

# **prior beliefs and projection**

an RSA-based approach

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workshop on “background beliefs in the construction of meaning”  
University of Tübingen, January 9-10, 2025



The Guardian, April 26 2004

“Geographically, Europe can be divided in two parts: Europe of the hare and Europe of the squirrel. Estonia is the latter: a squirrel could, without too much trouble, go from one end of the country to the other, jumping from tree to tree. Of course, **the squirrel doesn't know that Estonia includes hundreds of islands**, small and big. Estonia is a land of islands and forests. [...]”

~> Estonia includes hundreds of islands



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“know” presupposes that the content of its complement is common ground

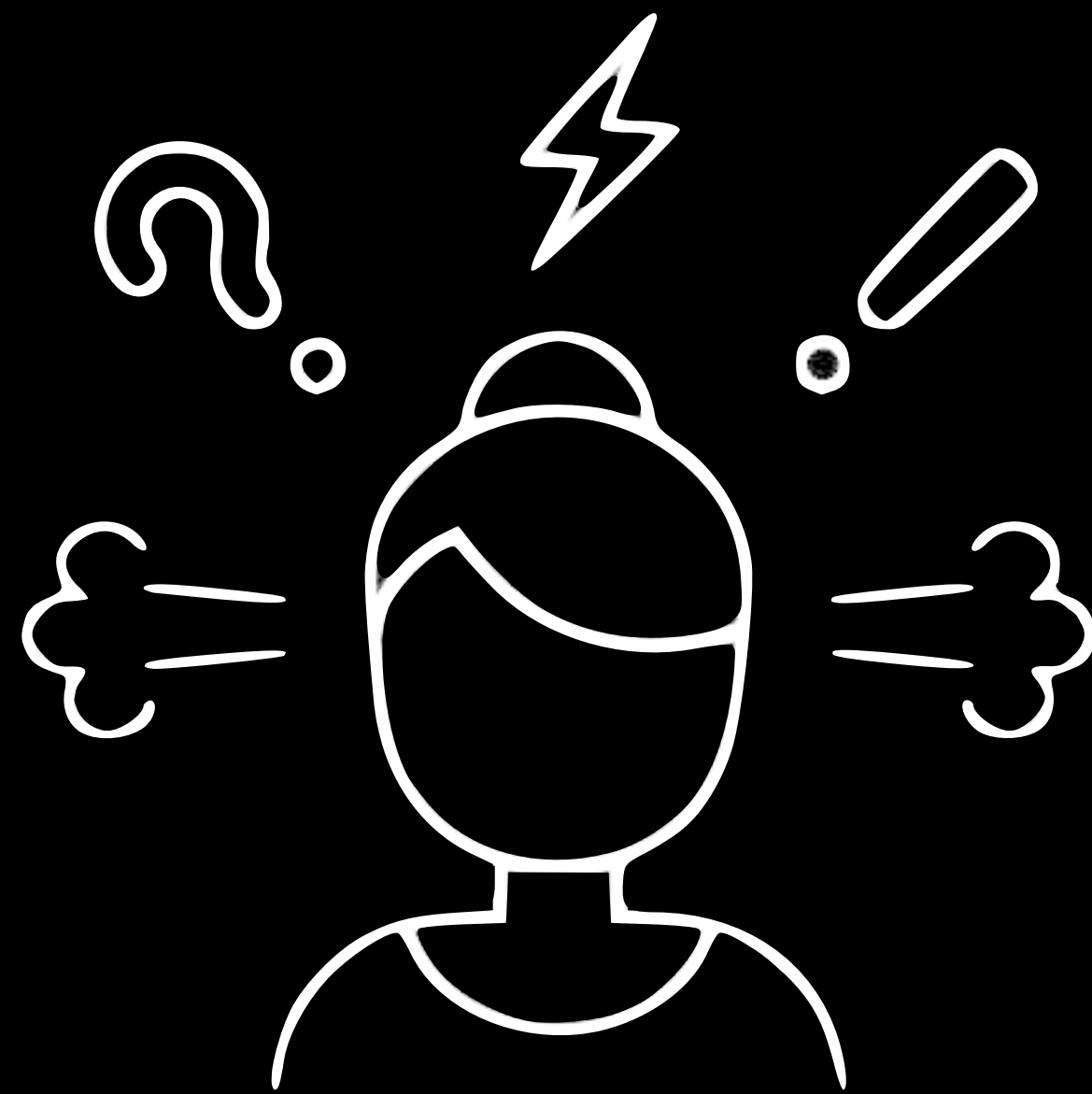
rescue strategy: accommodation

(e.g., Heim 1983, van der Sandt 1992)

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rescue strategy: accommodation

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accommodation is a rescue strategy but with “informative” presuppositions it must apply in the majority of examples

(e.g., Delin 1995, Spenader 2003)



# “informative” presuppositions

CC of clause-embedding predicates (*know, discover, realize, regret...*)

Pre-state of change-of-state predicates (*stop, continue,...*)

Content of temporal clauses (*before, after,...*)

Existential content of clefts (e.g., *It was Alvin who arrived*)

Possession content of possessive NPs (e.g., *Brenda’s parrot*)

Prejacent of *only* (e.g., *Only Cassie danced*)

Prejacent of manner adverb sentences (e.g., *Simone ran quickly*)

...

(e.g., Beaver, Geurts & Denlinger 2021)



The Guardian, April 26 2004

“Geographically, Europe can be divided in two parts: Europe of the hare and Europe of the squirrel. Estonia is the latter: a squirrel could, without too much trouble, go from one end of the country to the other, jumping from tree to tree. Of course, **the squirrel doesn't know that Estonia includes hundreds of islands**, small and big. Estonia is a land of islands and forests. [...]”

~> Estonia includes hundreds of islands



Nancy asks: “Does Cole know that Julian dances salsa?”

~→ Julian dances salsa

1. Nancy knows (and we know) that Julian is Cuban.
2. Nancy knows (and we know) that Julian is German.

(Degen & Tonhauser 2021, *Open Mind*; ms under review)

**desiderata**



## **desiderata**

**allow for the principled integration of information from multiple factors**  
(lexical entailments, compositional semantics, prior beliefs, QUDs,...)

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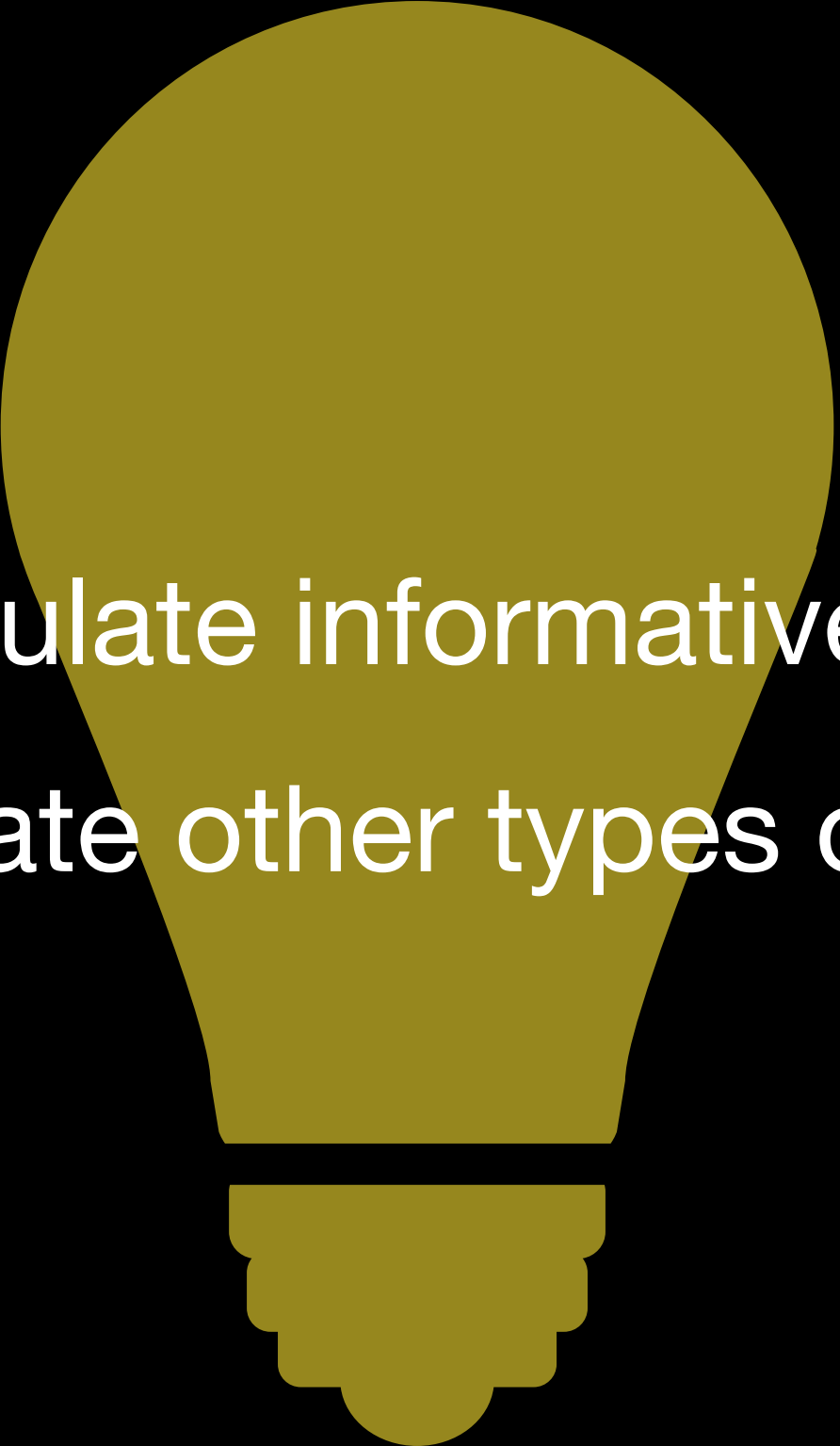
**predict probabilistic (not merely categorical) inferences**



instead of developing analyses tailored to informative presuppositions,  
we **can** and **should** develop more general analyses that make predictions about  
inferences drawn from utterances

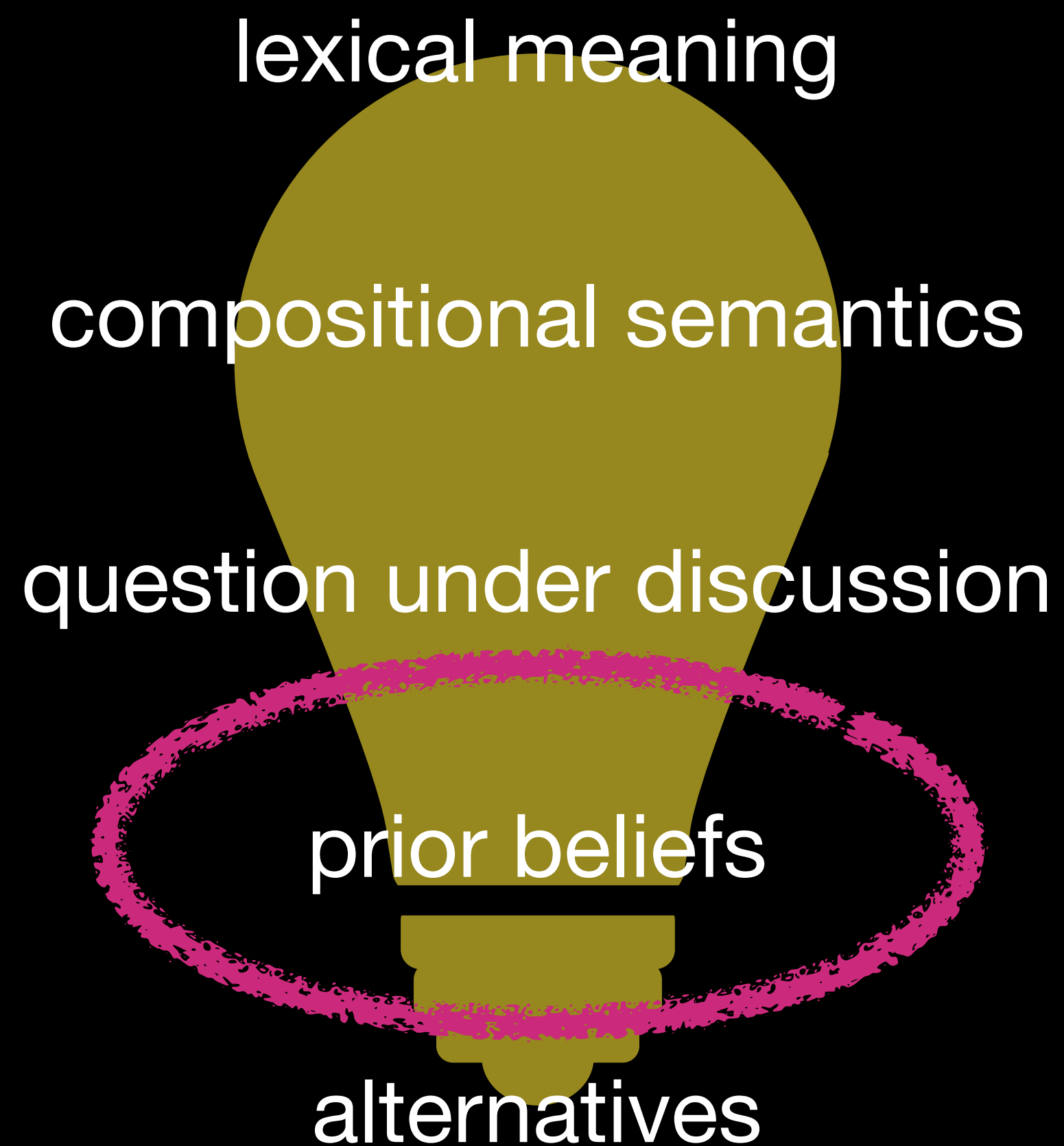
informative presuppositions are just one kind of inference





factors that modulate informative presuppositions  
also modulate other types of inferences

# factors that modulate informative presuppositions



(e.g., Abrusán 2011, 2016; Abusch 2002, 2010; Chemla 2009; Cummins & Rohde 2015; Degen & Tonhauser 2021, 2022, under review; Djärv & Bacovcin 2020; Romoli 2015; Simons et al 2010, 2017)

## **desiderata**

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## **Rational Speech Act (RSA) modeling framework**

(e.g., Frank & Goodman 2012; Goodman & Frank 2016)

Cole doesn't *think/know* that Charley speaks Spanish.



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↪ Charley speaks Spanish

Cole doesn't *think/know* that Charley speaks Spanish.

~ Charley speaks Spanish

**empirical targets**

***know* projects more than *think***

(e.g., Kiparsky & Kiparsky 1970; Degen & Tonhauser 2022)

**prior beliefs modulate projection**

(e.g., Mahler 2020, 2022; Degen & Tonhauser 2021)

**QUDs modulate projection**

(e.g., Abrusán 2011, 2016; Simons et al 2017; Tonhauser et al. 2018, Degen & Tonhauser under review)

# basic model

$$P_{L_0}(Q(w) \mid u, CG, Q) \propto \sum_{w' \in CG \cap \llbracket u \rrbracket} \delta_{Q(w)=Q(w')} \cdot P(w') \quad \text{literal listener}$$

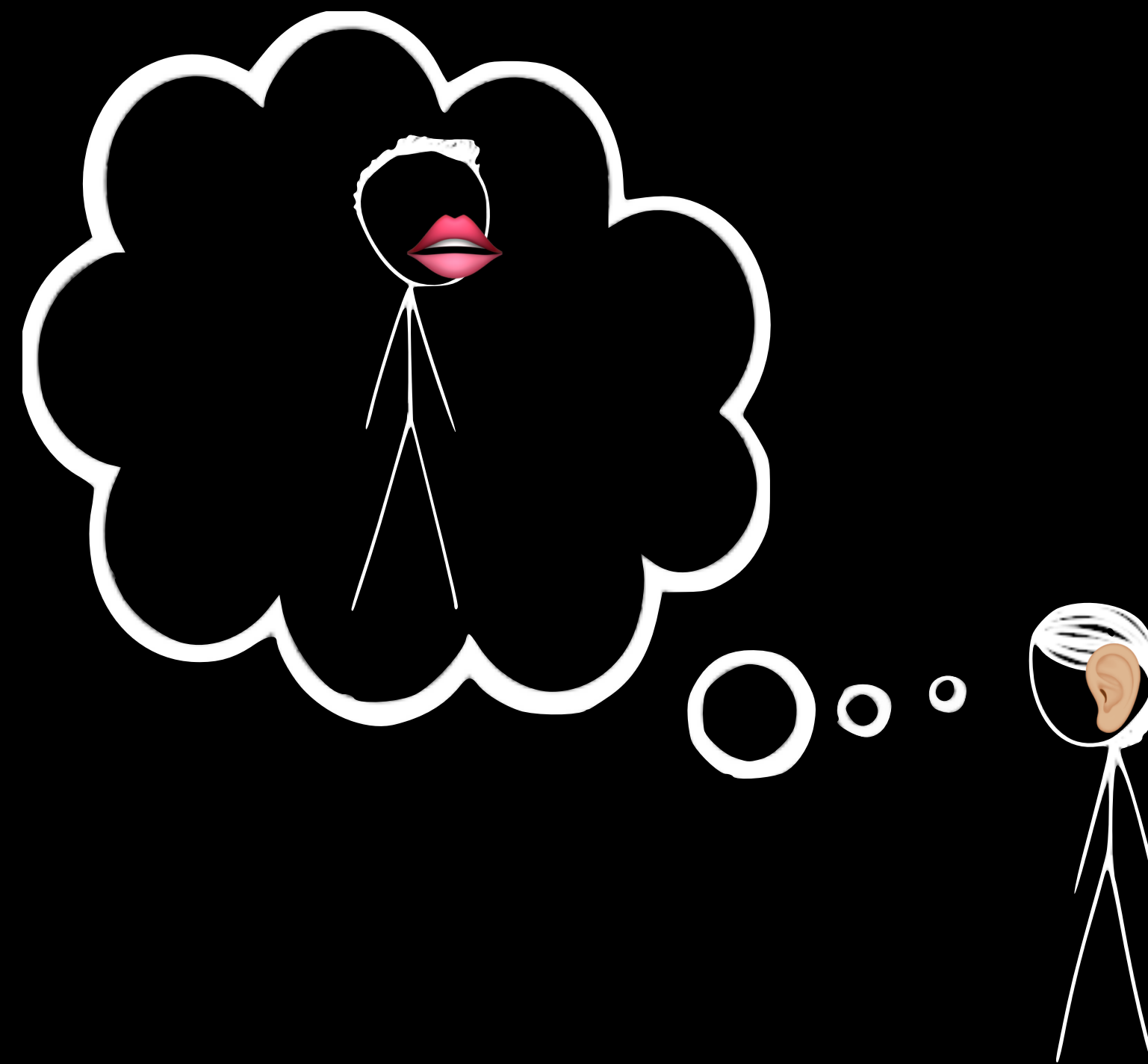
$$P_{S_1}(u \mid w, CG, Q) \propto \exp(\alpha(\log(P_{L_0}(Q(w) \mid u, CG, Q) - C(u)))) \quad \text{pragmatic speaker}$$

$$P_{L_1}(Q(w), CG \mid u, Q) \propto P_{S_1}(u \mid w, CG, Q) \cdot P(w) \cdot P(CG) \quad \text{pragmatic listener}$$

adapted from Qing et al. 2016 (*CogSci*) for *stop*

# basic model intuition

listeners interpret utterances by **reasoning about** what would have led **a speaker** to produce the utterance in the first place

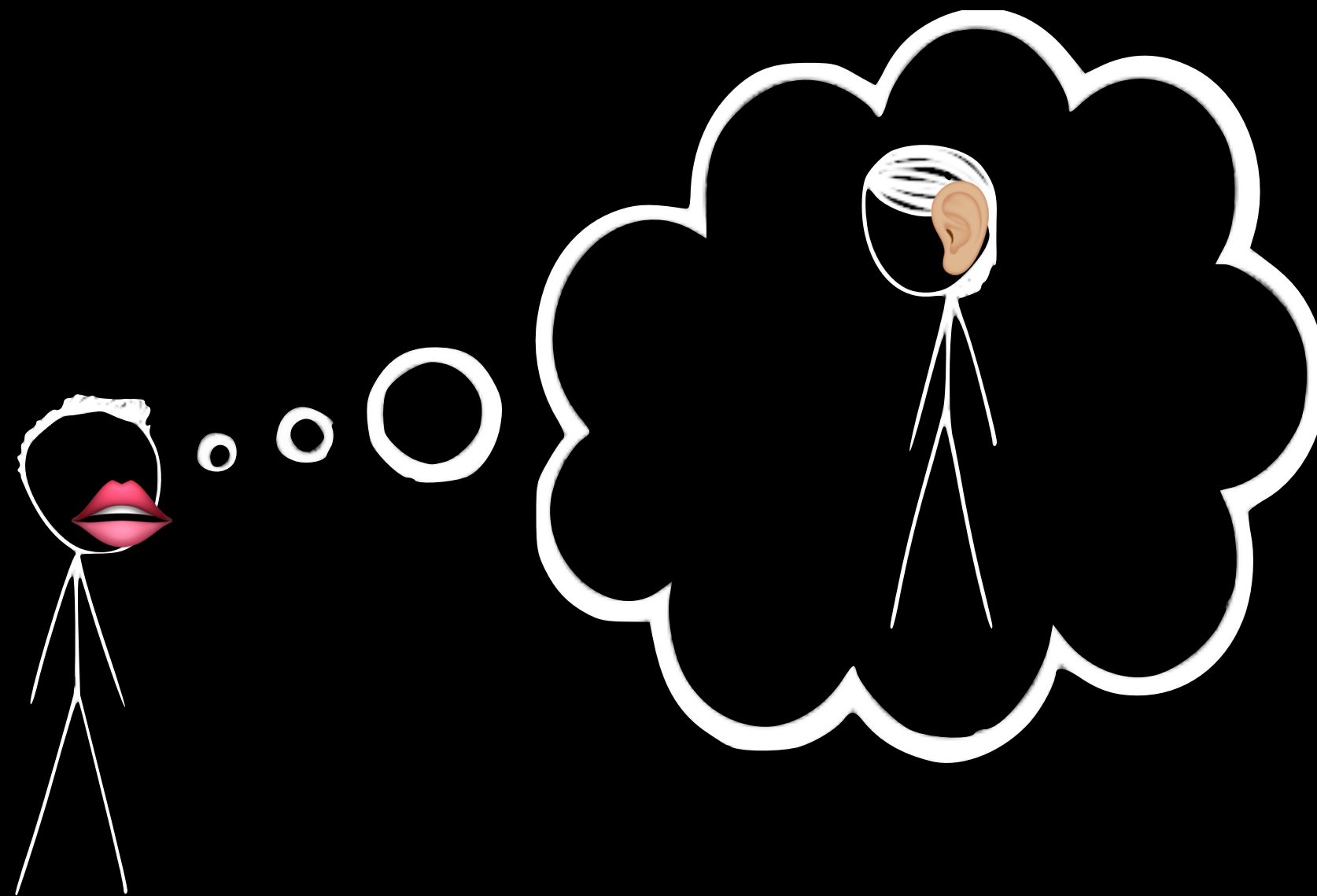




# basic model intuition

listeners interpret utterances by **reasoning about** what would have led **a speaker** to produce the utterance in the first place

speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



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speakers hold **private commitments** about how they take the world to be (i.e., relevant assumptions about the world)

# basic model intuition

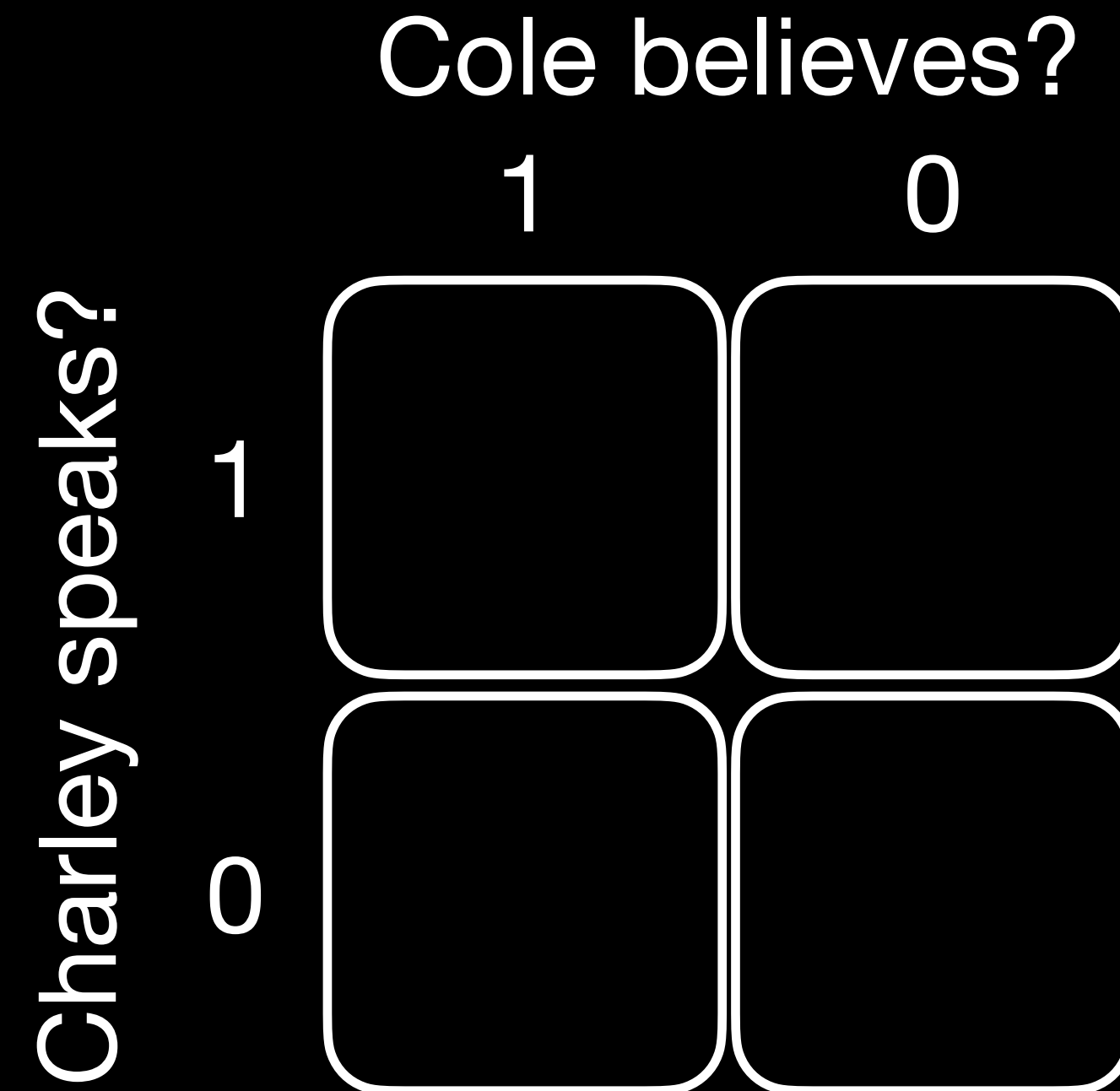
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speakers hold **private commitments** about how they take the world to be (i.e., relevant assumptions about the world)

a ***know*** utterance is **more useful** to a speaker who is already **privately committed to the content of the complement** being true

# basic model worlds



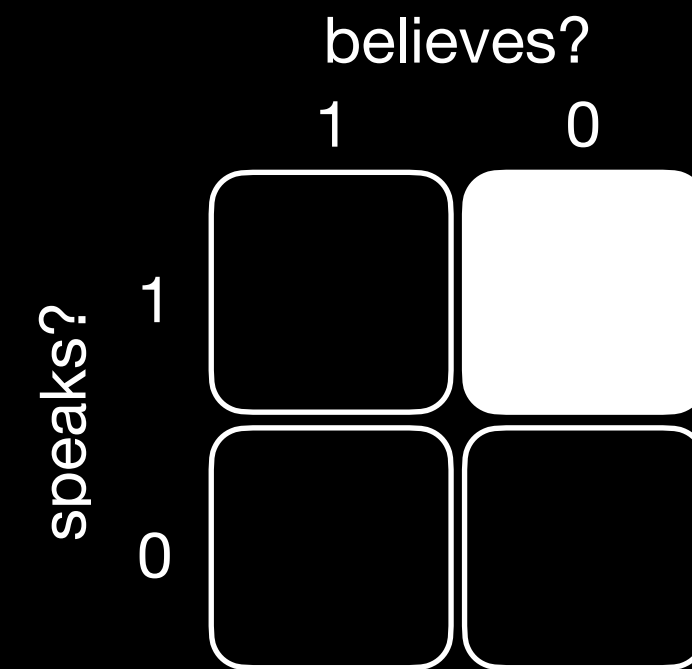
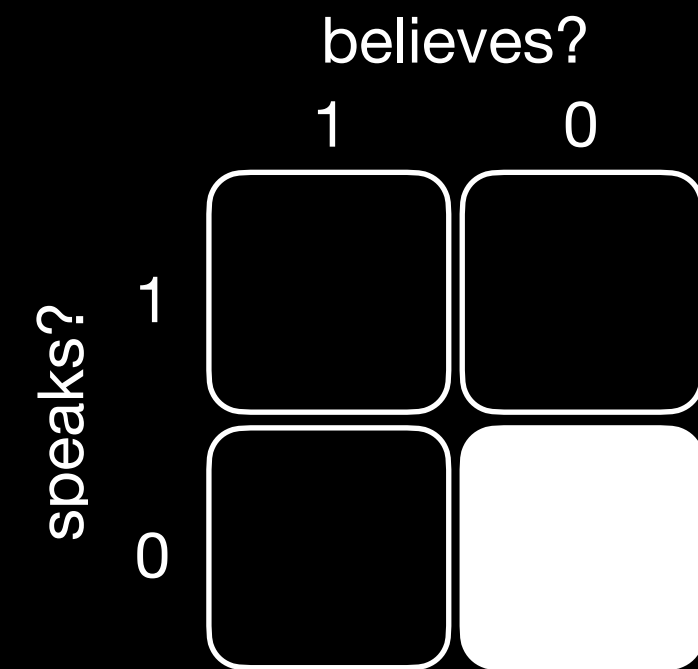
Cole doesn't *think/know* that Charley speaks Spanish.

# basic model worlds

		believes?	
		1	0
speaks?	1		
	0		

Cole doesn't *think/know* that Charley speaks Spanish.

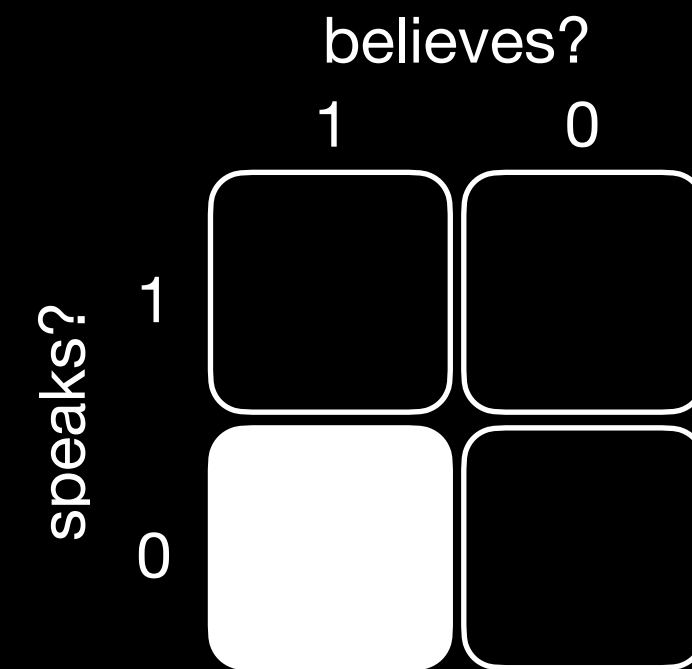
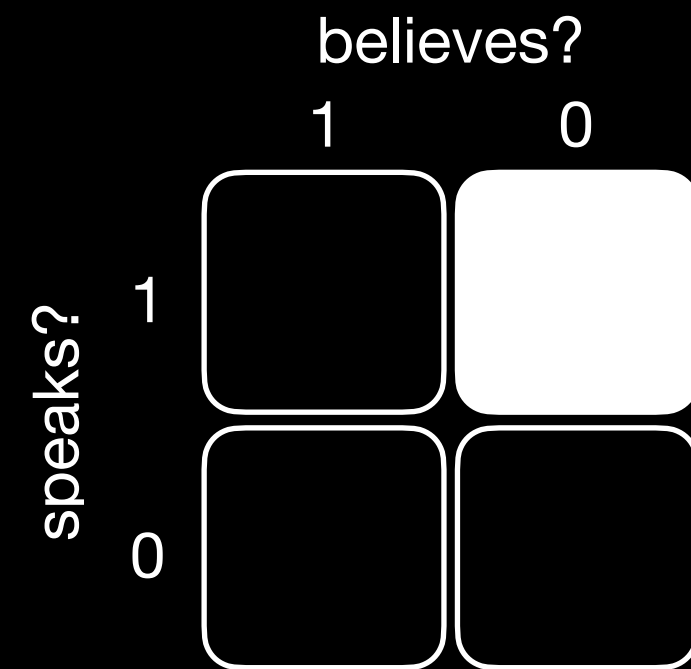
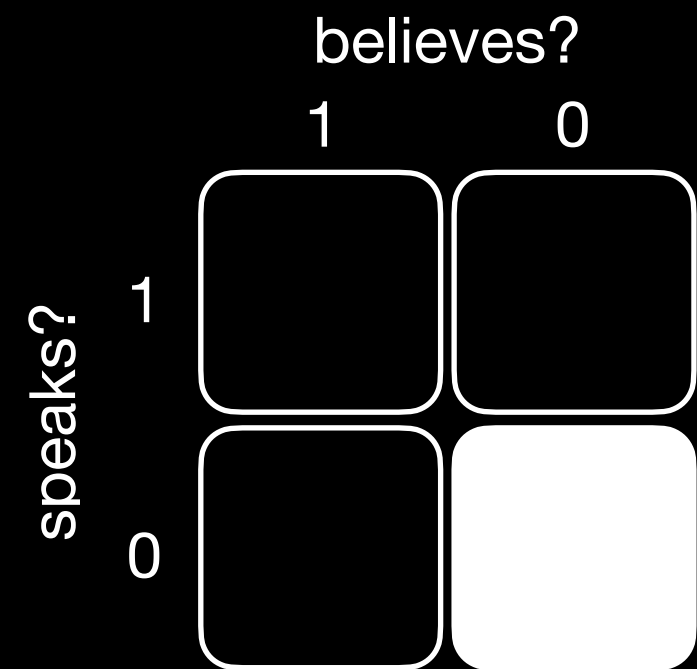
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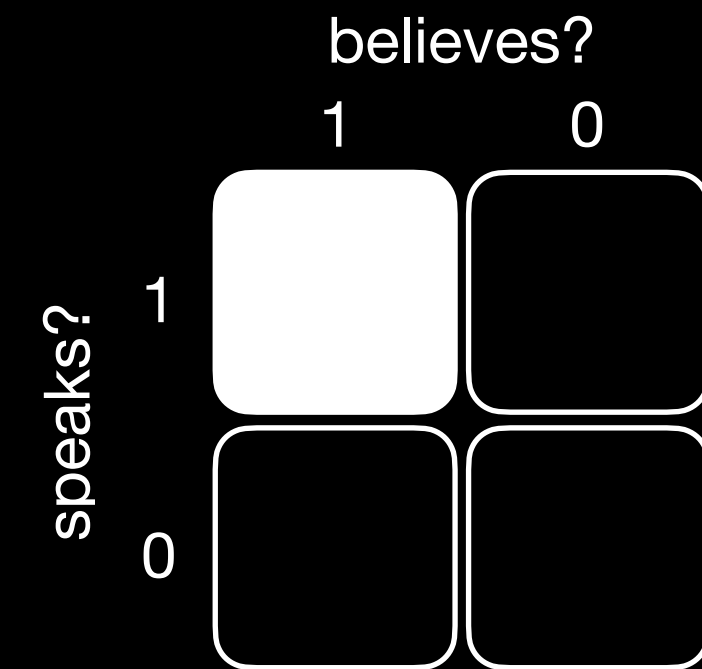
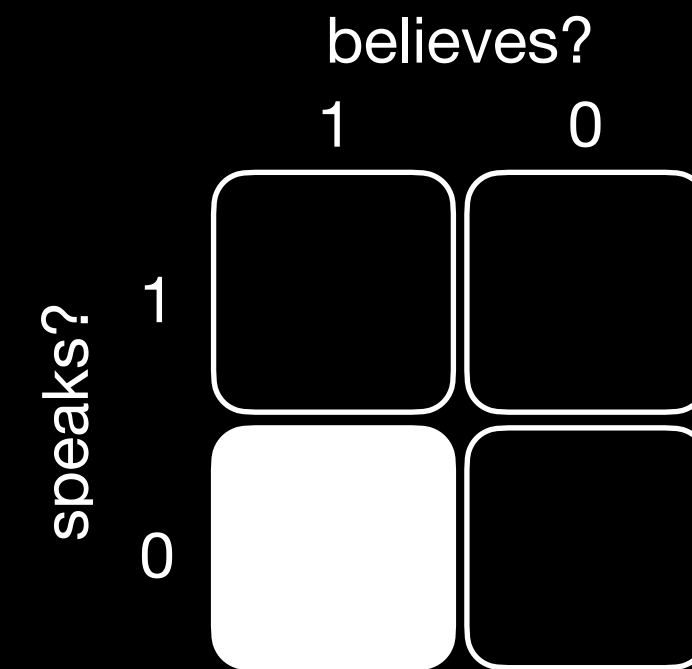
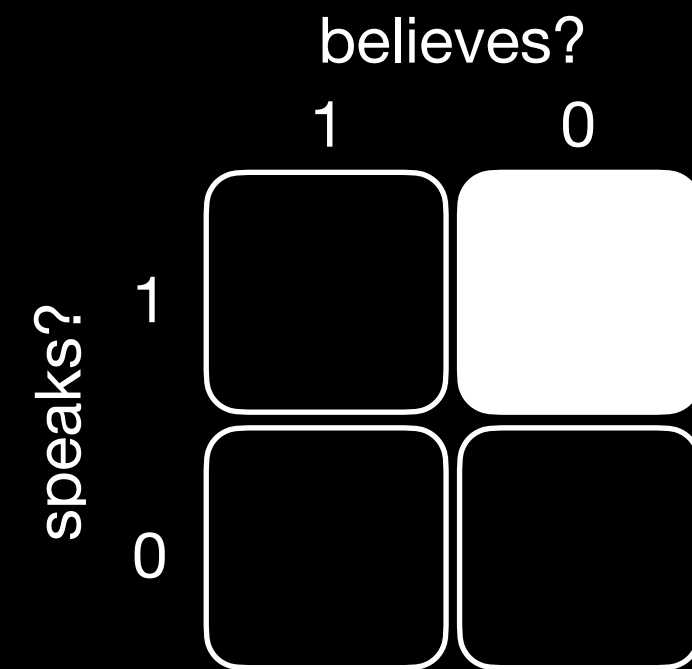
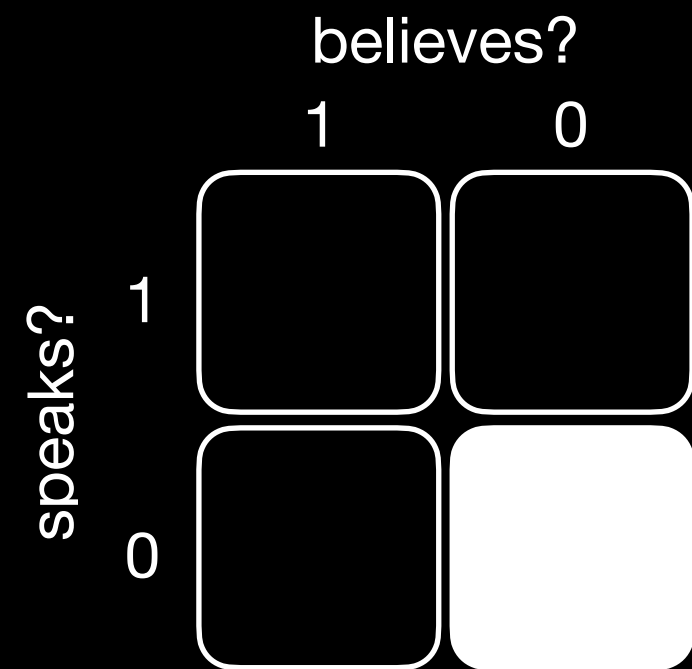


