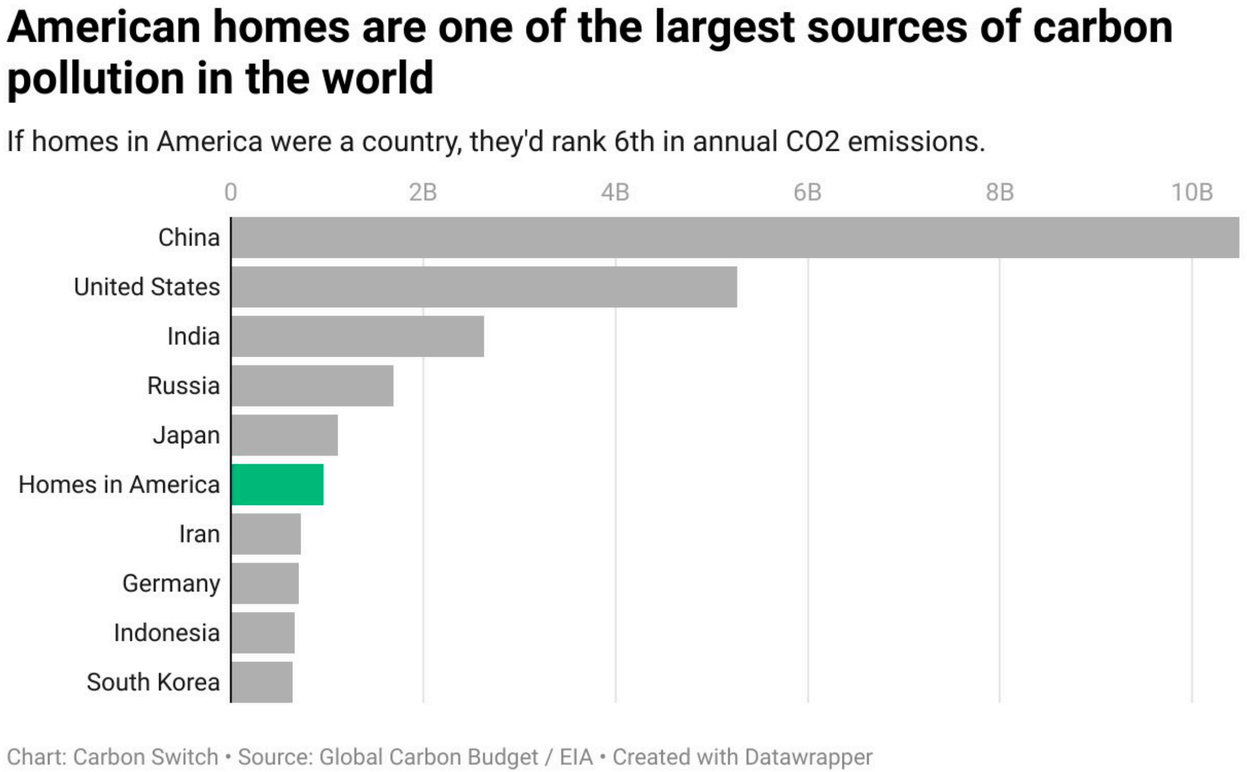
How cognitive science can help in the short-run

1. Motivate individuals to be more sustainable

Individual actions

Households responsible for 20% of energy emissions in US (Goldstein et al., 2020)

Households contribute to 74% of UK's total emissions (Baiocchi et al., 2010)

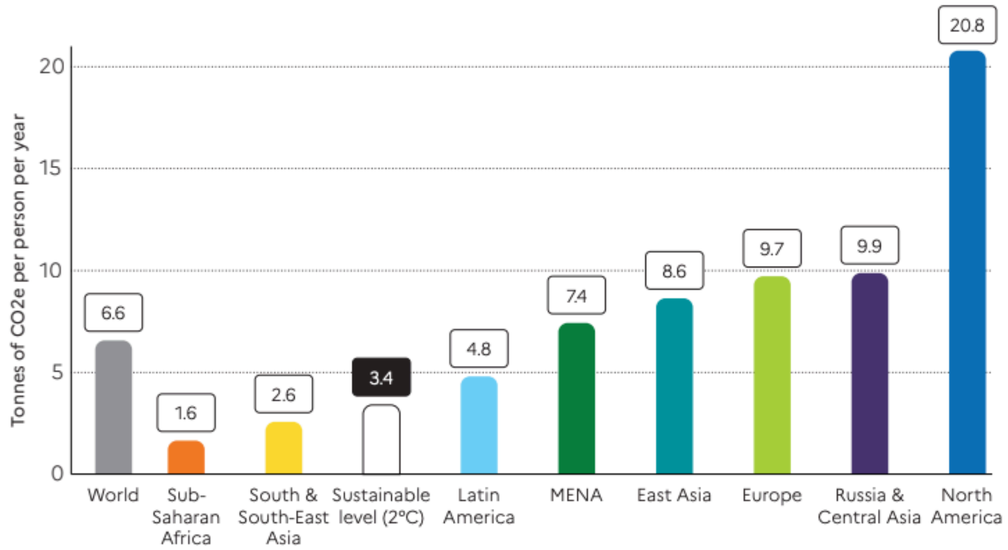


Individual actions

Shifting the focus from the average individual to the **super-rich** is important

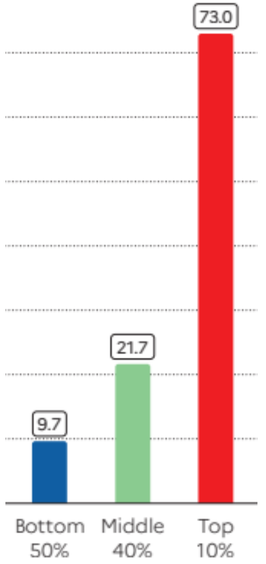
[Chancel, 2022; World Inequality Report, 2022]

First glance: reducing emissions of rich countries is important..



But this is driven primarily by **wealthy** individuals

This is the case in North America



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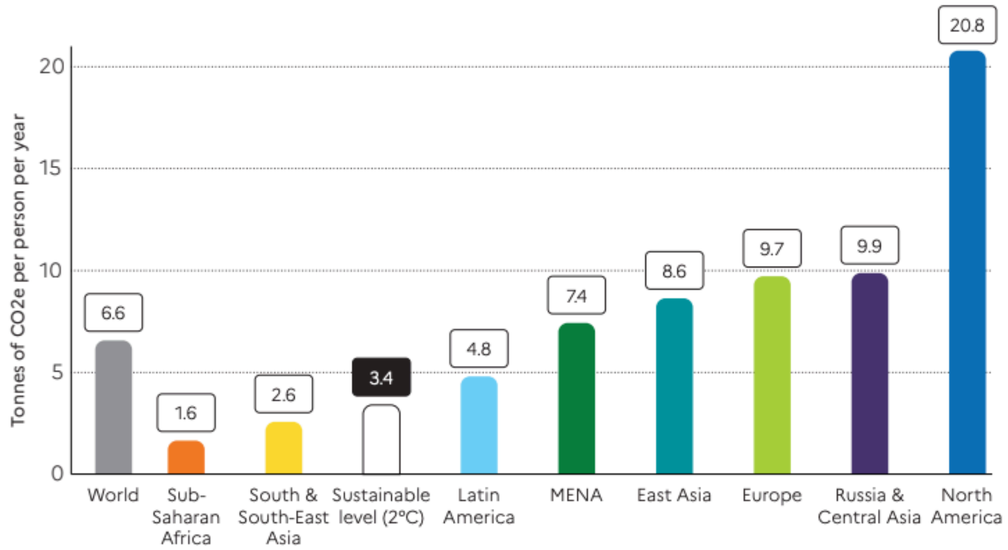

