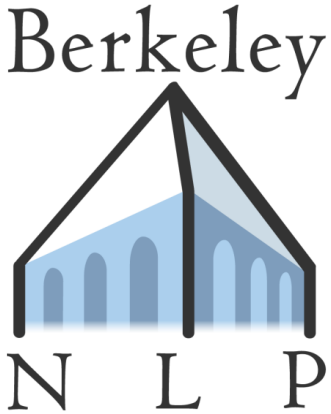
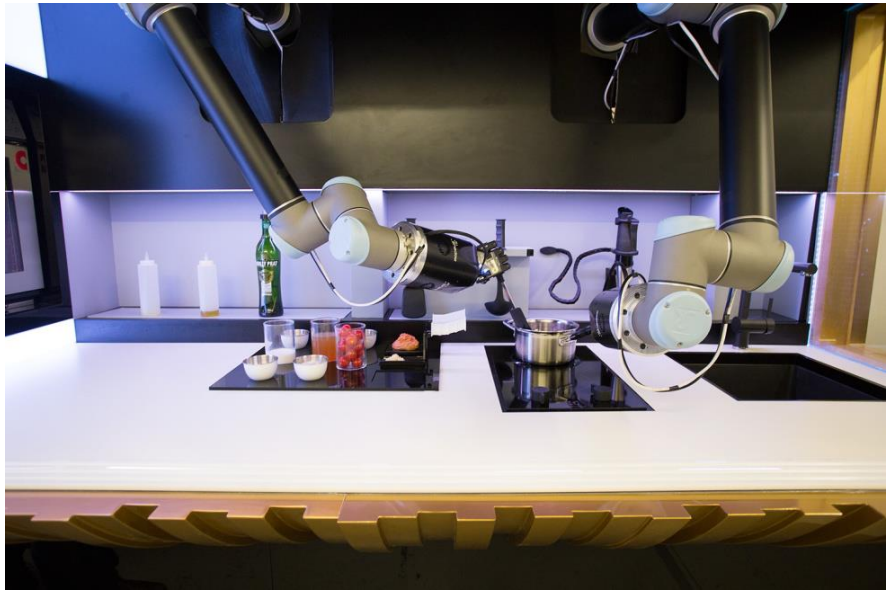
Pragmatic Models for Generating and Following Grounded Instructions



Daniel Fried

with Jacob Andreas, Ronghang Hu, Volkan Cirik, Anna Rohrbach, Sheng Shen,
Louis-Philippe Morency, Taylor Berg-Kirkpatrick, Kate Saenko, Trevor Darrell, and Dan Klein

Grounded Instructions



“Add the tomatoes and mix”

“Take me to the shop on the corner”

Semantics vs. Pragmatics

Semantic Grounding

What things in the world
does language refer to?

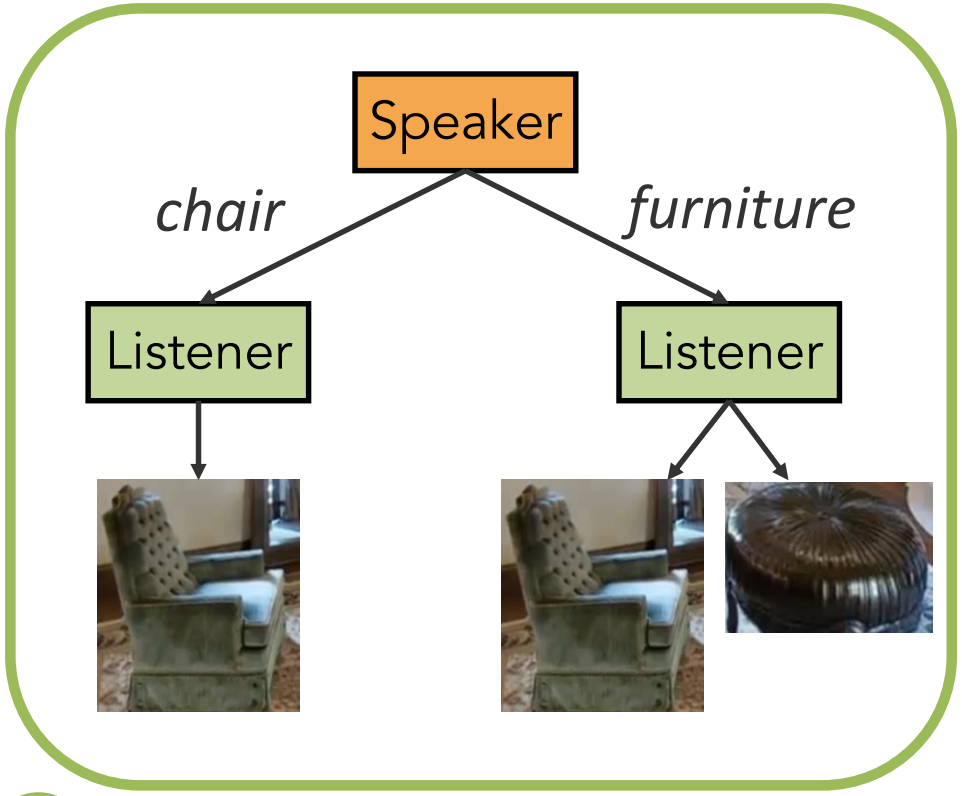
“Go to the chair”

Pragmatic Reasoning

How does context influence
interpretation and action?

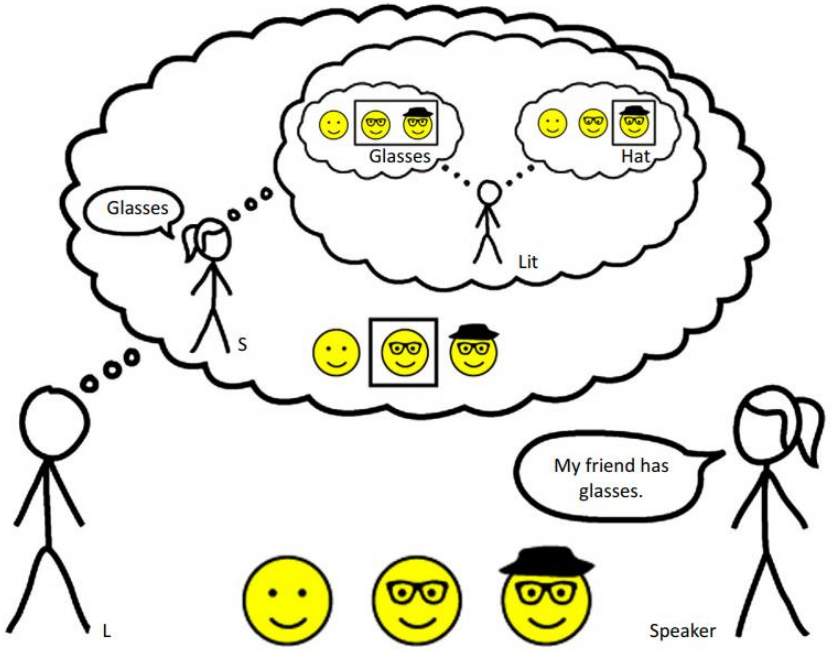
“Go to that piece of furniture”

Pragmatic Reasoning



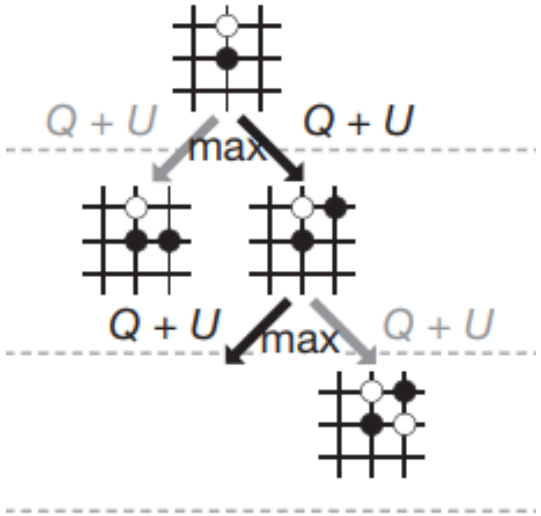
Planning and Predictive Power

RSA: Pragmatic behavior emerges from reasoning about simple agents

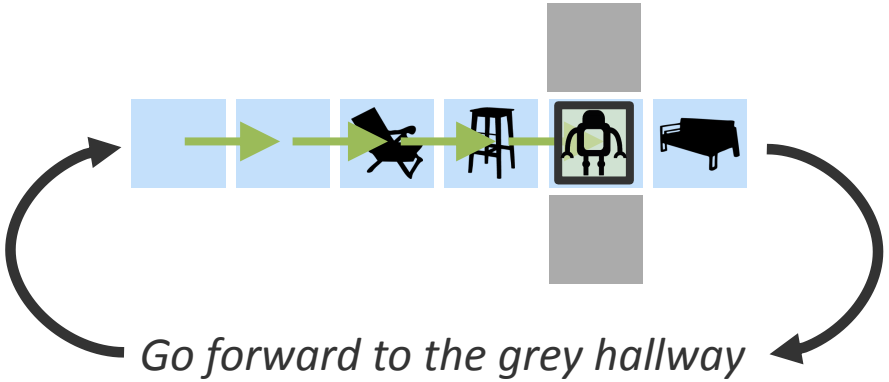


[e.g. Goodman and Frank 2016]

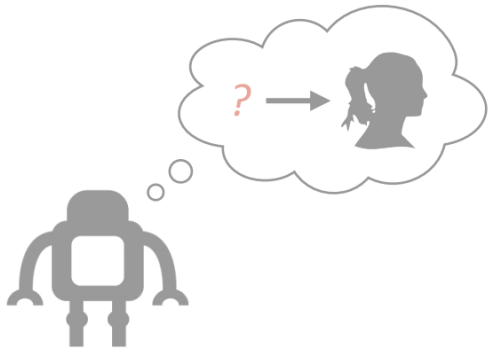
Games and MDPs: (simple) predictors are strengthened by adding search layers



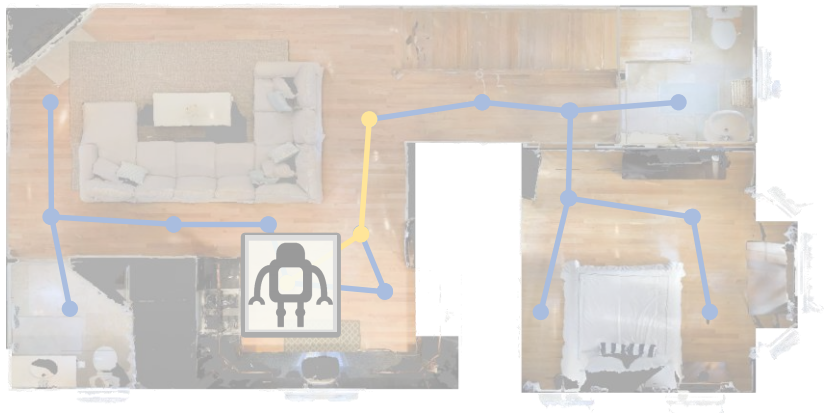
[e.g. Silver et al. 2017]



Semantic Models for Instructions

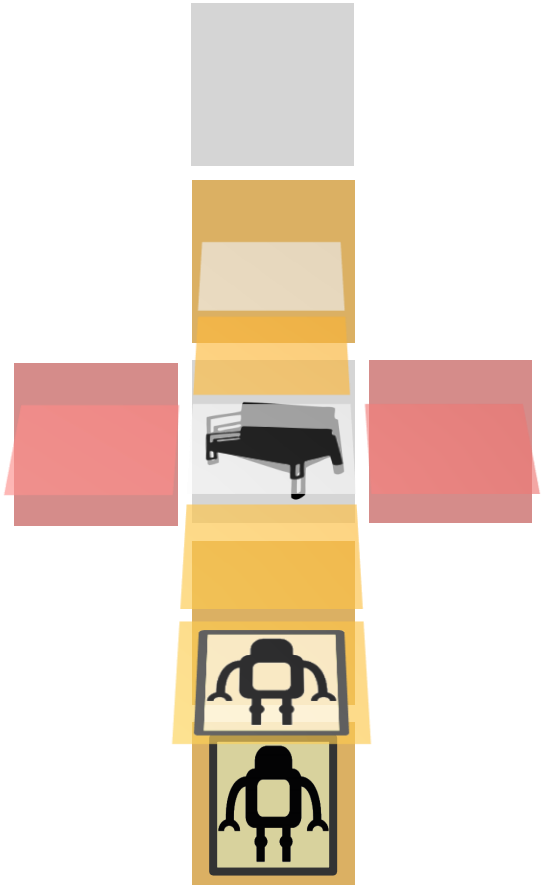


Pragmatic Reasoning



Grounding in the Real World

To Start: Virtual Environments

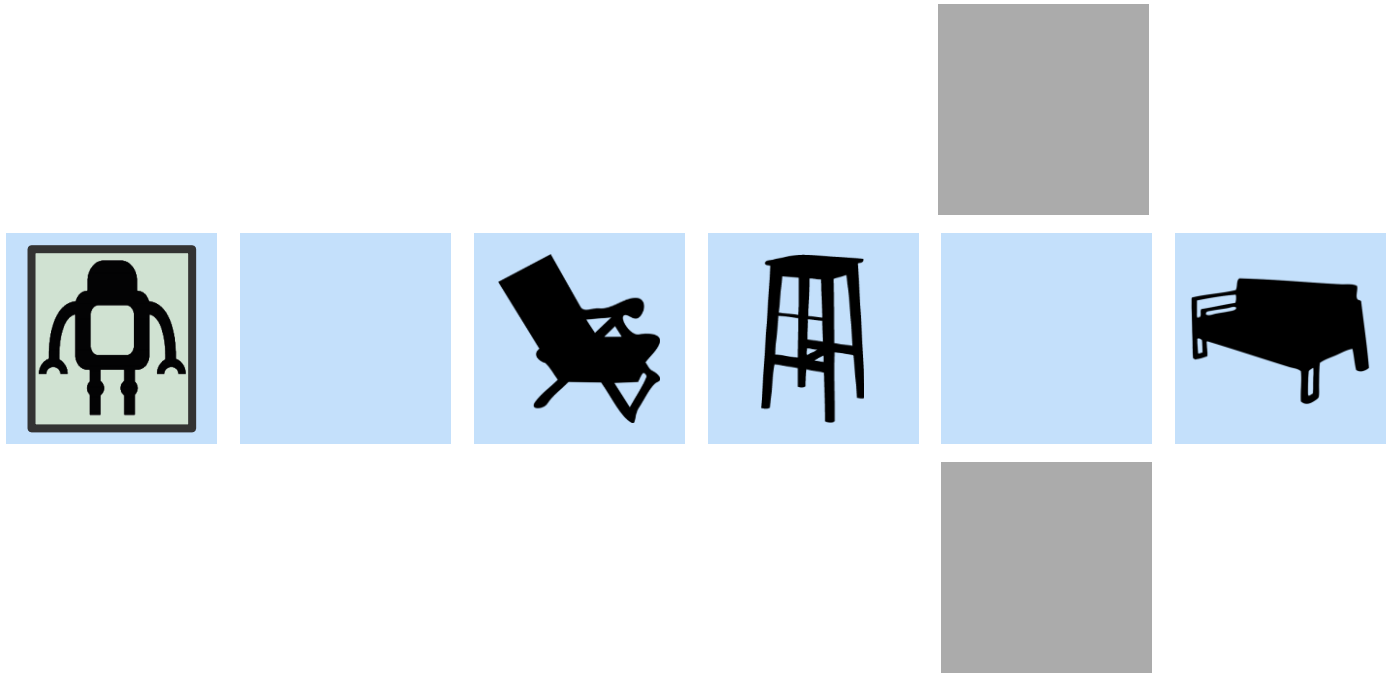


SAIL [MacMahon et al., 2006; Chen and Mooney, 2011]

Interpretation Task

Input instruction: *go forward to the grey hallway*

Output actions:



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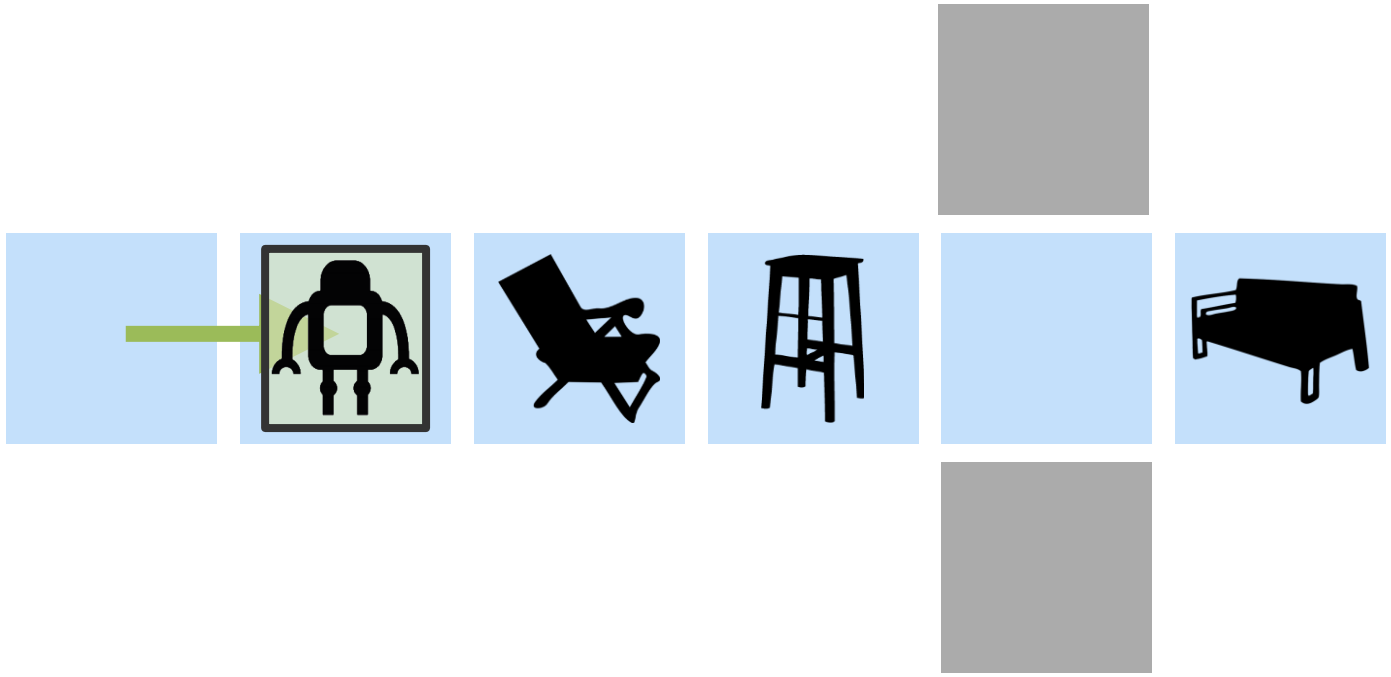

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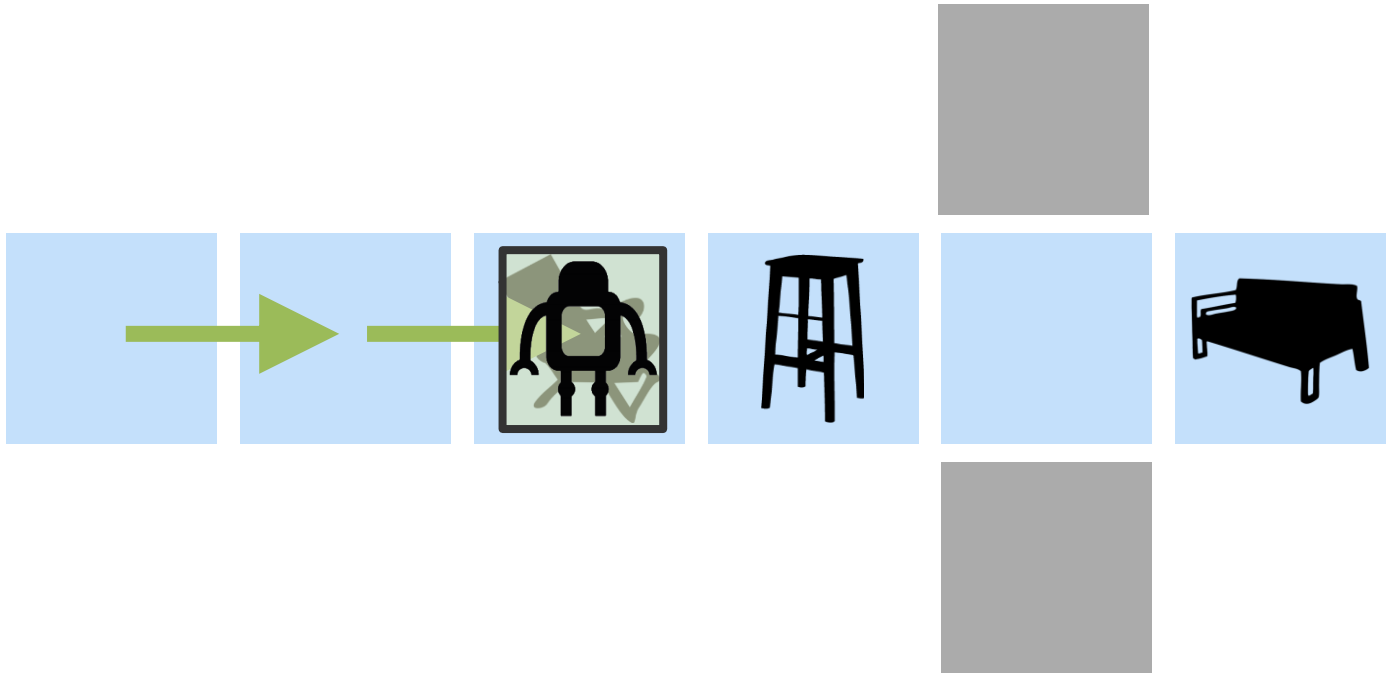