# basic model worlds



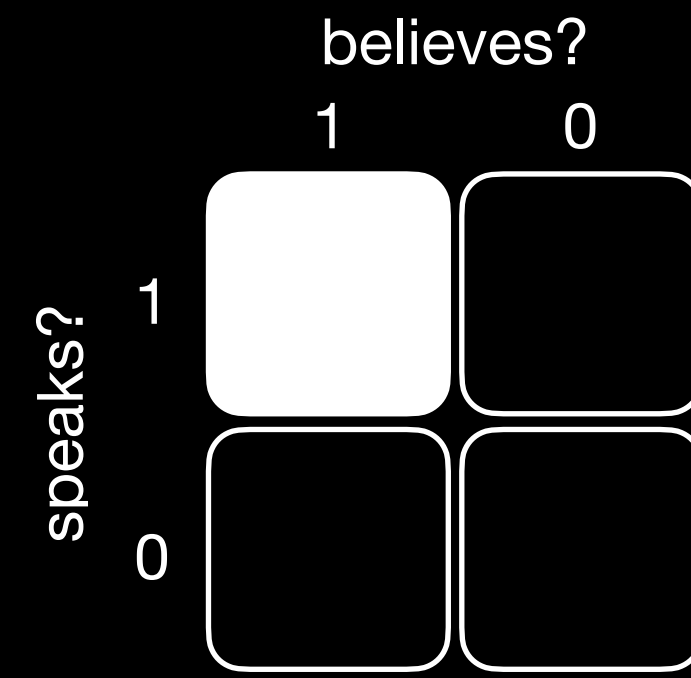
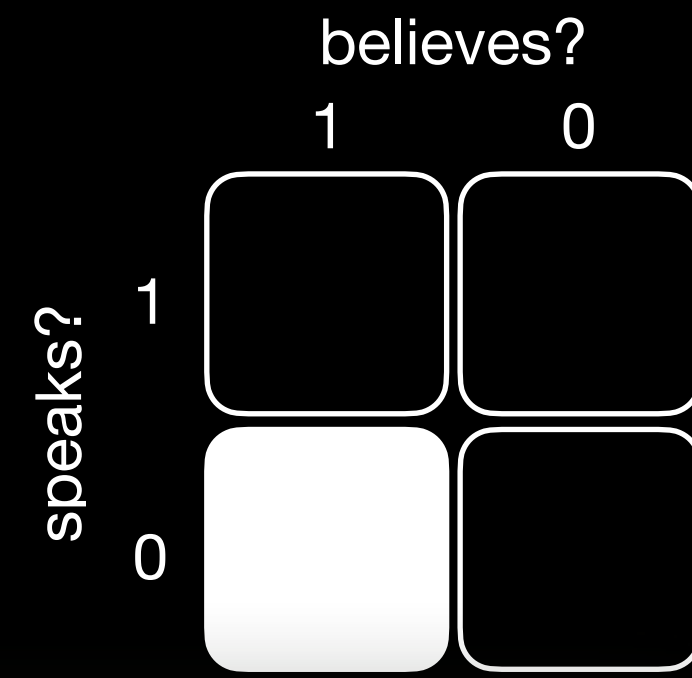
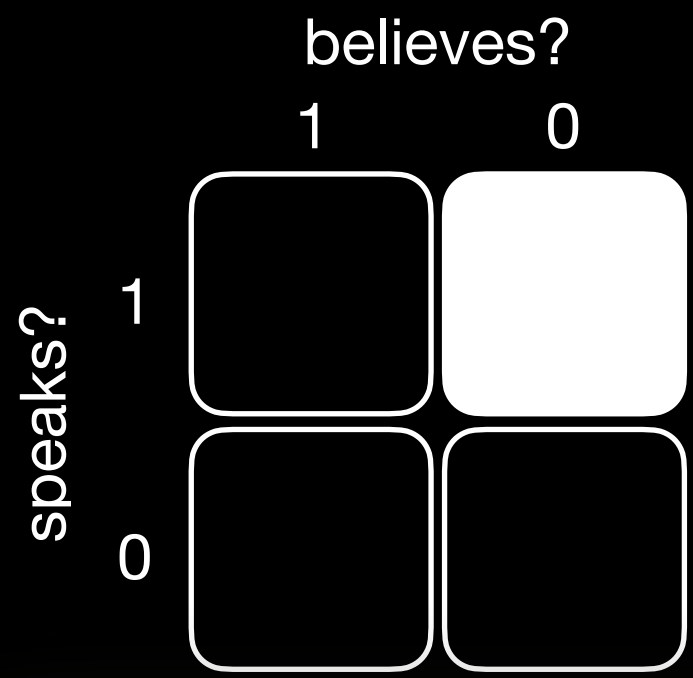
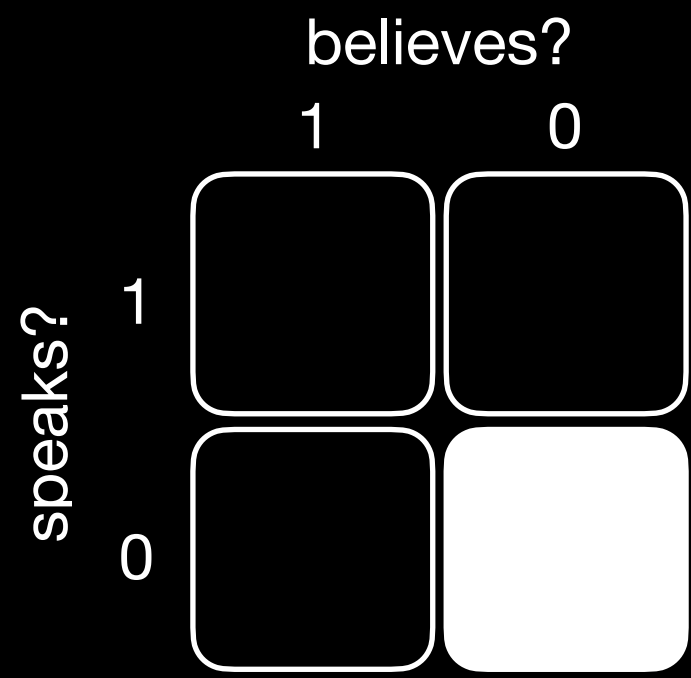
Cole doesn't *think/know* that Charley speaks Spanish.

# basic model worlds



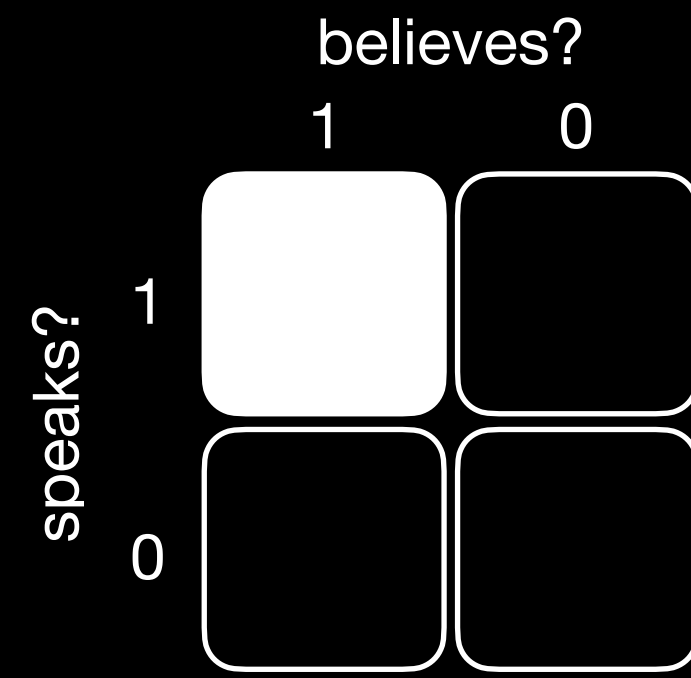
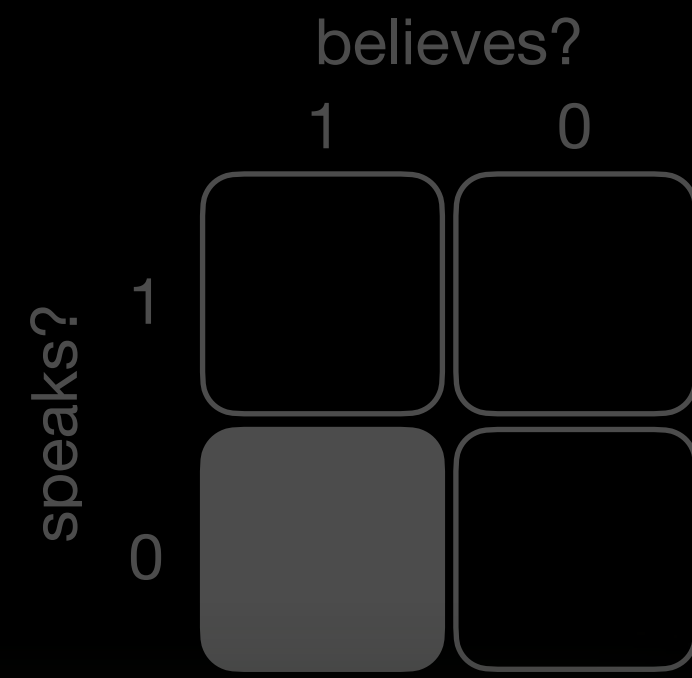
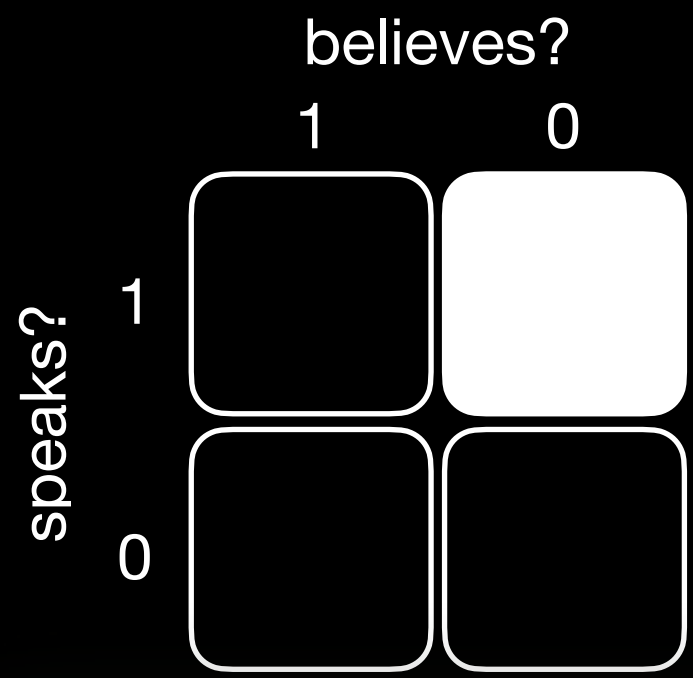
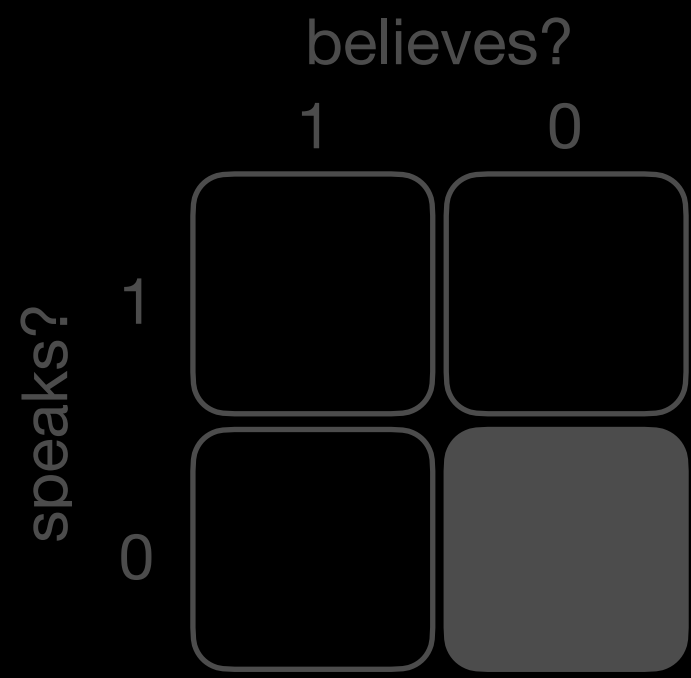
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# prior belief manipulation



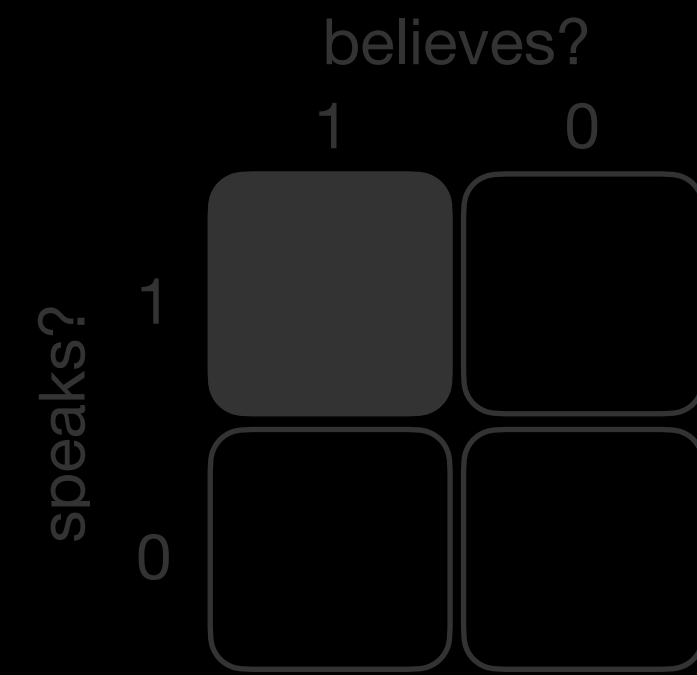
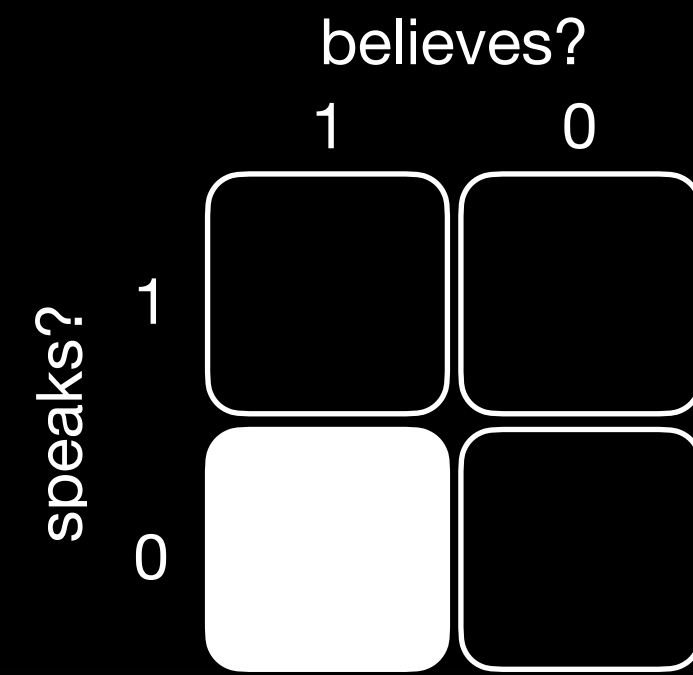
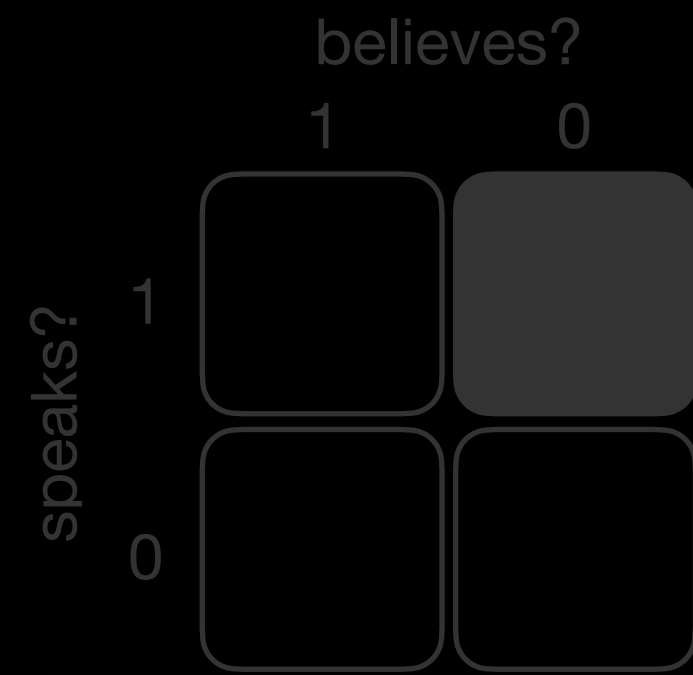
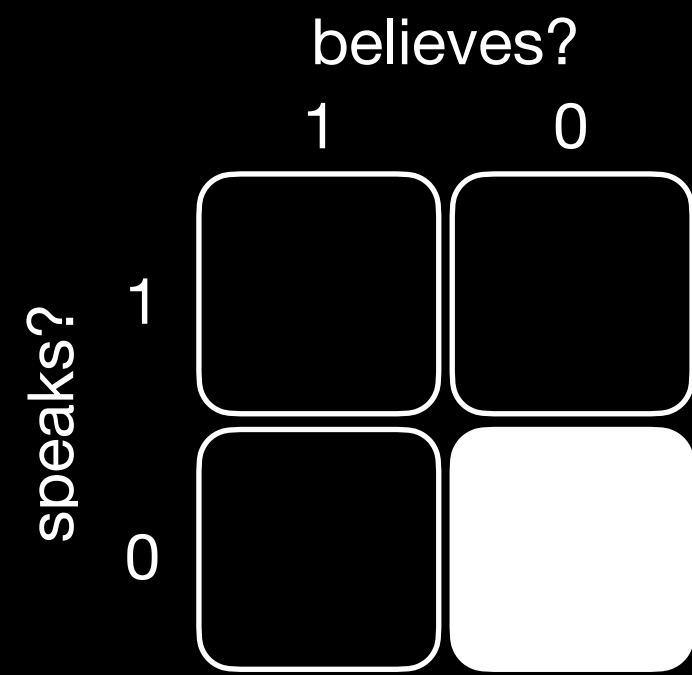
Charley lives in Mexico

# prior belief manipulation





# prior belief manipulation



# basic model utterances and semantics

Charley speaks Spanish.

		Cole believes?	
		1	0
Charley speaks?	1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	0	<input type="checkbox"/>	<input type="checkbox"/>

Charley doesn't speak Spanish.

		Cole believes?	
		1	0
Charley speaks?	1	<input type="checkbox"/>	<input type="checkbox"/>
	0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>



# basic model utterances and semantics

Charley speaks Spanish.

		Cole believes?	
		1	0
Charley speaks?	1		
	0		

Cole thinks that  
Charley speaks Spanish.

		Cole believes?	
		1	0
Charley speaks?	1		
	0		

Charley doesn't speak Spanish.

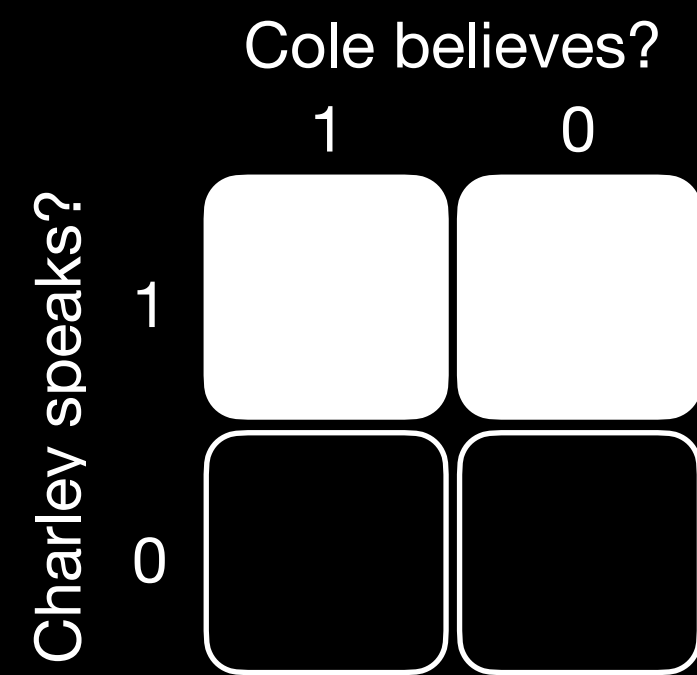
		Cole believes?	
		1	0
Charley speaks?	1		
	0		

Cole doesn't think that  
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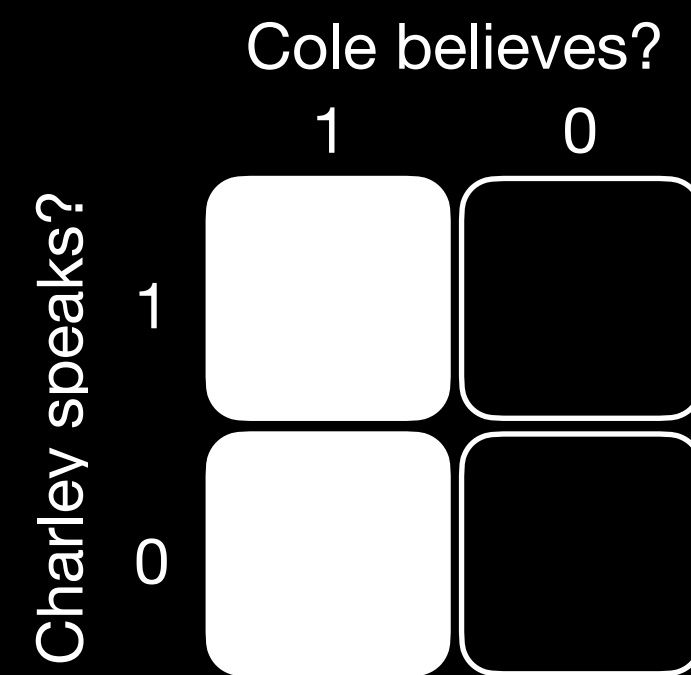
		Cole believes?	
		1	0
Charley speaks?	1		
	0		

# basic model utterances and semantics

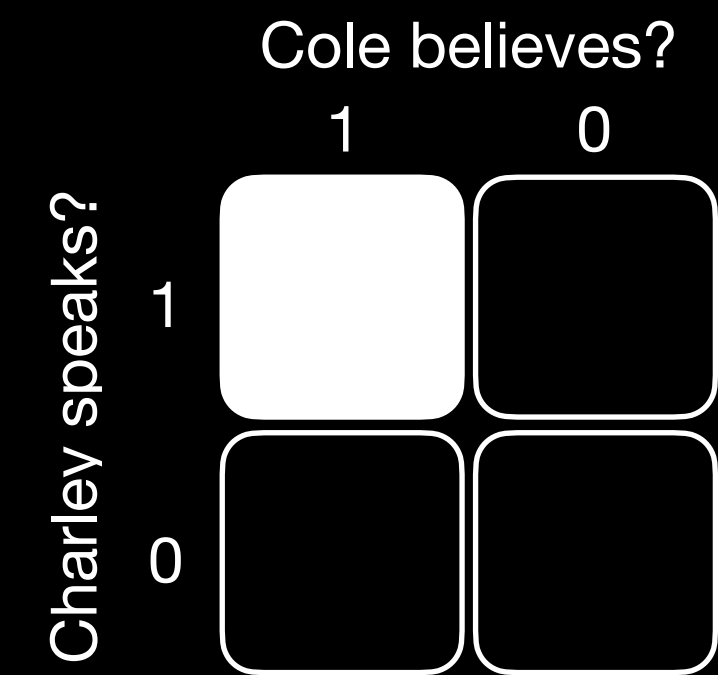
Charley speaks Spanish.



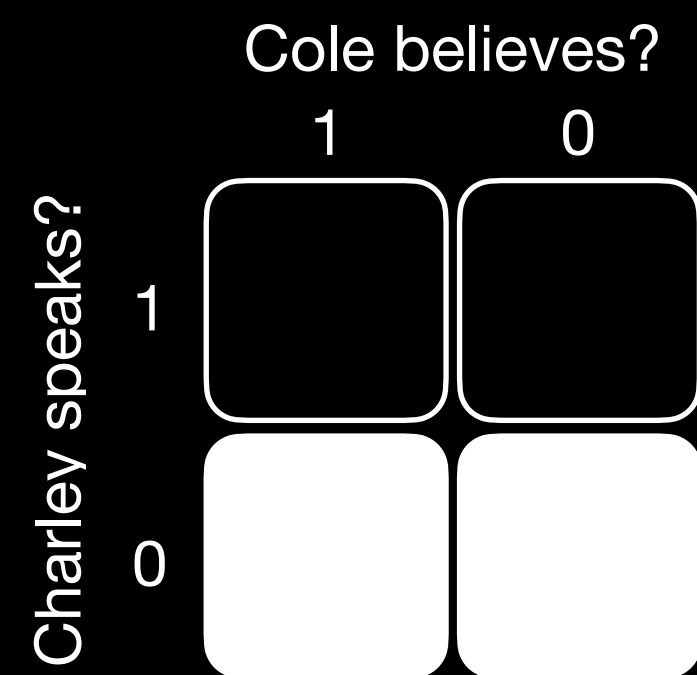
Cole thinks that  
Charley speaks Spanish.



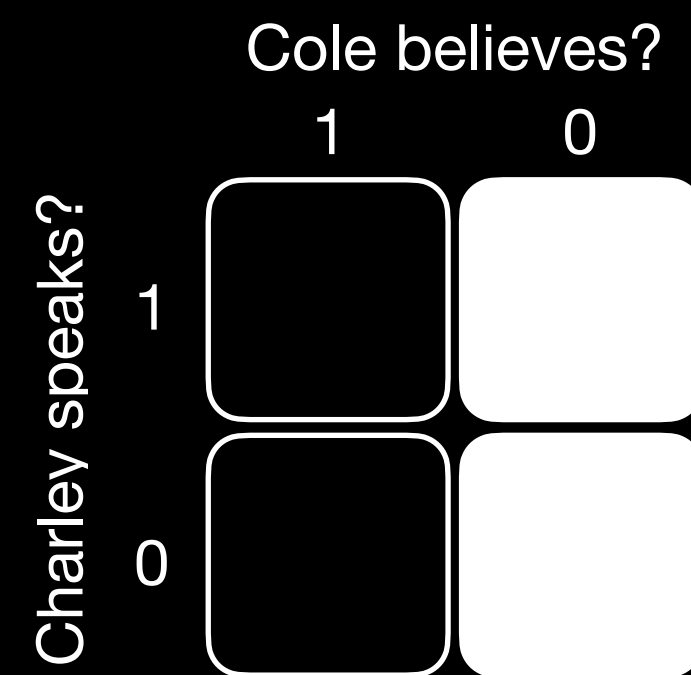
Cole knows that  
Charley speaks Spanish.



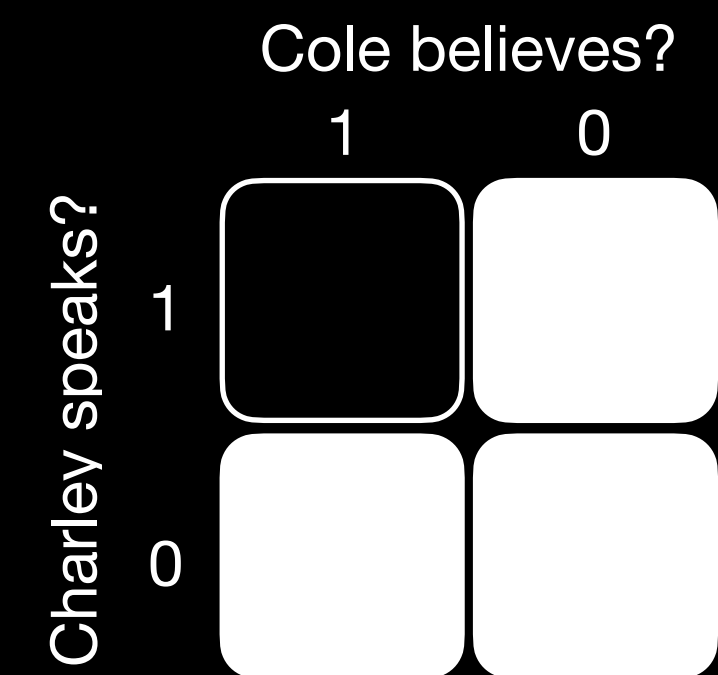
Charley doesn't speak Spanish.



Cole doesn't think that  
Charley speaks Spanish.



Cole doesn't know that  
Charley speaks Spanish.



# basic model utterances and semantics

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		Cole believes?	
		1	0
Charley speaks?	1		
	0		

Cole thinks that  
Charley speaks Spanish.

		Cole believes?	
		1	0
Charley speaks?	1		
	0		

Cole knows that  
Charley speaks Spanish.

		Cole believes?	
		1	0
Charley speaks?	1		
	0		

**lexical entailment coded,  
but no presupposition!**

Charley doesn't speak Spanish.

		Cole believes?	
		1	0
Charley speaks?	1		
	0		

Cole doesn't think that  
Charley speaks Spanish.

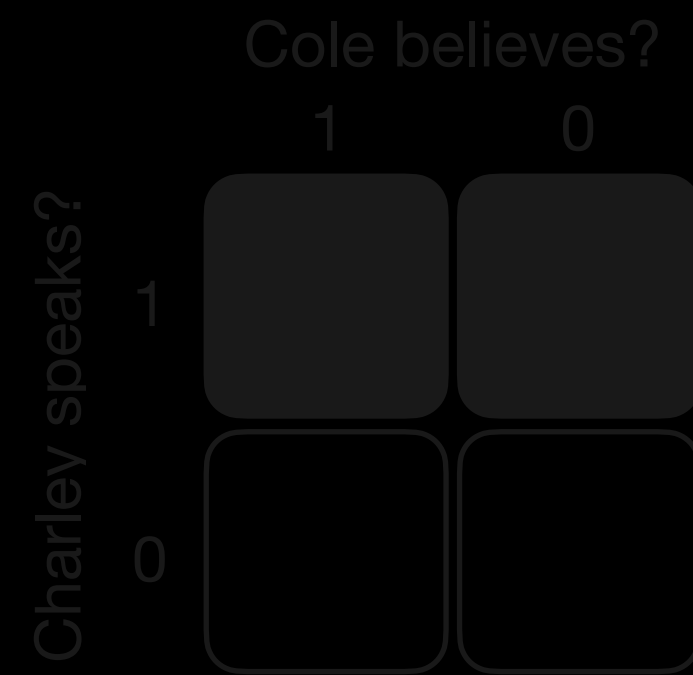
		Cole believes?	
		1	0
Charley speaks?	1		
	0		

Cole doesn't know that  
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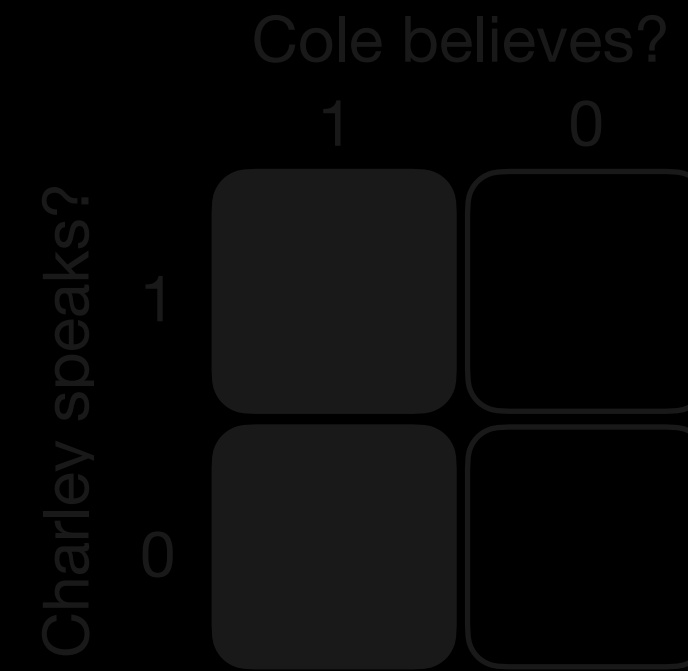
		Cole believes?	
		1	0
Charley speaks?	1		
	0		

# basic model utterances and semantics

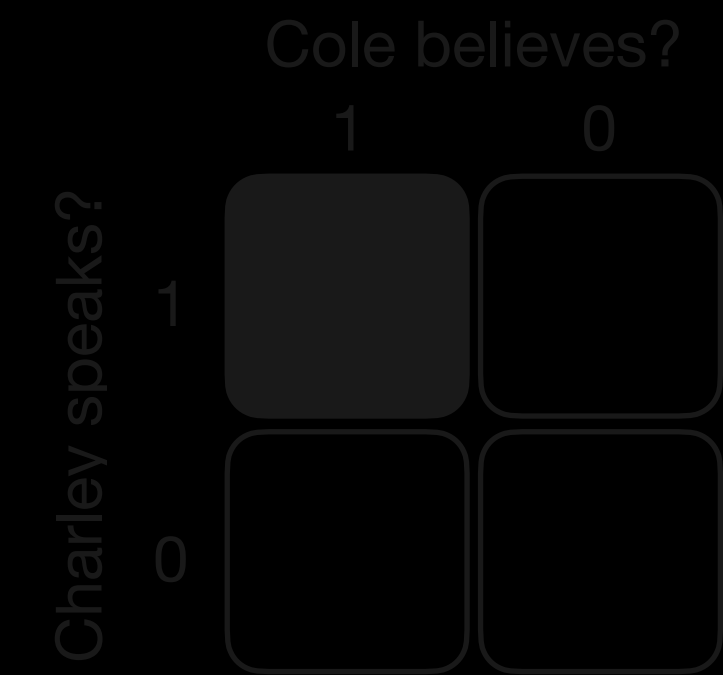
Charley speaks Spanish.



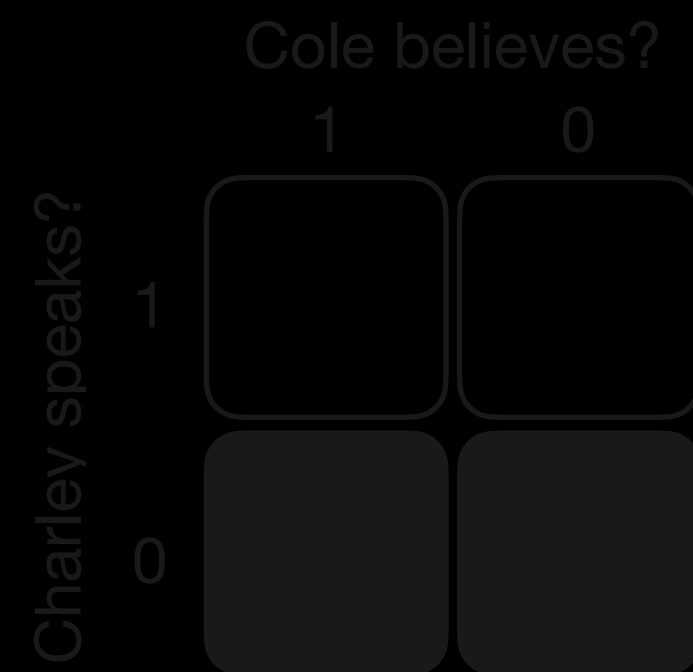
Cole thinks that Charley speaks Spanish.



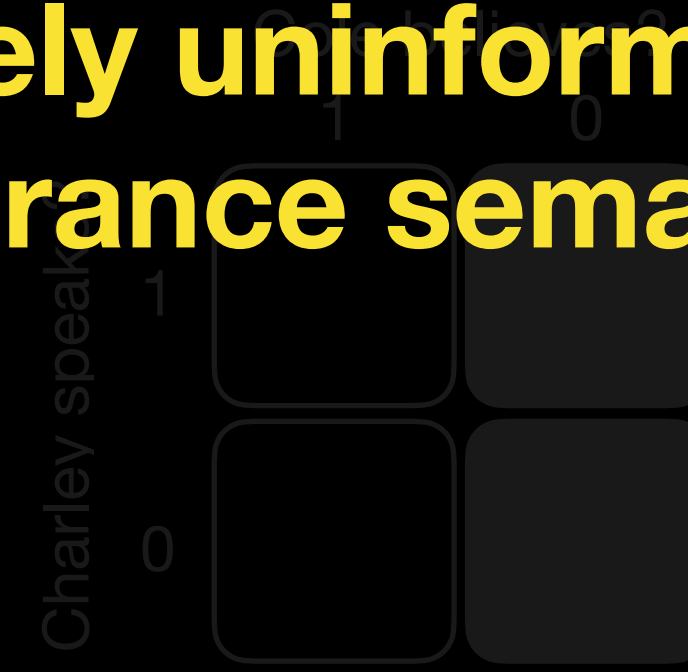
Cole knows that Charley speaks Spanish.