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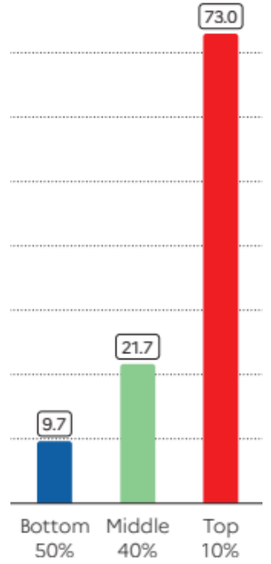
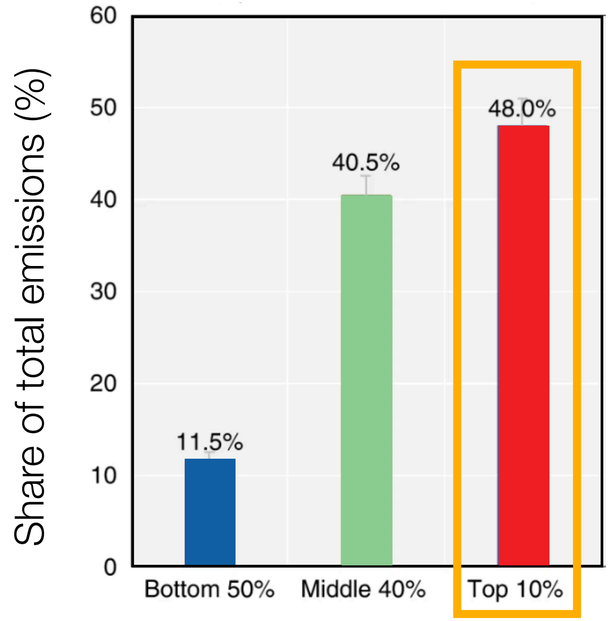


And the rest of the world…

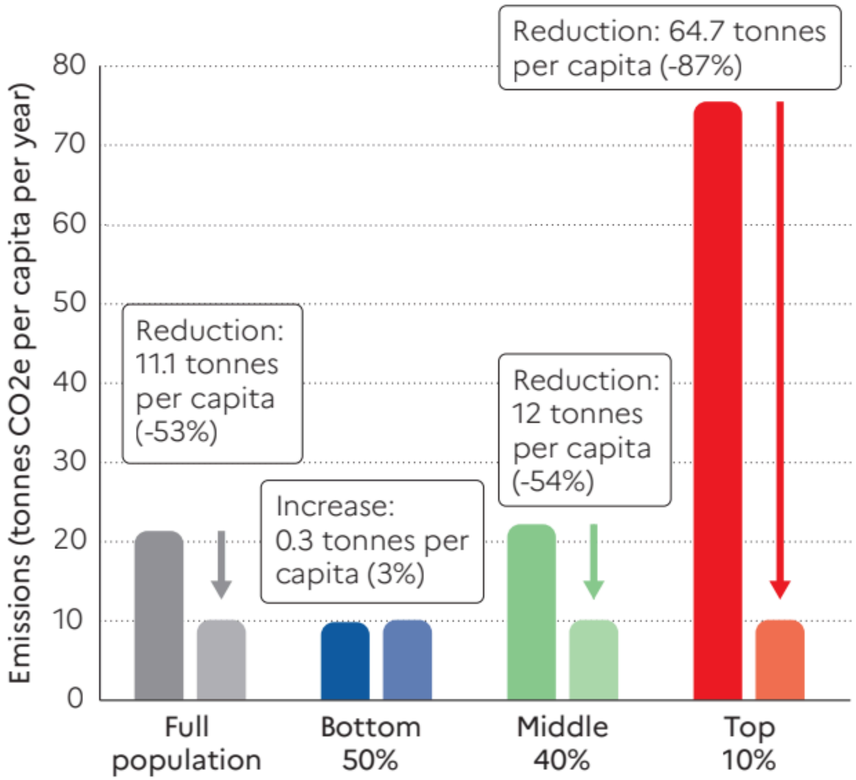


Individual actions

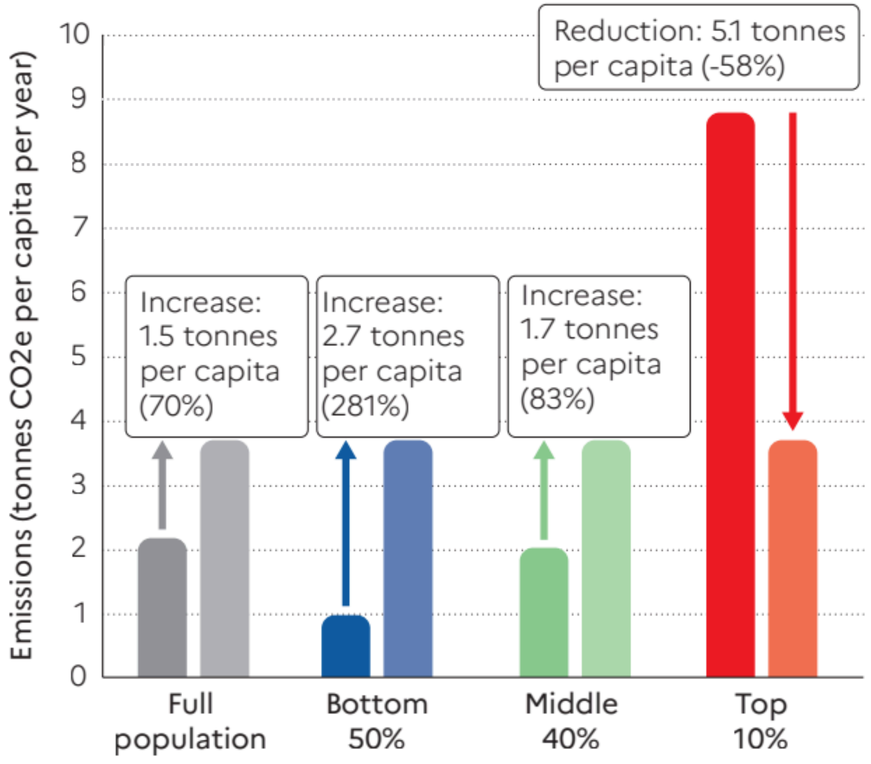
Whose emissions to reduce to meet Paris 2030 targets?

