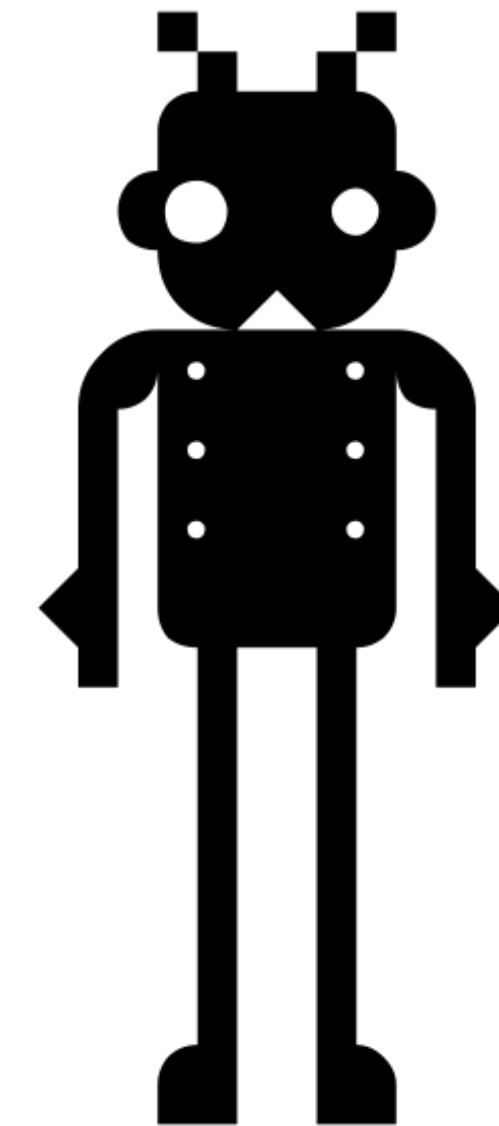


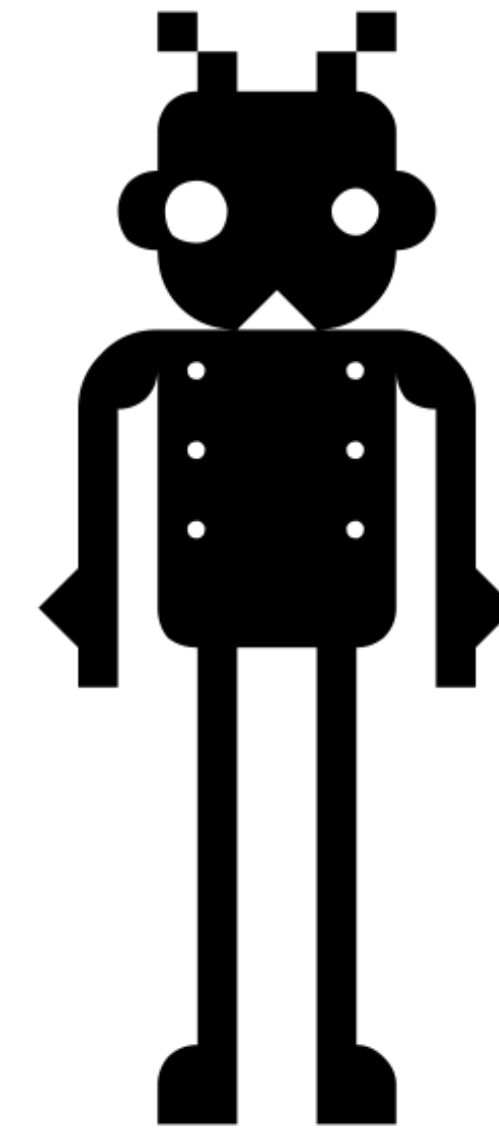
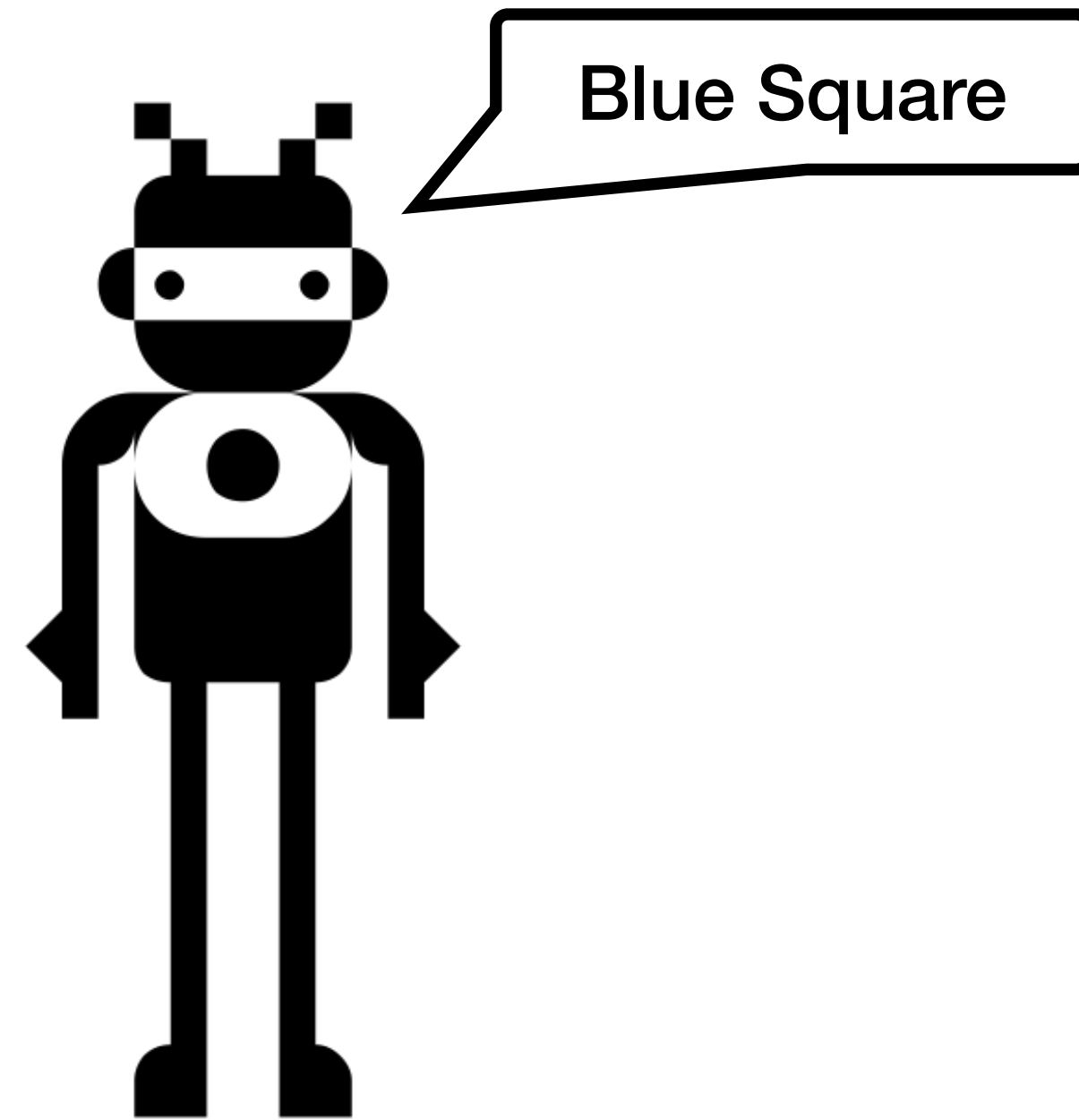
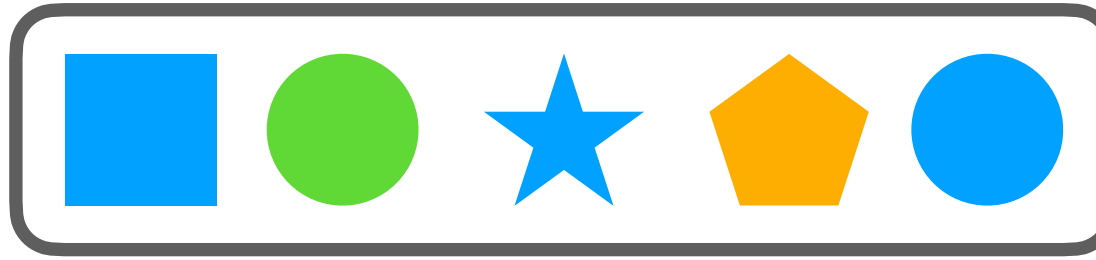
Few-shot Language Coordination by Modeling Theory of Mind

ICML 2021

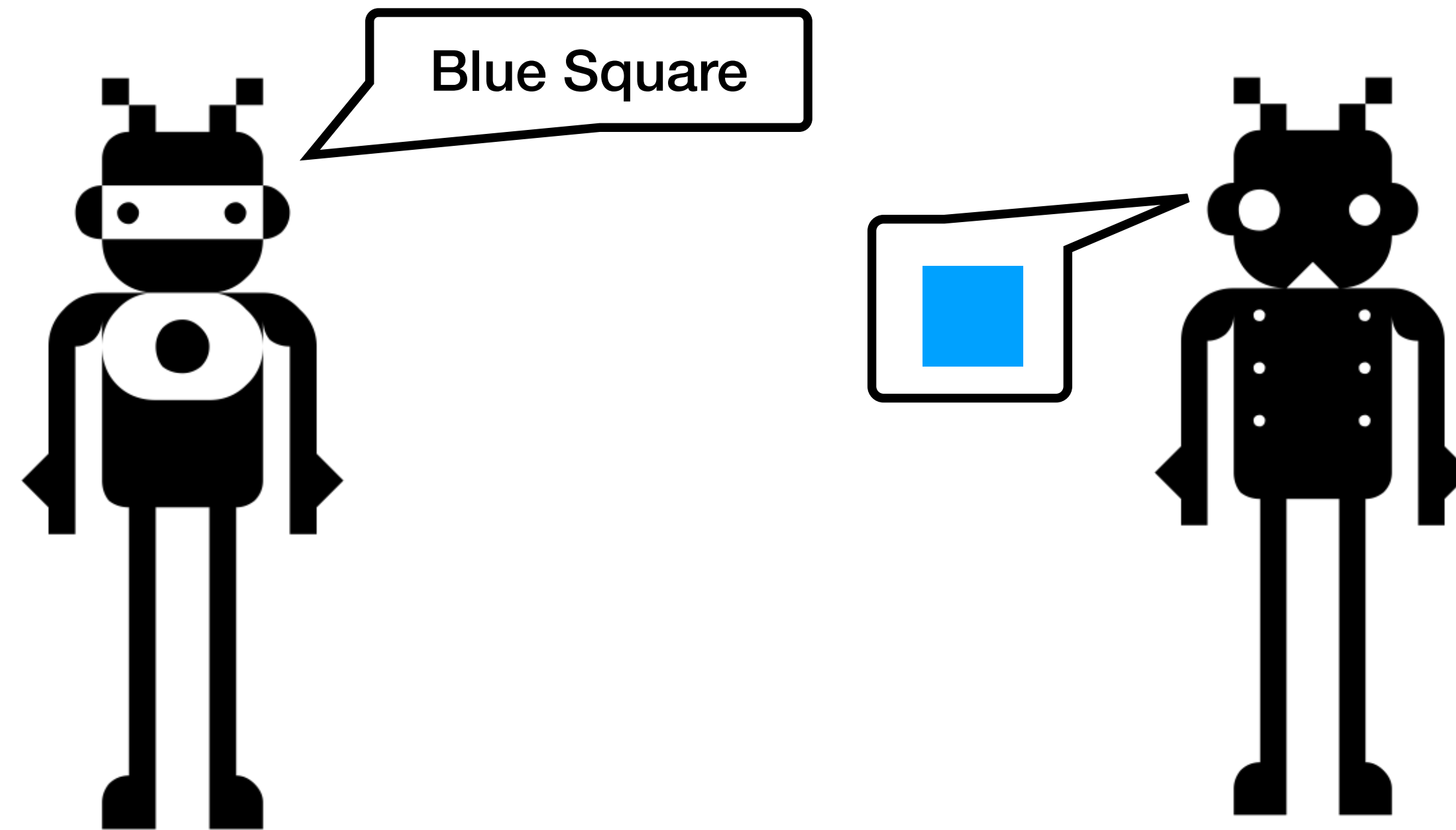
Hao Zhu, Graham Neubig, Yonatan Bisk
Carnegie Mellon University