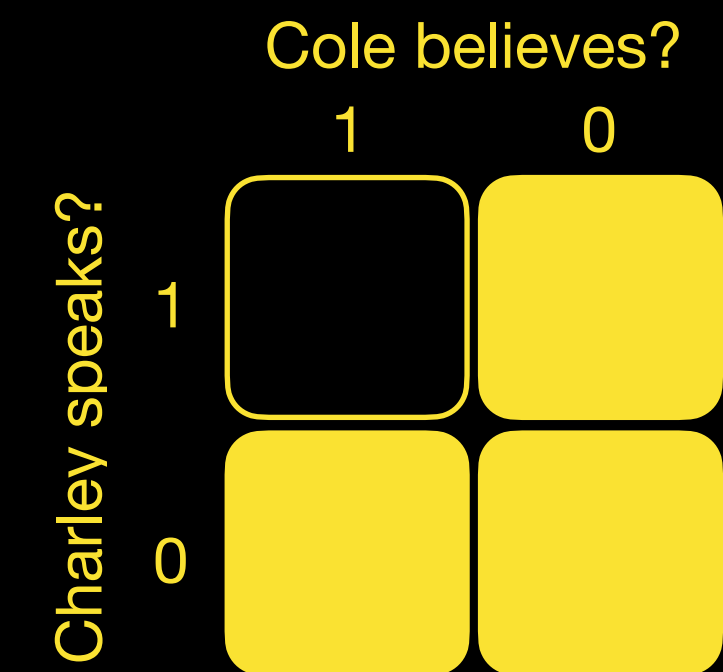
Charley doesn't speak Spanish.



Cole doesn't think that Charley speaks Spanish.



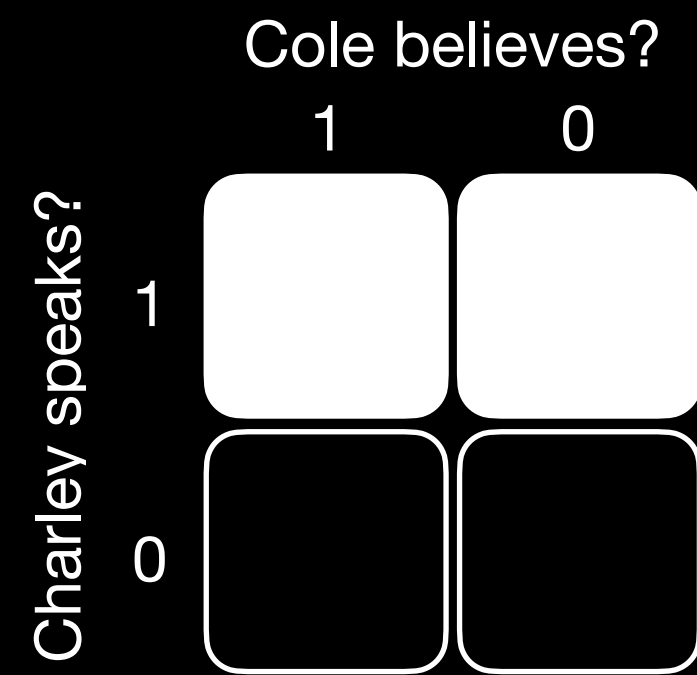
Cole doesn't know that Charley speaks Spanish.



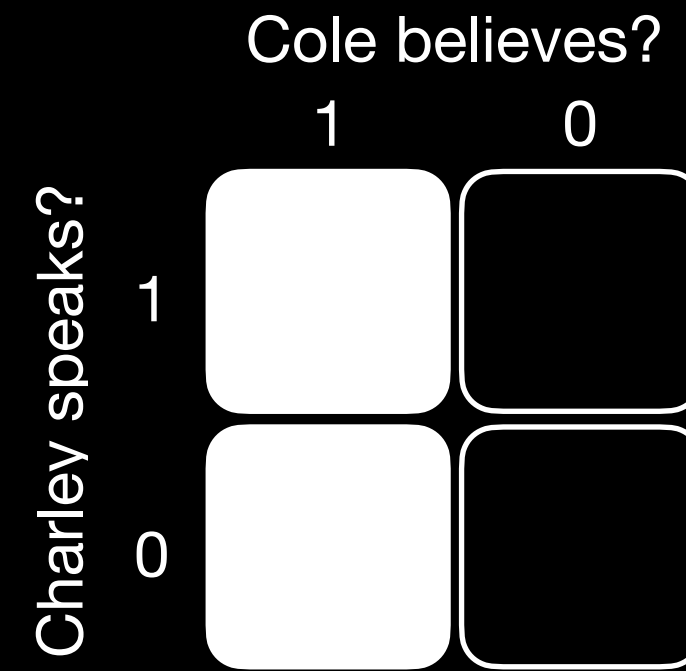
**relatively uninformative utterance semantics**

# basic model utterances and semantics

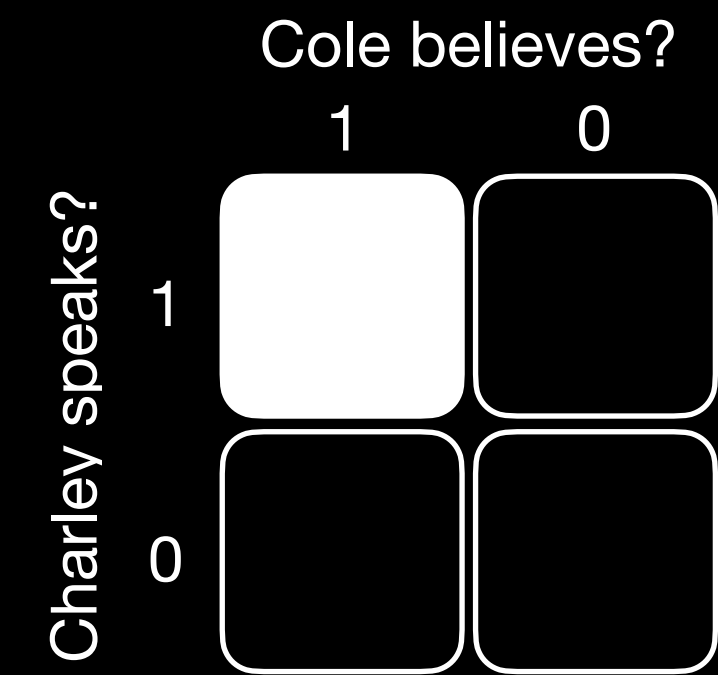
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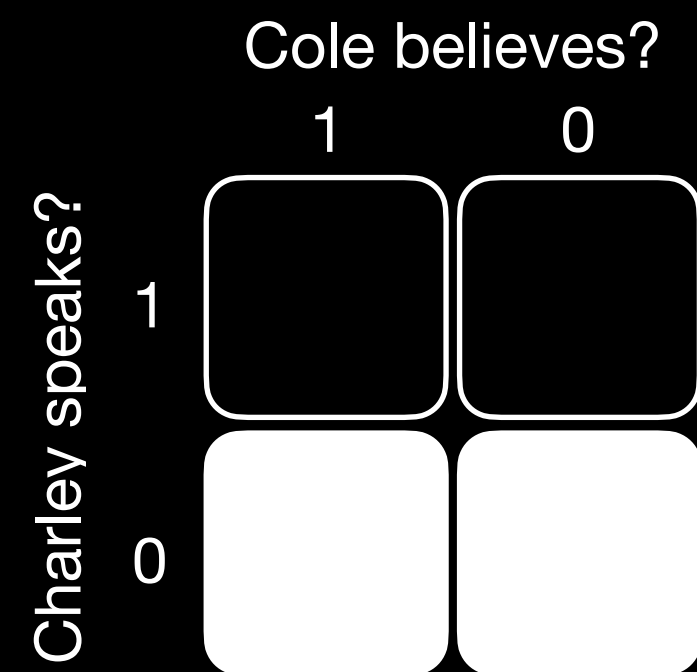
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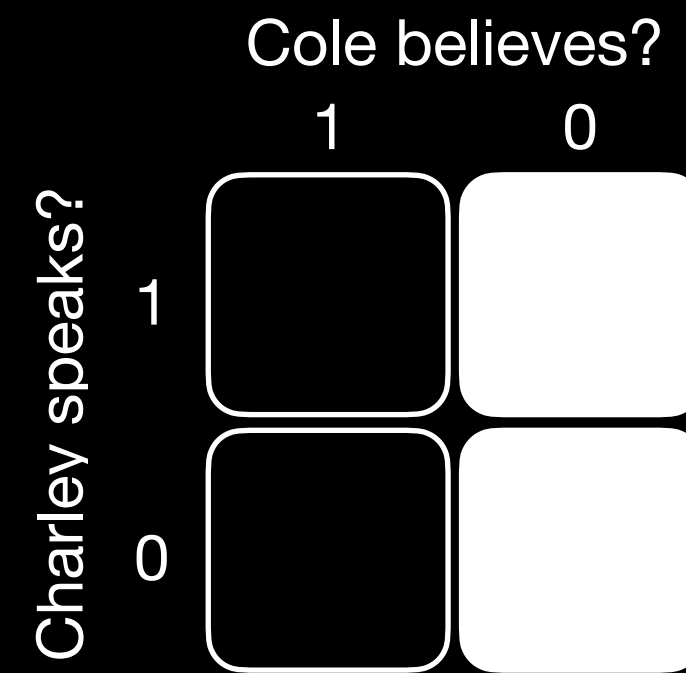
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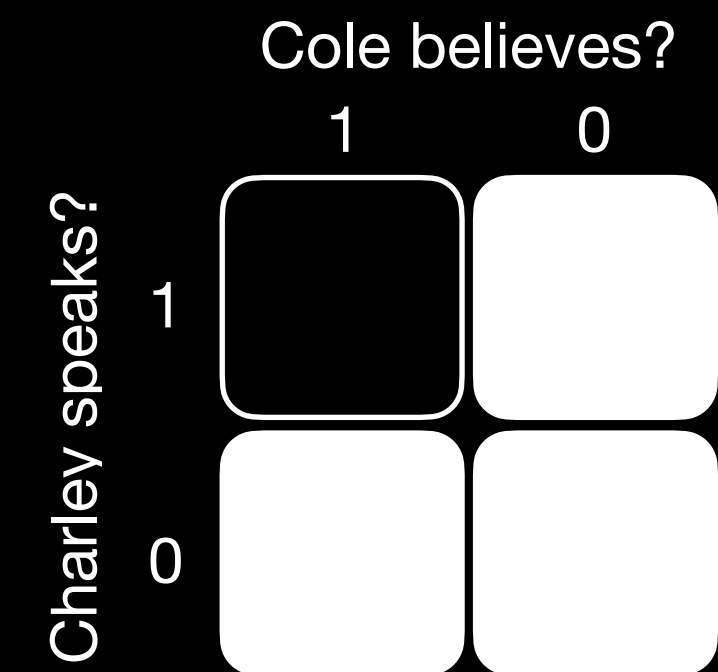
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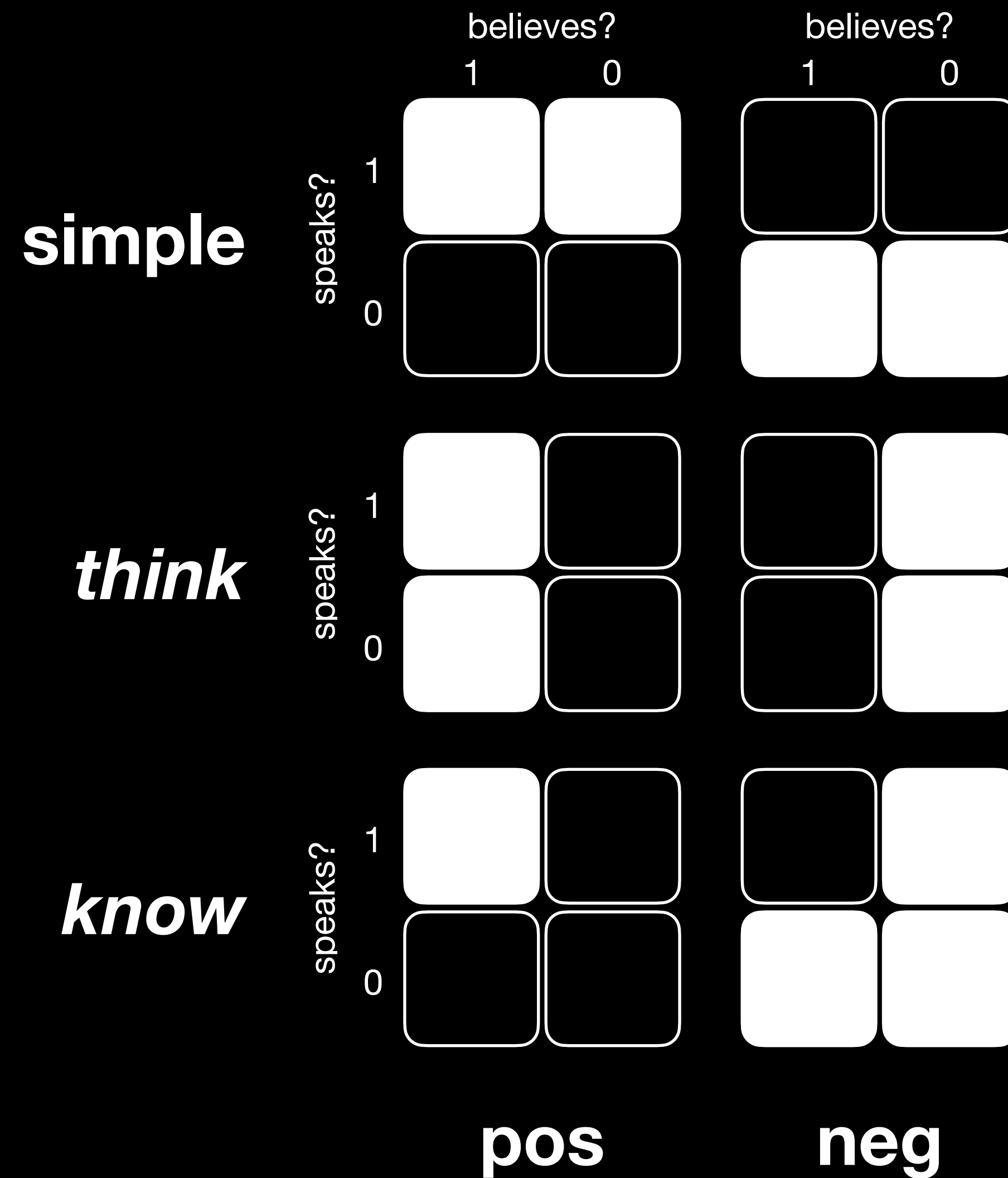
Cole doesn't think that Charley speaks Spanish.



Cole doesn't know that Charley speaks Spanish.



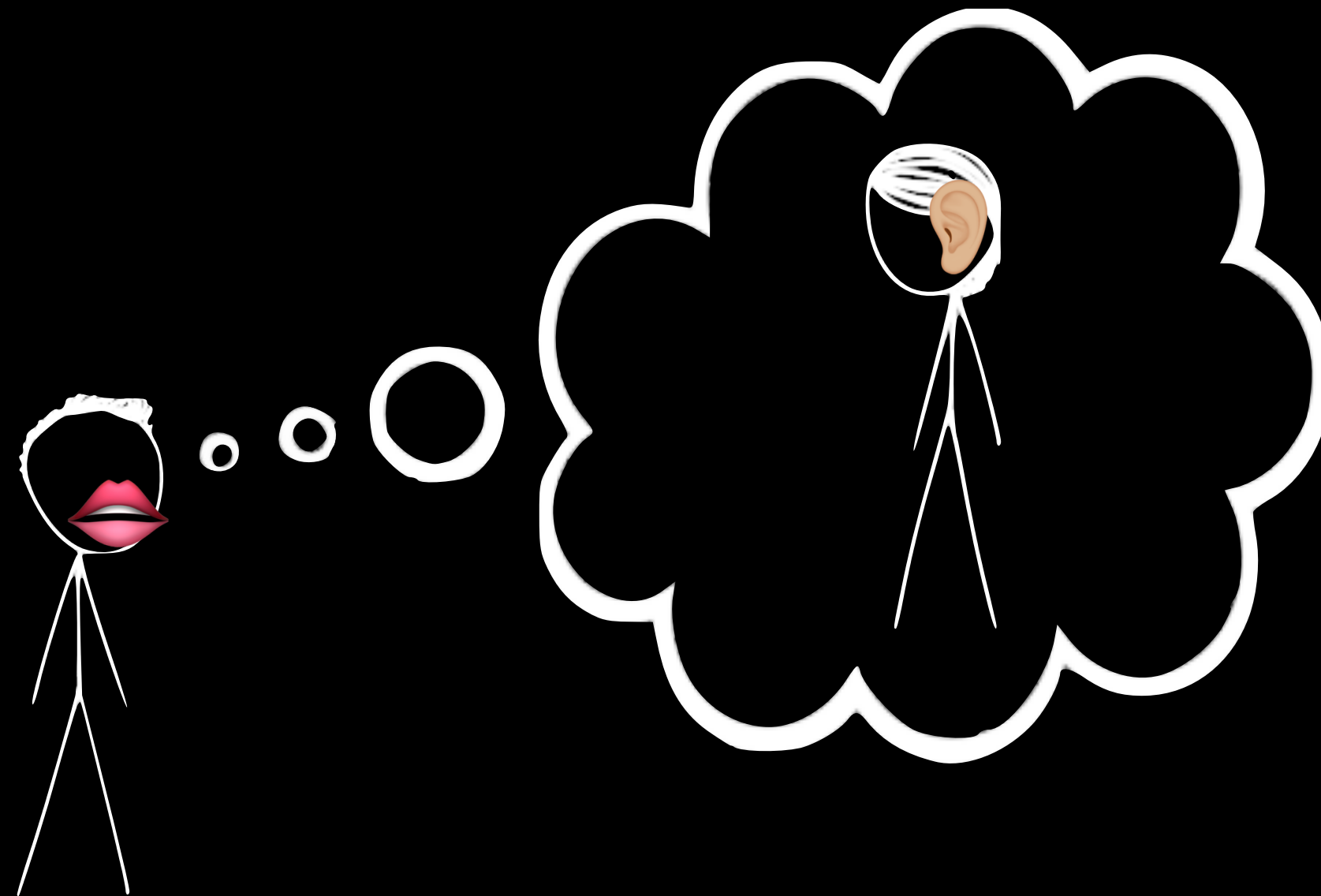
# basic model utterances and semantics





# speaker behavior

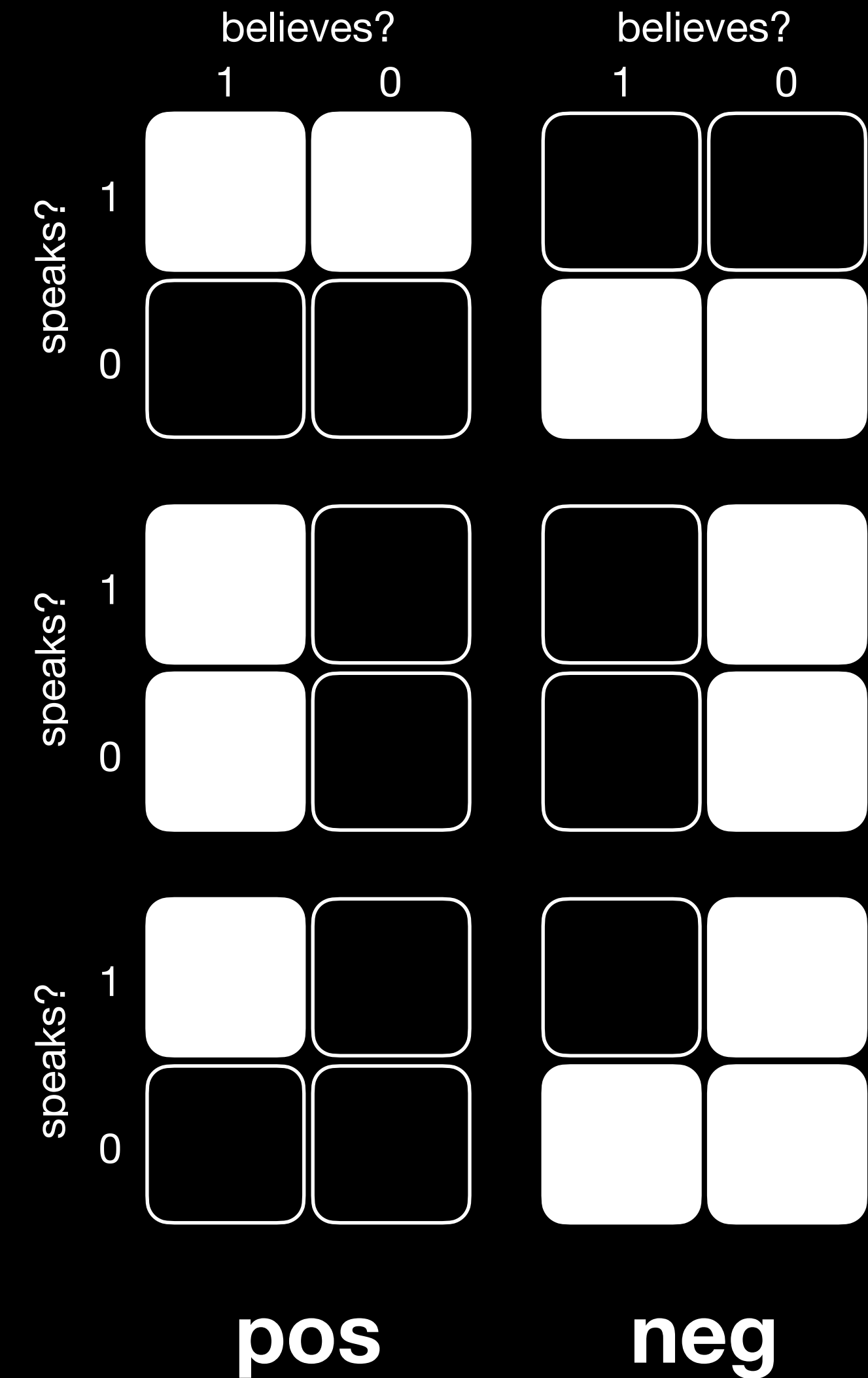
speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



**simple**

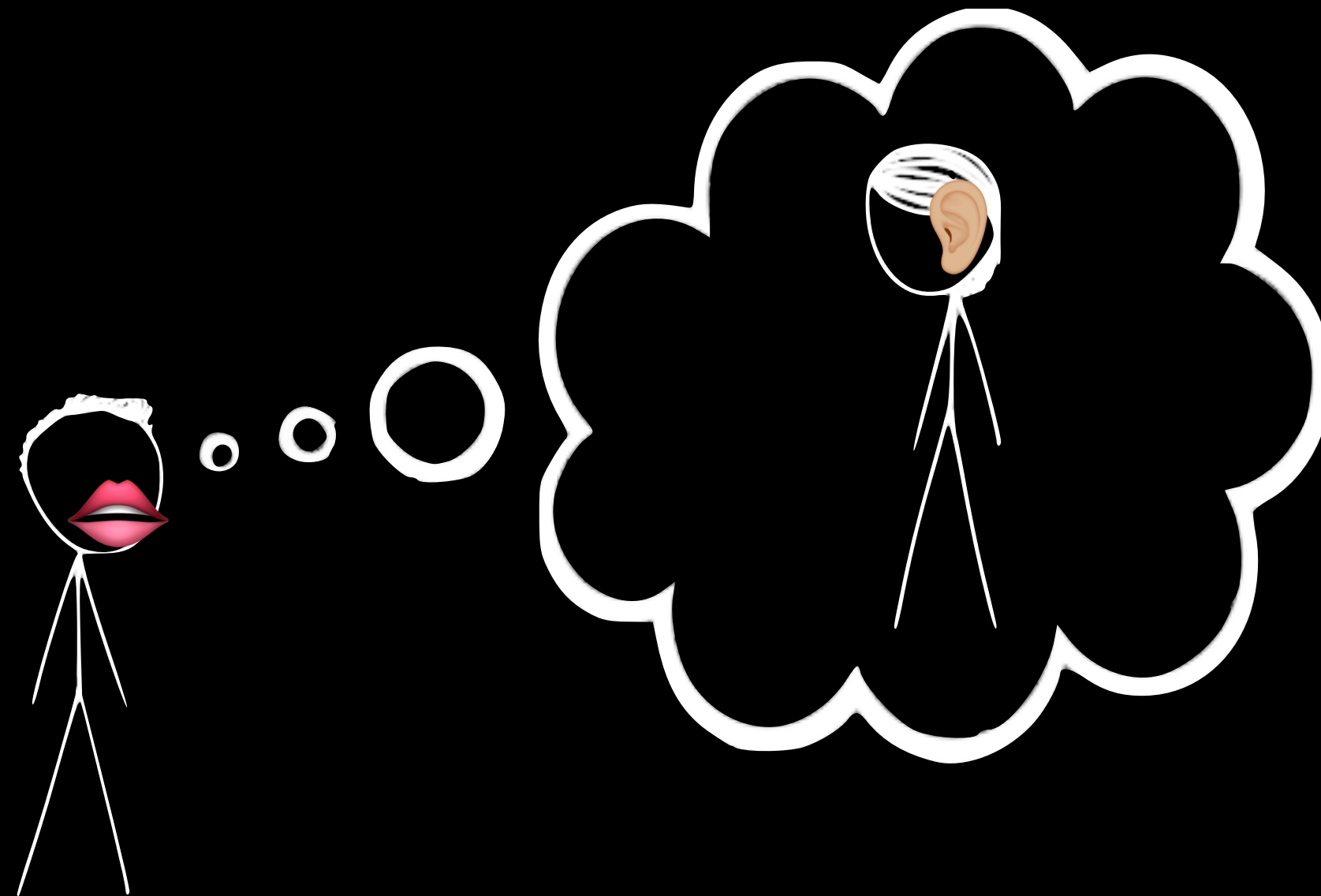
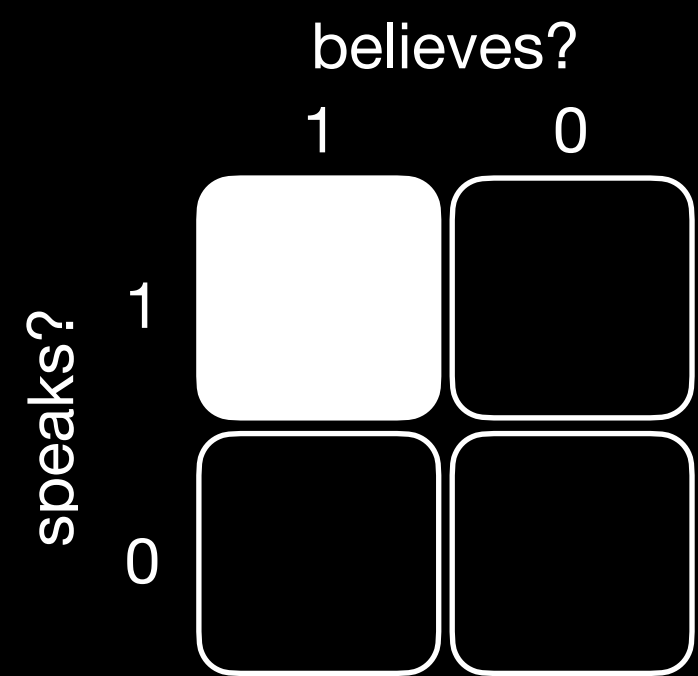
*think*

*know*

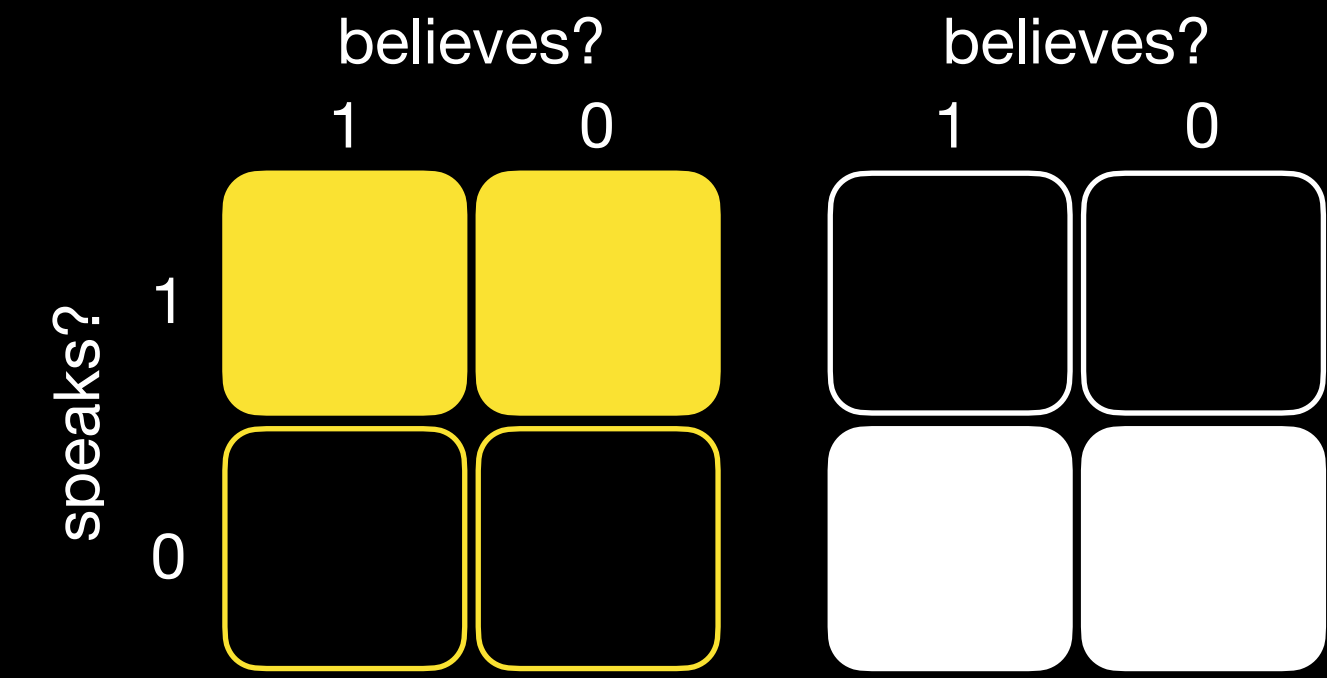


# speaker behavior

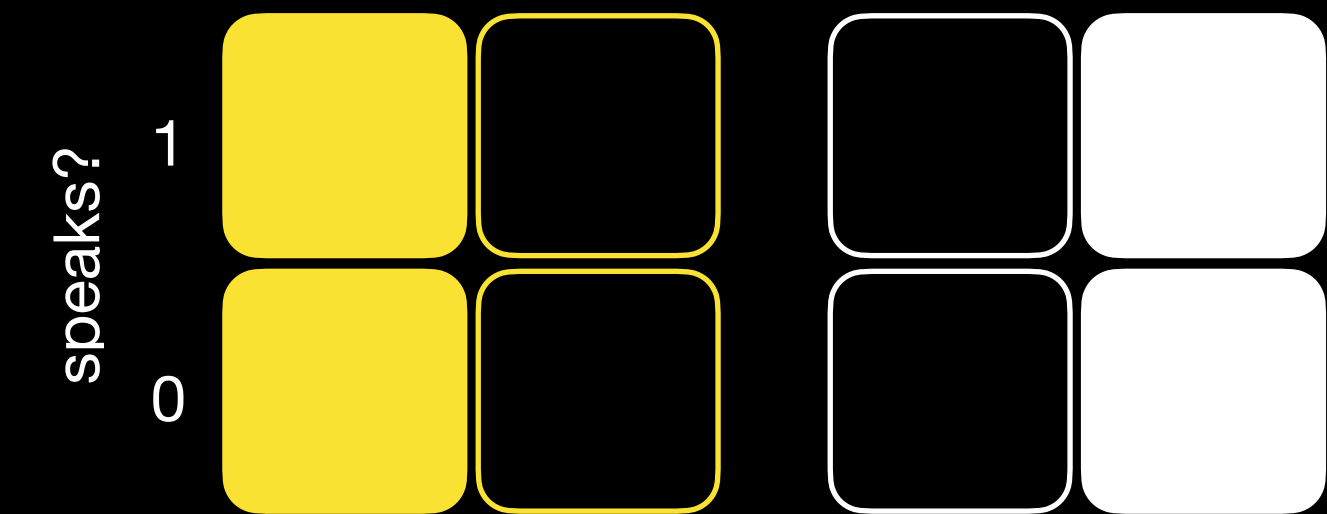
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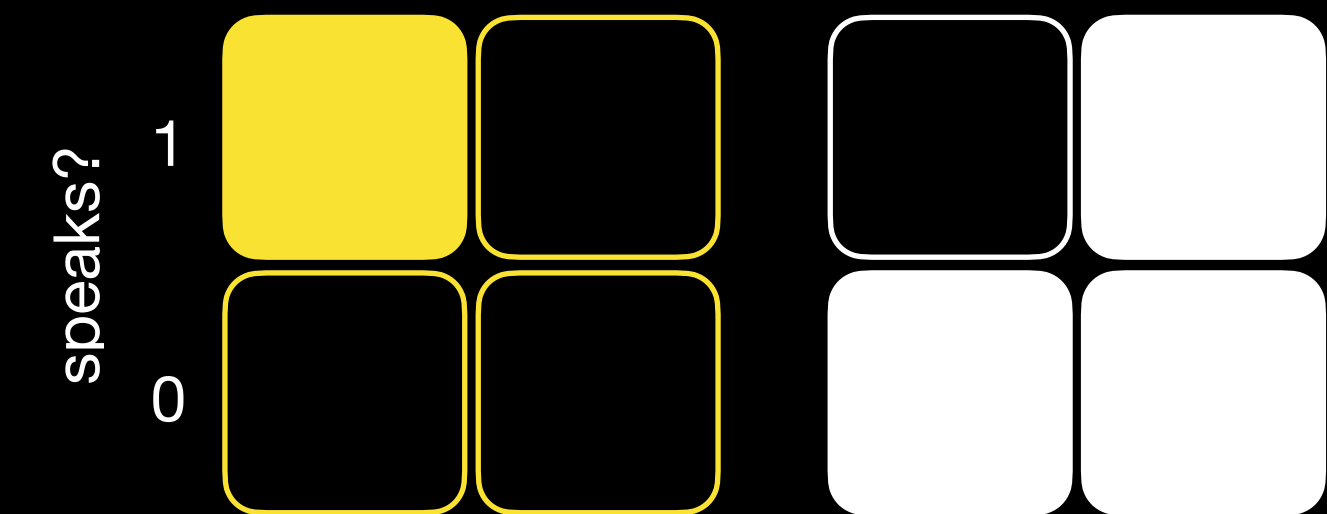
**simple**



**think**



**know**

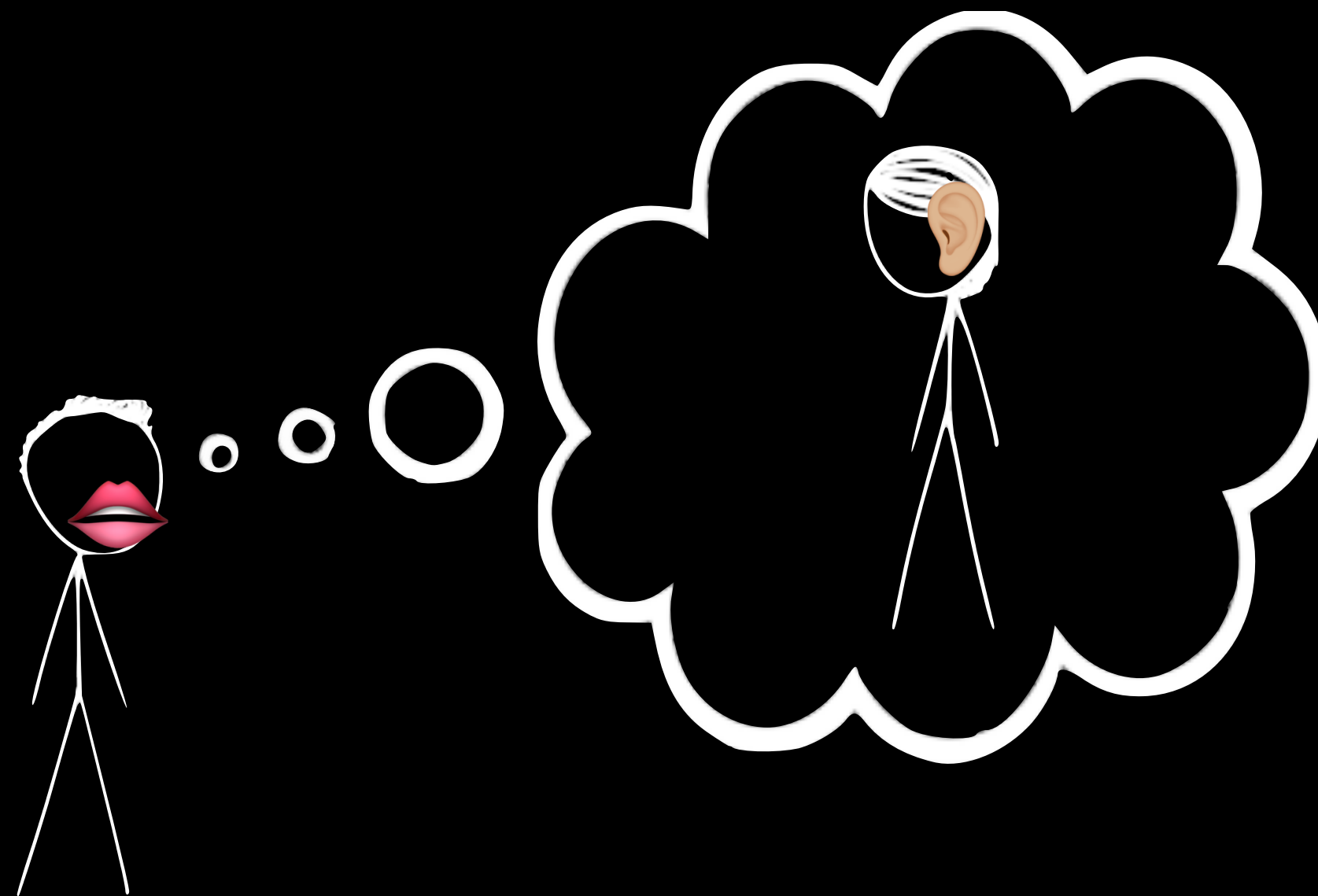
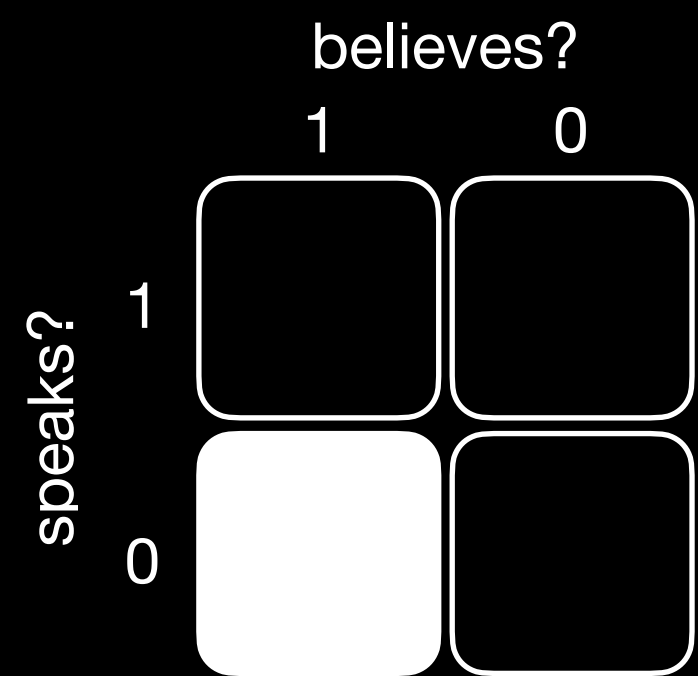


