

Learning Best Practices

Can Machine Learning
Substitute for Experiences?

INFORMS 2019

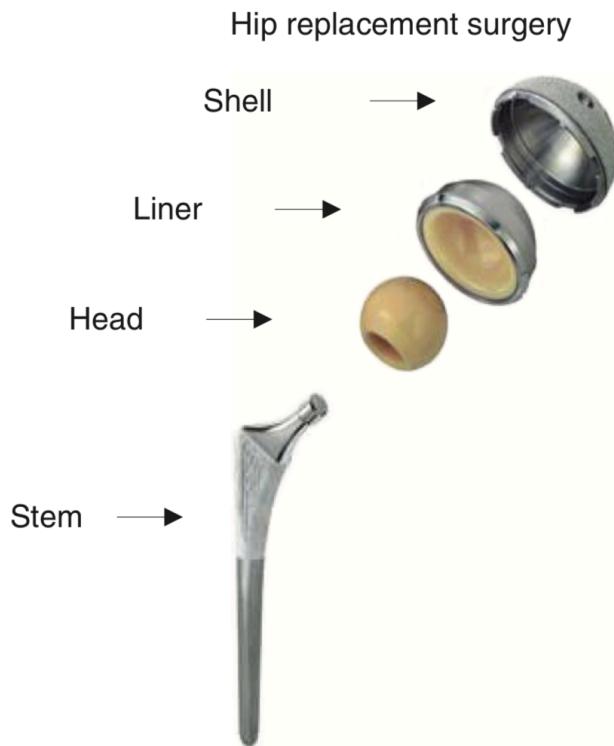


Park Sinchaisri (Wharton)
with Hamsa Bastani (Wharton), Osbert Bastani (Penn)



Learning Takes Time

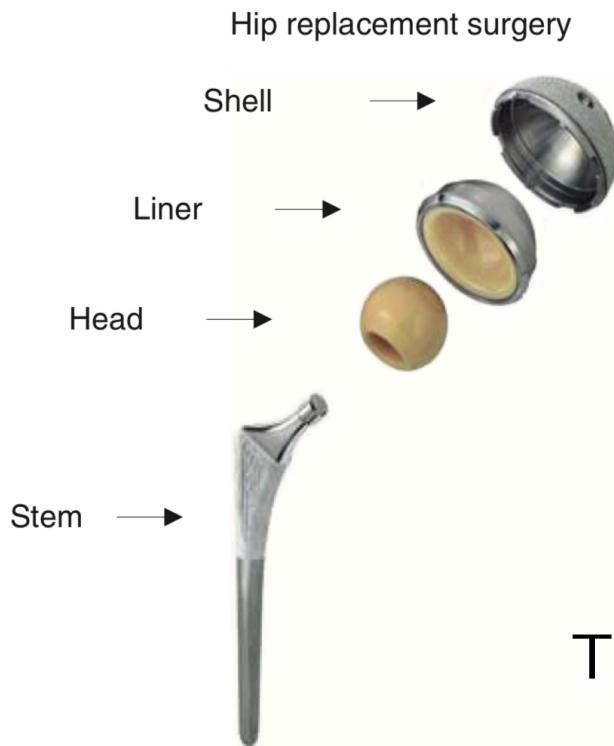
Learning Takes Time



“The first use of certain device versions can result in at least a **32.4% increase in surgery duration**, hurting quality and productivity.”

- Ramdas et al. 2018

Learning Takes Time

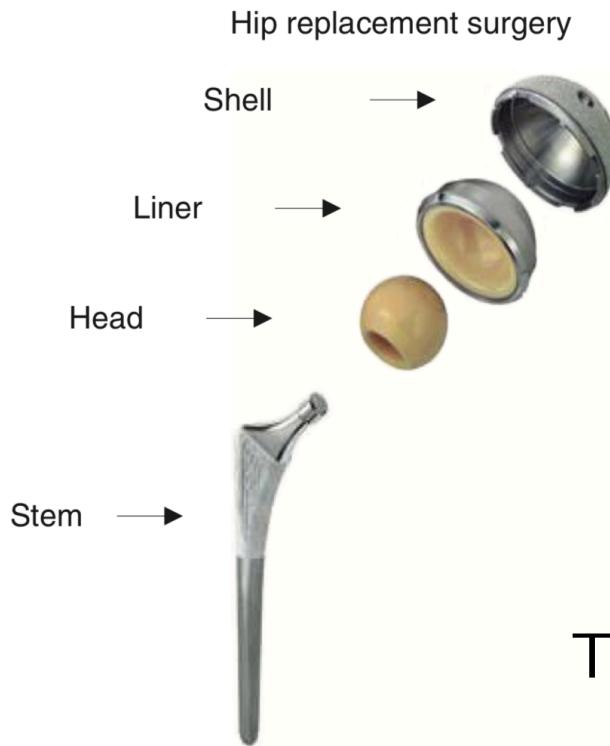


“The first use of certain device versions can result in at least a **32.4% increase in surgery duration**, hurting quality and productivity.”

- Ramdas et al. 2018

Training workers is really important, but there is a big cost upfront.

Learning Takes Time



“The first use of certain device versions can result in at least a **32.4% increase in surgery duration**, hurting quality and productivity.”

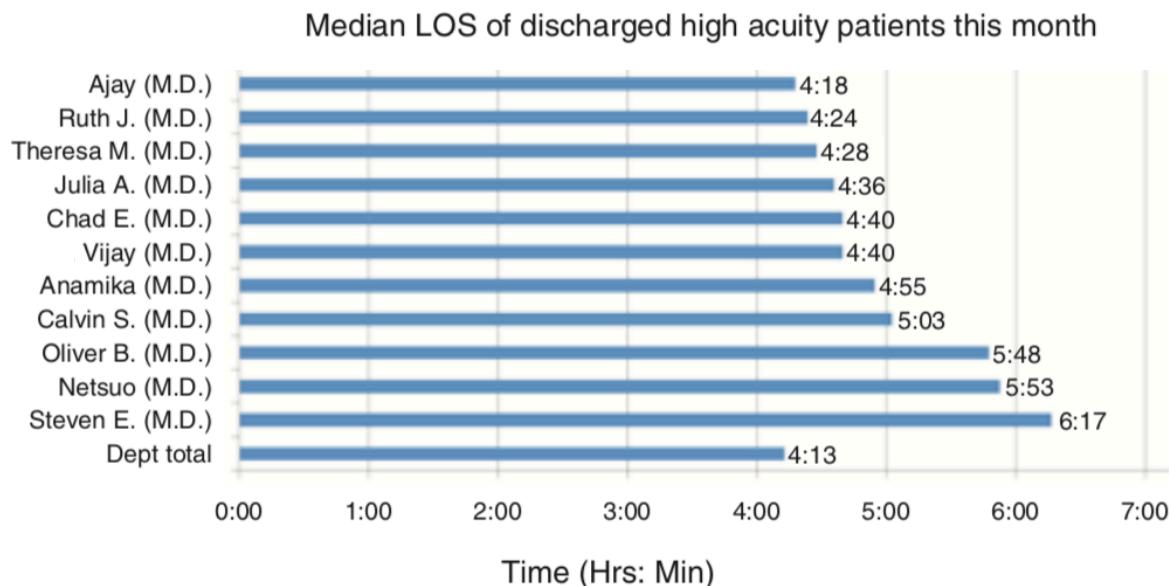
- Ramdas et al. 2018

Training workers is really important, but there is a big cost upfront.

Simple Tips?

Learning from Experts

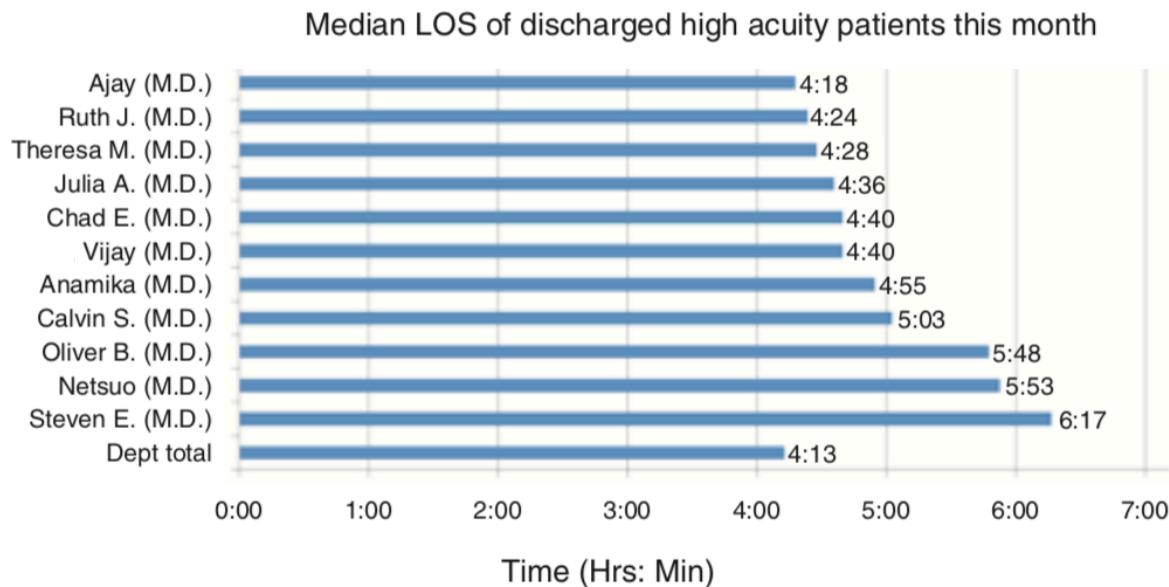
Learning from Experts



“The public disclosure of RPF allowed workers to identify their top-performing coworkers, which in turn enabled the identification and validation of best practices within the work group.”

- Song et al. 2018

Learning from Experts

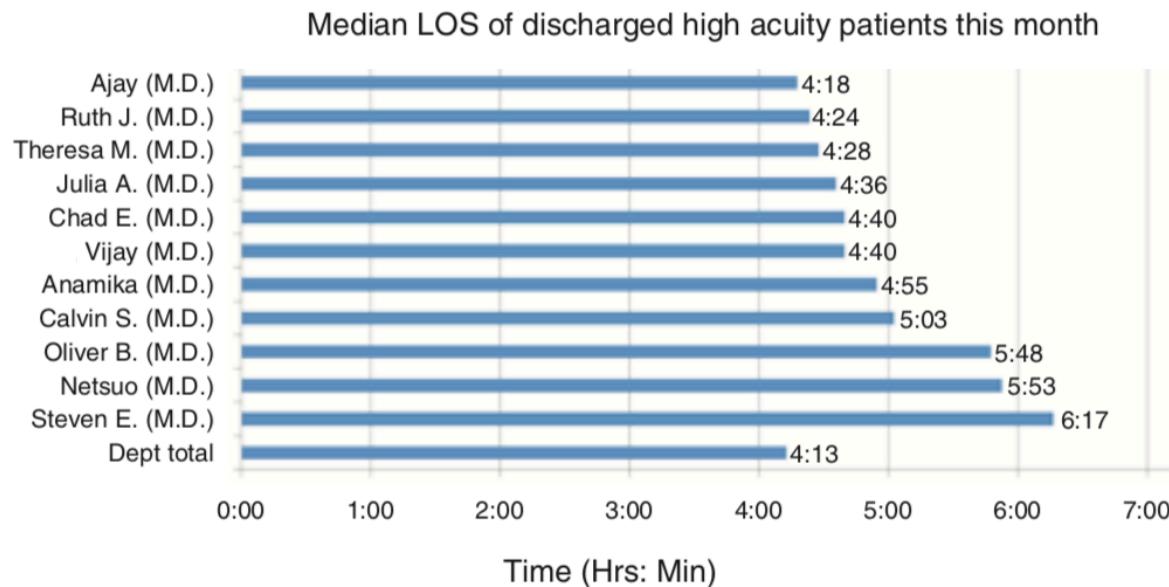


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But It's Still Hard

Learning from Experts



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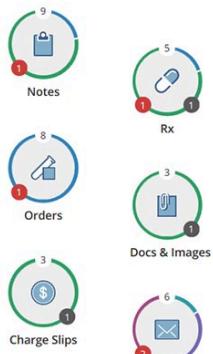
But It's Still Hard

Data!

Trace Data is Everywhere

Trace Data is Everywhere

Physicians

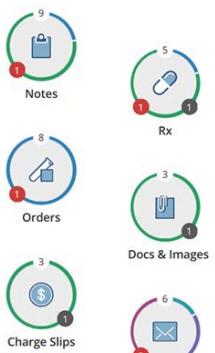


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<input type="checkbox"/> • BECK,ALIVIA	Zocor 20 mg		JACK,JACK,MD status: Unreviewed, held	05-18-17
<input type="checkbox"/> NORTON,BETHANY	Norvasc 10 mg		MILLER,ALEX,MD status: Unreviewed	05-18-17
<input type="checkbox"/> MONTGOMERY,BLAINE	Glucophage 850 mg		OSHEAJAMIE,MD reviewed by: PPMD_AKN... status: Reviewed	05-18-17
<input type="checkbox"/> KLECK,MICHAEL	Office Visit - Abbreviated		JONES,CAMERON,MD status: Reviewed by: SUSAN	05-12-17
<input type="checkbox"/> MCARDLE,HELEN	Office Visit - Mobile		JONES,CAMERON,MD status: Unreviewed	05-12-17
<input type="checkbox"/> BERN,MARC	Office Visit - Itemized Conditions		JONES,CAMERON,MD status: Unreviewed	05-12-17
<input type="checkbox"/> ANDERSON,JIIM	Advanced Directives Advanced Directives Addendum		JONES,CAMERON,MD status: Unreviewed	05-12-17
<input type="checkbox"/> BECKER,JOSEPH	Office Visit1		JONES,CAMERON,MD status: Unreviewed	05-02-17
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Trace Data is Everywhere

Physicians

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Uber Drivers

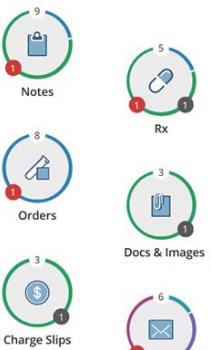


Whong 2014

Trace Data is Everywhere

Physicians

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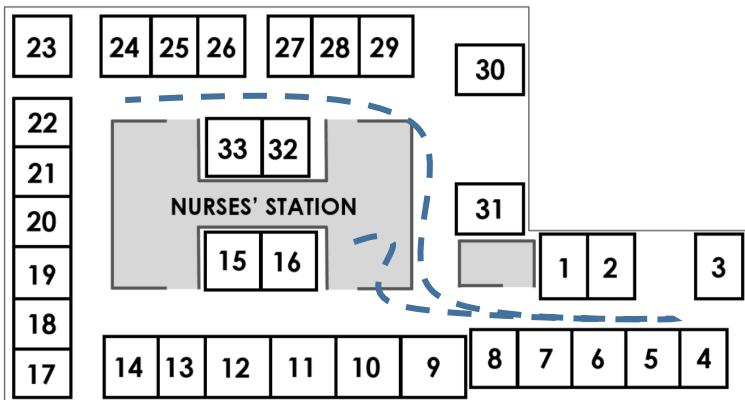


