



What's the best way to say this?

Agent-based Modeling



1. Rational speech act

Literal and pragmatic speakers/listeners, Bayesian inference

2. MATLAB

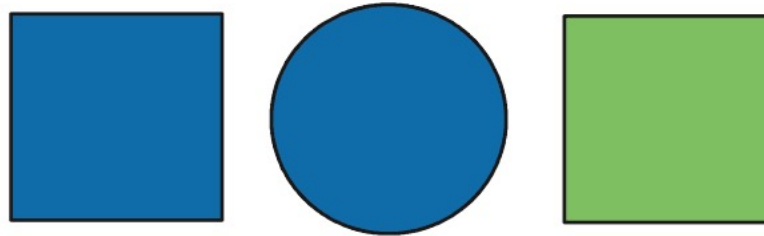
A primer

3. Breakout session

Building a pragmatic agent

Literal speaker, S0

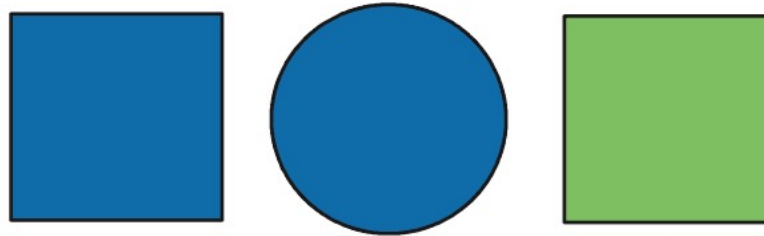
Speaker: Imagine you are talking to someone and you want to refer to the middle object. Which word would you use, “blue” or “circle”?



Blue	$\frac{1}{2}$	$\frac{1}{2}$	0
Green	0	0	$\frac{1}{2}$
Circle	0	$\frac{1}{2}$	0
Square	$\frac{1}{2}$	0	$\frac{1}{2}$
	2	2	2

Literal speaker, S0

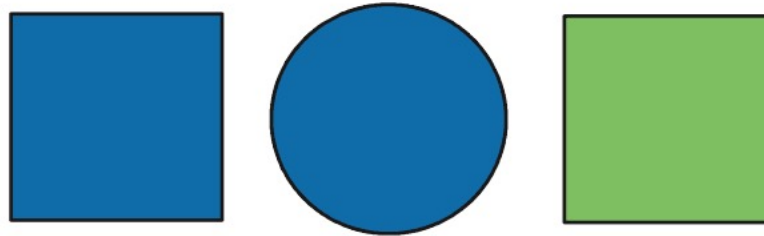
Speaker: Imagine you are talking to someone and you want to refer to the middle object. Which word would you use, “blue” or “circle”?



Blue	.5	.5	0
Green	0	0	.5
Circle	0	.5	0
Square	.5	0	.5

Literal listener, L0

Speaker: Imagine you are talking to someone and you want to refer to the middle object. Which word would you use, “blue” or “circle”?

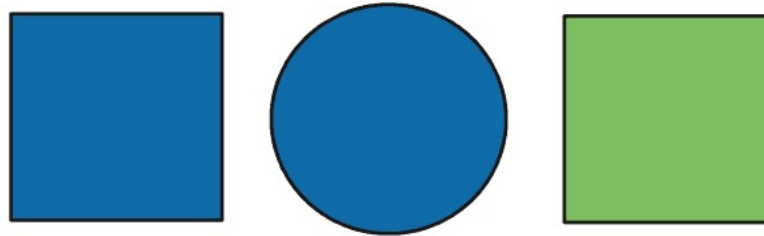


Blue	$\frac{1}{2}$	$\frac{1}{2}$	0	2
Green	0	0	$\frac{1}{1}$	1
Circle	0	$\frac{1}{1}$	0	1
Square	$\frac{1}{2}$	0	$\frac{1}{2}$	2

 listener's perspective

Literal listener, L0

Speaker: Imagine you are talking to someone and you want to refer to the middle object. Which word would you use, “**blue**” or “**circle**”?

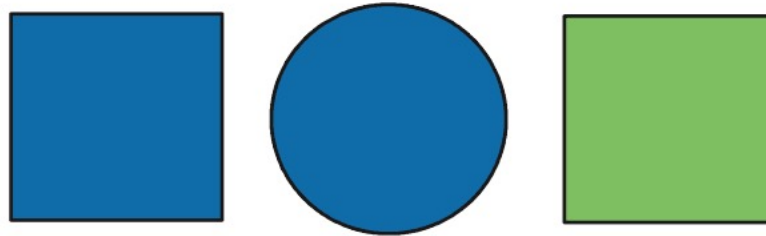


Blue	.5	.5	0
Green	0	0	1
Circle	0	1	0
Square	.5	0	.5

 listener's perspective

Pragmatic speaker, S1

Speaker: Imagine you are talking to someone and you want to refer to the middle object. Which word would you use, “blue” or “circle”?