**pos**

**neg**

# speaker behavior

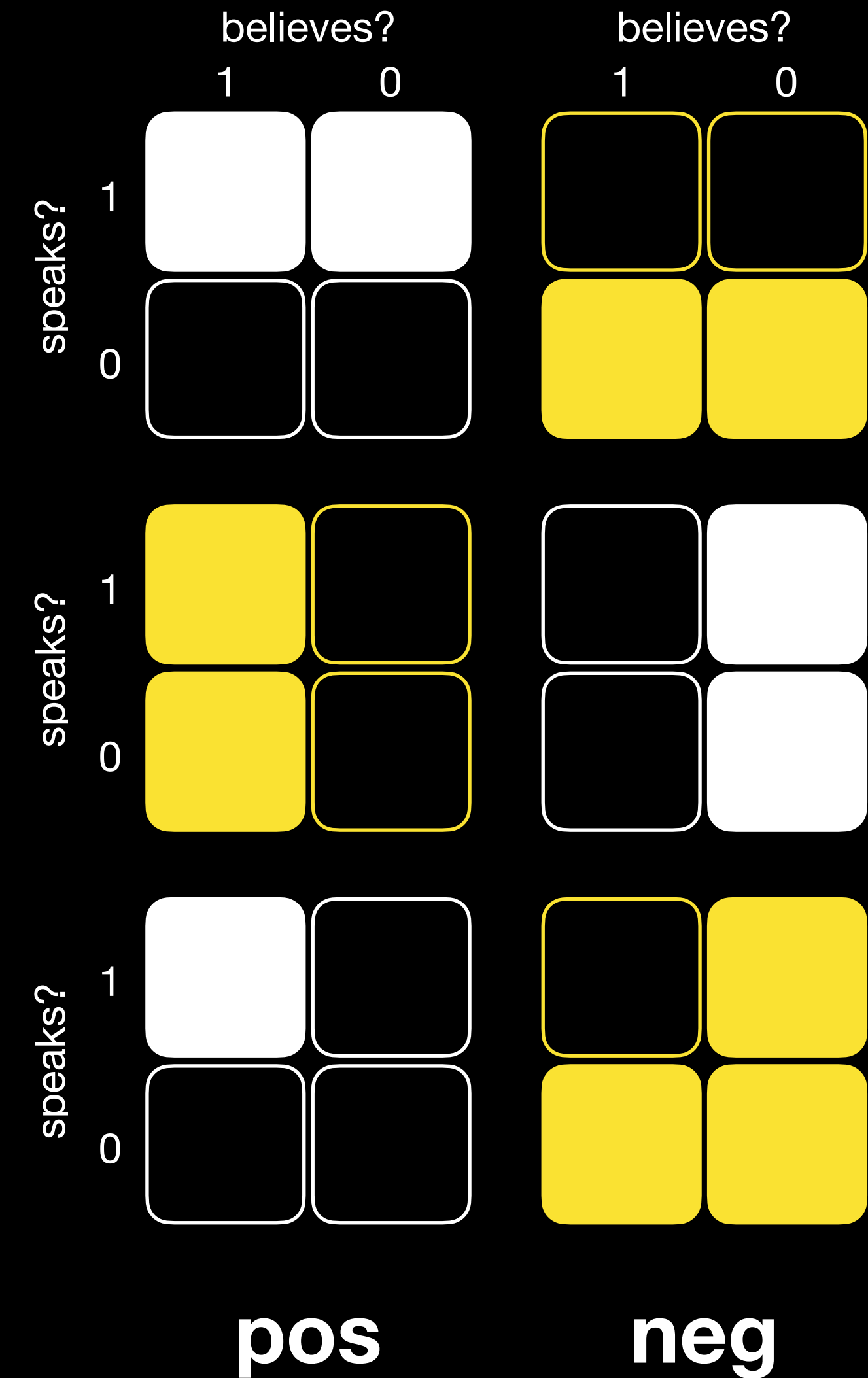
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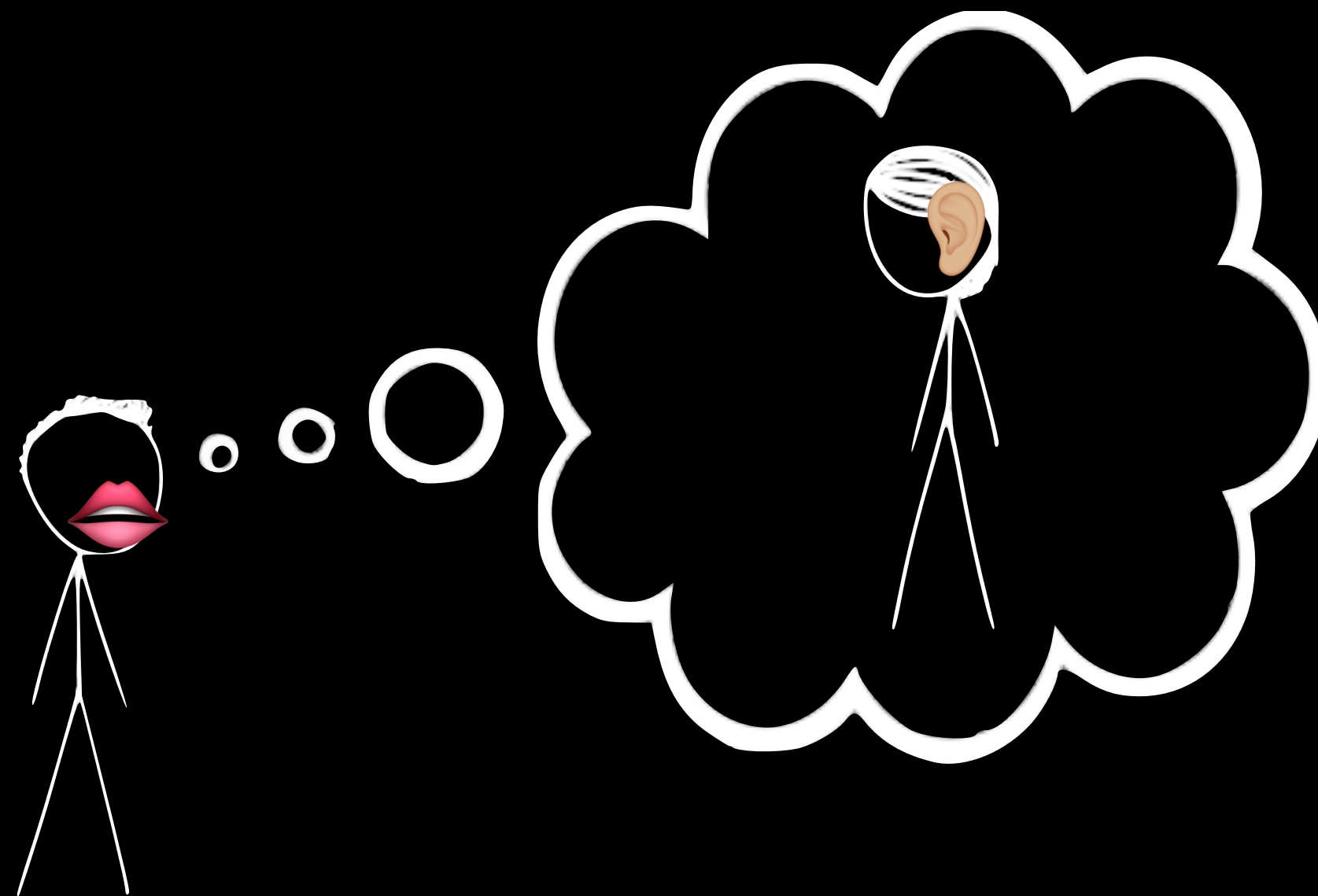
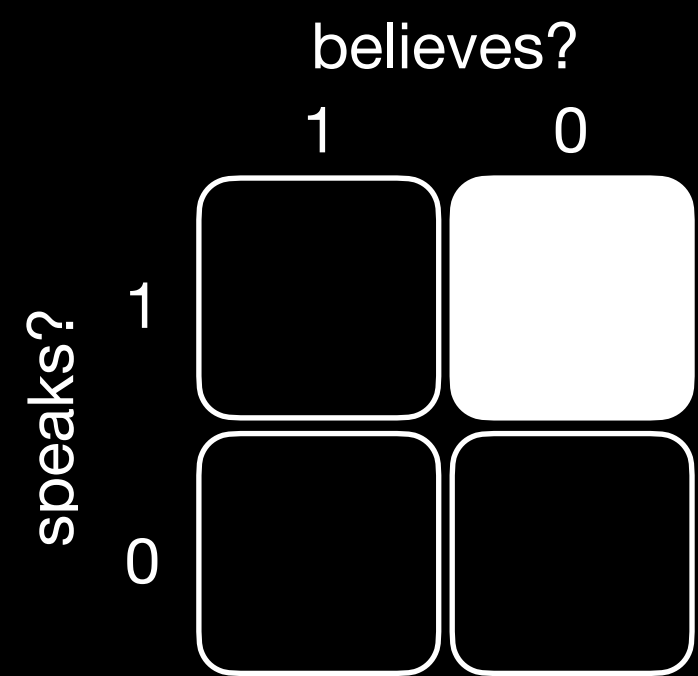
**think**

**know**

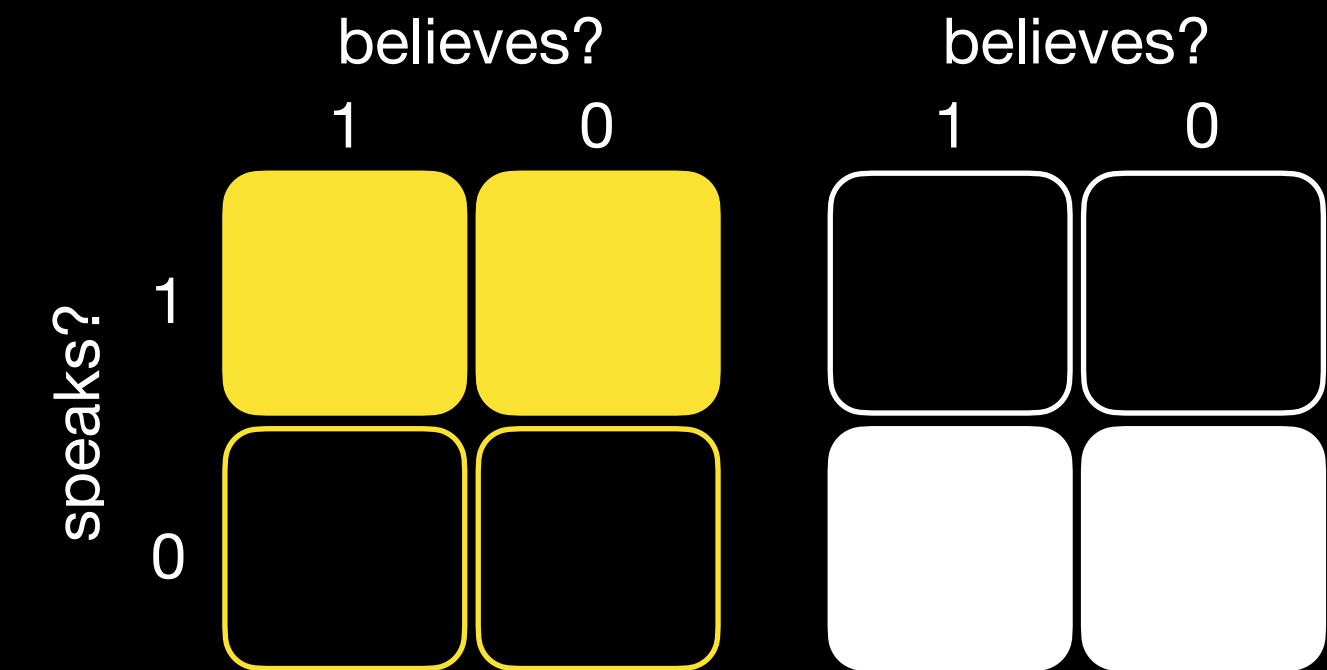


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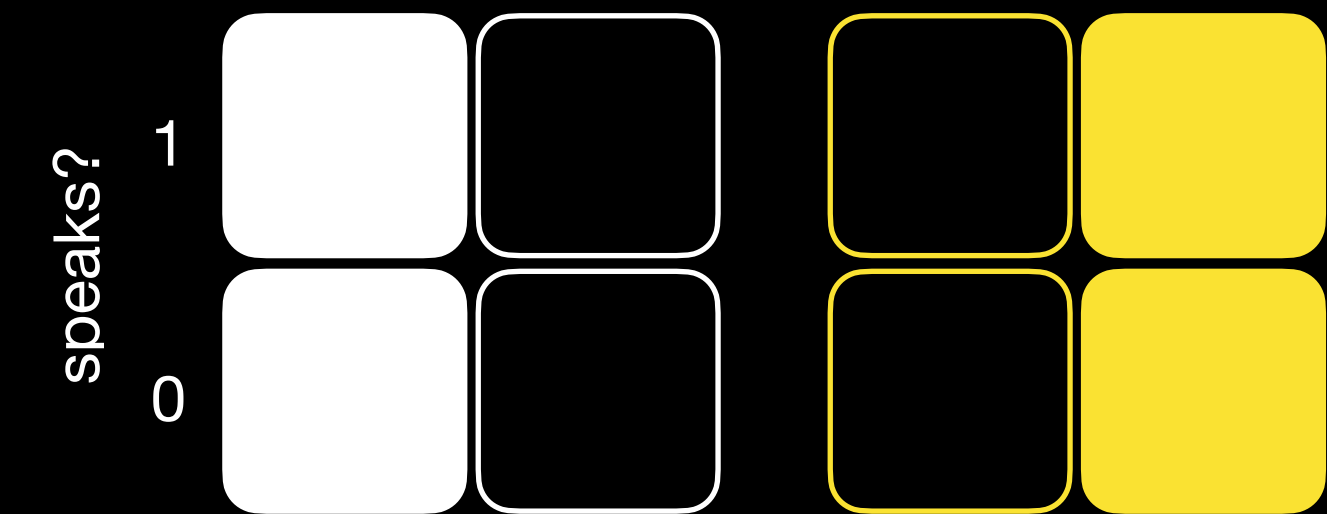
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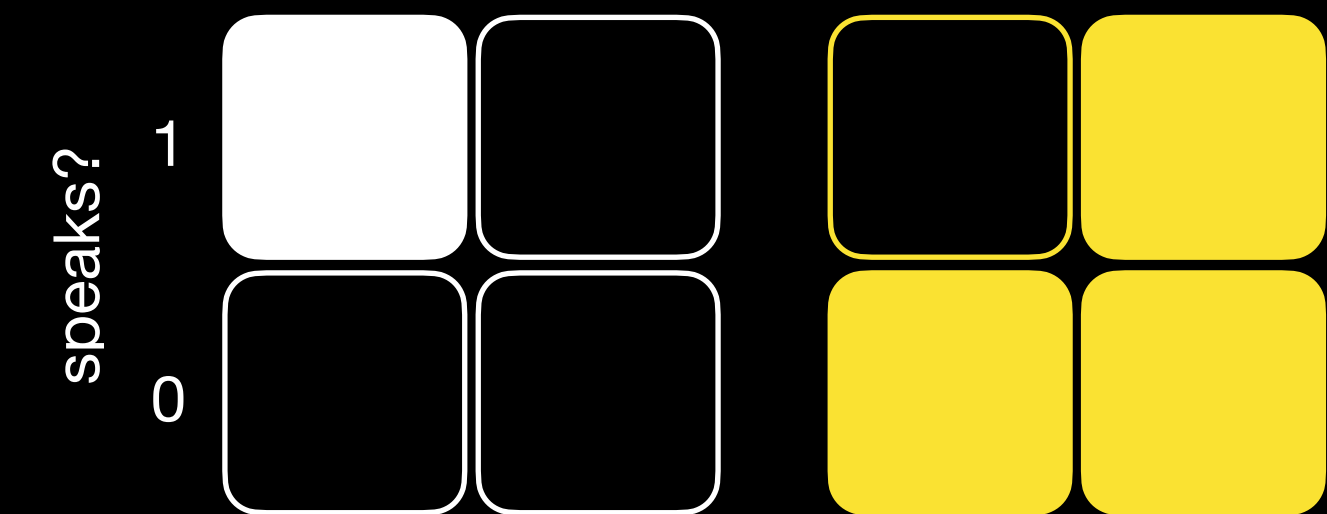
**simple**



**think**



**know**

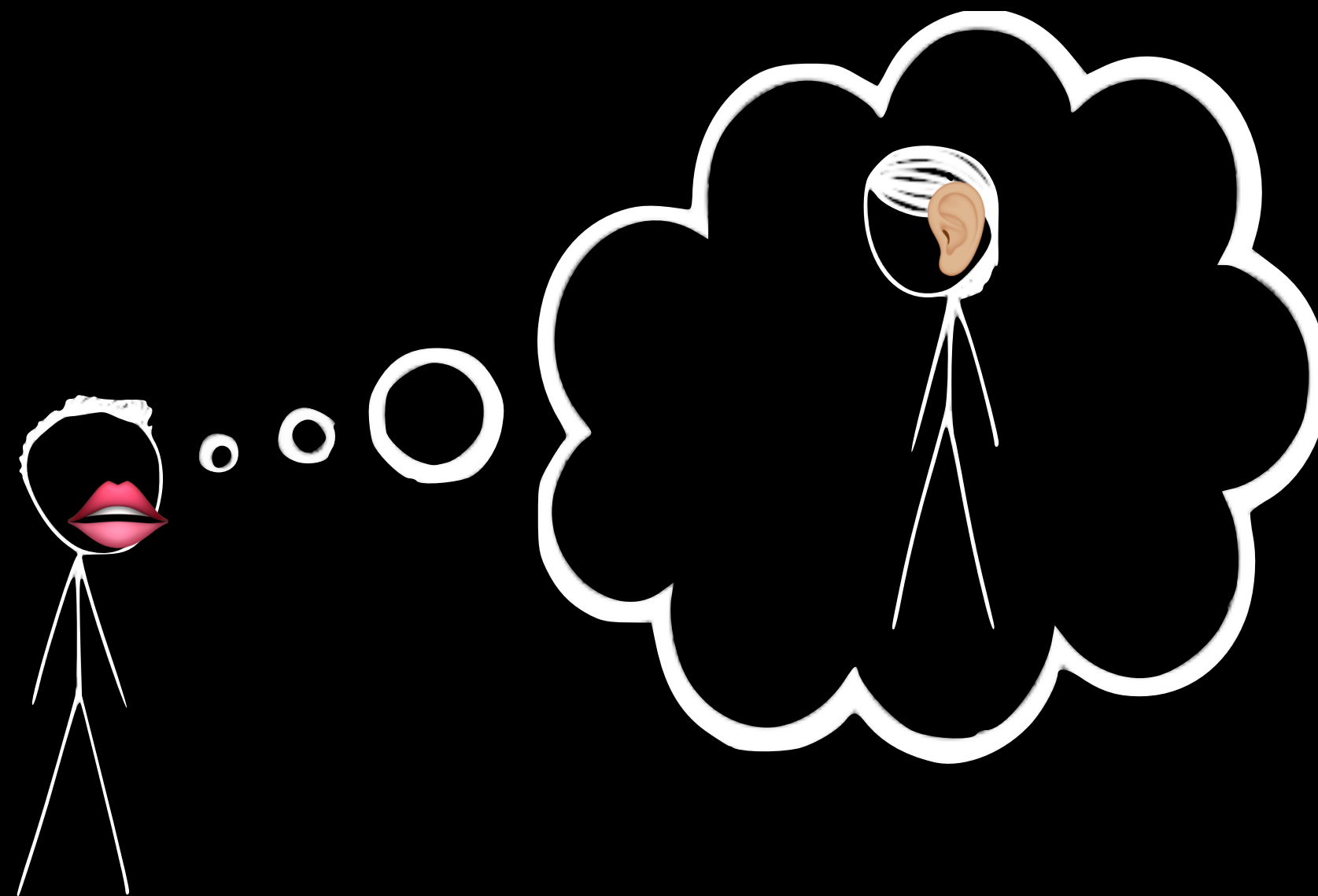
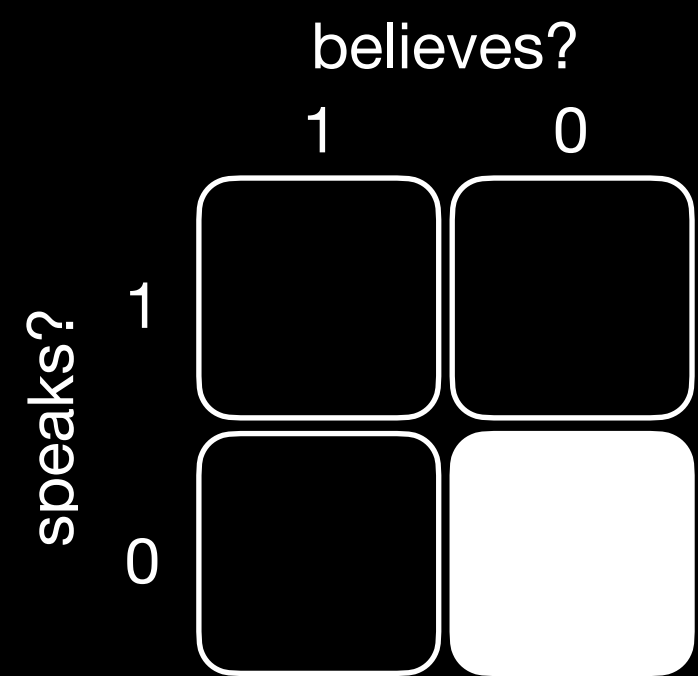


**pos**

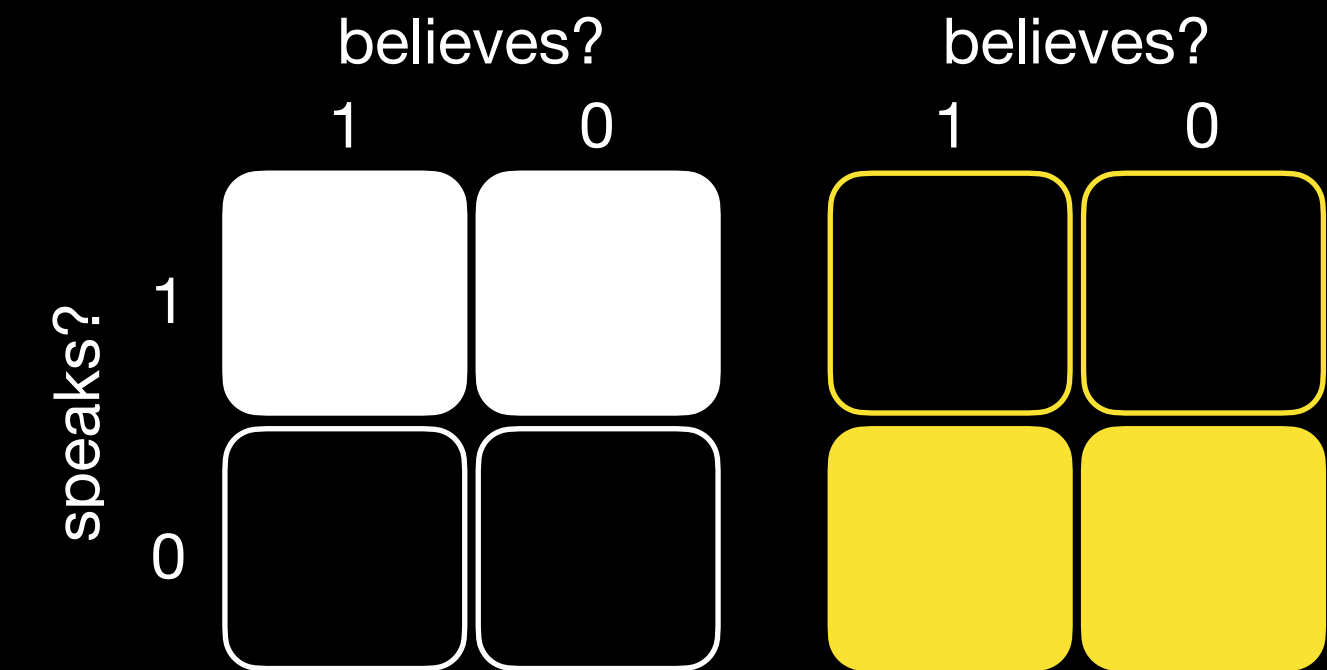
**neg**

# speaker behavior

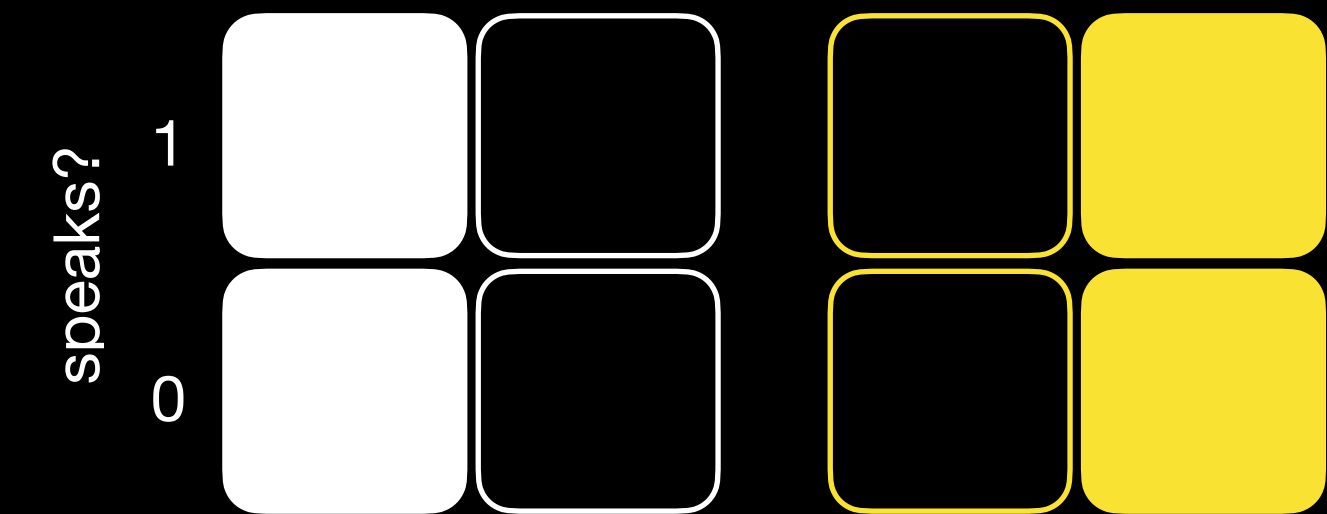
speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



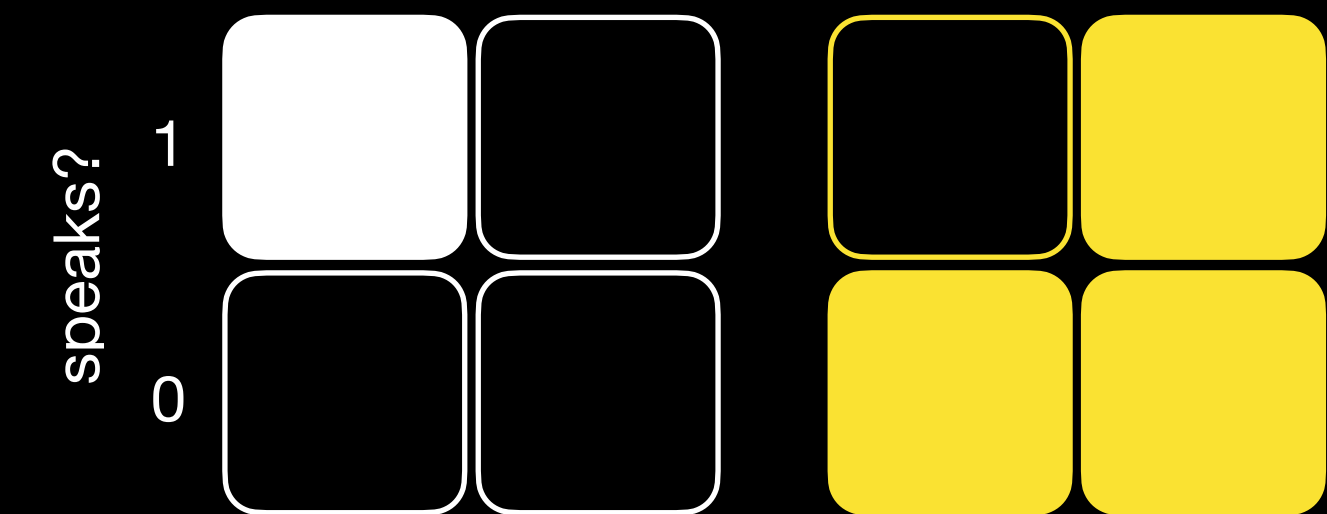
**simple**



**think**



**know**



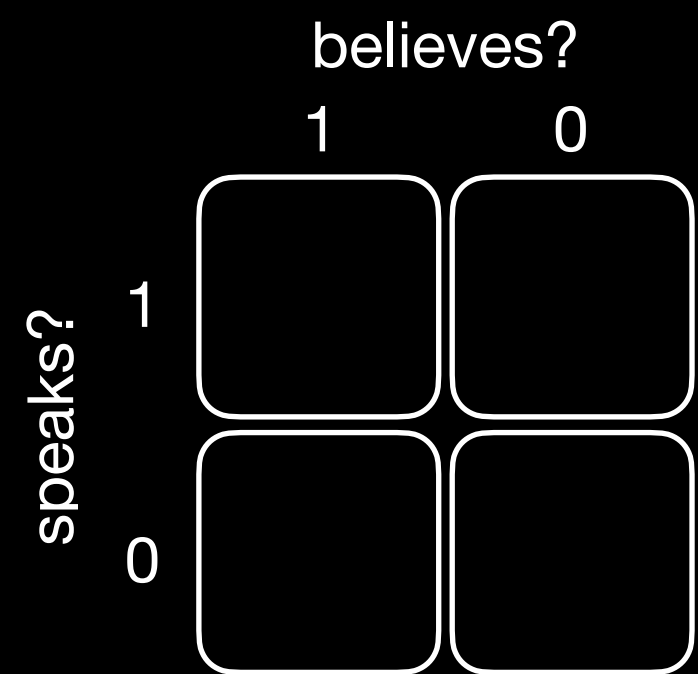
**pos**

**neg**

# speaker behavior

speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD

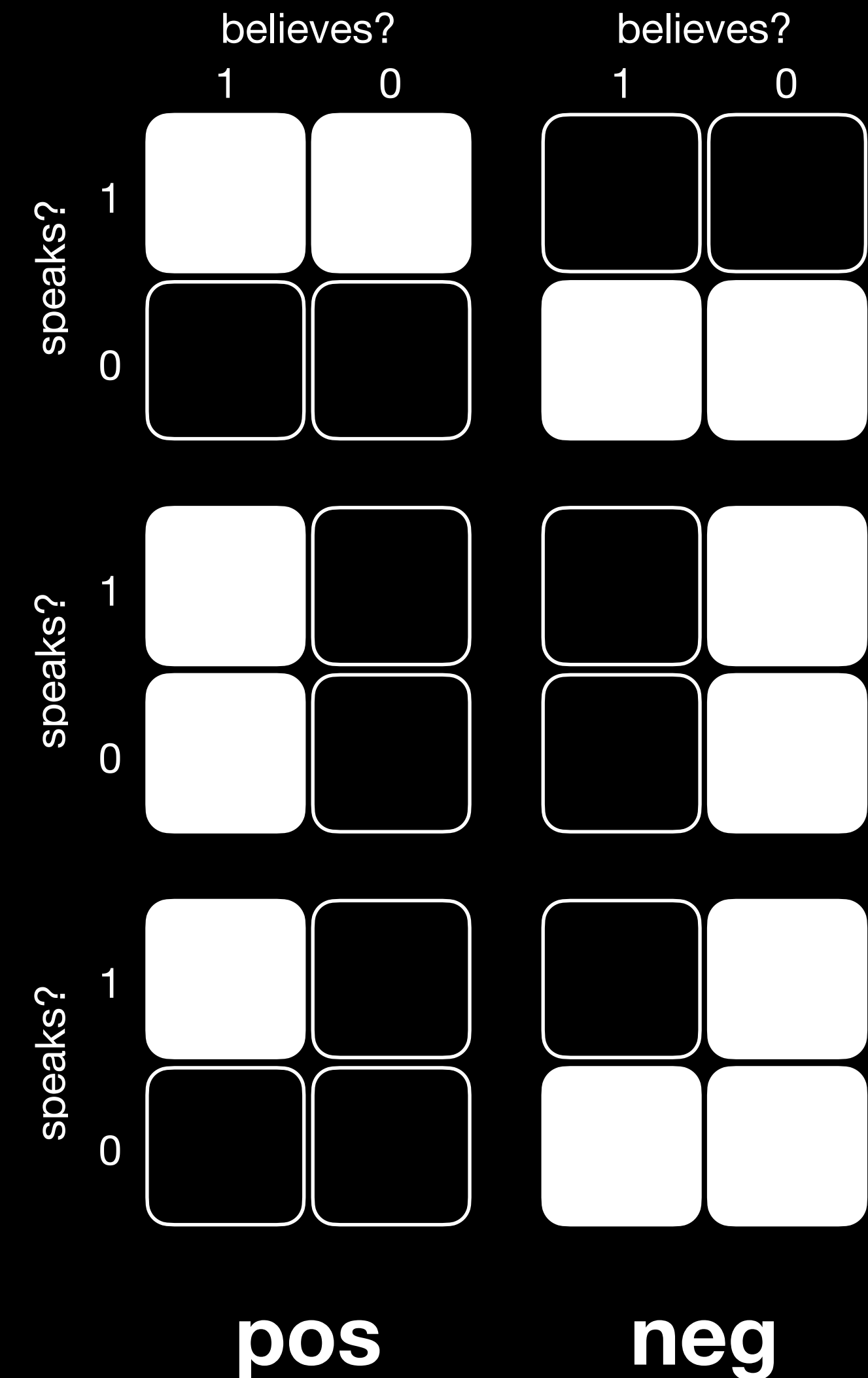
so far, we've considered the QUD  
*what is the state of the world?*



**simple**

*think*

*know*



# speaker behavior

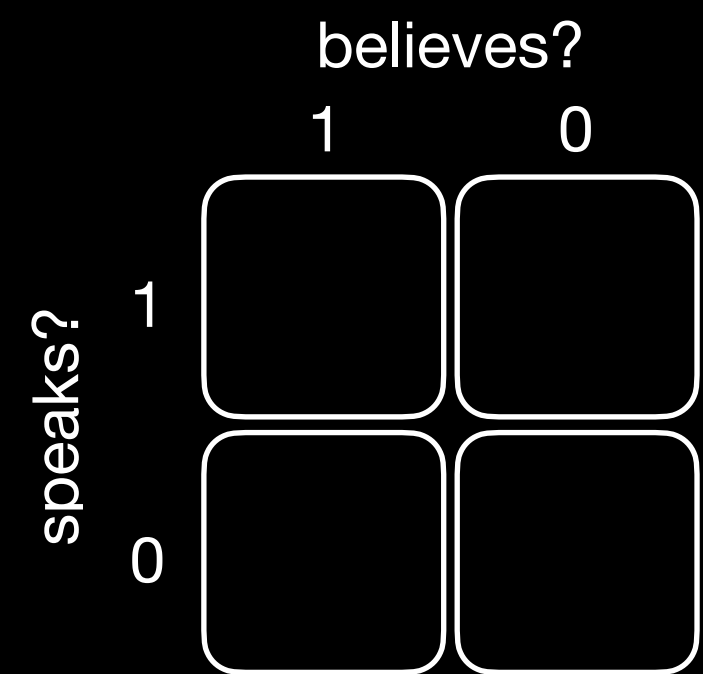
speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD

so far, we've considered the QUD  
*what is the state of the world?*

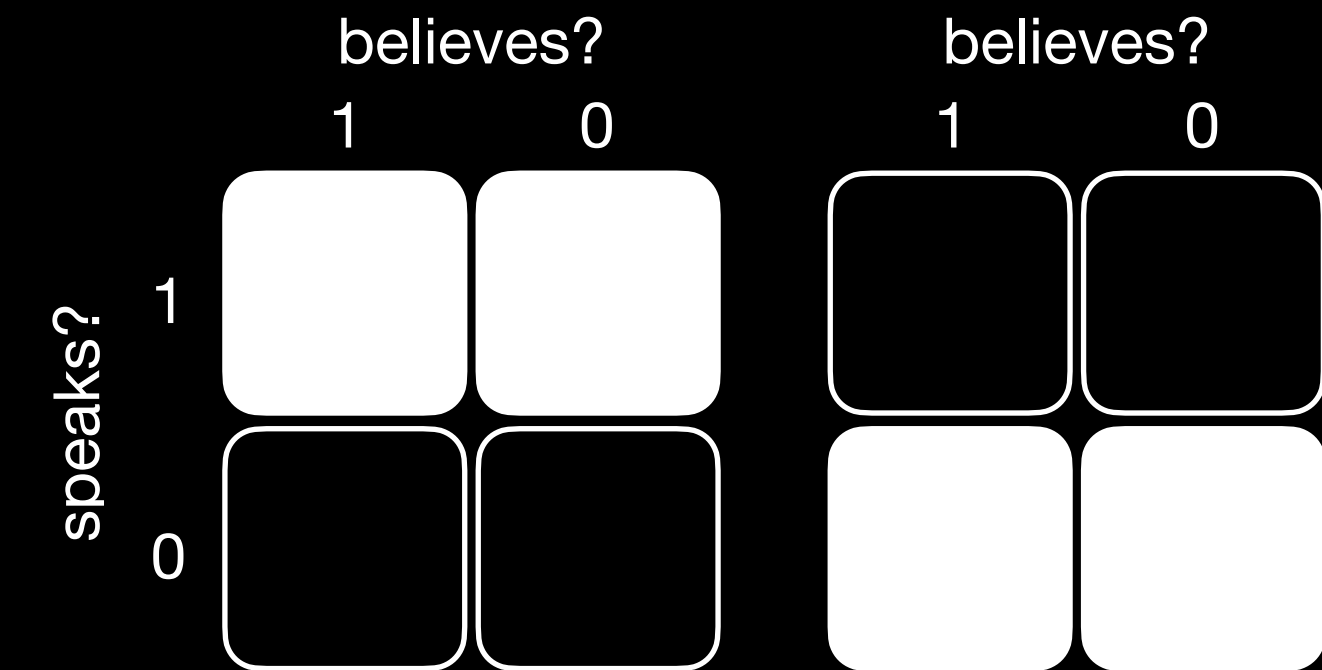
other QUDs:

*does Cole believe?*

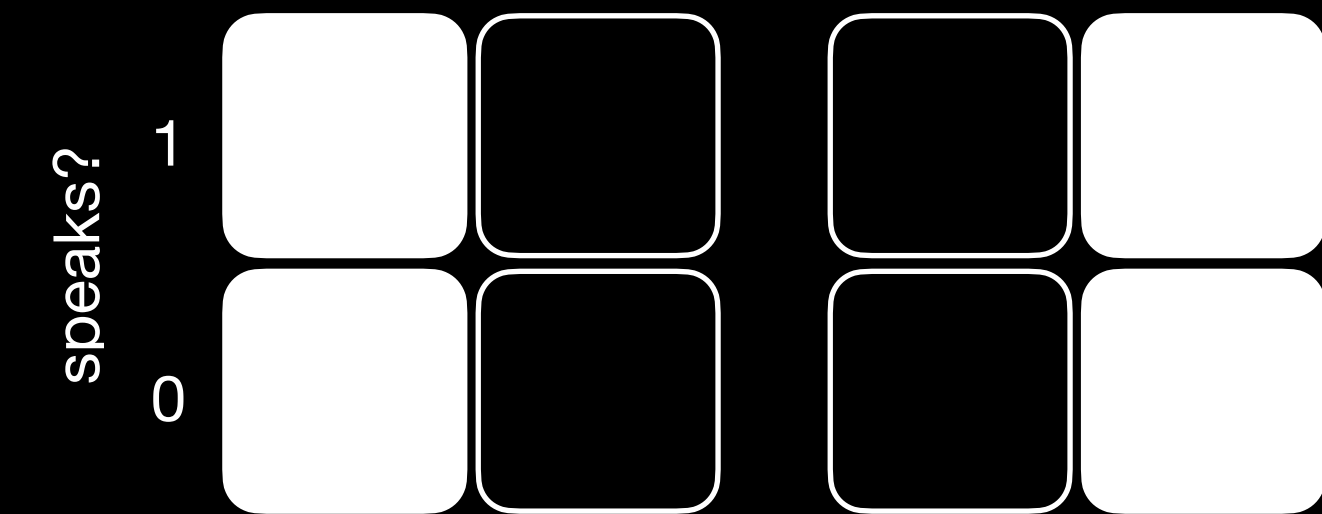
*does Charley speak Spanish?*



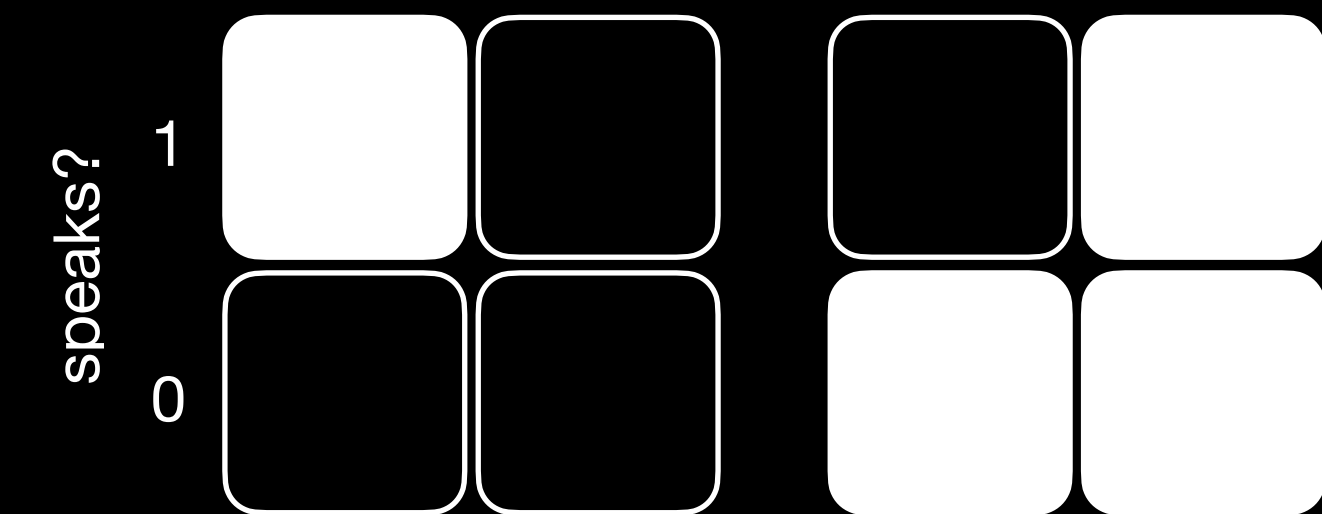
**simple**



**think**



**know**



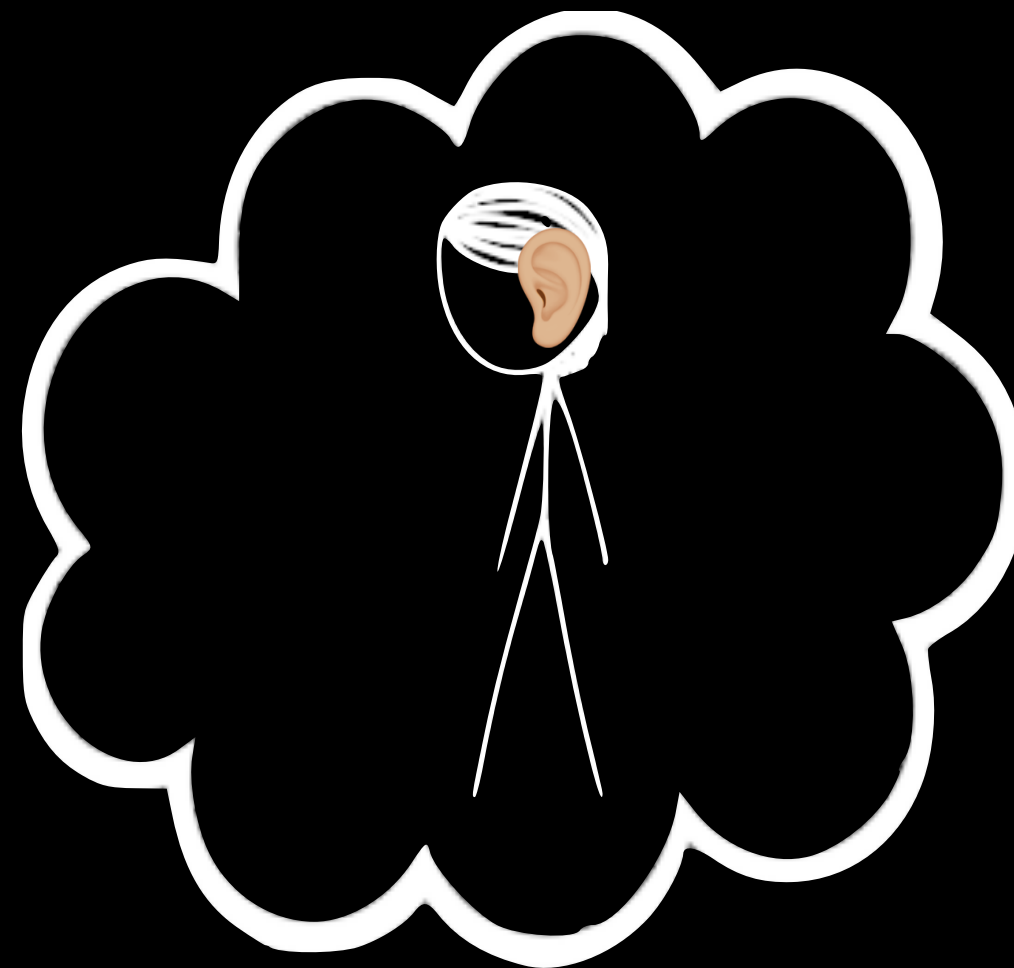
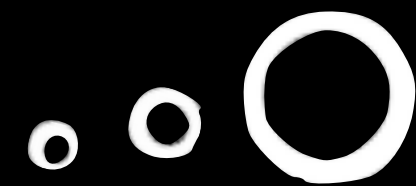
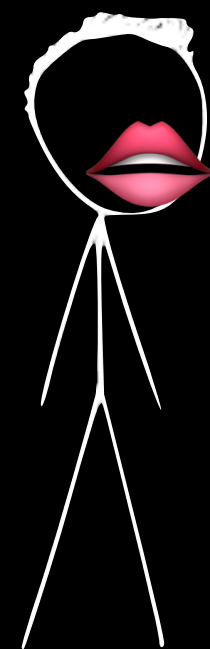
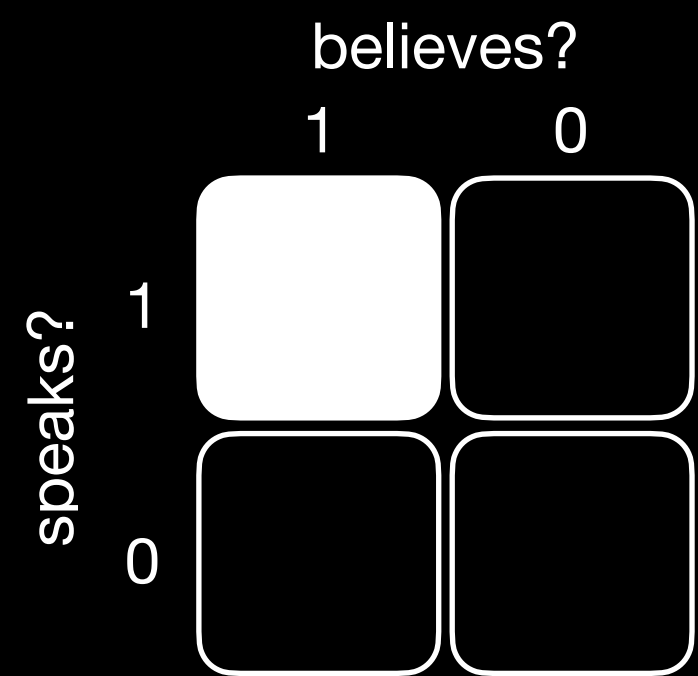
**pos**

**neg**



# speaker behavior

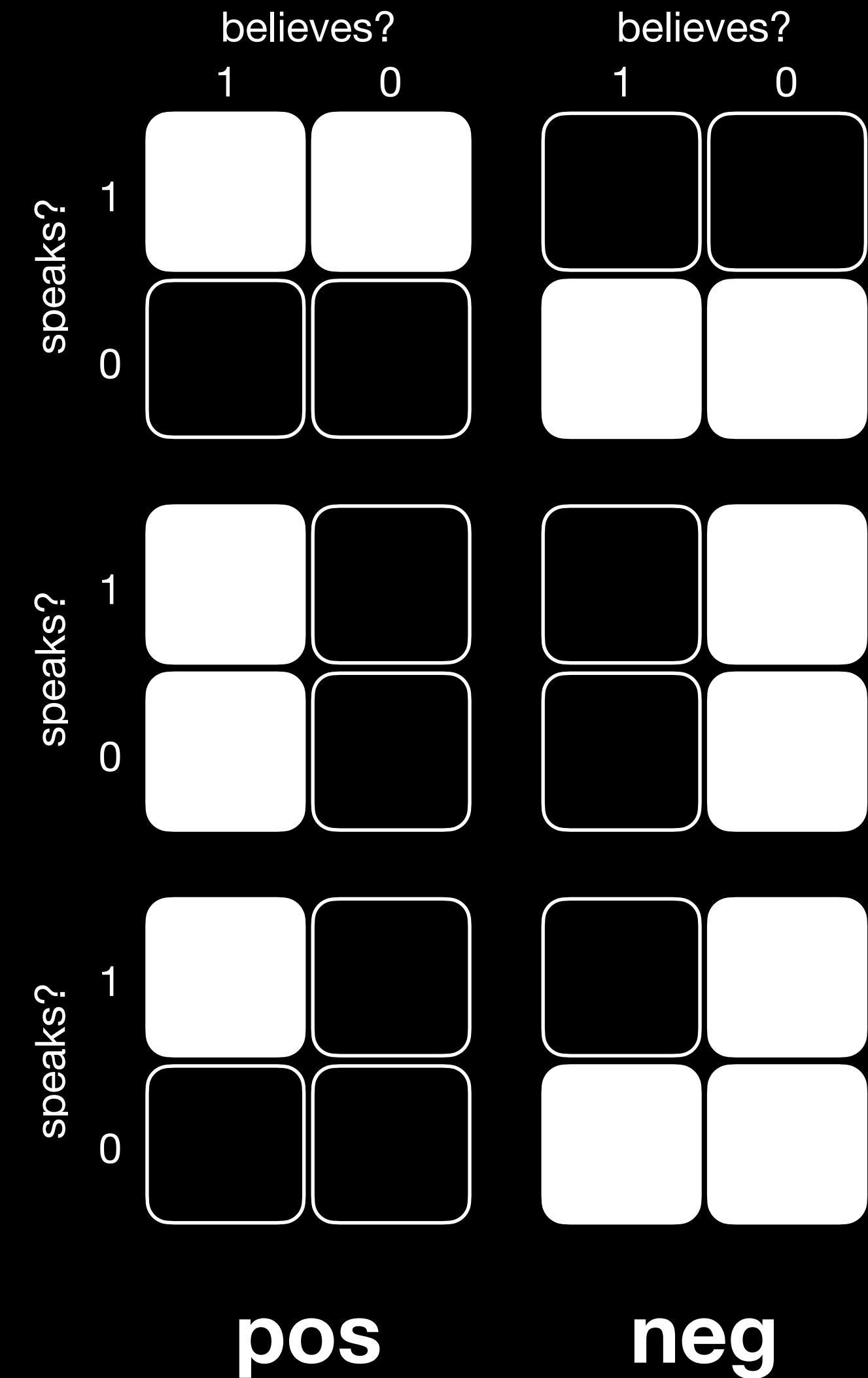
speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



**simple**

*think*

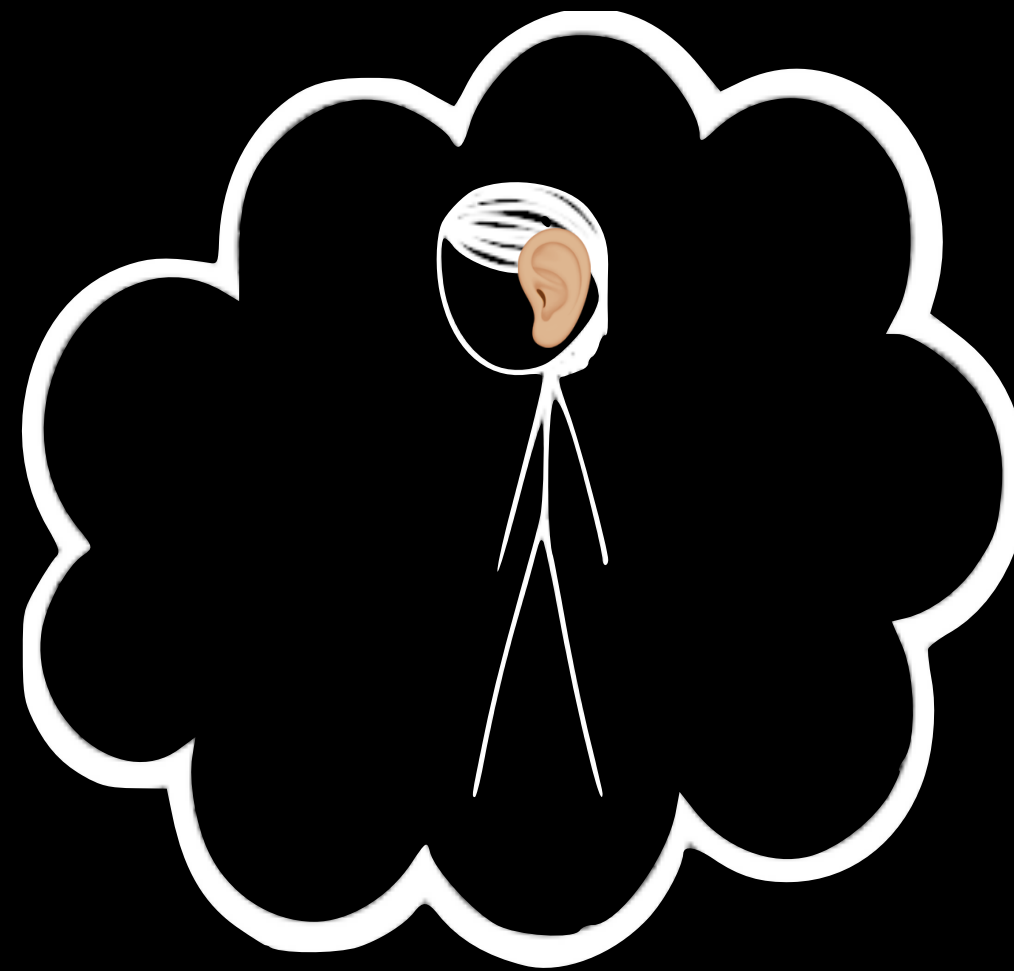
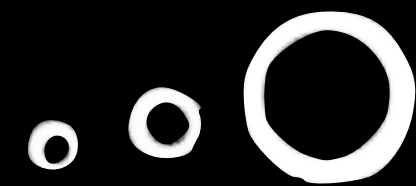
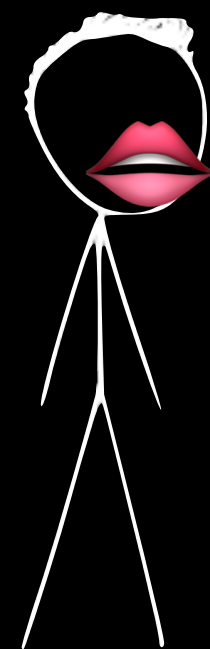
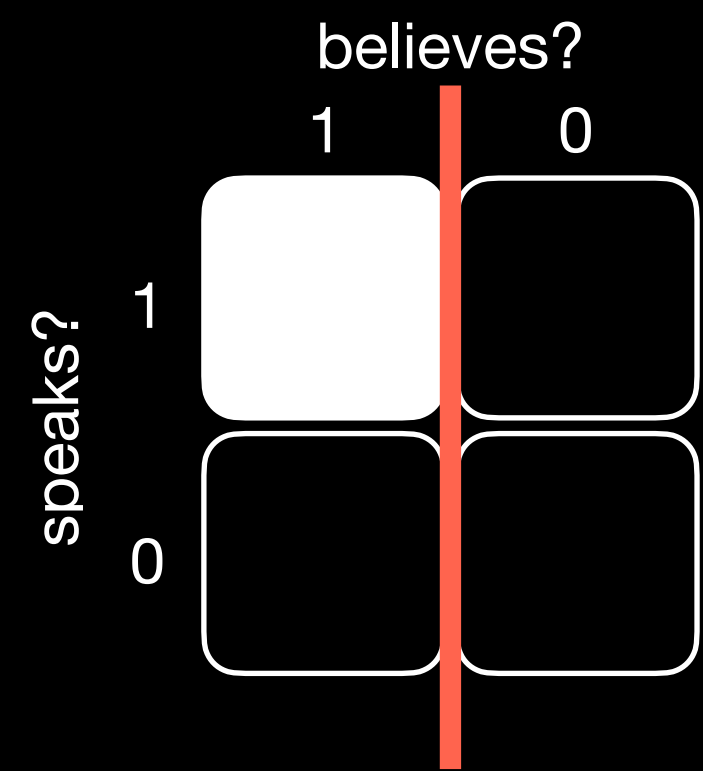
*know*



*does Cole believe?*

# speaker behavior

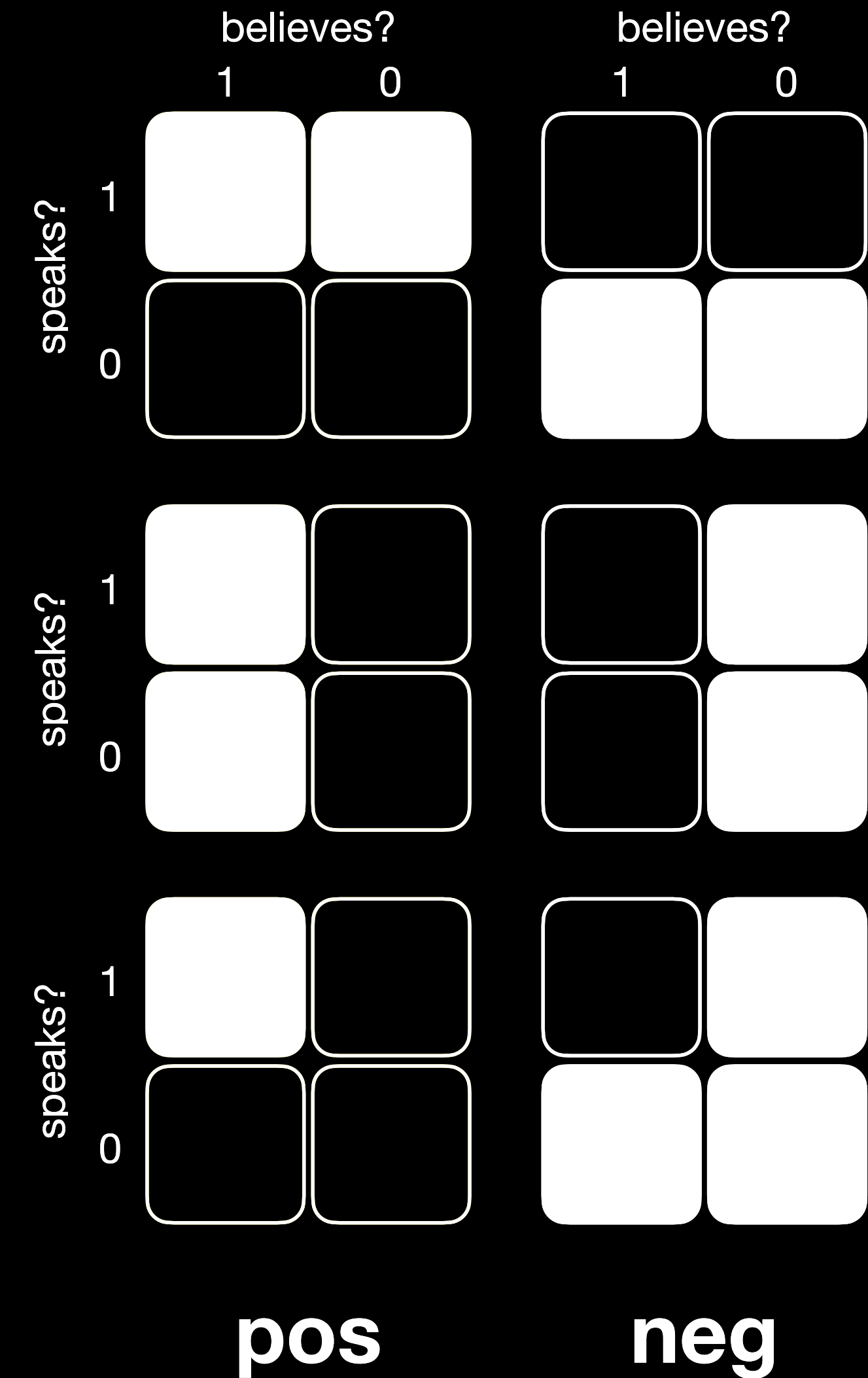
speakers **choose** to produce **utterances in proportion** to their **utility** for leading the **listener** to correctly resolve the QUD



**simple**

*think*

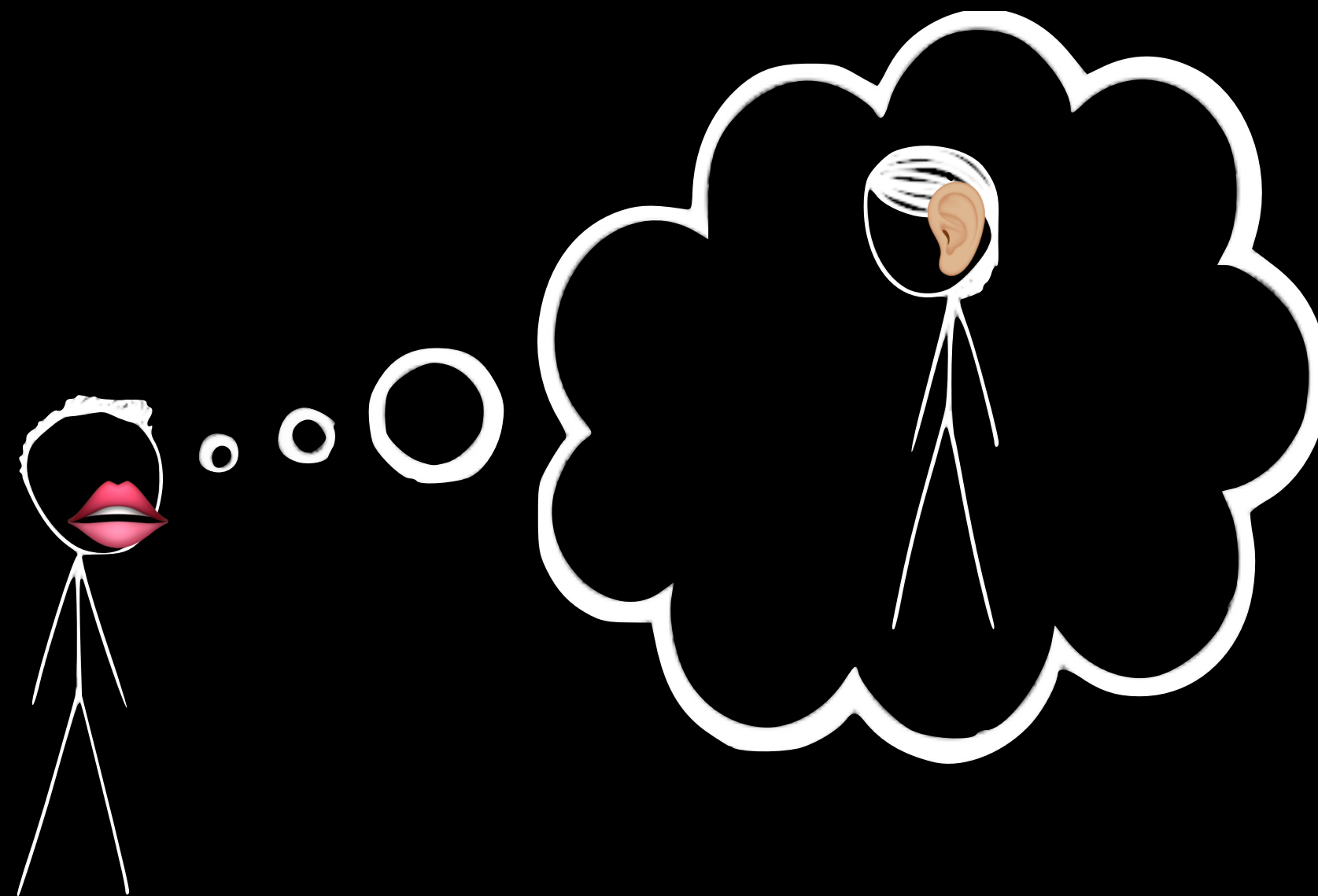
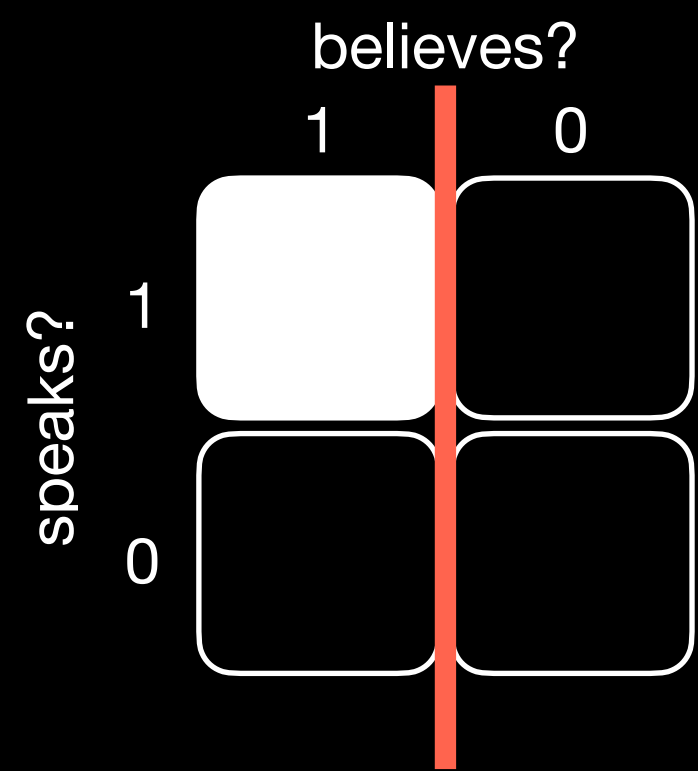
*know*



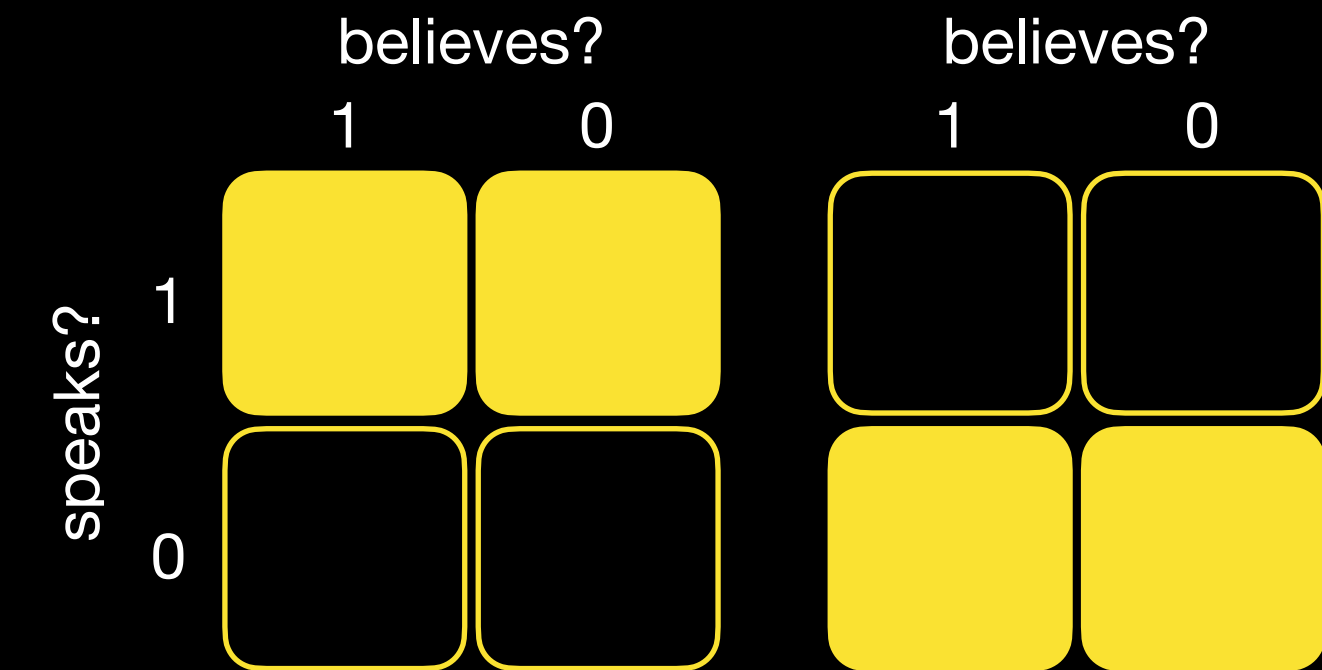
*does Cole believe?*

# speaker behavior

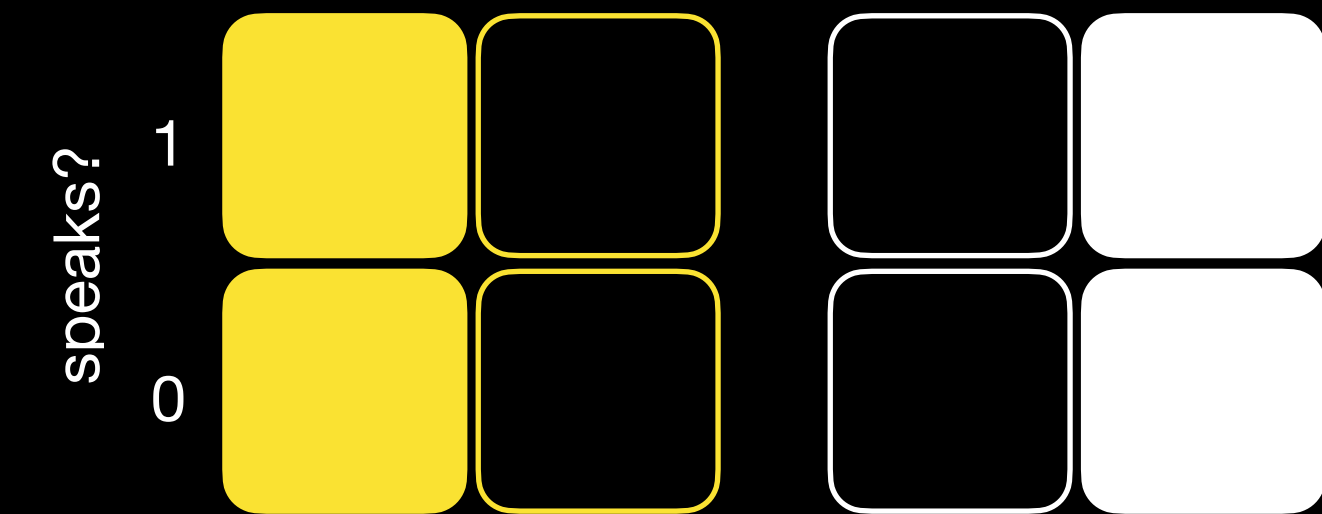
speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



**simple**



**think**



**know**



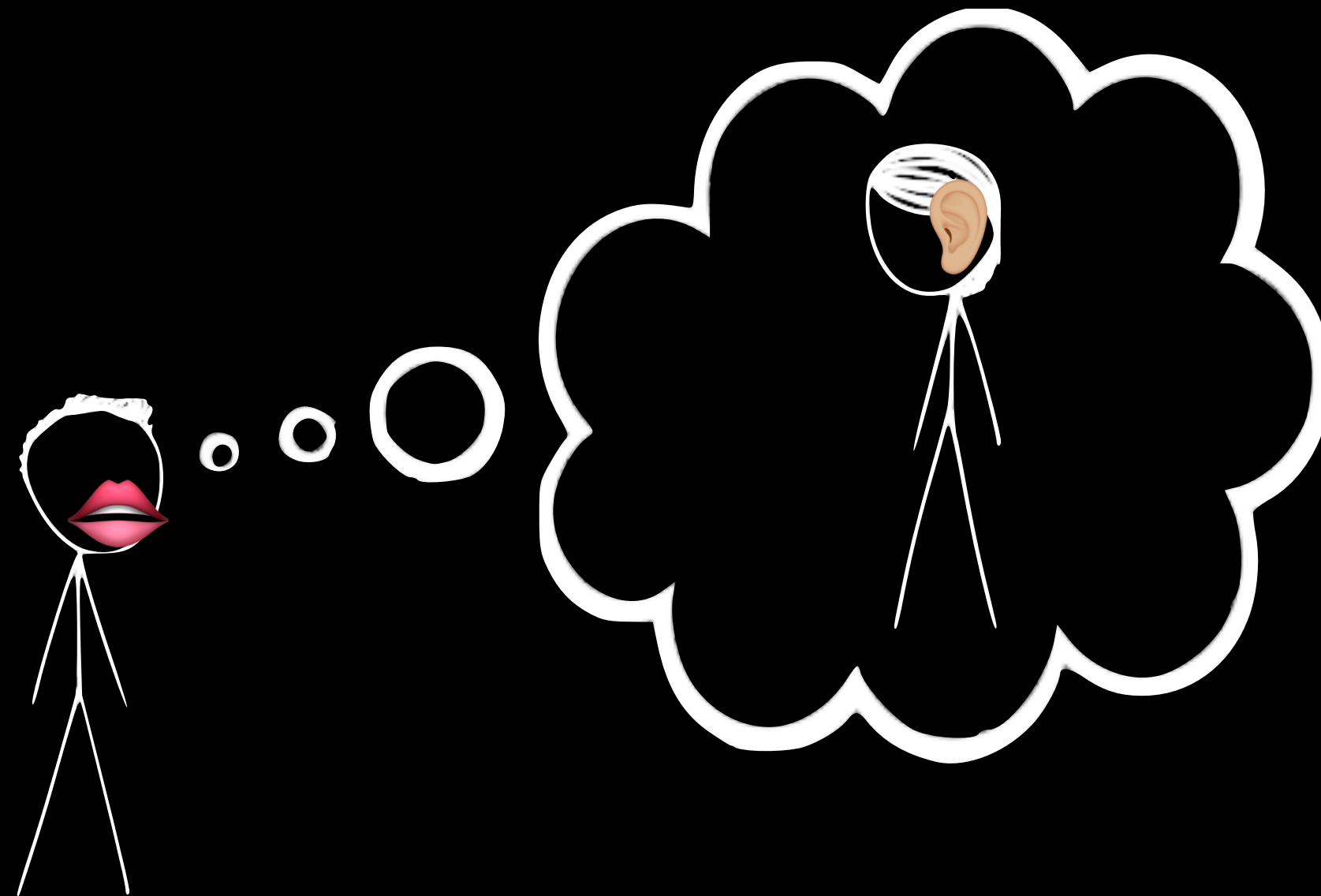
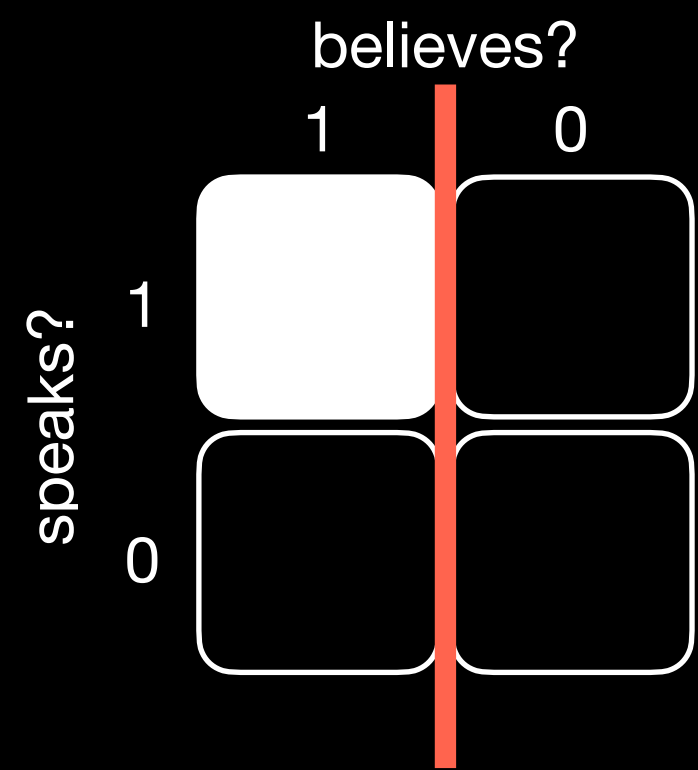
**pos**

