MACHINE LEARNING DEPARTMENT

Language Technologies Institute

Carnegie Mellon University

On Emergent Communication in Competitive Multi-agent Teams

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Grounded Language

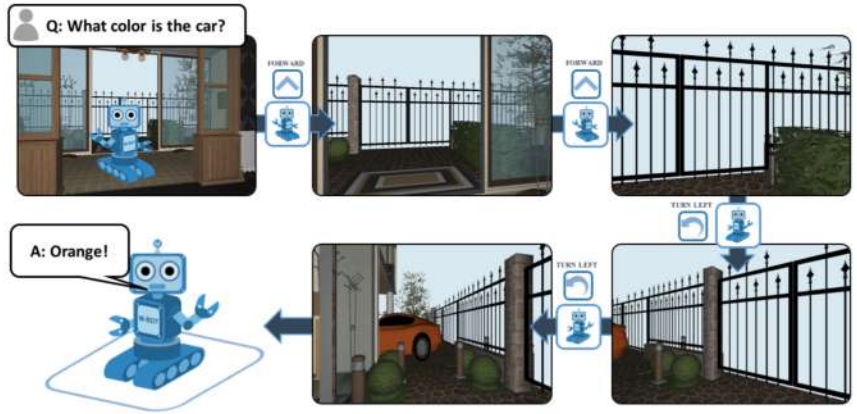
Task 1: Single Supporting Fact
Mary went to the bathroom.
John moved to the hallway.
Mary travelled to the office.
Where is Mary? A:office

Task 2: Two Supporting Facts
John is in the playground.
John picked up the football.
Bob went to the kitchen.
Where is the football? A:playground

Task 3: Three Supporting Facts
John picked up the apple.
John went to the office.
John went to the kitchen.
John dropped the apple.
Where was the apple before the kitchen? A:office

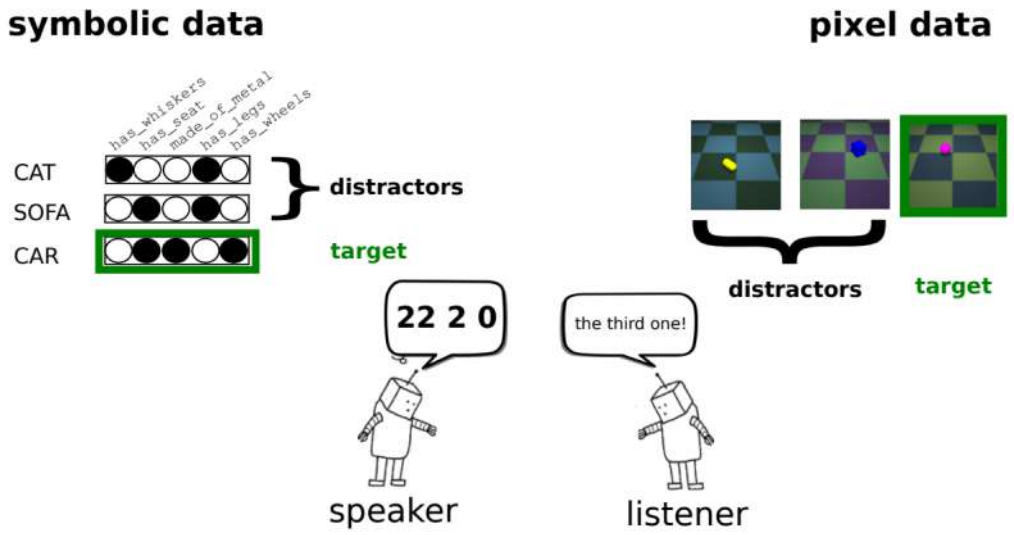
Task 4: Two Argument Relations
The office is north of the bedroom.
The bedroom is north of the bathroom.
The kitchen is west of the garden.
What is north of the bedroom? A: office
What is the bedroom north of? A: bathroom

[Weston et al., ICLR 2016]

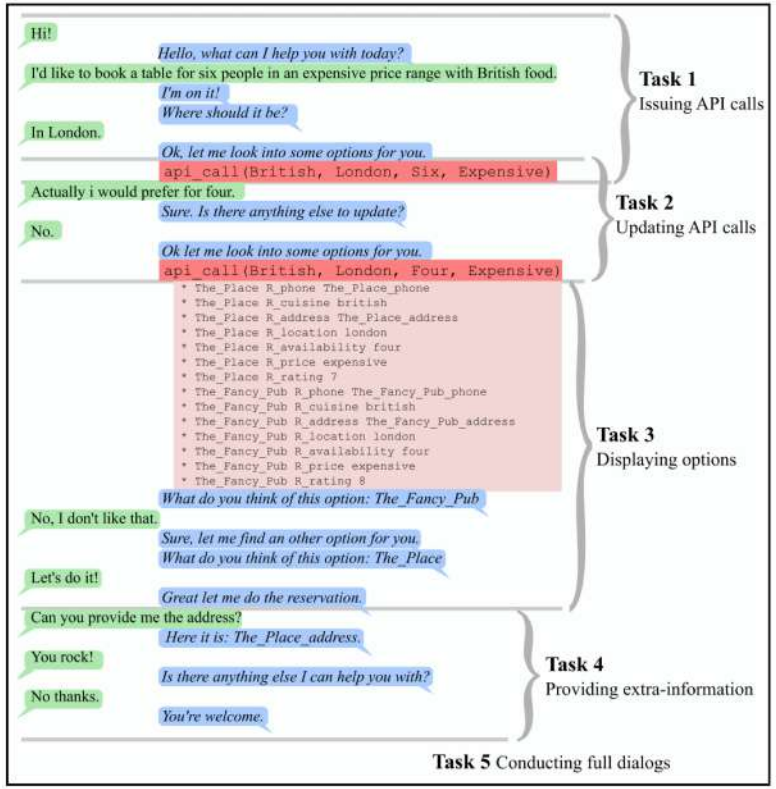


[Das et al., CVPR 2018]

Emergent Communication

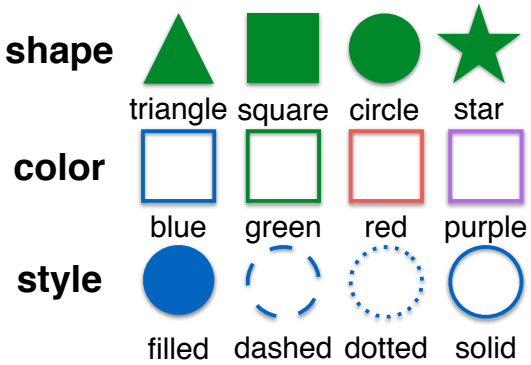


[Lazaridou et al., ICLR 2017,
Lazaridou et al., ICLR 2018]