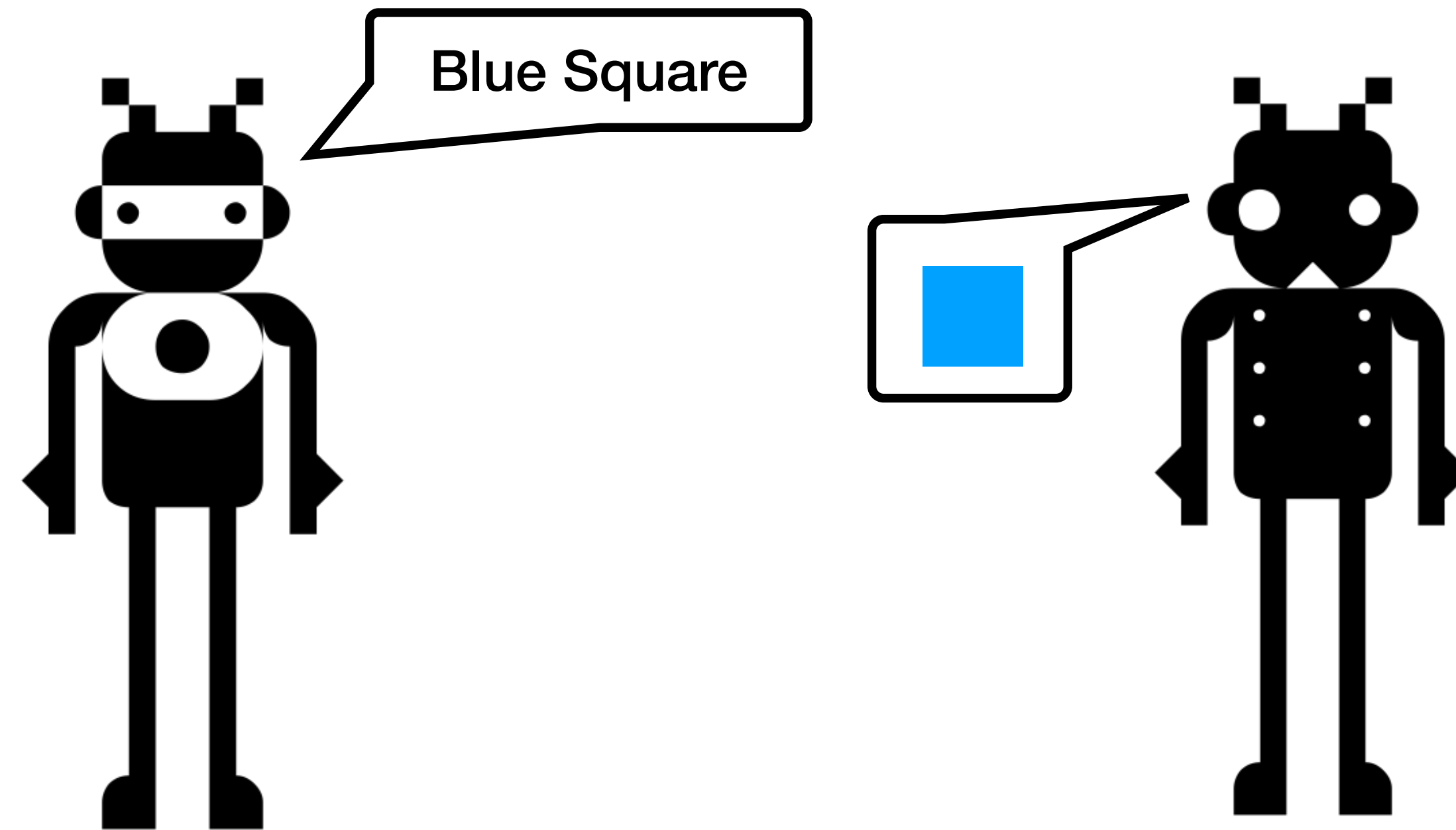
Referential Game



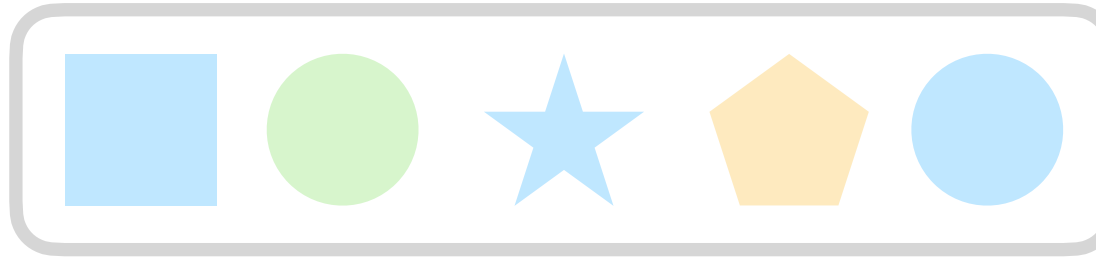
Referential Game



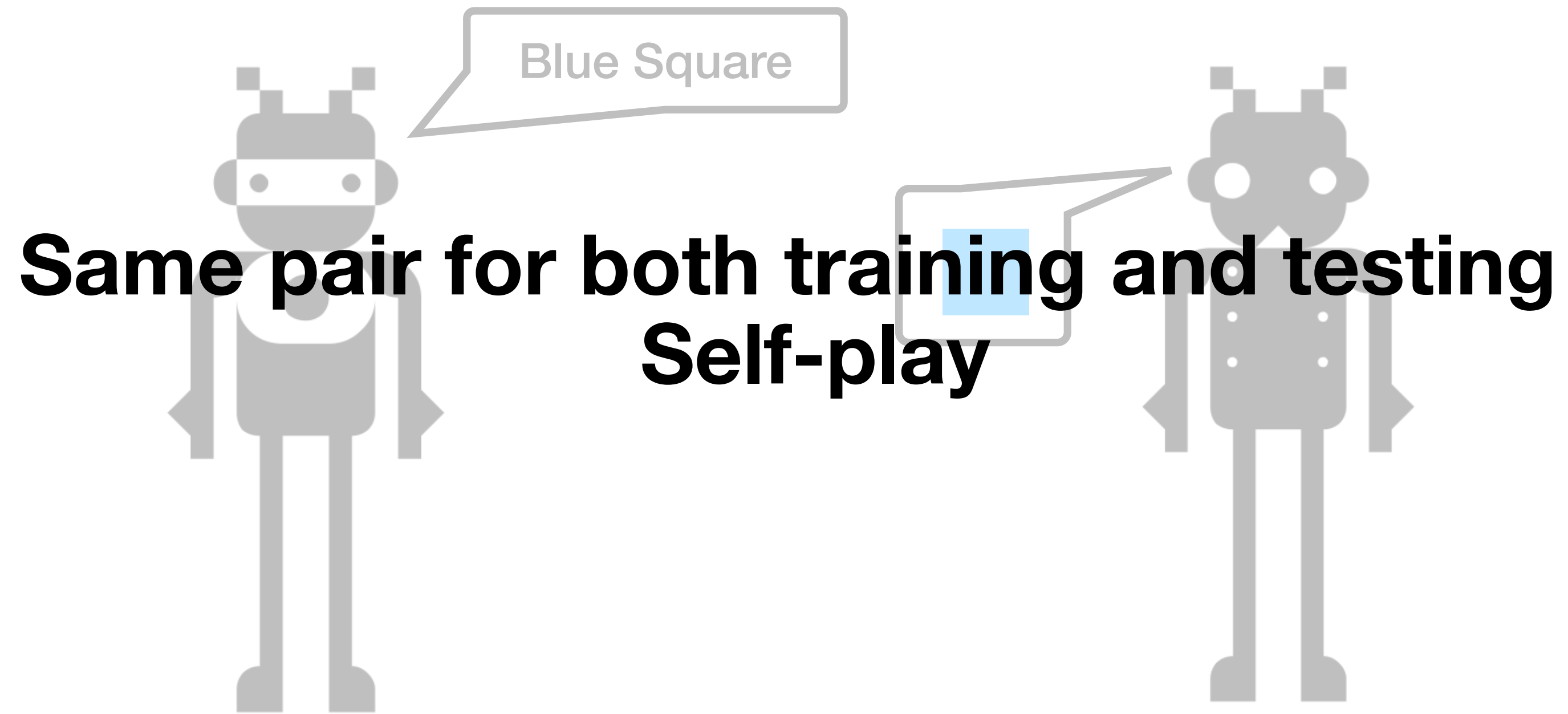
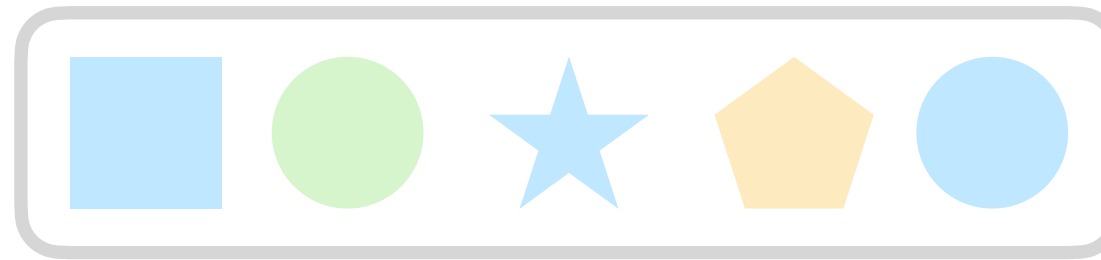
Referential Game



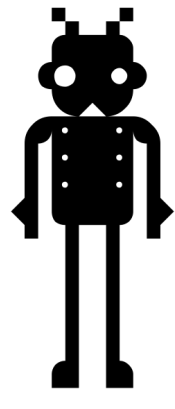
Referential Game



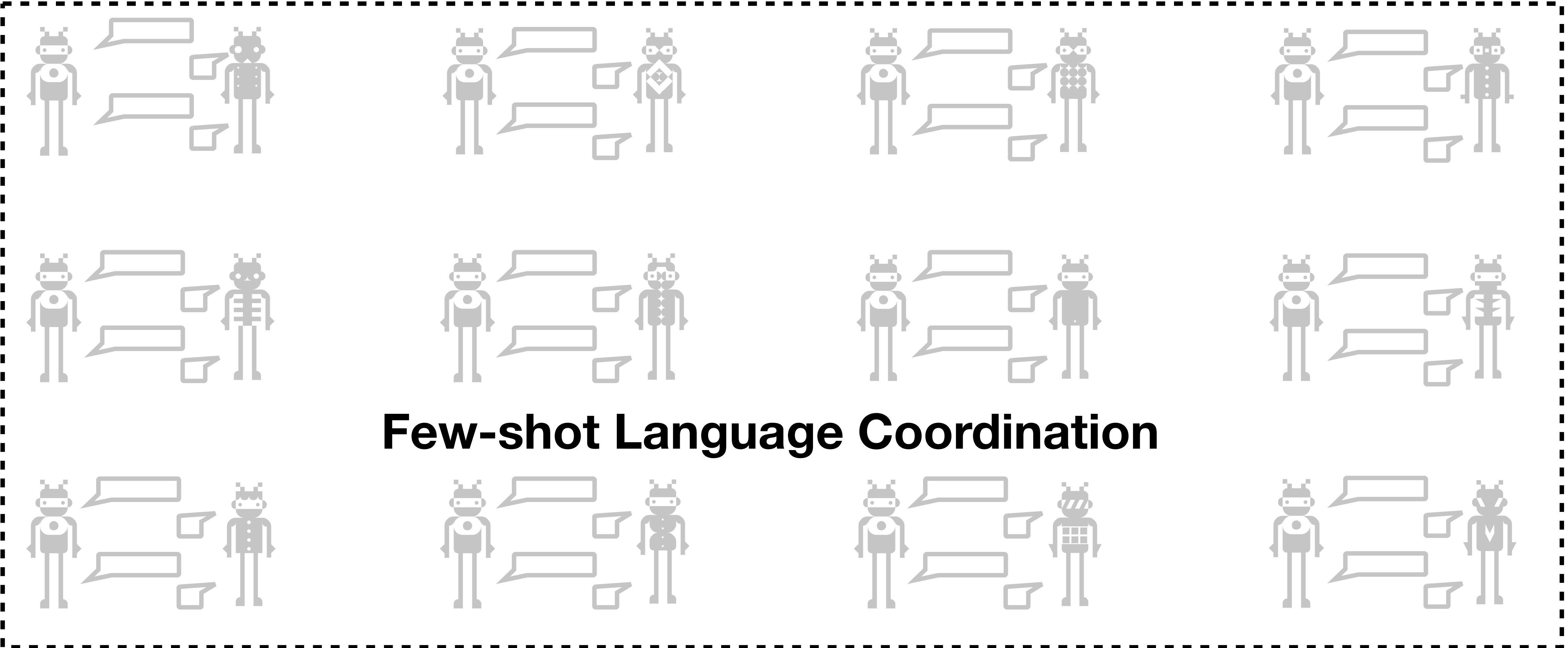
Referential Game



Referential Game

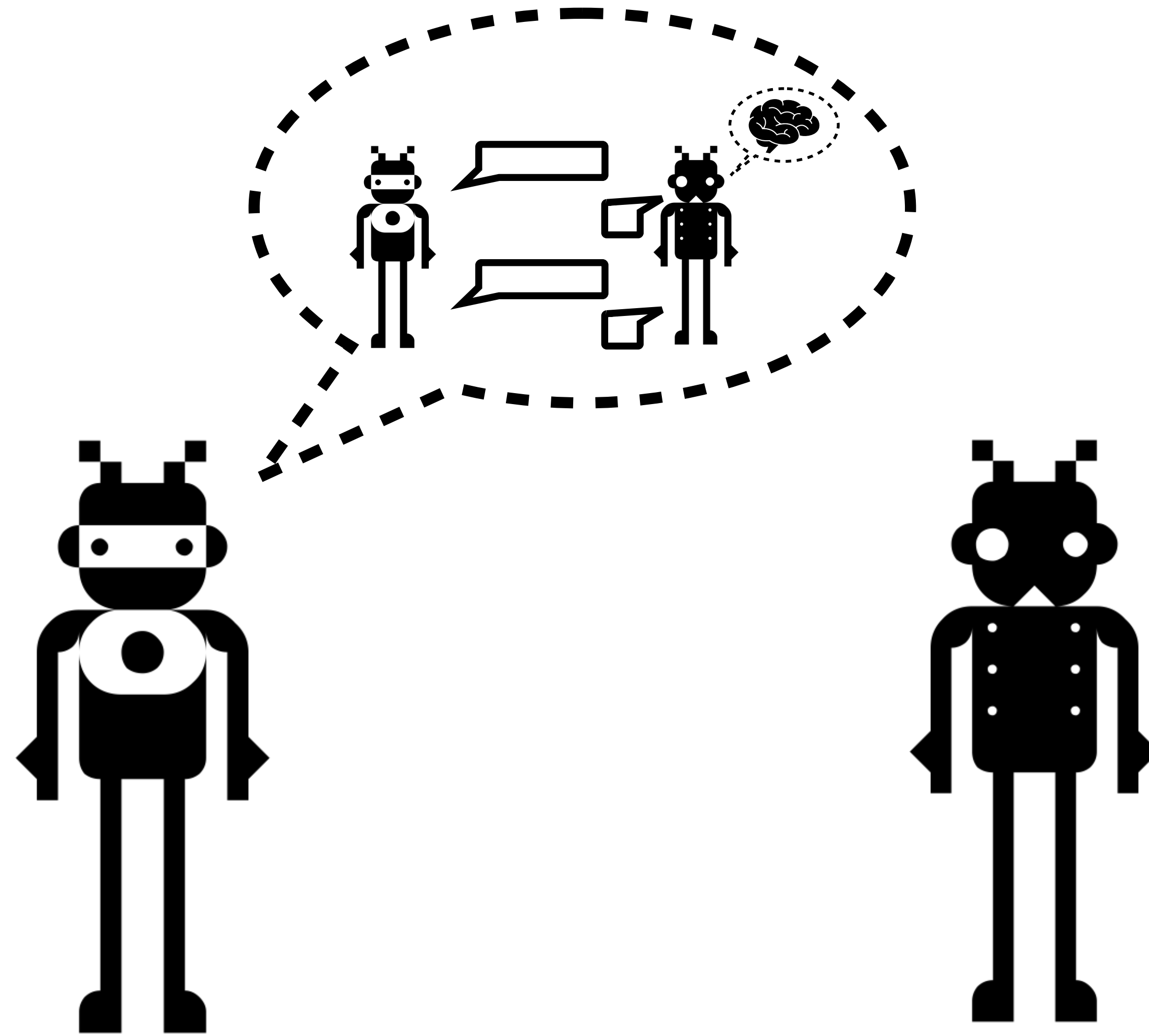






Few-shot Language Coordination





Theory-of-Mind

understand and act upon others' mental states

Can an agent, equipped with a model of theory of mind, quickly adapt to a listener's language in a few-shot language coordination game?

Goal: Pick and cool winebottle, place it on the dining table

Could you cool a bottle of wine and put it on the dining table?

go to cabinet

You arrive at the cabinet, closed.

no instruction

open cabinet

There is a bottle of wine in the cabinet.

no instruction

pick up winebottle

You have winebottle in your hand.

no instruction

(a)

no instruction

pick up winebottle

You have winebottle in your hand.

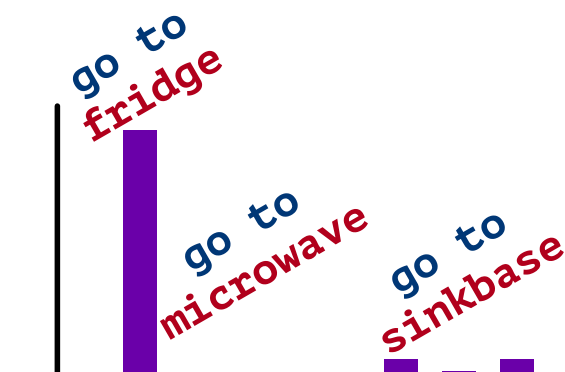
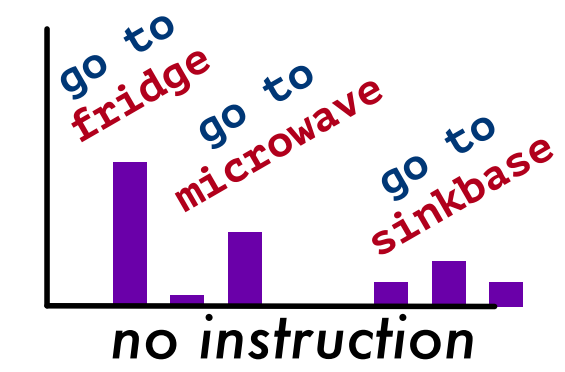
no instruction

go to microwave

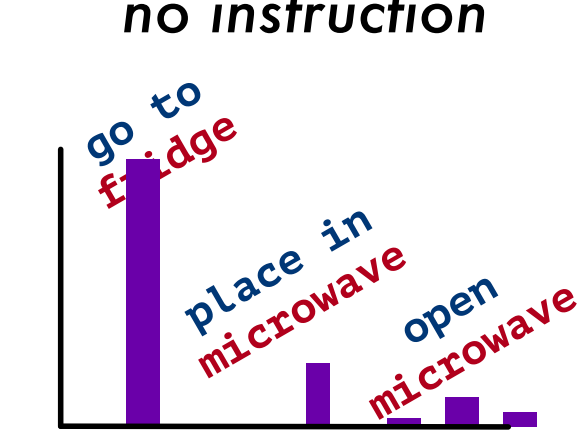
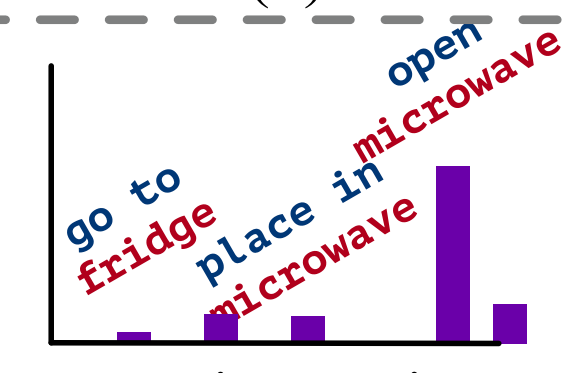
The microwave is closed.

walk to the fridge

(c)



(b)

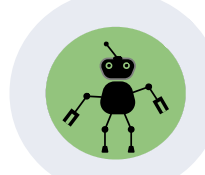


(d)

Goal: Pick and cool winebottle, place it on the dining table

 Could you cool a bottle of wine and put it on the dining table?  go to cabinet


You arrive at the cabinet, closed.

 no instruction  open cabinet

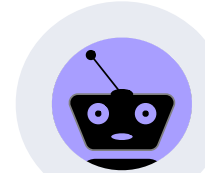
There is a bottle of wine in the cabinet.

 no instruction  pick up winebottle

You have winebottle in your hand.

 no instruction

(a)

 no instruction  pick up winebottle

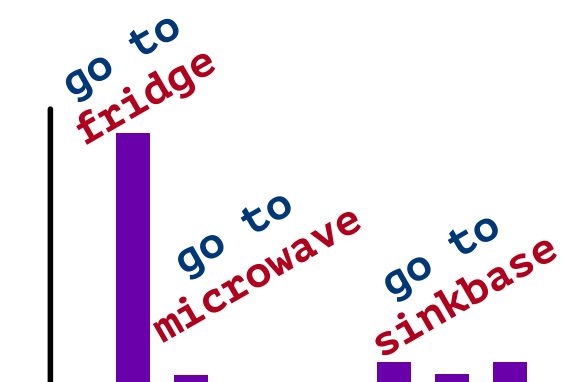
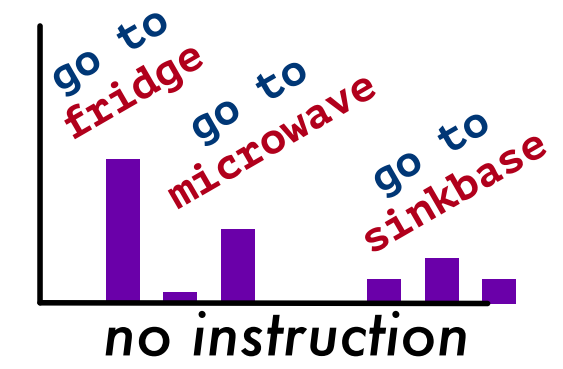
You have winebottle in your hand.