Interpretation Task

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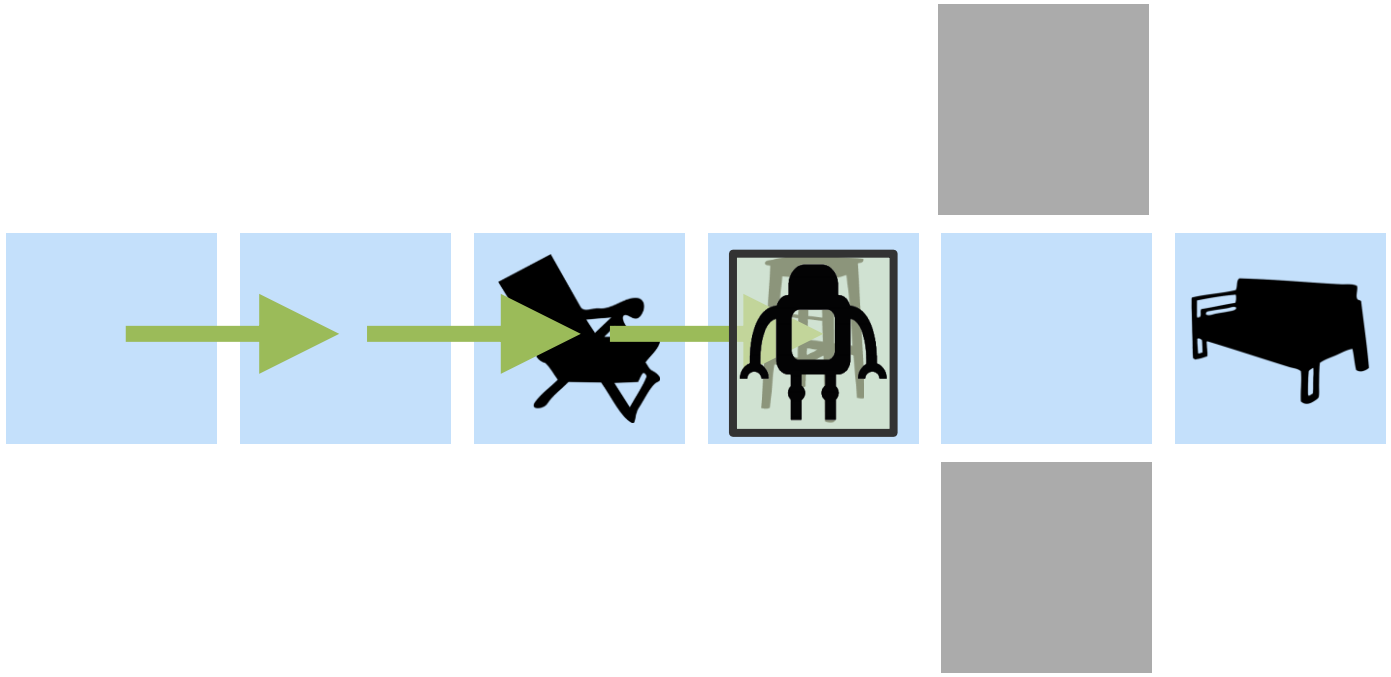

Interpretation Task

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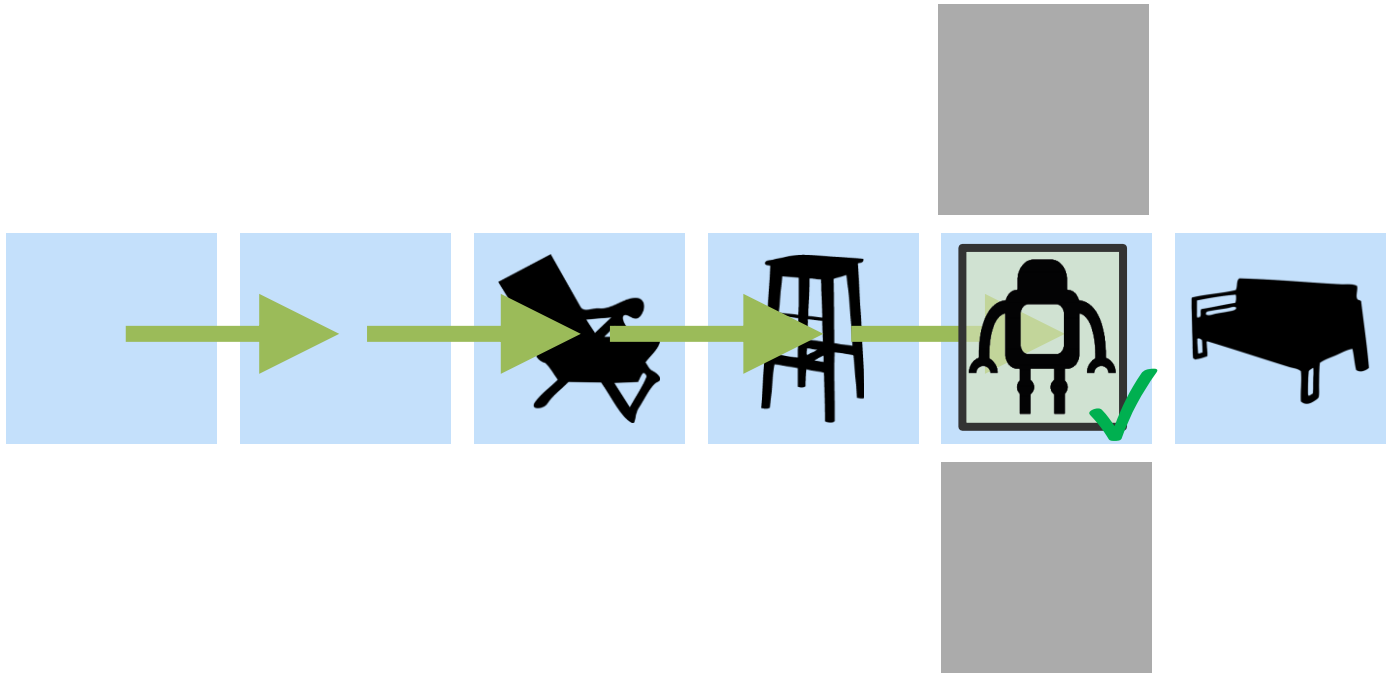
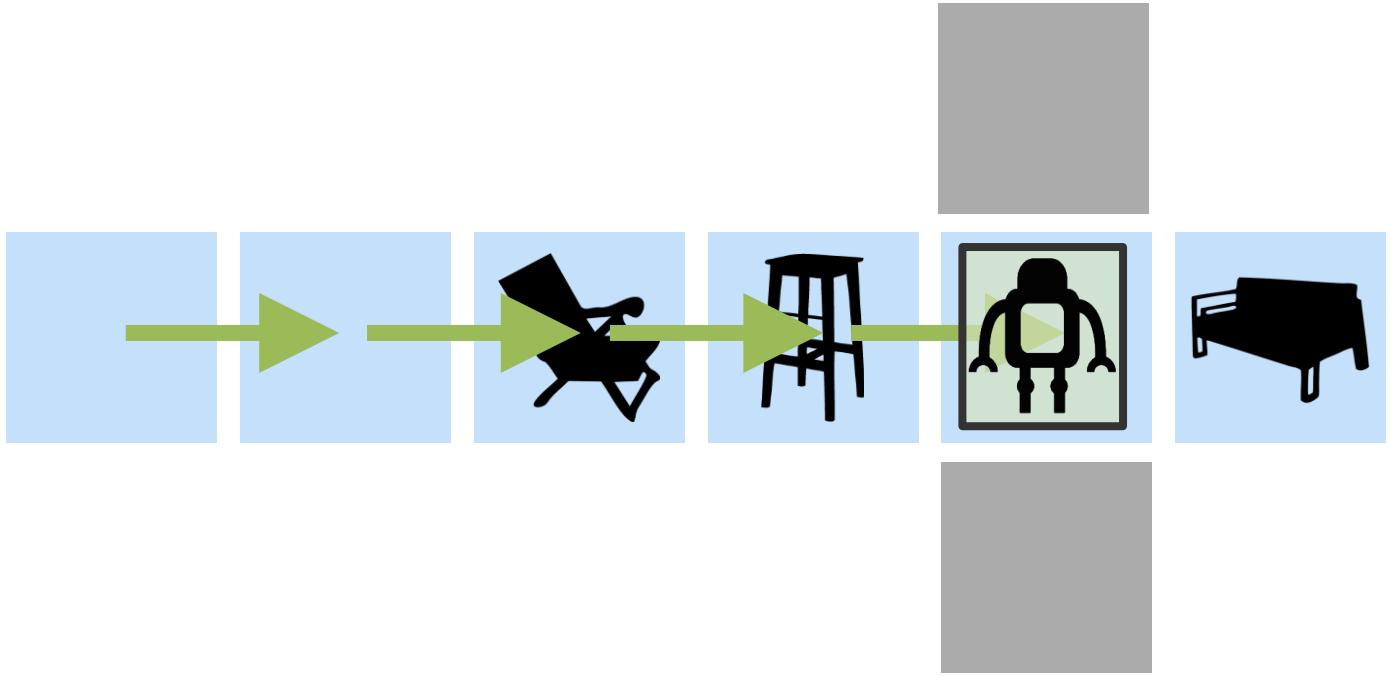


Generation Task

Input actions:



Output Instruction: *go forward to the grey hallway*

Models of Listeners and Speakers

Inputs

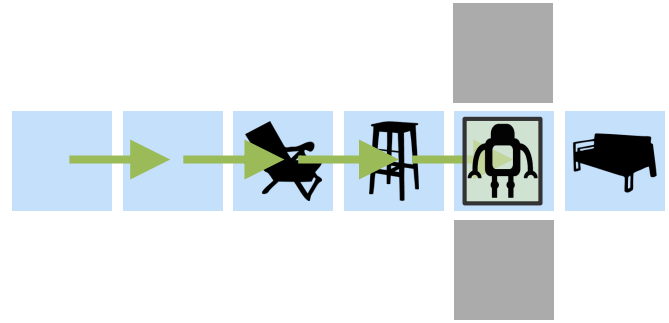
Outputs

go forward to the grey hallway

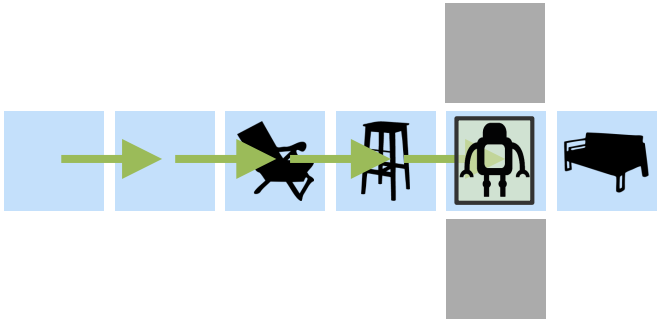
Instruction, i

Listener

$P_L(a \mid i)$



Actions, a



Actions, a

Speaker

$P_S(i \mid a)$

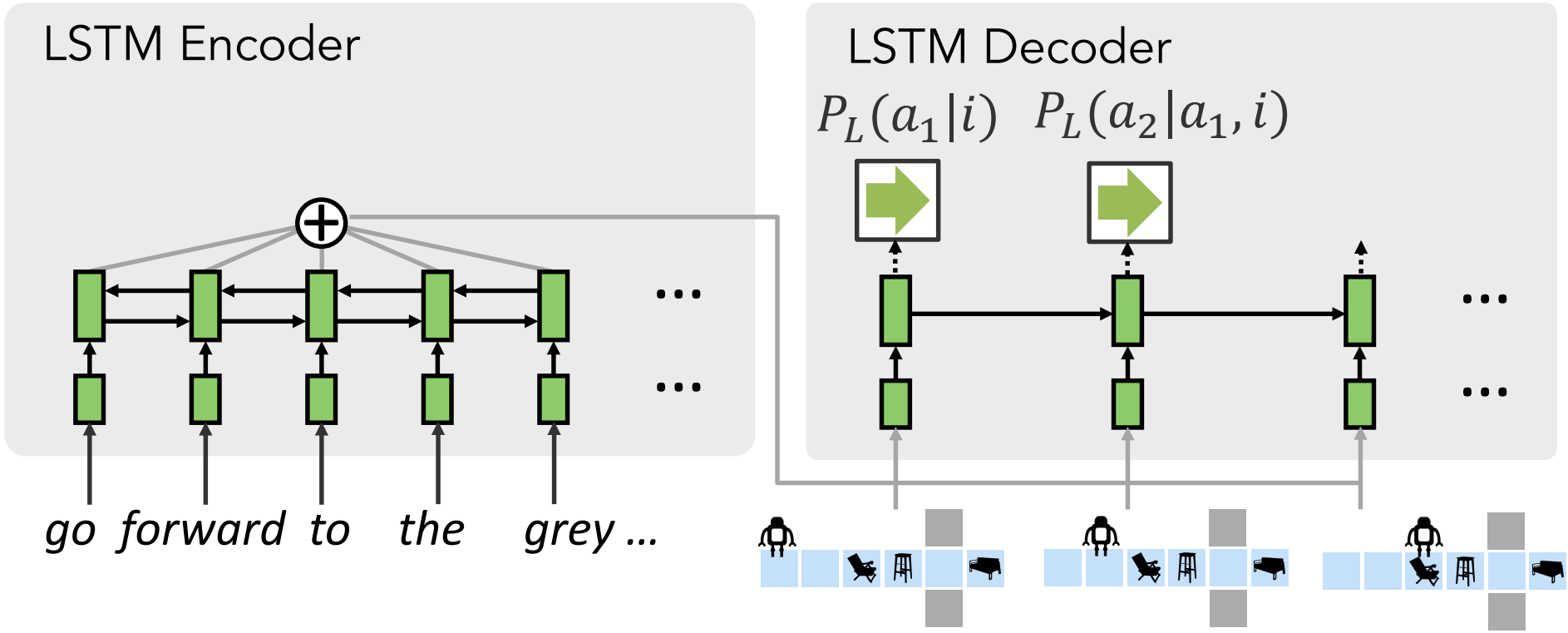
go forward to the grey hallway

Instruction, i

Base Models

Base Listener

$$P_L(a \mid i) = \prod_t P_L(a_t | a_{1:t-1}, i)$$

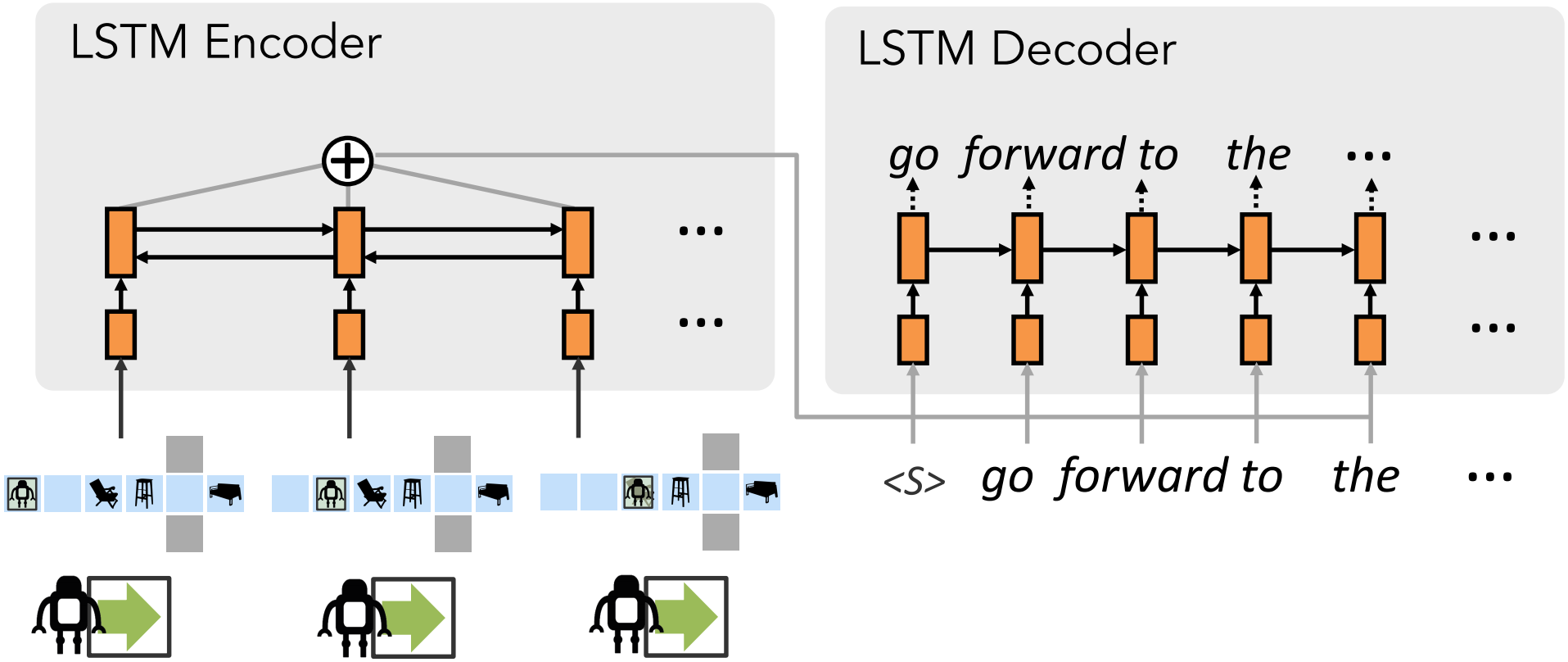


Based on Mei et al. [2016]

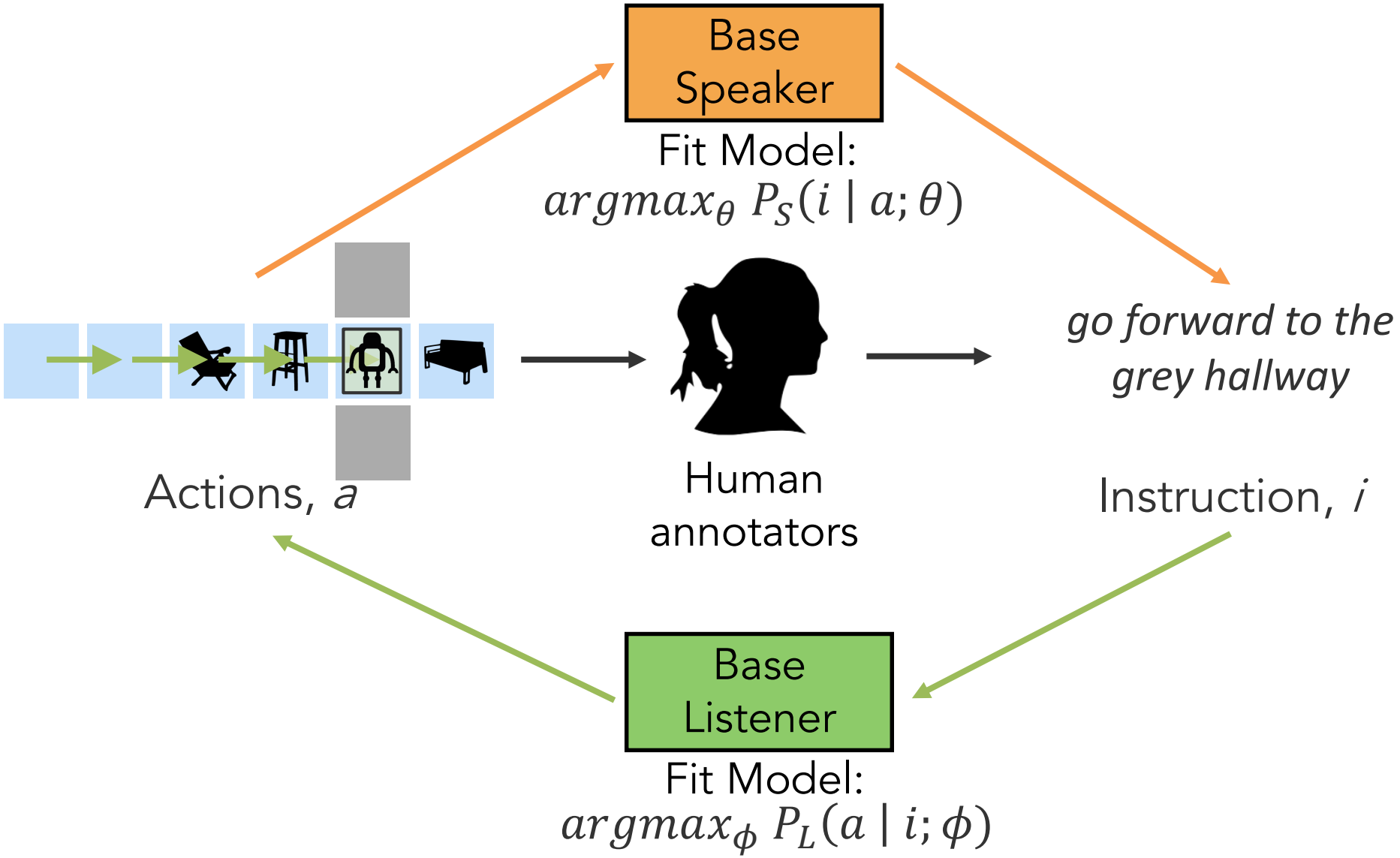
Base Models

Base Speaker

$$P_S(i \mid a) = \prod_t P_S(i_t | i_{1:t-1}, a)$$



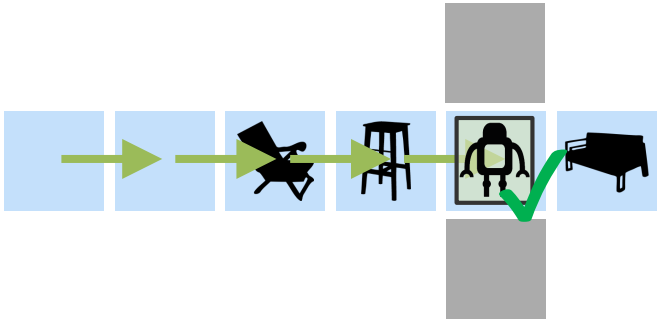
Training Models on Human Instructions



Listener Tasks

SAIL navigation [MacMahon et al., 2006; Chen and Mooney, 2011]

go forward to the grey hallway → Listener →

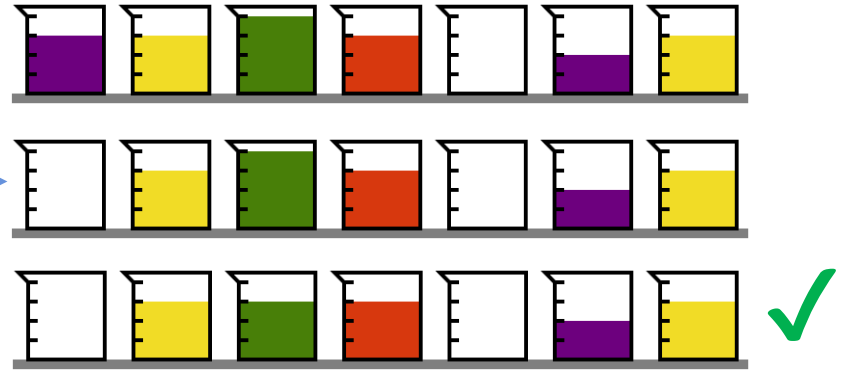


Sequential Context-dependent Execution (SCONE) [Long et al. 2016]