[Bordes et al., ICLR 2017]

Task and Talk



(a) Instances

(color, shape)
(shape, color)
(style, color)
(color, style)
(shape, style)
(style, shape)

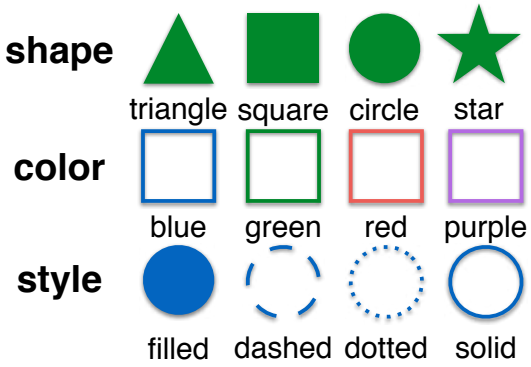
(b) Tasks

Q Bot

A Bot

[Kottur et al., EMNLP 2017]

Task and Talk



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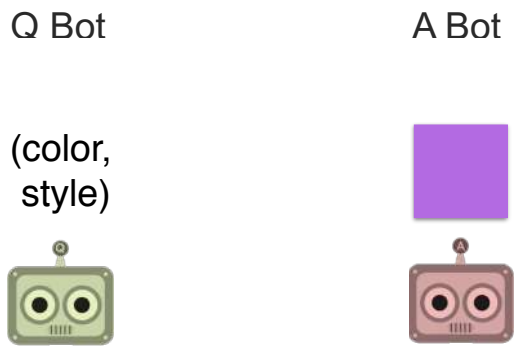
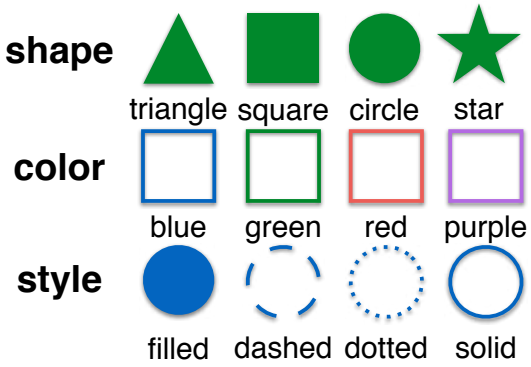


[Kottur et al., EMNLP 2017]

Task and Talk



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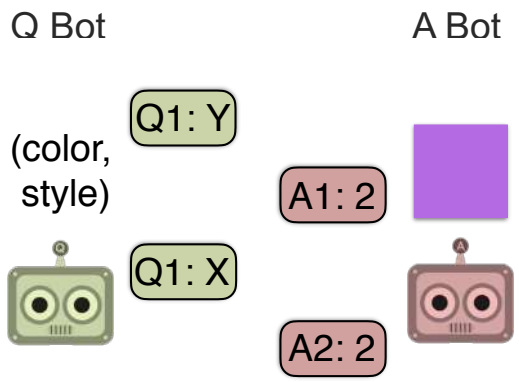
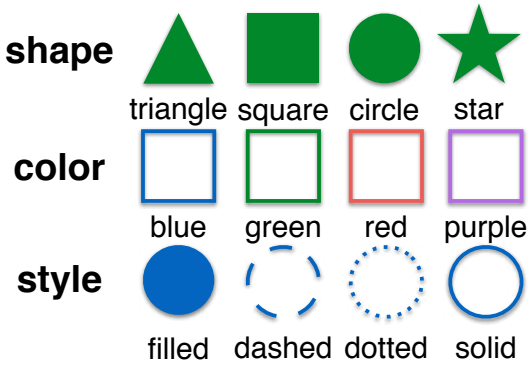


[Kottur et al., EMNLP 2017]

Task and Talk



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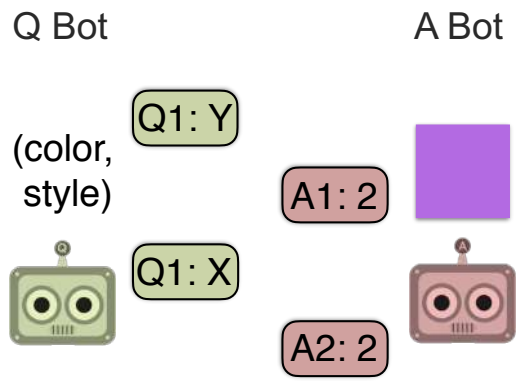
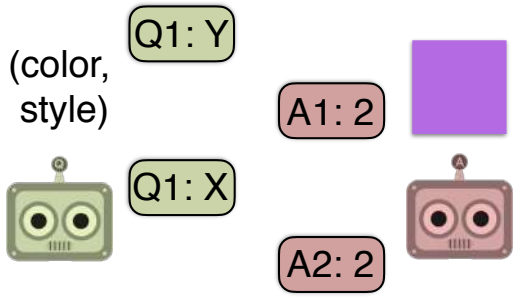


Prediction (purple, filled)

Result ✓

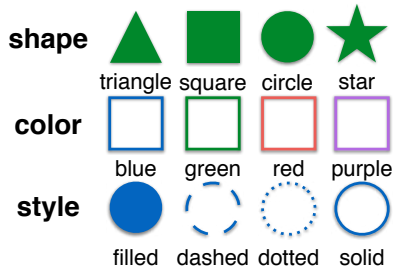
[Kottur et al., EMNLP 2017]