**neg**

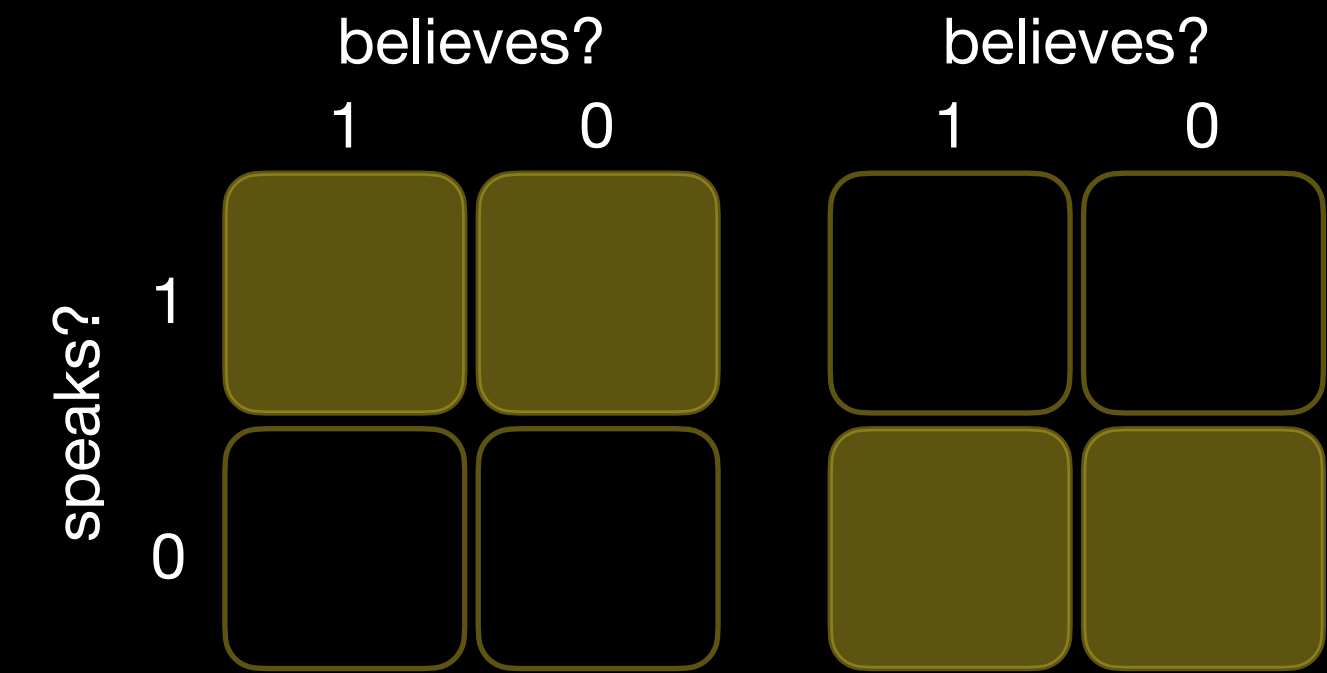
**does Cole believe?**

# speaker behavior

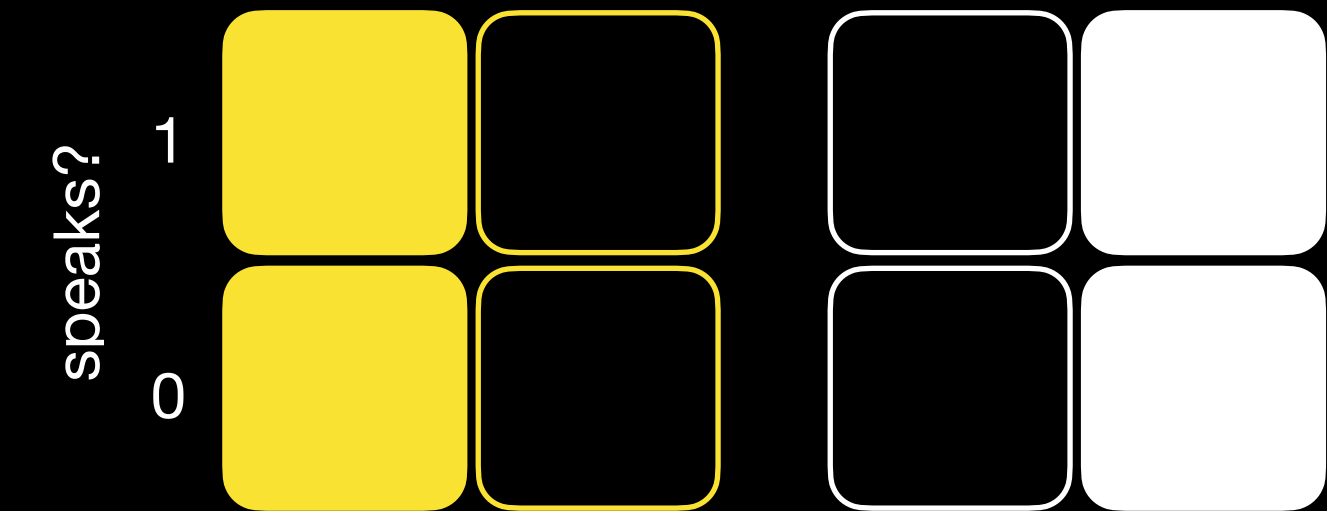
speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



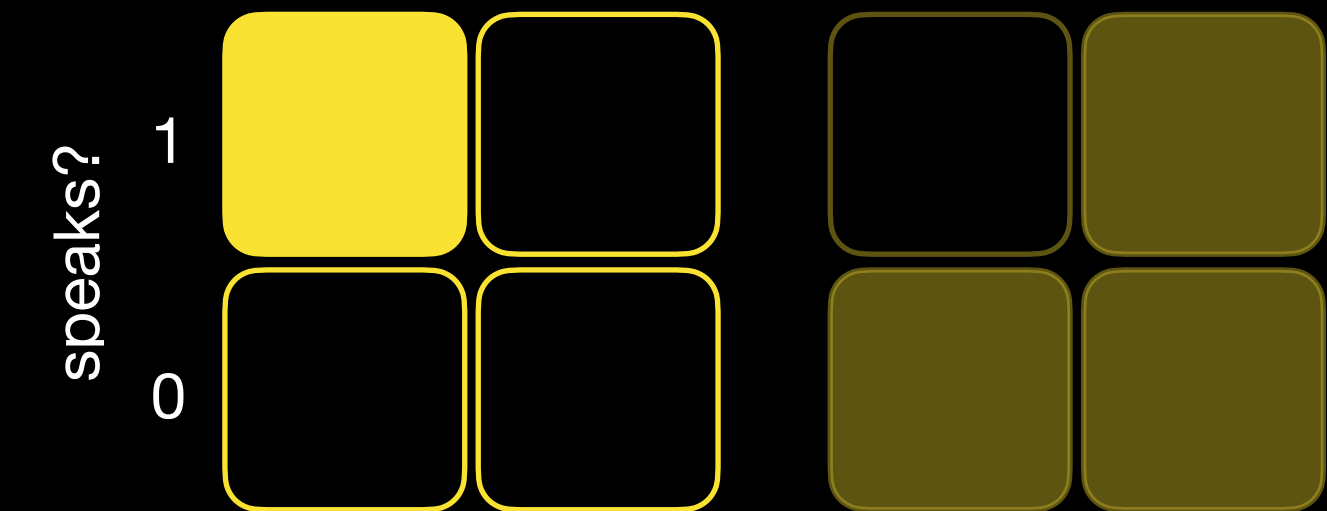
**simple**



**think**



**know**



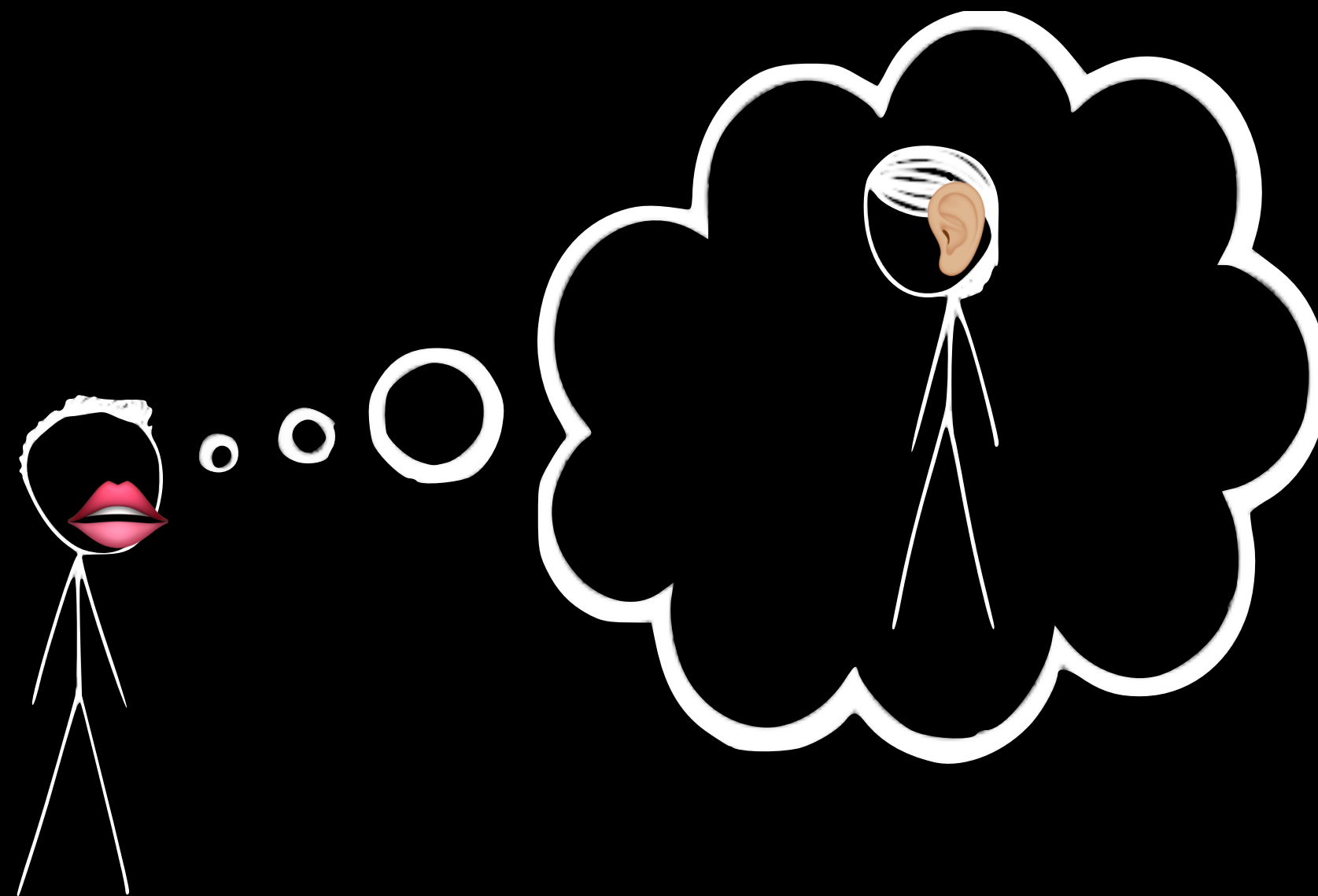
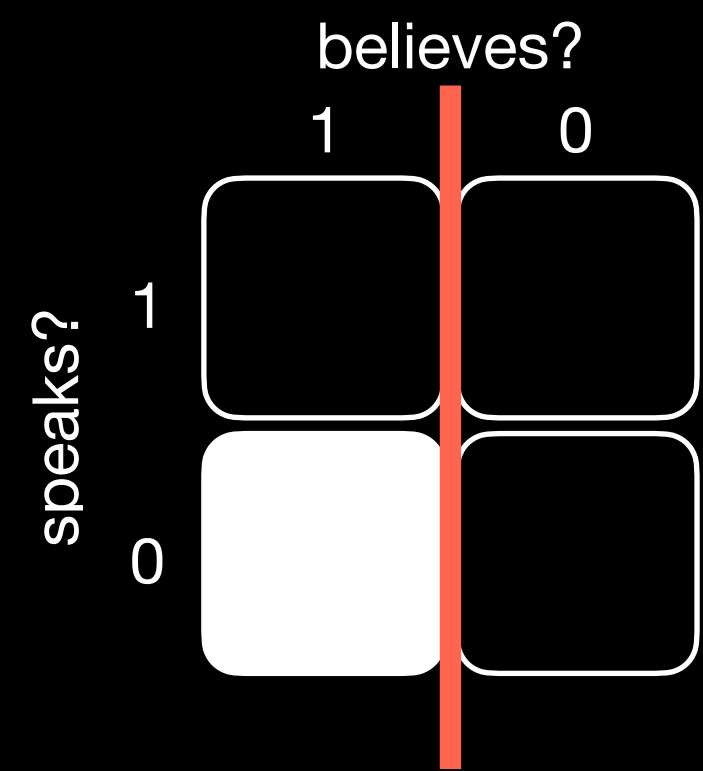
**pos**

**neg**

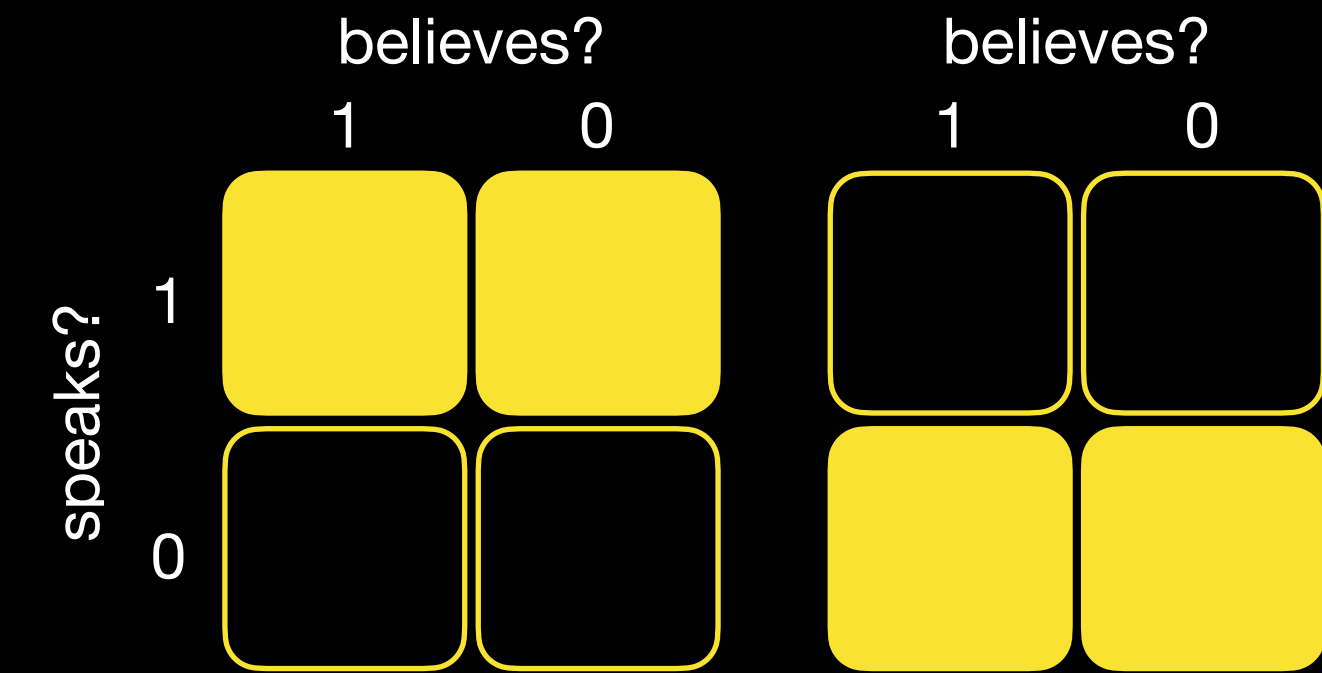
**does Cole believe?**

# speaker behavior

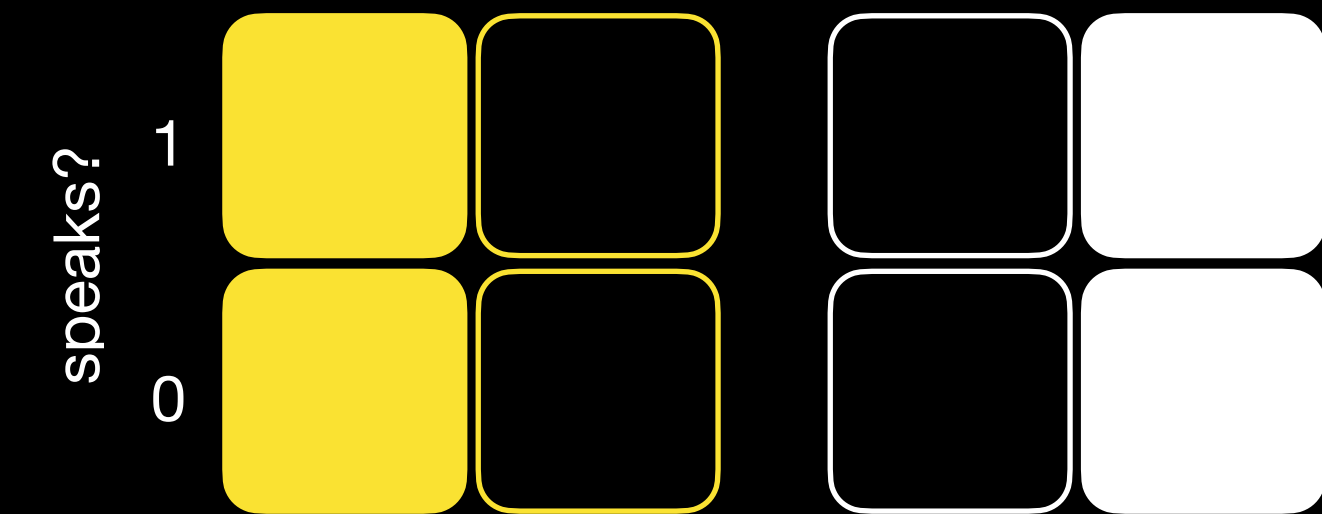
speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



**simple**



**think**



**know**



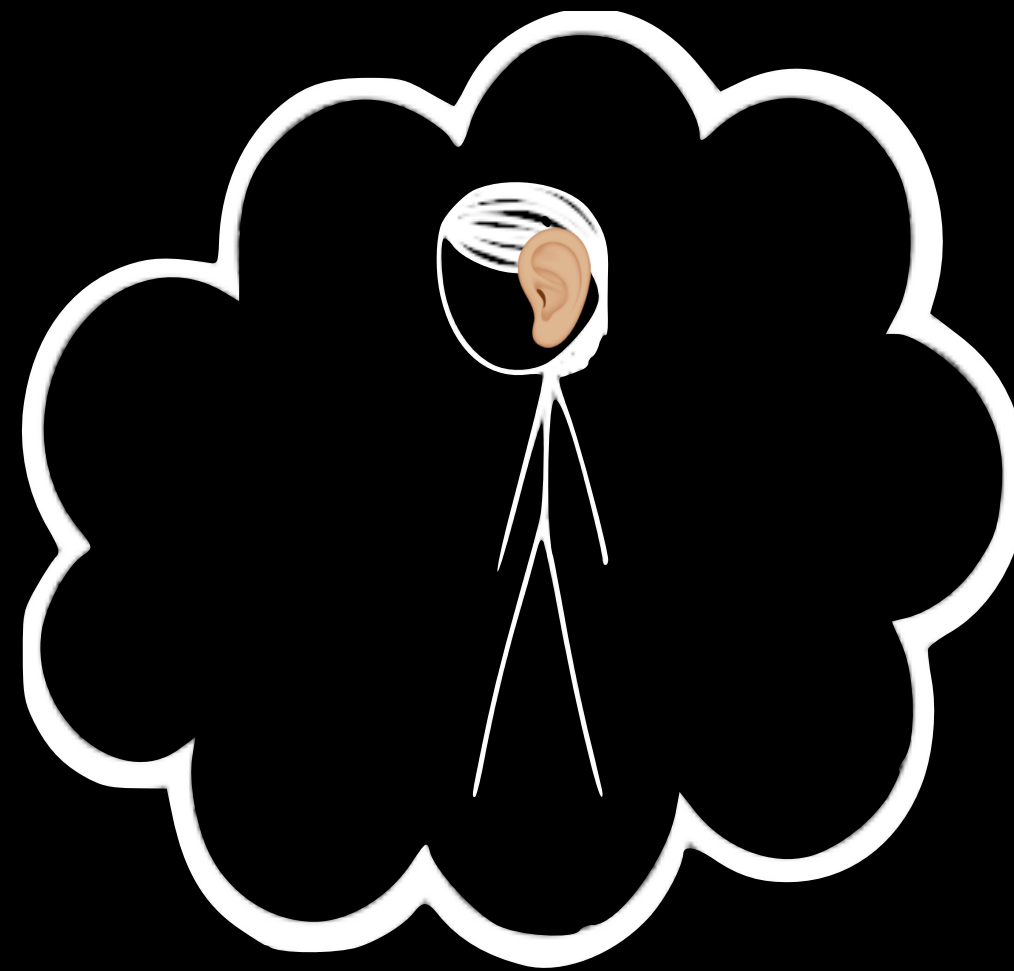
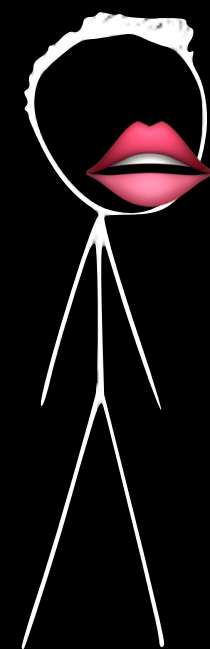
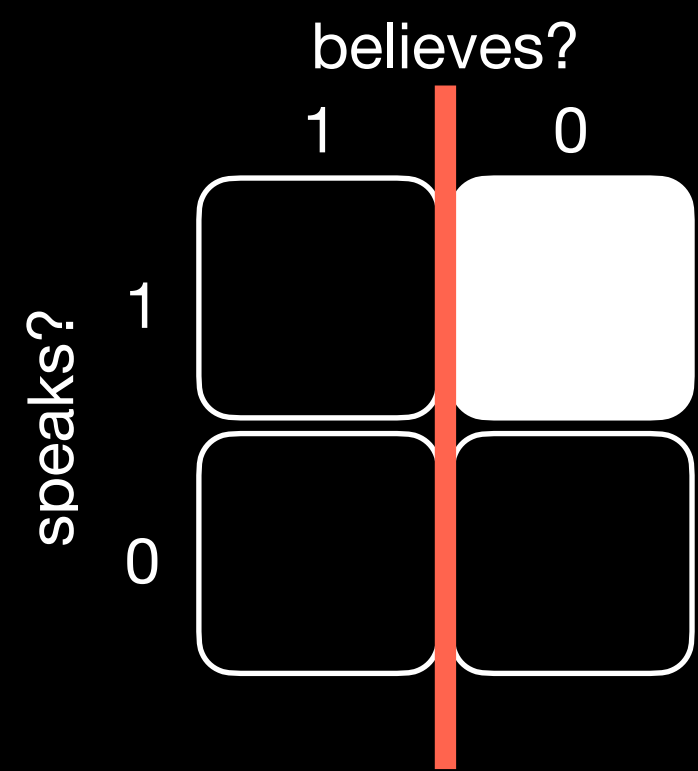
**pos**

**neg**

**does Cole believe?**

# speaker behavior

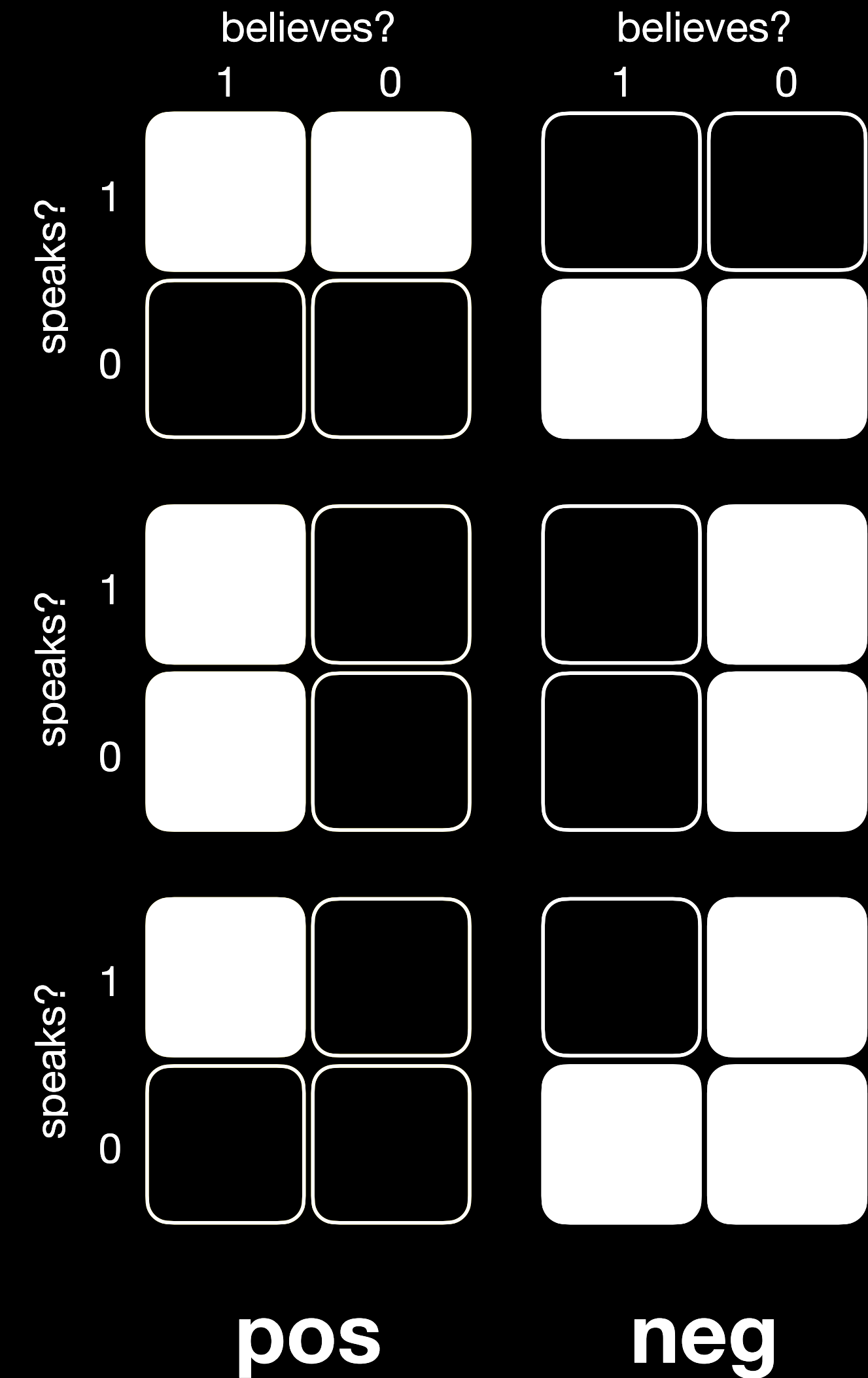
speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



**simple**

*think*

*know*

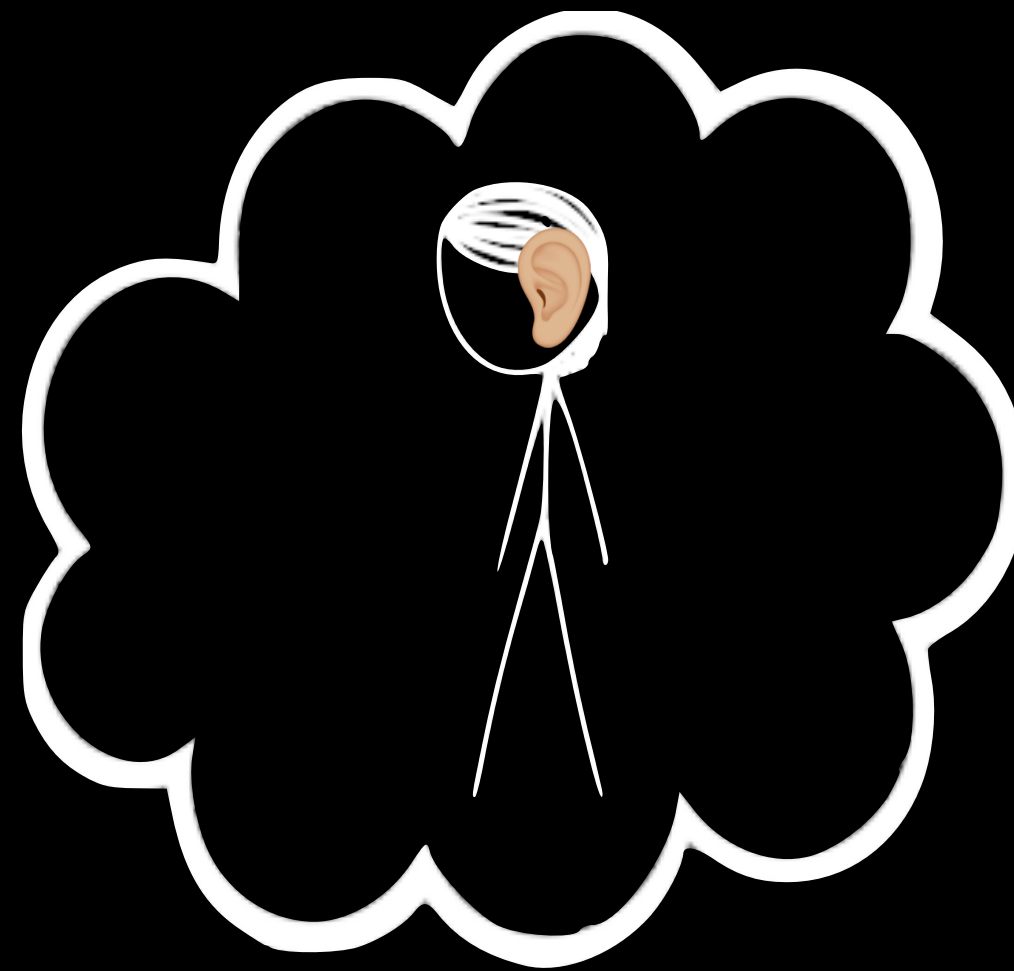
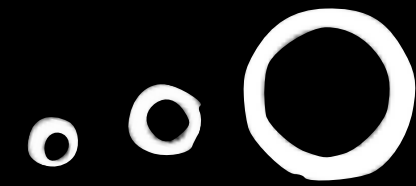
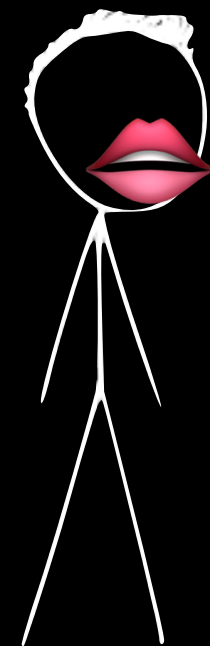
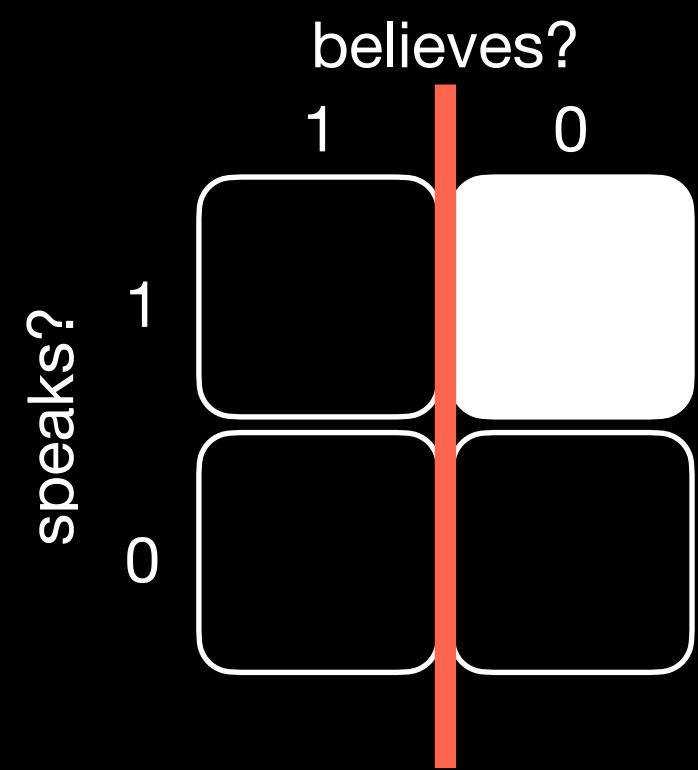


*does Cole believe?*



# speaker behavior

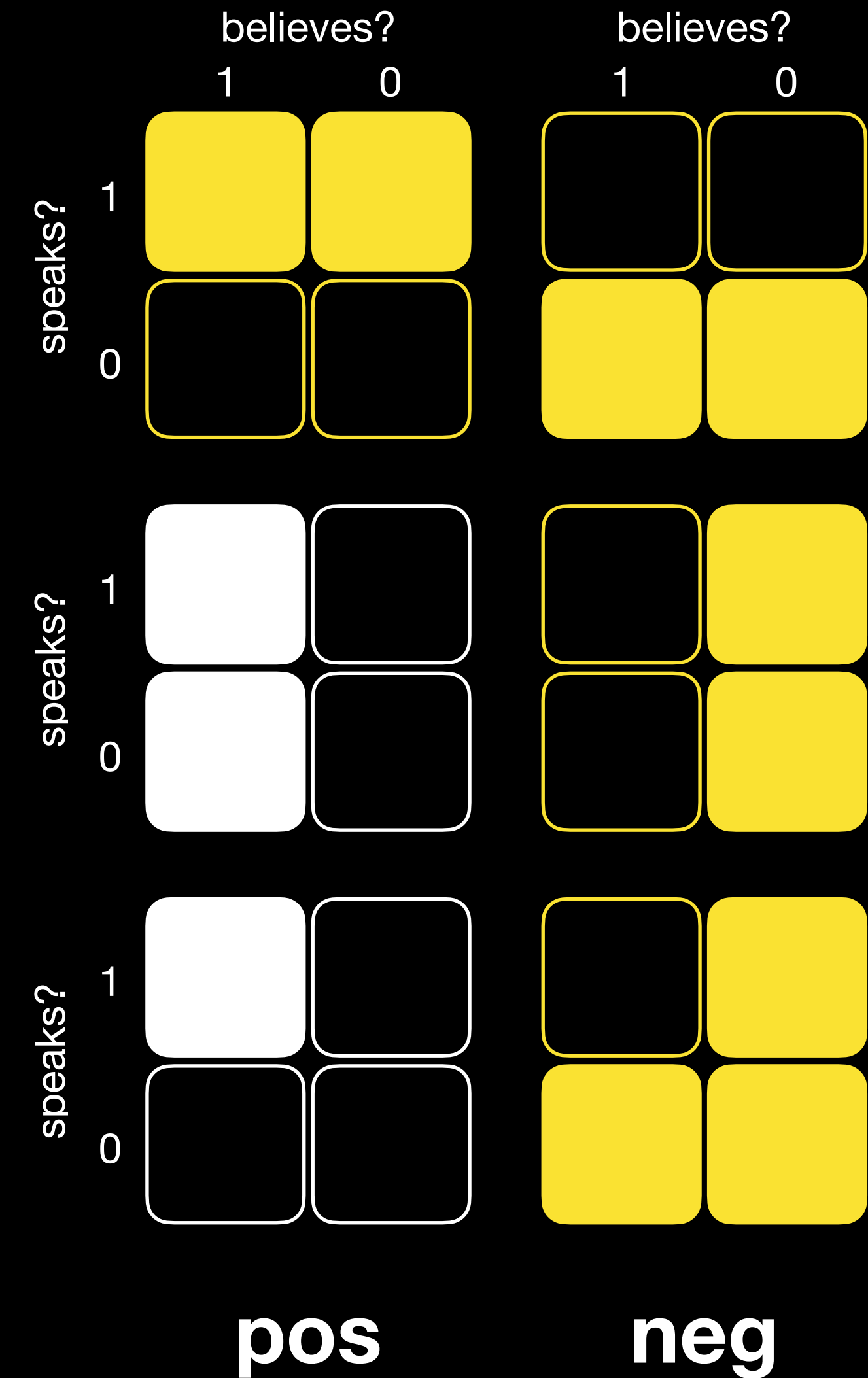
speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