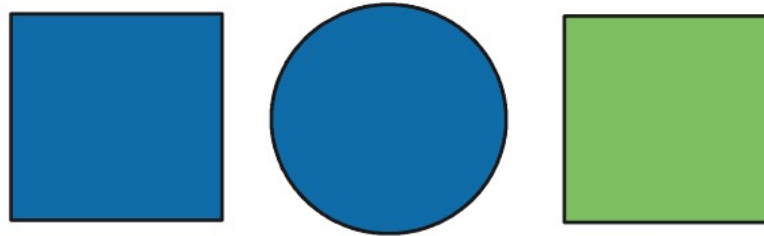


Blue	.5 _{/1}	.5 _{/1.5}	0
Green	0	0	1 _{/1.5}
Circle	0	1 _{/1.5}	0
Square	.5 _{/1}	0	.5 _{/1.5}
	1	1.5	1.5

 listener's perspective

Pragmatic speaker, S1

Speaker: Imagine you are talking to someone and you want to refer to the middle object. Which word would you use, “**blue**” or “**circle**”?

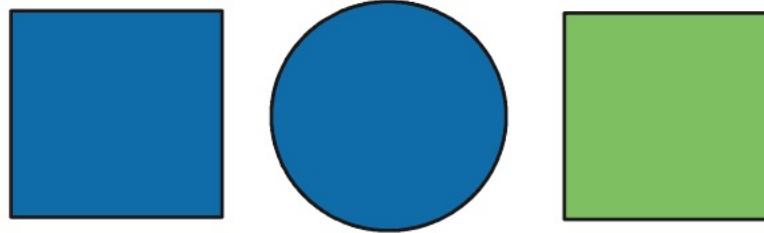


Blue	.5	.33	0
Green	0	0	.67
Circle	0	.67	0
Square	.5	0	.33

 listener's perspective

Pragmatic listener, L1

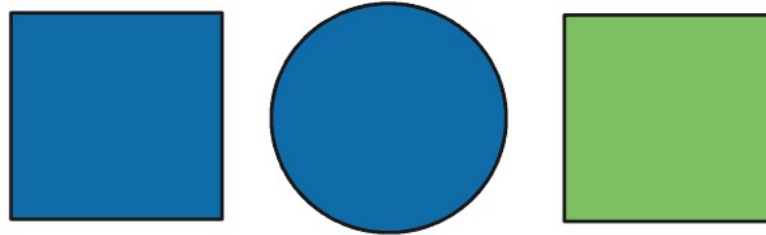
Listener/Saliency: Imagine someone is talking to you and uses [the word “**blue**”/a word you don’t know] to refer to one of these objects. Which object are they talking about?



Blue	.5 _{/.83}	.33 _{/.83}	0	.83
Green	0	0	.67 _{/.67}	.67
Circle	0	.67 _{/.67}	0	.67
Square	.5 _{/.83}	0	.33 _{/.83}	.83

Pragmatic listener, L1

Listener/Saliency: Imagine someone is talking to you and uses [the word “**blue**”/a word you don’t know] to refer to one of these objects. Which object are they talking about?



Blue	.6	.4	0
Green	0	0	1
Circle	0	1	0
Square	.6	0	.4

Bayesian inference

Likelihood speaker s would utter word w to refer to object r Prior probability that object r would be referred to

$$P(r_s | w, C) = \frac{P(w | r_s, C) P(r_s)}{\sum_{r' \in C} P(w | r', C) P(r')}$$

Likelihood that speaker s intended object r given uttered word w in context C

Normalizing constant, sum of the above computed for all referents in the context

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Array Creation

To create an array with four elements in a single row, separate the elements with either a comma (,) or a space.

```
a = [1 2 3 4]
```

```
a = 1×4
```

```
    1    2    3    4
```

This type of array is a *row vector*.