Competitive Emergent Communication



Cooperation **Competition**

Task, Talk, and Compete



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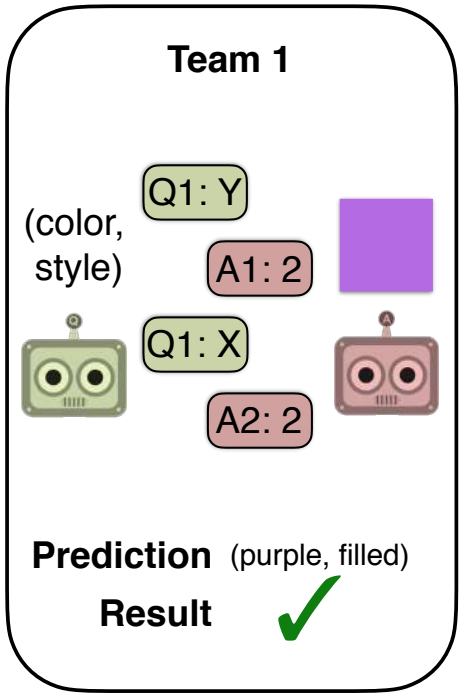
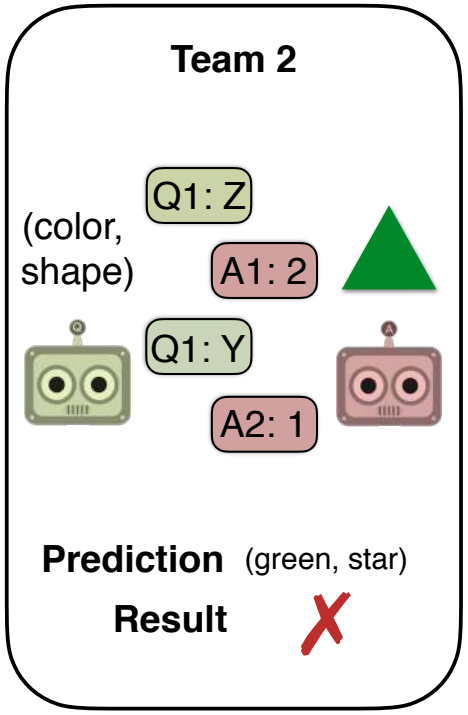
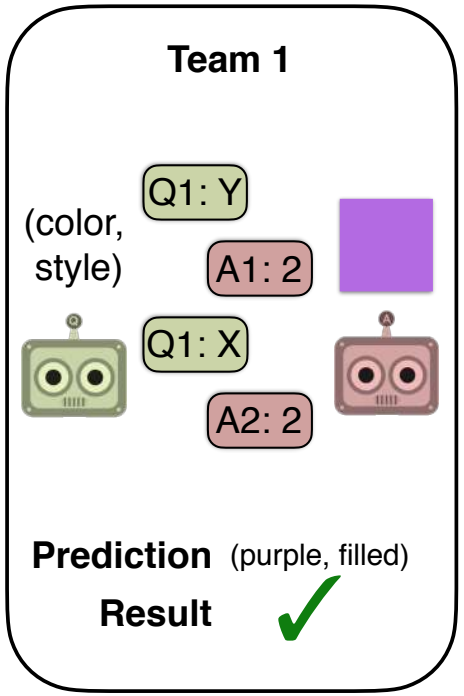
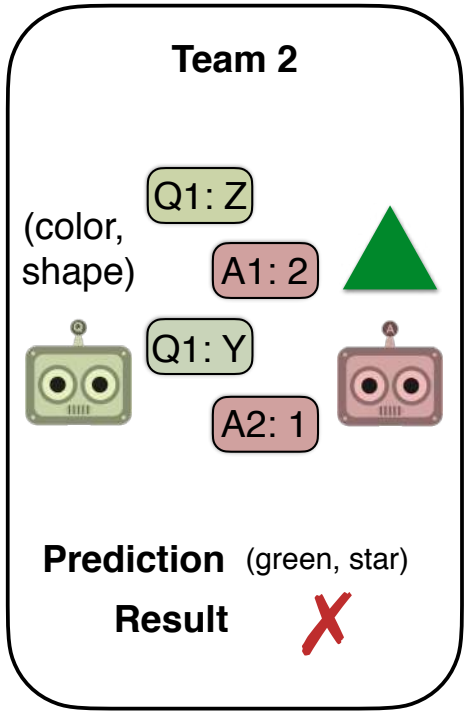




Sources of Competition





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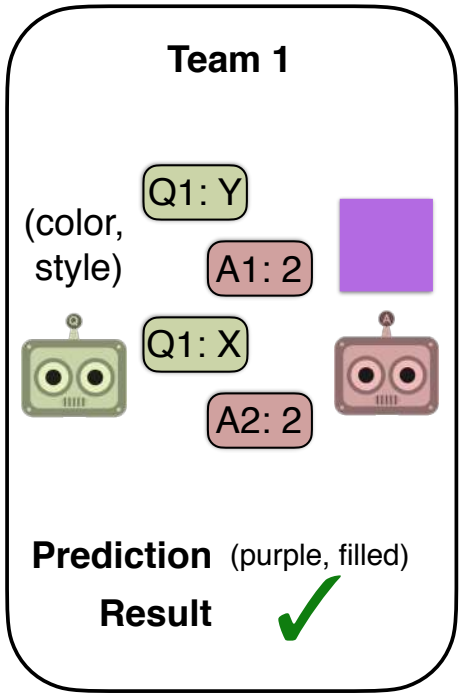