 no instruction  go to microwave

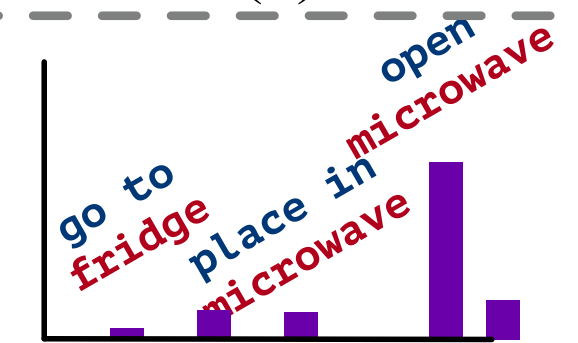
The microwave is closed.

 walk to the fridge

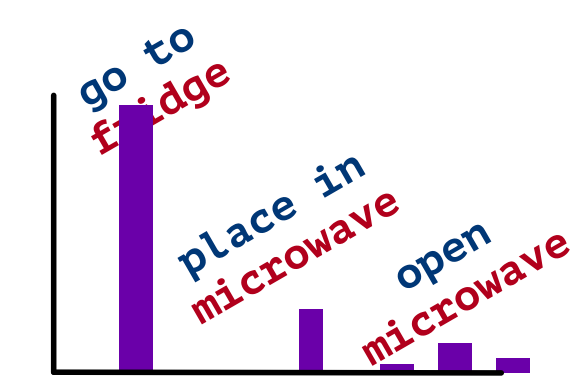
(c)



(b)



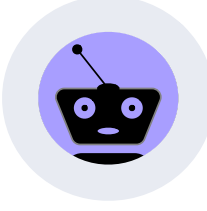
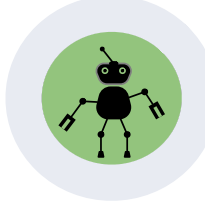
no instruction



walk to the fridge

(d)

Goal: Pick and cool winebottle, place it on the dining table

 Could you cool a bottle of wine and put it on the dining table? **go to cabinet** 

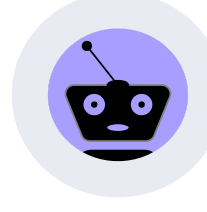
You arrive at the cabinet, closed.

 no instruction **open cabinet** 

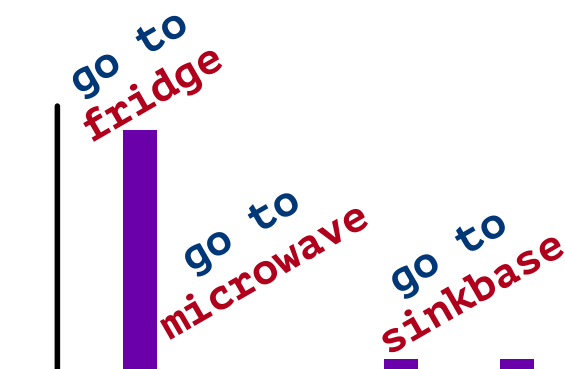
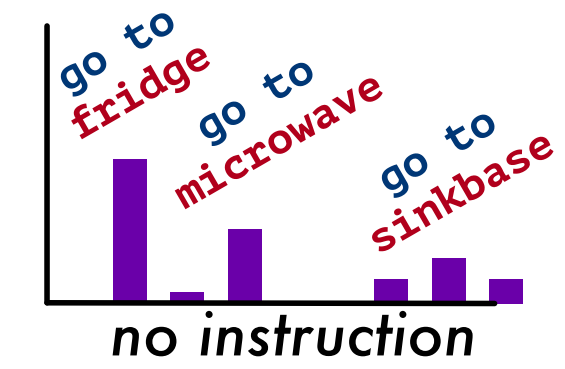
There is a bottle of wine in the cabinet.

 no instruction **pick up winebottle** 

You have winebottle in your hand.

 no instruction

(a)



(b)

 no instruction **pick up winebottle** 

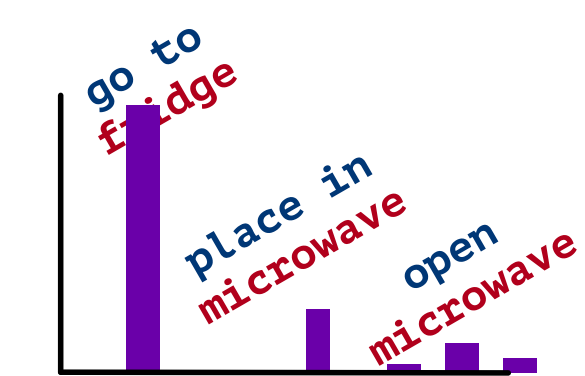
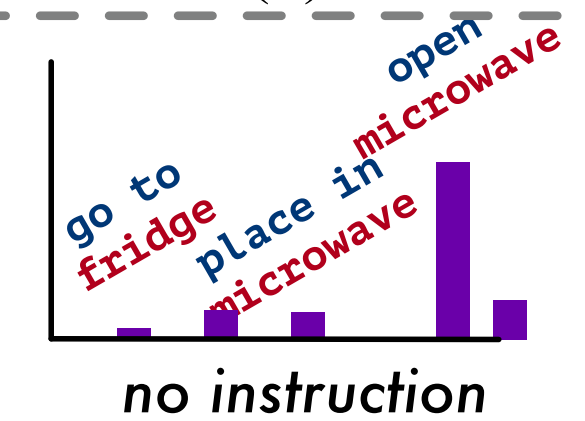
You have winebottle in your hand.

 no instruction **go to microwave** 

The microwave is closed.



 walk to the fridge

(c)



(d)

Goal: Pick and cool winebottle, place it on the dining table

 Could you cool a bottle of wine and put it on the dining table? go to cabinet 


You arrive at the cabinet, closed.

 no instruction open cabinet 

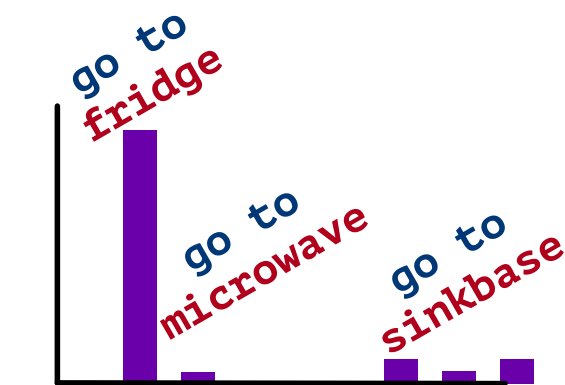
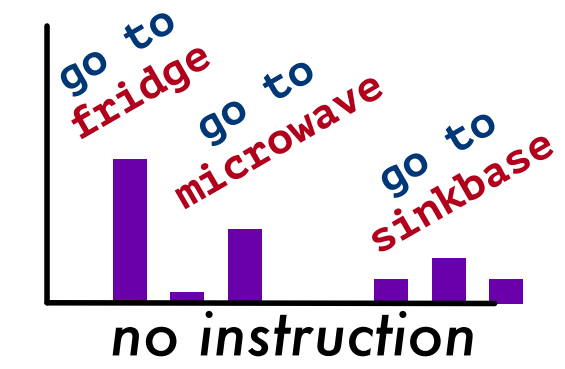
There is a bottle of wine in the cabinet.

 no instruction pick up winebottle 

You have winebottle in your hand.

 no instruction

(a)



(b)

 no instruction pick up winebottle 

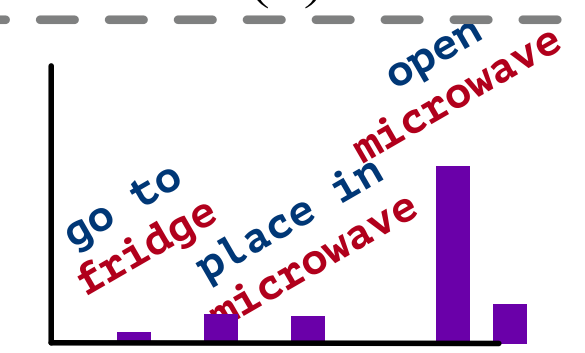
You have winebottle in your hand.

 no instruction go to microwave 

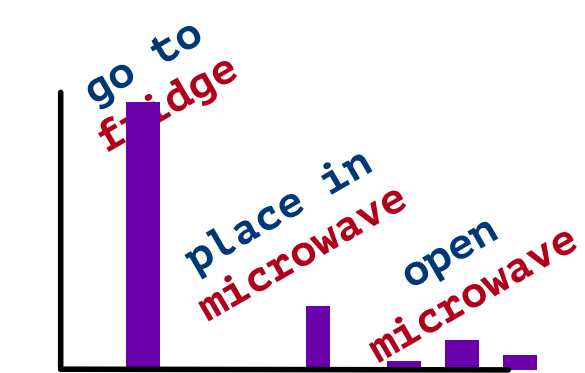
The microwave is closed.

 walk to the fridge

(c)


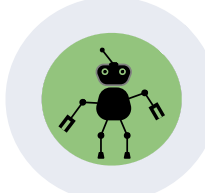


(d)



(d)

Goal: Pick and cool winebottle, place it on the dining table

 Could you cool a bottle of wine and put it on the dining table?  **go to cabinet**

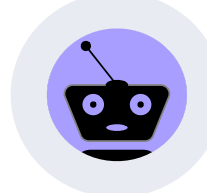
You arrive at the cabinet, closed.

 *no instruction*  **open cabinet**

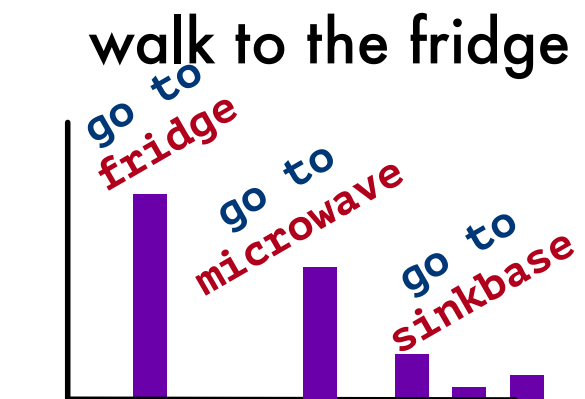
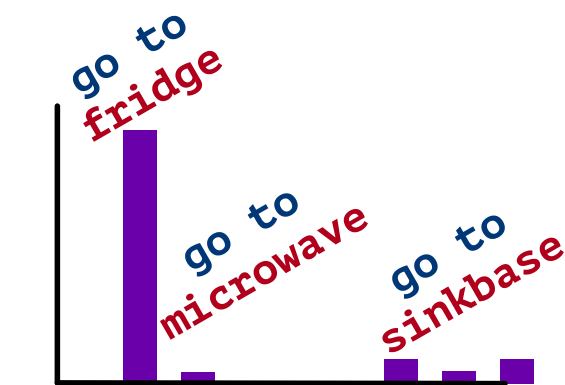
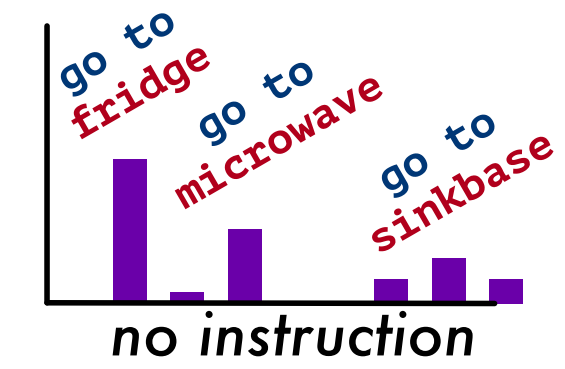
There is a bottle of wine in the cabinet.

 *no instruction*  **pick up winebottle**

You have winebottle in your hand.

 *no instruction*

(a)



(b)

 *no instruction*  **pick up winebottle**

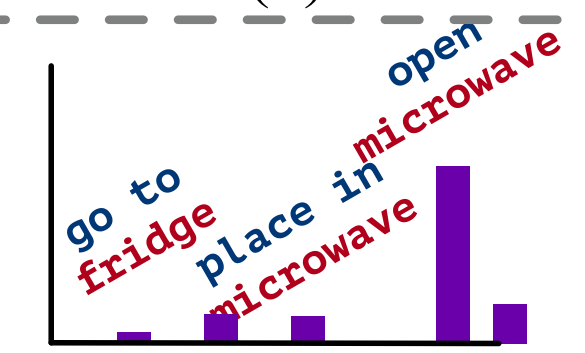
You have winebottle in your hand.

 *no instruction*  **go to microwave**

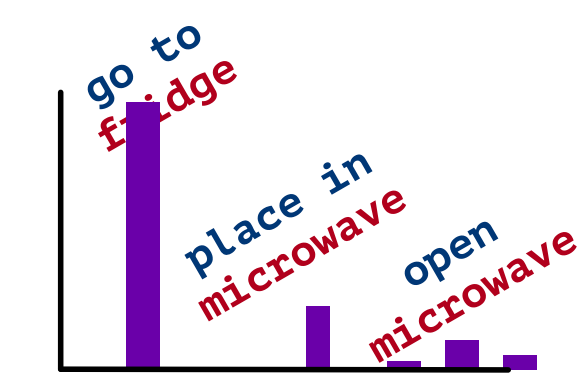
The microwave is closed.

 **walk to the fridge**

(c)



(d)



(d)

Goal: Pick and cool winebottle, place it on the dining table

Could you cool a bottle of wine and put it on the dining table? **go to cabinet**

You arrive at the cabinet, closed.

no instruction **open cabinet**

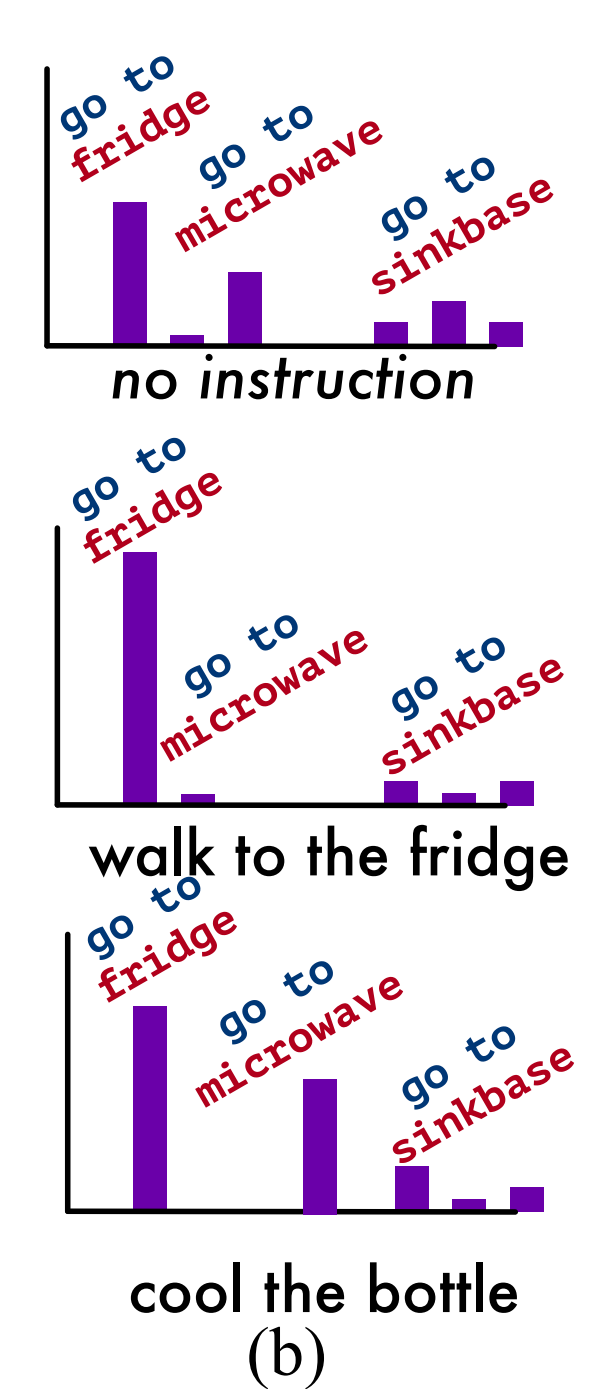
There is a bottle of wine in the cabinet.

no instruction **pick up winebottle**

You have winebottle in your hand.

no instruction

(a)



no instruction **pick up winebottle**

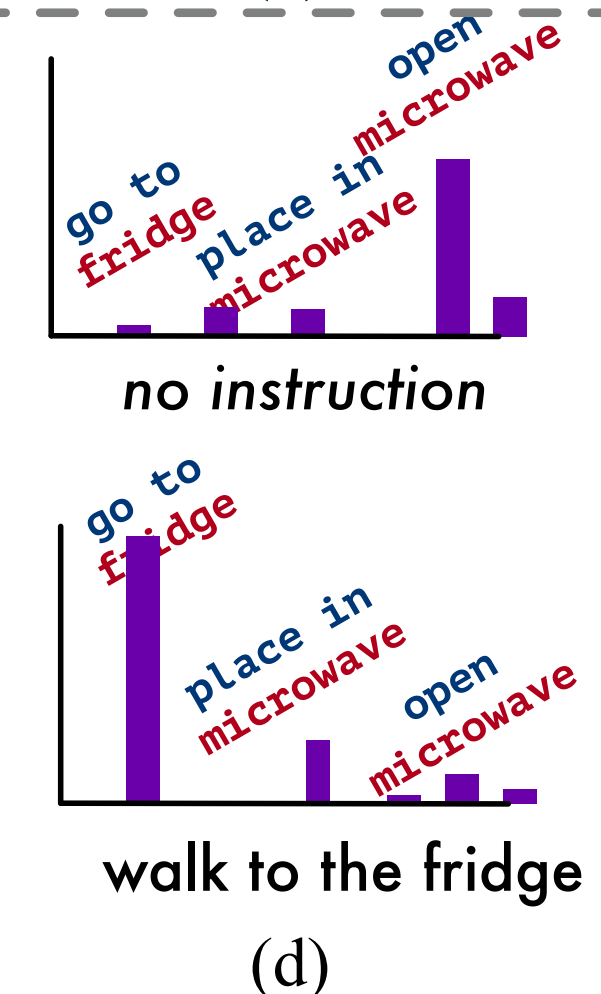
You have winebottle in your hand.

no instruction **go to microwave**

The microwave is closed.

walk to the fridge

(c)



Goal: Pick and cool winebottle, place it on the dining table

Human: Could you cool a bottle of wine and put it on the dining table? Robot: go to cabinet

You arrive at the cabinet, closed.