To create a matrix that has multiple rows, separate the rows with semicolons.

```
a = [1 2 3; 4 5 6; 7 8 10]
```

```
a = 3×3
```

```
    1    2    3
    4    5    6
    7    8   10
```

1. Rational speech act

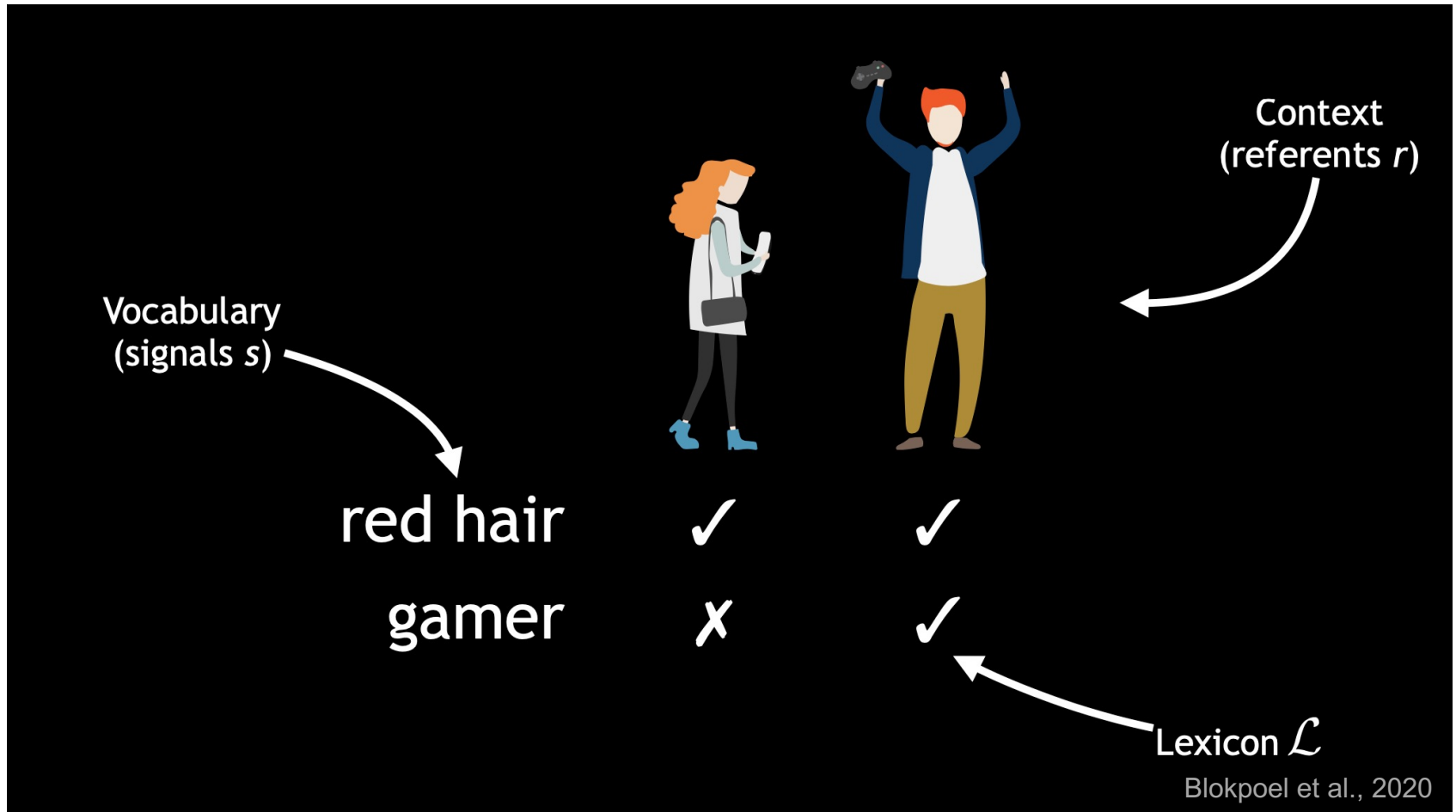
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Building a pragmatic agent



Whom is referred to with “red hair”?

open Lab2.m or .ipynb

Problem



red hair	✓	✓	✗
tall one	✗	✓	✗
gamer	✗	✓	✓

Whom is referred to with “red hair”, from the perspective of a literal and of a pragmatic listener?