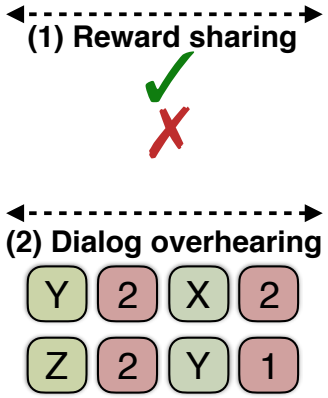

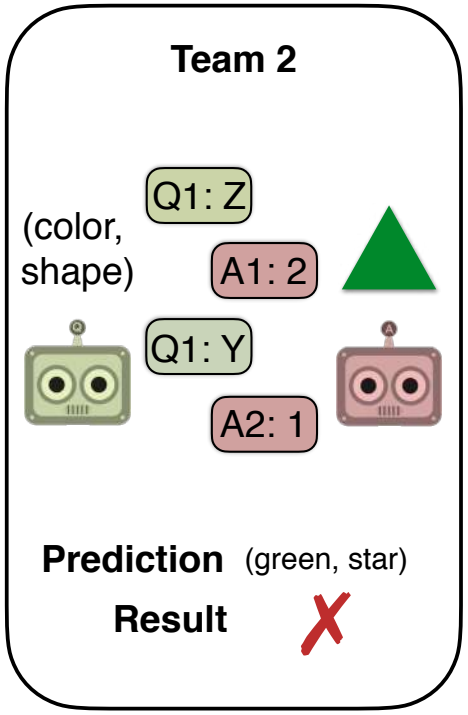

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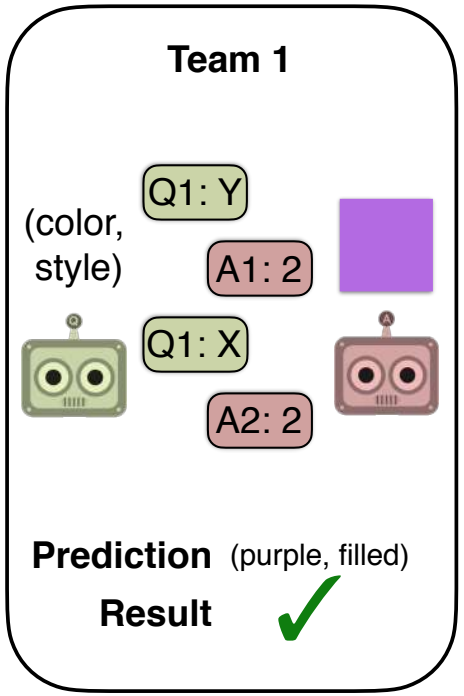
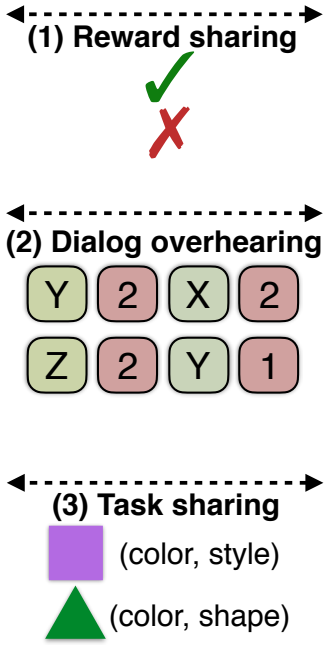
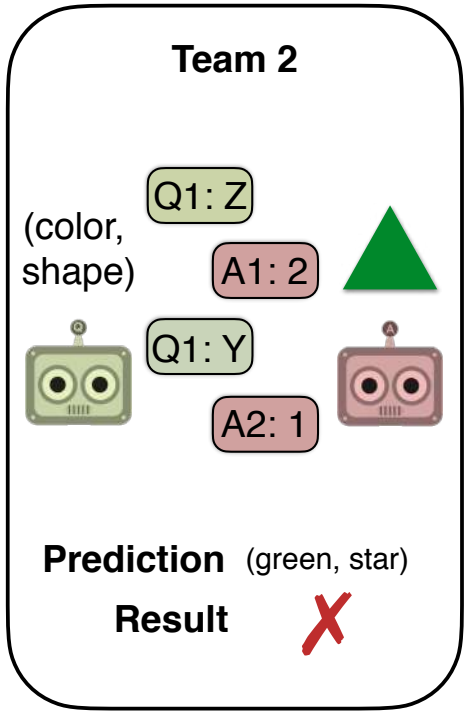
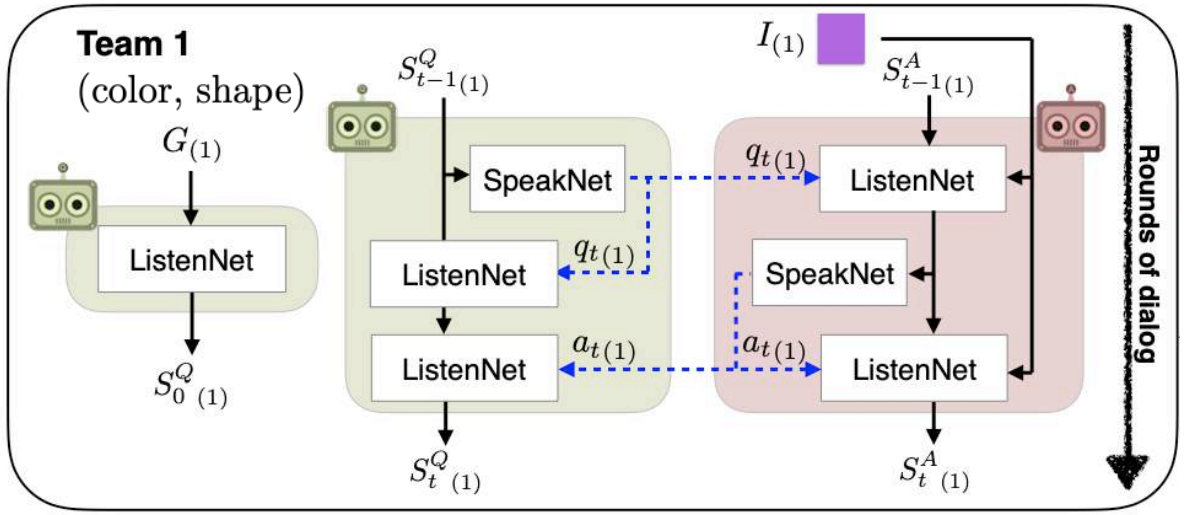