Human: no instruction Robot: open cabinet

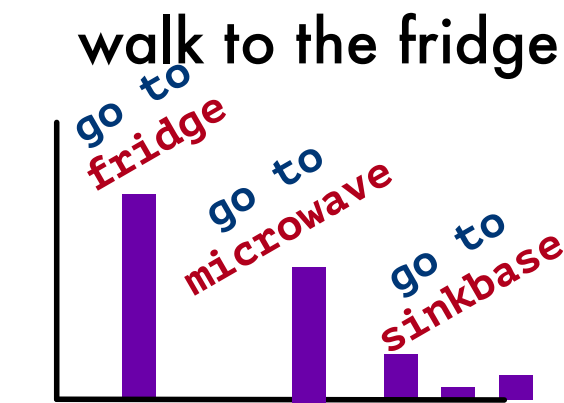
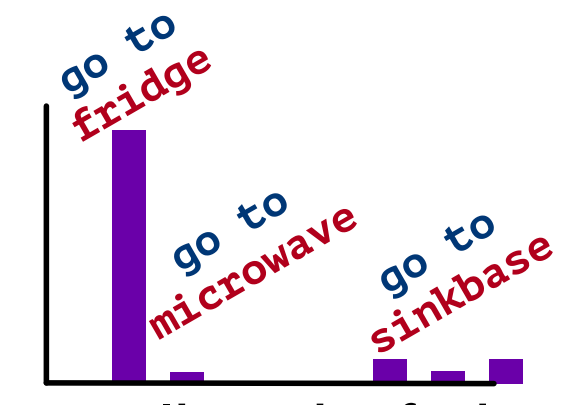
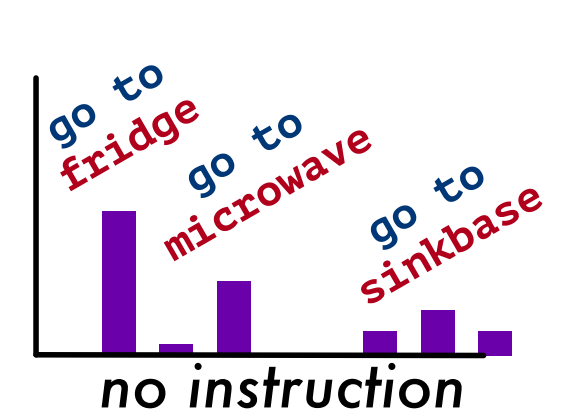
There is a bottle of wine in the cabinet.

Human: no instruction Robot: pick up winebottle

You have winebottle in your hand.

Human: no instruction

(a)



(b)

Human: no instruction Robot: pick up winebottle

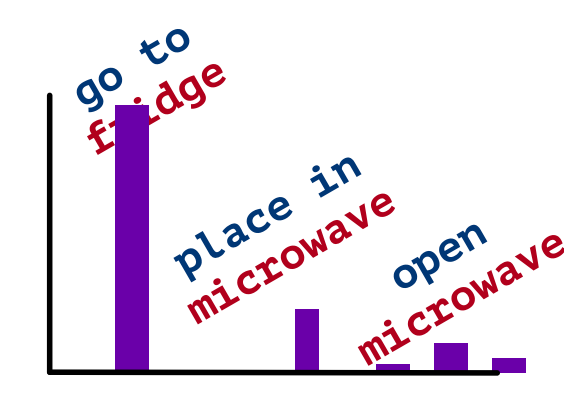
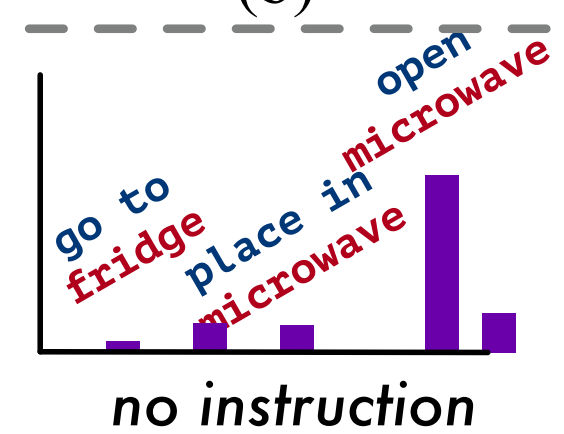
You have winebottle in your hand.

Human: no instruction Robot: go to microwave

The microwave is closed.


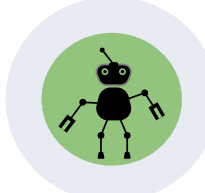
Human: walk to the fridge

(c)



(d)

Goal: Pick and cool winebottle, place it on the dining table

 Could you cool a bottle of wine and put it on the dining table?  **go to cabinet**

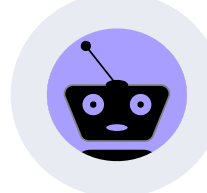
You arrive at the cabinet, closed.

 *no instruction*  **open cabinet**

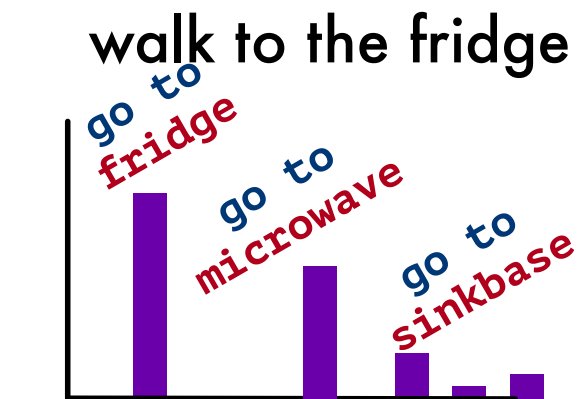
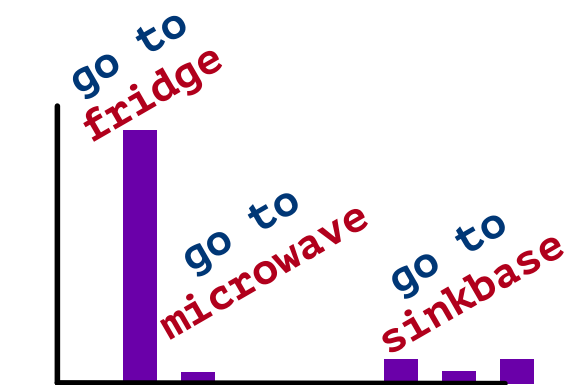
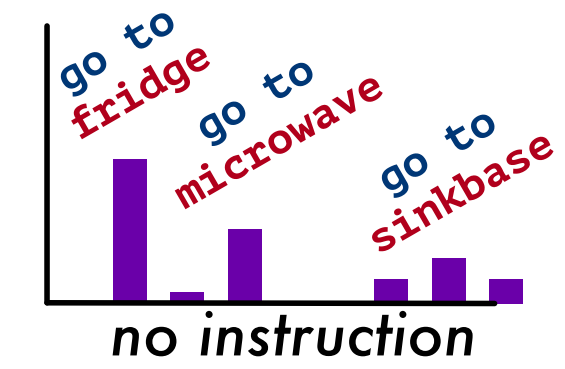
There is a bottle of wine in the cabinet.

 *no instruction*  **pick up winebottle**

You have winebottle in your hand.

 *no instruction*

(a)



(b)

 *no instruction*  **pick up winebottle**

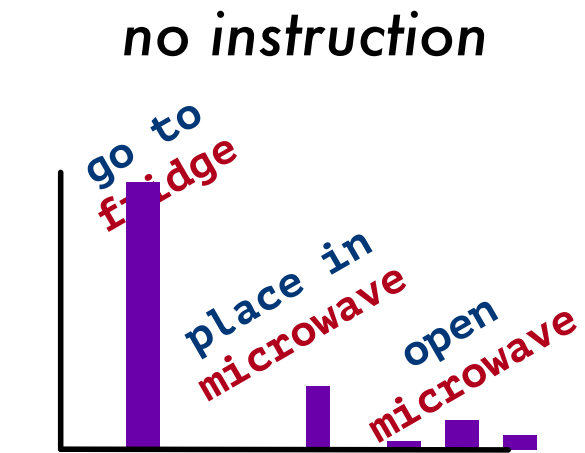
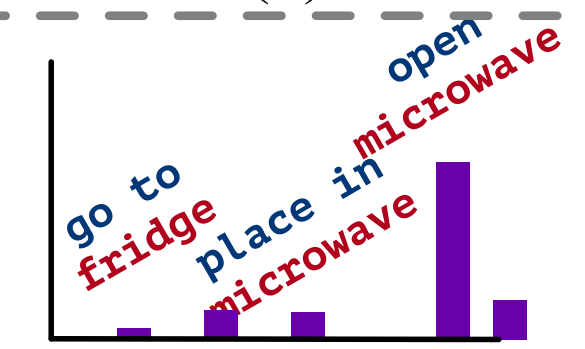
You have winebottle in your hand.

 *no instruction*  **go to microwave**

The microwave is closed.

 **walk to the fridge**

(c)



(d)

Goal: Pick and cool winebottle, place it on the dining table

Could you cool a bottle of wine and put it on the dining table?

go to cabinet

You arrive at the cabinet, closed.

no instruction

open cabinet

There is a bottle of wine in the cabinet.

no instruction

pick up winebottle

You have winebottle in your hand.

no instruction

(a)

no instruction

pick up winebottle

You have winebottle in your hand.

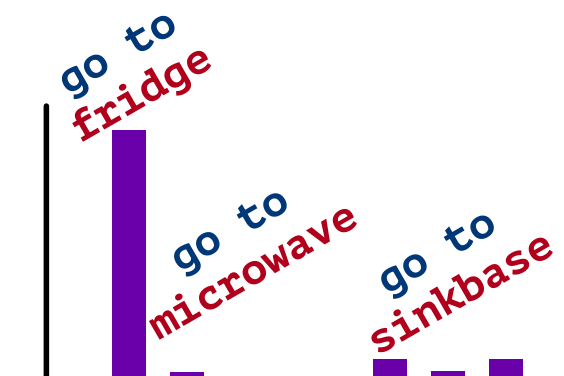
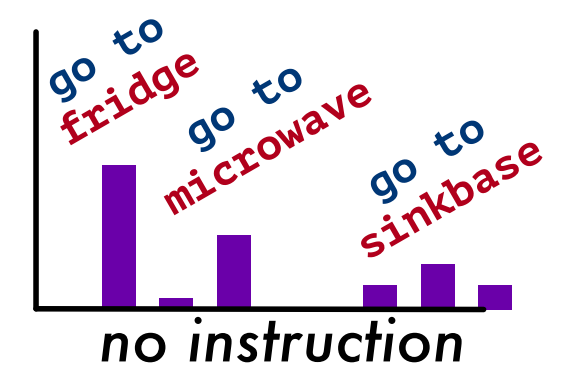
no instruction

go to microwave

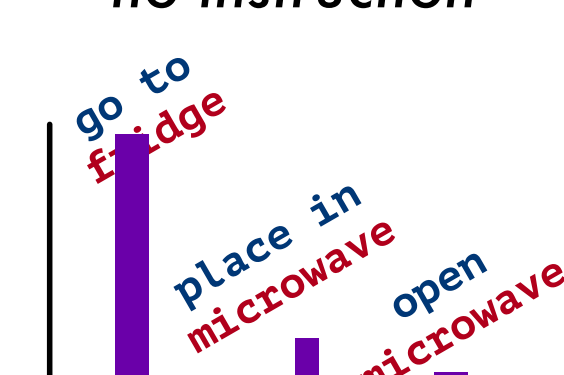
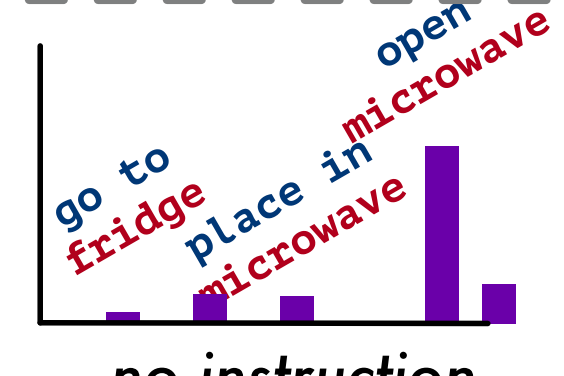
The microwave is closed.

walk to the fridge

(c)



(b)



(d)

Goal: Pick and cool winebottle, place it on the dining table

Could you cool a bottle of wine and put it on the dining table?

go to cabinet

You arrive at the cabinet, closed.

no instruction

open cabinet

There is a bottle of wine in the cabinet.

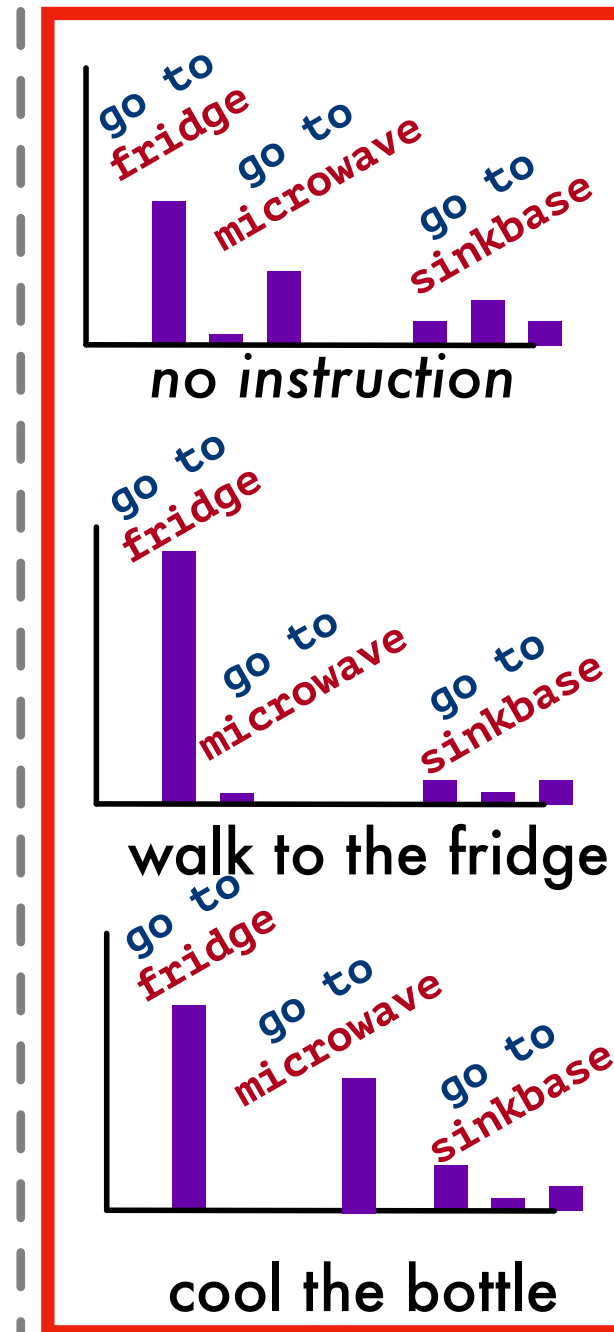
no instruction

pick up winebottle

You have winebottle in your hand.

no instruction

(a)



(b)

no instruction

pick up winebottle

You have winebottle in your hand.

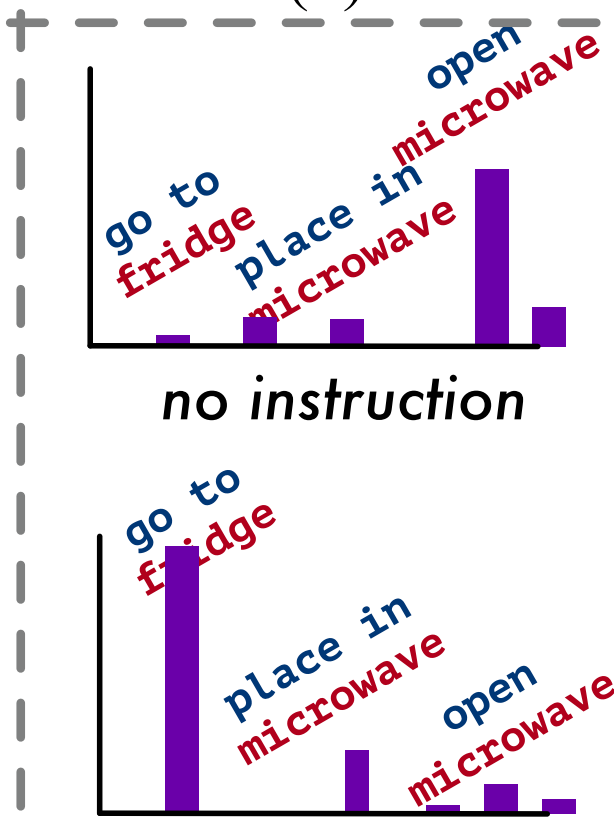
no instruction

go to microwave

The microwave is closed.

walk to the fridge

(c)



(d)

Goal: Pick and cool winebottle, place it on the dining table

Human: Could you cool a bottle of wine and put it on the dining table? Robot: go to cabinet

You arrive at the cabinet, closed.