Alchemy task

1. remove all the purple chemical from the beaker on the far left
2. do the same with one unit of green chemical

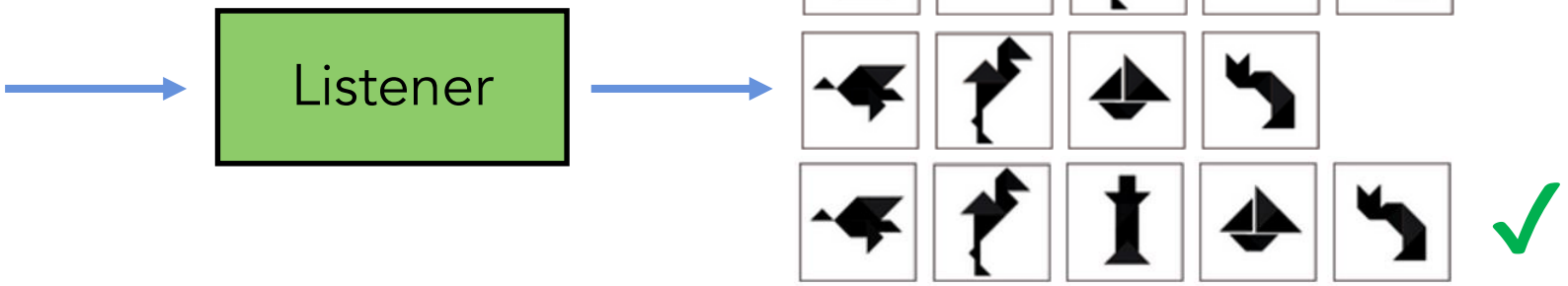
→ Listener →



Listener Tasks

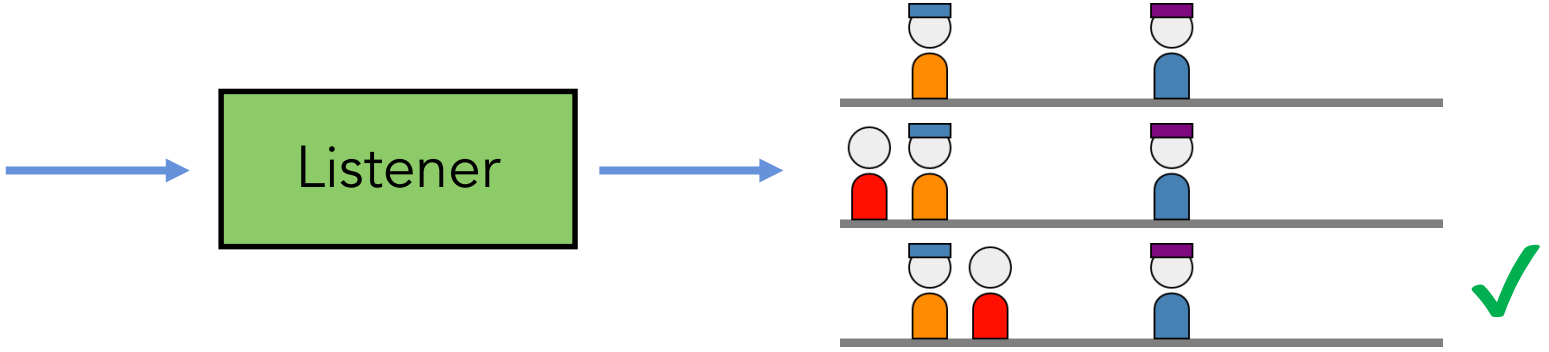
SCONE, Tangrams task

1. remove first figure
2. add it back into middle spot

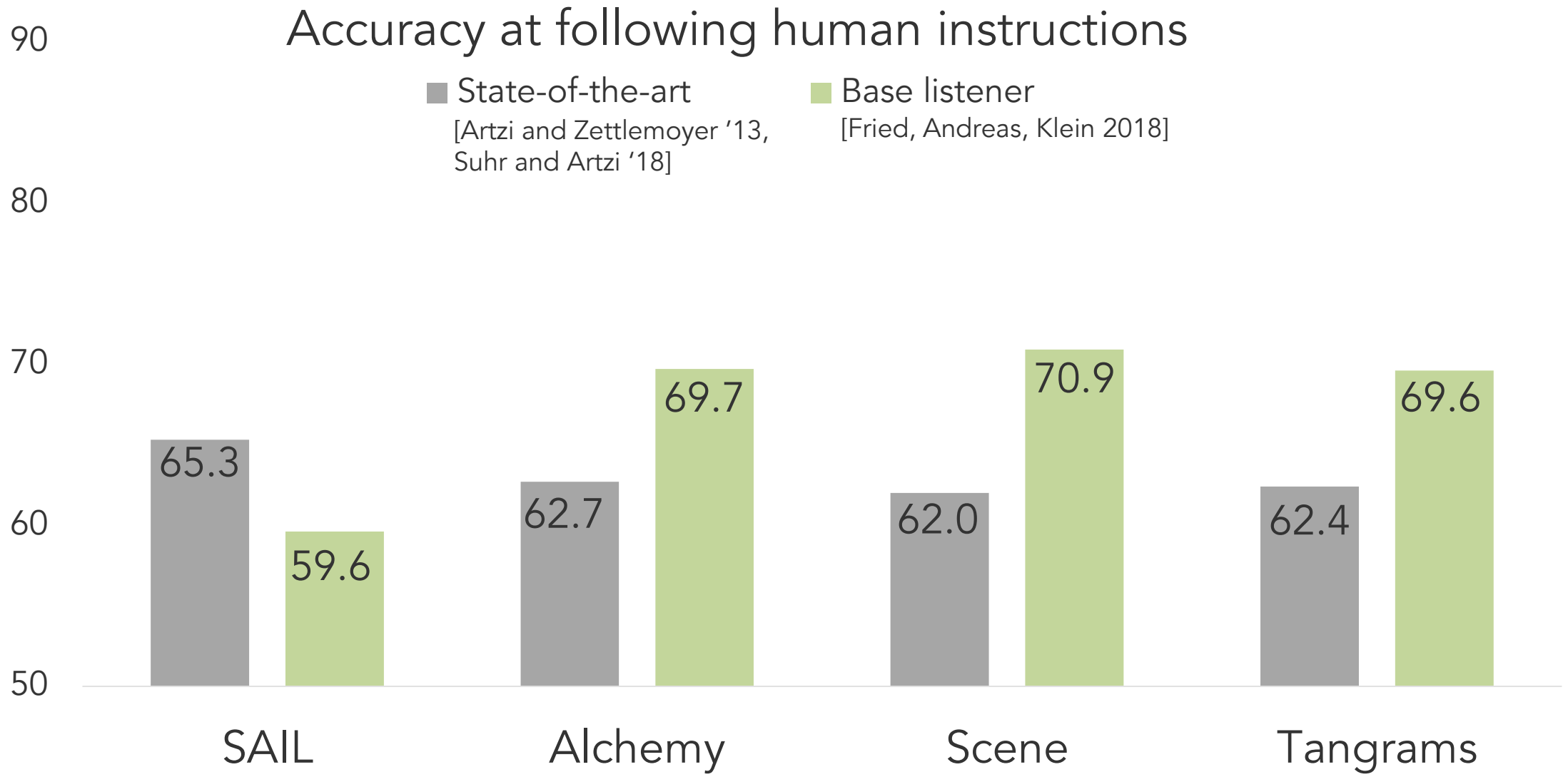


SCONE, Scene task

1. a red guy appears on the far left
2. then to orange's other side



Strong Base Listeners

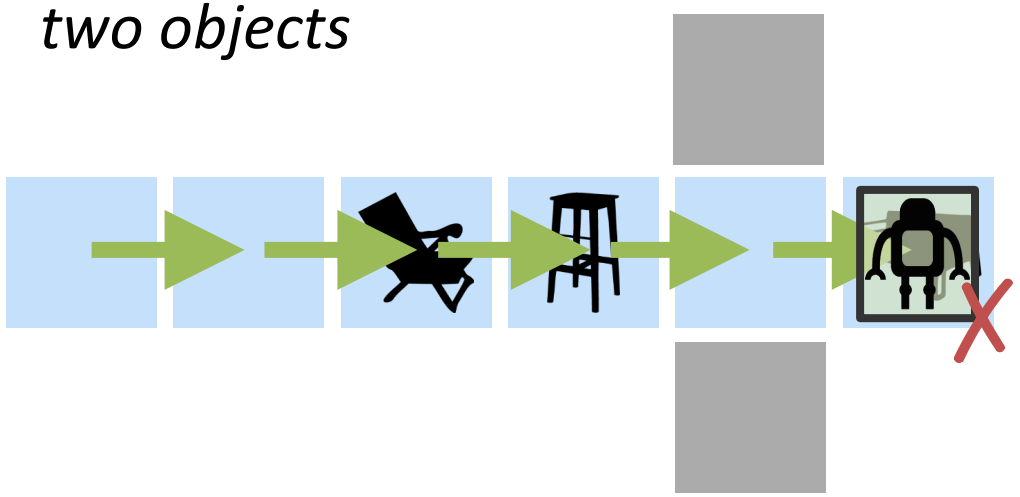


A Failure Mode: Ambiguity

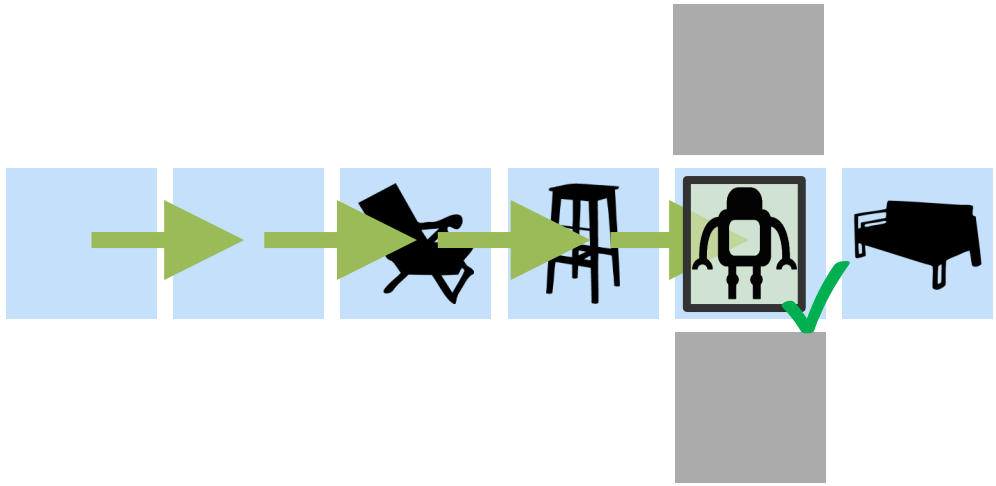
Instruction

walk along the blue carpet and you pass two objects

Base Listener

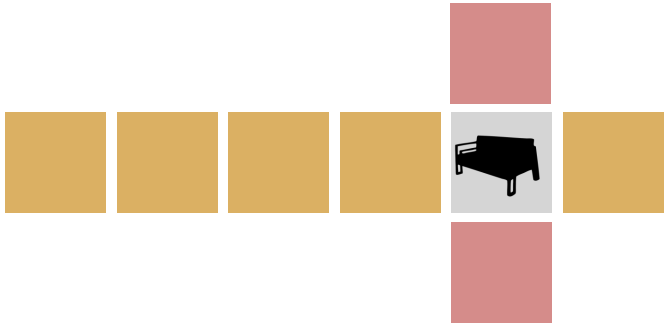


Correct



Speaker Task and Evaluation

Speaker produces an instruction



Speaker

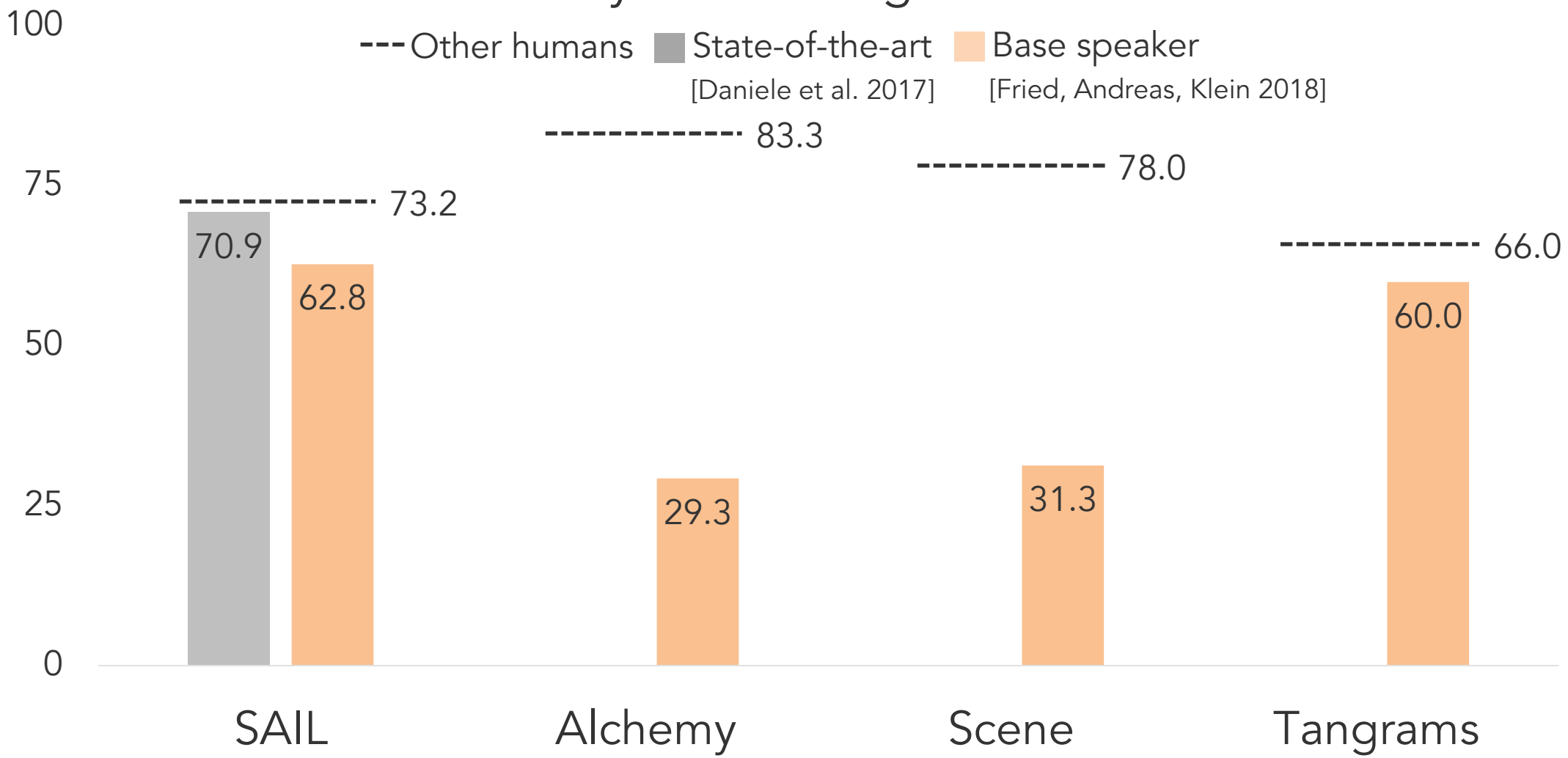
walk along the wood path to the chair

Humans try to interpret it

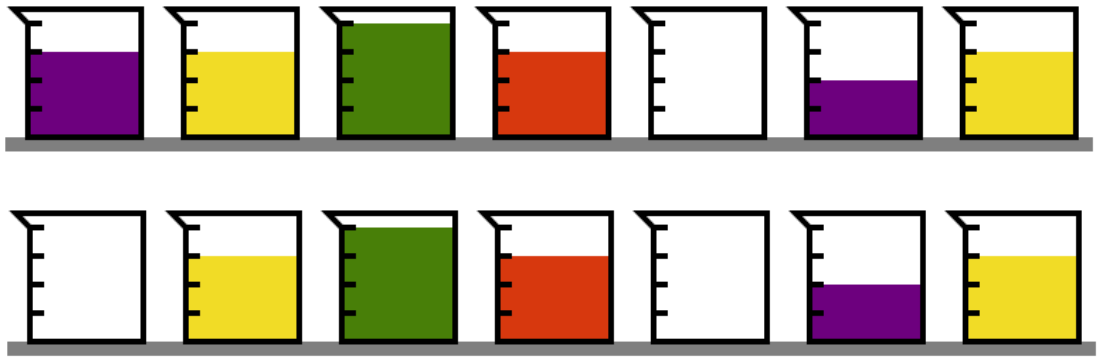
walk along the wood path to the chair

Human direction followers (MTurk)

Generation is Hard to Imitate!