Neural Architecture



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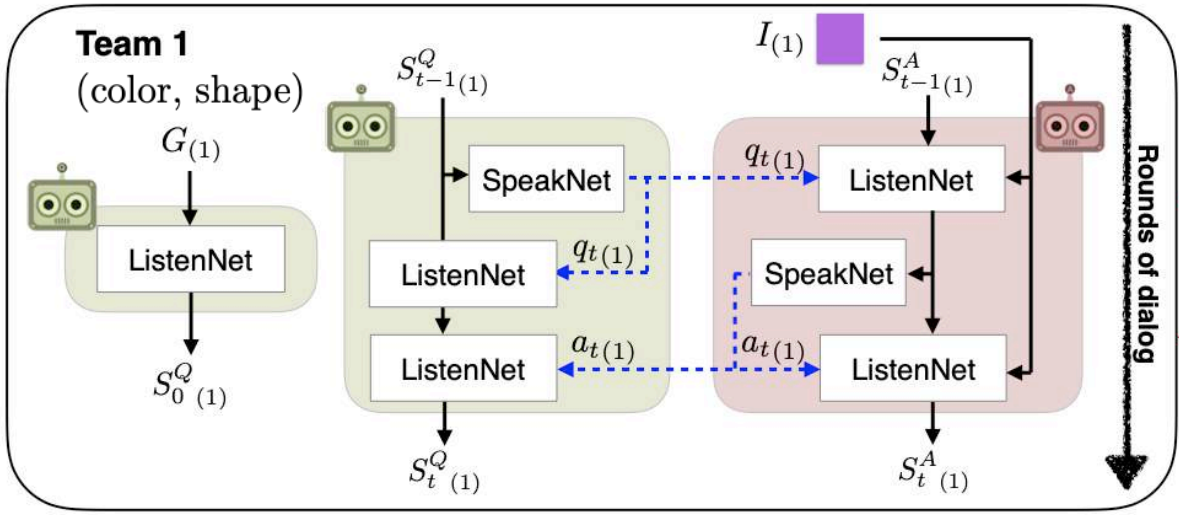
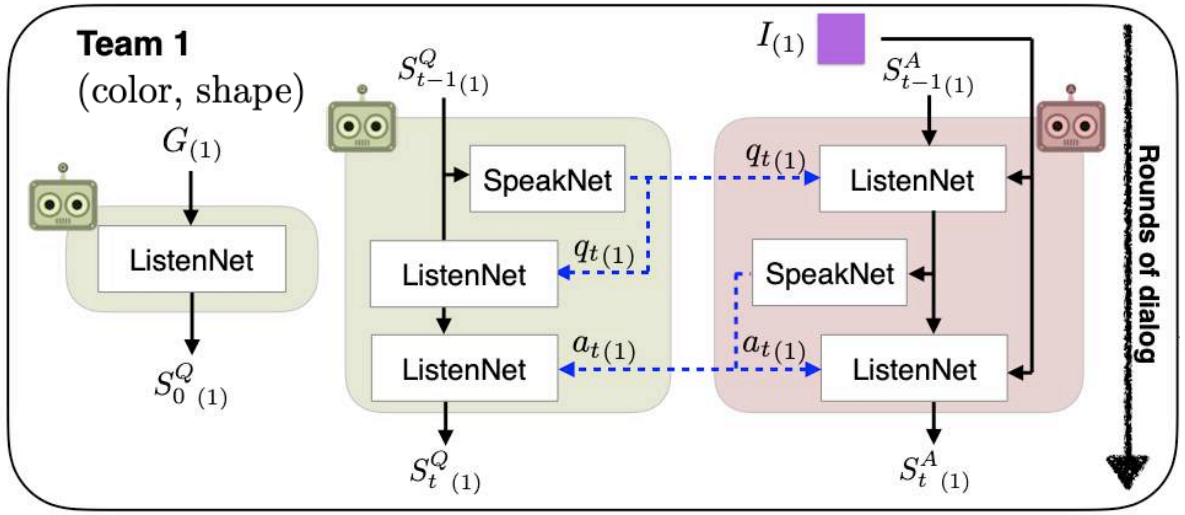


Q-bot $S_t^Q = [G, q_1, a_1, \ldots, q_{t-1}, a_{t-1}] \rightarrow q_t \in V_Q$

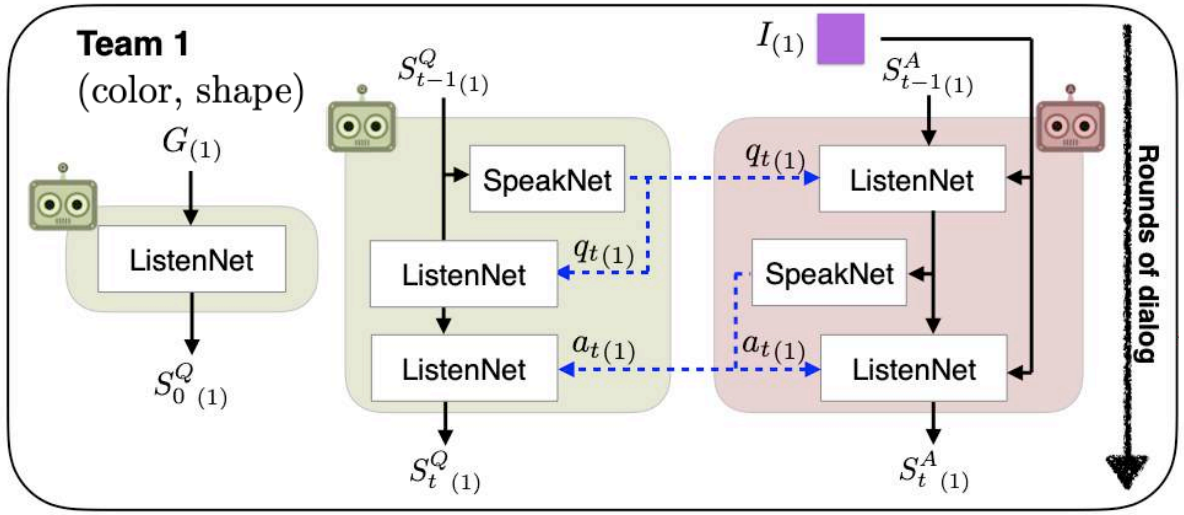
A-bot $S_t^A = [I, q_1, a_1, \ldots, q_{t-1}, a_{t-1}, q_t] \rightarrow a_t \in V_A$

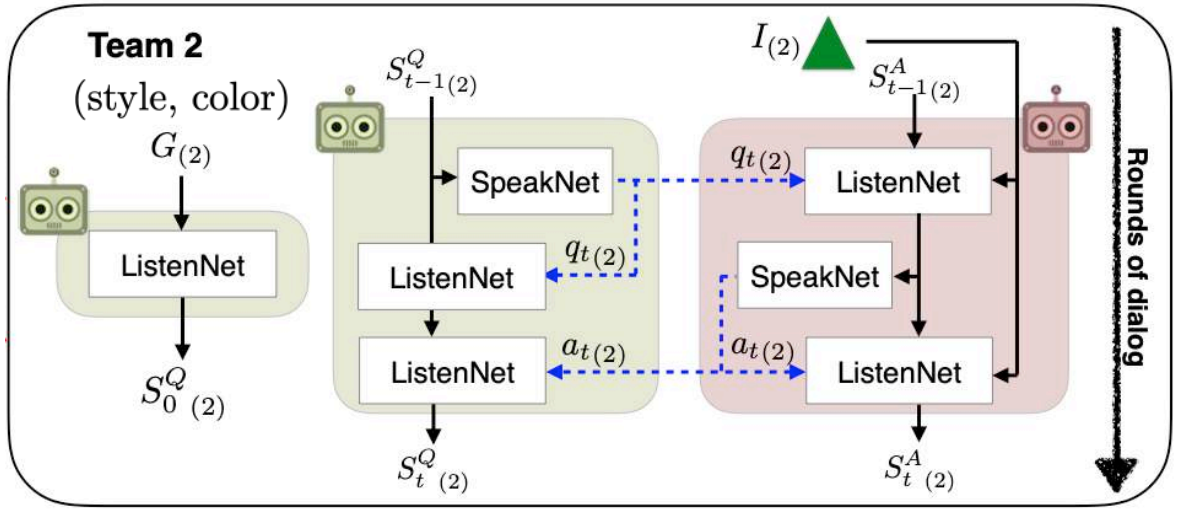
Neural Architecture



Trained to maximize expected reward using reinforce algorithm
+R for correct, -10R for incorrect