**simple**

**think**

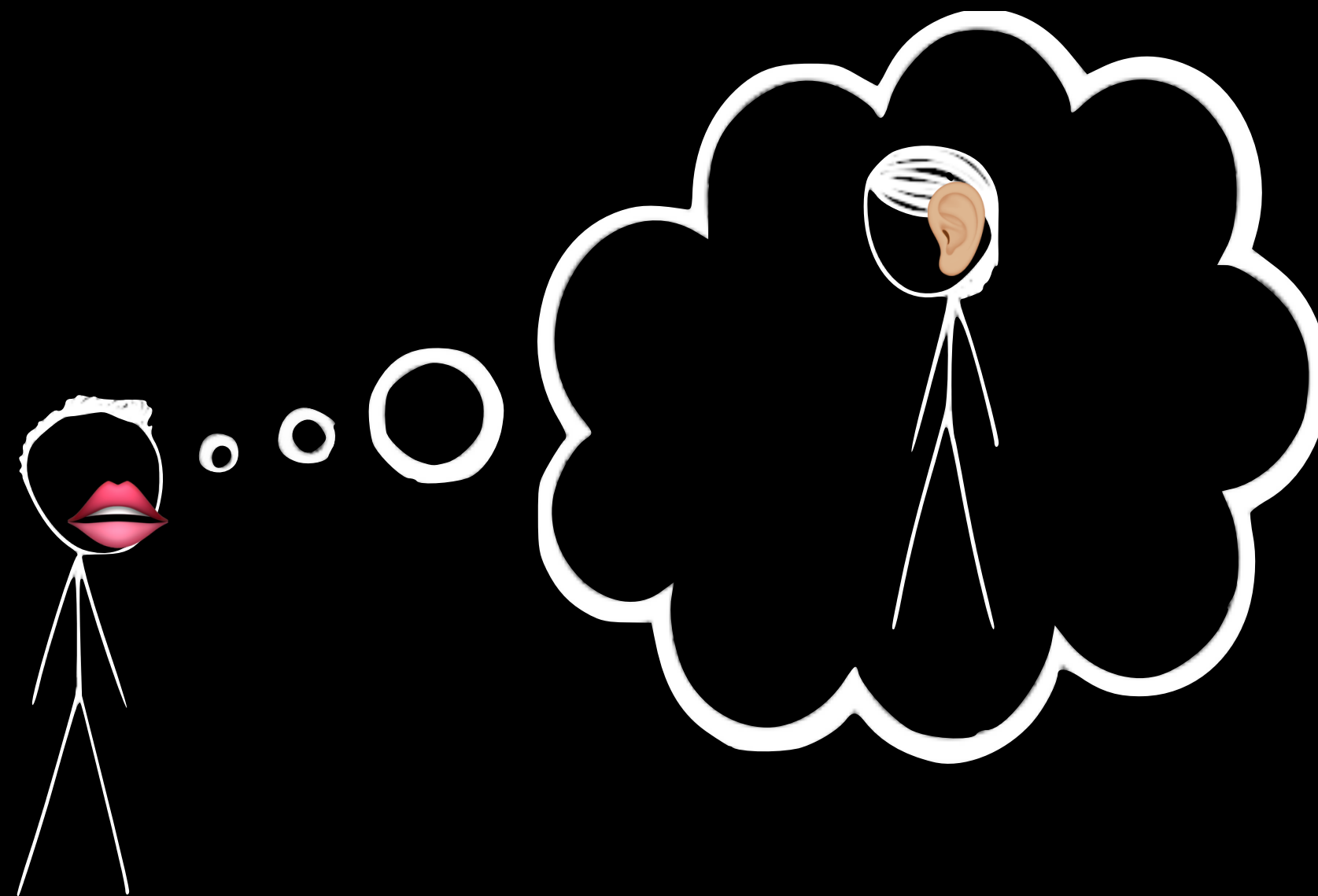
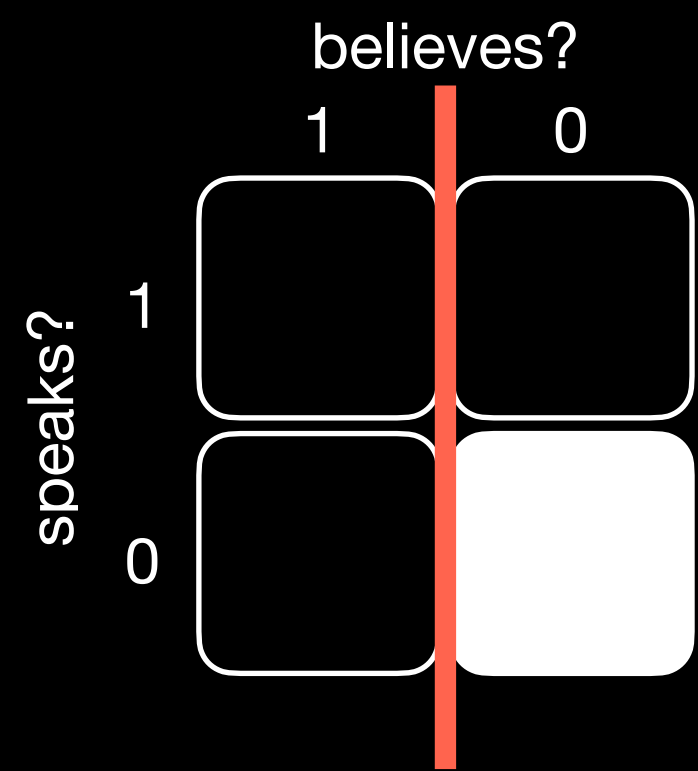
**know**



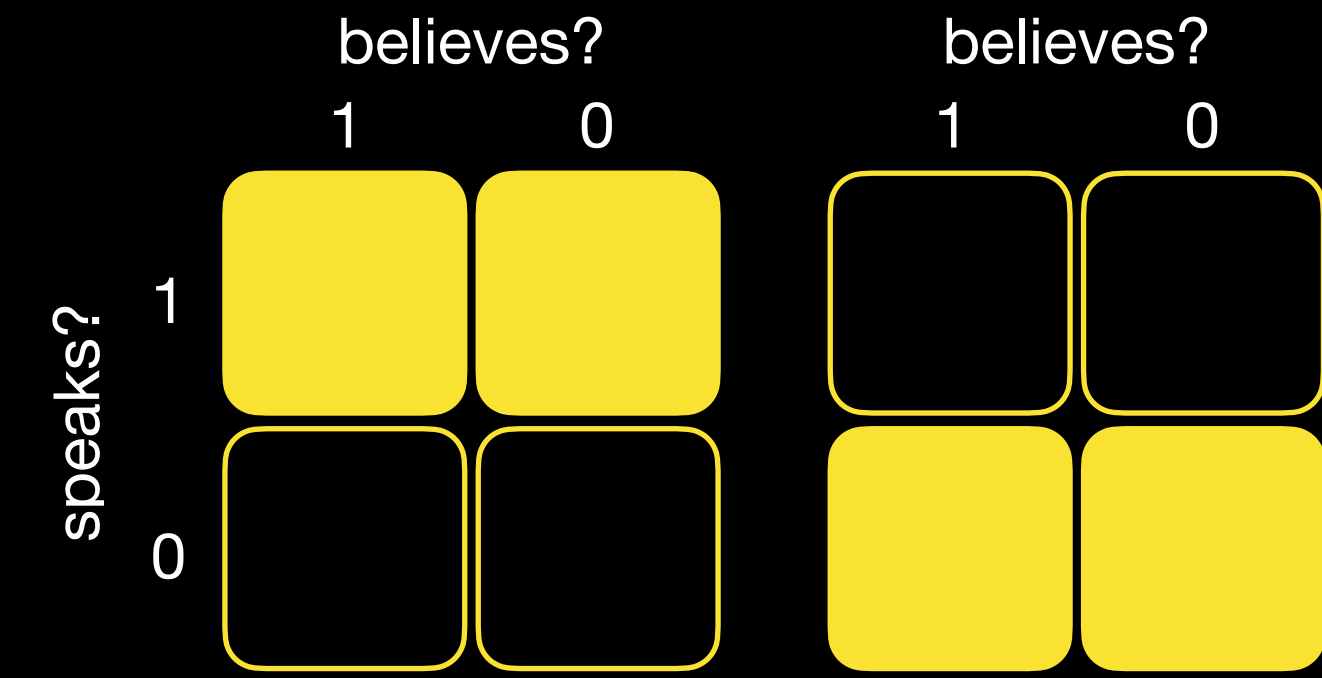
**does Cole believe?**

# speaker behavior

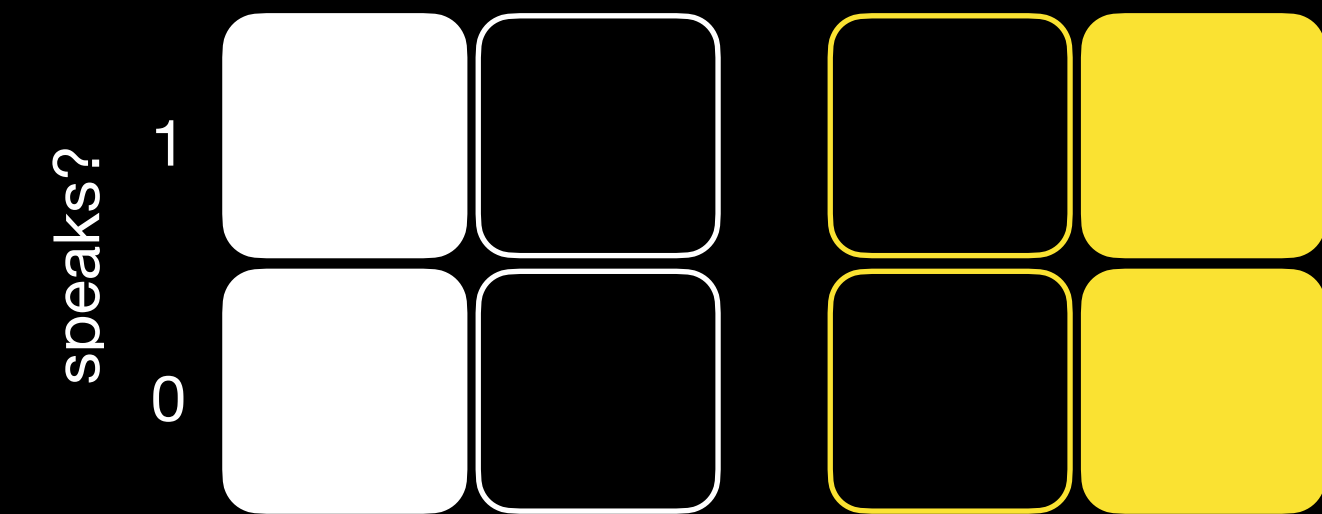
speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



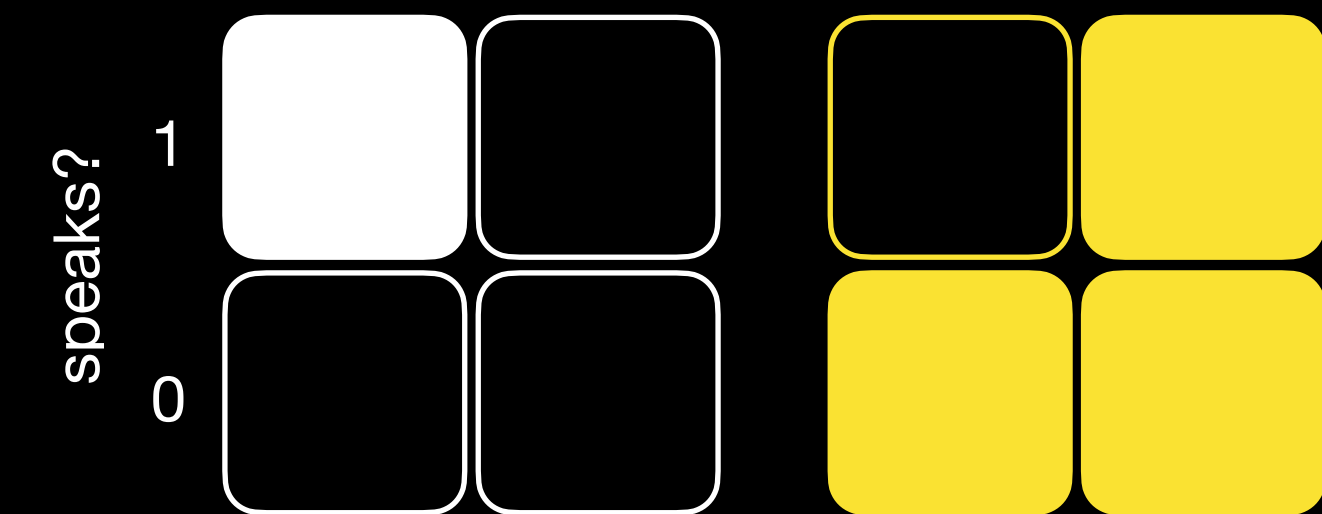
**simple**



**think**



**know**



**pos**

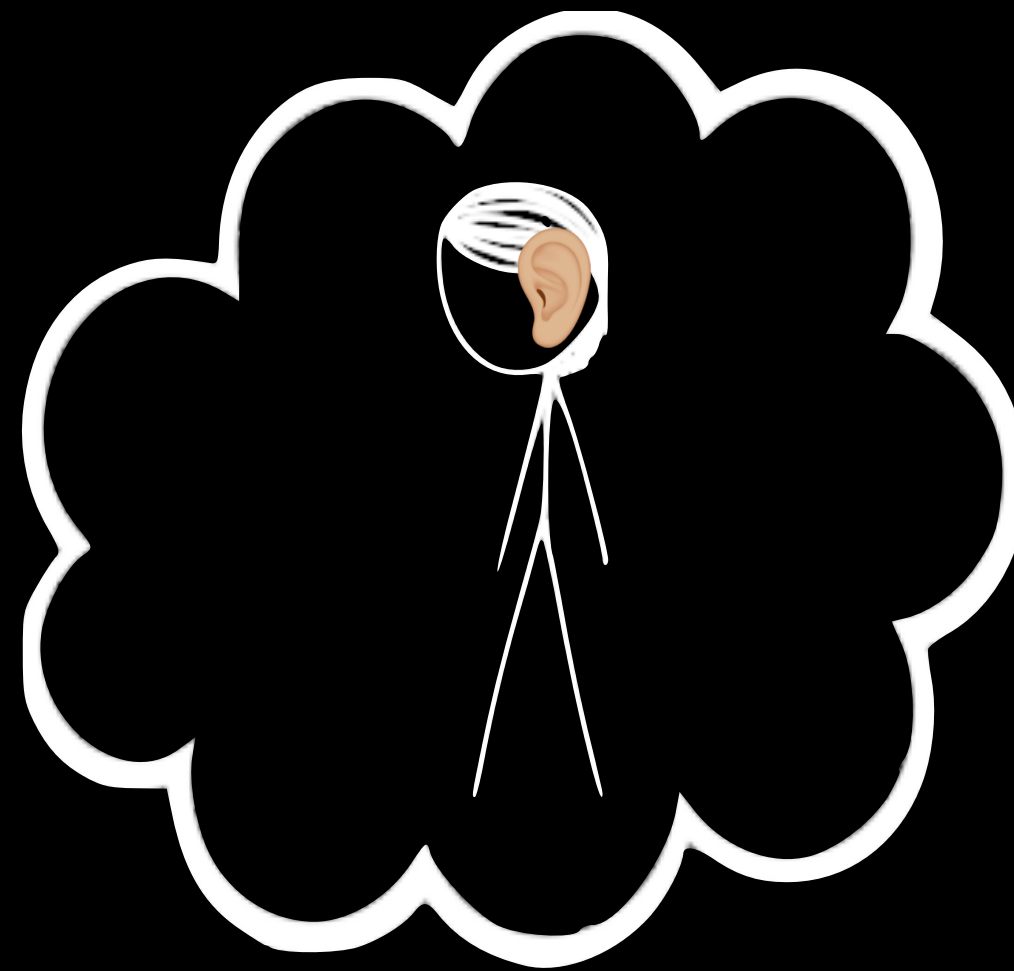
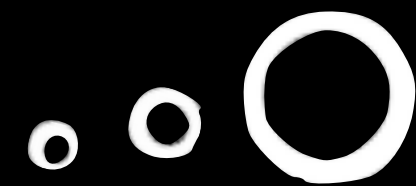
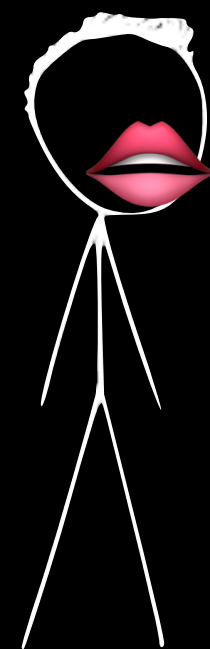
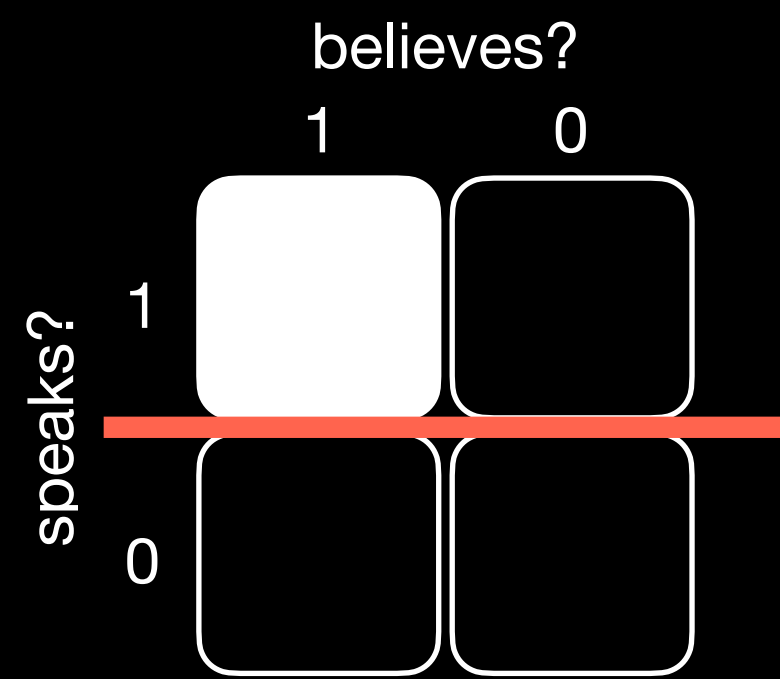
**neg**

**does Cole believe?**



# speaker behavior

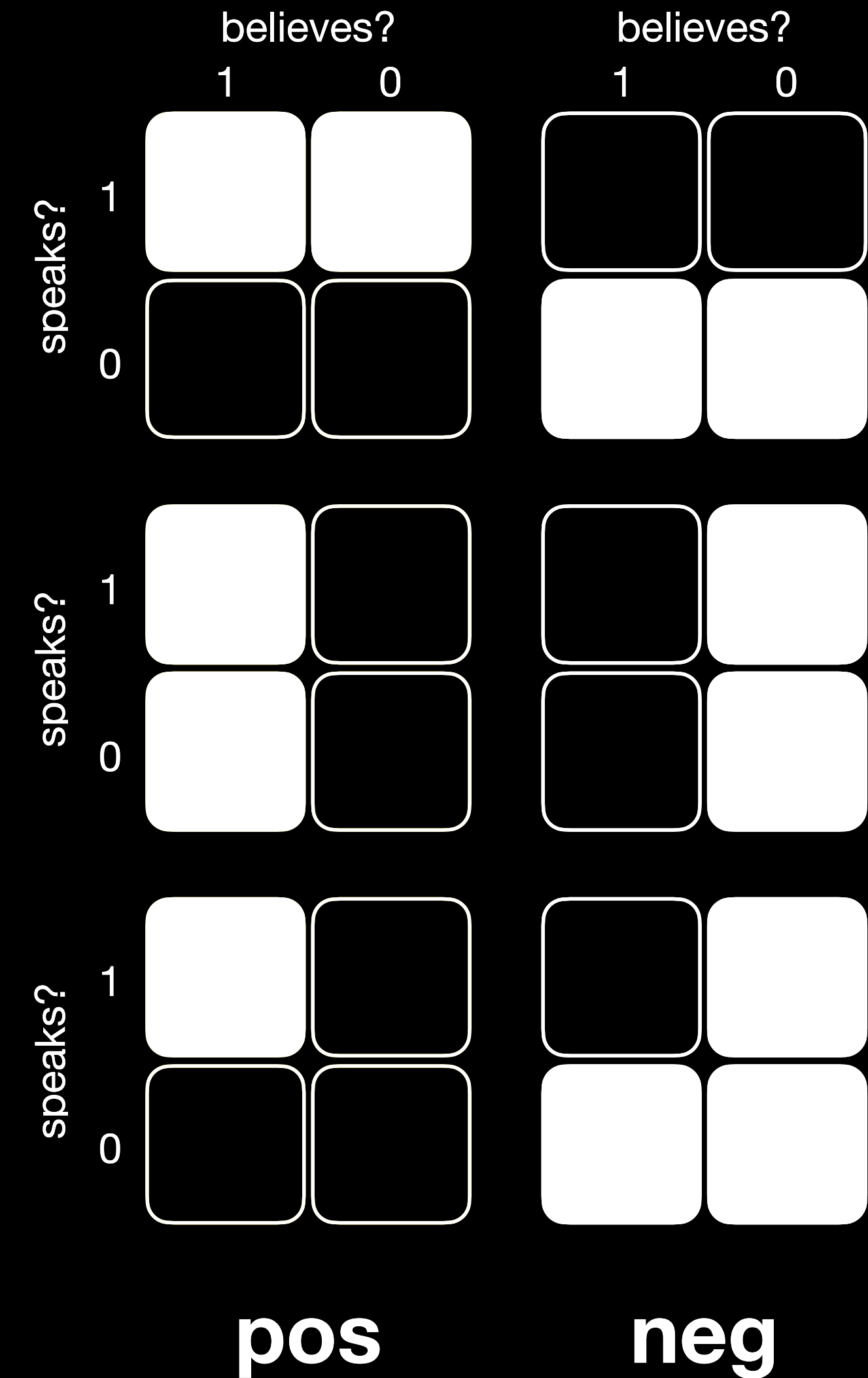
speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



**simple**

*think*

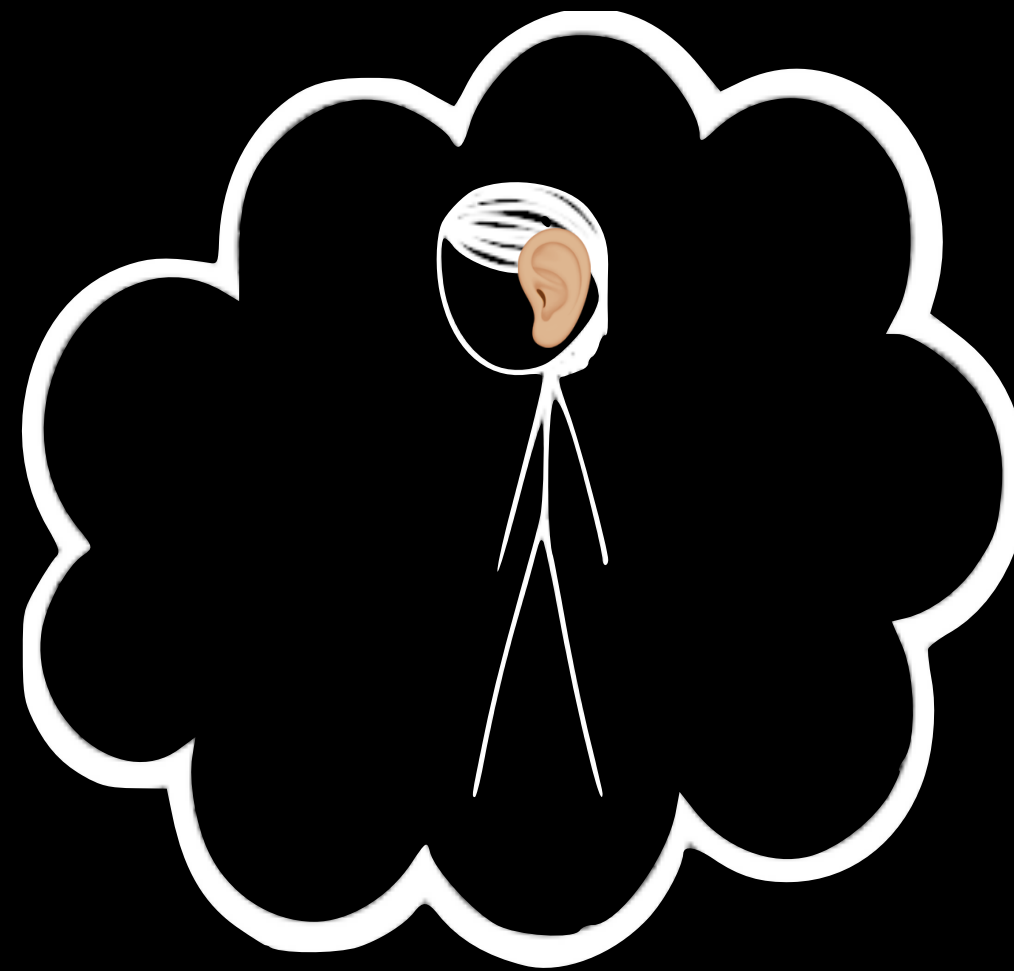
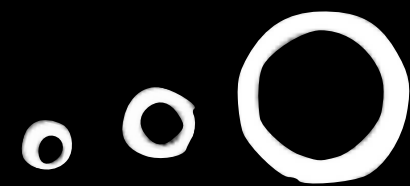
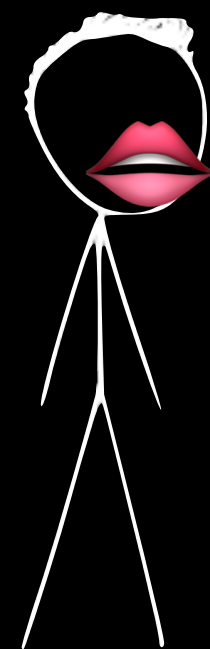
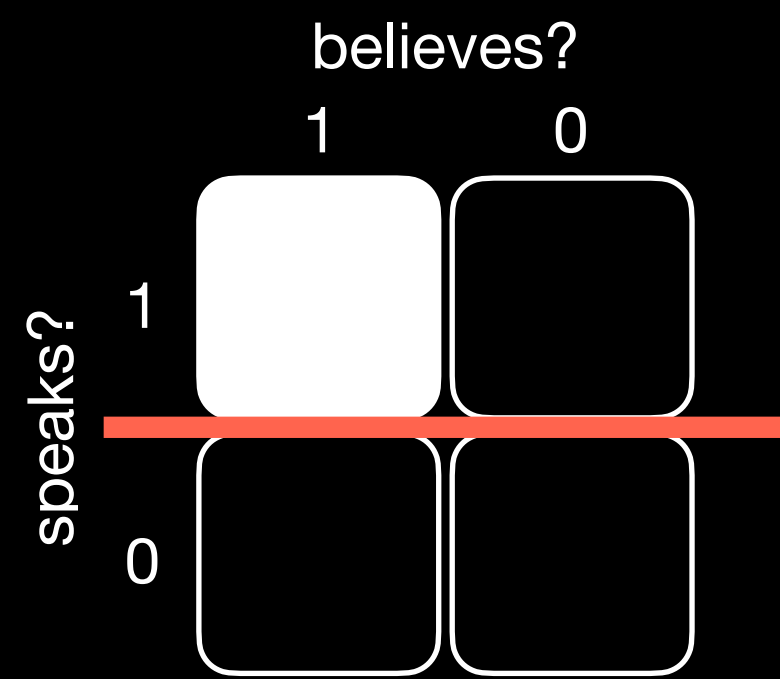
*know*



*does Charley speak Spanish?*

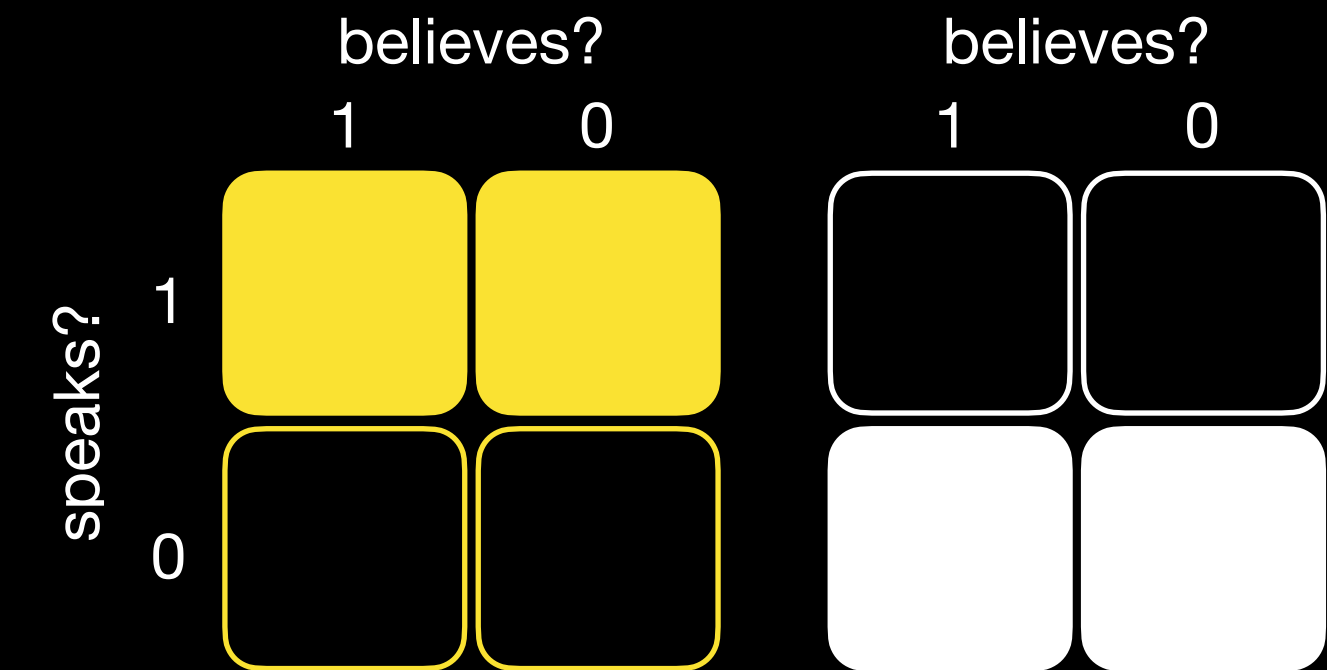
# speaker behavior

speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD

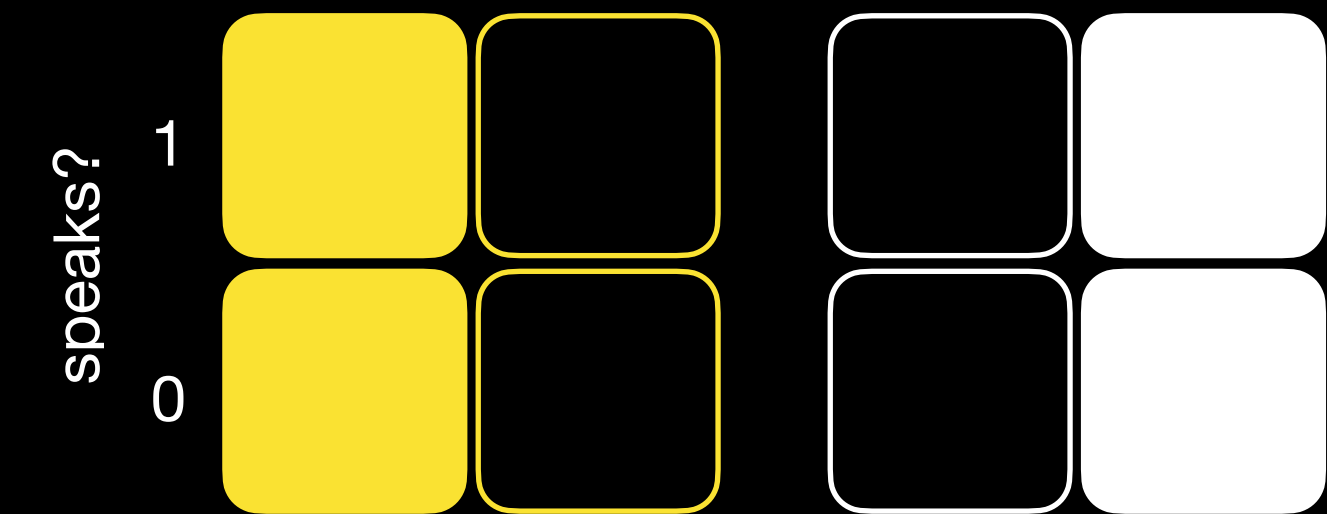


*does Charley speak Spanish?*

**simple**



*think*



*know*

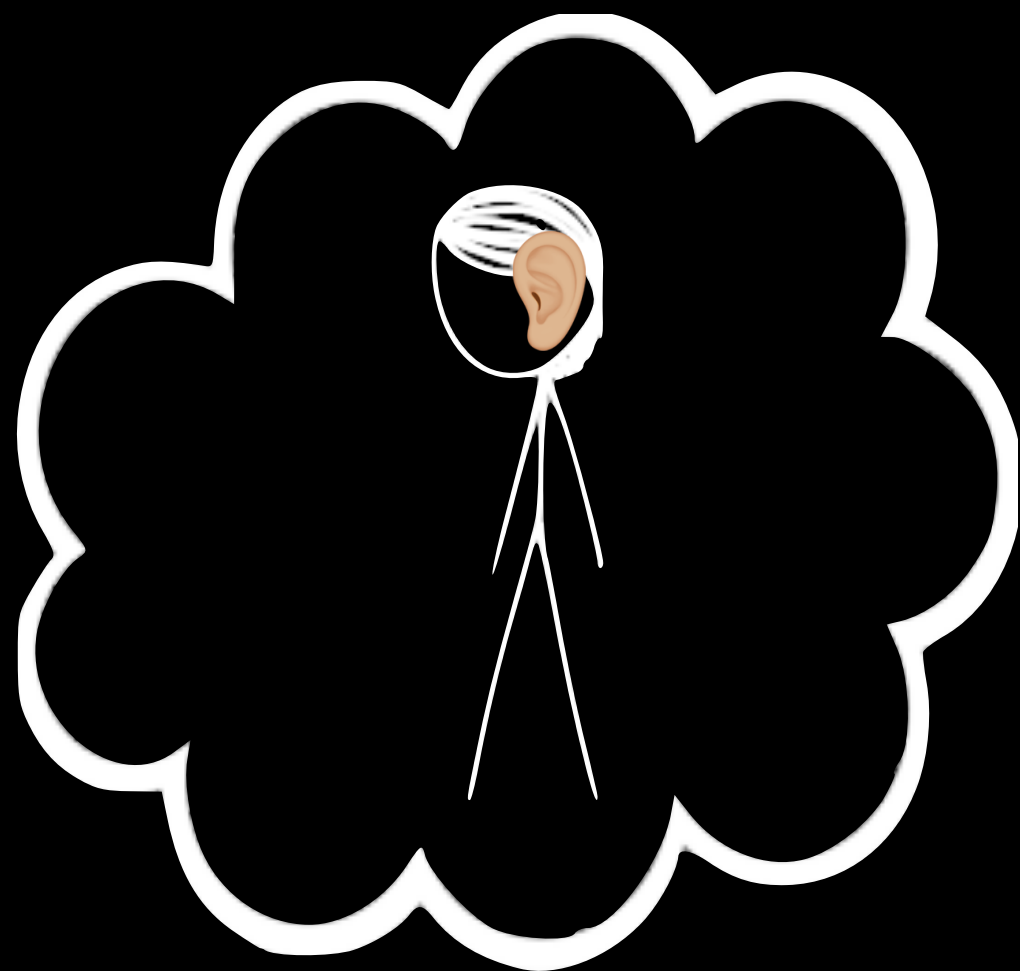
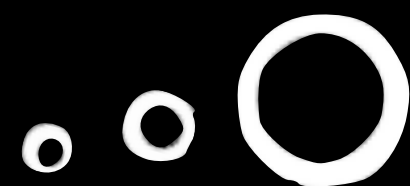
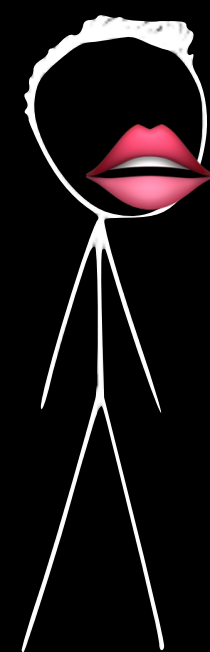
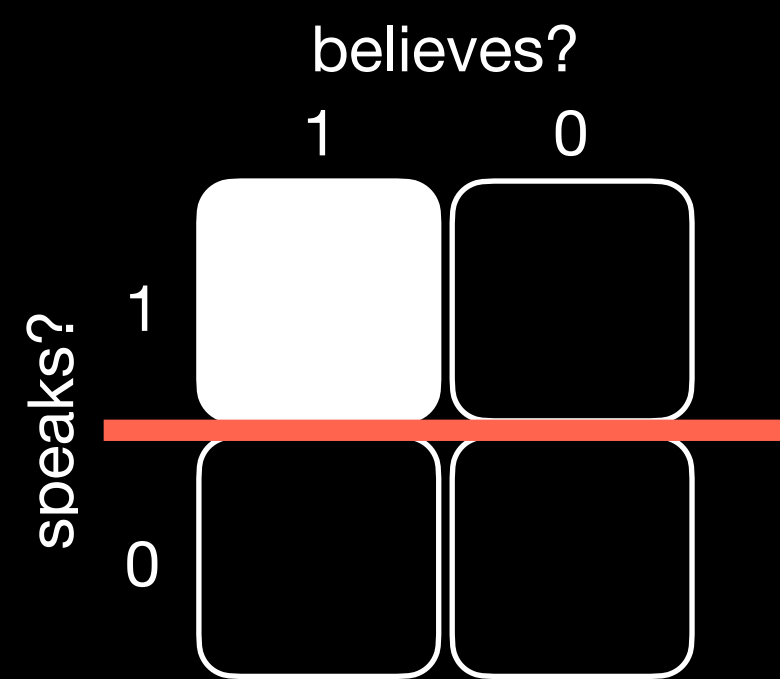