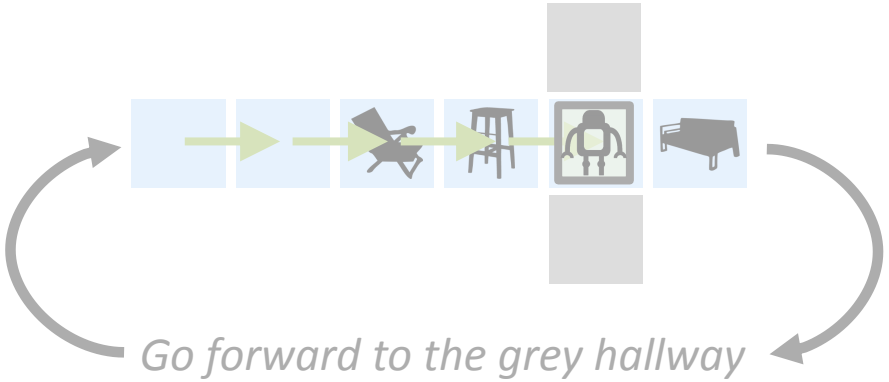
Ambiguity Strikes Again



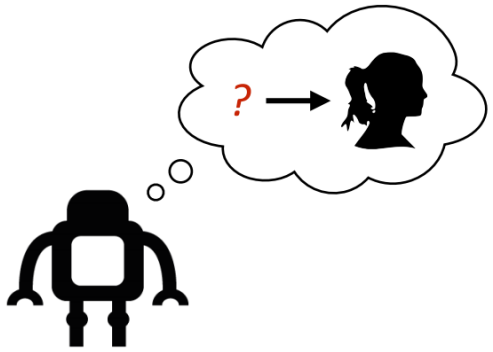
Base Speaker

throw out the purple chemical

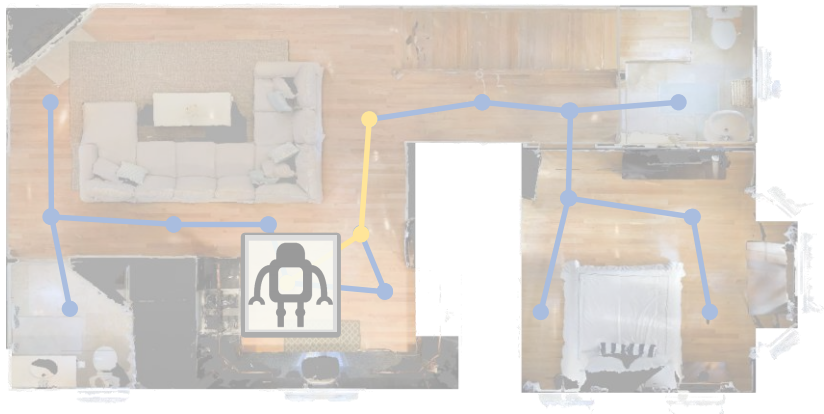
✗



Semantic Models for Instructions



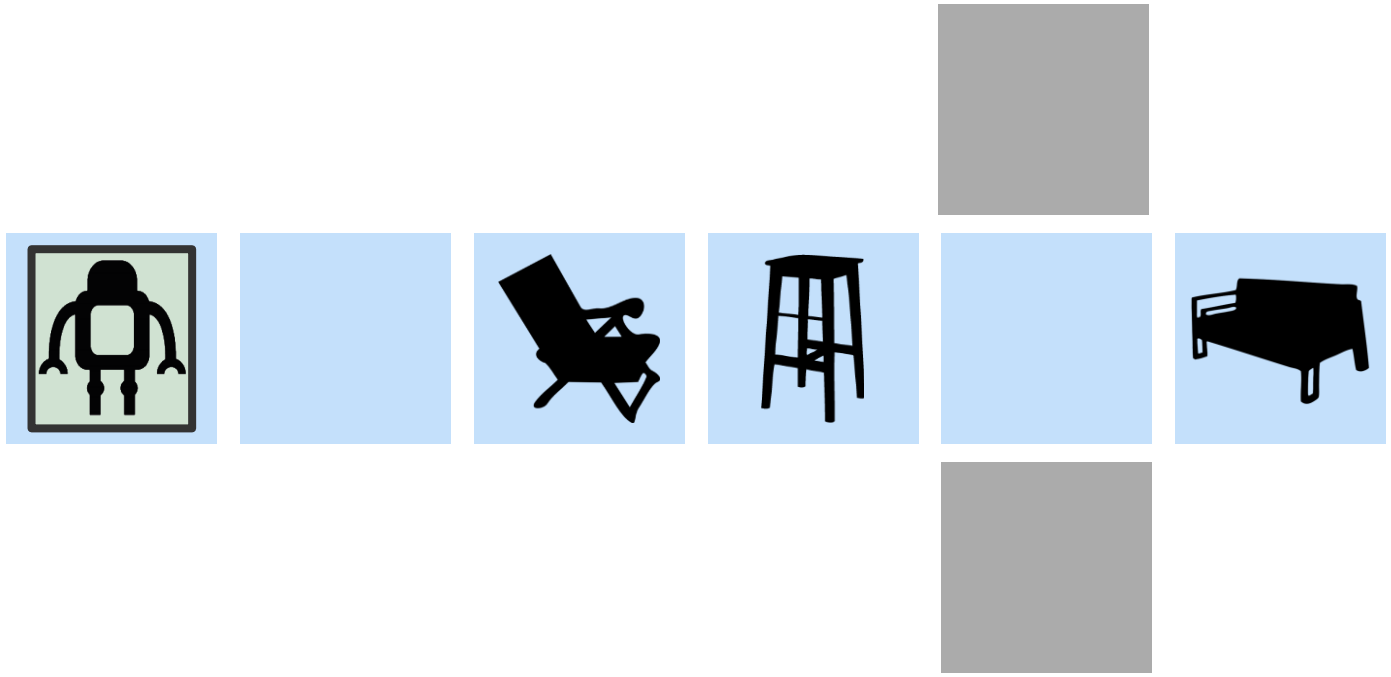
Pragmatic Reasoning



Grounding in the Real World

Interpreting Ambiguity

Instruction: *walk along the blue carpet and you pass two objects*



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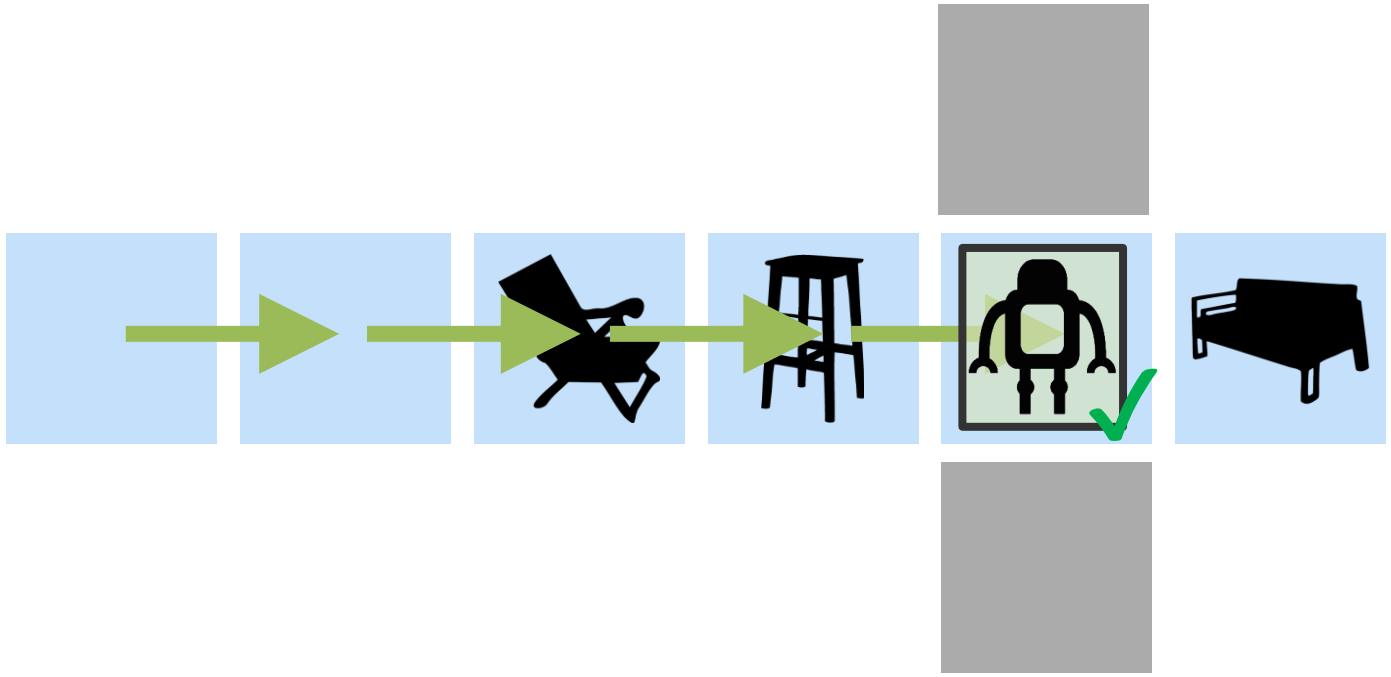

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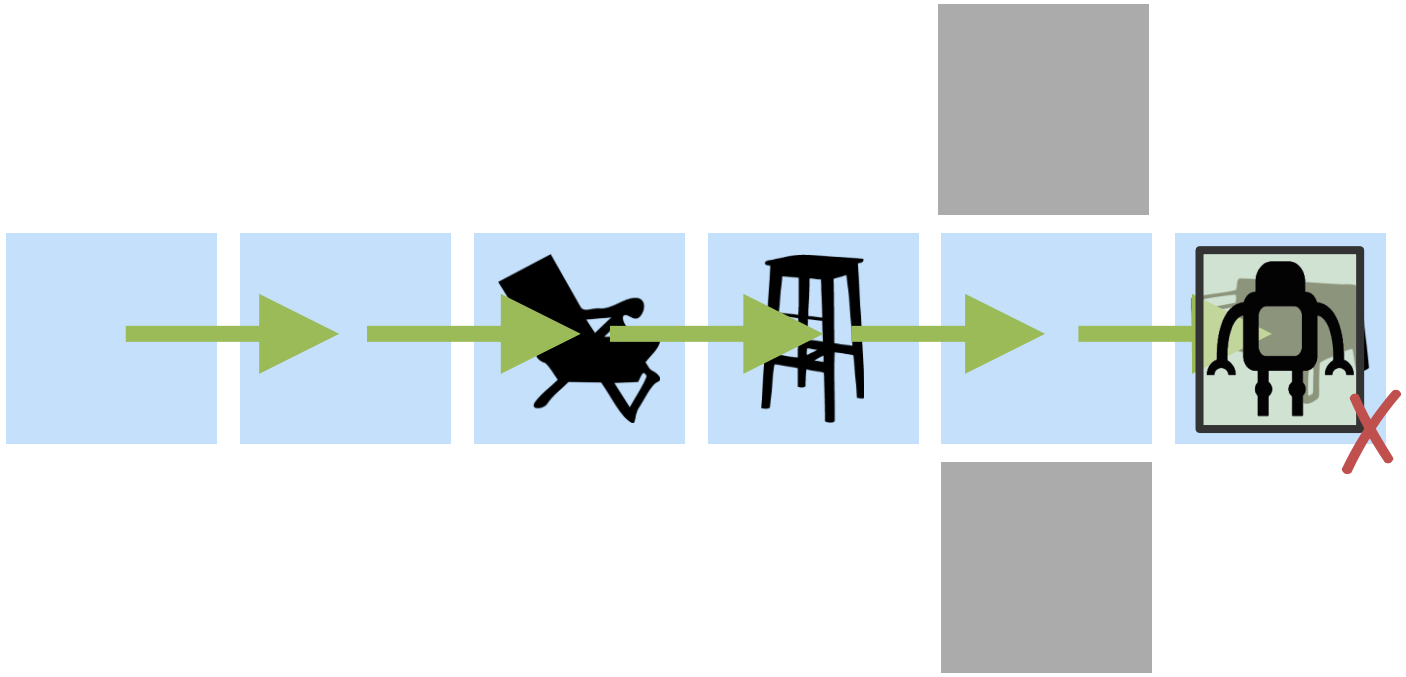

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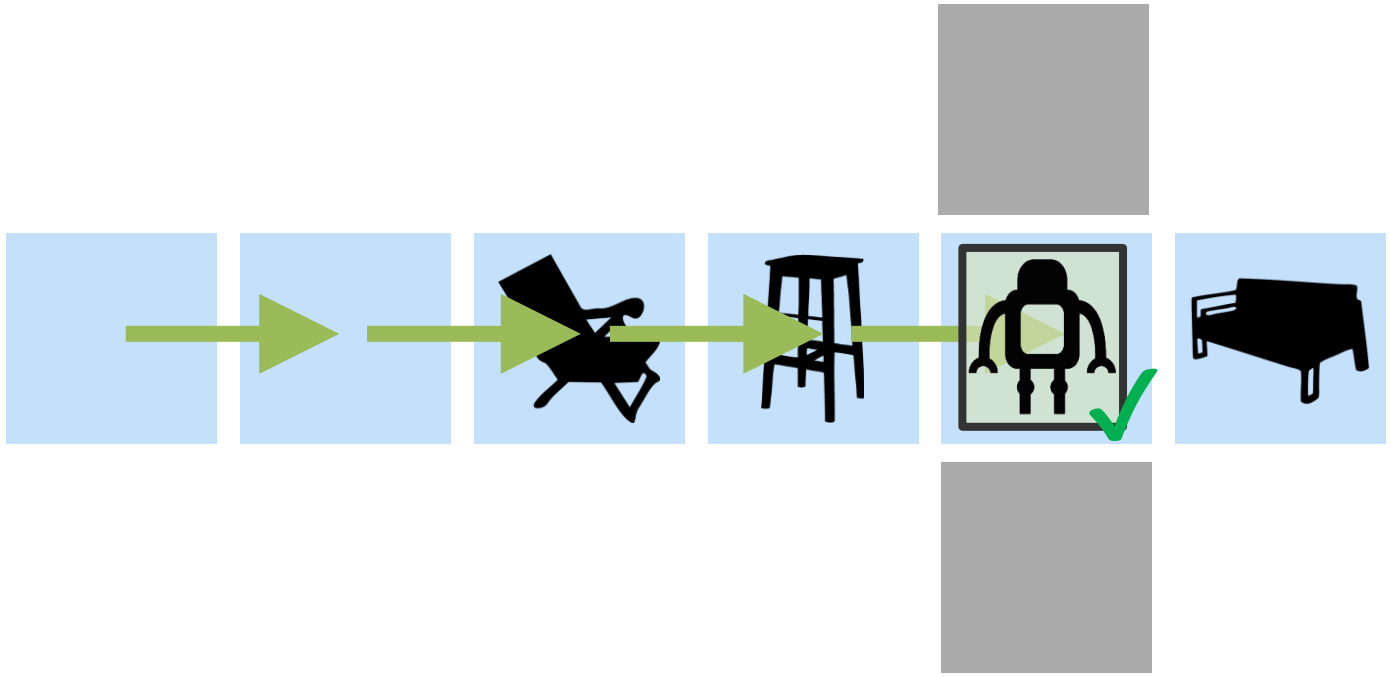
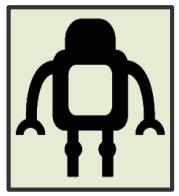


Listener: Reasoning About Routes

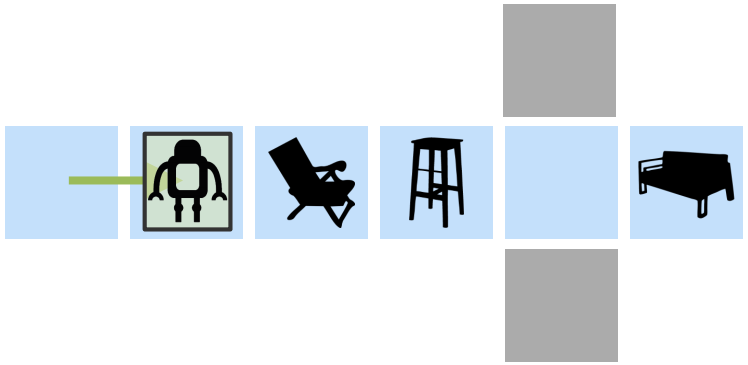
?

walk along the blue carpet and you pass two objects

walk along the blue carpet and you pass two objects



Listener: Reasoning About Routes



walk along the blue carpet and you pass two objects

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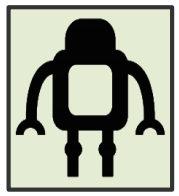
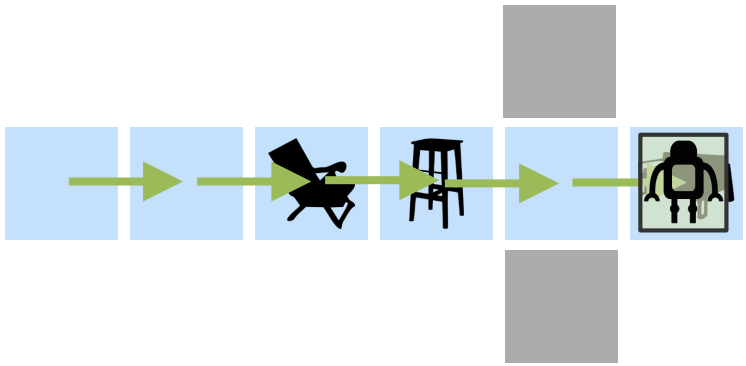


Listener: Reasoning About Routes



walk along the blue carpet and you pass two objects

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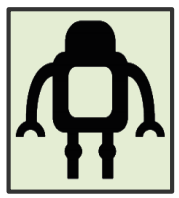
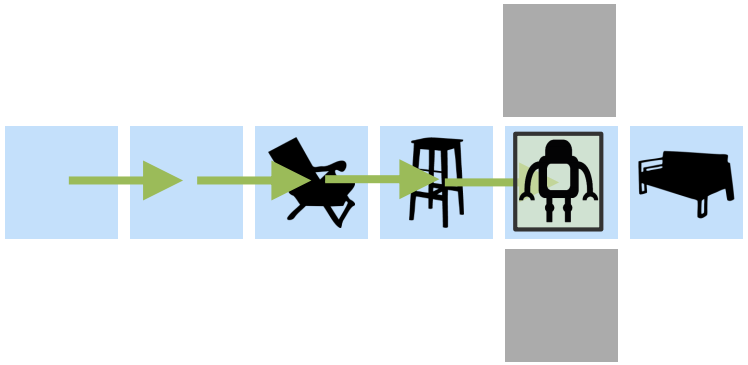


Listener: Reasoning About Routes



walk along the blue carpet and you pass two objects

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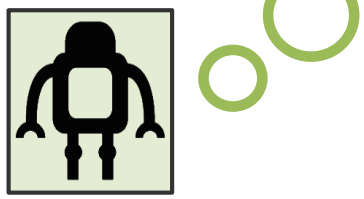
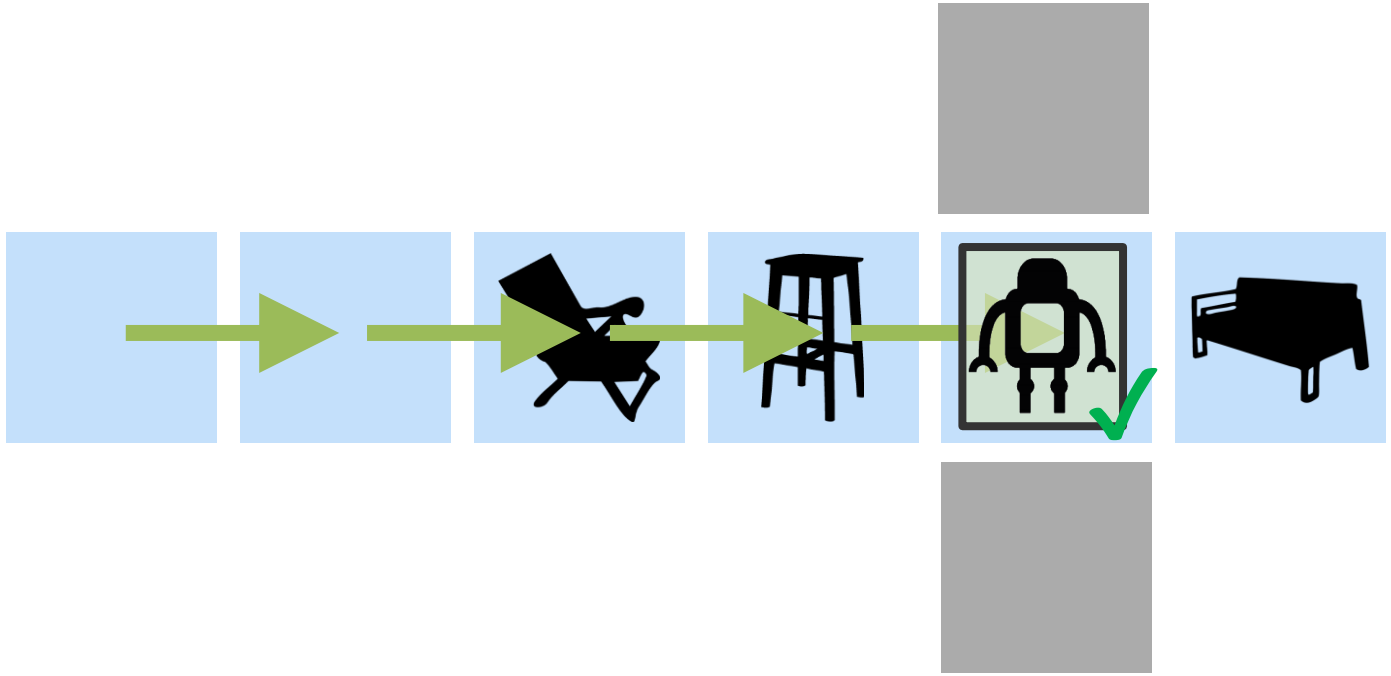
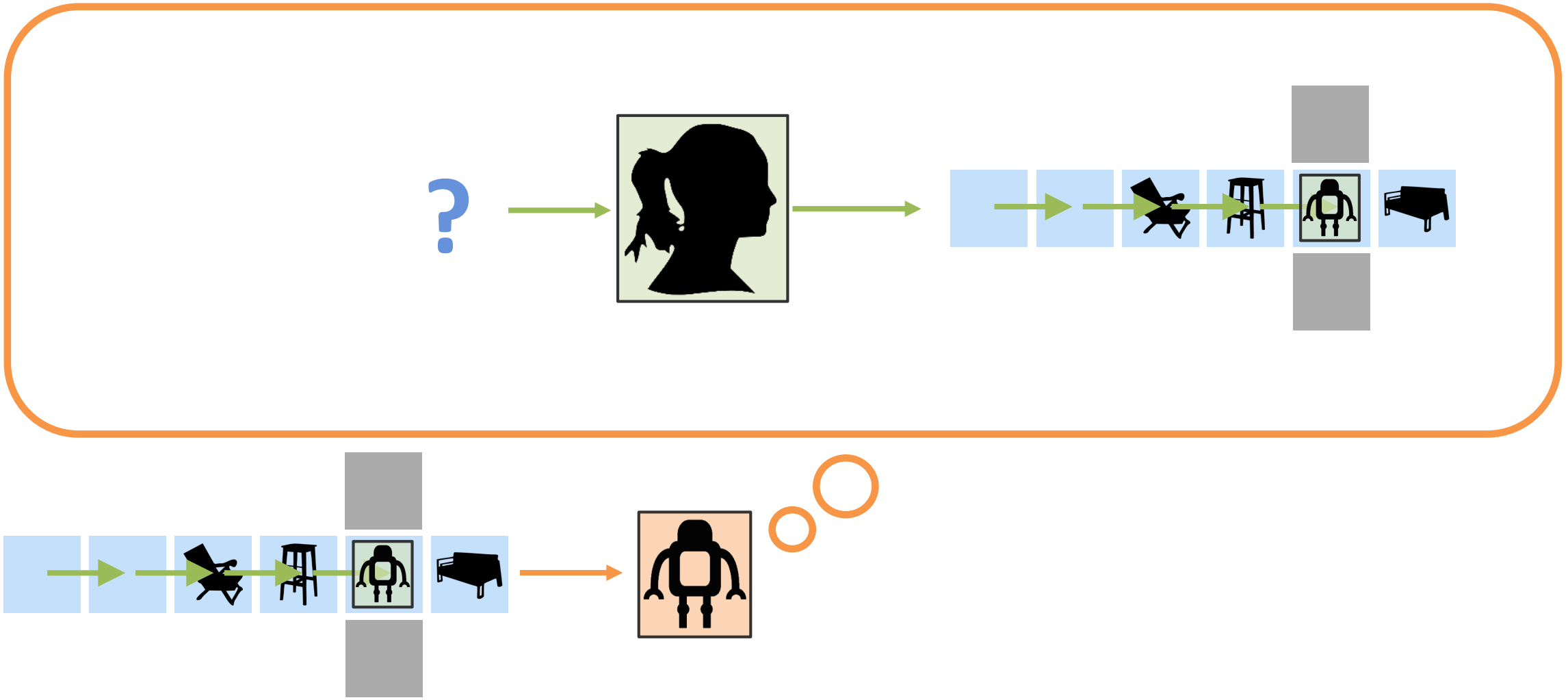