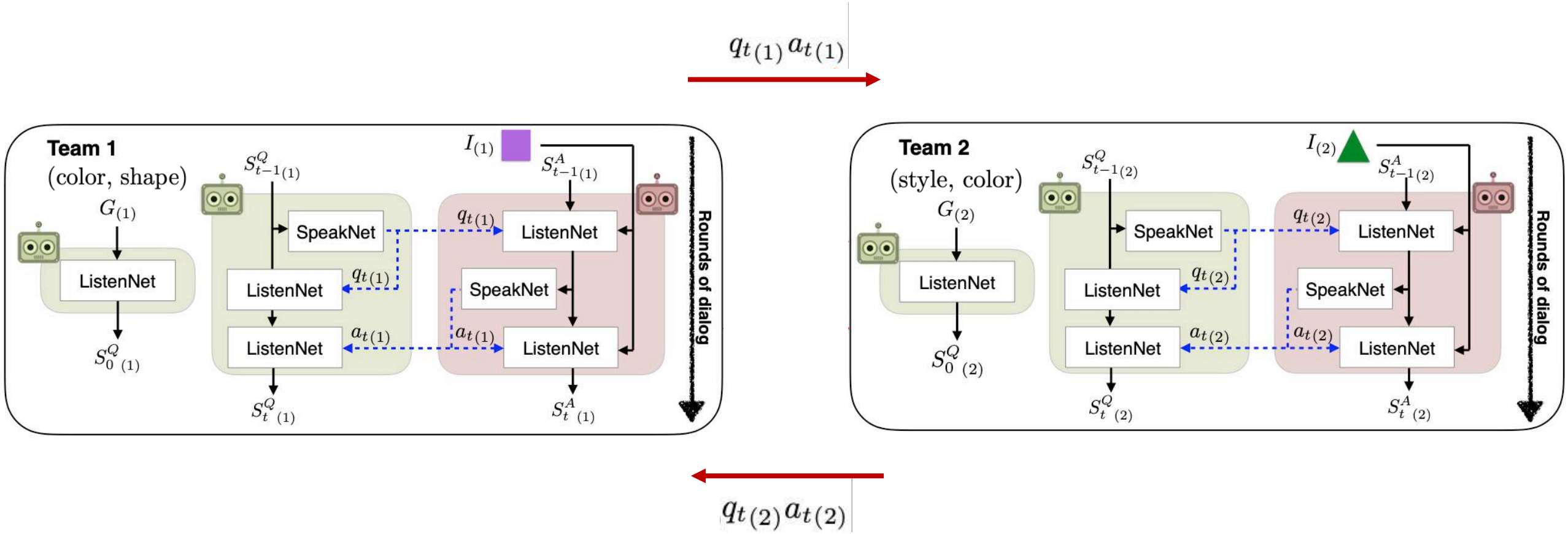
Reward Sharing



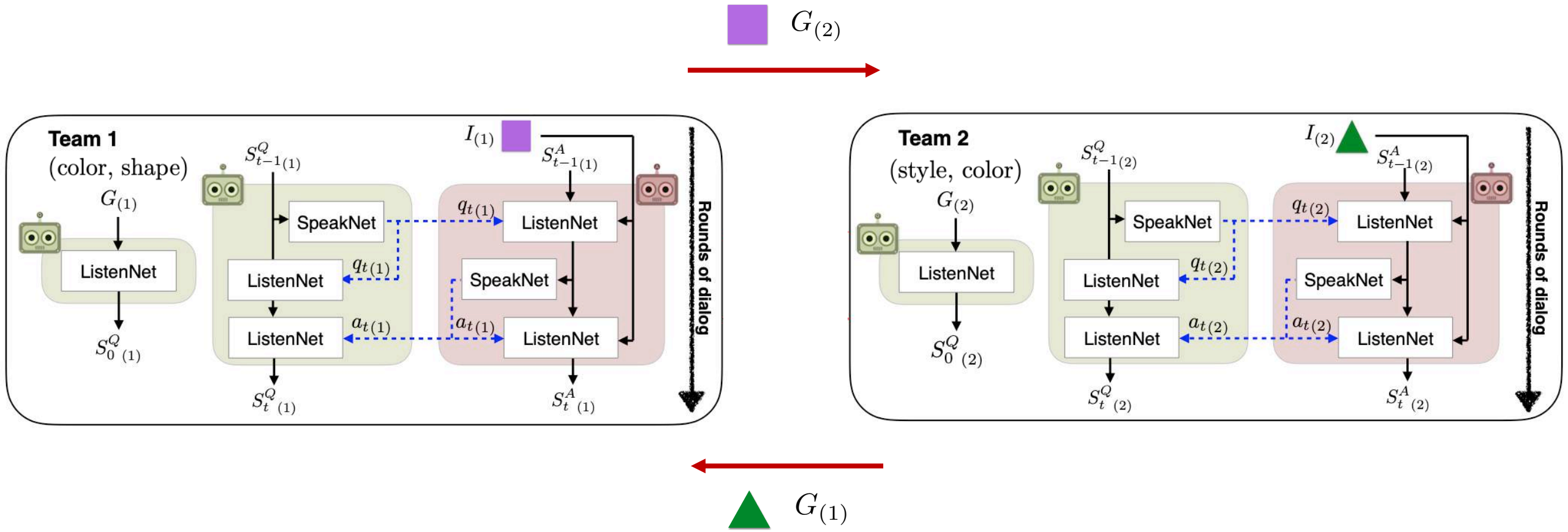


	Team 2 ✓	Team 2 ✗
Team 1 ✓	$(+R, +R)$	$(+R, -100R)$
Team 1 ✗	$(-100R, +R)$	$(-10R, -10R)$