[Chancel, 2022; World Inequality Report, 2022]

Emissions reduction requirement to meet Paris 2030 targets in the US



Emissions reduction requirement to meet Paris 2030 targets in India



Individual actions

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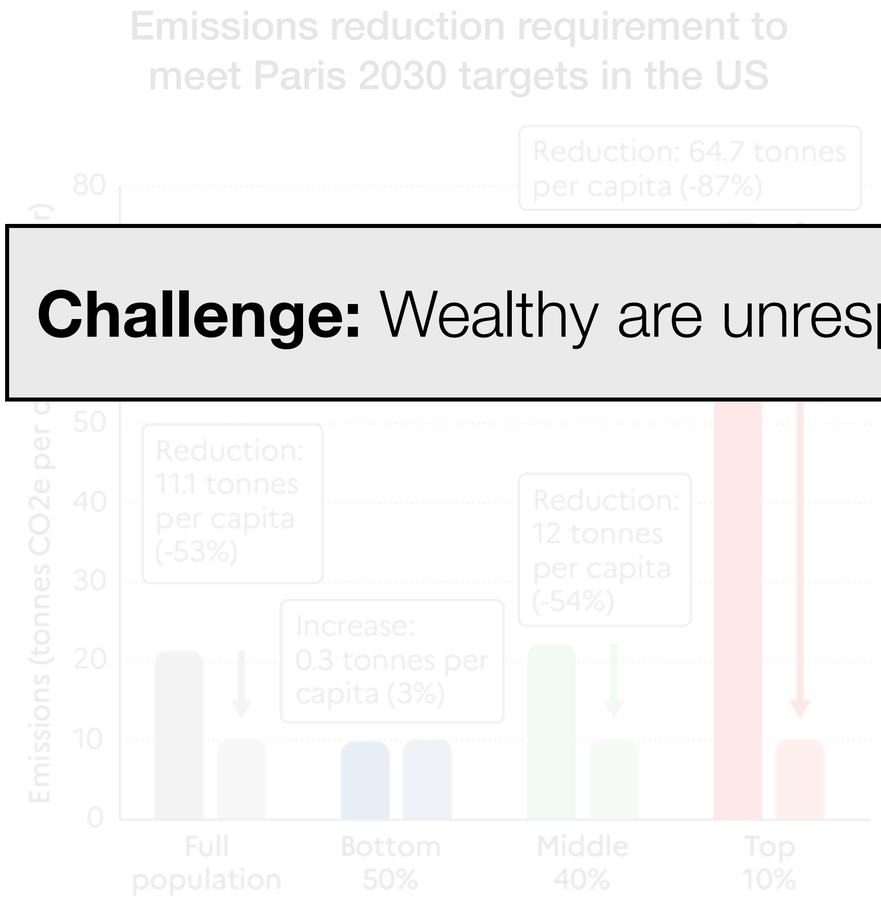
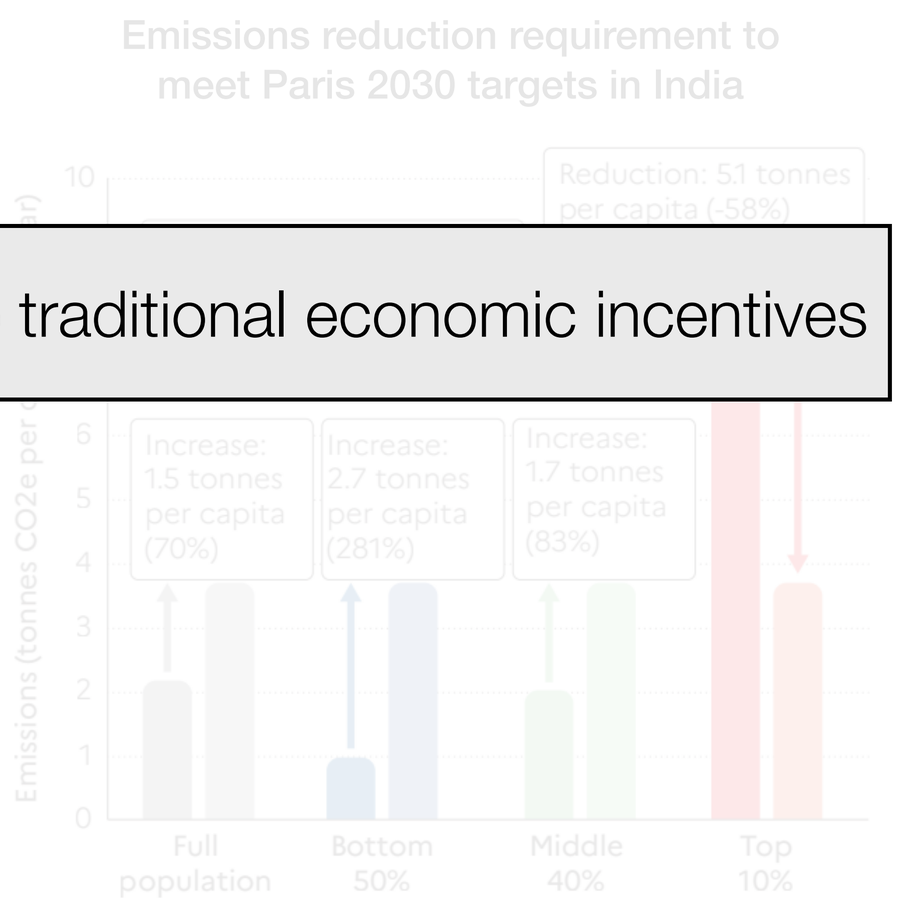




Challenge: Wealthy are unresponsive to traditional economic incentives

Motivating the wealthy to reduce consumption

co-lead:
Gordon Kraft-Todd

People have “prosocial motivations”

[Fehr & Fischbacher, 2003; Zaki & Mitchell, 2011]

In economic games, framing public goods interactions in language emphasizing terms like “community” and “cooperation” leads to greater prosocial behavior

[Libermann et al., 2004; Engel & Rand, 2014]

Appeals to “prosocial” motives are more effective than “financial” self-interested appeals

[Betsch et al., 2017; Jordan et al., 2020]

Kraft-Todd*, **Dubey***, Yoeli, Rand, Bhanot. Under revision

Research question

Are wealthy more responsive to sustainability messages that emphasize prosocial benefits compared to financial benefits?