Generating Instructions



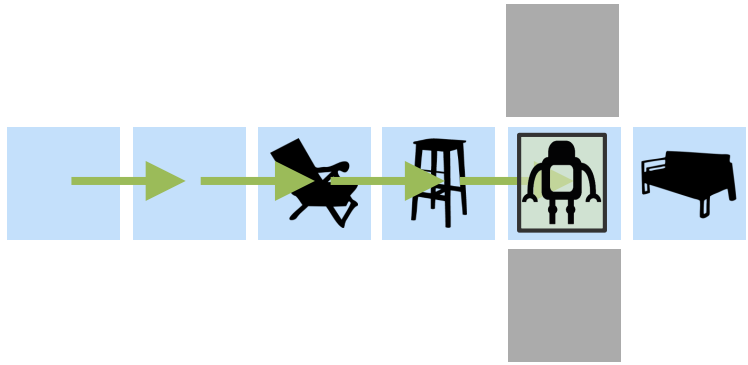
Generated Instruction: *go forward four segments to the intersection with the bare concrete hall*

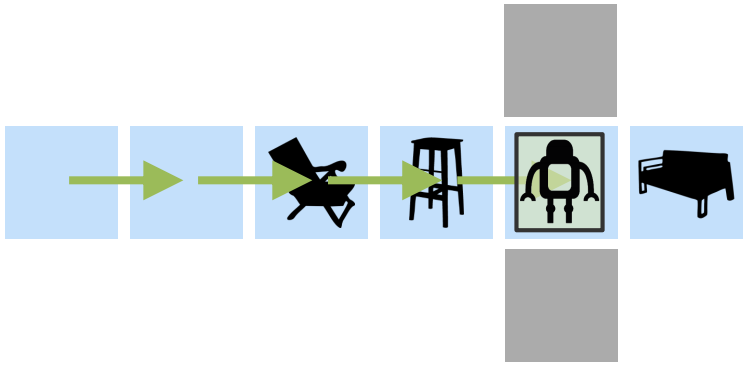
Speaker: Reasoning About Interpretation

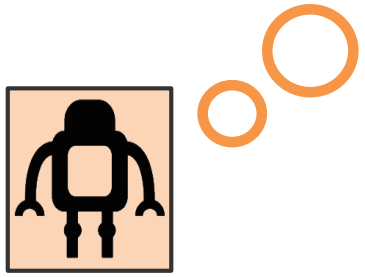


Speaker: Reasoning About Interpretation

go forward four segments to the intersection with the bare concrete hall







Explicit Pragmatic Reasoning

Interpretation

"blue"

Frank and Goodman, 2012;
Goodman and Stühlmuller, 2013;
Wang et al., 2016

Generation

"The sun is in the sky"

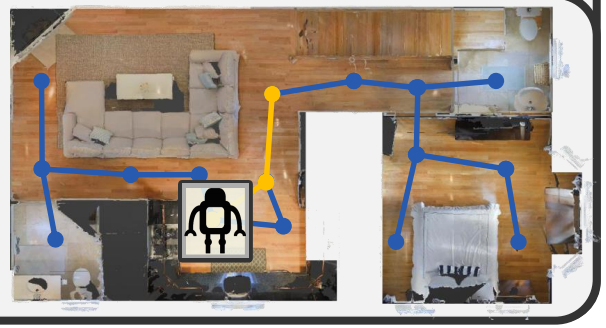
Golland et al., 2010;
Monroe and Potts, 2015; Mao et al., 2016; Cohn-Gordon et al. 2018…