Dialog Overhearing



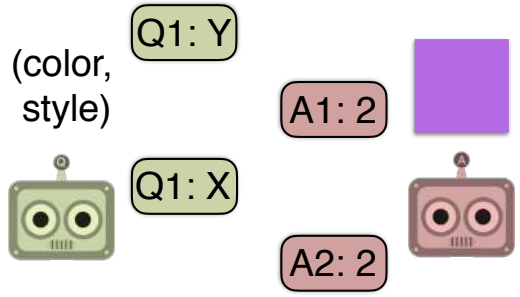
Task Sharing



Experimental Setip

Baseline: [Kottur et al., EMNLP 2017]
Rewards: (+R, -100R) reward structure
Params: double number of parameters
Double: 2 teams trained independently

Cooperative baselines



Prediction (purple, filled)

Result ✓

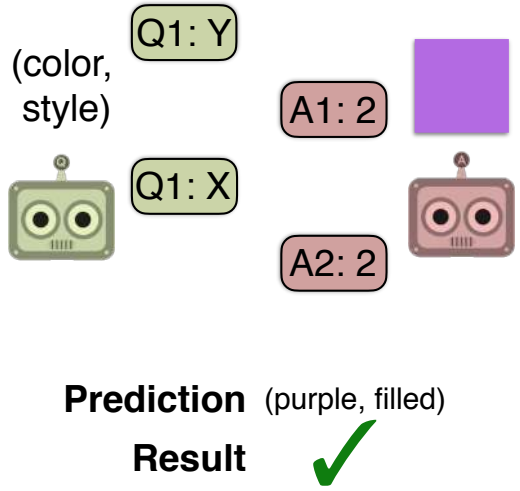
Experimental Setip

Baseline: [Kottur et al., EMNLP 2017]
Rewards: (+R, -100R) reward structure
Params: double number of parameters
Double: 2 teams trained independently

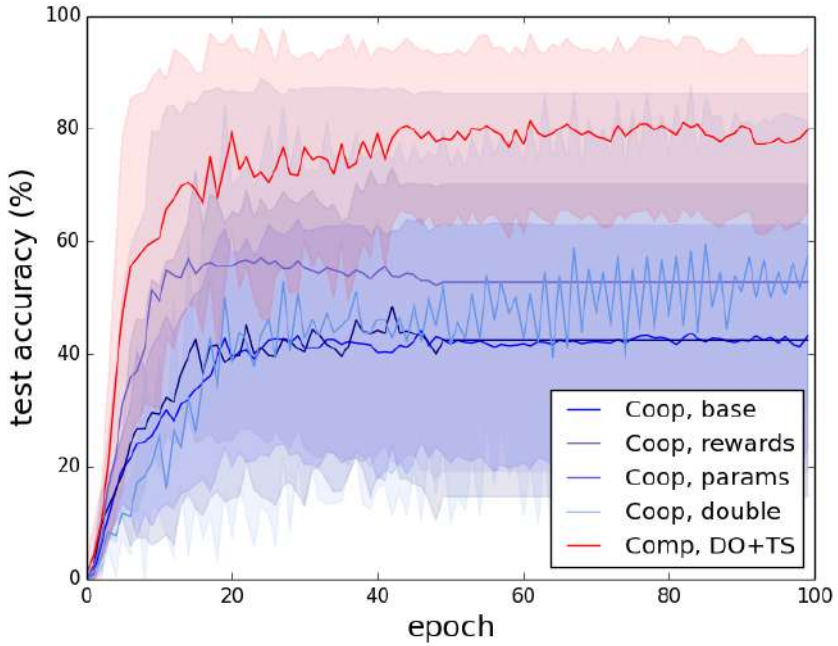
Cooperative baselines

RS: reward sharing
DO: dialog overhearing
TS: task sharing

Competitive methods



Results



(a)

DO + TS: 75.8%

Double: 57.8%
Params: 53.3%
Rewards: 49.7%
Baseline: 45.6%

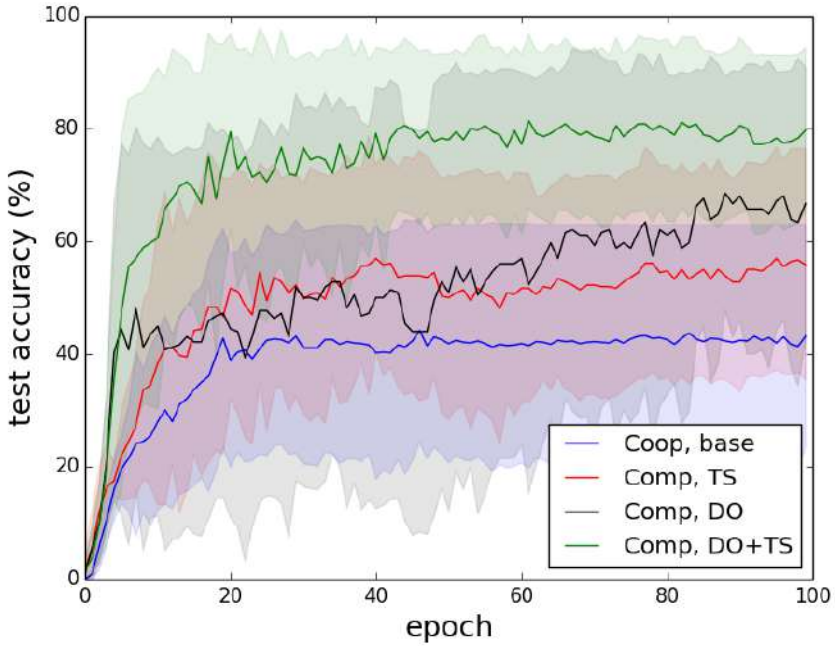
Competitive methods

Cooperative baselines

Competition improves generalization (test accuracy)
Faster rates of convergence

[Kottur et al., EMNLP 2017]

Results: task sharing and dialog overhearing



(b)