Uber Drivers



Whong 2014

Nurses



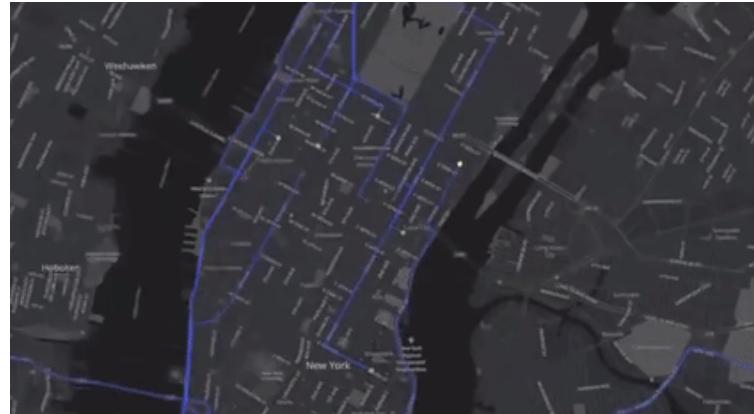
Meng et al. 2018

Trace Data is Everywhere

Physicians

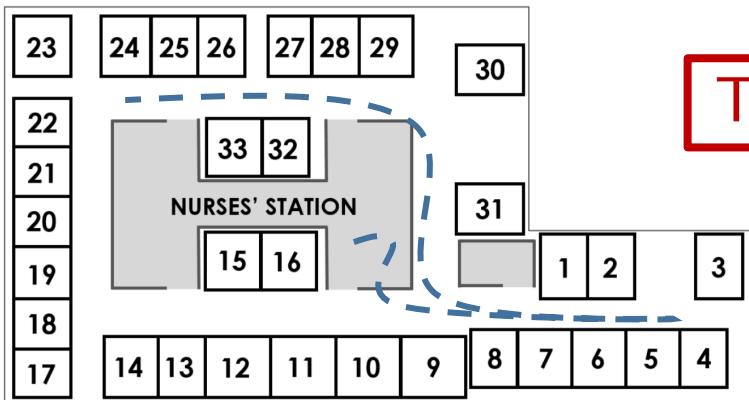
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Uber Drivers



Whong 2014

Nurses



Trace data

Meng et al. 2018

Tips

Our Paper

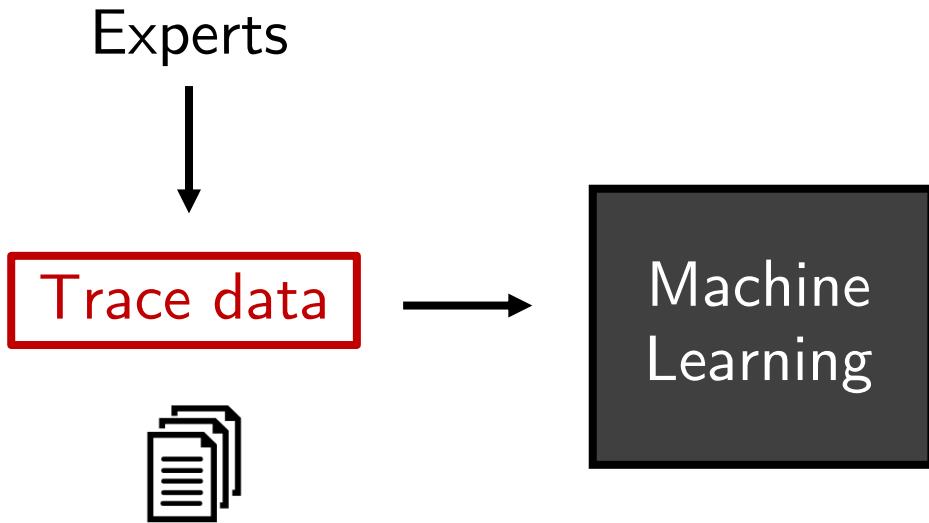
Experts



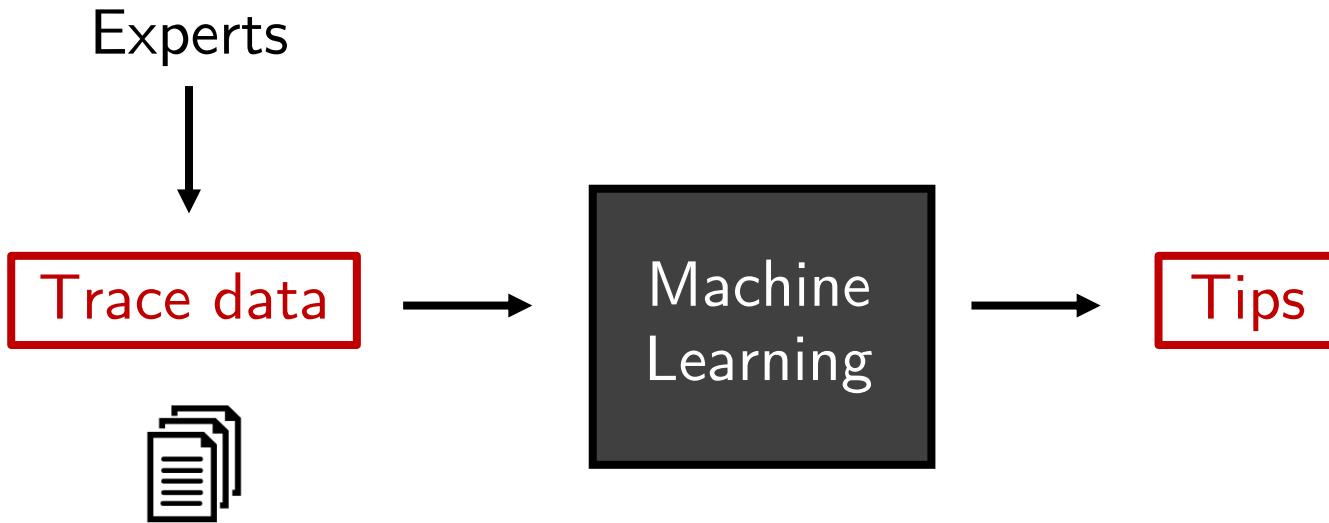
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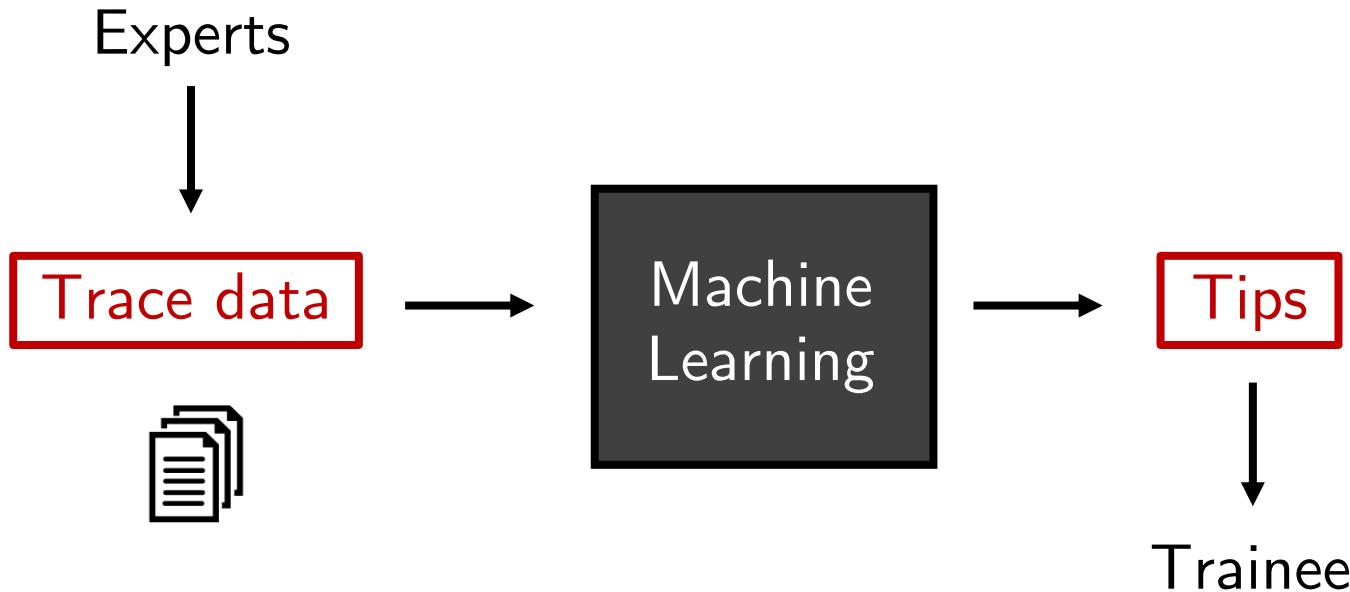
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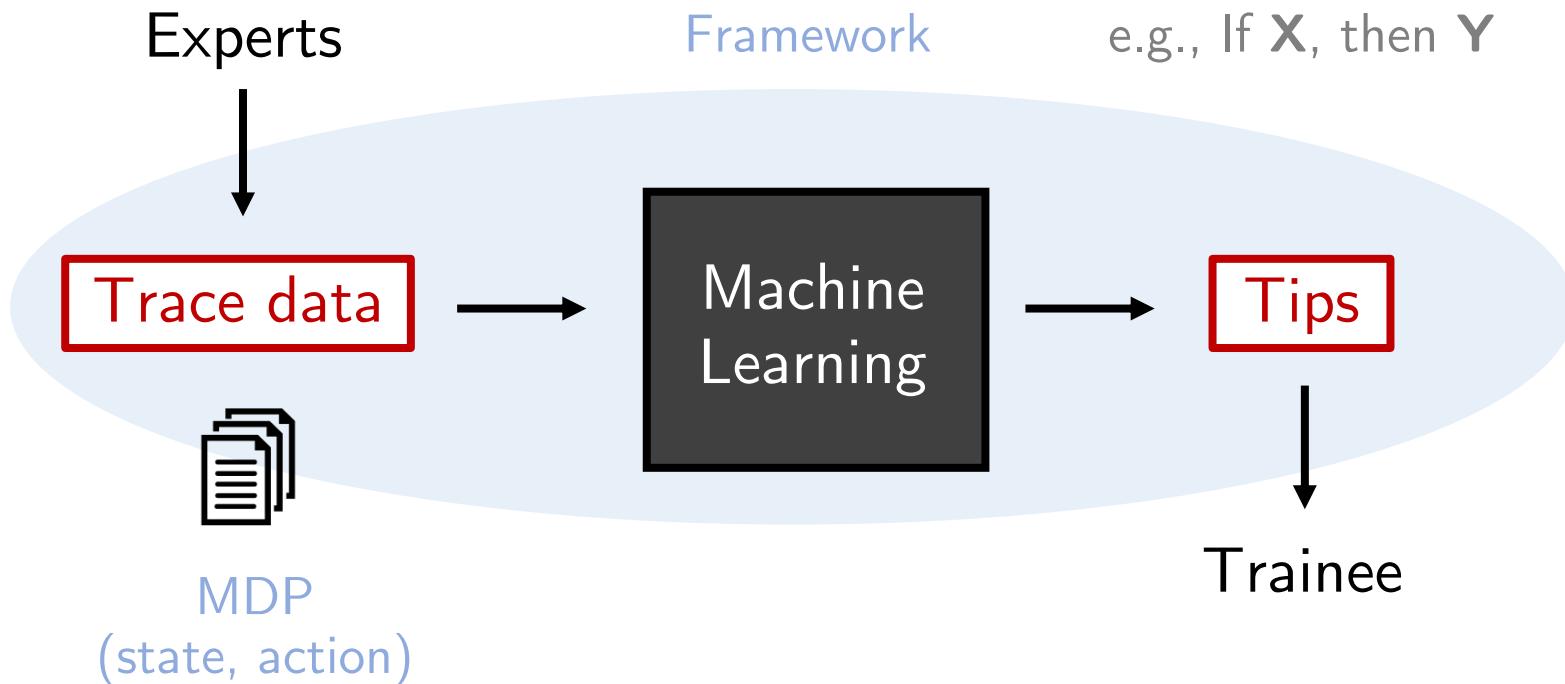
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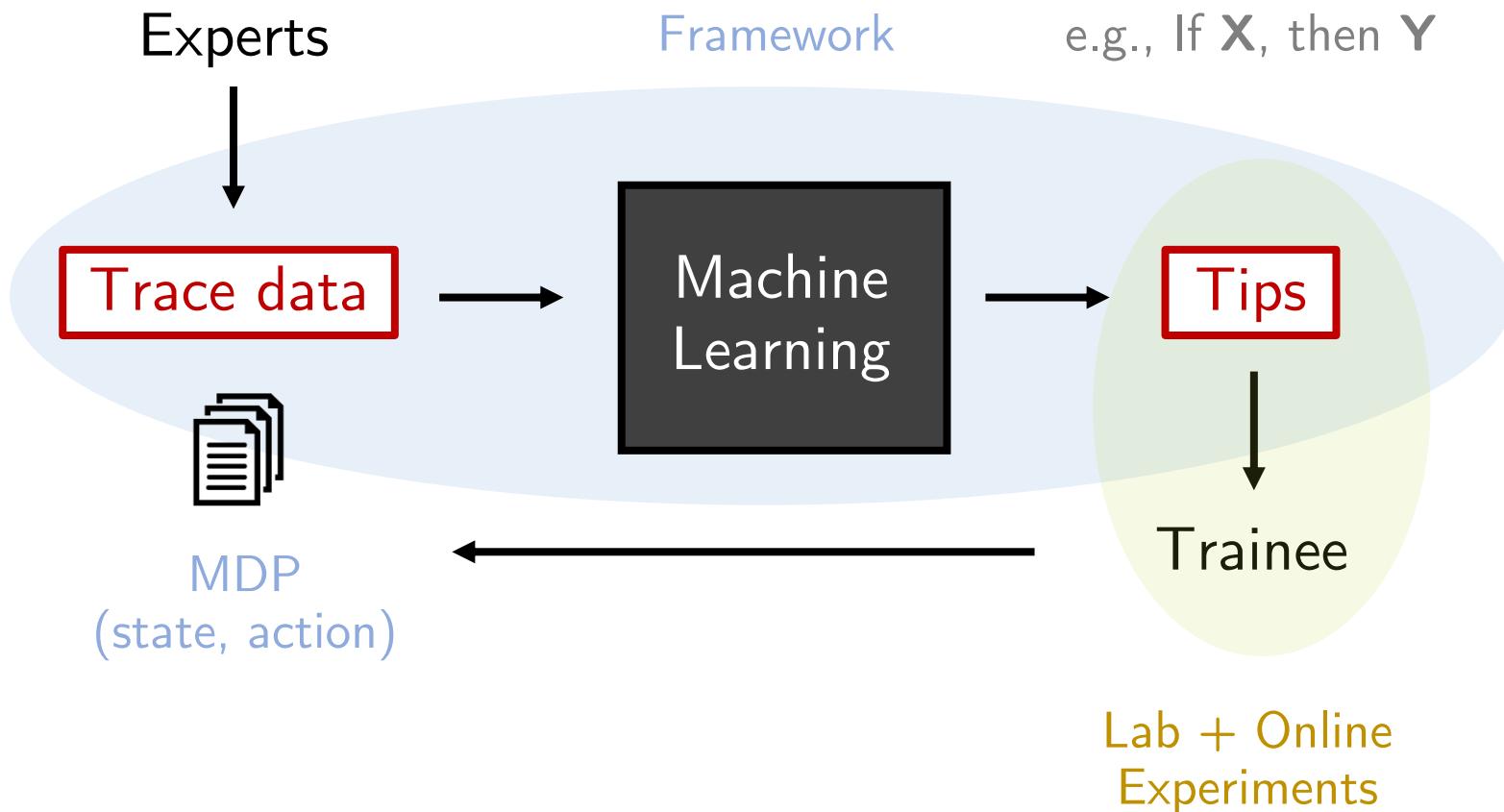
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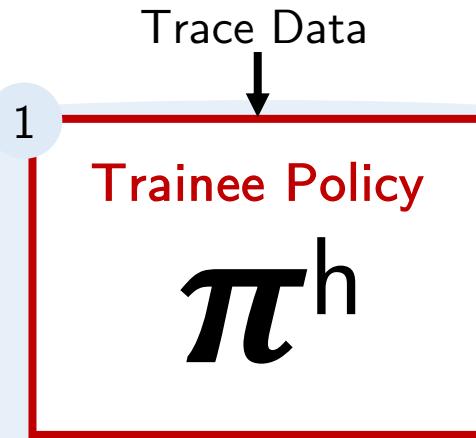