Human: no instruction Robot: open cabinet

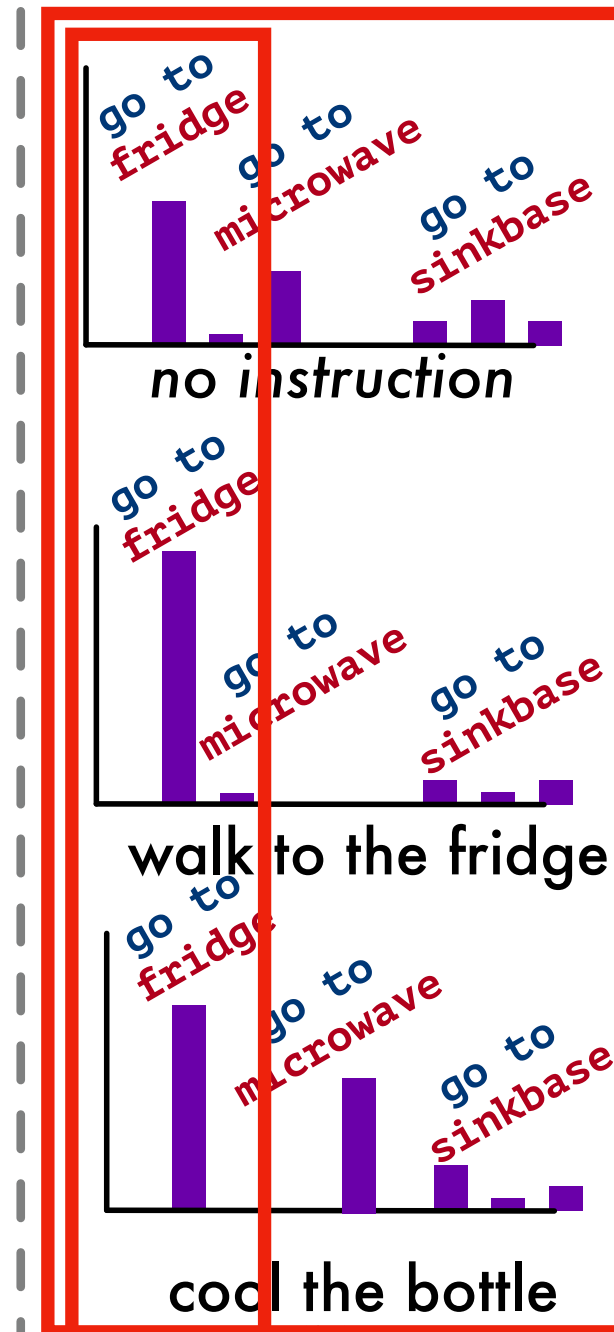
There is a bottle of wine in the cabinet.

Human: no instruction Robot: pick up winebottle

You have winebottle in your hand.

Human: no instruction

(a)



(b)

Human: no instruction Robot: pick up winebottle

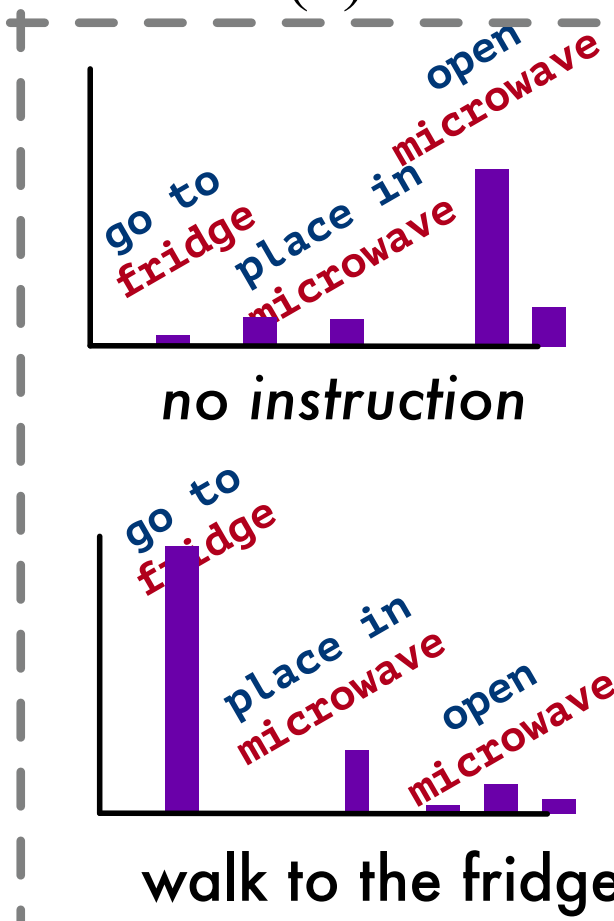
You have winebottle in your hand.

Human: no instruction Robot: go to microwave

The microwave is closed.


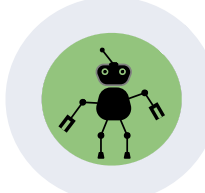
Human: walk to the fridge

(c)



(d)

Goal: Pick and cool winebottle, place it on the dining table

 Could you cool a bottle of wine and put it on the dining table?  **go to cabinet**

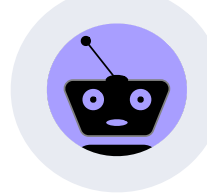
You arrive at the cabinet, closed.

 *no instruction*  **open cabinet**

There is a bottle of wine in the cabinet.

 *no instruction*  **pick up winebottle**

You have winebottle in your hand.

 *no instruction*

(a)

 *no instruction*  **pick up winebottle**

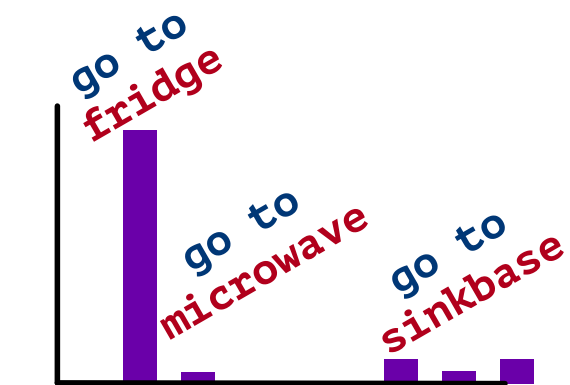
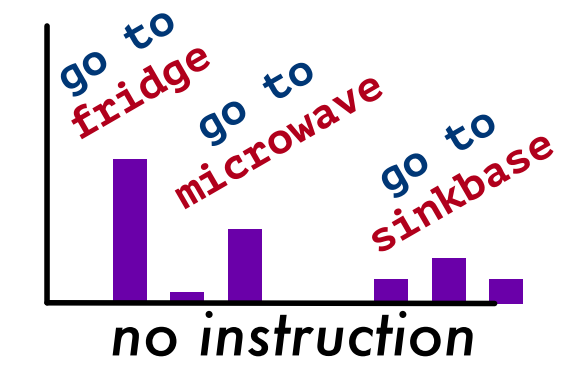
You have winebottle in your hand.

 *no instruction*  **go to microwave**

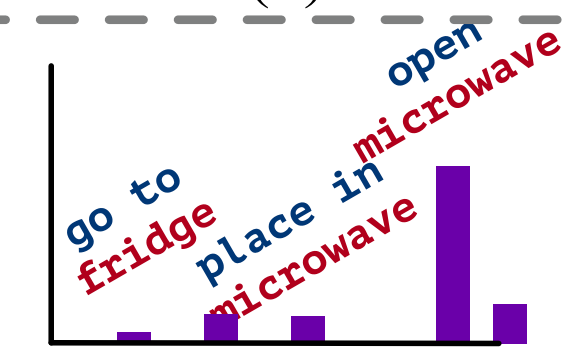
The microwave is closed.

 **walk to the fridge**

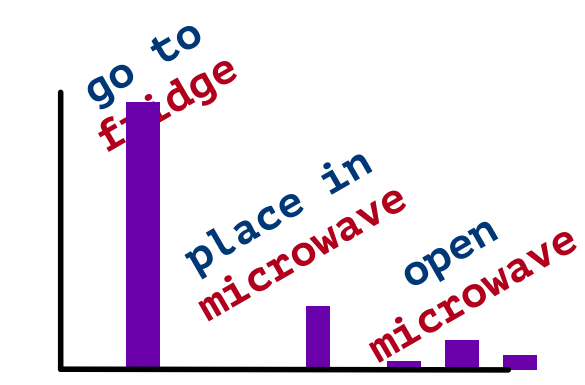
(c)



(b)


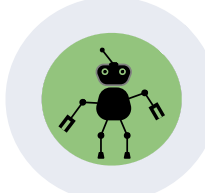


(d)




(d)


Goal: Pick and cool winebottle, place it on the dining table

 Could you cool a bottle of wine and put it on the dining table?  **go to cabinet**

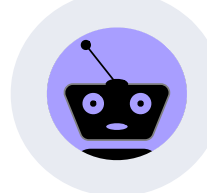
You arrive at the cabinet, closed.

 *no instruction*  **open cabinet**

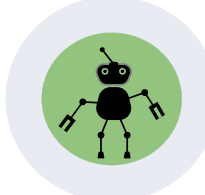
There is a bottle of wine in the cabinet.

 *no instruction*  **pick up winebottle**

You have winebottle in your hand.

 *no instruction*

(a)

 *no instruction*  **pick up winebottle**

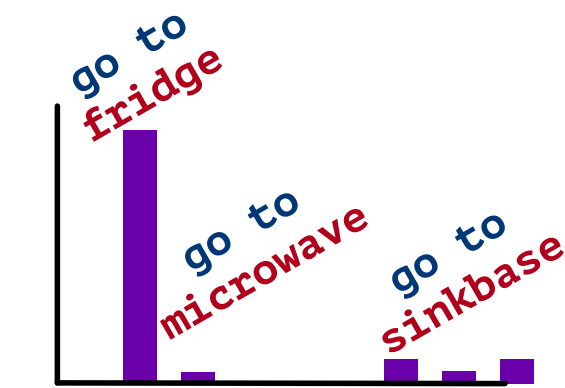
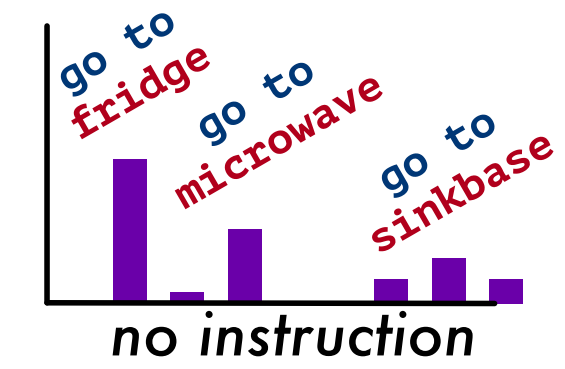
You have winebottle in your hand.

 *no instruction*  **go to microwave**

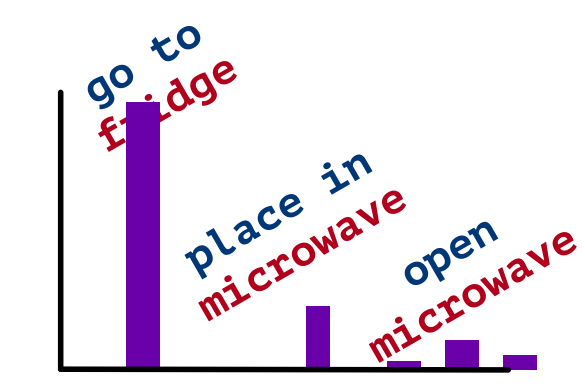
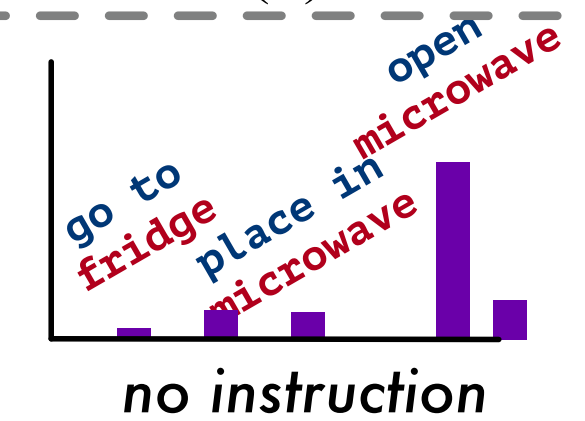
The microwave is closed.

 **walk to the fridge**

(c)

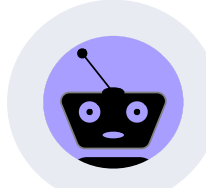
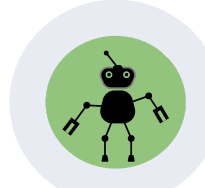


(b)



(d)

Goal: Pick and cool winebottle, place it on the dining table

 Could you cool a bottle of wine and put it on the dining table?  **go to cabinet**

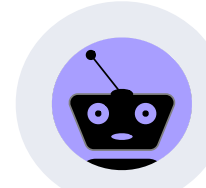
You arrive at the cabinet, closed.

 **no instruction**  **open cabinet**

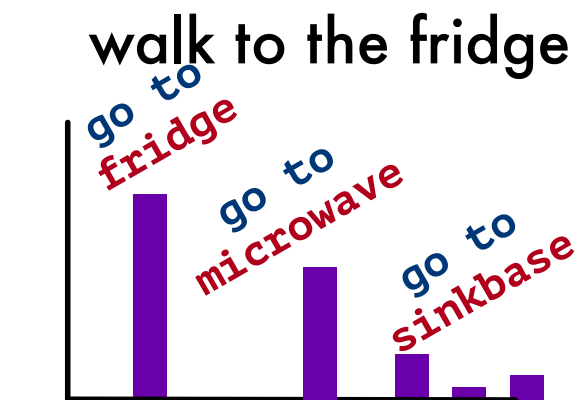
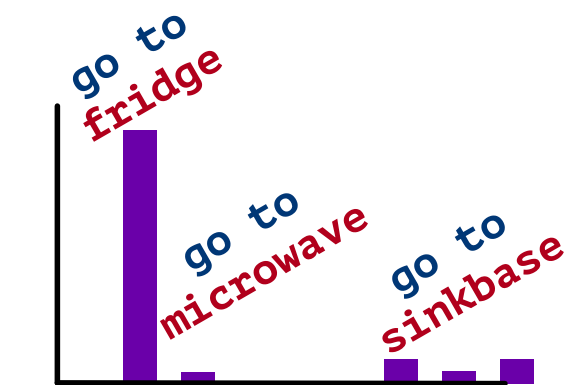
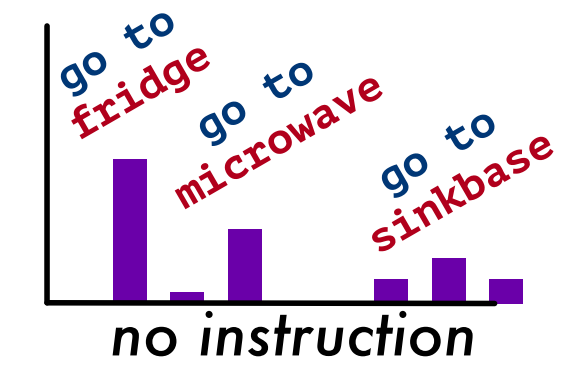
There is a bottle of wine in the cabinet.

 **no instruction**  **pick up winebottle**

You have winebottle in your hand.

 **no instruction**

(a)



(b)

 **no instruction**  **pick up winebottle**

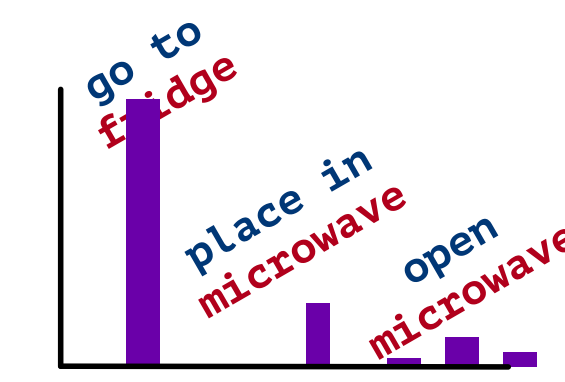
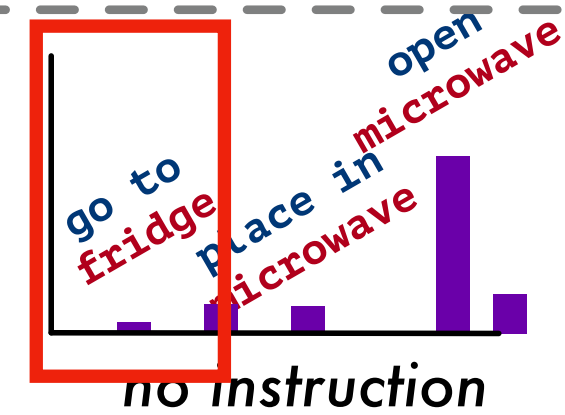
You have winebottle in your hand.