TS: 53.1%
DO: 65.7%
DO + TS: 75.8%

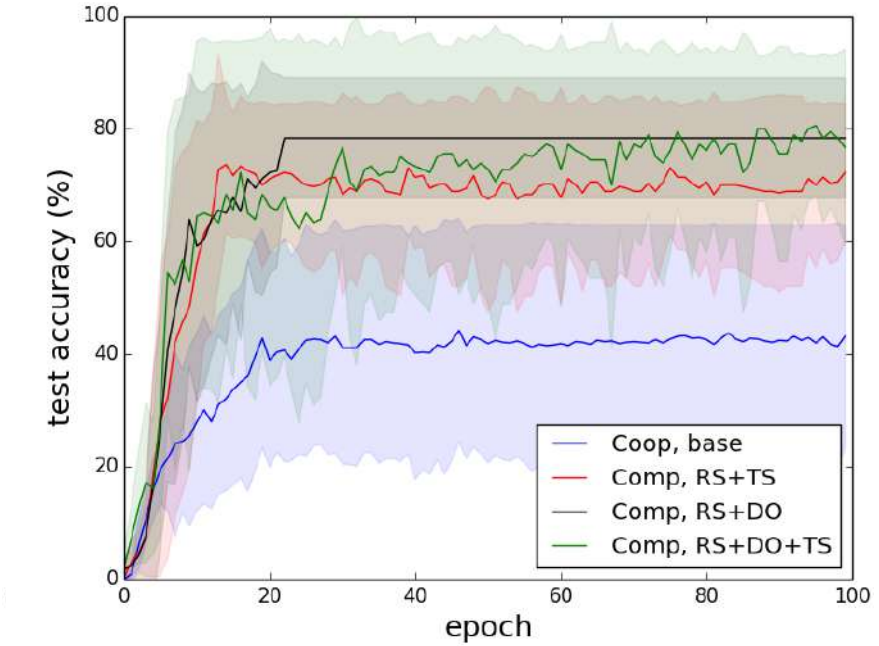
Baseline: 45.6%

Competitive methods

Cooperative baselines

Sharing messages via overhearing dialog improves performance
Composing sources of competition improves performance

Results: adding reward sharing



(c)

RS + TS: 68.9%
RS + DO: 78.3%
RS + DO+ TS: 77.2%

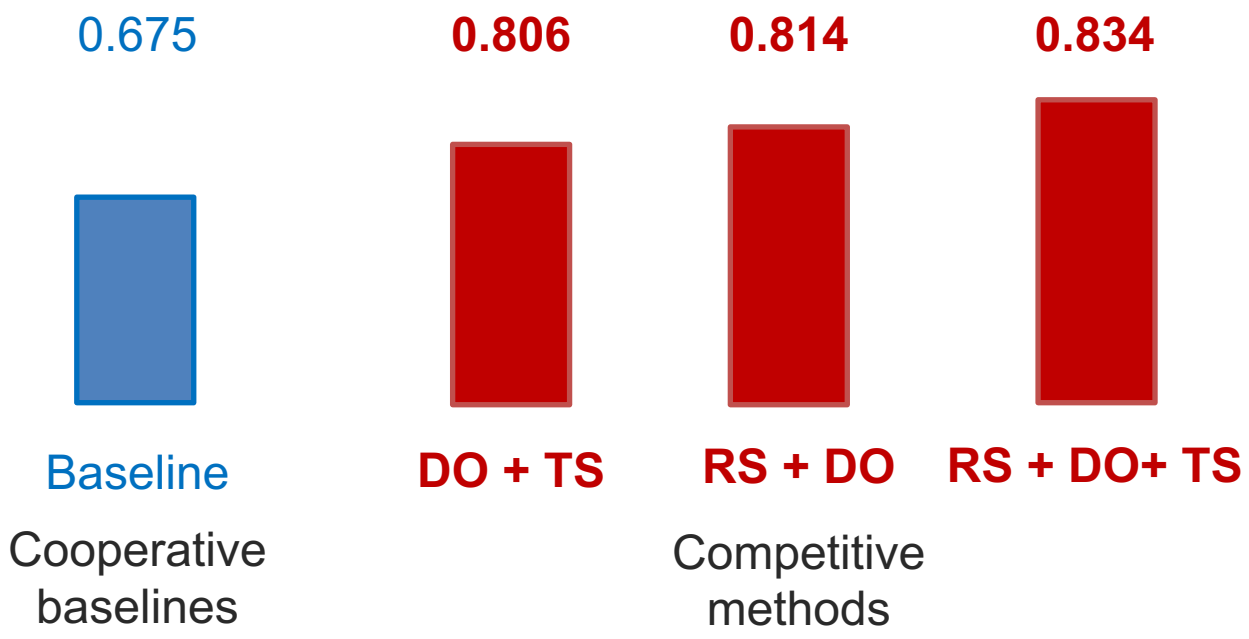
Competitive methods

Baseline: 45.6%

Cooperative baselines

Composing sources of competition improves performance

Measuring information in language

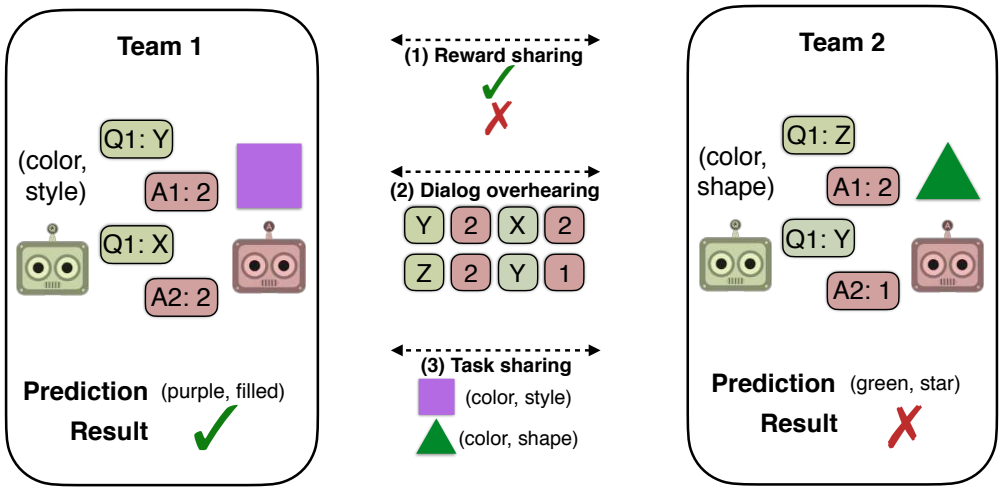


Higher IC scores when trained with competition
Correlated with task performance

[Jaques et al., ICML 2019]

Conclusion

Paper: https://arxiv.org/abs/2003.01848
Code: https://github.com/pliang279/Competitive-Emergent-Communication



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