In Search of the Dream Team

Temporally Constrained Multi-Armed Bandits For Identifying Effective Team Structures

Sharon Zhou, Melissa Valentine, Michael Bernstein
Stanford University
What is the best way to organize teams?
Rapidly try different strategies and converge on one
Rapidly try different strategies and converge on one

DreamTeam
Rapidly try different strategies and converge on one DreamTeam
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- There is no universally ideal way to structure all teams

Lawrence and Lorsch 1967
Donaldson 1999
Rapidly try different strategies and converge on one

- There is no universally ideal way to structure all teams

- It depends on the team members and their task

Lawrence and Lorsch 1967
Donaldson 1999
Novel algorithm to avoid overwhelming teams with deluge of different strategies
- Novel algorithm to avoid overwhelming teams with deluge of different strategies

- Our system, DreamTeam, outperformed manager-led and self-managed teams by over 40% on performance
Design
Roles, norms, and interaction patterns that define how we collaborate are called *team structures*
There are no universally ideal team structures
There are no universally ideal team structures

- Structural contingency theory
There are no universally ideal team structures

- Structural contingency theory
- Effective team structures depend on the members and their task
There are no universally ideal team structures

- Structural contingency theory
- Effective team structures depend on the members and their task
- Wrong structures lead to dysfunctional teams

Ilgen et al. 2005
Schippers et al. 2014
Ancona et al. 2001
Arrow 1997
TEAM STRUCTURES

Hierarchy
None, Centralized, Decentralized

Interaction Patterns
Emergent, Round-robin, Equally distributed

Norms of Engagement
None, Professional, Informal

Decision-Making Norms
None, Divergent, Convergent, Informed, Rapid

Feedback Norms
None, Encouraging, Critical
One configuration of team structures

Hierarchy
  Centralized

Interaction Patterns
  Equally distributed

Norms of Engagement
  Professional

Decision-Making Norms
  Convergent

Feedback Norms
  Encouraging
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Hierarchy

Centralized

Decentralized

Zappos.com
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TEAM A Bandit Exploration
TEAM B Bandit Exploration
TEAM C Bandit Exploration
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Bandit Exploration

TEAM B

Bandit Exploration

TEAM C

Bandit Exploration
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Time
Dream Team

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Teams form on Slack

hakuna
hello
9:21 AM
Teams form on Slack

hakuna  9:21 AM
    hello

matata  9:21 AM
    hi
Teams form on Slack

hakuna 9:21 AM
hello

matata 9:21 AM
hi

Hi everyone!
Teams form on Slack

hakuna 9:21 AM
hello

matata 9:21 AM
hi

simba 9:21 AM
Hi everyone!
Teams form on Slack

hakuna 9:21 AM
hello

matata 9:21 AM
hi

simba 9:21 AM
Hi everyone!

game-robot 9:21 AM
INSTRUCTIONS

SUBMISSION
Teams form on Slack

hakuna 9:21 AM
hello

matata 9:21 AM
hi

simba 9:21 AM
Hi everyone!

game-robot 9:21 AM
APP
INSTRUCTIONS

SUBMISSION

maybe it's the rising sun
Teams form on Slack

hakuna 9:21 AM
hello

matata 9:21 AM
hi

simba 9:21 AM
Hi everyone!

game-robot 9:21 AM
INSTRUCTIONS

SUBMISSION

simba 9:21 AM
maybe it's the rising sun
Coordination-robot gives teams structural interventions
Coordination-robot gives teams structural interventions

END OF ROUND

This round change the following...

Be super cheery! Make sure to write encouraging comments to all your teammates, despite any losses!
Coordination-robot gives teams structural interventions

**game-robot**  APP  9:43 AM

END OF ROUND

**coordination-robot**  APP  9:43 AM

This round change the following...

Be super cheery! Make sure to write encouraging comments to all your teammates, despite any losses!

**go team!**
Coordination-robot gives teams structural interventions

END OF ROUND

This round change the following...