Motivating the wealthy to reduce consumption

Study 1: Field experiment of home mailer campaign to *N*=10,500 high-income households in Connecticut, Aug 2017-April 2018

Study 2: Three field experiments (one pre-registered) of Facebook ads across 6 states in New England; 313,764 impressions, 96,892 unique users

Kraft-Todd*, **Dubey***, Yoeli, Rand, Bhanot. Under revision

Motivating the wealthy to reduce consumption

Economic framing

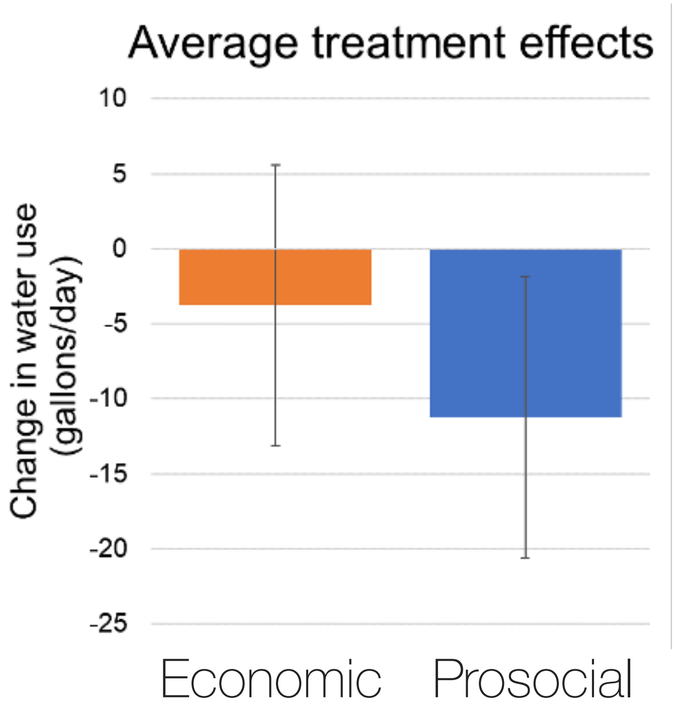
It's YOUR money

Excess water use wastes your money.
Find customized tips on how you can save water and benefit your wallet

Prosocial framing

It's OUR environment

Excess water use harms our environment.
Find customized tips on how you can save water and benefit Connecticut's environment



Kraft-Todd*, **Dubey***, Yoeli, Rand, Bhanot. Under revision

Implications for motivating the wealthy

Messages that tap into *intrinsic motives* are more powerful than simple economic incentives

11.1 million gallons of water saved

Equivalent to 444,000 showers (10 minutes per shower)

Water drank by

181,000

People in a year

How cognitive science can help current efforts

Motivate **wealthy** individuals to be more sustainable

Future directions

1. **Psychology of abundance**
   - When does having ***too much*** influence cognition & decision-making?
   - Perceptions about risks and climate change among the wealthy
   - Modeling and understand “not in my backyard” (Stokes et al., 2023)

2. **Driving climate action among the wealthy**
   - Focus on people who *already* believe in climate change
   - Large-scale field studies testing multiple interventions at once

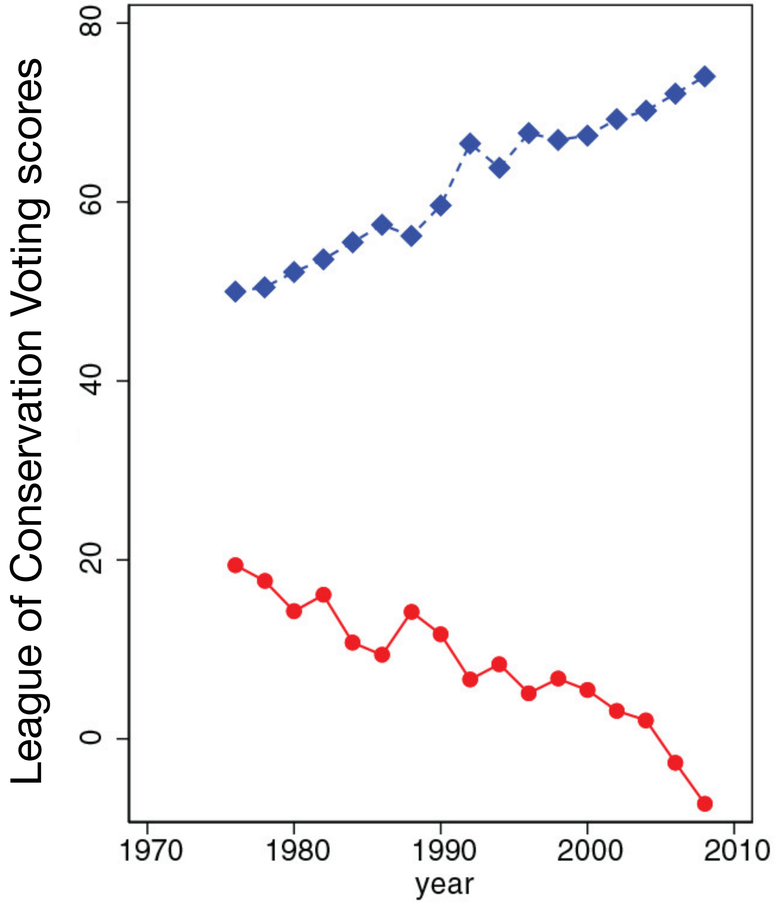
How cognitive science can help current efforts

Motivate **wealthy** individuals to be more sustainable

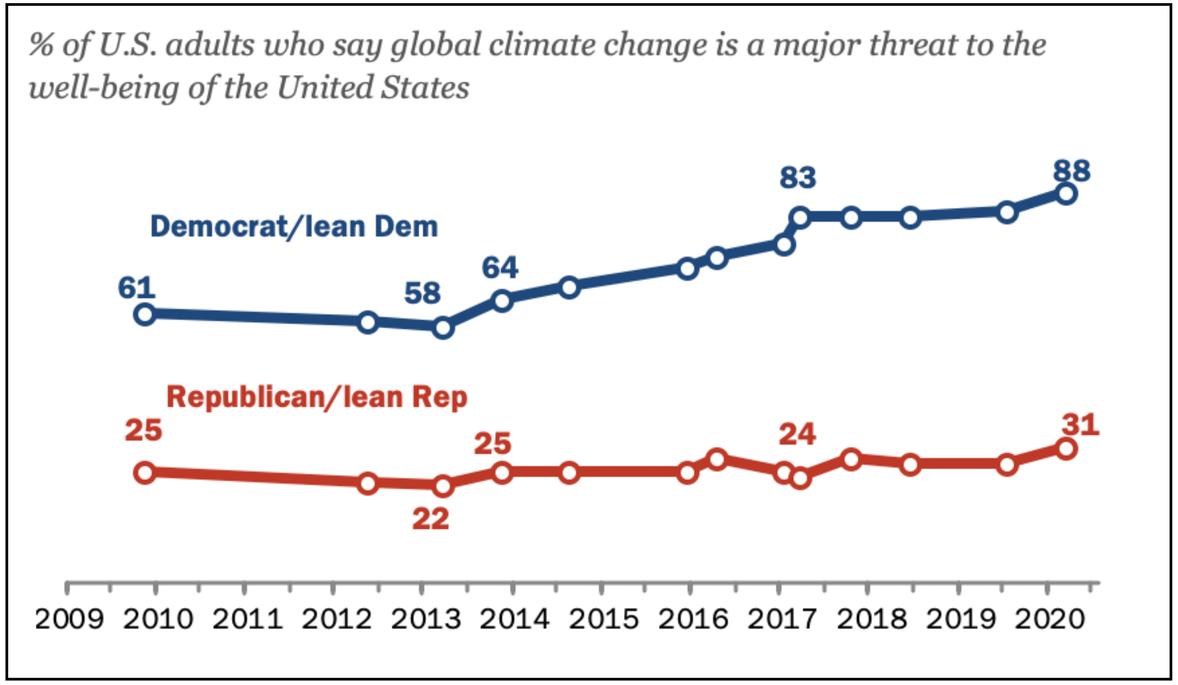
Help efforts aiming to bring **systemic** changes