 **no instruction**  **go to microwave**

The microwave is closed.


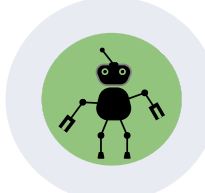
 **walk to the fridge**

(c)

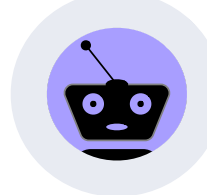


(d)

Goal: Pick and cool winebottle, place it on the dining table

 Could you cool a bottle of wine and put it on the dining table?  **go to cabinet**

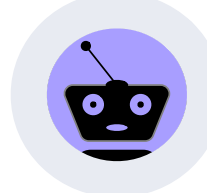
You arrive at the cabinet, closed.

 *no instruction*  **open cabinet**

There is a bottle of wine in the cabinet.

 *no instruction*  **pick up winebottle**

You have winebottle in your hand.

 *no instruction*

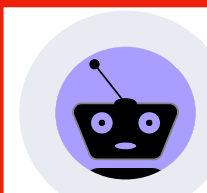
(a)

 *no instruction*  **pick up winebottle**

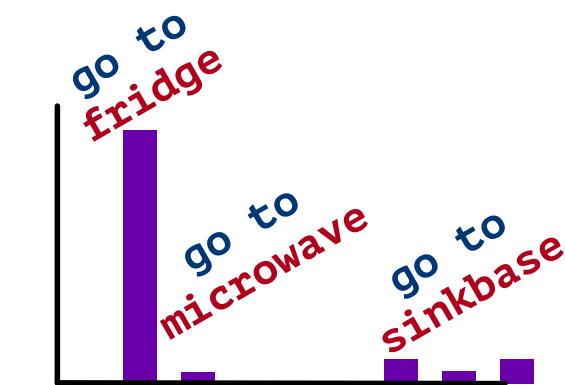
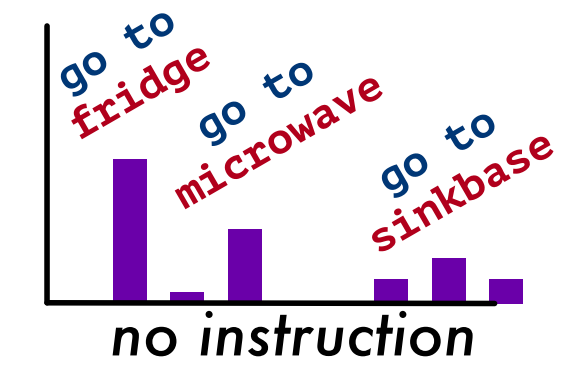
You have winebottle in your hand.

 *no instruction*  **go to microwave**

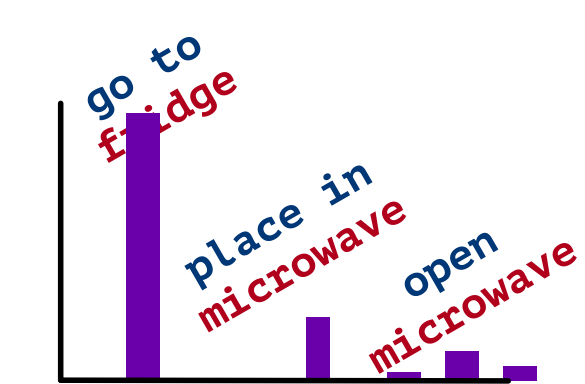
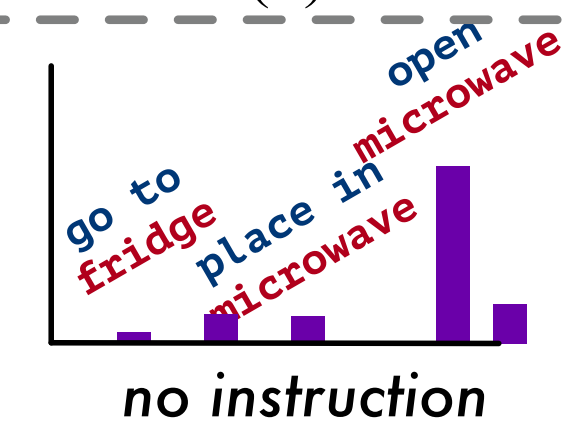
The microwave is closed.

 **walk to the fridge**

(c)



(b)



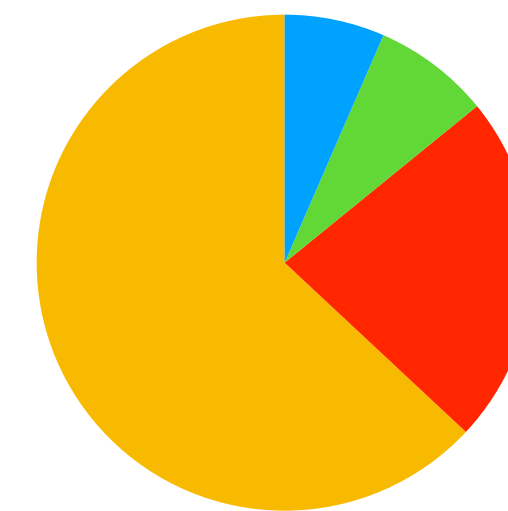
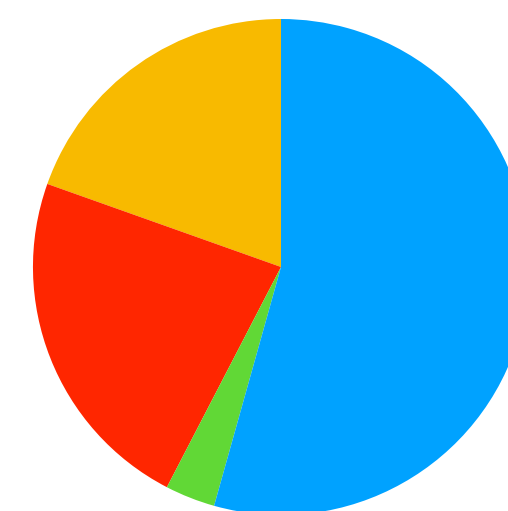
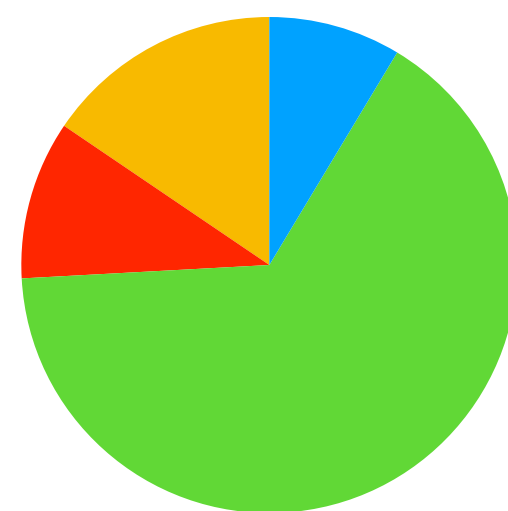
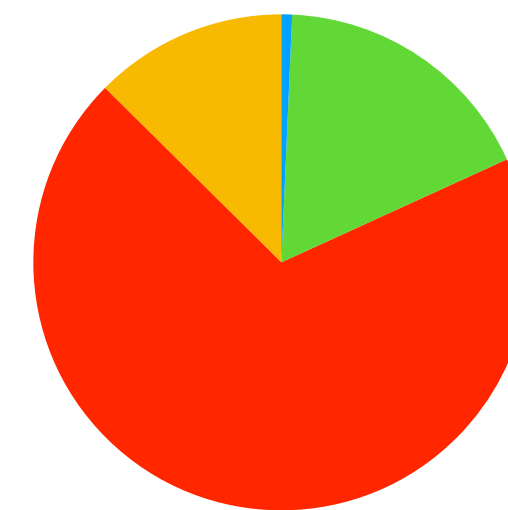
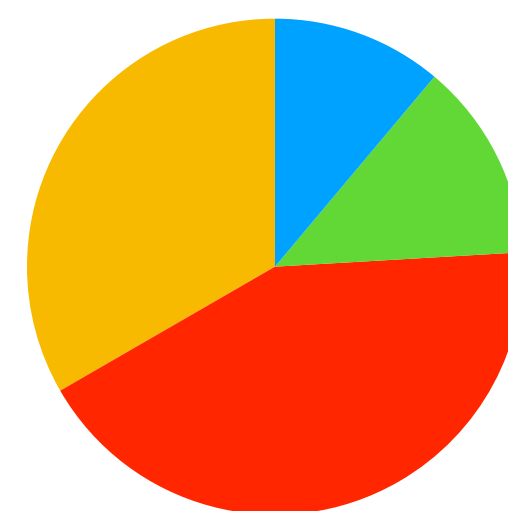
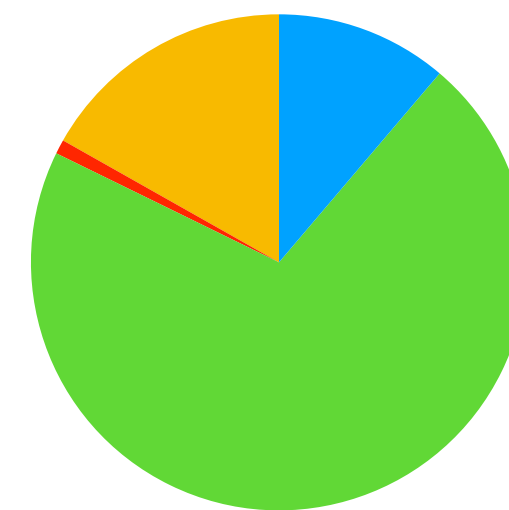
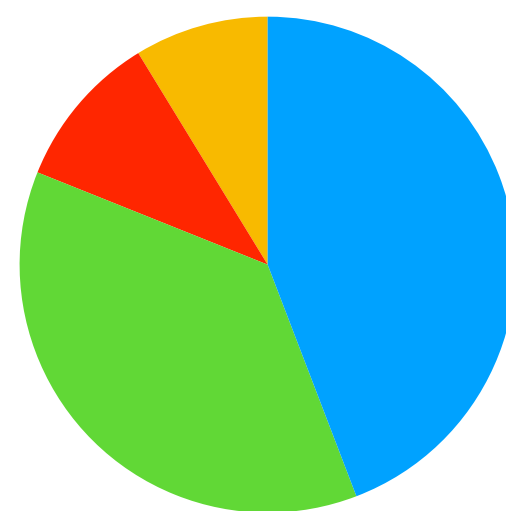
(d)

A blue rounded rectangle containing ten horizontal blue lines, serving as a template for text input.A green rounded rectangle containing ten horizontal green lines, serving as a template for text input.A yellow rounded rectangle containing ten horizontal yellow lines, serving as a template for text input.A red rounded rectangle containing ten horizontal red lines, serving as a template for text input.

Corpora



Corpora



Training Data Distributions Sampled from Dirichlet Distribution

一个人在海滩上放风筝。
一群斑马站在草地上。
一个公共汽车停在路边。

Warm a cup and put it on the dining table.
Get a knife and put it on the countertop.
Place the plate in the sink.

A man flying a kite on the beach.
A group of zebras are standing on the grass.
A bus stopped on the side of the road.

Cool the wine bottle.
Put the knife on the dining table.
Find the pick up a fork.

ビーチで凧を飛ばしている男。
シマウマのグループが草の上に立っています。
バスが道路脇に停車した。

Find a plate.
Take the knife to the cabinet.
Bring the wine bottle to the dining table.

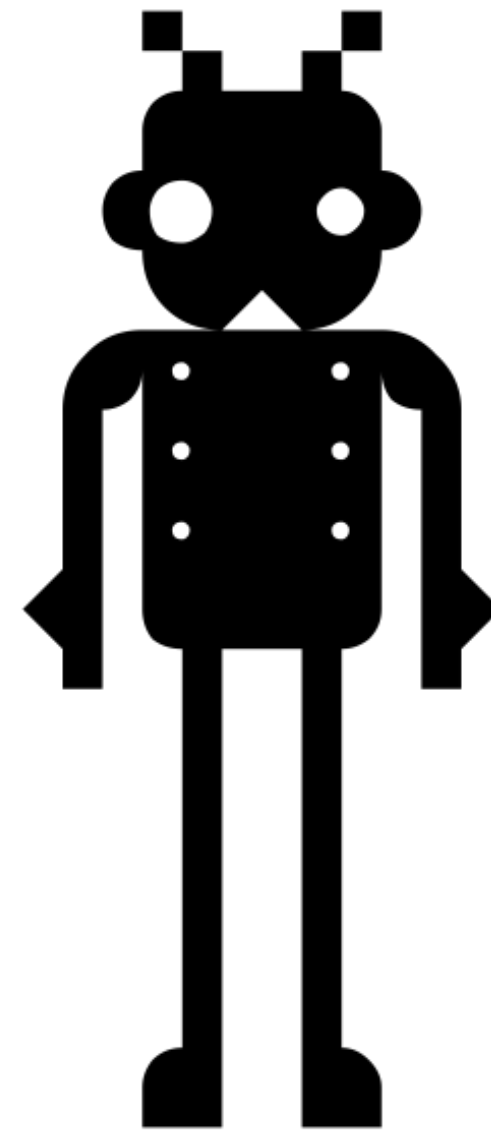
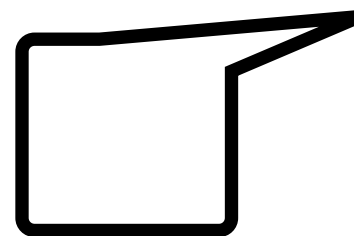
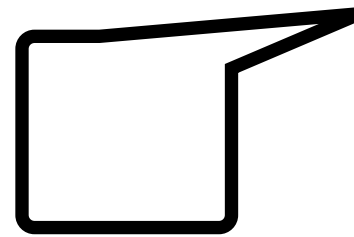
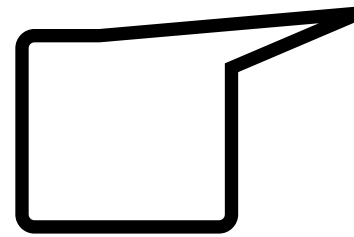
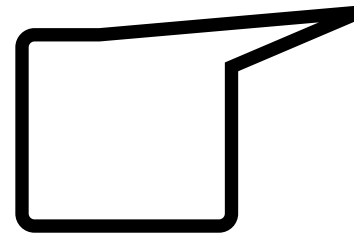
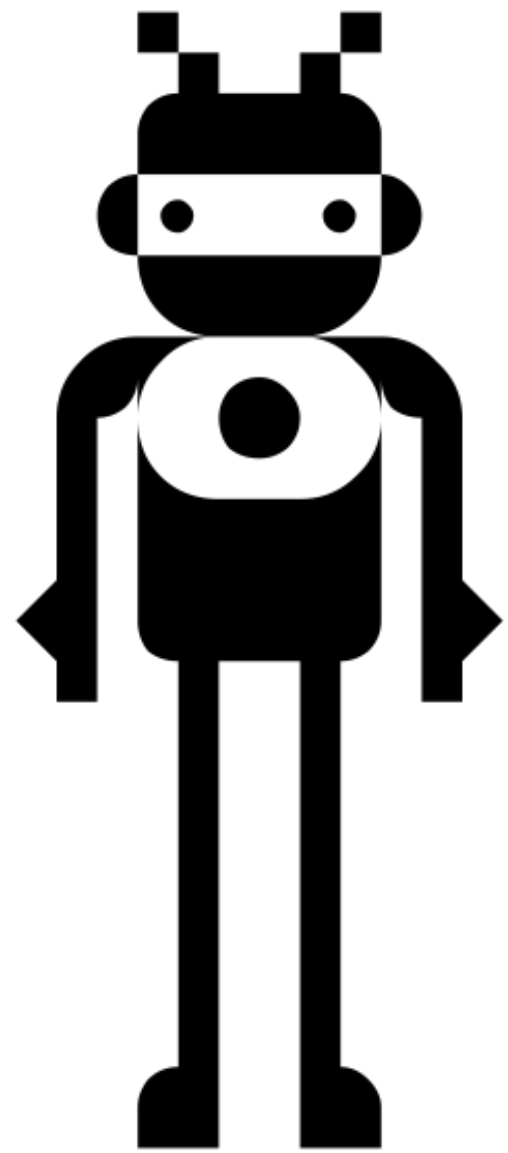
Ein Mann, der einen Drachen am Strand fliegt.
Eine Gruppe Zebras steht auf dem Gras.
Am Straßenrand hielt ein Bus.