Be super cheery! Make sure to write encouraging comments to all your teammates, despite any losses!

go team!
Across rounds, teams adapt to changing structures
System
DreamTeam is powered by a network of multi-armed bandits
DreamTeam is powered by a network of multi-armed bandits

Multi-armed bandits efficiently
- explore different options (arms)
- exploit the best arms over time
DreamTeam is powered by a network of multi-armed bandits

Multi-armed bandits efficiently
- explore different options (arms)
- exploit the best arms over time

Hierarchy
- None
- Centralized
- Decentralized

Interaction Patterns
- None
- Professional
- Informal

Norms of Engagement
- None
- Encouraging
- Critical

Decision-Making Norms
- None
- Divergent
- Convergent
- Informed
- Rapid

Feedback Norms
- None
- Emergent
- Round-robin
- Equally distributed
DreamTeam is powered by a network of multi-armed bandits

Multi-armed bandits efficiently
- explore different options (arms)
- exploit the best arms over time
DreamTeam is powered by a network of multi-armed bandits

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None, Professional, Informal

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None, Divergent, Convergent, Informed, Rapid

Feedback Norms
None, Encouraging, Critical

Gbellion et al. 2011
Caron and Bhagat 2013
Cesa-Bianchi et al. 2013
Bandits suggest an overwhelming number of changes
Bandits suggest an overwhelming number of changes

Hierarchy
- Decentralized

Interaction Patterns
- Round-robin

Norms of Engagement
- Informal

Decision-Making Norms
- Divergent

Feedback Norms
- Critical
Bandits suggest an overwhelming number of changes

Hierarchy
None

Interaction Patterns
Equally distributed

Norms of Engagement
None

Decision-Making Norms
Rapid

Feedback Norms
Encouraging
Bandits suggest an overwhelming number of changes

Hierarchy
- Centralized

Interaction Patterns
- Equally distributed

Norms of Engagement
- None

Decision-Making Norms
- Rapid

Feedback Norms
- Encouraging
How many changes can be made at once?
How many changes can be made at once?
How many changes can be made at once?

- Teams’ receptiveness to structural change varied temporally
- Most receptive near the midpoint of their progress
How many changes can be made at once?

- Teams’ receptiveness to structural change varied temporally
- Most receptive near the midpoint of their progress
Use constraints to limit total changes across the network
Use constraints to limit total changes across the network

\[ E[\text{changes}] = 5 \]
Use constraints to limit total changes across the network

$E[\text{changes}] = 5 > \text{Constraint} = 2$
Use constraints to limit total changes across the network

\[ E[\text{changes}] = 5 > \text{Constraint} = 2 \]
Use constraints to limit total changes across the network

- .6
Use constraints to limit total changes across the network

\[-0.6\]

\[\theta_1 = 0.4\]
\[\theta_2 = 0.4\]
\[\theta_3 = 0.2\]
Use constraints to limit total changes across the network

\[ \theta_1 = .4 \]
\[ \theta_2 = .4 \]
\[ \theta_3 = .2 \]

Thompson sampling probabilities \( \theta_i \) represent likelihood of choosing arm \( i \)

Agrawal and Goyal 2012
Use constraints to limit total changes across the network.

Thompson sampling probabilities $\theta_i$ represent likelihood of choosing arm $i$.

Agrawal and Goyal 2012
Use constraints to limit total changes across the network

Thompson sampling probabilities represent likelihood of choosing arm

\[ \theta_1 = 0.4 \]
\[ \theta_2 = 0.4 \]
\[ \theta_3 = 0.2 \]

\[ \cdot 0.4(1-\delta) = 0.3 \]

\[ \theta_1 = 0.1 \]
\[ \theta_2 = 0.1 \]
\[ \theta_3 = 0.8 \]
Use constraints to limit total changes across the network

\[ \theta'_{i} = \begin{cases} 
\theta_{i}\delta, & \text{if } i \neq c \\
\theta_{i} + \sum_{j \neq c} \theta_{j}(1 - \delta), & \text{if } i = c 
\end{cases} \]
Use constraints to limit total changes across the network

E[changes] = 5 > Constraint = 2

\[ \begin{align*}
\theta_1 &= 0.4 \\
\theta_2 &= 0.4 \\
\theta_3 &= 0.2 \\
\end{align*} \]

\[ \delta = 0.25 \]

\[ \begin{align*}
\theta_1 &= 0.1 \\
\theta_2 &= 0.1 \\
\theta_3 &= 0.8 \\
\end{align*} \]
Use constraints to limit total changes across the network

$E[\text{changes}] = 5 > \text{Constraint} = 2$

$E[\text{changes}] = 2$
How do we prioritize what should change?
How do we prioritize what should change?

- Team are receptive to changes in some dimensions earlier, others later

Marks et al 2001
How do we prioritize what should change?