Important to enact ambitious green **policies** to implement systemic changes

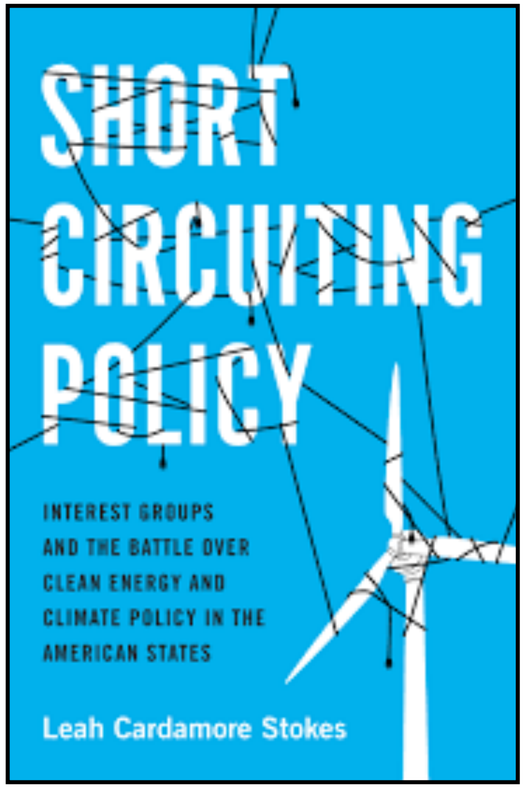
Polarization about climate policies in the congress

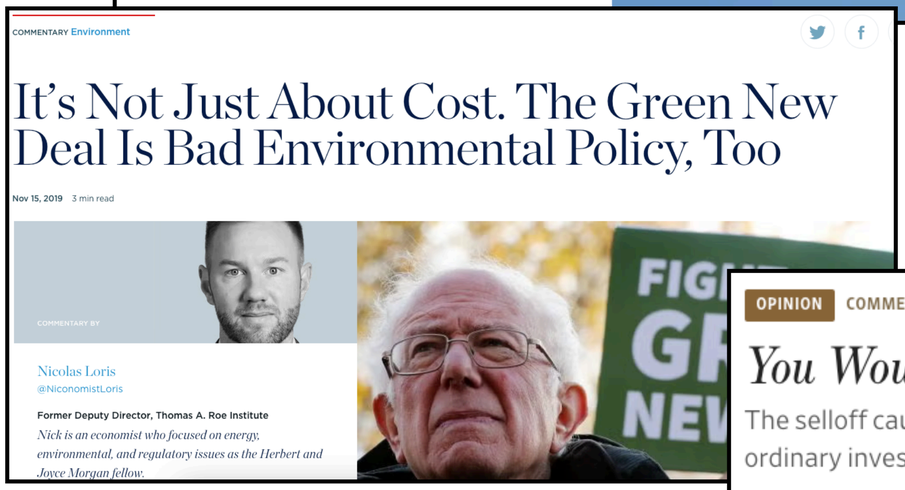


Polarization about climate change within the American public



Climate policies are *notoriously* difficult to pass





Even when enacted, climate policies face backlash and are rolled back

[Harrison 2012; Martinez-Alvarez et al., 2022]

Yellow jacket movement, France

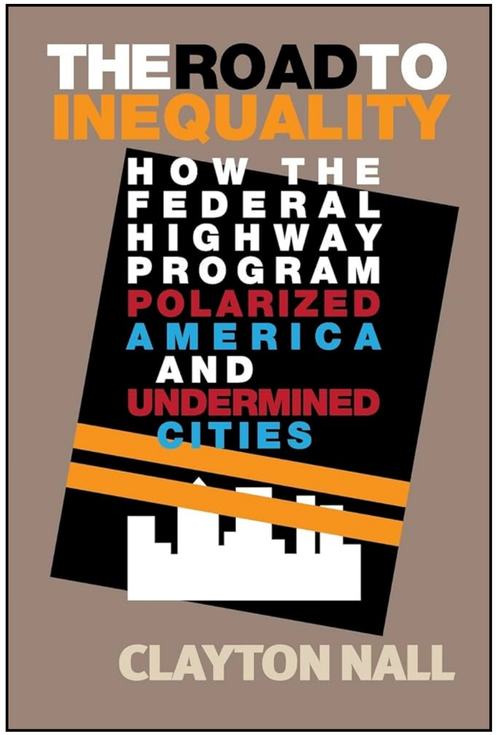
We need a formal understanding of the psychology of climate policy-making

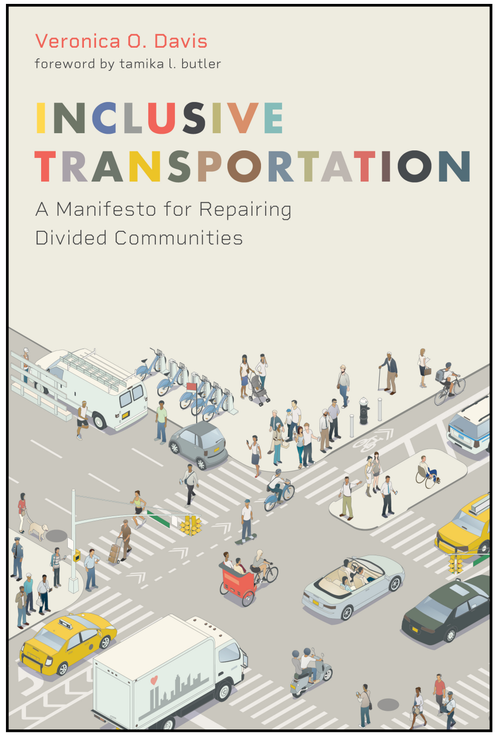
AI as a cognitive *tool* to

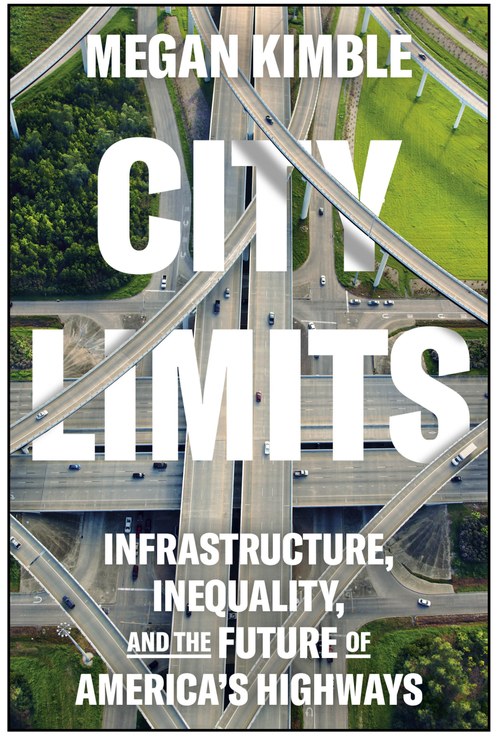
- Reduce polarization and enhance communication of climate policies
- Understand psychological factors underlying policies
- Design human-centric policies