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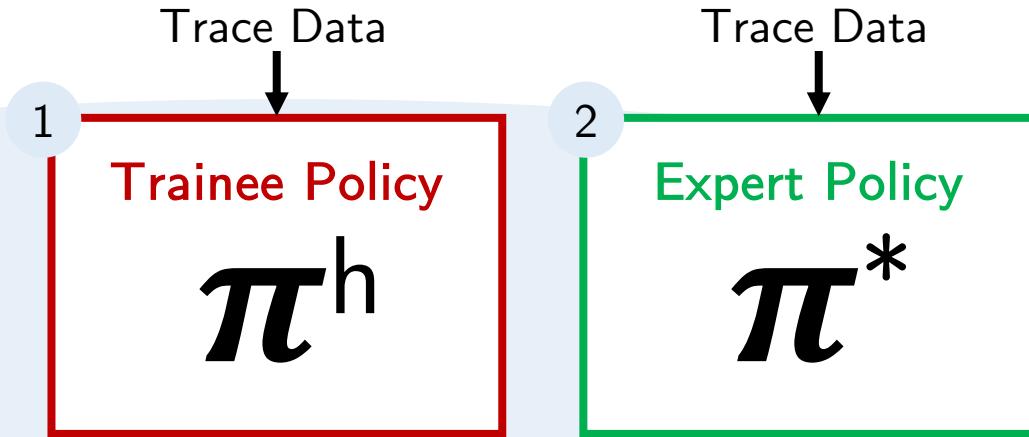
Our Framework

Our Framework



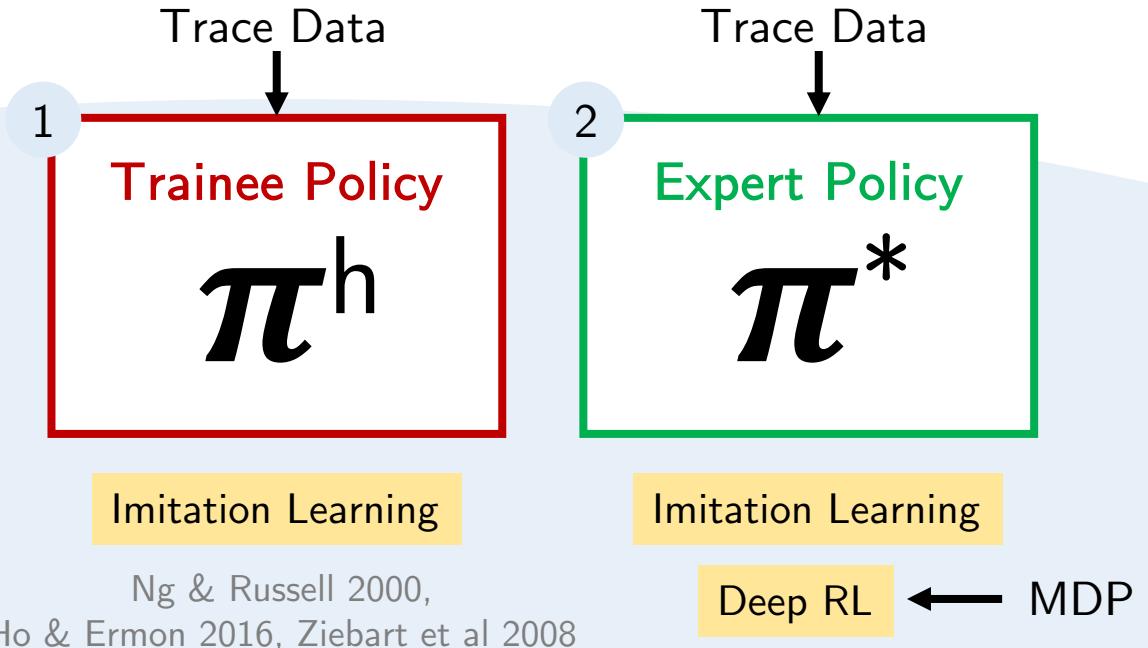
Ng & Russell 2000,
Ho & Ermon 2016, Ziebart et al 2008

Our Framework

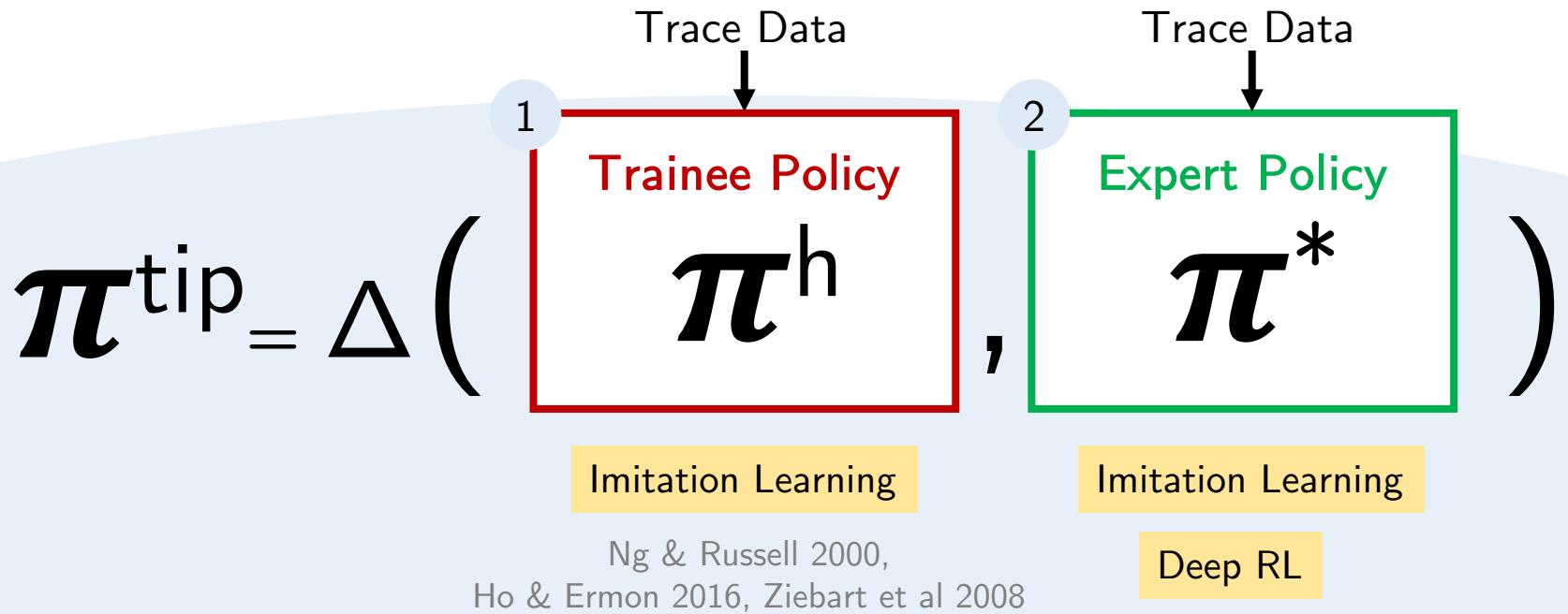


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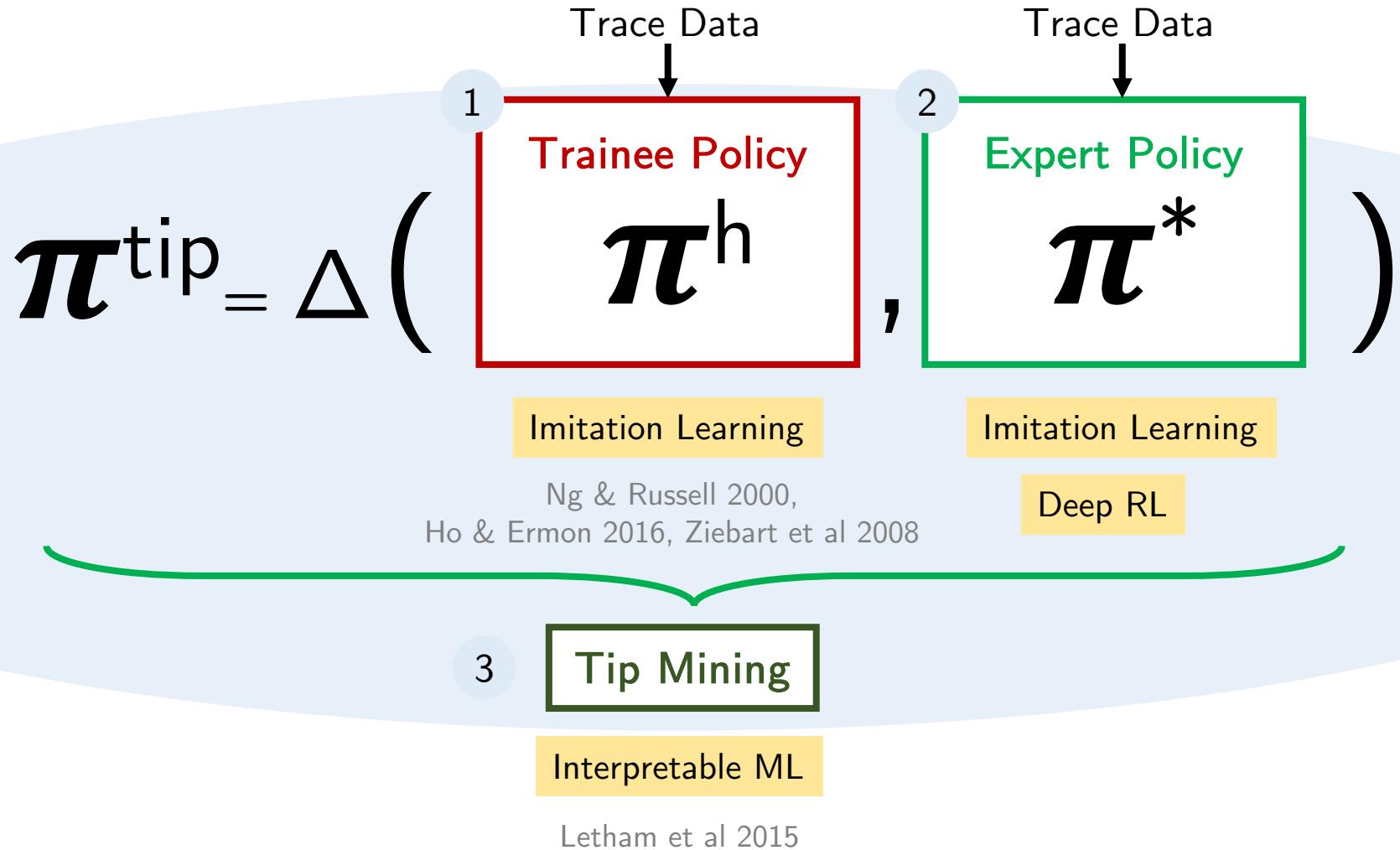
Our Framework



Our Framework



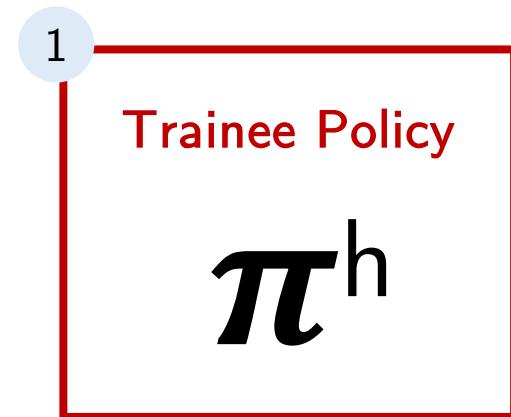
Our Framework



Learning Trainee Policy

- Supervised Learning
 - Random Forests/
Gradient Boosting Machine

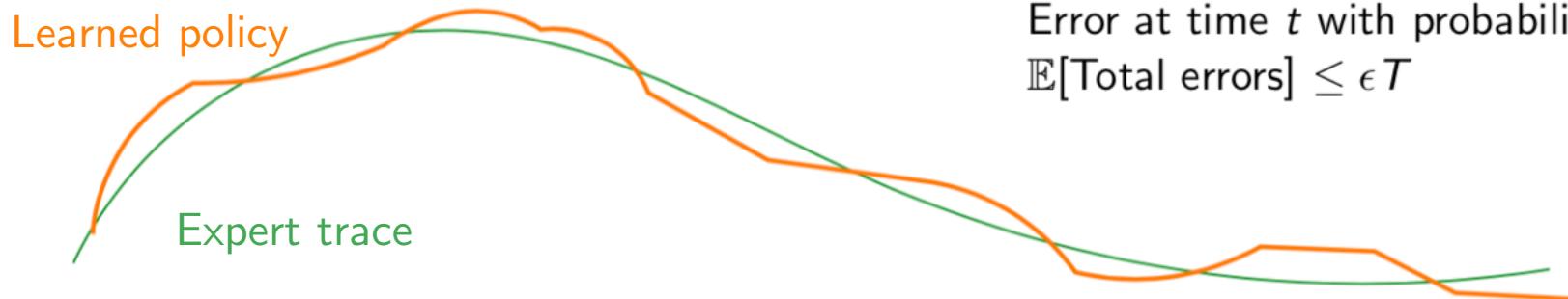
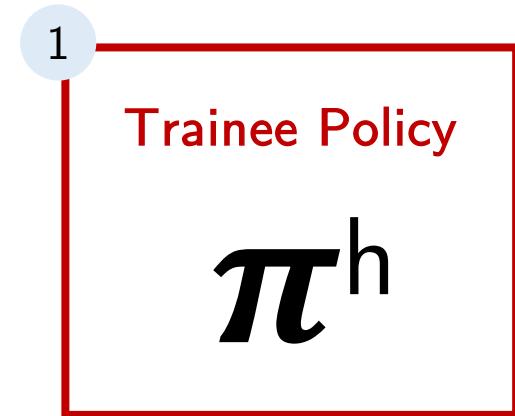
State \longrightarrow Action