- Team are receptive to changes in some dimensions earlier, others later
Evaluation
135 people from Amazon Mechanical Turk
135 people from Amazon Mechanical Turk

45 teams on Slack
135 people from Amazon Mechanical Turk

45 teams on Slack

Task adapted from Codenames
1. Manager-chosen
   List of team structures given to an elected manager
1. **Manager-chosen**
   List of team structures given to an elected manager

2. **Collectively-chosen**
   List of team structures given for teams to choose
1. **Manager-chosen**
   List of team structures given to an elected manager

2. **Collectively-chosen**
   List of team structures given for teams to choose

3. **Unconstrained bandit-chosen**
   Team structures chosen by unconstrained bandits, communicated with coordination-robot
1. **Manager-chosen**
   List of team structures given to an elected manager

2. **Collectively-chosen**
   List of team structures given for teams to choose

3. **Unconstrained bandit-chosen**
   Team structures chosen by unconstrained bandits, communicated with coordination-robot

4. **Control**
   No intervention
1. Manager-chosen
   List of team structures given to an elected manager

2. Collectively-chosen
   List of team structures given for teams to choose

3. Unconstrained bandit-chosen
   Team structures chosen by unconstrained bandits, communicated with coordination-robot

4. Control
   No intervention

5. DreamTeam
   Team structures chosen by temporally constrained bandits, communicated with coordination-robot
DreamTeam teams significantly outperform other conditions

Measured performance using scores on 10 rounds of the task.

DreamTeam outperformed:

Manager-chosen by 46%
Collectively-chosen 45%
Unconstrained bandit-chosen 41%
Control 38%

Repeated measures ANCOVA $p<0.05$, all post-hoc Tukey pairwise comparisons to Dreamteam $p<0.05$. $N=45$.
We used a non-intervention training round as a covariate, to control for teams’ initial performance.
Managers were risk-averse and hesitant to explore

- 2 structures explored on average
- At most 3 combinations explored, as opposed to 8-9 in the bandit conditions
- Managers also varied in involving team for feedback or imposing recommendations

Do you like the first way better?
Managers were risk-averse and hesitant to explore

- 2 structures explored on average
- At most 3 combinations explored, as opposed to 8-9 in the bandit conditions
- Managers also varied in involving team for feedback or imposing recommendations

chuchotant 4:19PM
ok, for this round, if you have gifs, I love them for fun

joeyq 4:20PM
sorry, I'm not a giffer

chuchotant 4:20PM
lol
Overwhelmed, teams under unconstrained bandits ignored changes

- 33% of teams ignored the chosen structures
- Difficult to galvanize collective effort, e.g. leadership election, round-robin participation

coordination-robot  APP
This round, do the following differently from last round, please!

Take turns suggesting answers. Make an order of who goes 1st, 2nd, 3rd.

You’re a democracy. Vote on what to submit and respect the majority vote. Do not submit until there’s a majority on one of them.

Take time explaining the answers you suggest and reflect on why a previous submission was right or wrong.

Add some fun with images, emojis, and GIFs to your discussion. Spend time getting to know your teammates.
DreamTeam teams engaged with the exploration of novel structures
DreamTeam teams engaged with the exploration of novel structures

anne_turker 1:40 PM
I’m scared to type anything
DreamTeam teams engaged with the exploration of novel structures

anne_turker  1:40 PM
I’m scared to type anything

coordination-robot  APP  2:11 PM
This round, do the following differently from last round, please!
Be super cheery! Make sure to write encouraging comments to all your teammates, don’t let anyone do other.

Note: We’re trying to help your team work better with these guidelines. Please fulfill them as they affect compensation.

nickbstack  2:11 PM
go team!!!!

loulou  2:11 PM
we are killin it

anne_turker  2:12 PM
you guys are awesome!!!!
DreamTeam teams engaged with the exploration of novel structures

anne_turker  1:40 PM
I’m scared to type anything

anne_turker  2:55 PM
You guys were the best team ever!

coordination-robot  APP  2:11 PM
This round, do the following differently from last round, please!

Be super cheery! Make sure to write encouraging comments to all your teammates, and support one another.

Note: We’re trying to help your team work better with these guidelines. Please fulfill them as they do affect compensation.

nickbstack  2:11 PM
go team!!!!

loulou  2:11 PM
we are killin it

anne_turker  2:12 PM
you guys are awesome!!!!
Effective structures varied substantially

Supports structural contingency theory:
There are no universally ideal structures
Limitations & Opportunities

- Feedback focused on performance, not yet on self-reported metrics

- The same task iteratively, not yet the changing demands or tasks of a team
Discussion
The future of work opens opportunities for computationally augmented teams

- Help overcome manager biases of team’s needs through exploration
The future of work opens opportunities for computationally augmented teams

- Help overcome manager biases of team’s needs through exploration

- Represent a step toward a partnership between computation and collaboration
The future of work opens opportunities for computationally augmented teams