Listener L_1


$$\Pr_{L_n}(r|s, \mathcal{L}) = \frac{\Pr_{S_n}(s|r, \mathcal{L})}{\sum_{(s, r') \in \mathcal{L}} \Pr_{S_n}(s|r', \mathcal{L})}$$

Speaker S_1

$$\Pr_{S_n}(s|r, \mathcal{L}) = \frac{\Pr_{L_{n-1}}(r|s, \mathcal{L})}{\sum_{(s', r) \in \mathcal{L}} \Pr_{L_{n-1}}(s'|r, \mathcal{L})}$$

Listener L_0

$$\Pr_{L_0}(r|s, \mathcal{L}) = \frac{\mathcal{L}(s, r)}{\sum_{(s, r') \in \mathcal{L}} \mathcal{L}(s, r')}$$



Solution

red hair
tall one
gamer

Whom is referred to with “red hair”, from the perspective of a literal and of a pragmatic listener?

Listener L_1


$$\Pr_{L_n}(r|s, \mathcal{L}) = \frac{\Pr_{S_n}(s|r, \mathcal{L})}{\sum_{(s,r') \in \mathcal{L}} \Pr_{S_n}(s|r', \mathcal{L})}$$

← Speaker S_1

$$\Pr_{S_n}(s|r, \mathcal{L}) = \frac{\Pr_{L_{n-1}}(r|s, \mathcal{L})}{\sum_{(s',r) \in \mathcal{L}} \Pr_{L_{n-1}}(s'|r, \mathcal{L})}$$

← Listener L_0

$$\Pr_{L_0}(r|s, \mathcal{L}) = \frac{\mathcal{L}(s, r)}{\sum_{(s,r') \in \mathcal{L}} \mathcal{L}(s, r')}$$



Solution	red hair	0.5	0.5	0.0
	tall one	0.0	1.0	0.0
	gamer	0.0	0.5	0.5

Whom is referred to with “red hair”, from the perspective of a literal and of a pragmatic listener?

Listener L_1

$$\Pr_{L_1}(r|s, \mathcal{L}) = \frac{\Pr_{S_1}(s|r, \mathcal{L})}{\sum_{(s,r') \in \mathcal{L}} \Pr_{S_1}(s|r', \mathcal{L})}$$



Speaker S_1

$$\Pr_{S_1}(s|r, \mathcal{L}) = \frac{\Pr_{L_0}(r|s, \mathcal{L})}{\sum_{(s',r) \in \mathcal{L}} \Pr_{L_0}(r|s', \mathcal{L})}$$



Listener L_0

$$\Pr_{L_0}(r|s, \mathcal{L}) = \frac{\mathcal{L}(s,r)}{\sum_{(s,r') \in \mathcal{L}} \mathcal{L}(s,r')}$$

Solution



red hair	1.0	0.25	0.0
tall one	0.0	0.5	0.0
gamer	0.0	0.25	1.0

Whom is referred to with “red hair”, from the perspective of a literal and of a pragmatic listener?

Listener L_1

$$\Pr_{L_n}(r|s, \mathcal{L}) = \frac{\Pr_{S_n}(s|r, \mathcal{L})}{\sum_{(s,r') \in \mathcal{L}} \Pr_{S_n}(s|r', \mathcal{L})}$$

Speaker S_1

$$\Pr_{S_n}(s|r, \mathcal{L}) = \frac{\Pr_{L_{n-1}}(r|s, \mathcal{L})}{\sum_{(s',r) \in \mathcal{L}} \Pr_{L_{n-1}}(s'|r, \mathcal{L})}$$

Listener L_0

$$\Pr_{L_0}(r|s, \mathcal{L}) = \frac{\mathcal{L}(s, r)}{\sum_{(s,r') \in \mathcal{L}} \mathcal{L}(s, r')}$$

Solution



red hair	0.8	0.2	0.0
tall one	0.0	1.0	0.0
gamer	0.0	0.2	0.8

Whom is referred to with “red hair”, from the perspective of a literal and of a pragmatic listener?



	red hair	0.5	0.5	0.0		$P(\text{red hair})=1.0$	
L_0	tall one	0.0	1.0	0.0	\times	$P(\text{tall one})=0.0$	$=$
	gamer	0.0	0.5	0.5		$P(\text{gamer})=0.0$	

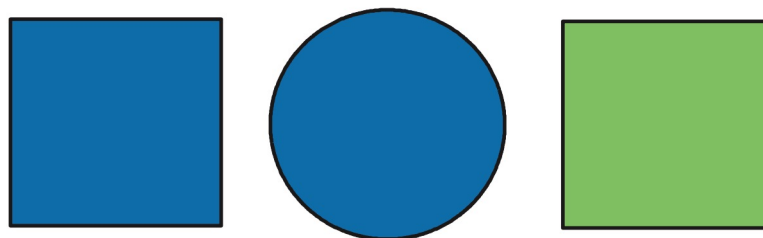
$P(\text{👩})=0.5$
 $P(\text{👨})=0.5$
 $P(\text{👤})=0.0$

Whom is referred to with “red hair”, from the perspective of a literal and of a pragmatic listener?