Learning Trainee Policy

- Supervised Learning
 - Random Forests/
Gradient Boosting Machine

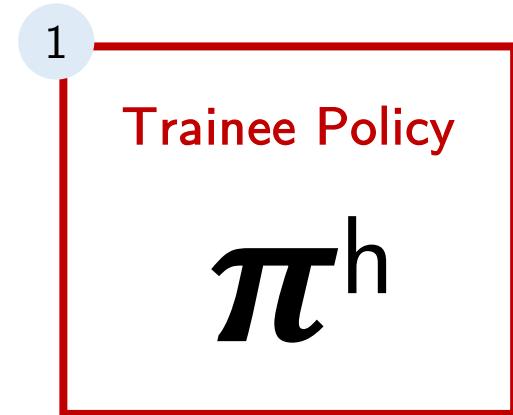
State \longrightarrow Action



Learning Trainee Policy

- Supervised Learning
 - Random Forests/
Gradient Boosting Machine

State \longrightarrow Action



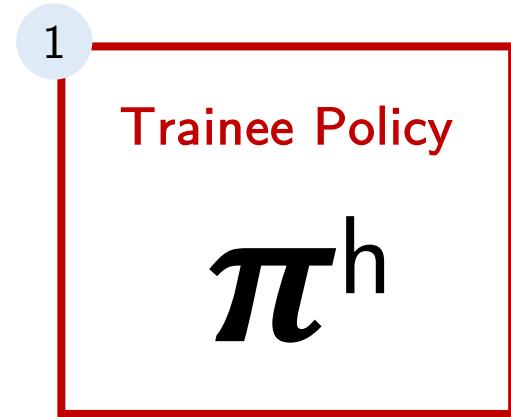
i.i.d. (state, action) pairs, ignores temporal structure

Learning Trainee Policy

- Supervised Learning
 - Random Forests/
Gradient Boosting Machine

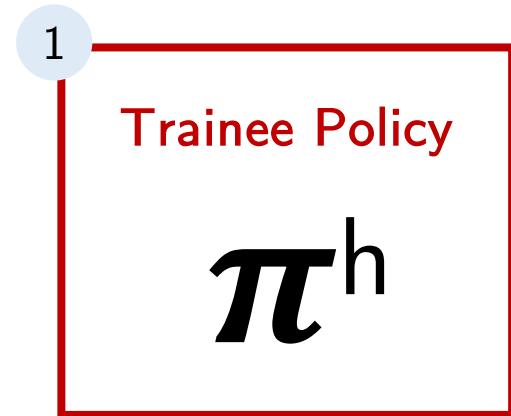
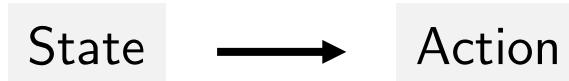
State → Action

0
0
0
0 → Predict 0
0
1
0
0

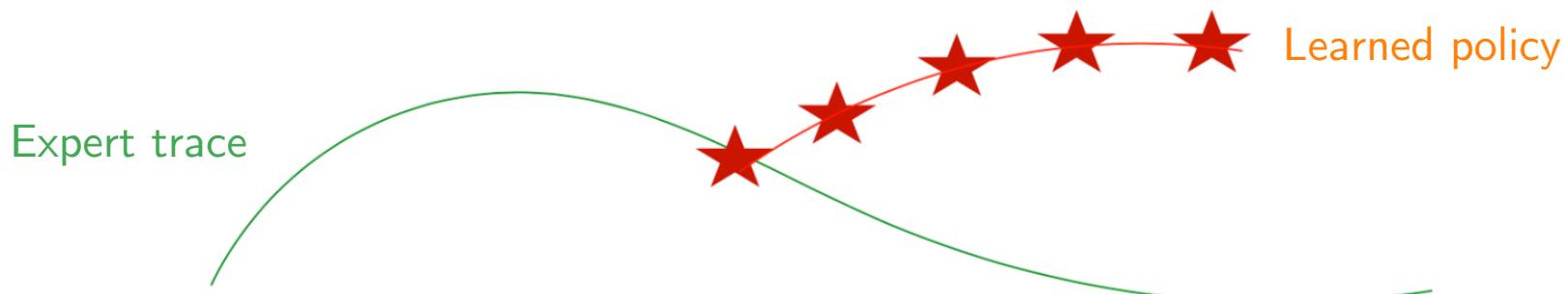


Learning Trainee Policy

- Supervised Learning
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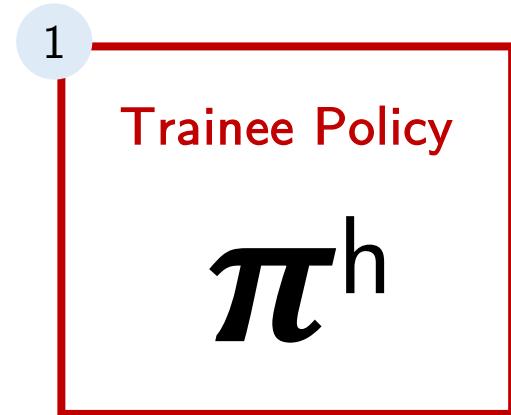


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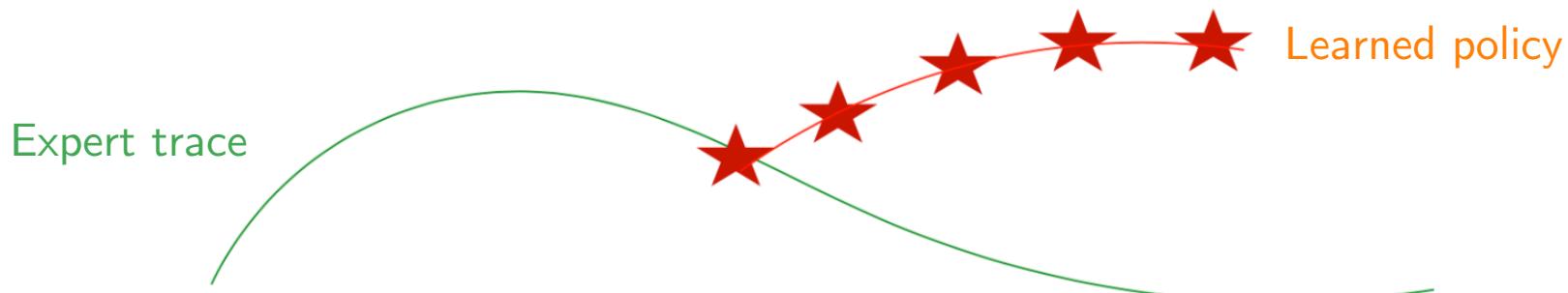


Learning Trainee Policy

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i.i.d. (state, action) pairs, ignores temporal structure

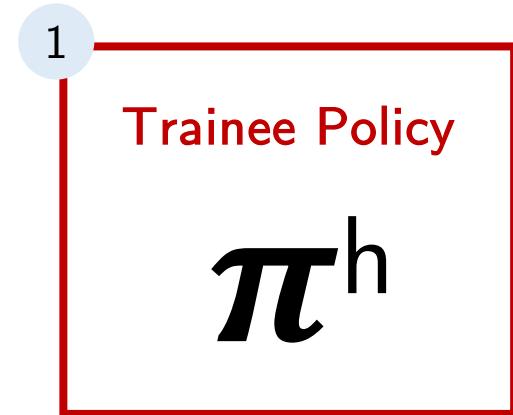


$$\mathbb{E}[\text{Total errors}] \leq \epsilon(T + (T - 1) + (T - 2) \dots + 1) \propto \epsilon T^2$$

- Ross et al 2011

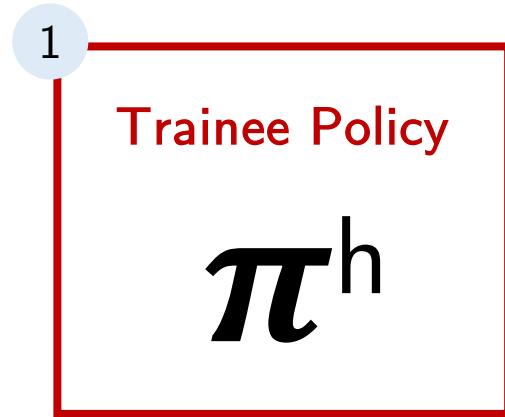
Imitation Learning

- Generative Adversarial IL
 - Learn the policy directly



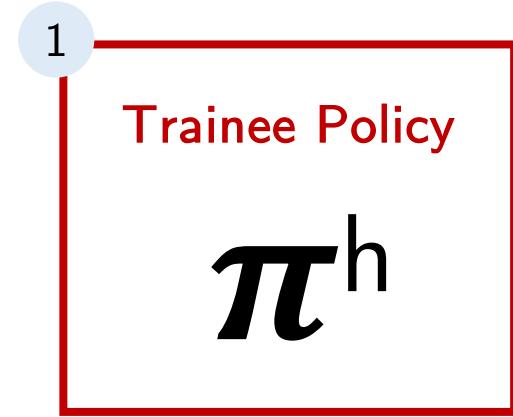
Imitation Learning

- Generative Adversarial IL
 - Learn the policy directly
 - Two neural networks:
 - Train a policy π^θ (gradient descent)
 - Discriminator (trained on trace data)



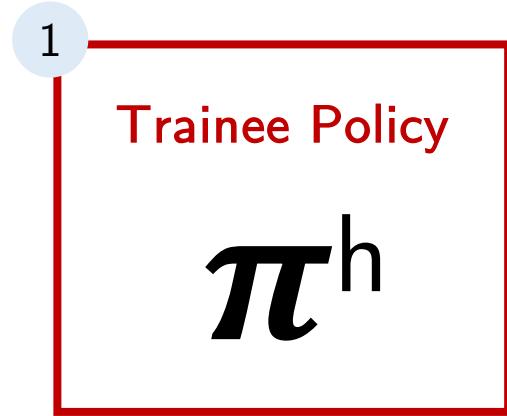
Imitation Learning

- Generative Adversarial IL
 - Learn the policy directly
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 - Discriminator (trained on trace data)
 - Find π^θ such that discriminator cannot distinguish between states from π^θ as opposed to those from π^h



Imitation Learning

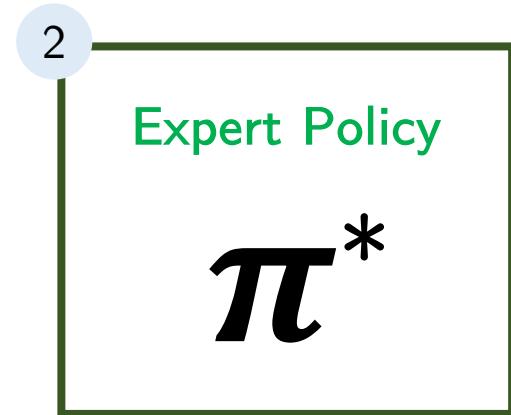
- Generative Adversarial IL
 - Learn the policy directly
 - Two neural networks:
 - Train a policy π^θ (gradient descent)
 - Discriminator (trained on trace data)
 - Find π^θ such that discriminator cannot distinguish between states from π^θ as opposed to those from π^h
 - Preserves (state, action) distribution



Learning Expert Policy

Reward function unknown

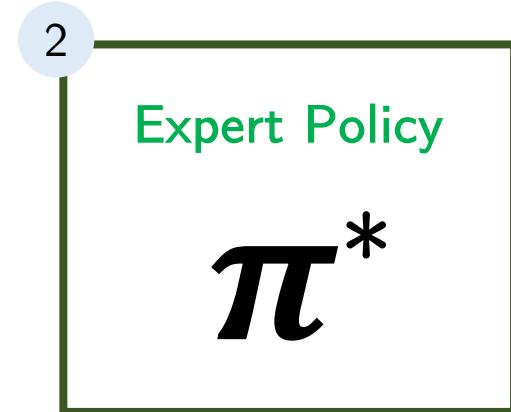
- Imitation learning from experts



Learning Expert Policy

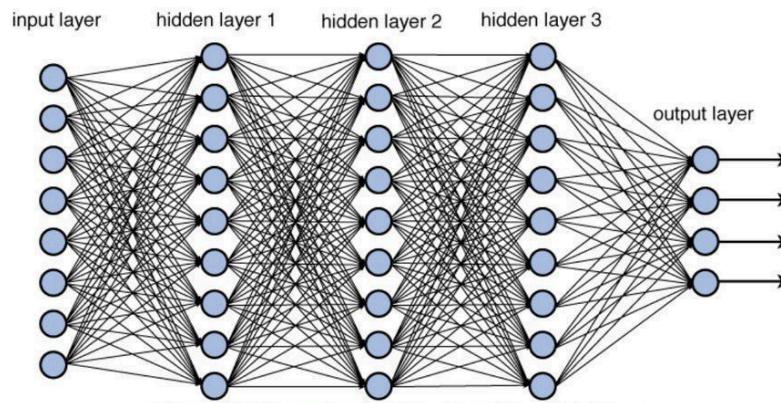
Reward function unknown

- Imitation learning from experts



Inferred reward function

- Our experiment: we know MDP.
- Solve for optimal policy with deep neural network



Learning Tips

3

Tip Mining

- Interpretable Bayesian Rule Lists
 - Adapt from Letham et al 2015
 - **If [feature], then [label]**
 - e.g., if high blood pressure, then stroke