Both

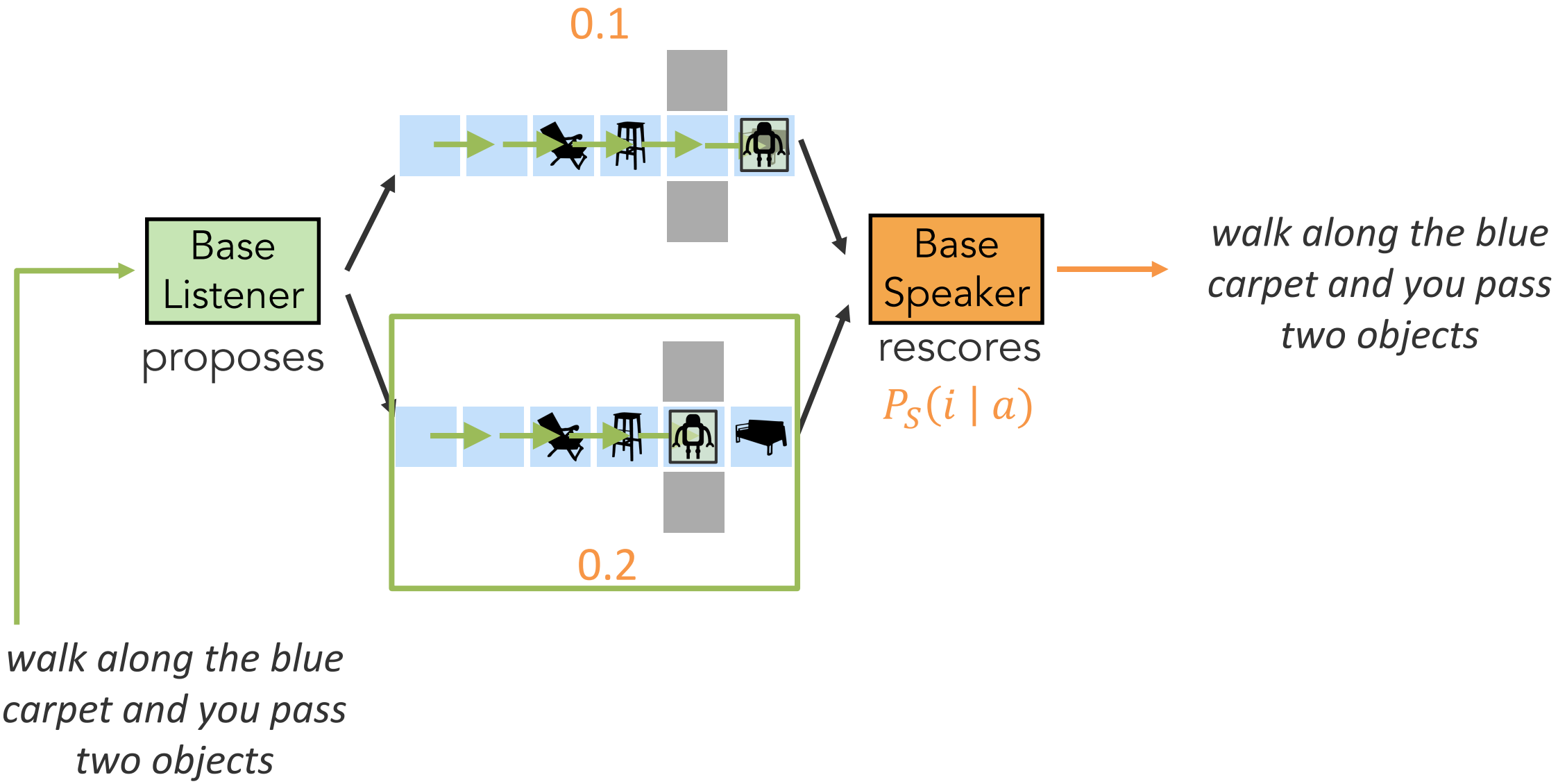
Monroe et al. 2017,
Khani et al. 2018

Our work

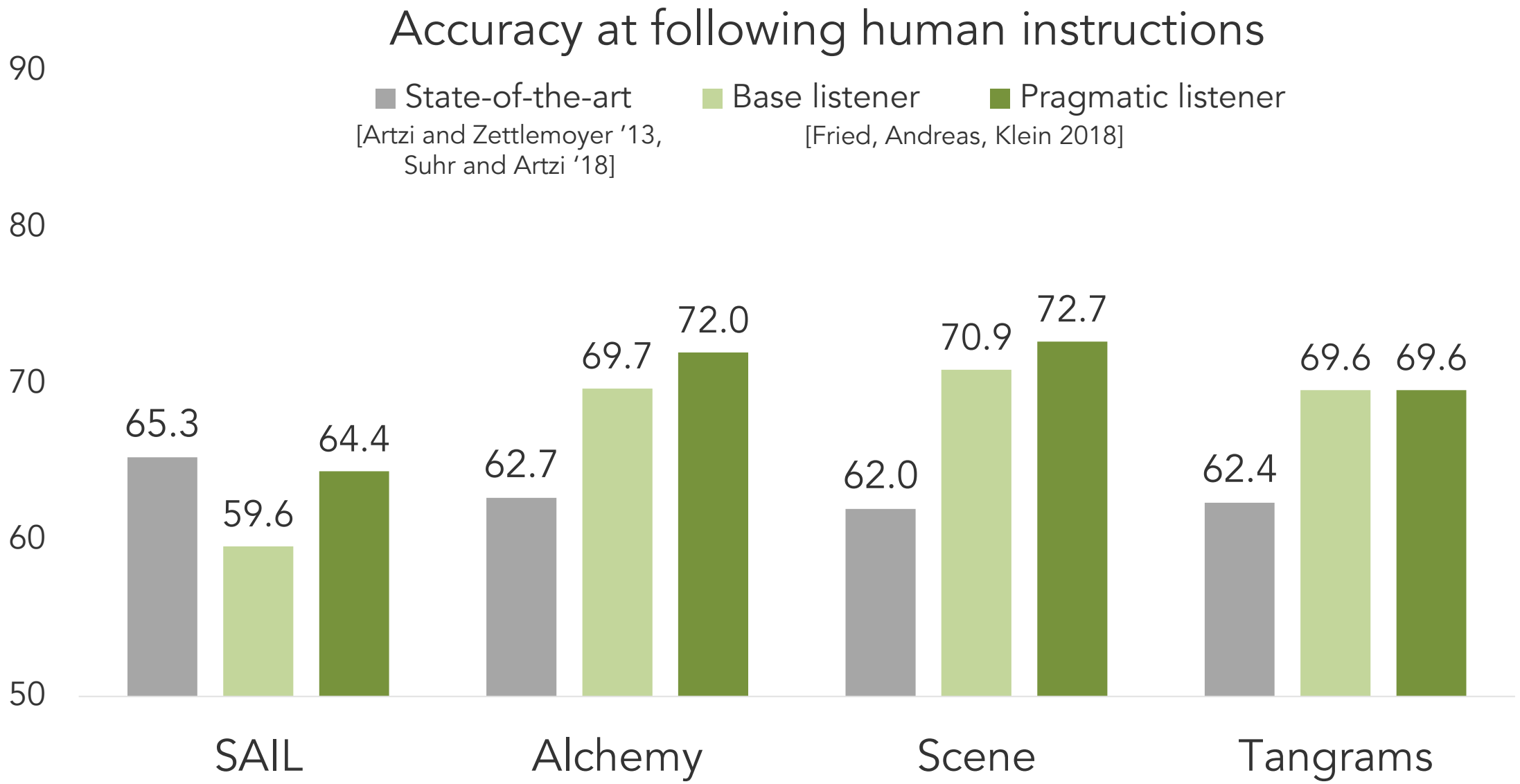
Large, structured domains



Building a Pragmatic Listener



Listener Results

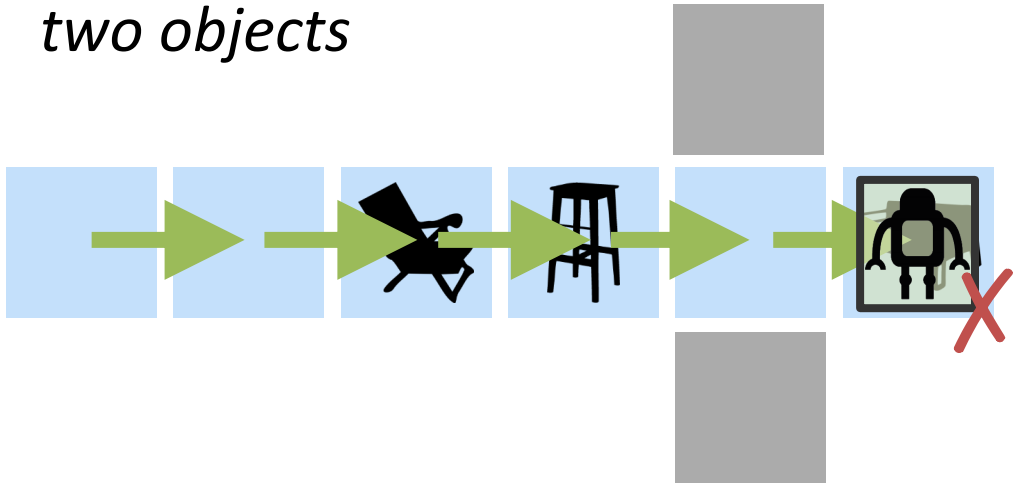


Listener Examples

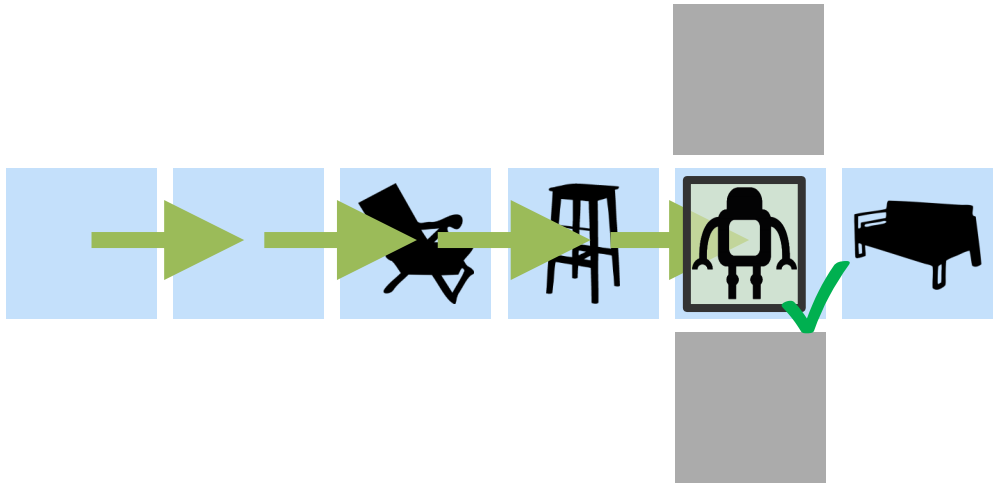
Instruction

walk along the blue carpet and you pass two objects

Base Listener

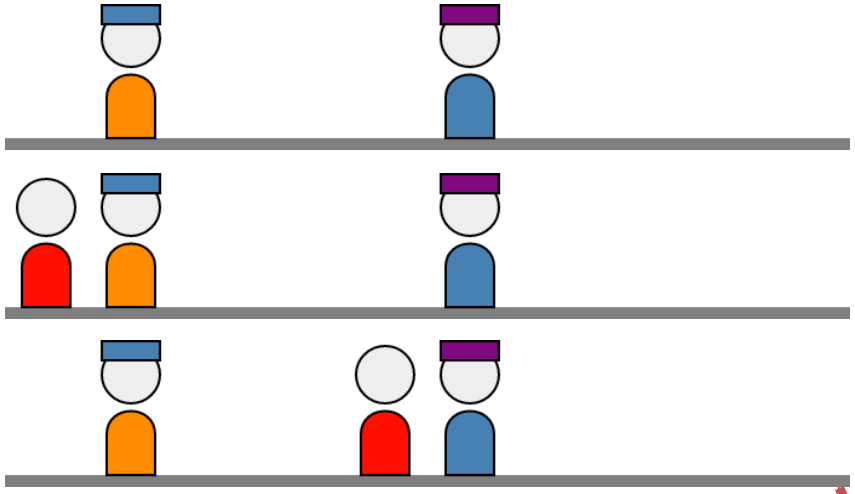


Pragmatic Listener

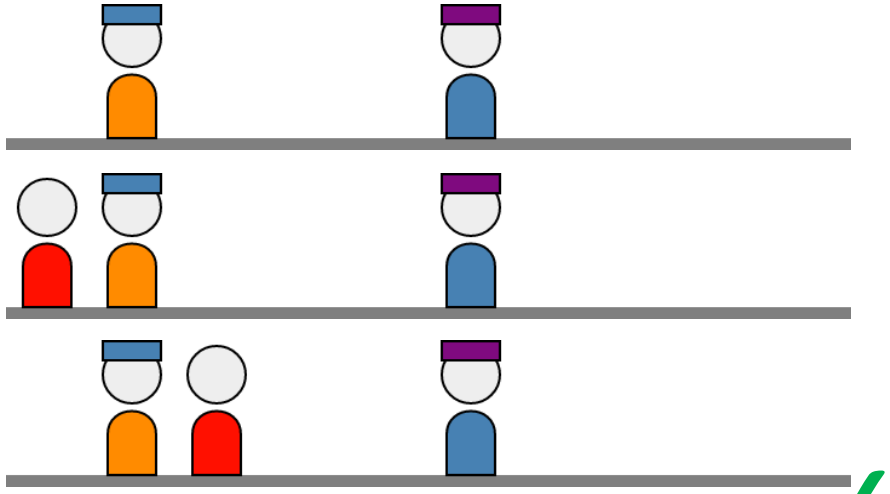


Listener Examples

Instruction *a red guy appears on the far left then to orange's other side*

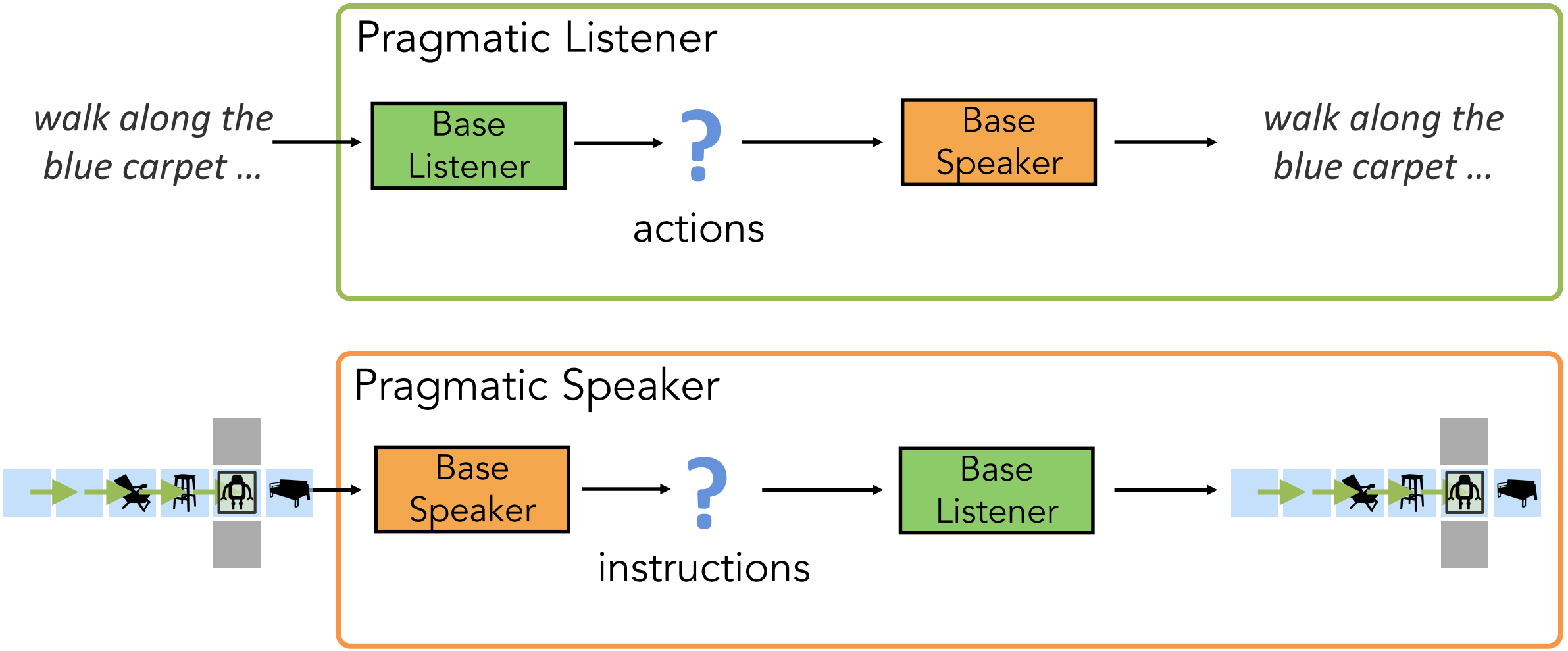


Base Listener

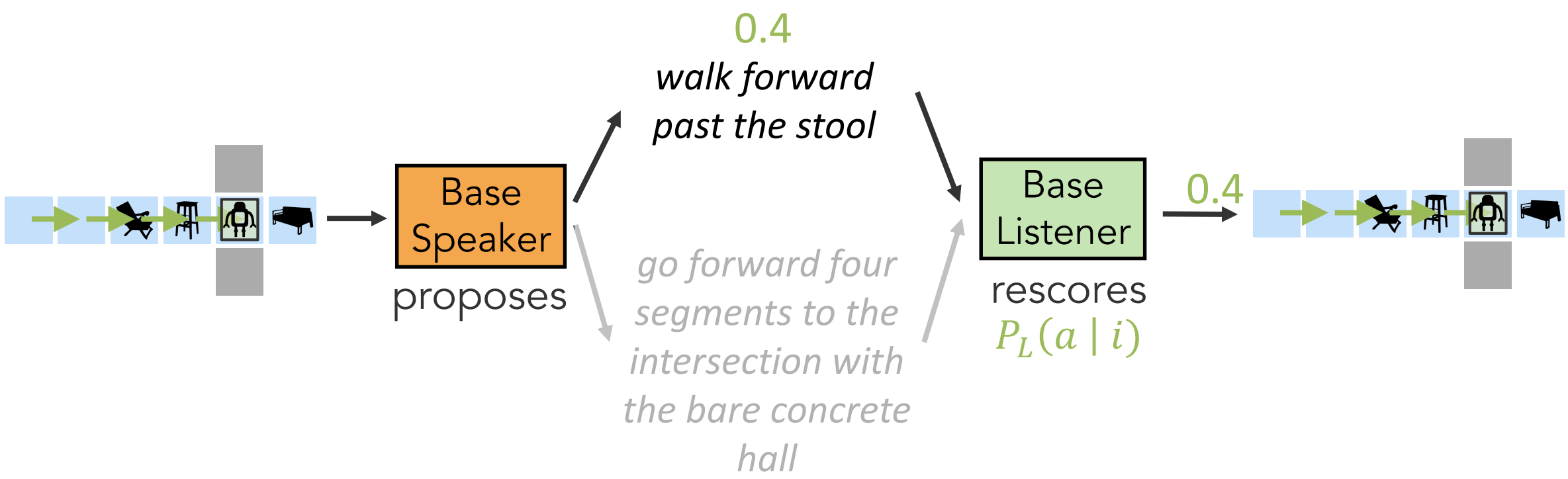


Pragmatic Listener

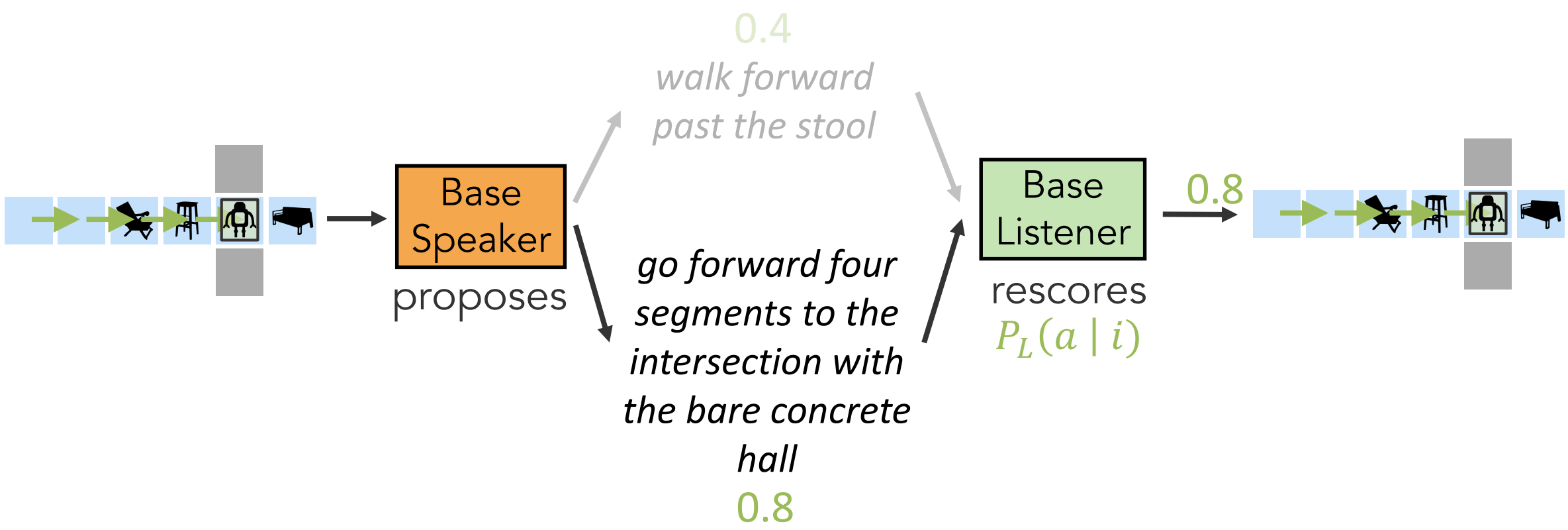
Unified Pragmatic Inference



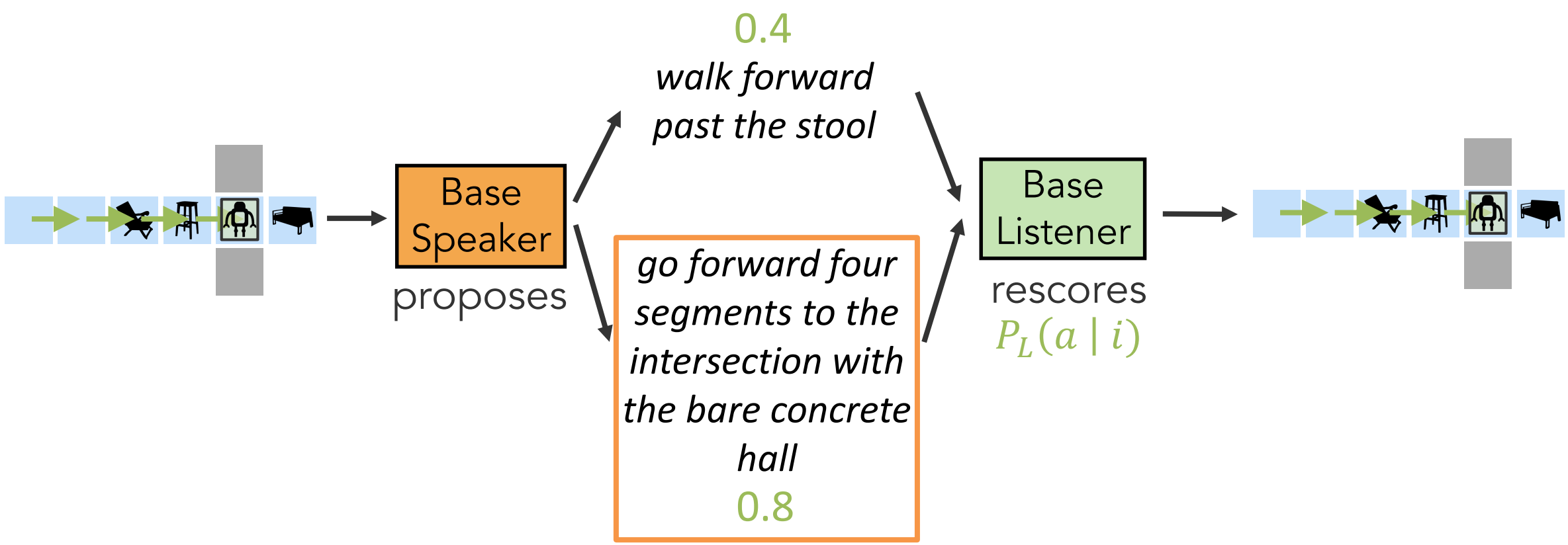
Building a Pragmatic Speaker



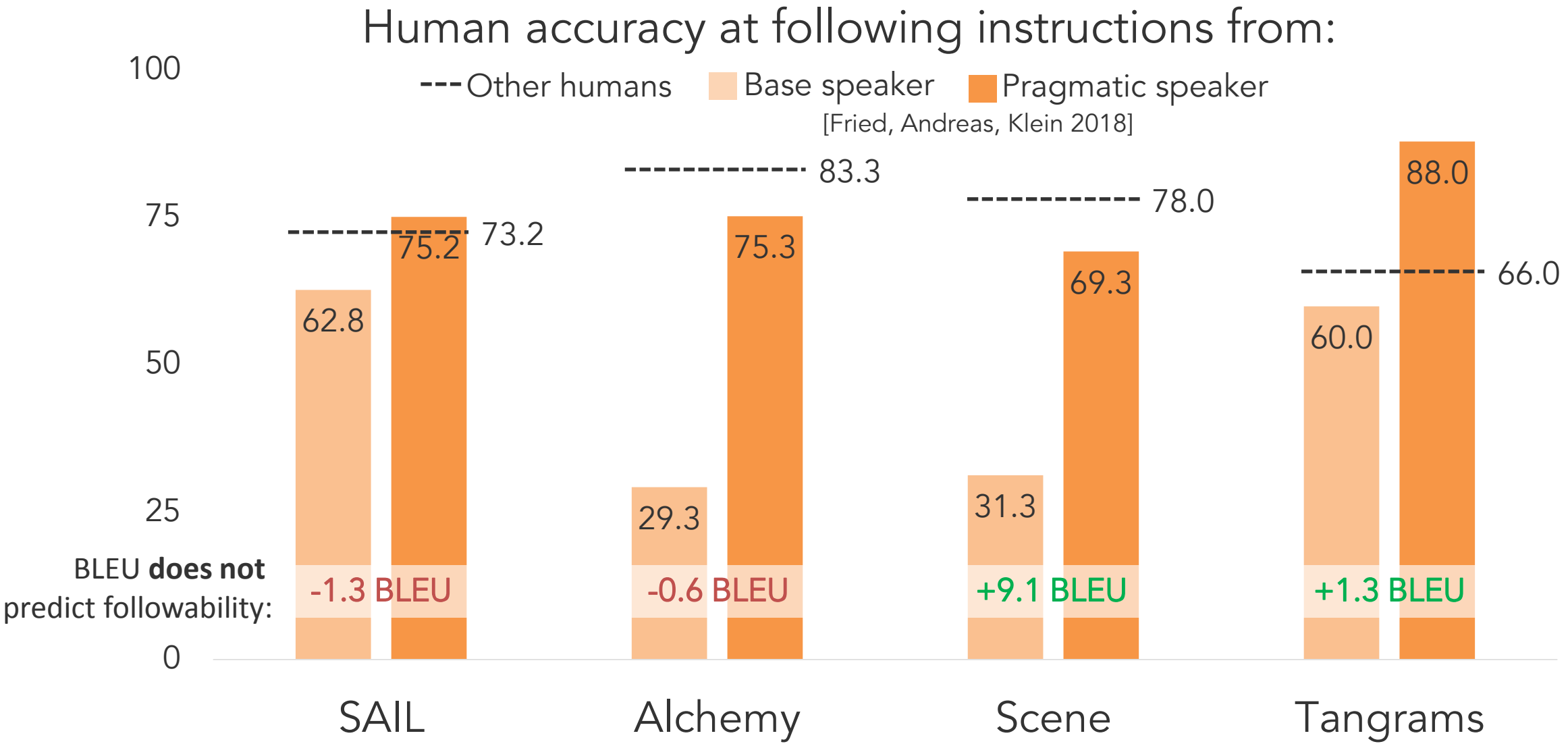
Building a Pragmatic Speaker



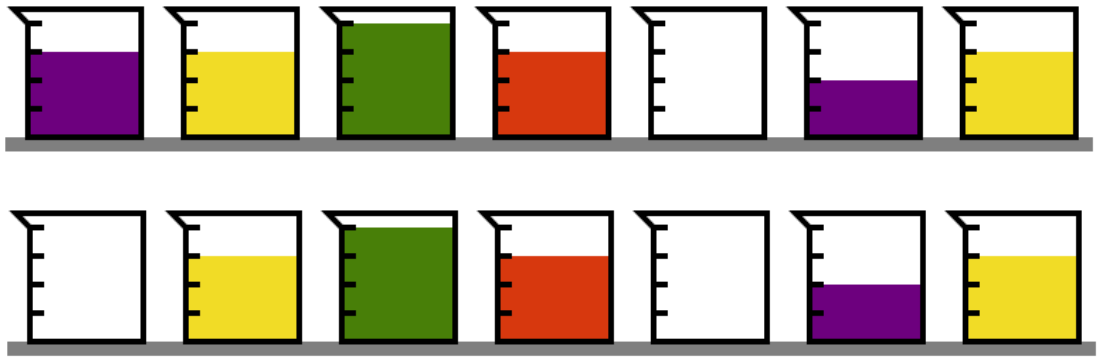
Building a Pragmatic Speaker



Speaker Results

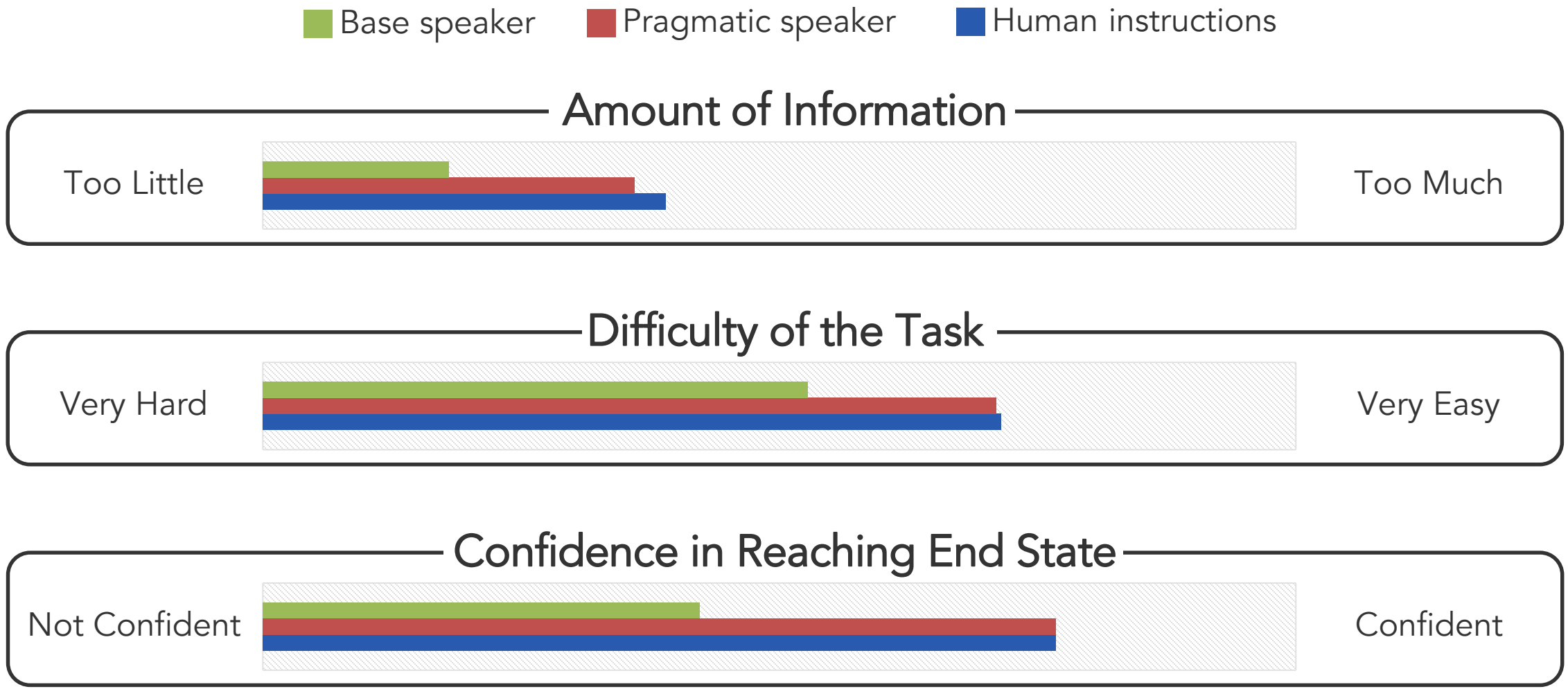


Pragmatics and Communicative Success



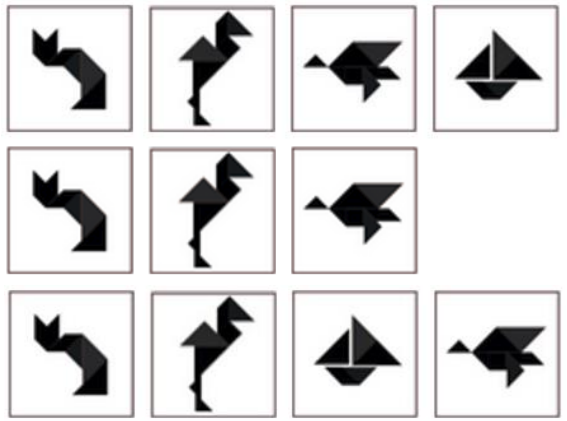
Base Speaker	*throw out the purple chemical*	✗
Pragmatic Speaker	*throw out the first purple chemical*	✓
Human	*remove all the purple chemical from the beaker on the far left*	✓

Instruction Quality: Alchemy

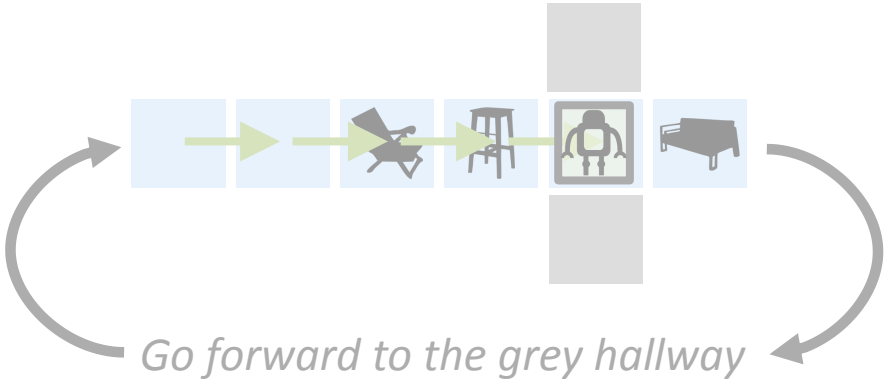


Averaged from 3 or 5 point Likert scales [Daniele et al. 2017]. Differences between base and pragmatic all statistically significant by χ^2 on counts.

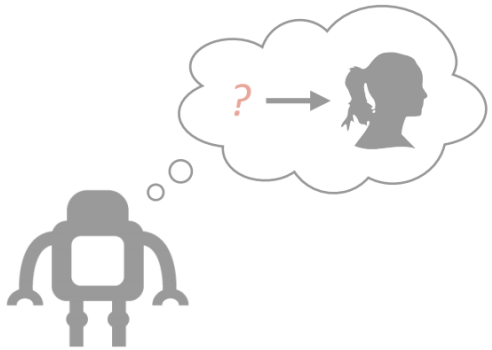
Pragmatics and Communicative Success



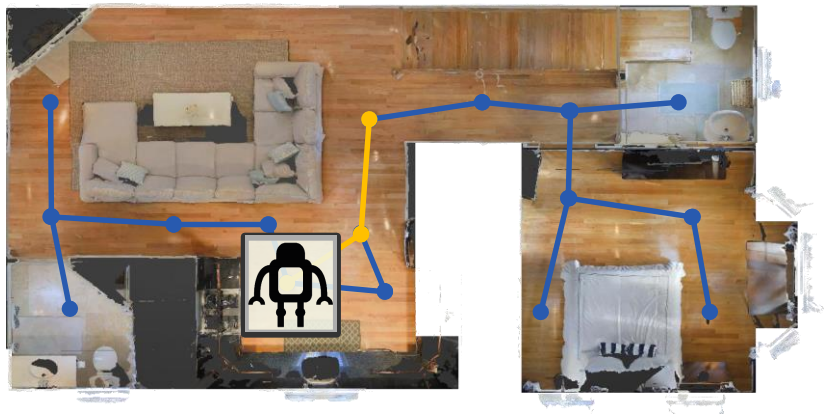
Base Speaker	*remove the last figure* *add it back*	✗
Pragmatic Speaker	*remove the last figure* *add it back in the 3rd position*	✓
Human	*take away the last item* *undo the last step*	✗



Semantic Models for Instructions



Pragmatic Reasoning

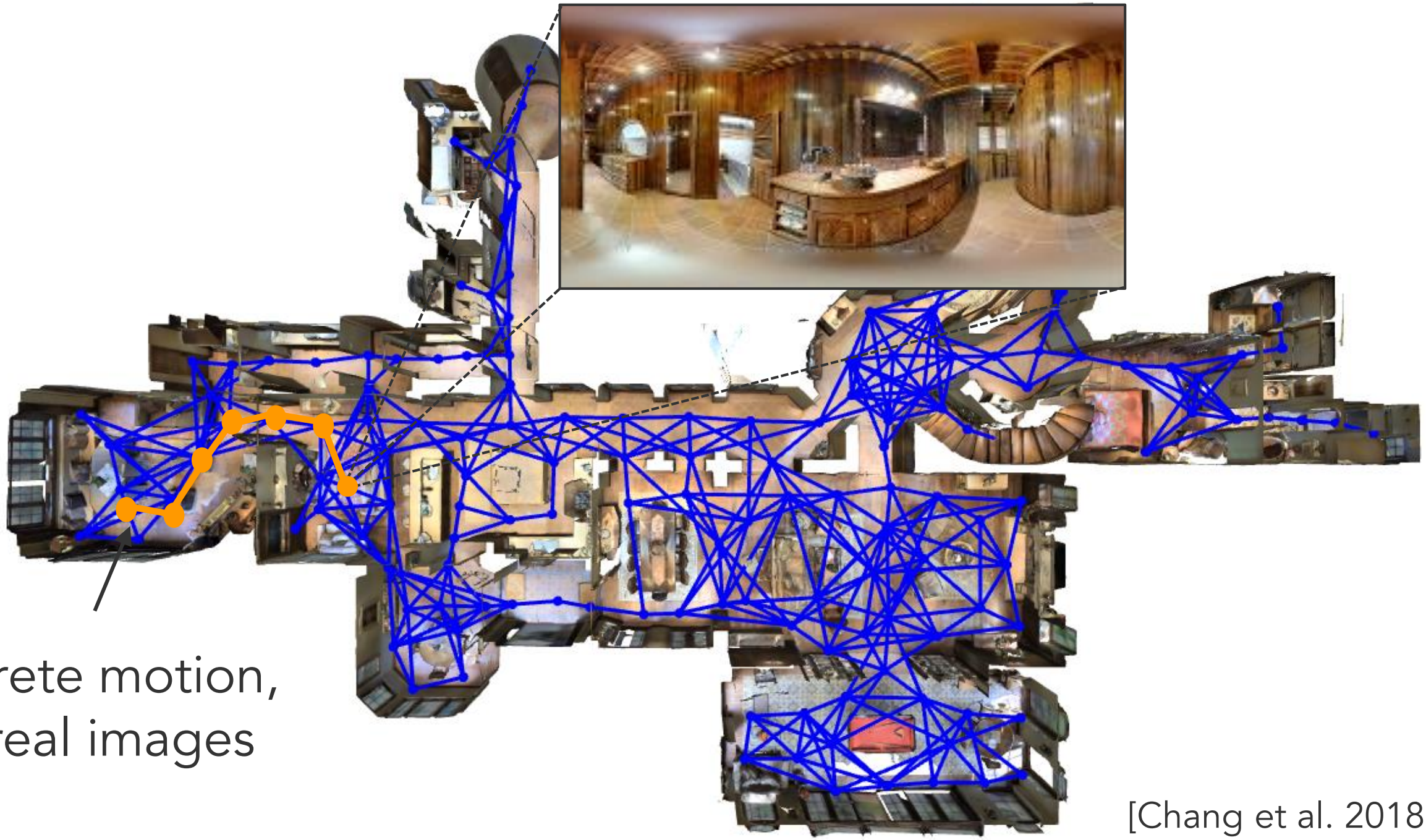


Grounding in the Real World

Room-to-Room Navigation Task

Turn left and take a right at the table. Take a left at the painting and then take your first right. Wait next to the exercise equipment.