- Measure of a word's uncertainty given “context”
(set of possible signals and referents)
- Scalability in terms of multi-order reasoning
- But, assumes humans are rational thinkers
- Requires exhaustive definition of the “context”
- Questionable if it scales to the real world or
maps onto human cognition

- Audience Design

Bonus: Computer says no



“blue”



$1/2$
$1/2$

$1/2$

0

0

$1/2$

2

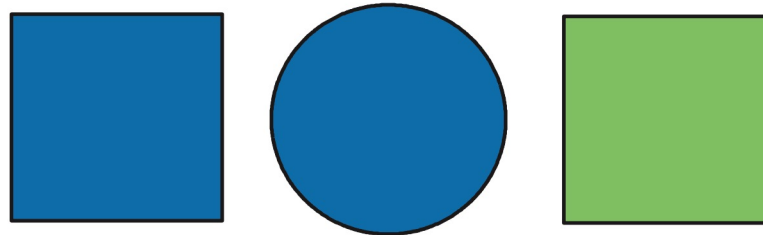
2



listener's perspective

L0 correctly interprets the composite signal as referring to the blue square

Bonus: Computer says no



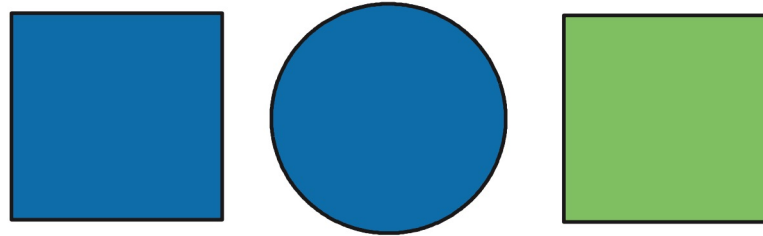

“blue”



.5	.5	0
.5	0	.5
1	.5	.5

 listener's perspective

L0 correctly interprets the composite signal as referring to the blue square




“blue”



.5 /1

.5 /*.5*

0

.5 /1

0

.5 /*.5*

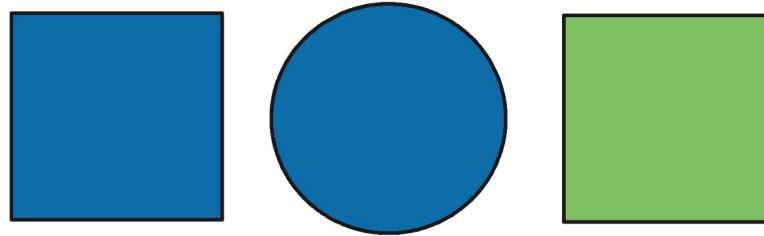
1

.5

.5

 listener's perspective

Perspective of pragmatic speaker, S1




“blue”



.5
/1.5

1
/1.5

0

1.5

.5
/1.5

0

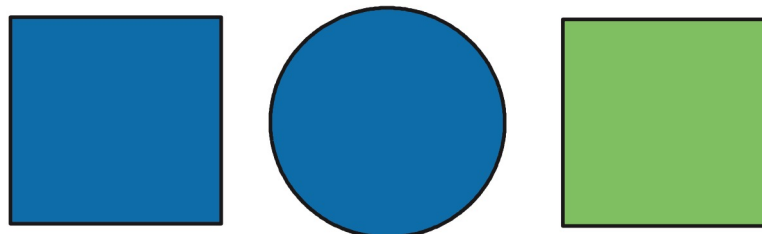
1
/1.5

1.5



listener's
perspective

Bonus: Computer says no

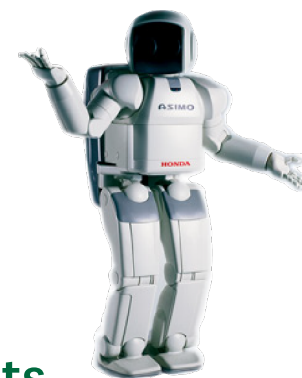


“blue”



.33	.66	0
.33	0	.66
.66	.66	.66

← listener's perspective



L1 cannot reliably distinguish between the three referents

“blue”



1.05 1.2 .75

L1 selects a non-intended referent

← listener's perspective