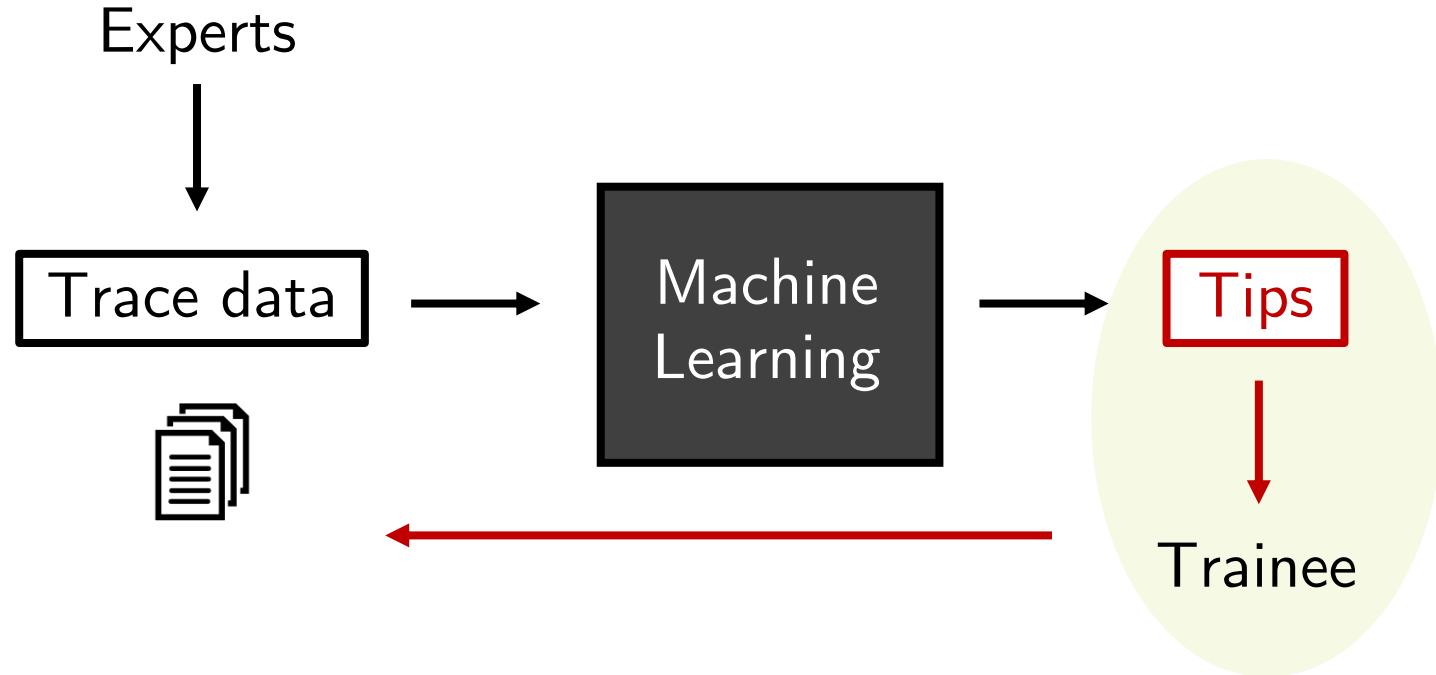
Learning Tips

3

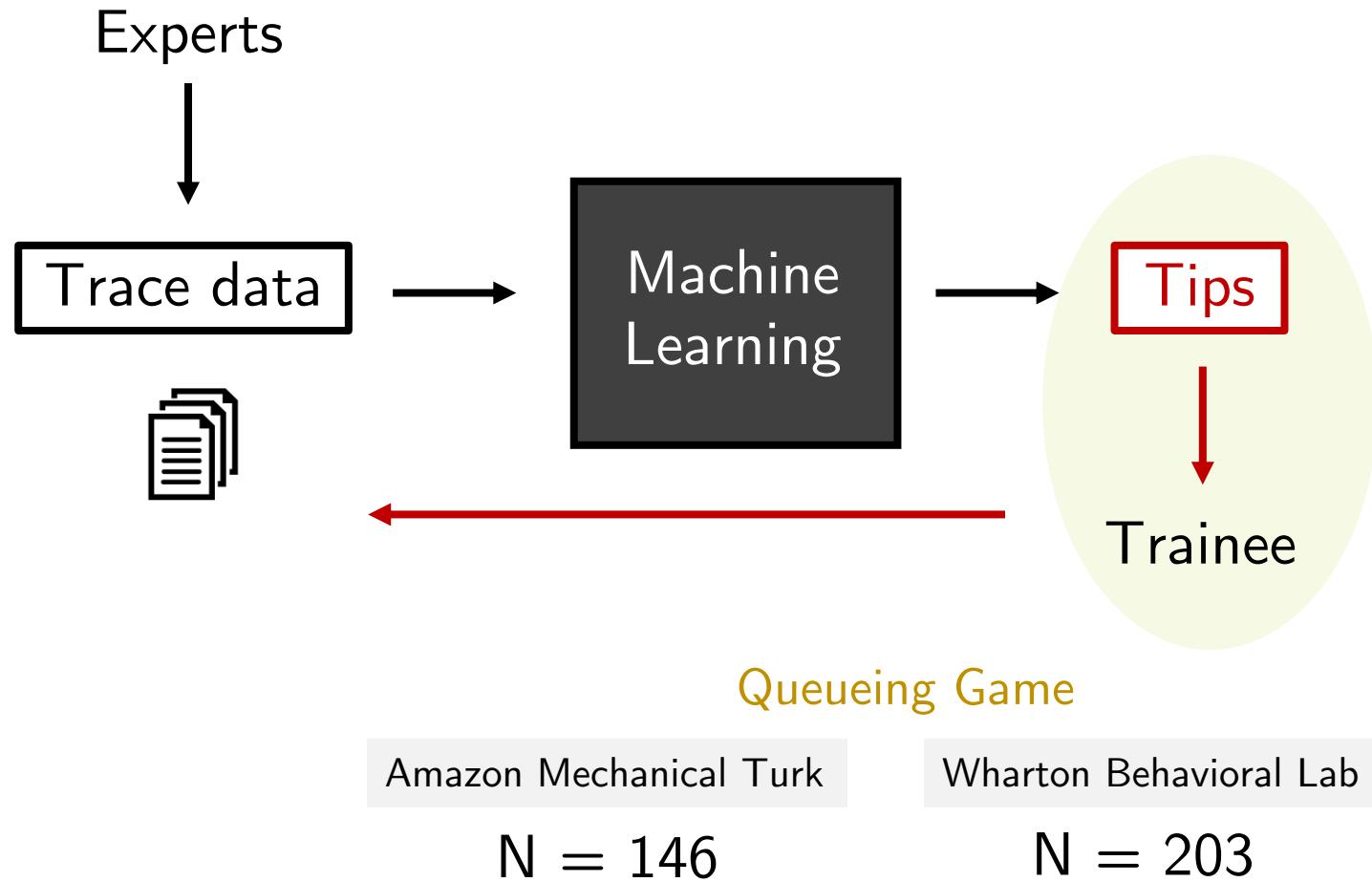
Tip Mining

- Interpretable Bayesian Rule Lists
 - Adapt from Letham et al 2015
 - **If [feature], then [label]**
 - e.g., if high blood pressure, then stroke
- Our context
 - **If [state], then take [action]**
 - Pre-mined frequent patterns into a decision list using Bayesian statistics