- Help overcome manager biases of team’s needs through exploration

- Represent a step toward a partnership between computation and collaboration
DreamAdvisor

Involvement
- hands-on / hands-off

Meetings
- every day / every week / ad hoc

Level of feedback
- high-level / low-level / everything

???
In Search of the Dream Team

Temporally Constrained Multi-Armed Bandits For Identifying Effective Team Structures

Sharon Zhou, Melissa Valentine, Michael Bernstein
Stanford University
Contributions

1. Concept of computationally empowered identification of effective team structures

2. A system — DreamTeam — manifesting this concept

3. Temporal constraints which regulate exploration timing in a network of multi-armed bandits

4. An evaluation demonstrating that this approach outperforms traditional ones on a complex collaborative task
Multi-armed bandits overwhelm teams with simultaneous change

<table>
<thead>
<tr>
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<tbody>
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Temporally constrained multi-armed bandits

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HCI systems have been designed for specific structures.

Interaction Patterns equally distributed

Meeting Mediator: Enhancing Group Collaboration with Sociometric Feedback

Abstract
In this paper we present the Meeting Mediator (MM), a real-time, personal, and portable system providing feedback to enhance group collaboration. Social interactions are captured using Sociometric badges and are visualized on mobile phones to promote change in behavior. In a study on brainstorming and problem-solving meetings, MM had a significant effect on overlapping speaking time and interactivity level without distracting the subjects. Our system encourages effective group dynamics that may lead to higher performance and satisfaction. We envision MM to be deployed in real-world organizations to improve interactions across various group collaboration contexts.
HCI systems have been designed for specific structures.

Interaction Patterns

round-robin

Turn-Taking Protocols for

Mouse-Driven Collaborative Environments

Kori Inkpen¹, Joanna McGrenere², Kellogg S. Booth¹, Maria Klawe¹

¹Department of Computer Science
The University of British Columbia
Vancouver, British Columbia, V6T 1Z4, Canada
HCI systems have been designed for specific structures

Decision-Making Norms

divergent

Mechanical Novel: Crowdsourcing Complex Work through Reflection and Revision

Joy Kim, Sarah Sterman, Allegra Argent Beal Cohen, Michael S. Bernstein
Stanford University
{jojo0808, ssterman, aacohen}@stanford.edu, msb@cs.stanford.edu

TRACT
Crowdsourcing systems accomplish large tasks with scale and speed by breaking work down into independent micro-tasks. These microtask systems present work in an asset-line-like structure called a workflow [6], using mechanical novel forms of normative decision making in divergent ways.

large tasks by decomposing work into independent micro-tasks. These microtask systems present work in an asset-line-like structure called a workflow [6], using mechanical novel forms of normative decision making in divergent ways.
HCI systems have been designed for specific structures

Decision-Making Norms

convergent

ConsensUs: Supporting Multi-Criteria Group Decisions by Visualizing Points of Disagreement

WEICHEN LIU, University of California San Diego
SIJIA XIAO, Georgia Institute of Technology
JACOB T. BROWNE, University of California San Diego
MING YANG, Cornell University
STEVEN P. DOW, University of California San Diego
Use constraints to shift the probability of exploring

- Thompson sampling probabilities $\theta_i$ represent likelihood of choosing arm $i$

BEFORE

- $\theta_1 = 0.4$
- $\theta_2 = 0.4$
- $\theta_3 = 0.2$

CURRENT ARM

\[ \delta \]

ROUGHDS

EARLY

LATE

ONGOING
Use constraints to shift the probability of exploring

- Thompson sampling probabilities \( \theta_i \) represent likelihood of choosing arm

\[
\begin{align*}
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\theta_2 &= .4 \\
\theta_3 &= .2 \\
\end{align*}
\]
Teams demonstrated polarizing performance in other conditions

Collectively-chosen:
- Lack of coordination, chaotic behavior
- Members sometimes stepped up to lead or coordinate

brettalen 4:41 PM
he submits them before i can read them

yancy 4:41 PM
it works well in WoW, gotta spam those keys
**bbrookes03**  5:36 PM  
Console: relief, game  //  Compound: facility, interest, reaction  //  Conduct: Etiquette, music, operate

**aine**  5:36 PM  
console relief game/ compound facility operate interest /conduct etiquette music reactions?  
Brookes makes more sense

**rzmarie**  5:37 PM  
Ok, go with Brookes, ya?

**aine**  5:37 PM  🌟  
yep

**rzmarie**  5:37 PM  
!submit relief, game