Case study: Sustainable transport policies

Transforming America's car-centric infrastructure is crucial for reducing emissions and addressing social & economic inequality

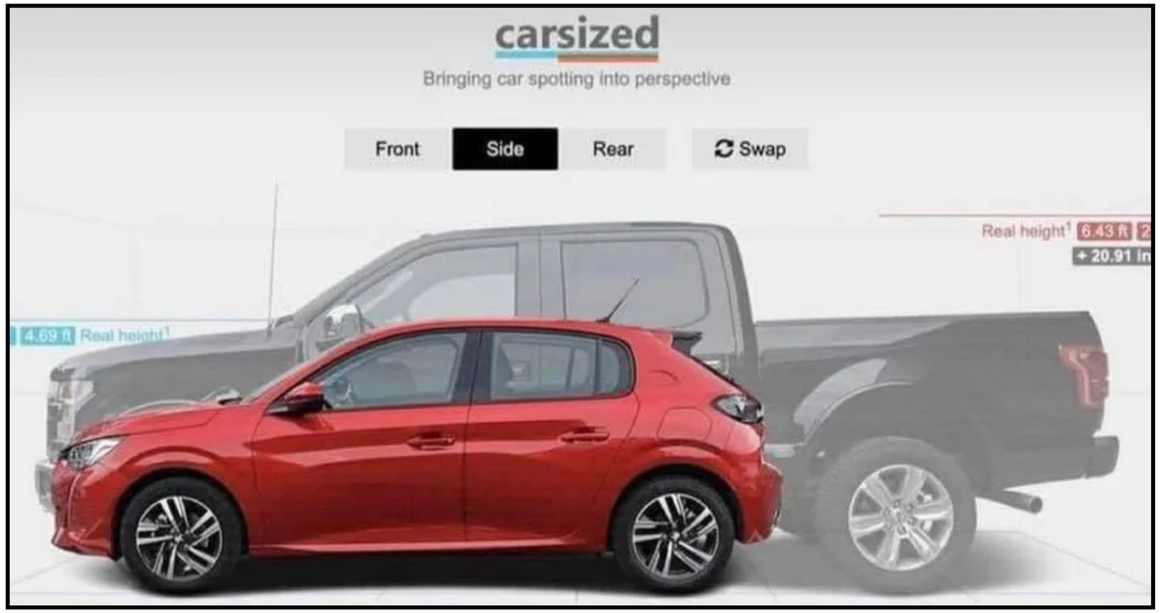


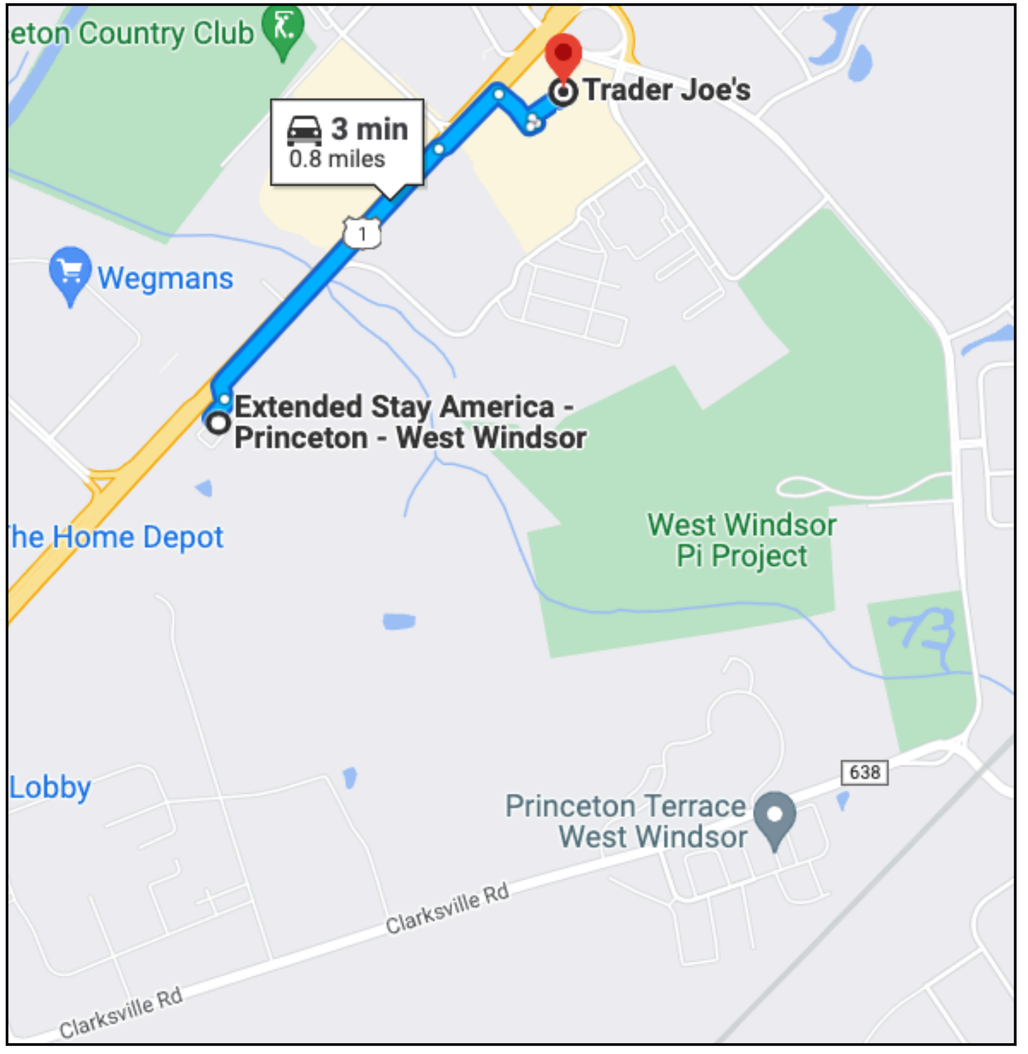


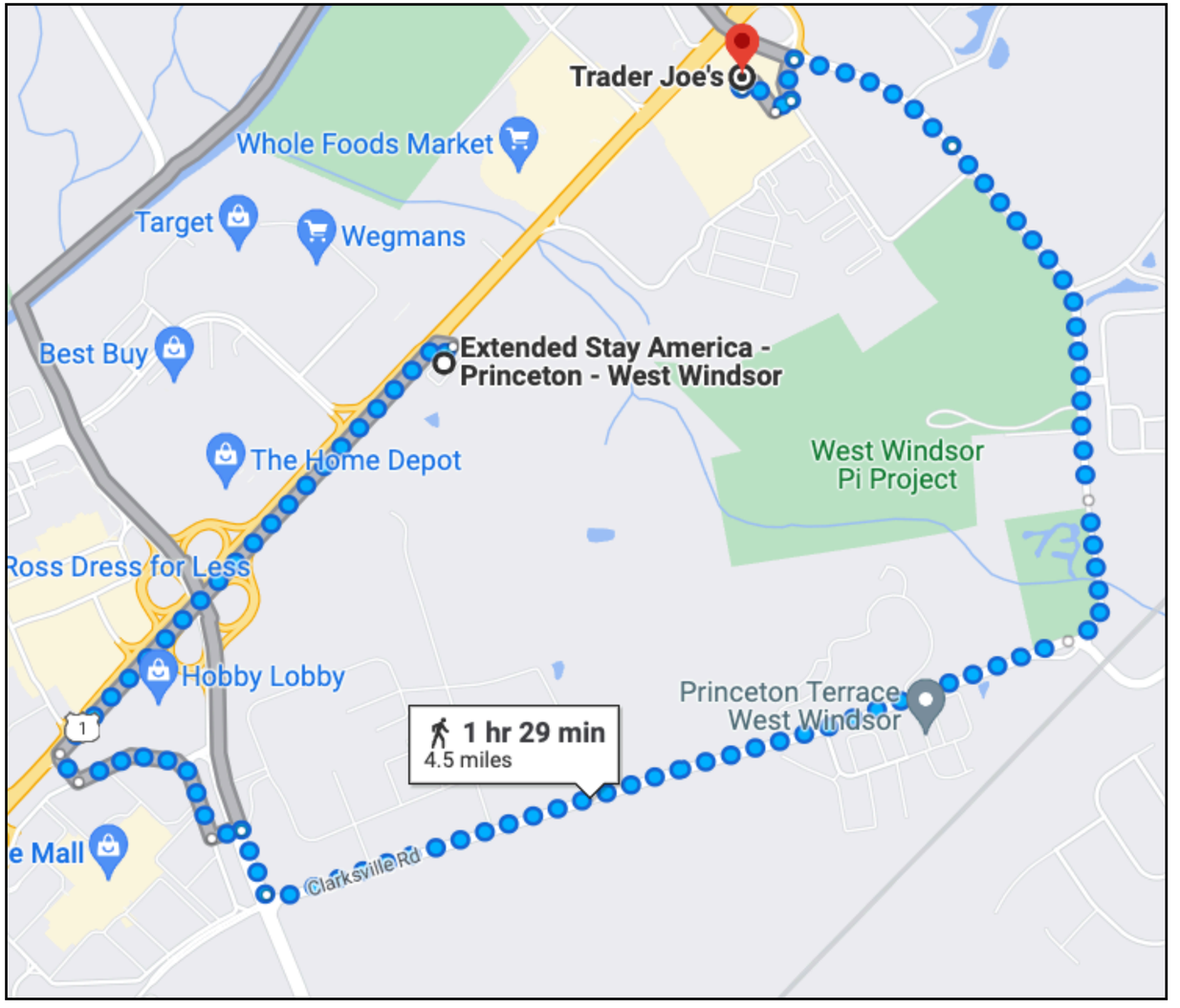


A common sight in America…

Average **European car size** vs.
American car size




eton Country Club
Trader Joe's
3 min
0.8 miles
1
Wegmans
Extended Stay America -
Princeton - West Windsor
he Home Depot
West Windsor
Pi Project
Lobby
638
Princeton Terrace
West Windsor
Clarksville Rd
Clarksville Rd