Pick up the pan
Go to the cabinet
Open the fridge

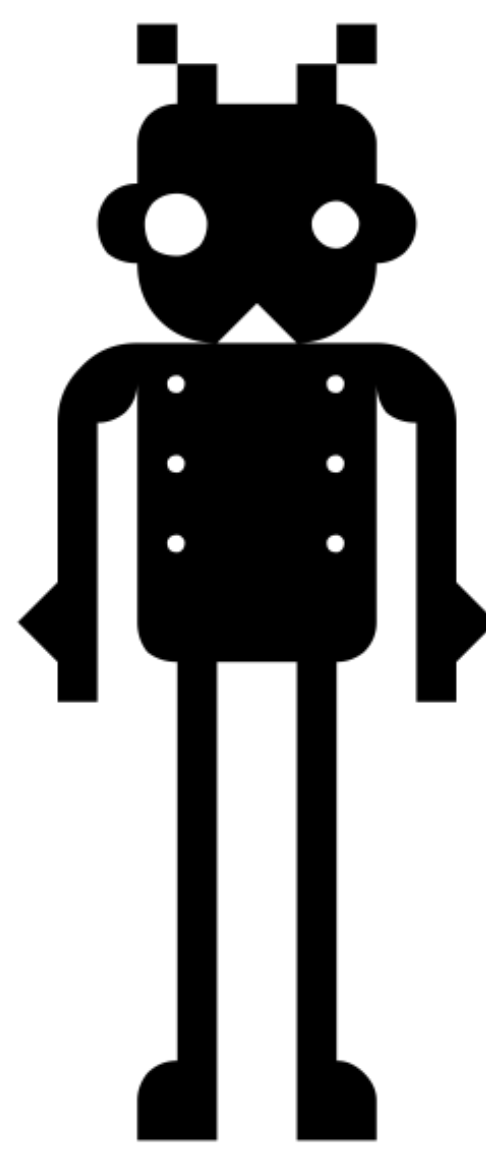
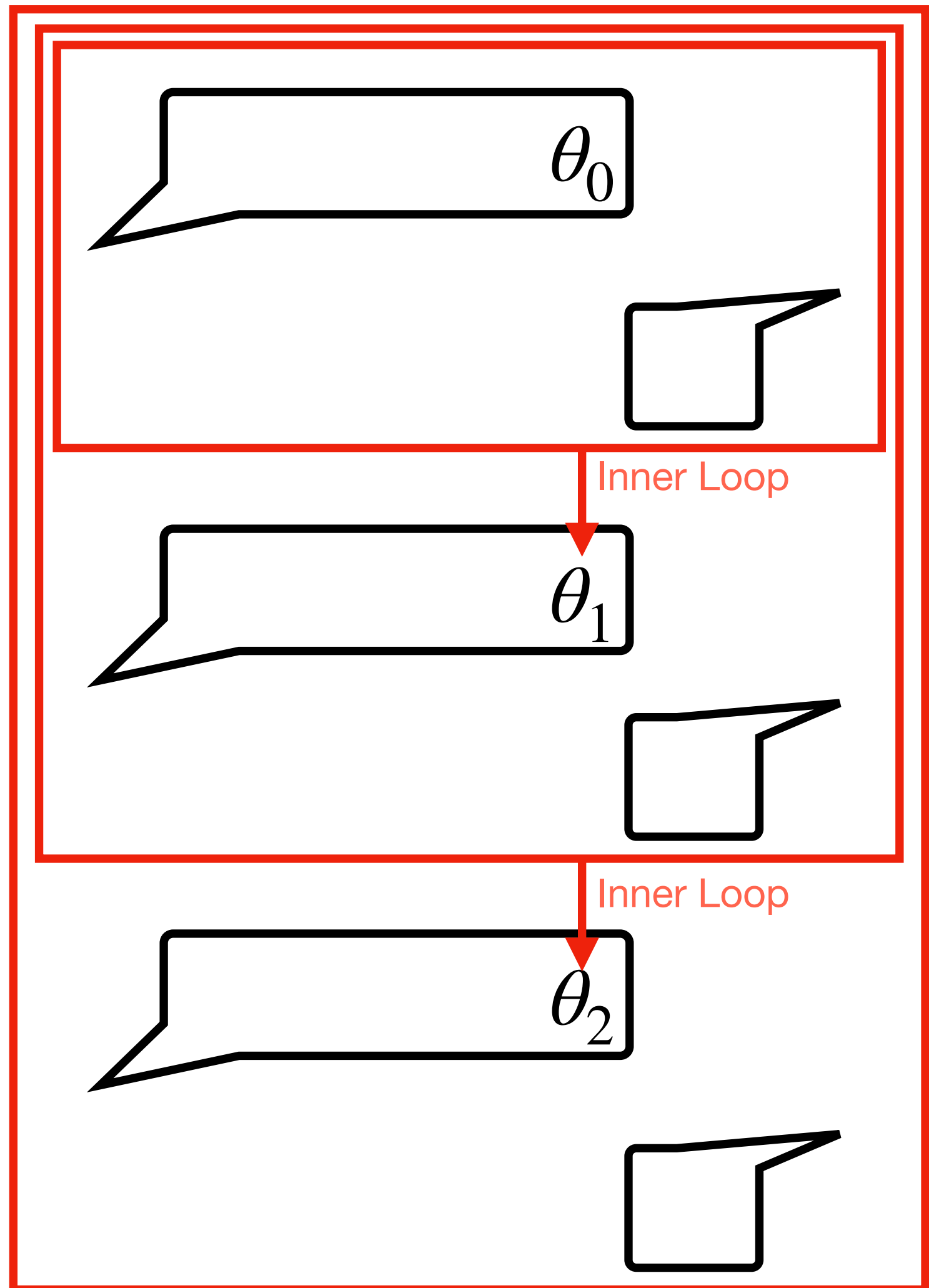
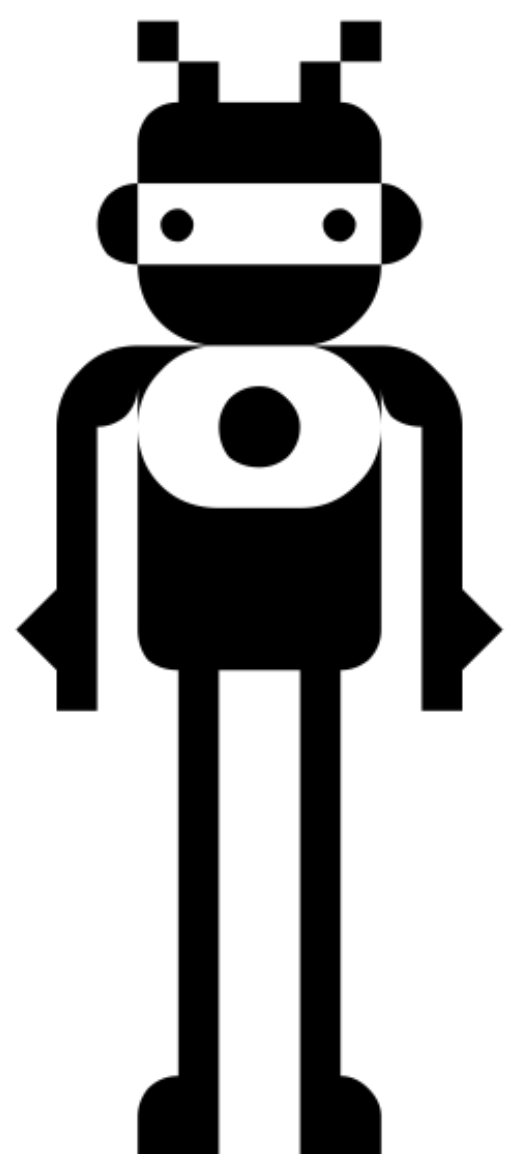
Corpora

Multilingual Referential Games

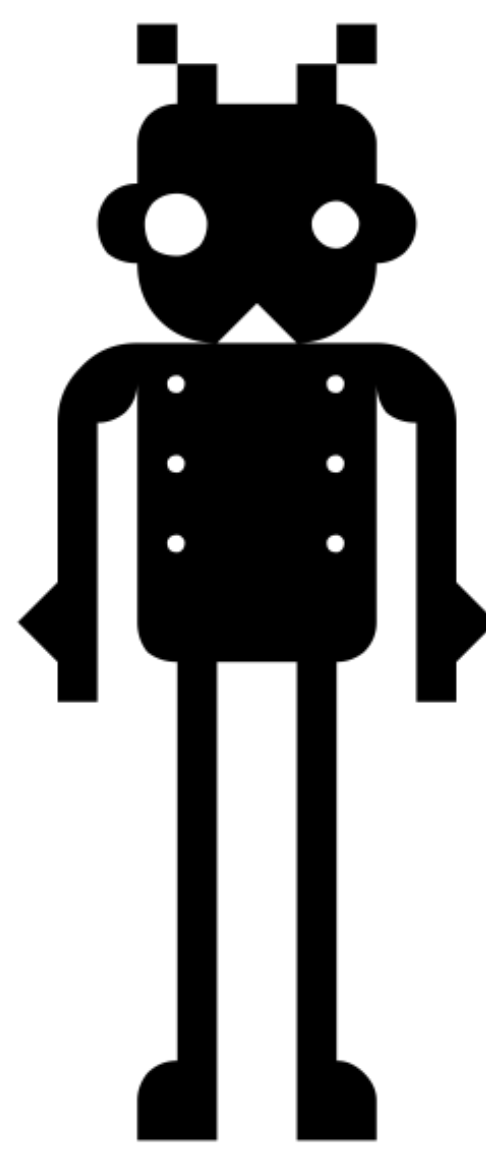
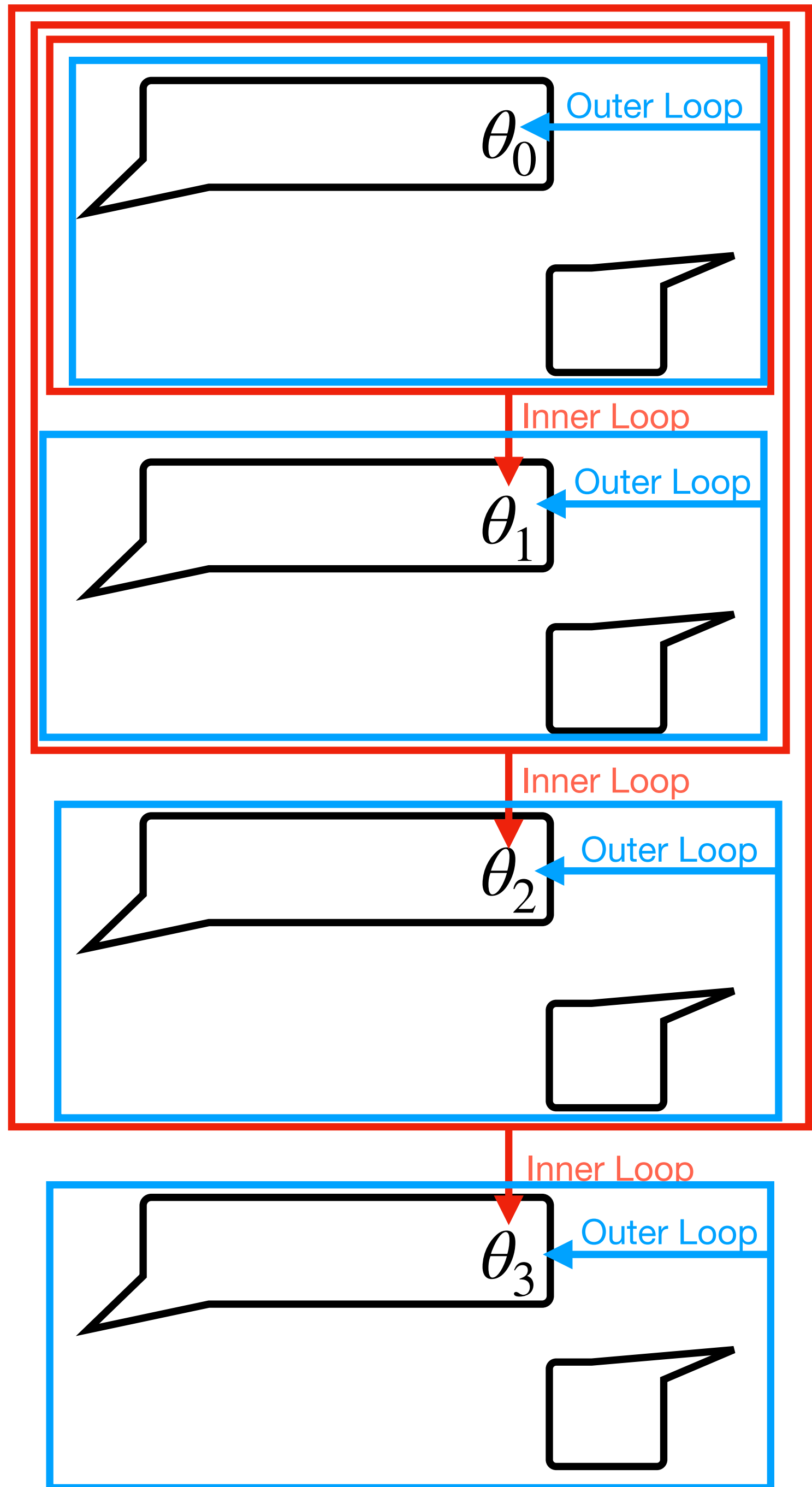
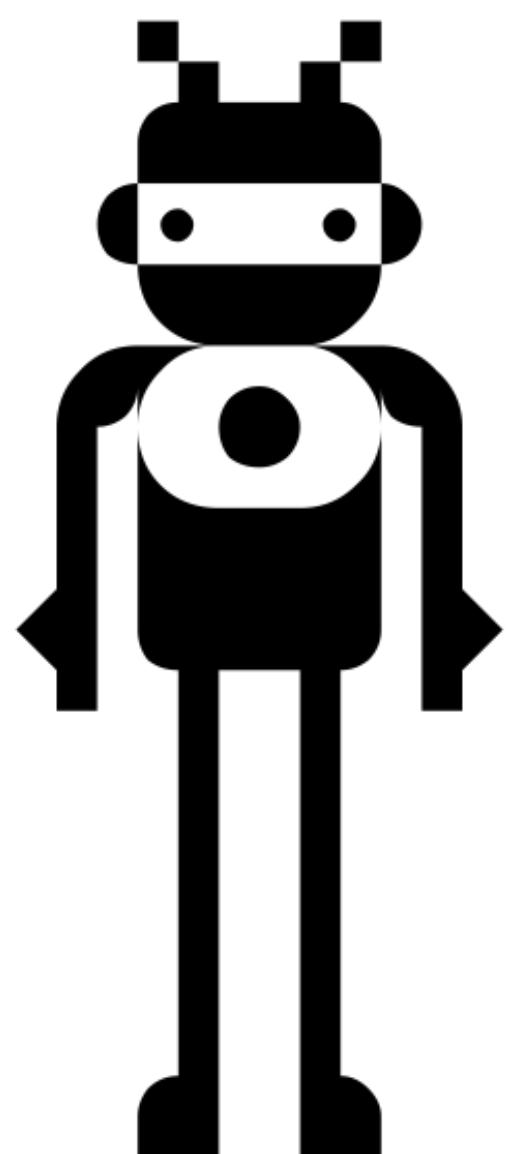
ALFWorld Task Navigation