Our Paper



Our Paper



Queueing Game

Burger Queen

Participant

Queueing Game

Burger Queen

Alice



Bob

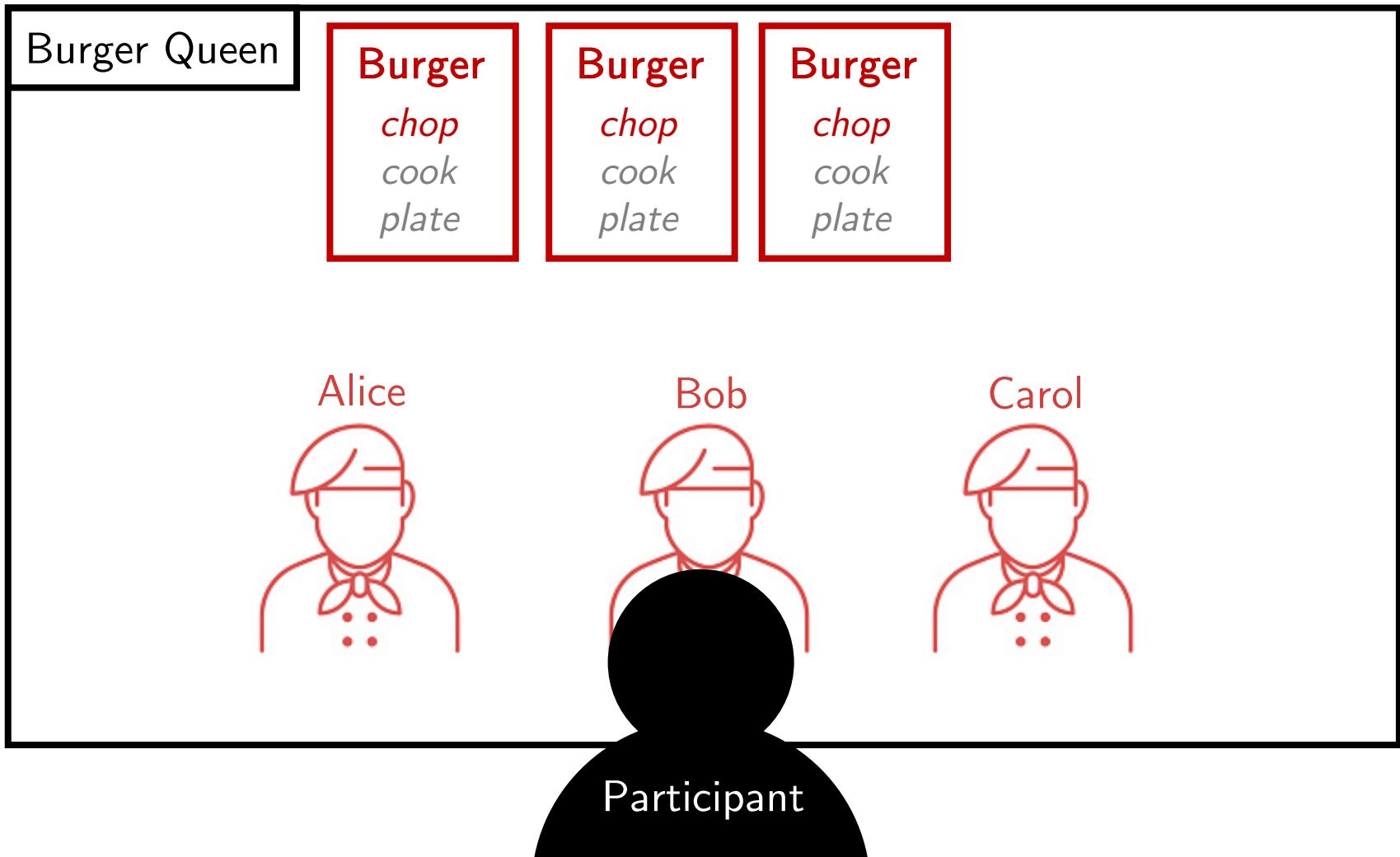


Carol

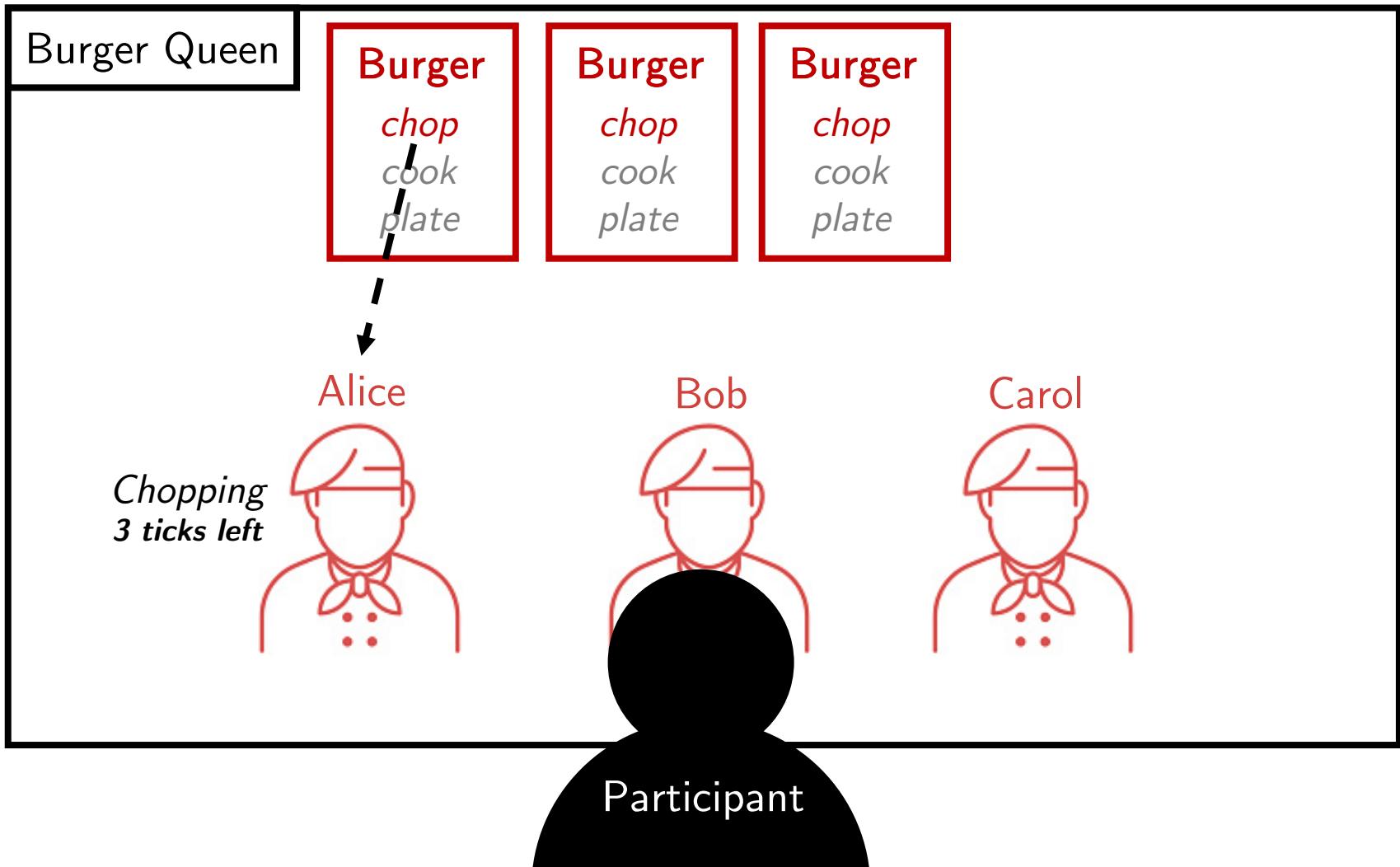


Participant

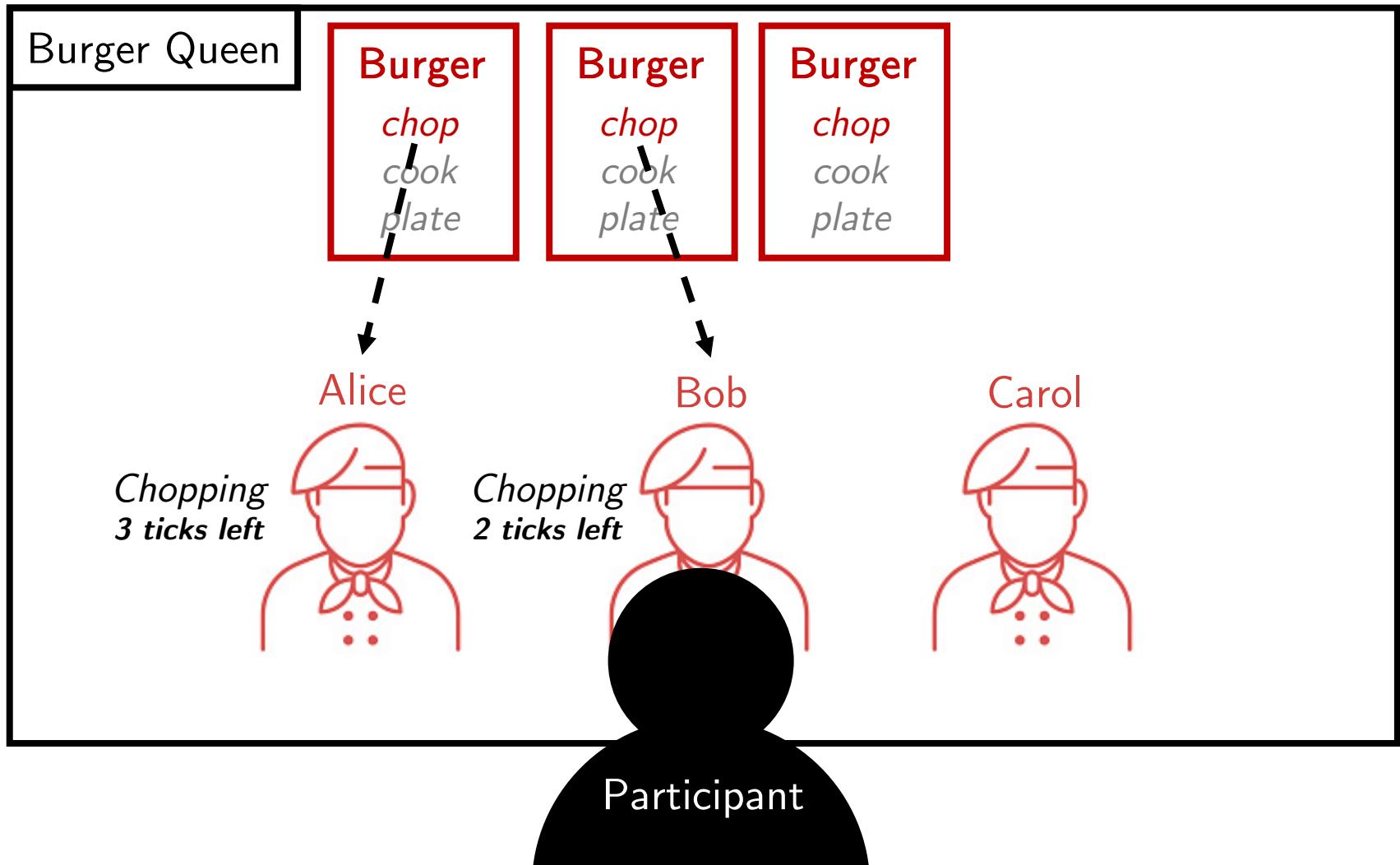
Queueing Game



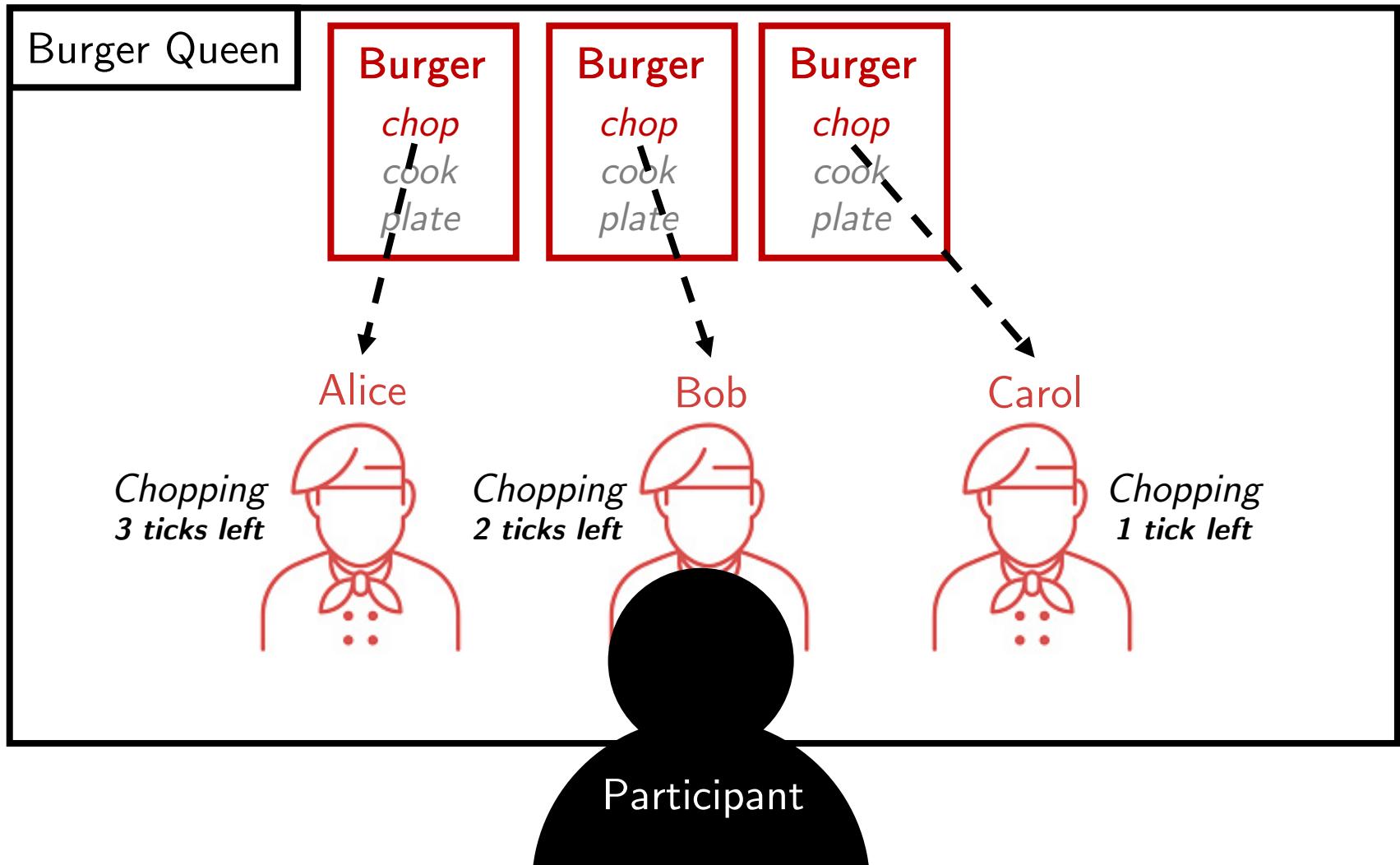
Queueing Game



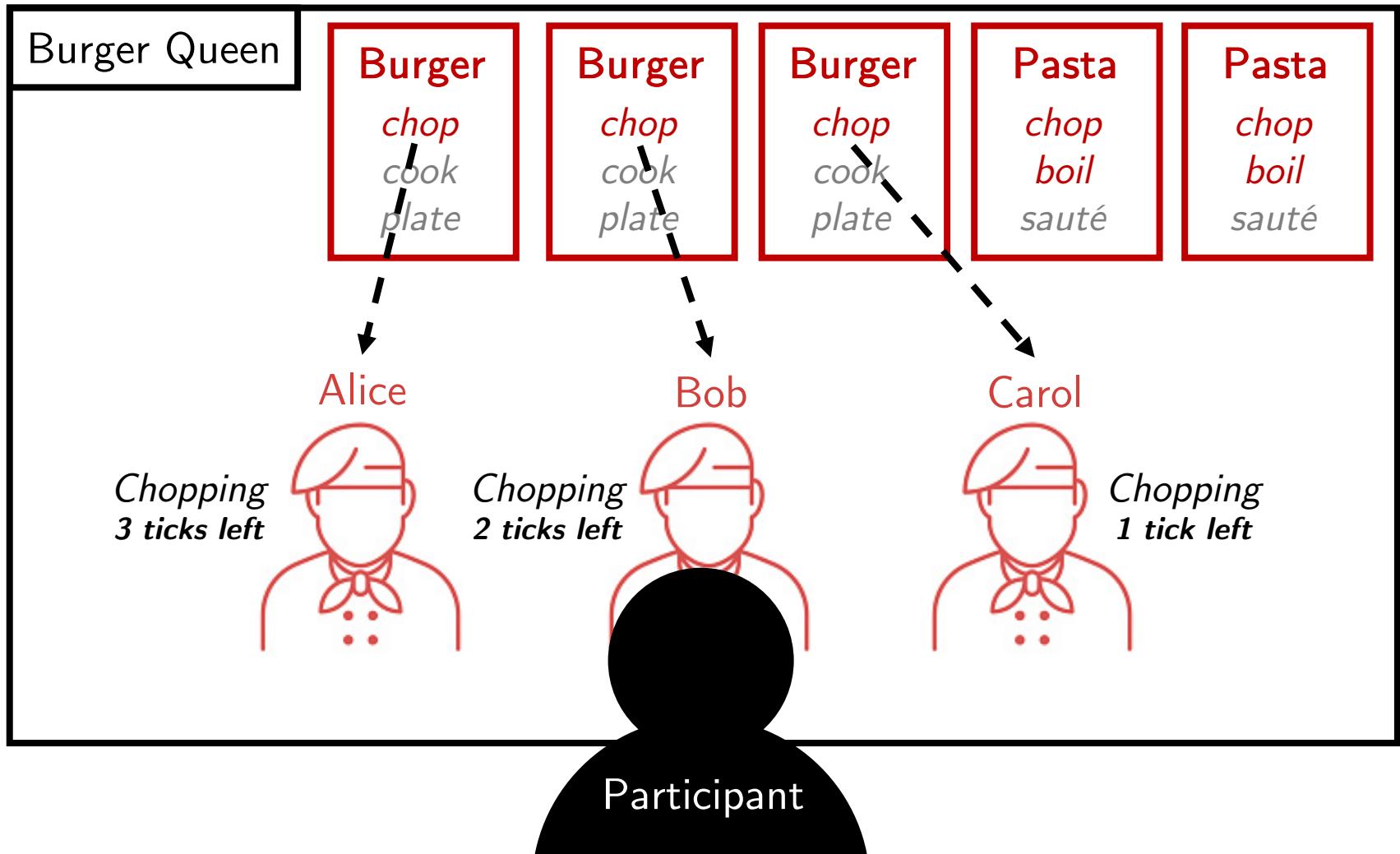
Queueing Game



Queueing Game



Queueing Game

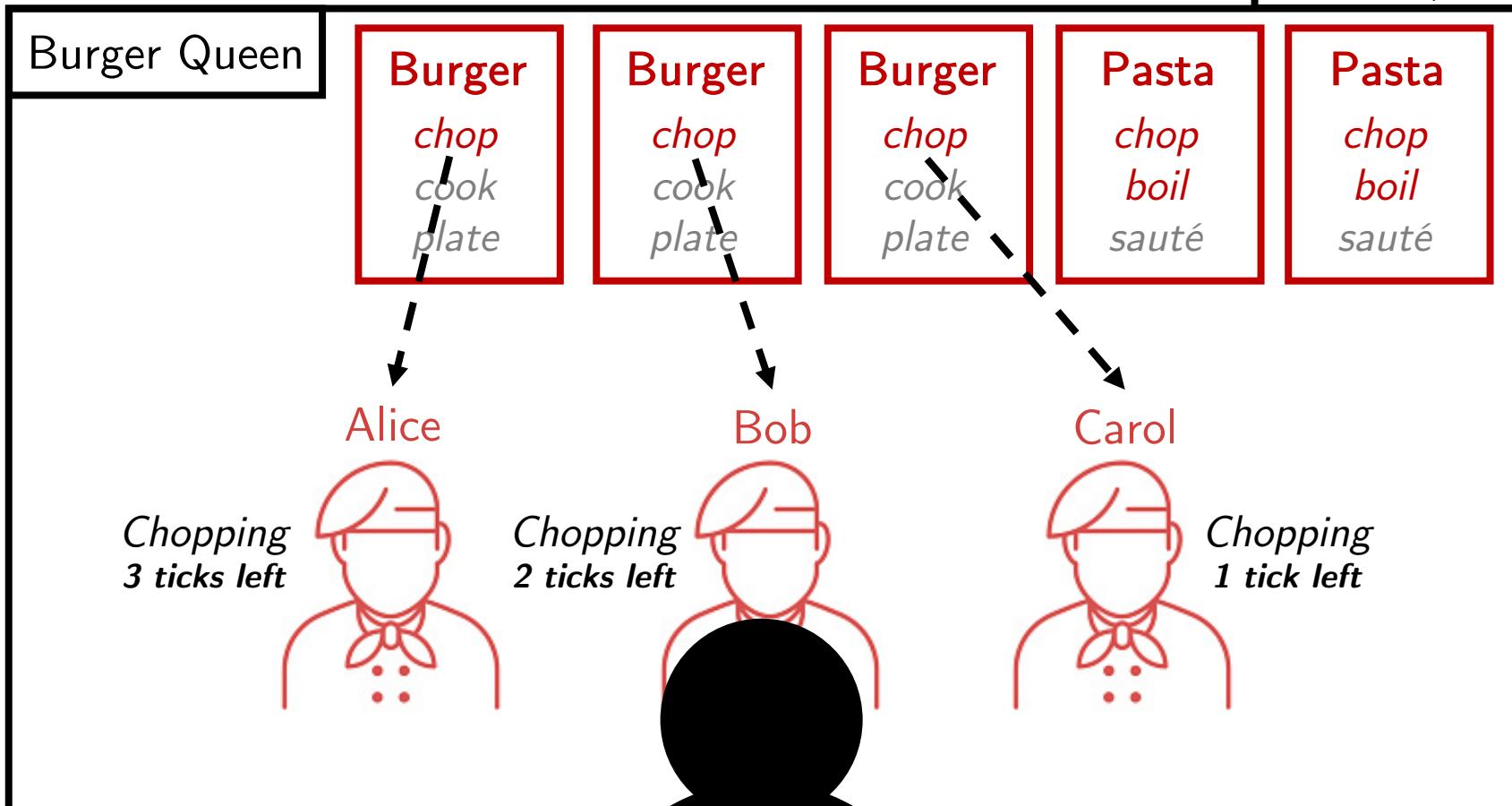


Queueing Game

Reward: 0

4 seconds left

Tick #1/23



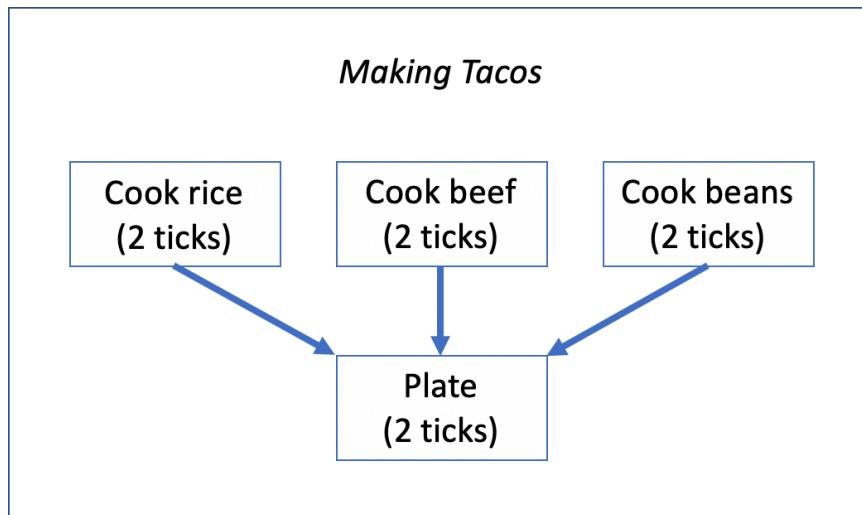
Experiment Learning Workers' Skills



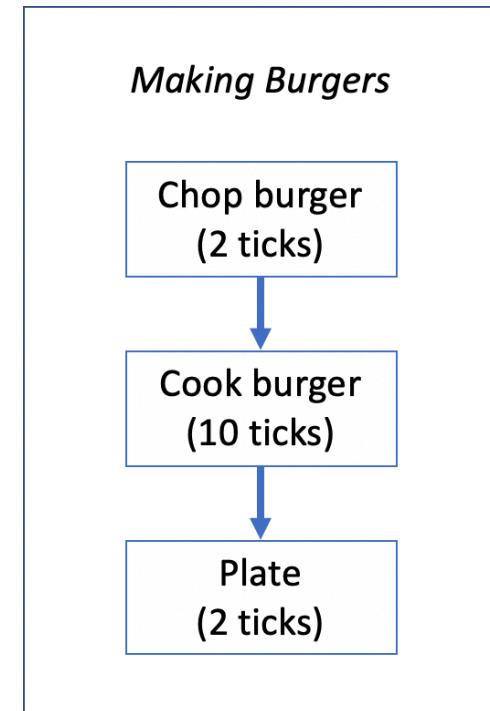
<i>Role:</i>	Server	Sous-Chef	Chef
<i>Chopping:</i>	Slow	Fast	Fast
<i>Cooking:</i>	Slow	Medium	Fast
<i>Plating:</i>	Fast	Medium	Slow

Unknown to participants

Experiment Learning Tasks

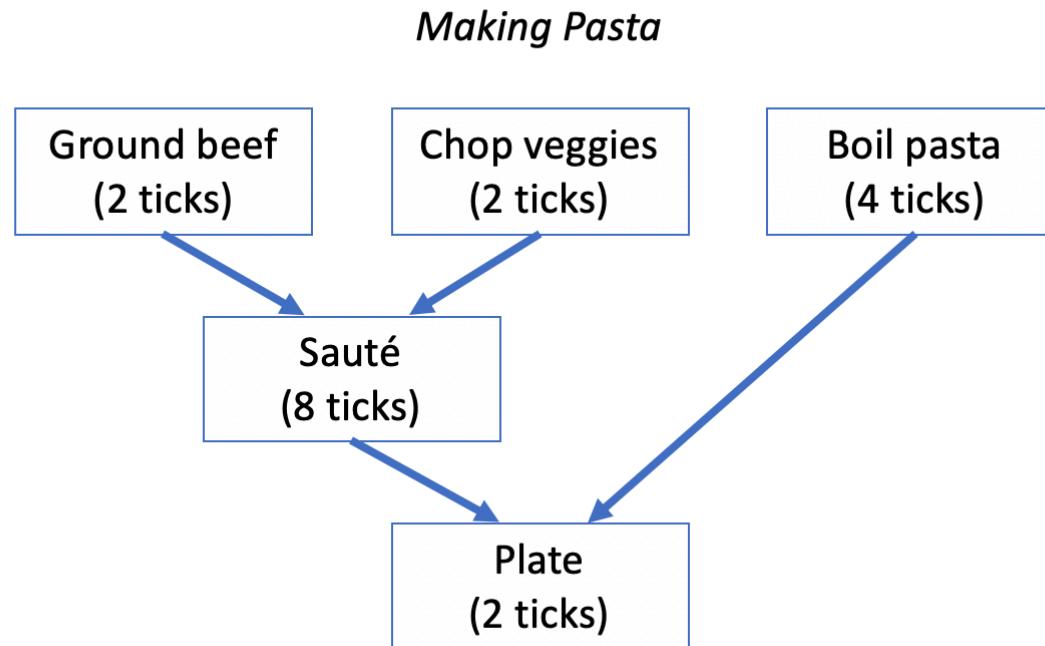


Parallel Tasks



Sequential Tasks

Experiment Learning Tasks



Hybrid Tasks (Both Parallel and Sequential)

Experiment

Handcrafted Tips

Control

No tips.