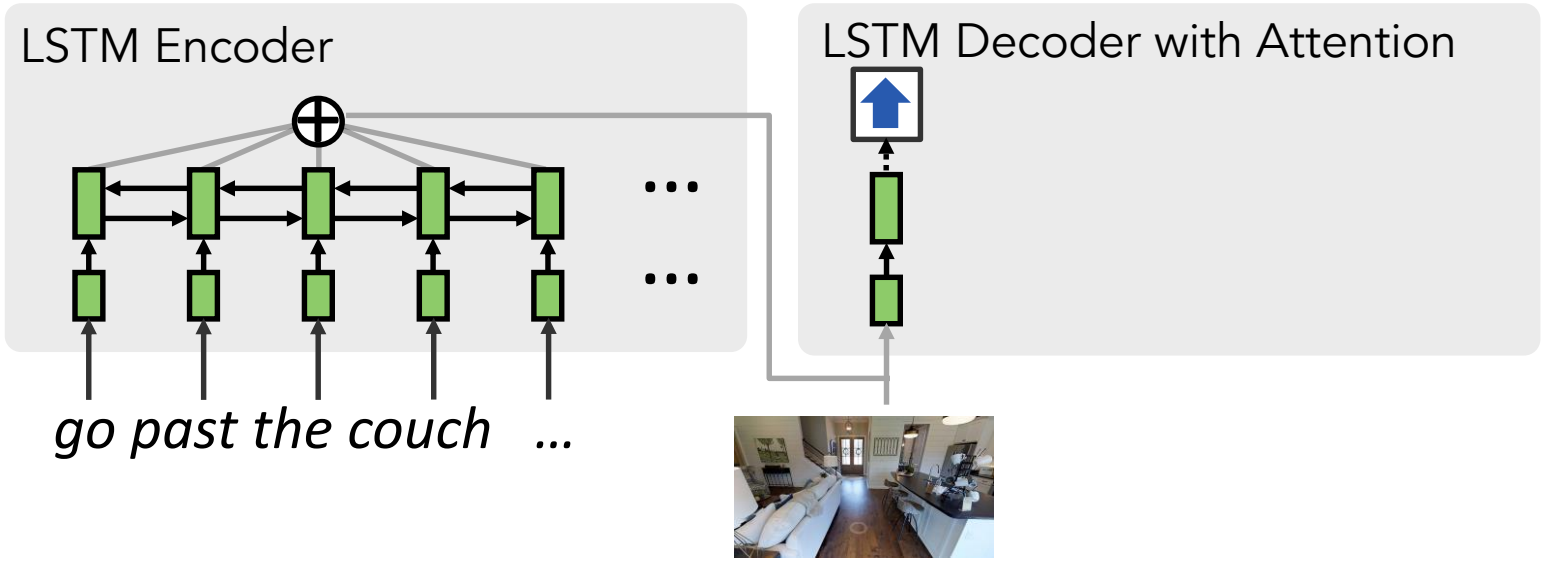
[Anderson et al., 2018]

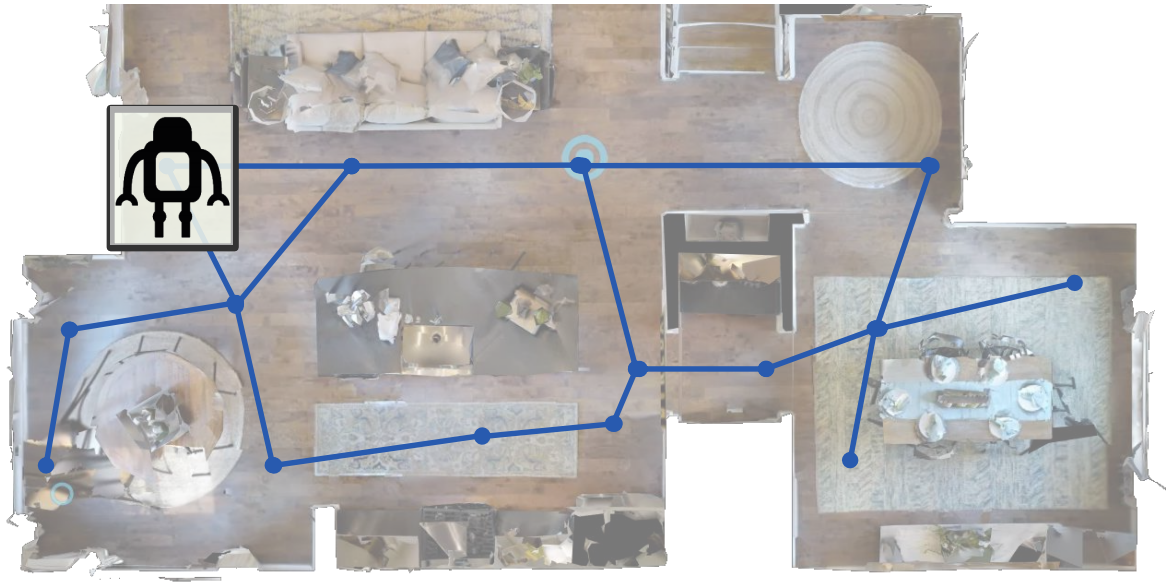


Discrete motion,
but real images

[Chang et al. 2018]

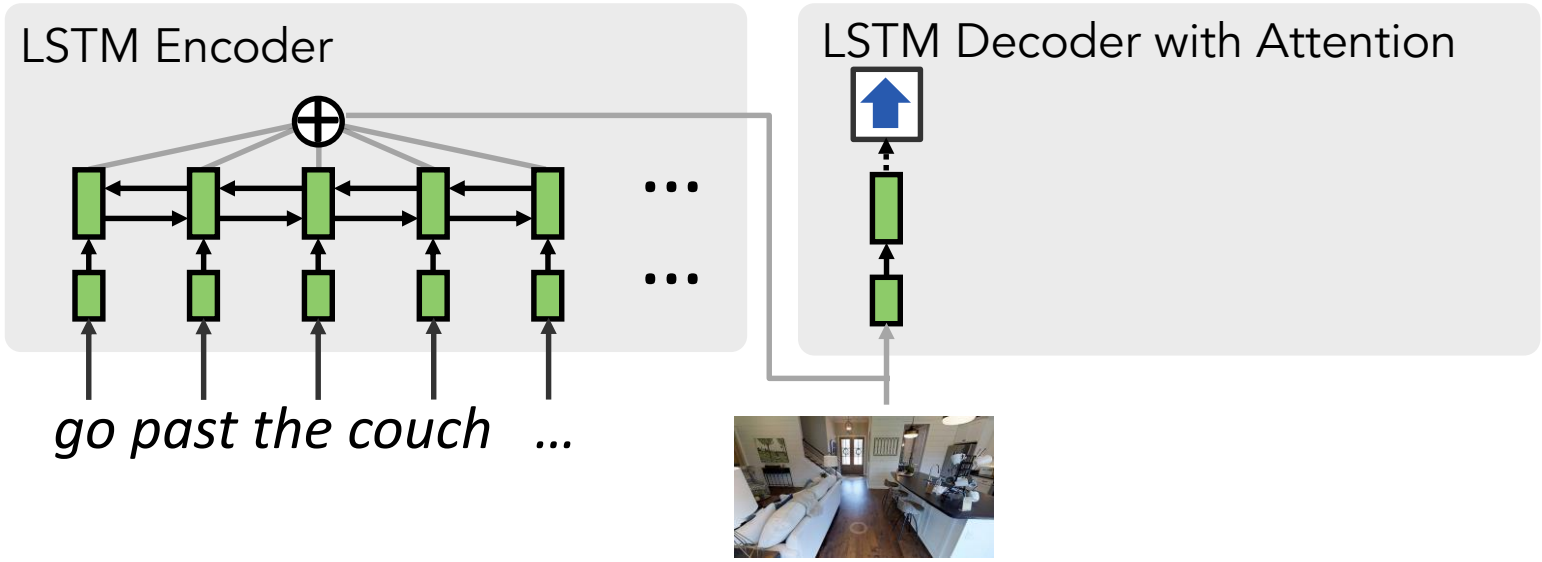
Base Follower Model

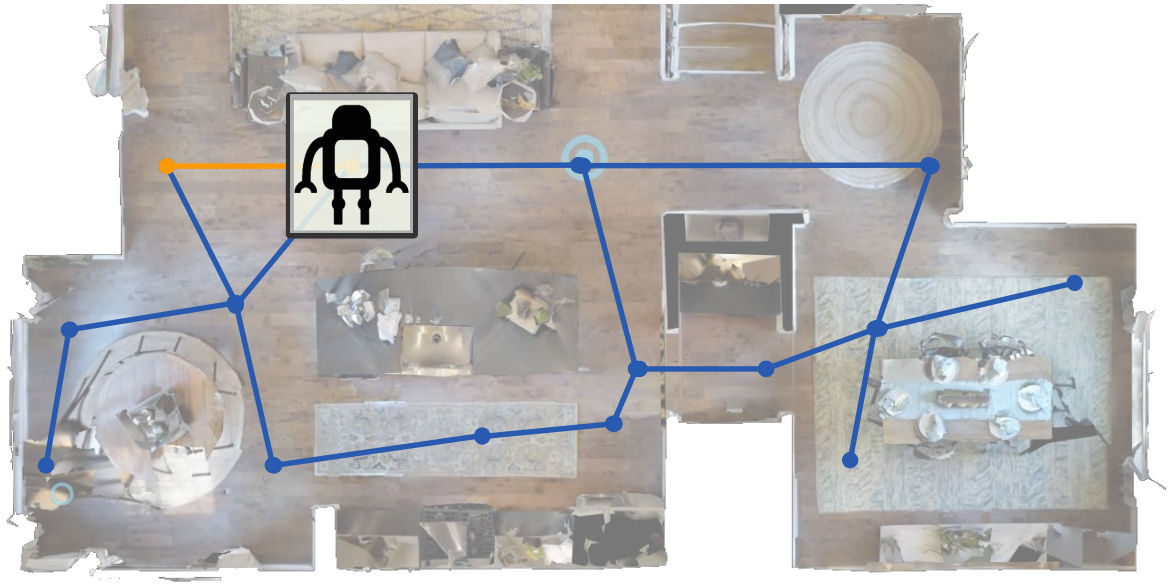




[Anderson et al., 2018]

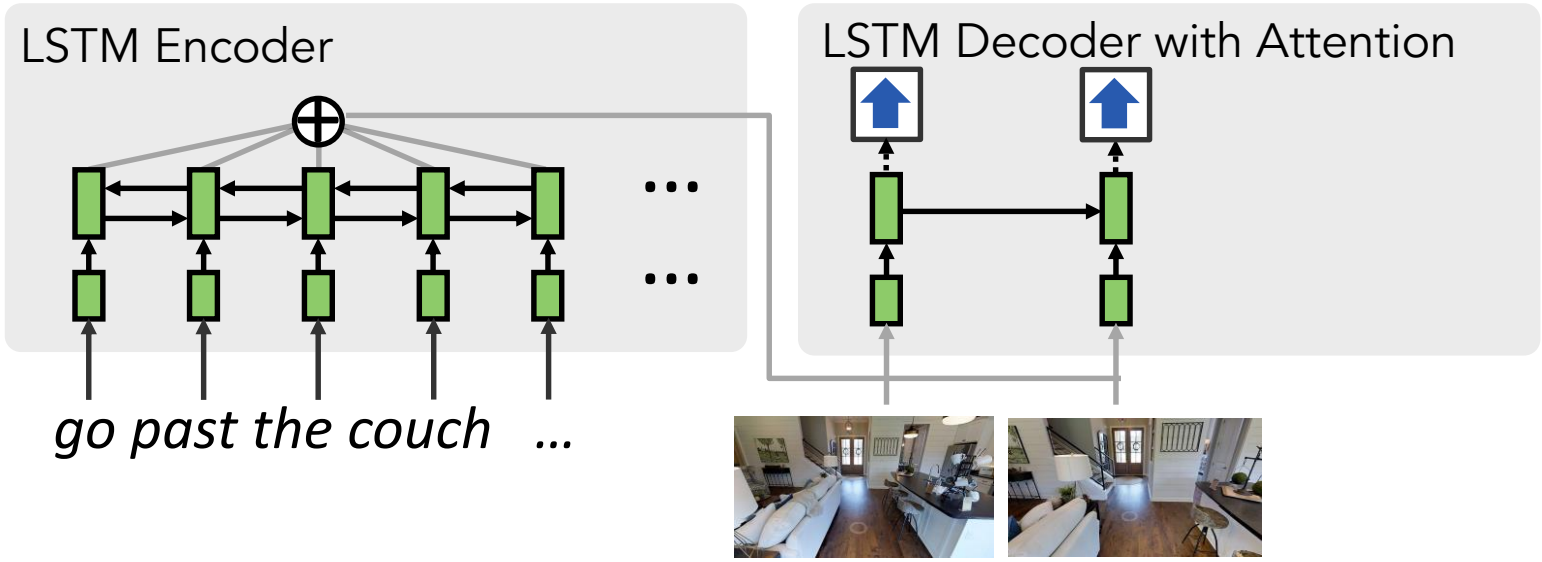
Base Follower Model

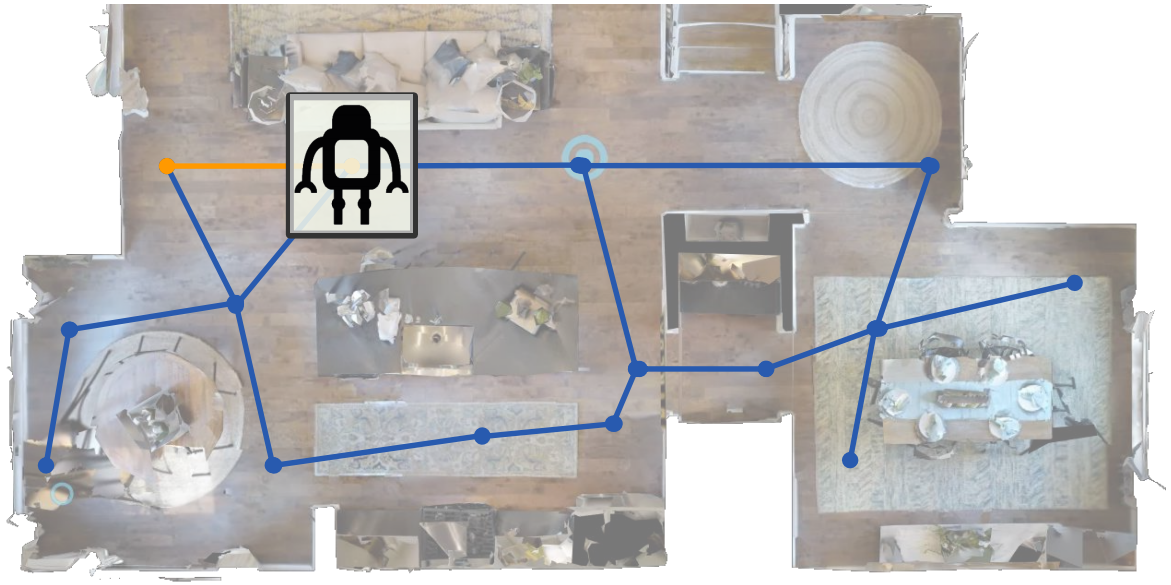




[Anderson et al., 2018]

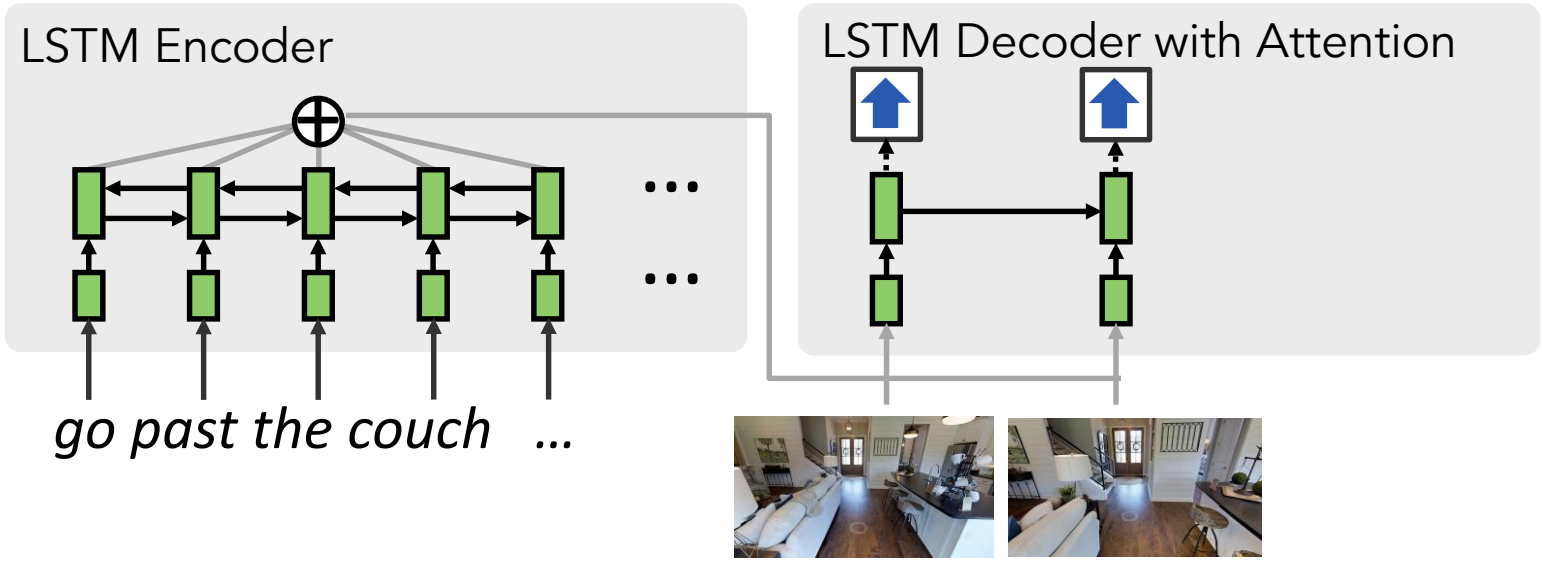
Base Follower Model

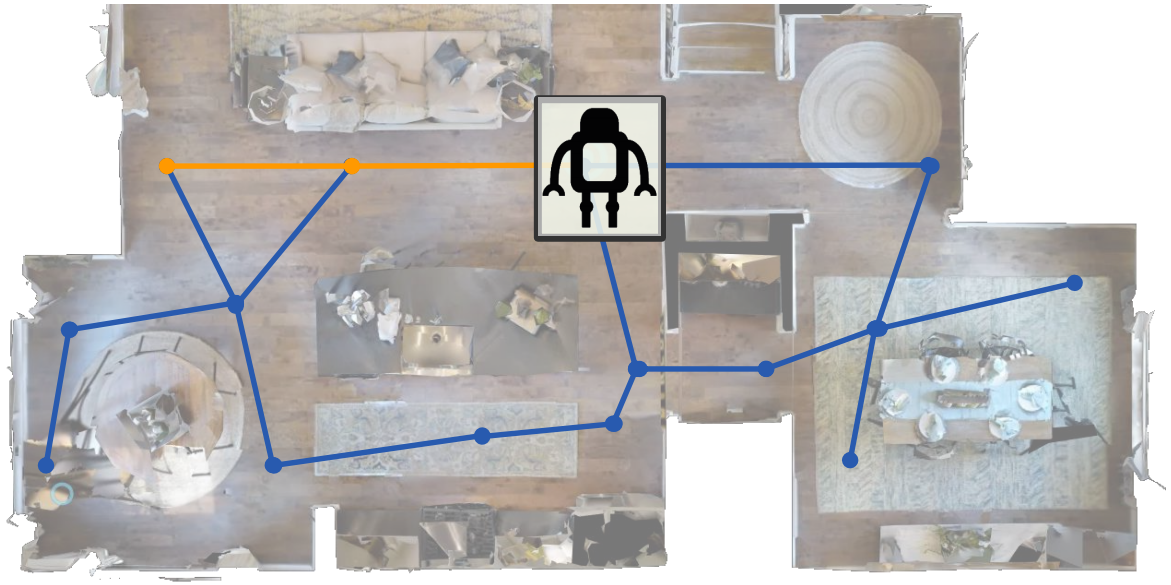




[Anderson et al., 2018]