Trader Joe's
Whole Foods Market
Target
Wegmans
Best Buy
Extended Stay America -
Princeton - West Windsor
The Home Depot
West Windsor
Pi Project
Ross Dress for Less
Hobby Lobby
1
1 hr 29 min
4.5 miles
Princeton Terrace
West Windsor
e Mall
Clarksville Rd

Challenge: Americans are polarized about public transportation and are reluctant to support sustainable transport policies

[Nall, 2018; Neves and Brand, 2019]

Building a less car-dependent America

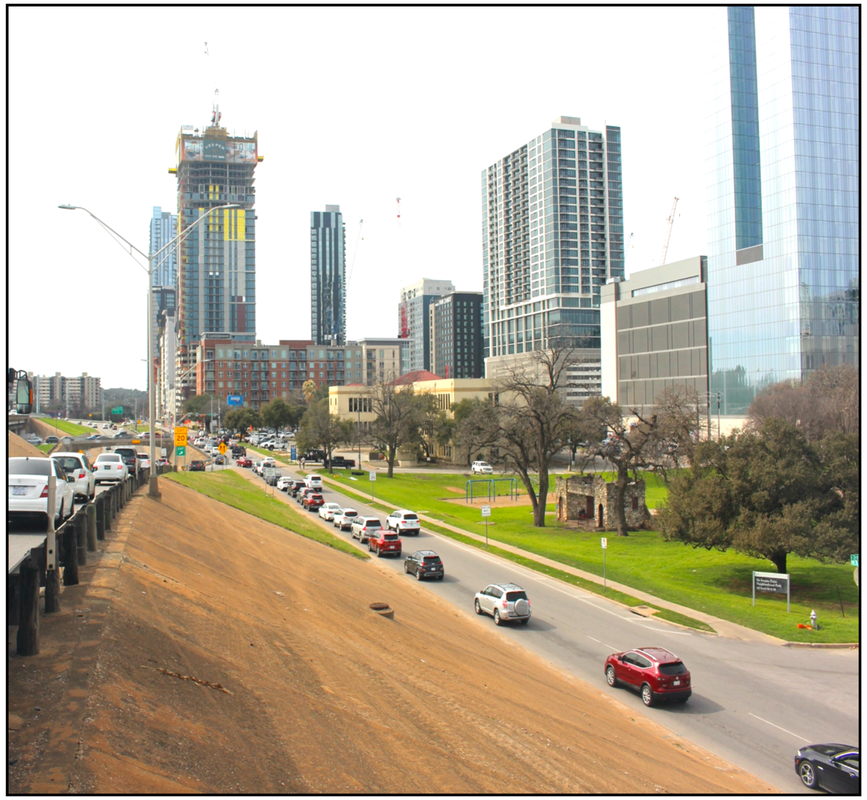
Evoking the **imagination**
as a strategy of influence

[Escalas, 2004; Petrova & Cialdini, 2018]