Tips

Experiment Handcrafted Tips

Control

No tips.

Tips

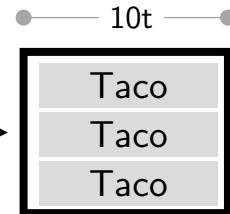
“Prioritize cooking and chopping tasks for Bob and Carol, and plating tasks for Alice.”

“...Carol should NEVER plate, and Alice should NEVER cook (it’s better to leave them idle than to give them these tasks.)”

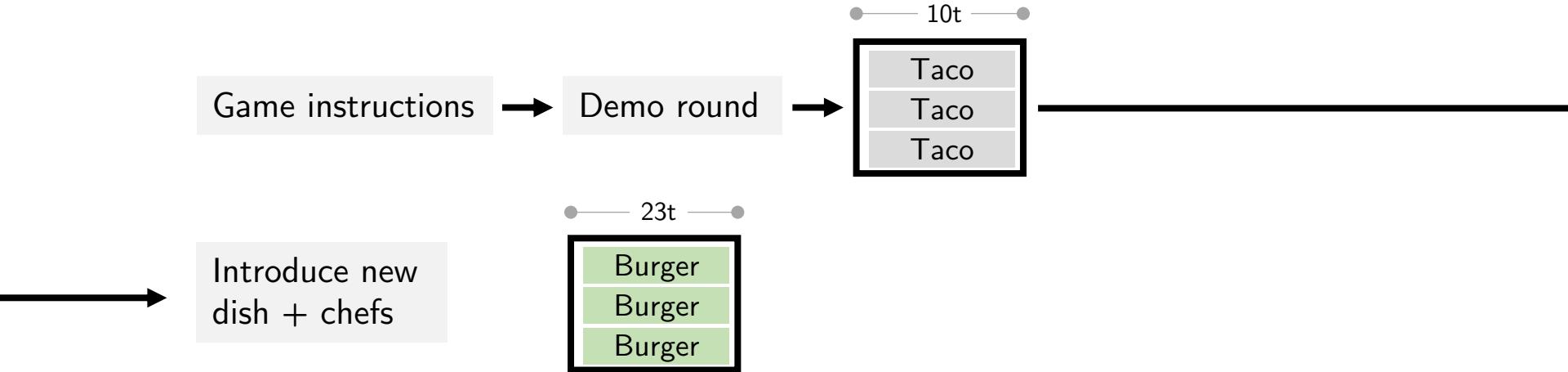
Experiment Flow

Game instructions

→ Demo round →



Experiment Flow



Experiment Flow

Game instructions

→ Demo round

Flow

10t

Taco
Taco
Taco

23t

Burger
Burger
Burger

Tips

23t

Burger
Burger
Burger

Tips

23t

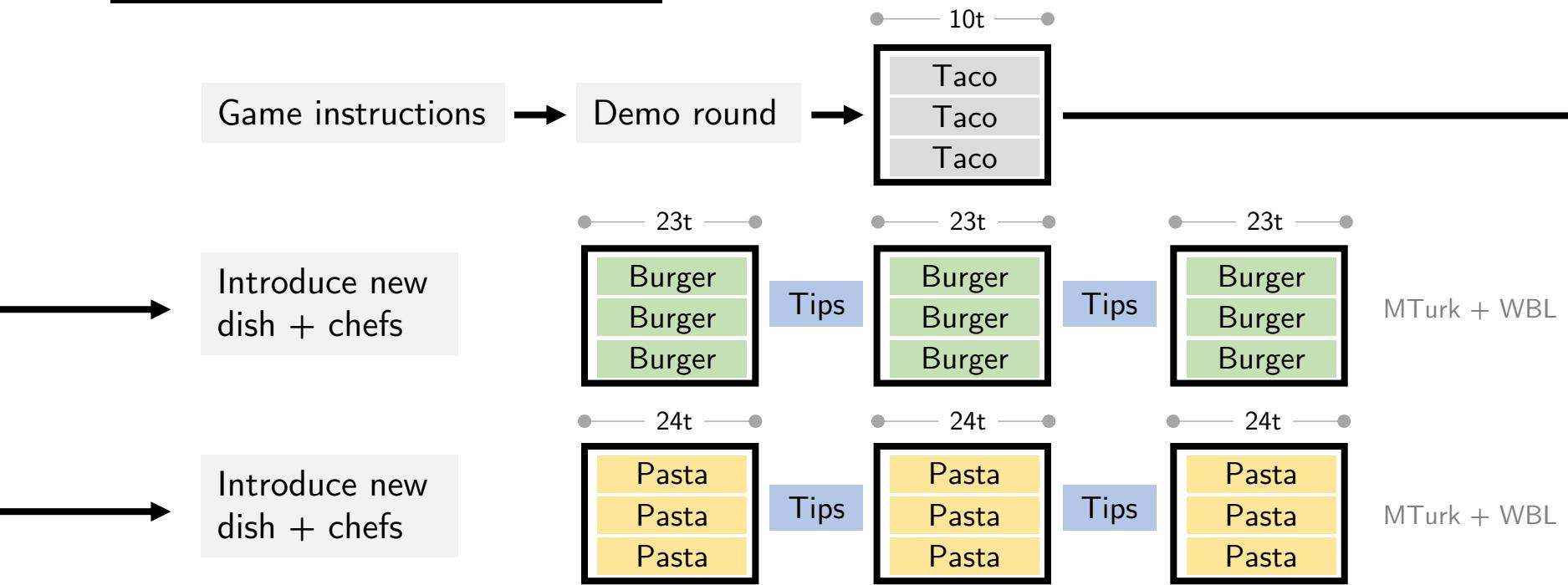
Burger
Burger
Burger

MTurk + WBL

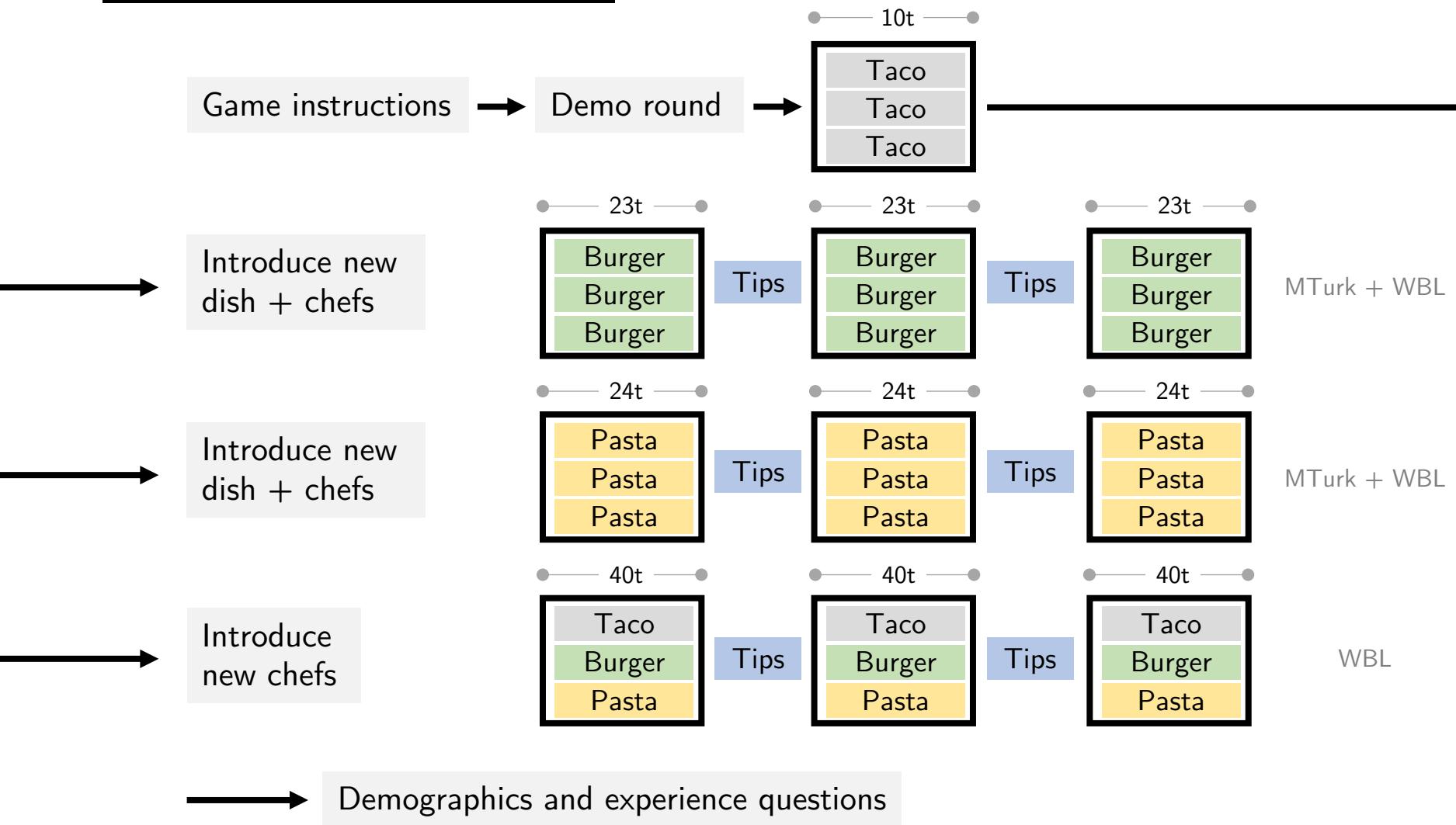
Introduce new dish + chefs



Experiment Flow

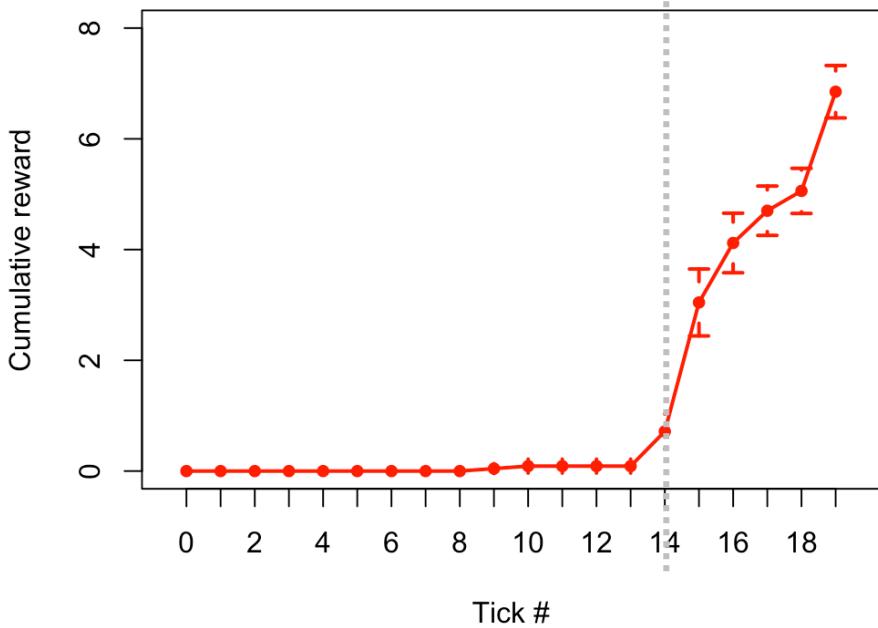


Experiment Flow

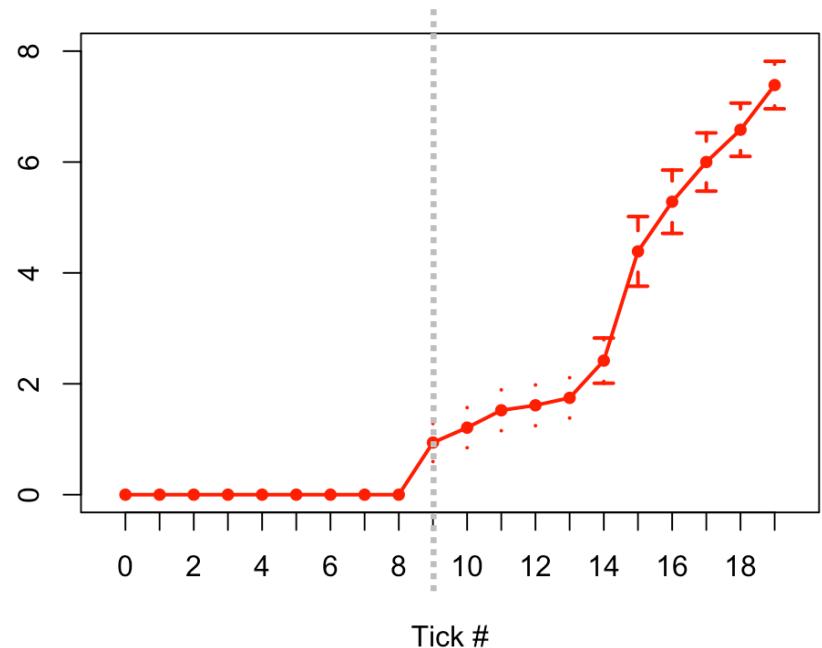


Results Performance

Burger #1



Burger #3

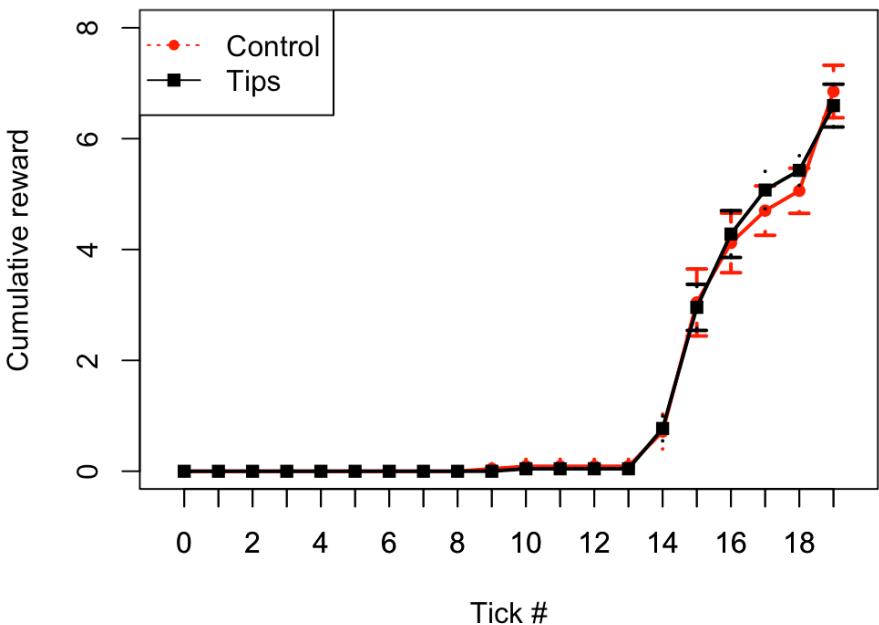


Control: Over time, people improve.