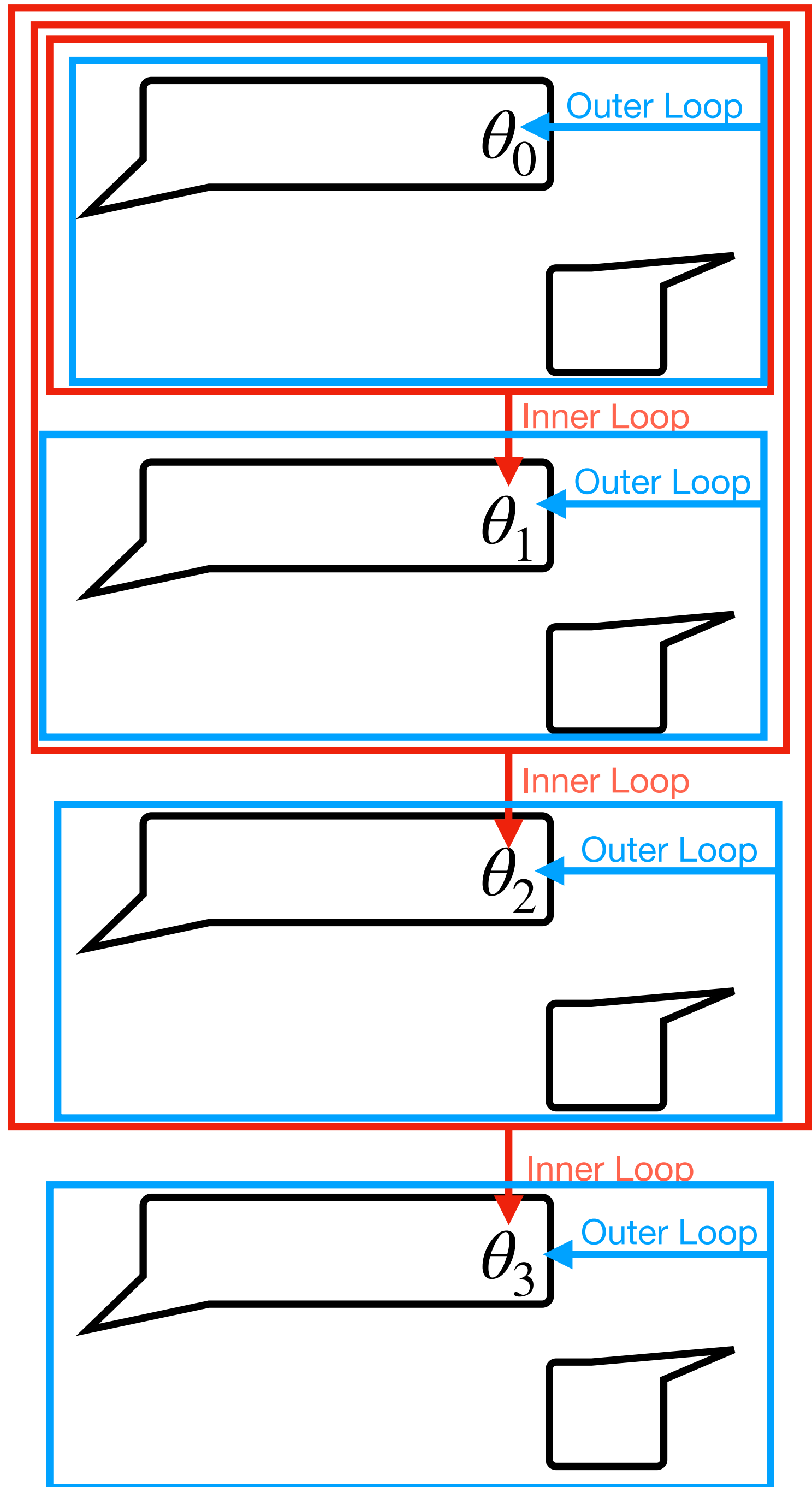
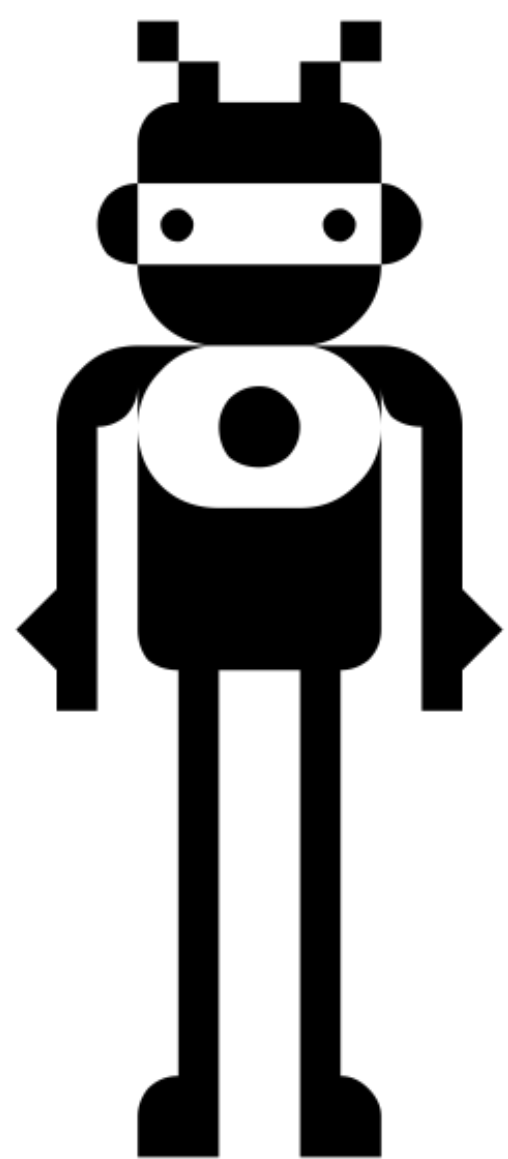
Training ToM Model with MAML



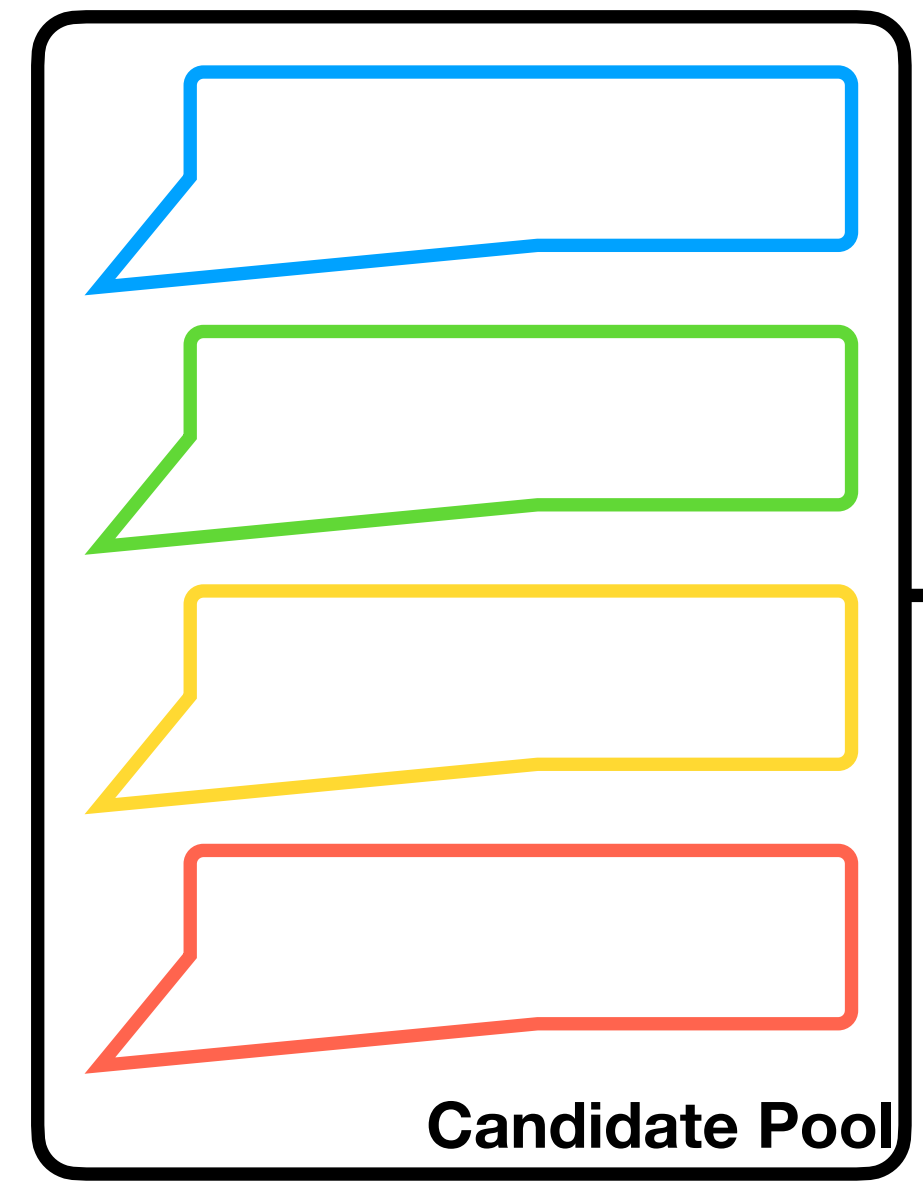
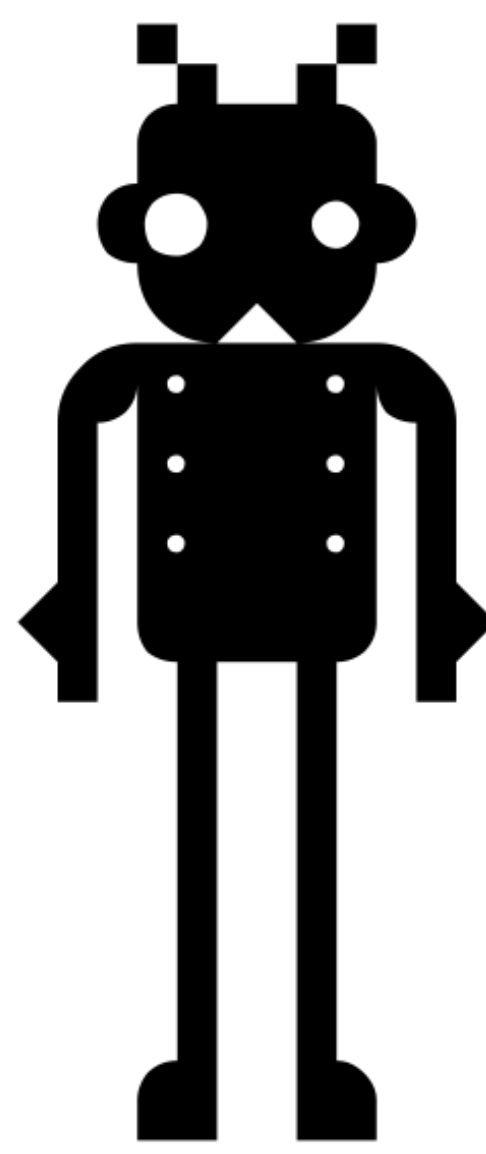
Training ToM Model with MAML



Training ToM Model with MAML

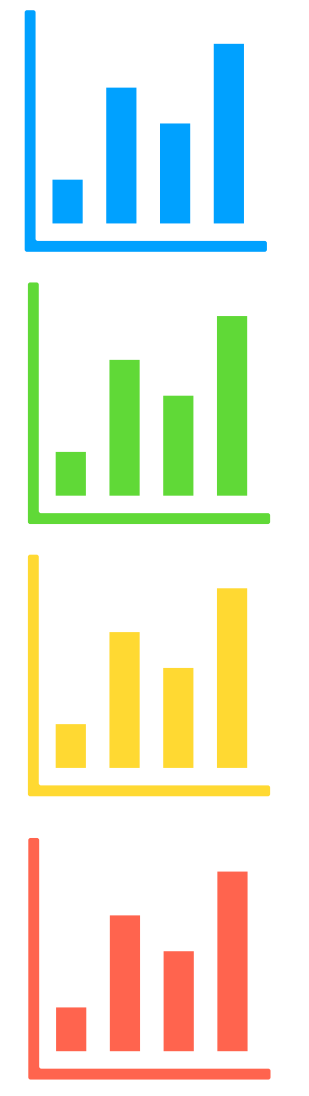


Training ToM Model with MAML

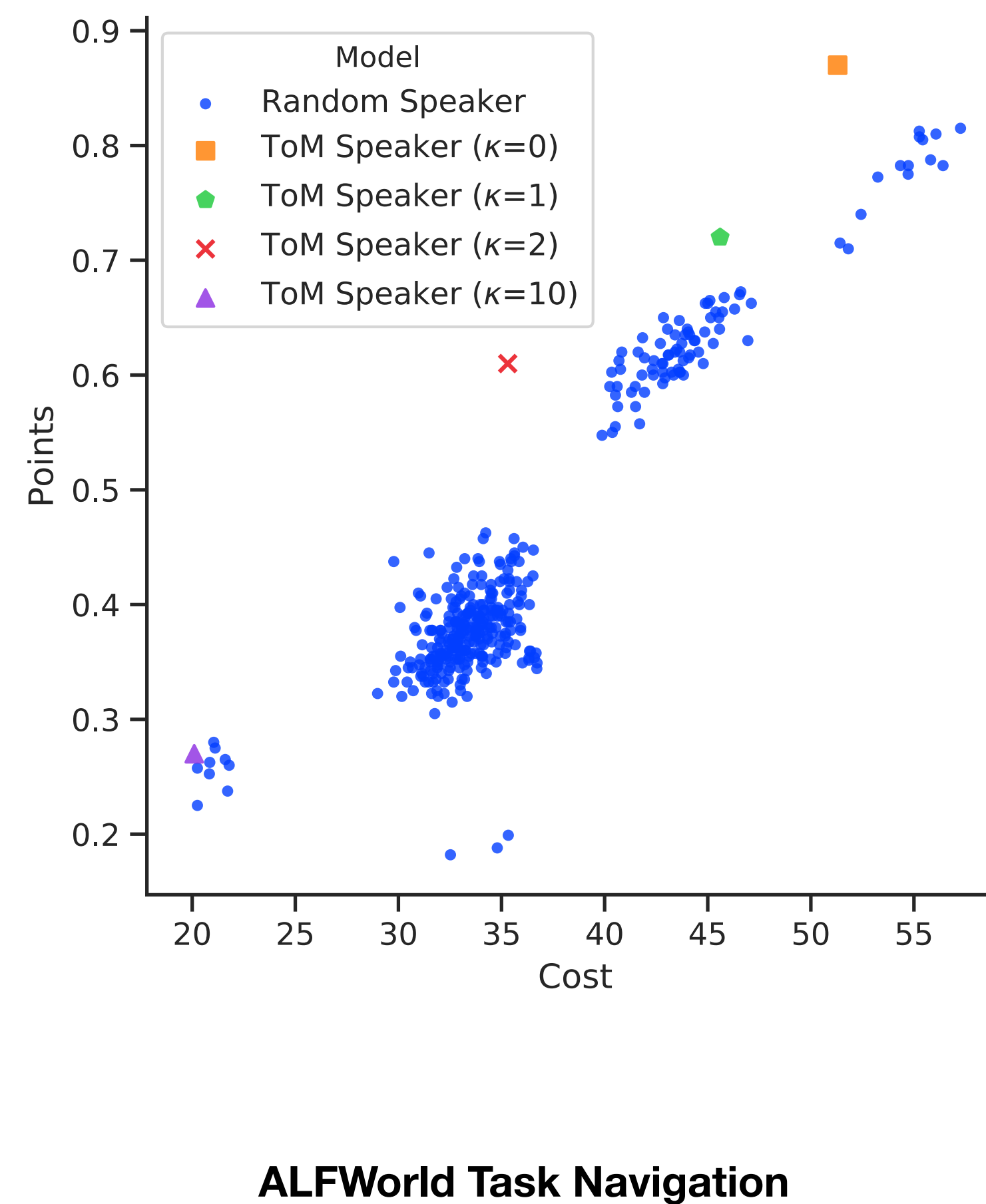
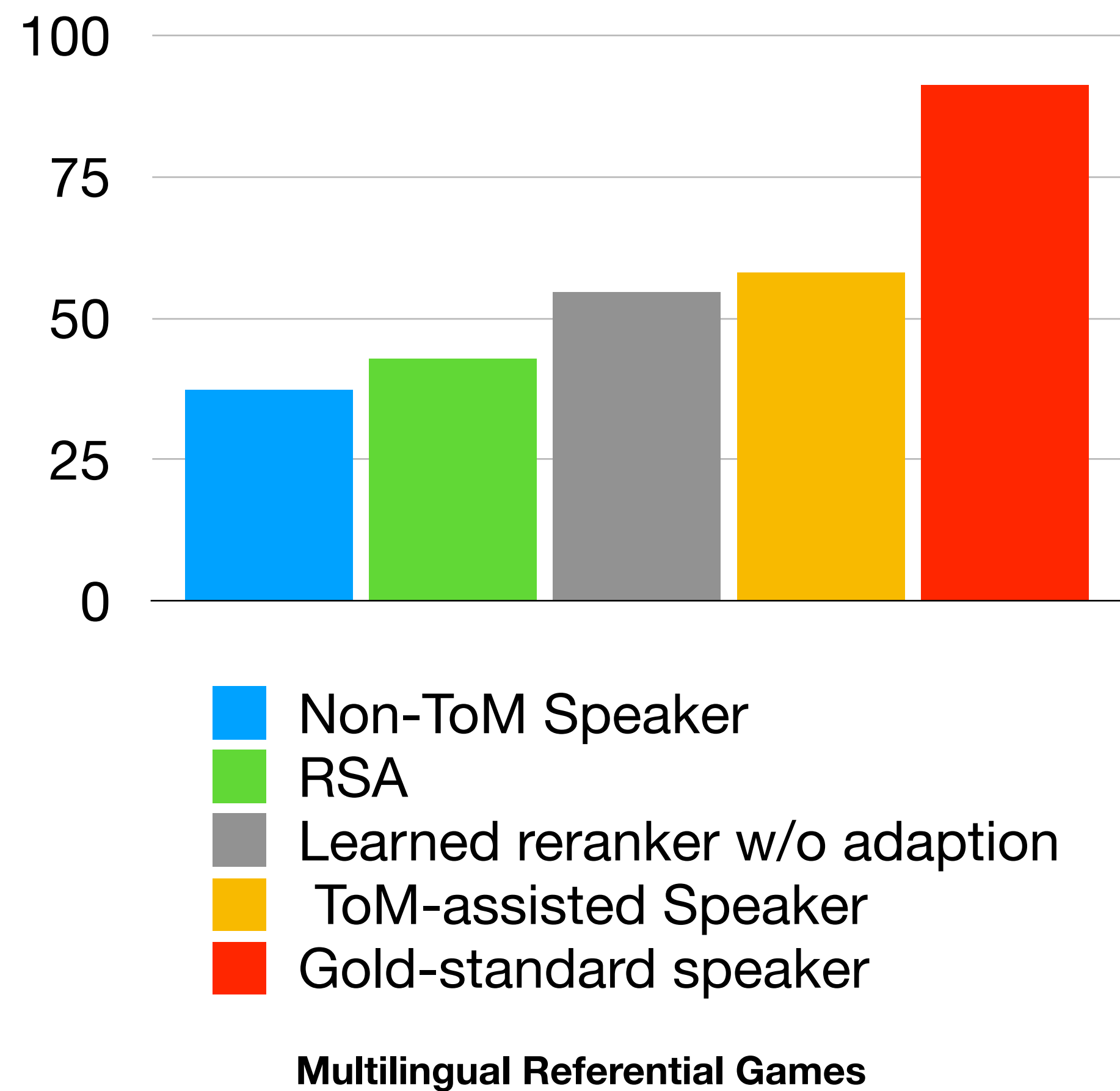


θ_i

Choose the candidate maximizing the probability (modulo cost)



Results



Thank you

<https://github.com/CLAW-Lab/ToM>