Dubey, Hardy, Griffiths, and Bhui (2024). *Nature Sustainability*

Building a less car-dependent America

Our cities today
Car dependent, congested, & polluted



How they can be in future
Walkable, greener, & public transport

Generated using AI

Dubey, Hardy, Griffiths, and Bhui (2024). *Nature Sustainability*

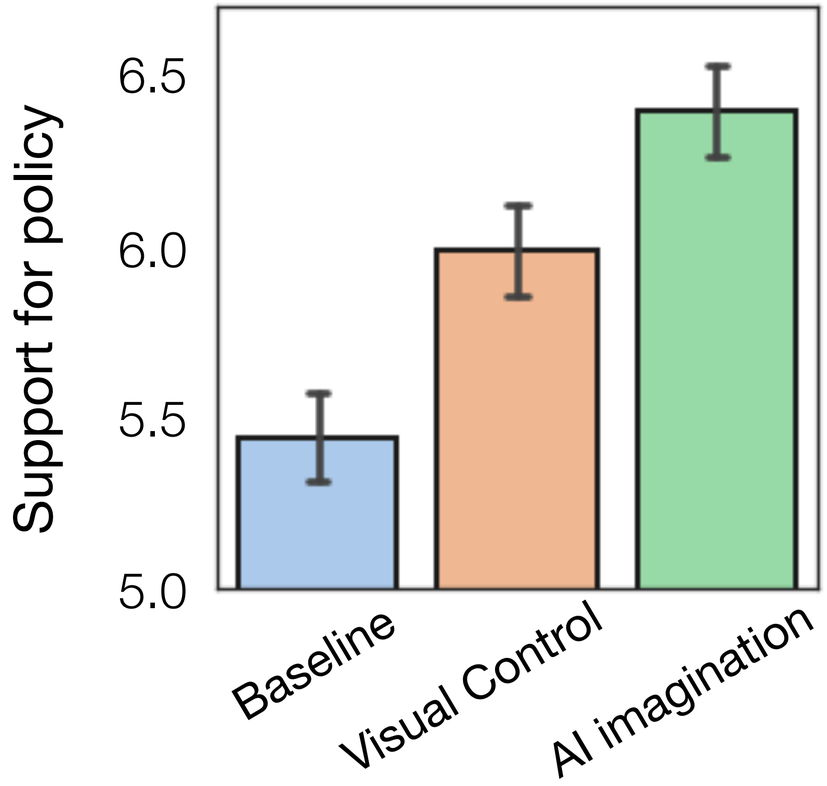
Main Goal: Highlight importance of helping people *imagine* outcomes of sustainable policies

AI merely serves as a *tool* to generate realistic and personalized images

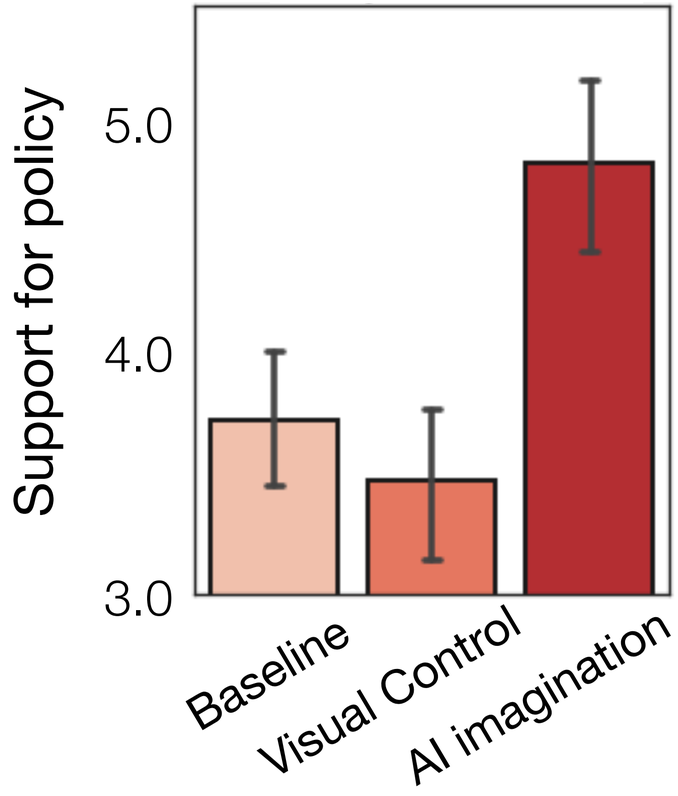
Building a less car-dependent America

[N=1529]

Increased support for the transport policy that proposed to make US less car-reliant



Our intervention is particularly effective at shifting opinion of Republicans

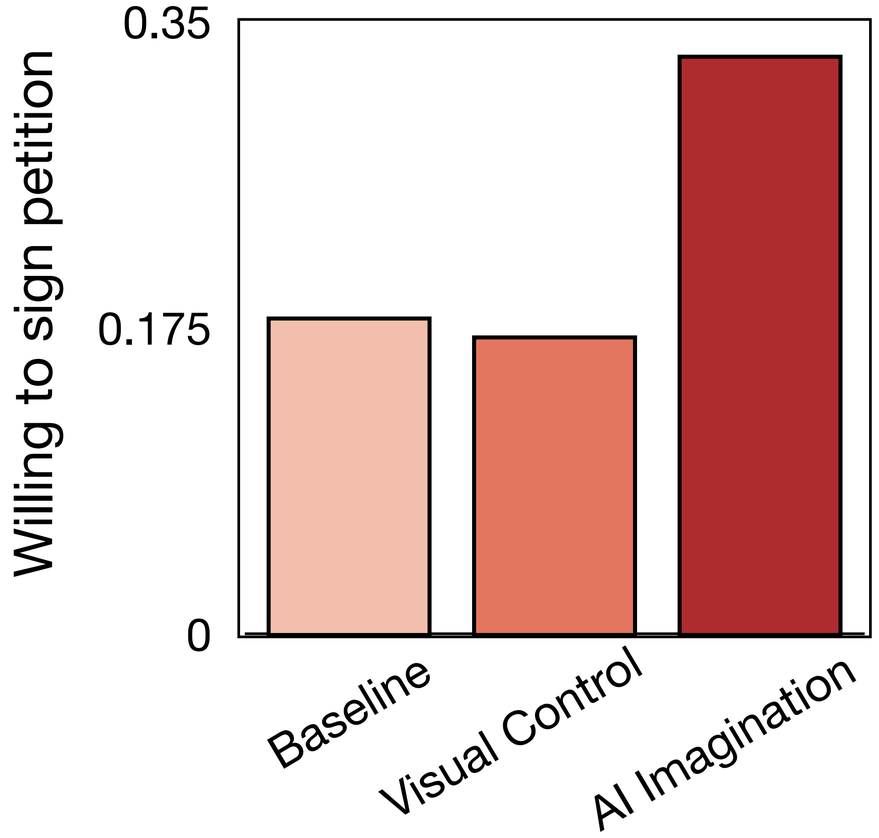


Dubey, Hardy, Griffiths, and Bhui (2024). *Nature Sustainability*

Building a less car-dependent America

[N=1529]

Increased proportion of Republicans are willing to sign the car-free US petition



Dubey, Hardy, Griffiths, and Bhui (2024). *Nature Sustainability*

Future directions

1. Reduce polarization about green policies

Current: One-shot communication about a policy

Future: *Repeated* interactions i.e., dialogues about a policy proposal

Akin to simulating a town-hall with a senator or policy-maker, where one can ask questions and address concerns about a policy

2. Design human-centric policies

AI as a tool to maximize public approval — how can we redesign existing policy proposals such that they are less likely to face public resistance?

Climate change is fundamentally an issue of

human behavior

What cognitive science can do to help in **future**

Understand cognitive underpinnings of climate **inaction**

What cognitive science can do to help in the **short run**

Motivate **wealthy** individuals to be more sustainable

Understand psychology of climate **policy-making**

Epilogue: My pessimistic-optimistic vision for the future

Computational cognitive science has a ***lot*** to offer for climate change research

But we can't probably do much right now… (i.e., climate change
isn't going to be solved with my bite-sized research so far..)

My hope and goal

Help make cognitive science make an integral part of climate policy-making
10-15 years down the line

If we want to make an impact 10-15 years from now, we need to start *now*