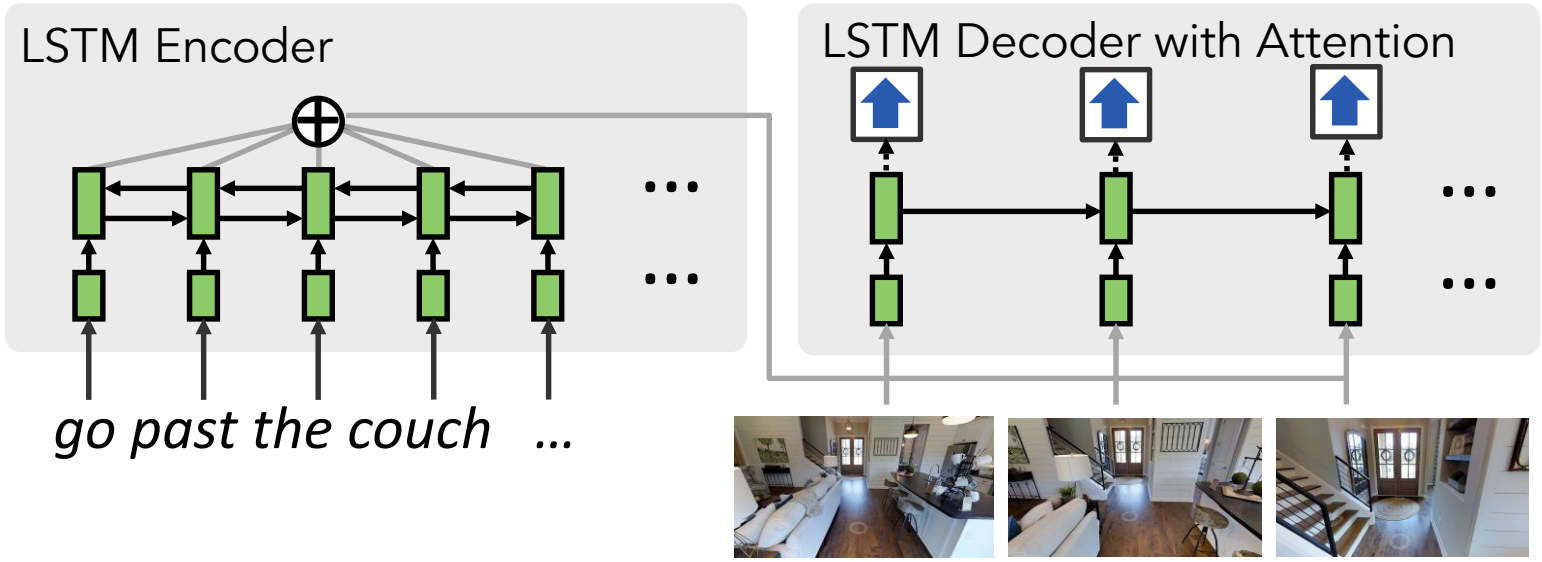
Base Follower Model

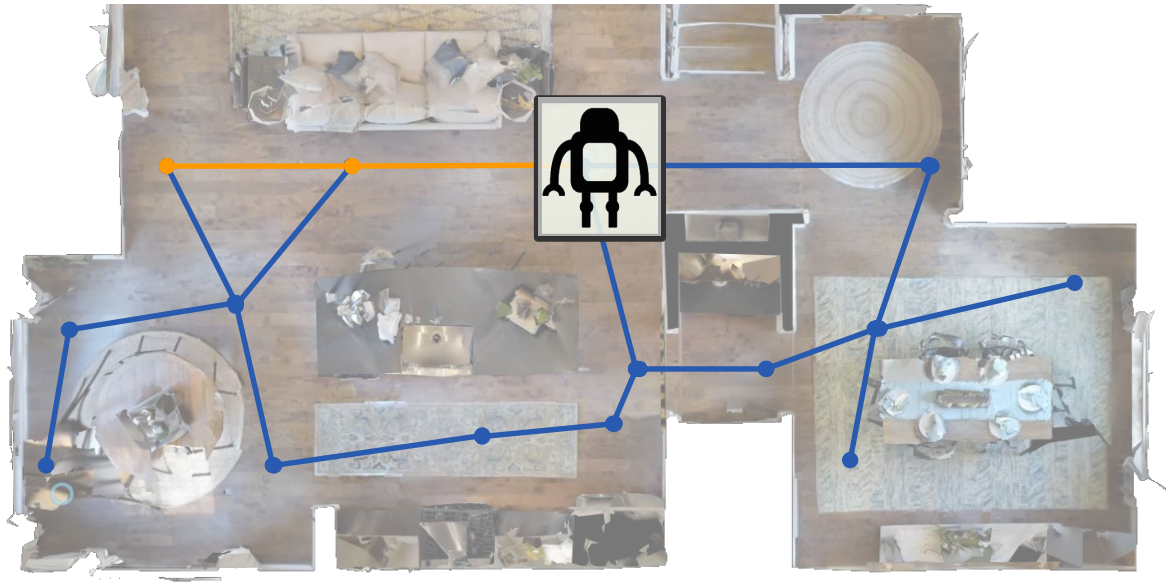




[Anderson et al., 2018]

Base Follower Model

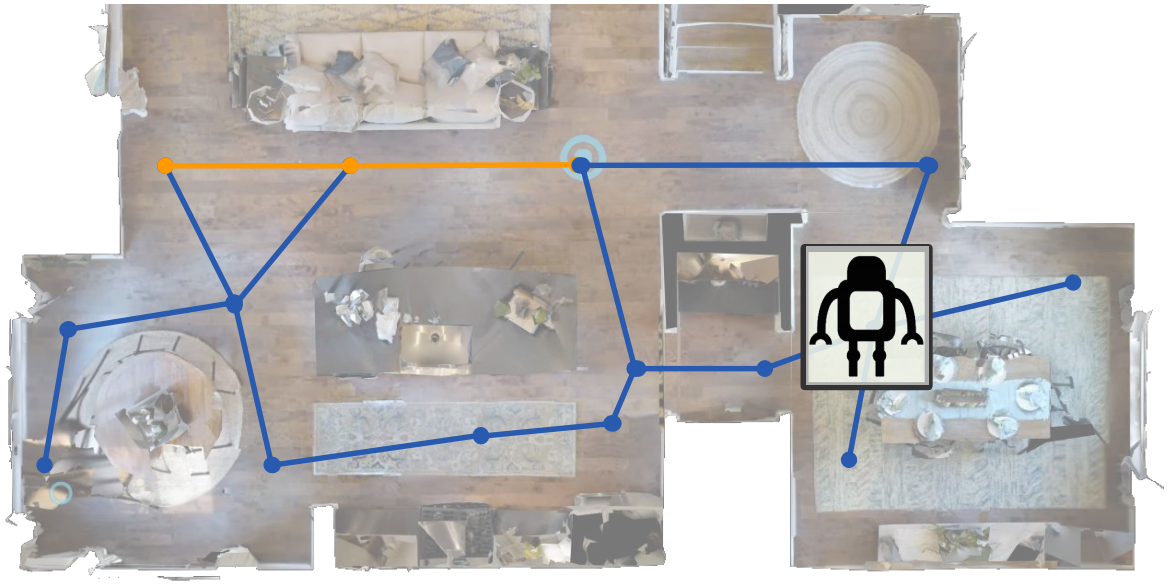




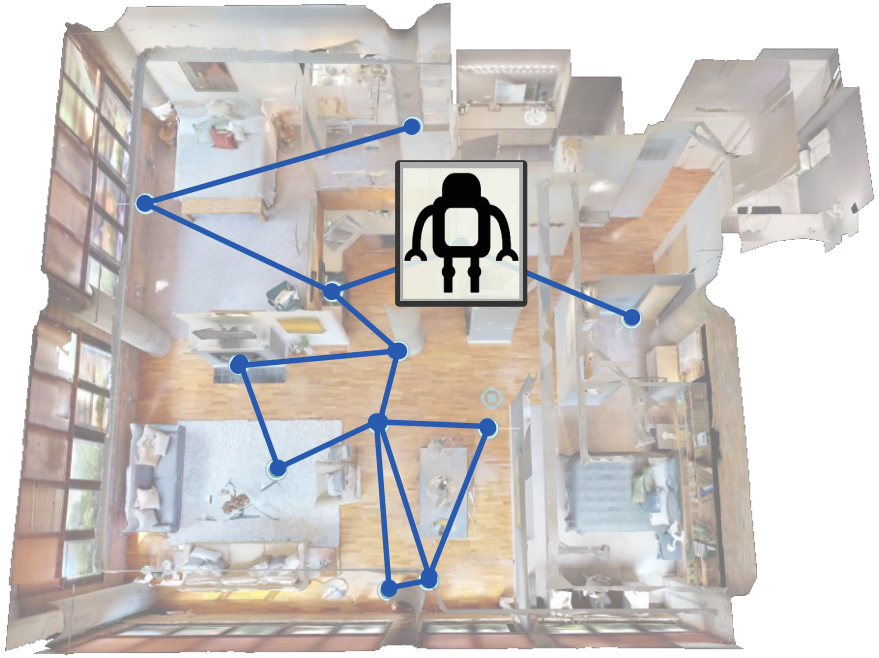
[Anderson et al., 2018]

Generalization to New Environments

Two test sets

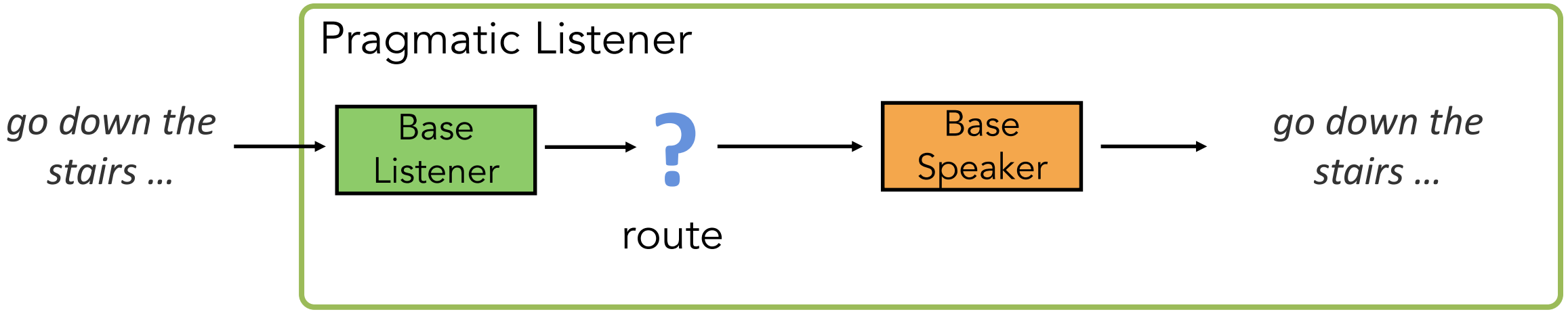


Seen
(Old environments, but new routes)

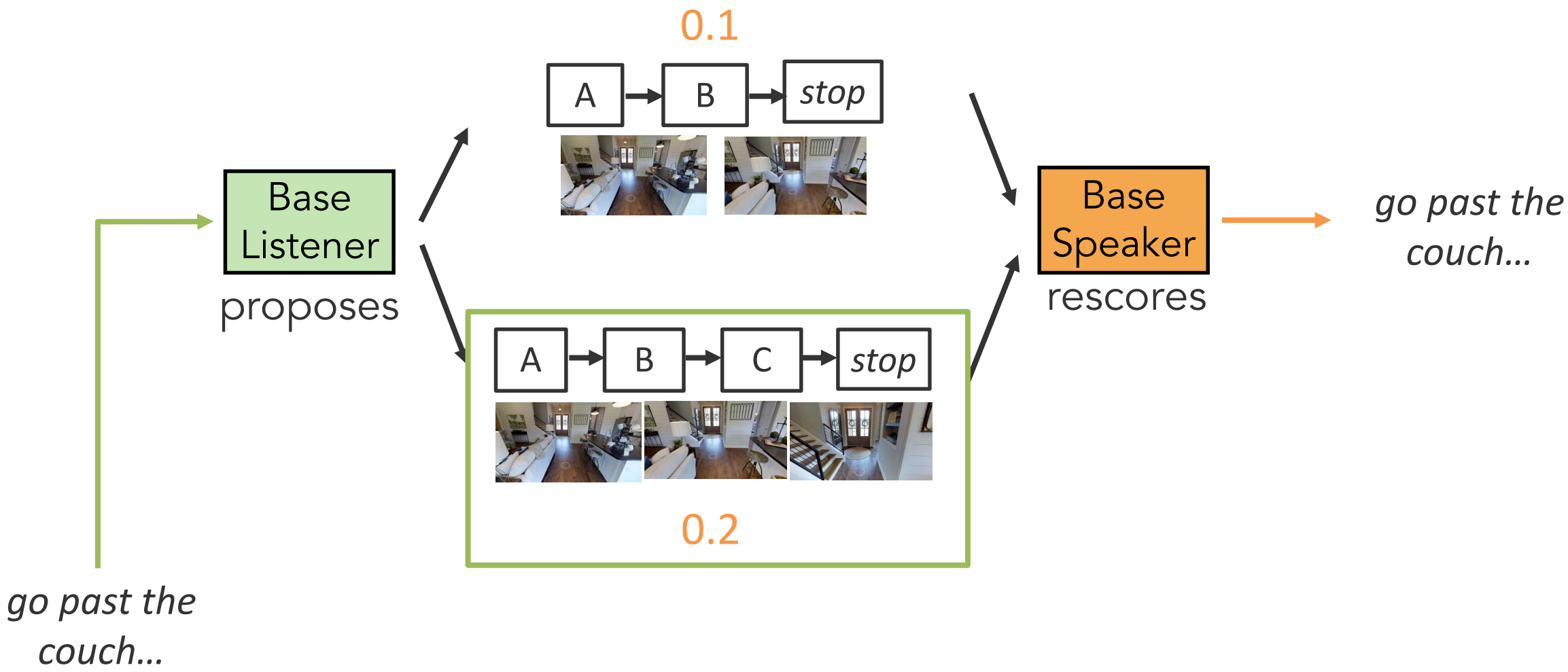


Unseen
(New environments and new routes)

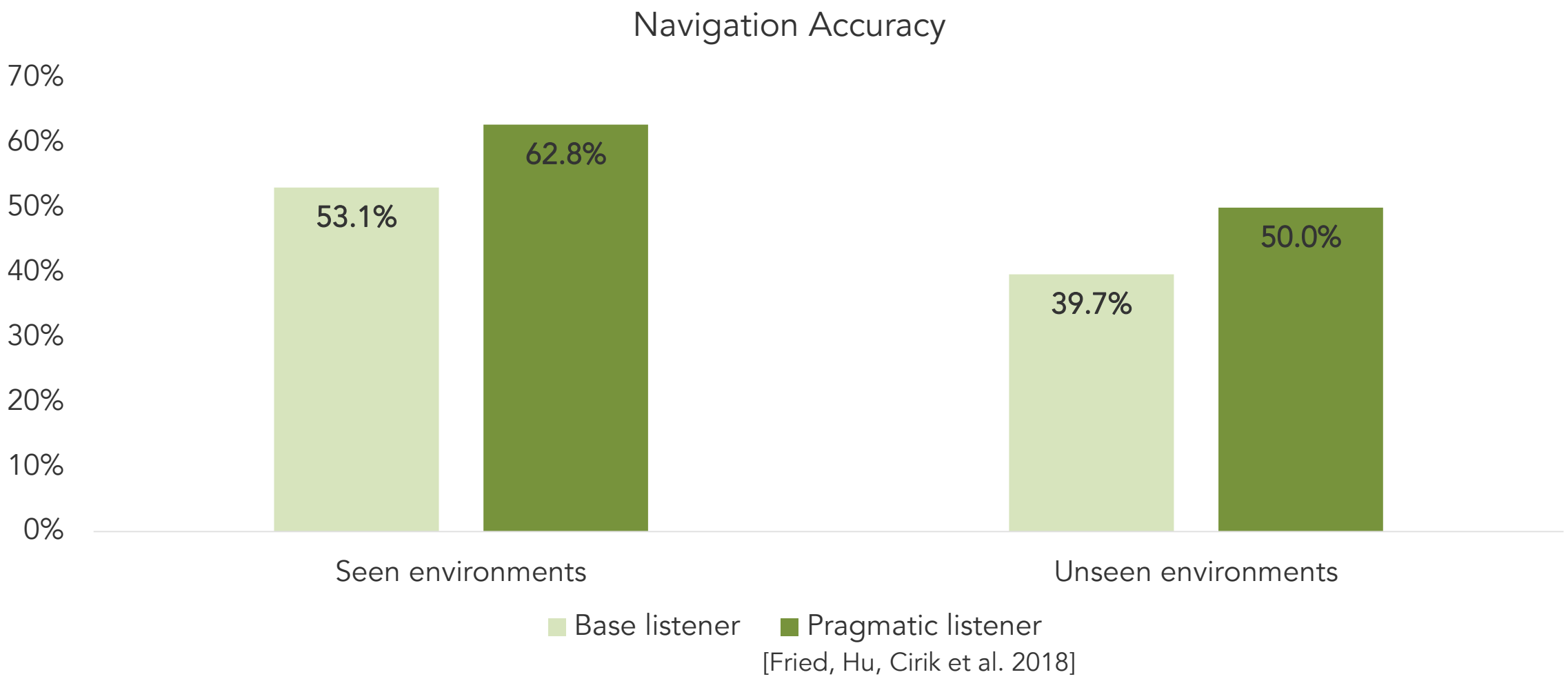
Pragmatic Inference



Pragmatic Inference



Pragmatic Inference



[Fried, Hu, Cirik et al. 2018]

Walk past hall table. Walk into bedroom. Make left at table clock. Wait at bathroom door threshold.

Base listener

Walk past hall table. Walk into bedroom. Make left at table clock. Wait at bathroom door threshold.

Pragmatic listener

Pragmatic Speaker

Human Description:
walk through the kitchen. go right into the living room and stop by the rug.

Base Speaker:
walk past the dining room table and chairs and wait there .

Pragmatic Speaker:
walk past the dining room table and chairs and take a right into the living room. stop once you are on the rug.

Pragmatic Speakers in Other Domains

Generation from Meaning Representations

Input:

```
Name[Fitzbillies],
EatType[Coffee Shop],
PriceRange[Cheap],
CustomerRating[5 out of 5],
Area[Riverside],
FamilyFriendly[Yes]
```

Base Speaker:

Fitzbillies is a family friendly coffee shop located near the river.

Pragmatic Speaker:

Fitzbillies is a family friendly coffee shop that serves English food. It is located in riverside area. It has a customer rating of 5 out of 5 and is cheap.

Abstractive Summarization

Input:

The 1-0 scoreline that took Barcelona through to the Champions League quarterfinals made their clash with Manchester City all seem rather academic.

Base Speaker:

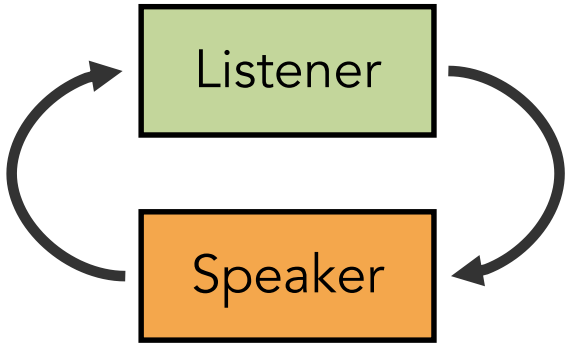
Barcelona beat Barcelona 1-0 in the Champions League quarterfinals.

Pragmatic Speaker:

Barcelona beat Manchester City 1-0 in the Champions League.

[Shen, Fried, Andreas, Klein 2019]

Summary



Unified procedure for sequential interpretation and generation

Reasoning counterfactually, and about likely interpretations

Pragmatics helps for complex tasks in real-world domains

Thank you!

https://github.com/dpfried/pragmatic-instructions
https://github.com/ronghanghu/speaker_follower