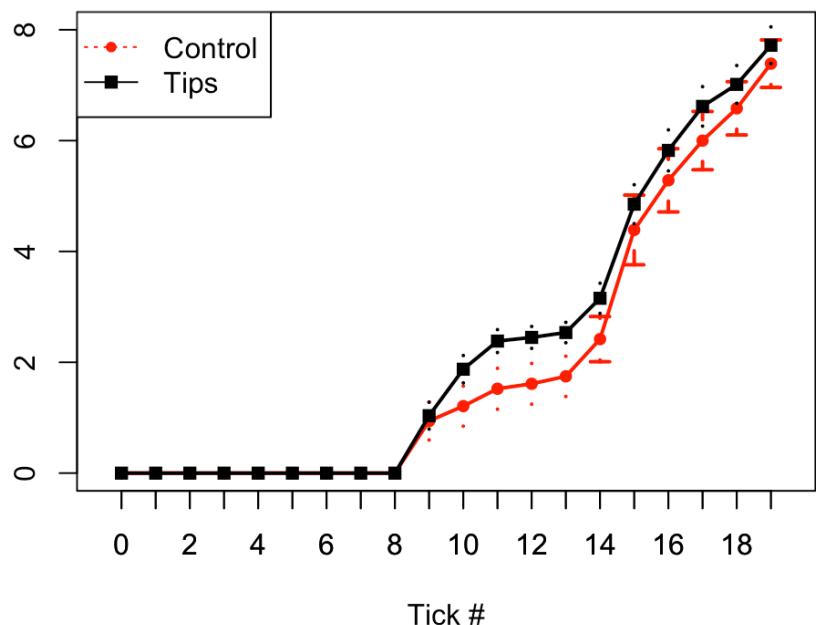
Results

Tips Help

Burger #1



Burger #3



With Tips: Higher score, improve faster

Results

Tips Help

Suboptimal Decisions e.g., assigning high-skilled chef to plate a dish

%	Burger #1	#2	#3	Pasta #1	#2	#3
Control	5.49	3.88	3.31	3.26	2.81	2.54
Tips	2.78	1.53	1.30	1.38	1.16	0.84

With Tips: Higher score, improve faster, make fewer suboptimal decisions

Results

Tips Help

Suboptimal Decisions

e.g., assigning high-skilled chef to plate a dish

%	Burger #1	#2	#3	Pasta #1	#2	#3
Control	5.49	3.88	3.31	3.26	2.81	2.54
Tips	2.78	1.53	1.30	1.38	1.16	0.84

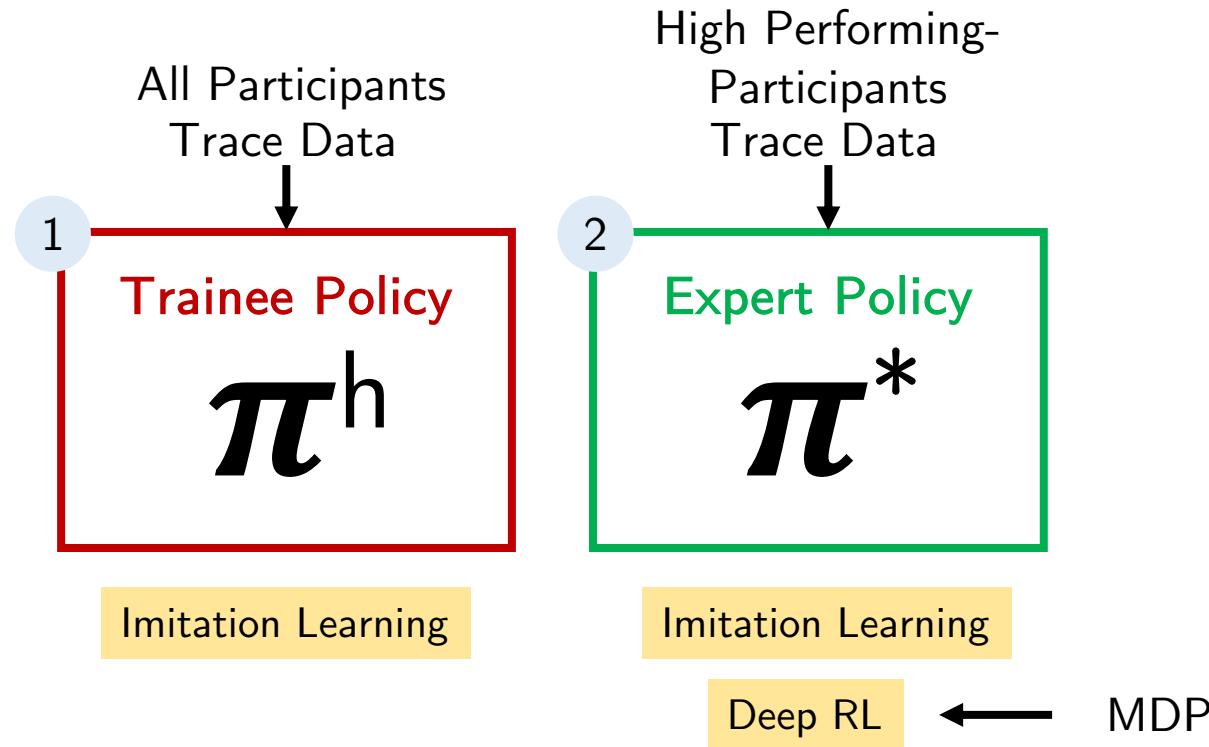
With Tips: Higher score, improve faster, make fewer suboptimal decisions

In our setting, people can potentially improve ✓

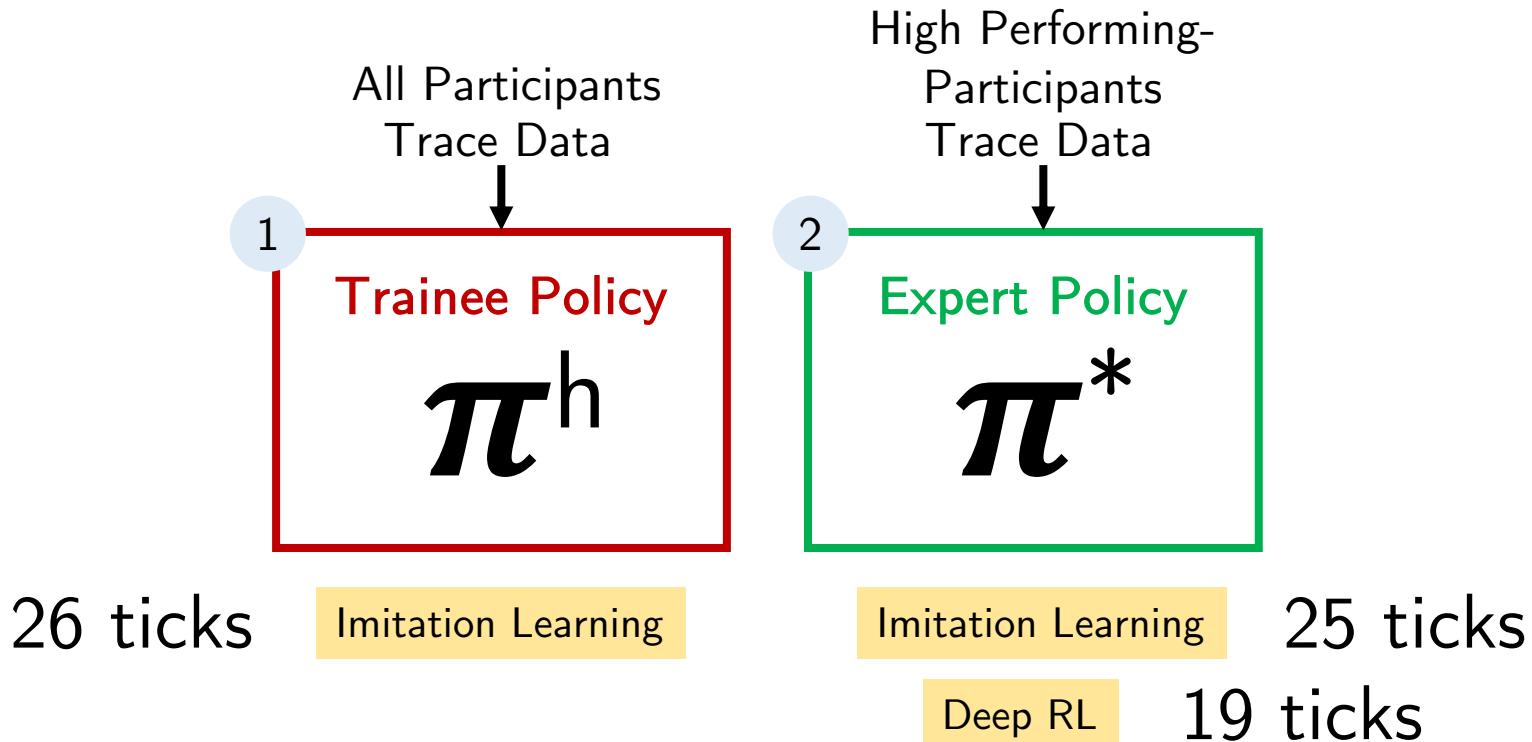
Obtain trace data to estimate policies ✓

Automatically extract tips ✓

Results Extracting Policies



Results Extracting Policies



Results

Extracting Tips

3

Tip Mining

- Balance best improvement and confidence

Available Workers

Open Tasks

Action

Results

Extracting Tips

3

Tip Mining

- Balance best improvement and confidence



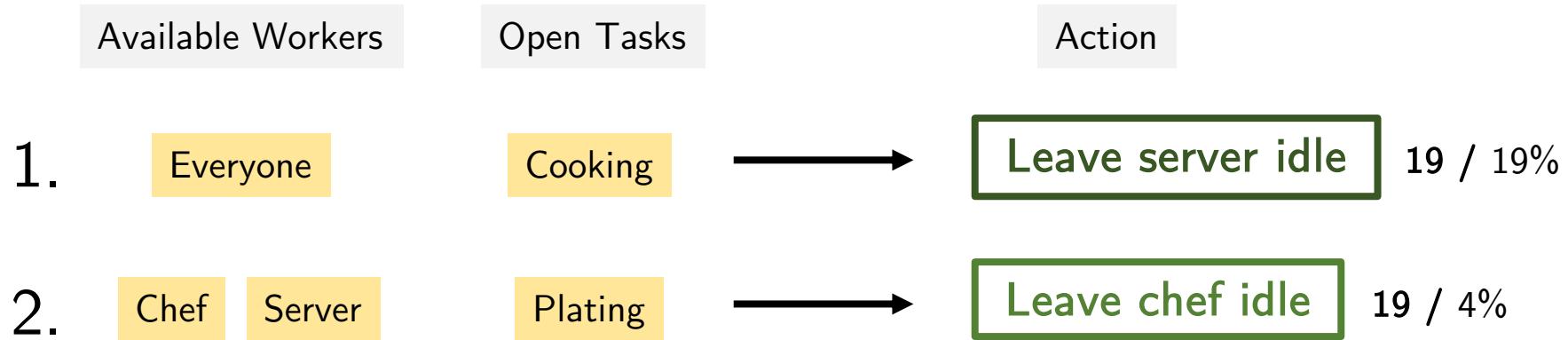
Results

Extracting Tips

3

Tip Mining

- Balance best improvement and confidence



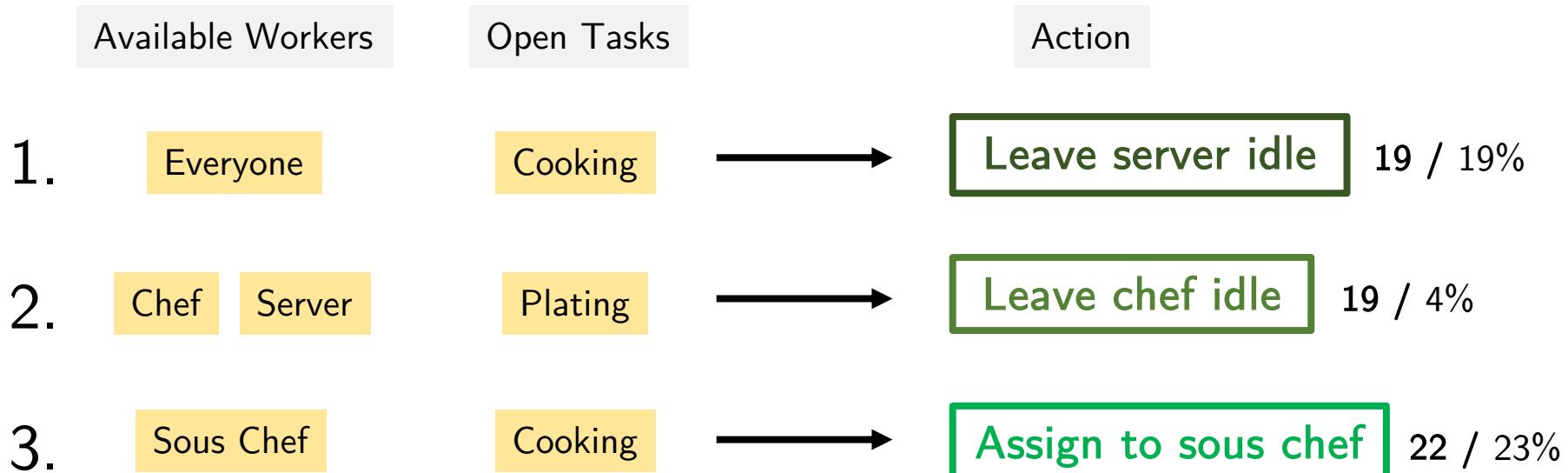
Results

Extracting Tips

3

Tip Mining

- Balance best improvement and confidence



On-Going Work

- Improve tips learning algorithms
- Implement personalized tips in the next phase of experiments
- Extend to team collaboration



Summary

ML to automatically help people improve in a personalized and dynamic way