**pos**

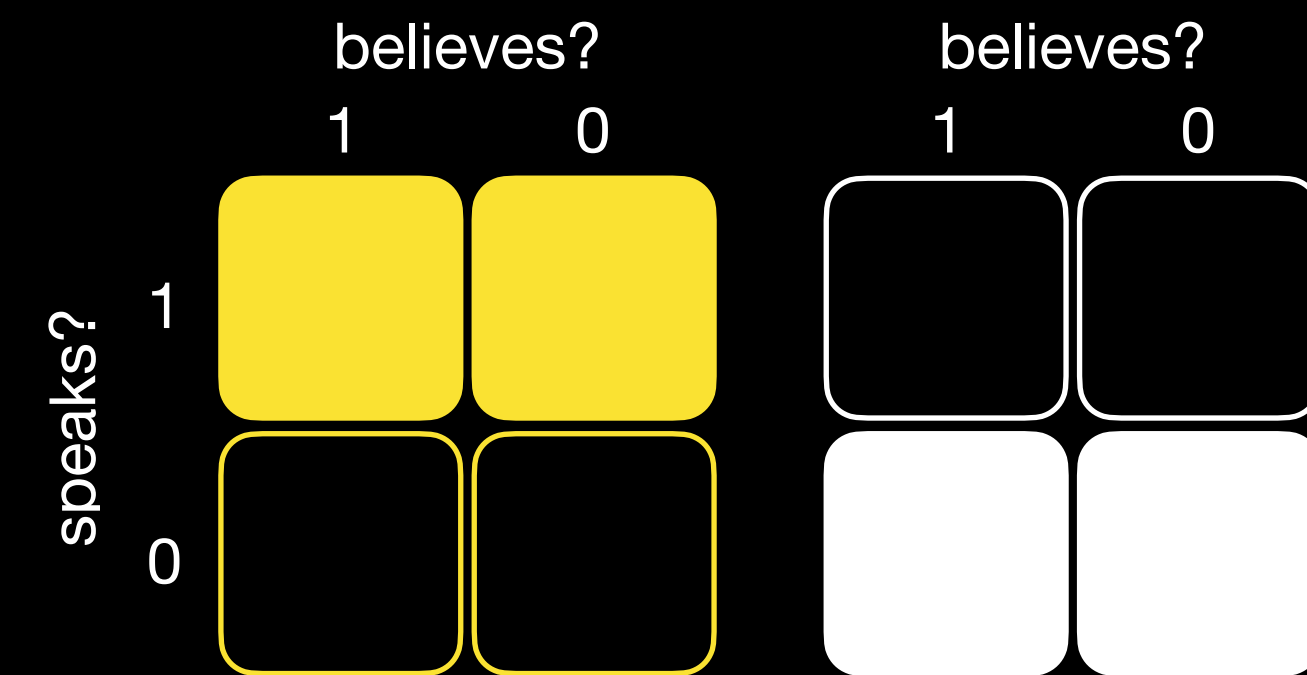
**neg**

# speaker behavior

speakers **choose** to produce **utterances in proportion to their utility** for leading the **listener** to correctly resolve the QUD



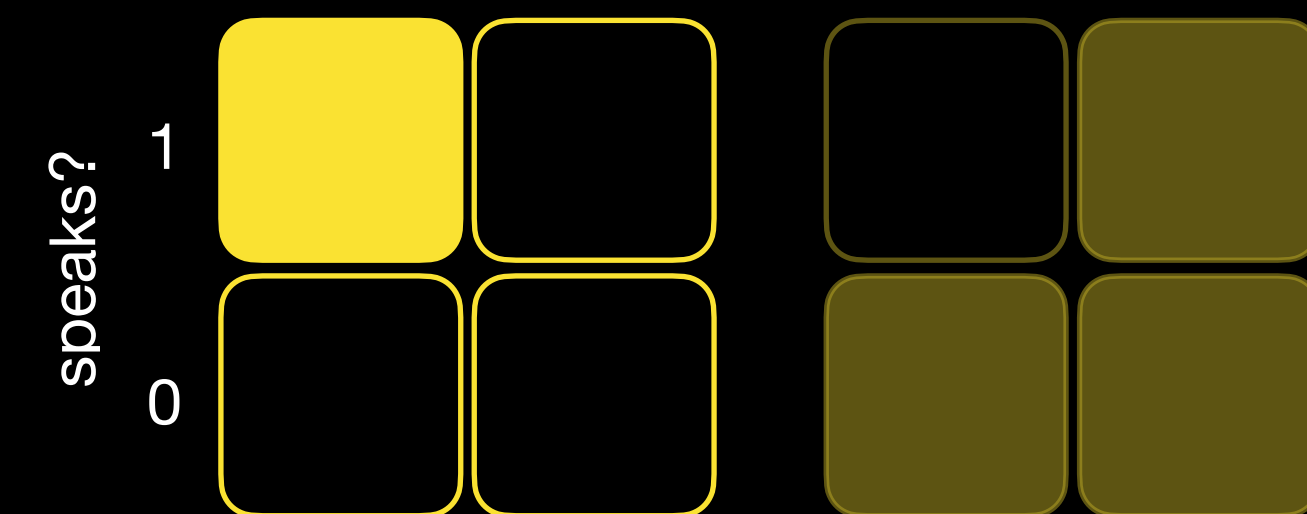
**simple**



**think**



**know**

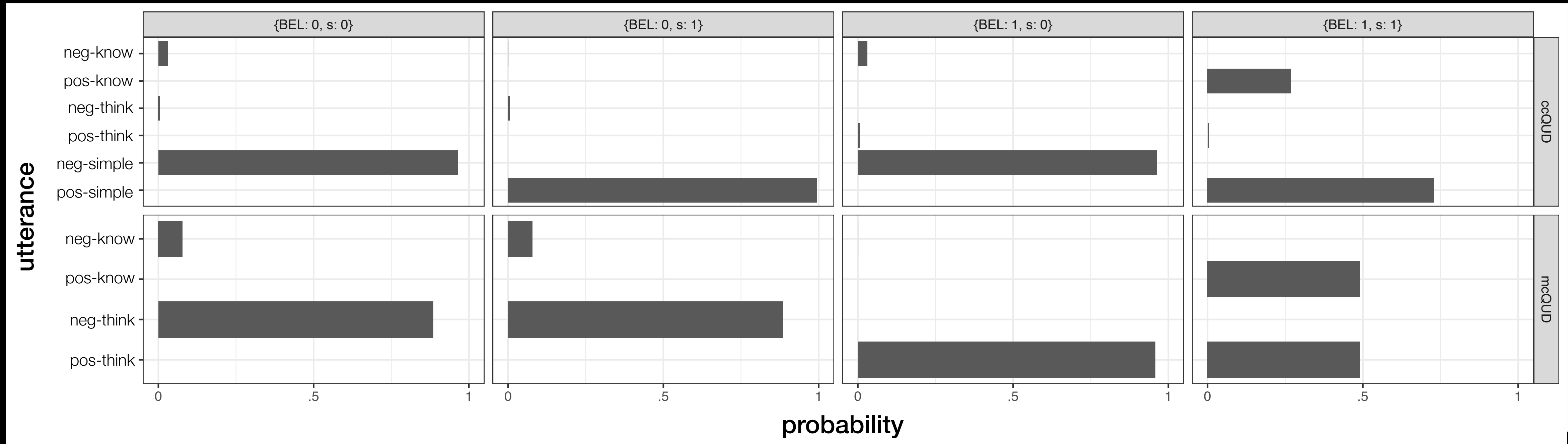
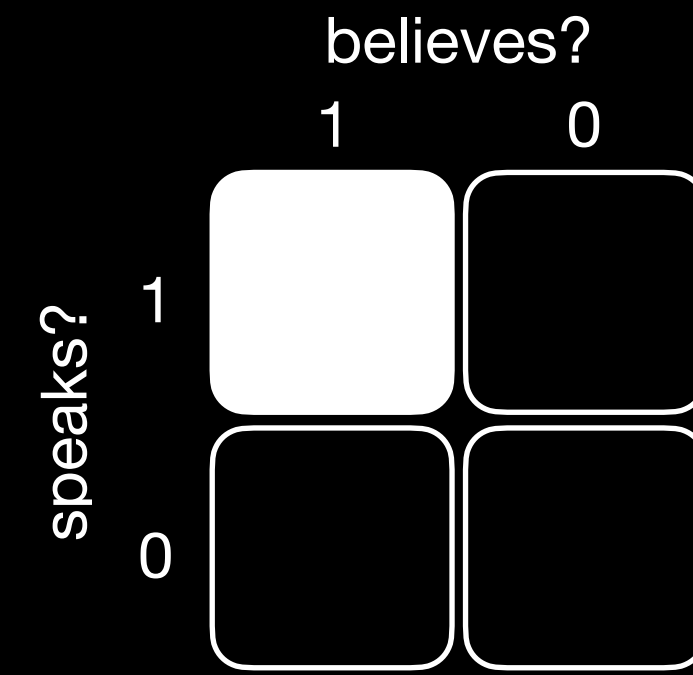
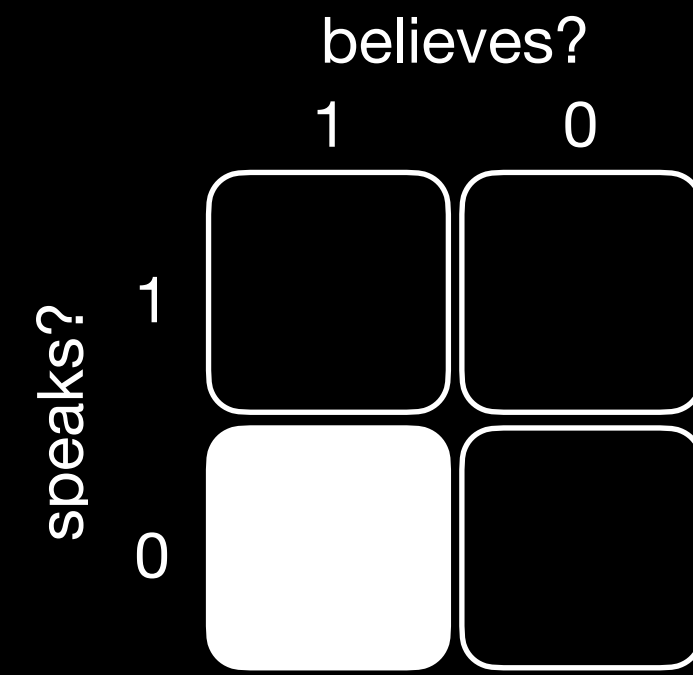
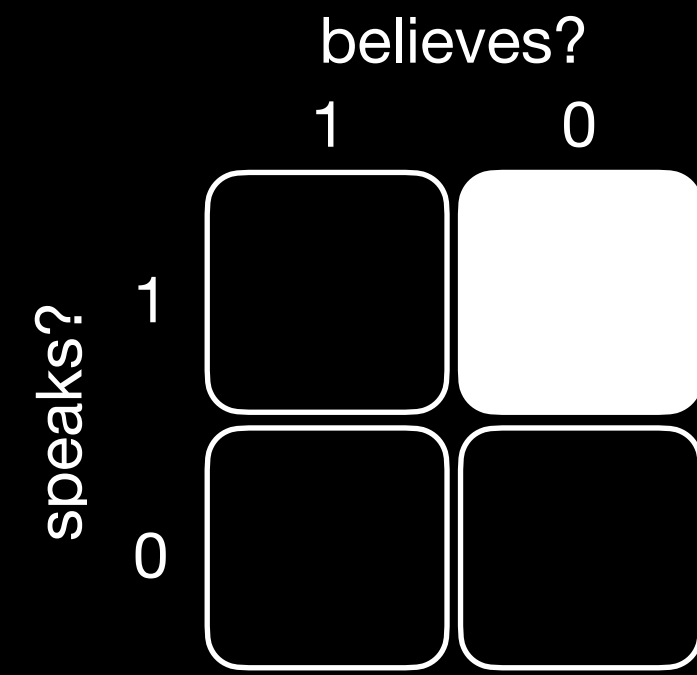
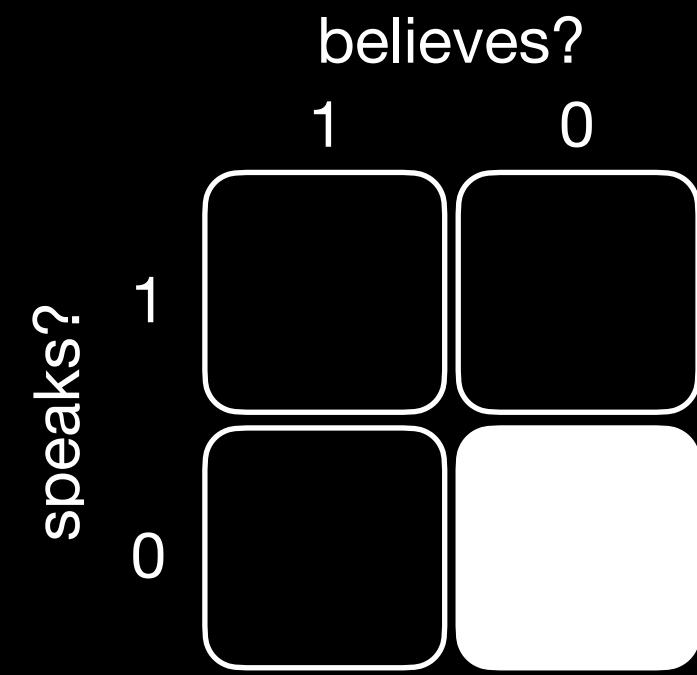


**does Charley speak Spanish?**

**pos**

**neg**

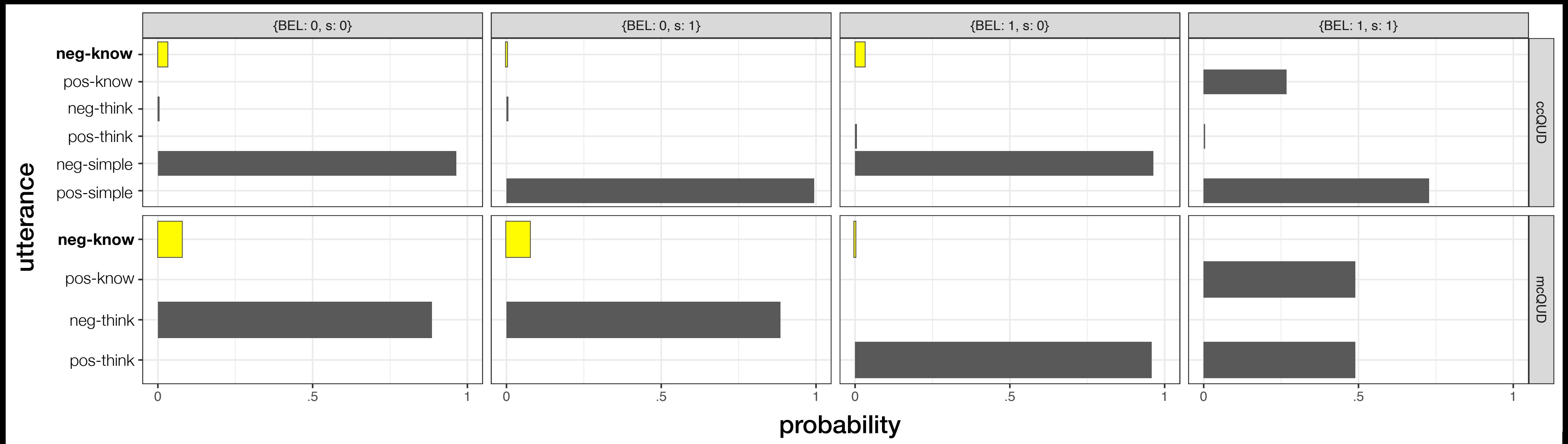
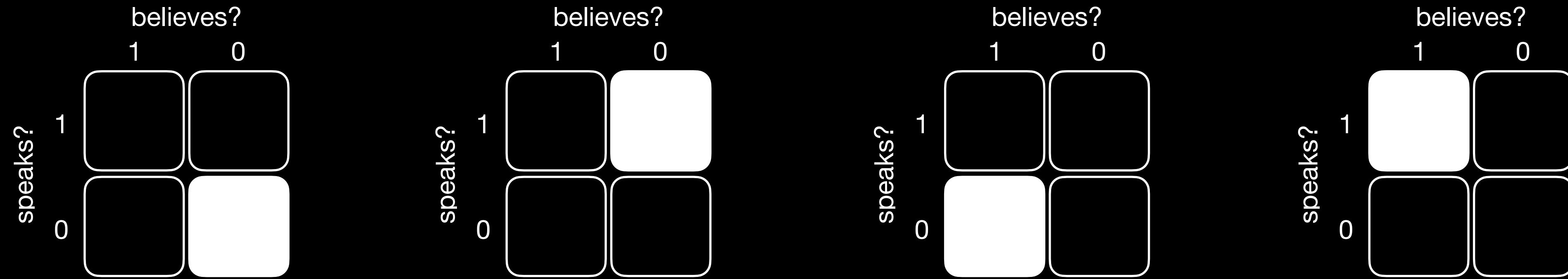
# which utterance does the speaker choose?



does Charley speak?

does Cole believe?

# which utterance does the speaker choose?



does Charley speak?  
does Cole believe?

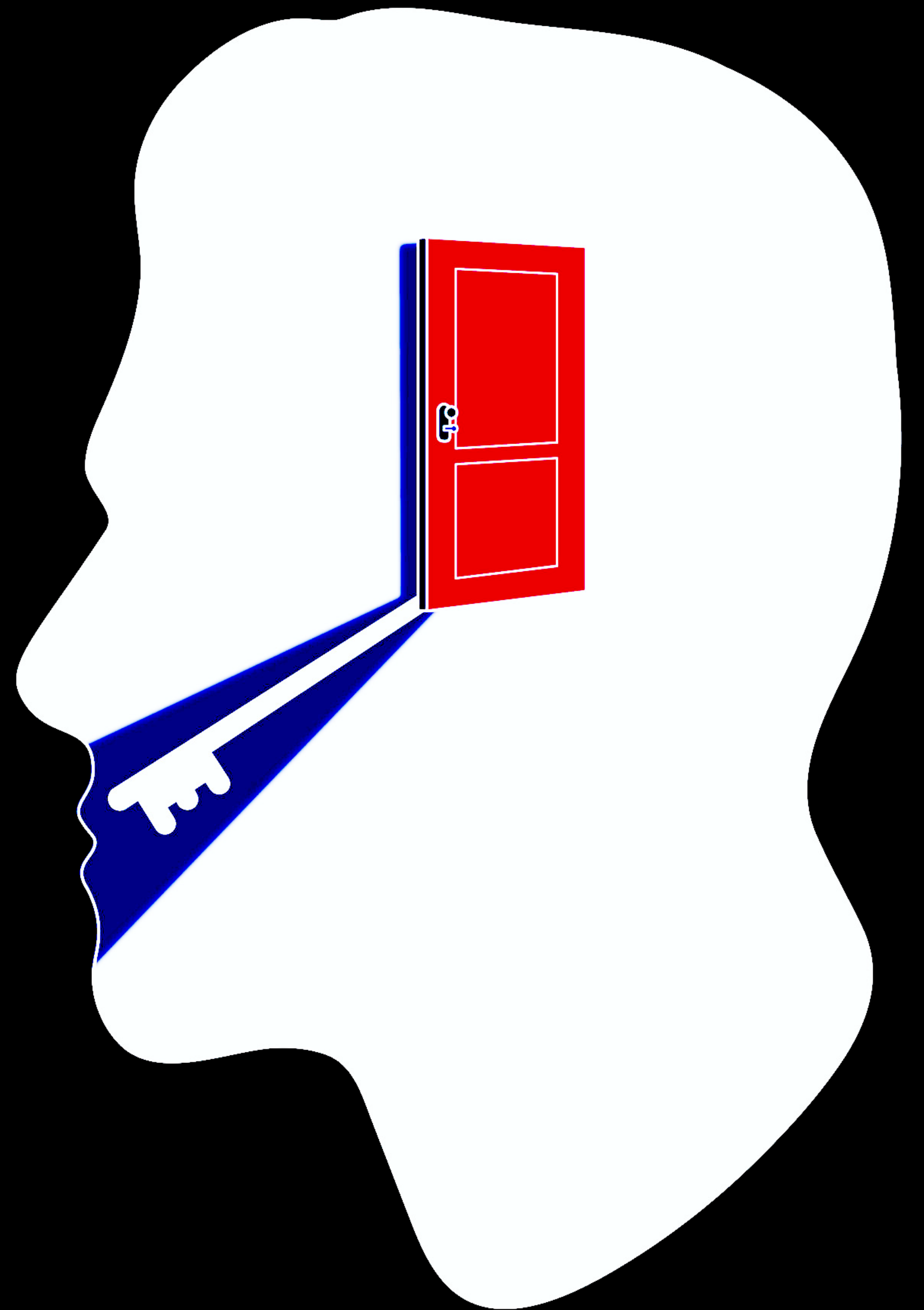
**neg-know** has low utility because it has a weak semantics



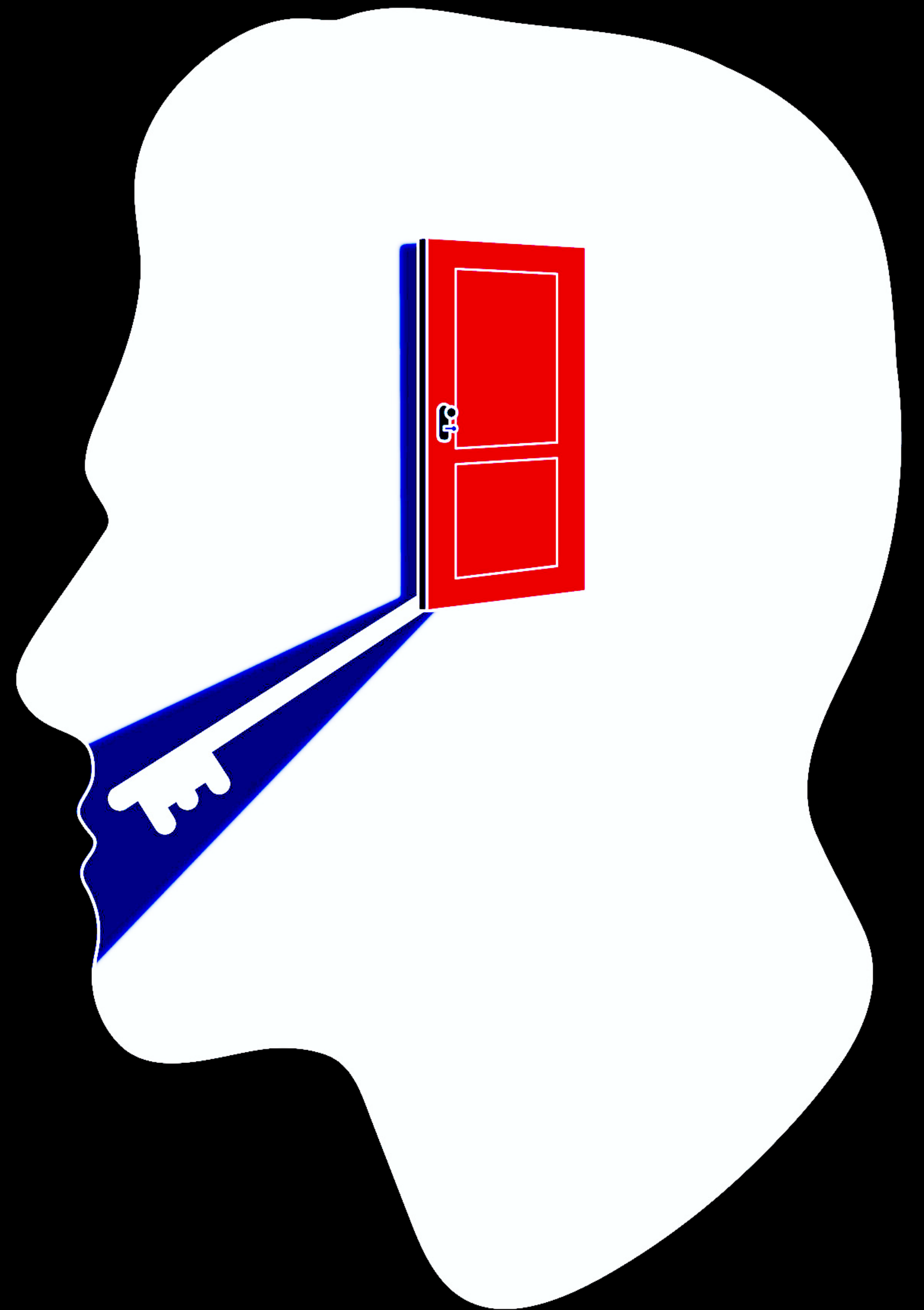
One more thing...



private assumptions

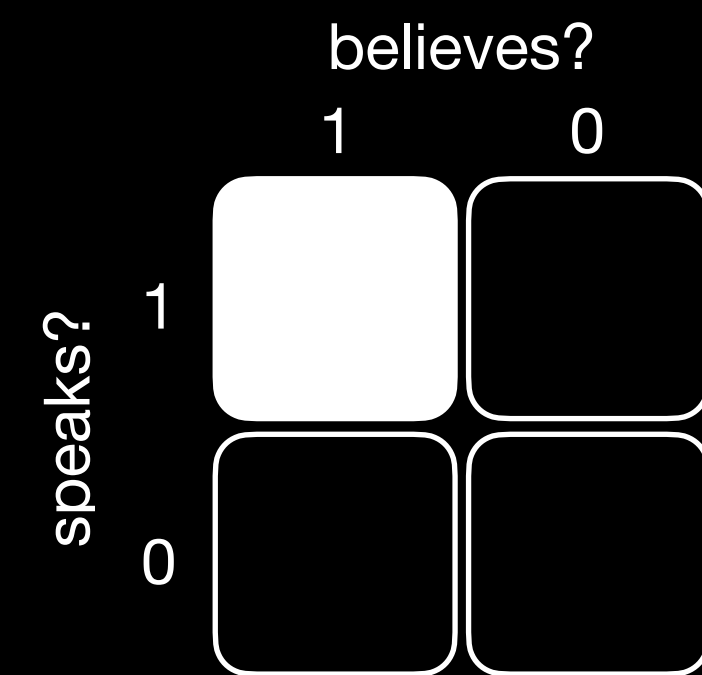
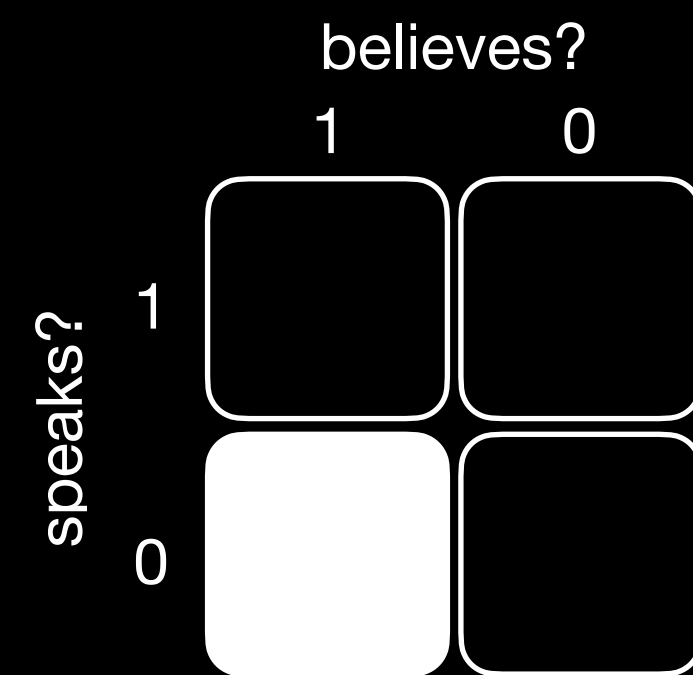
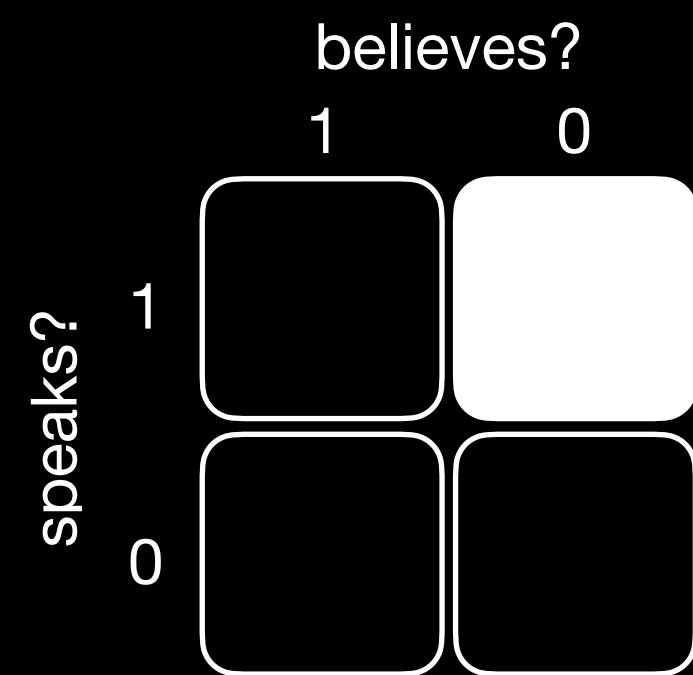
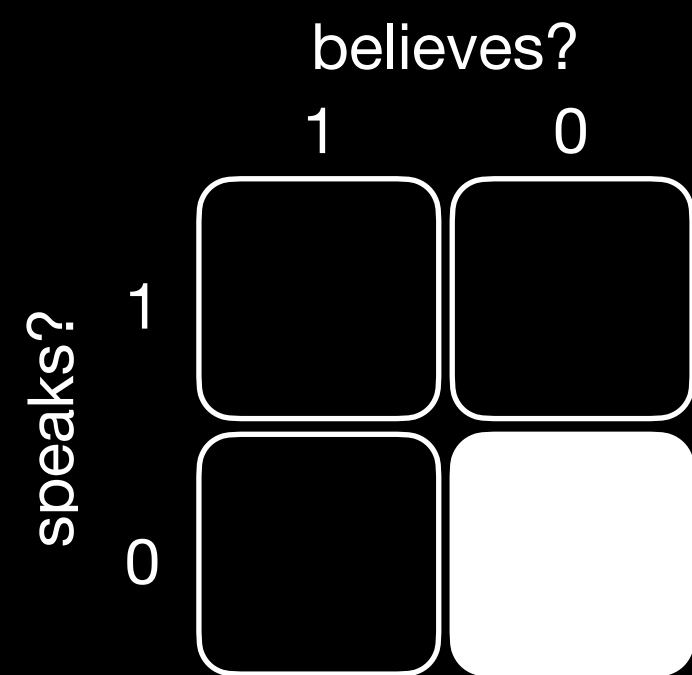


the speaker wants to convey  
an answer to the QUD that is  
**consistent with their  
private assumptions**

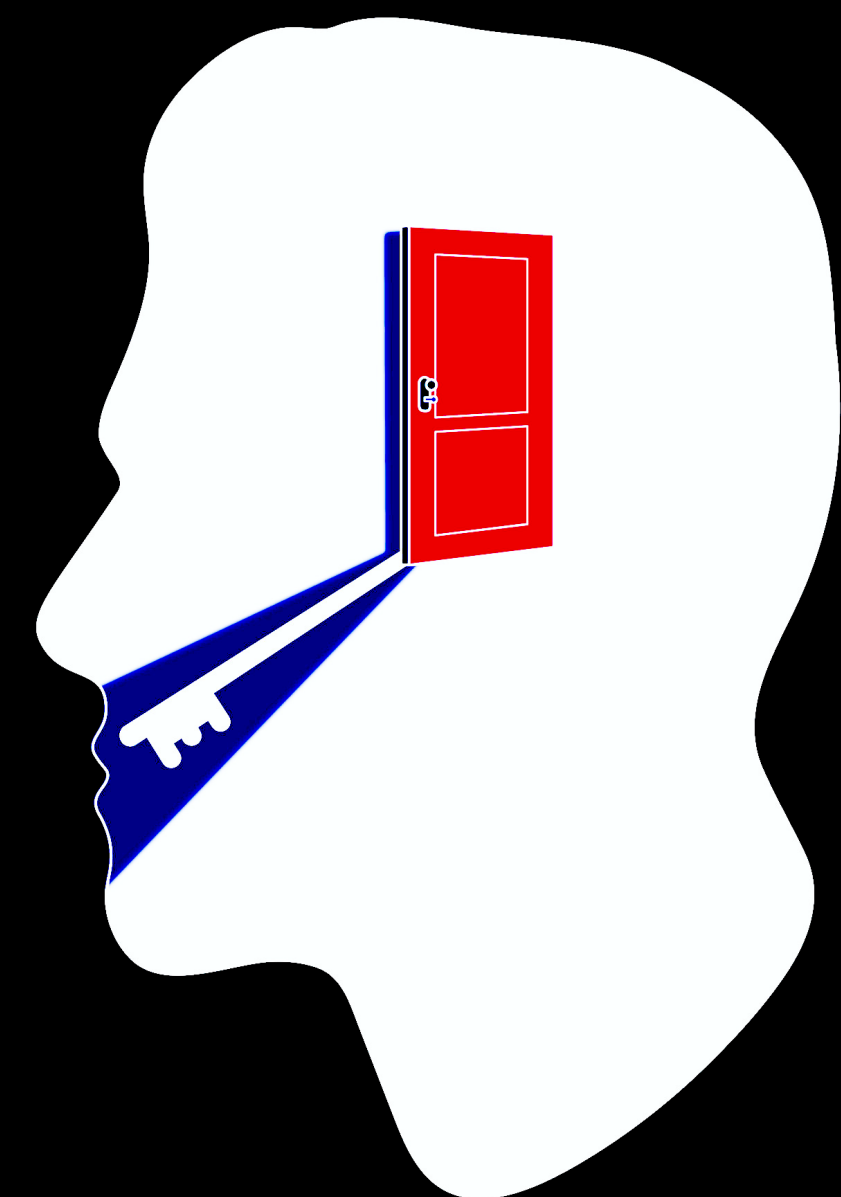




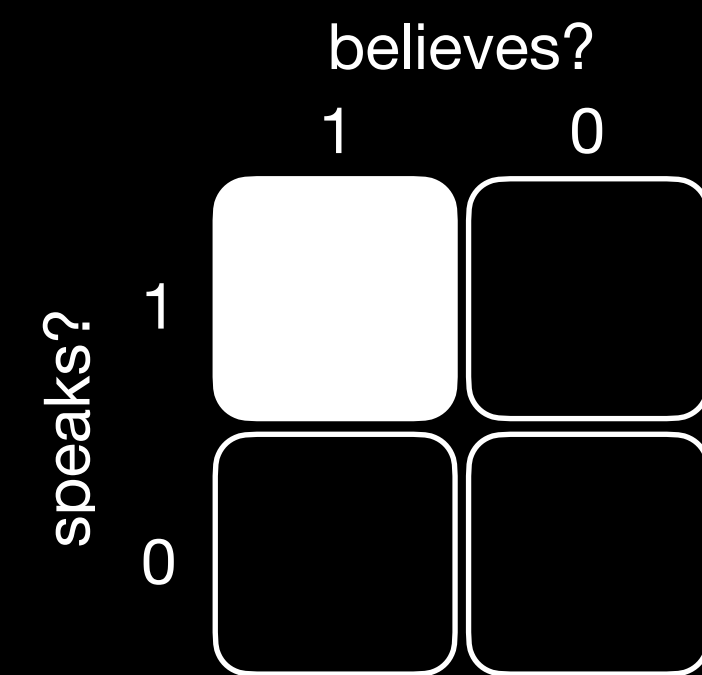
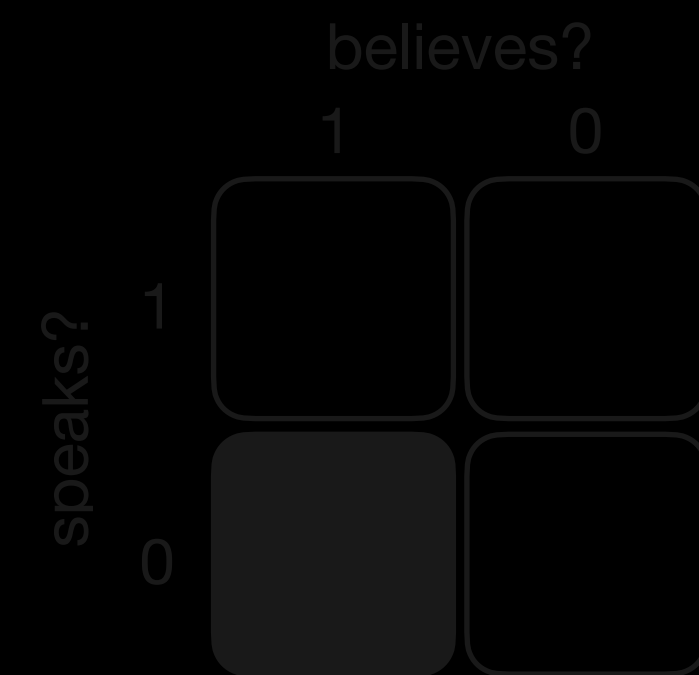
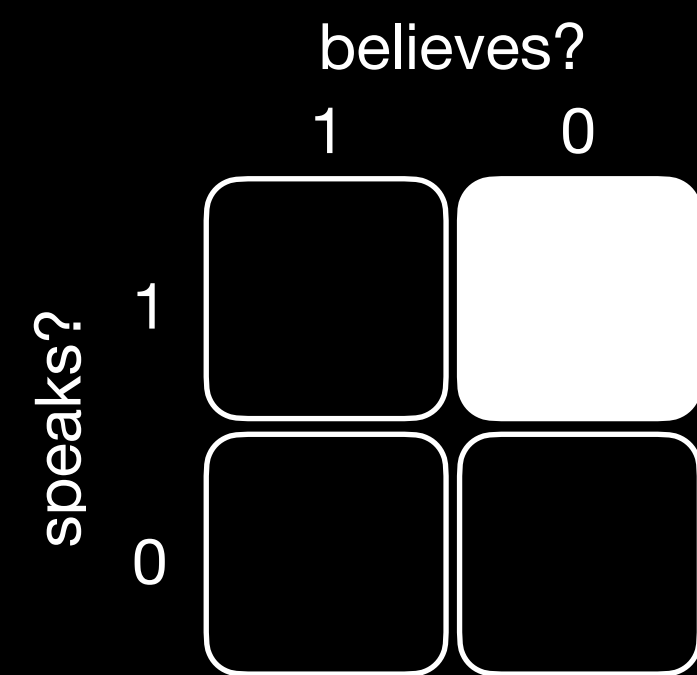
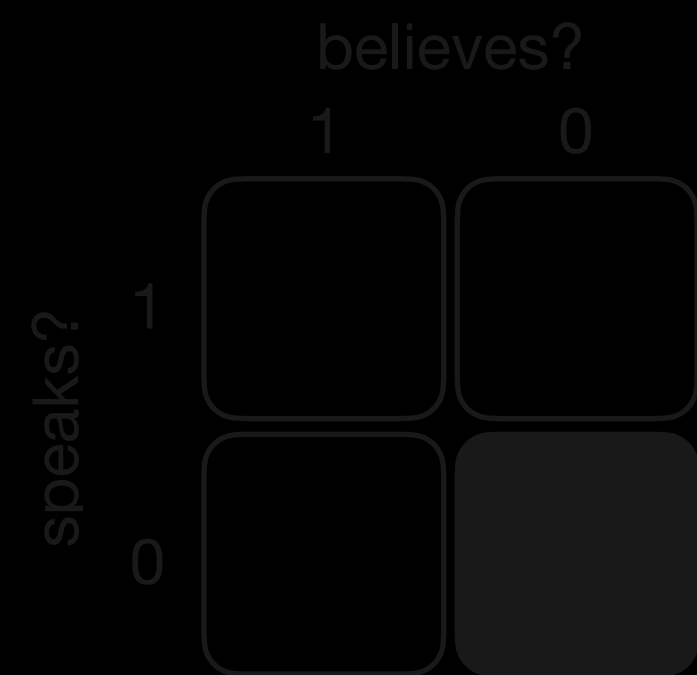
**private assumptions:** what the speaker assumes to be true



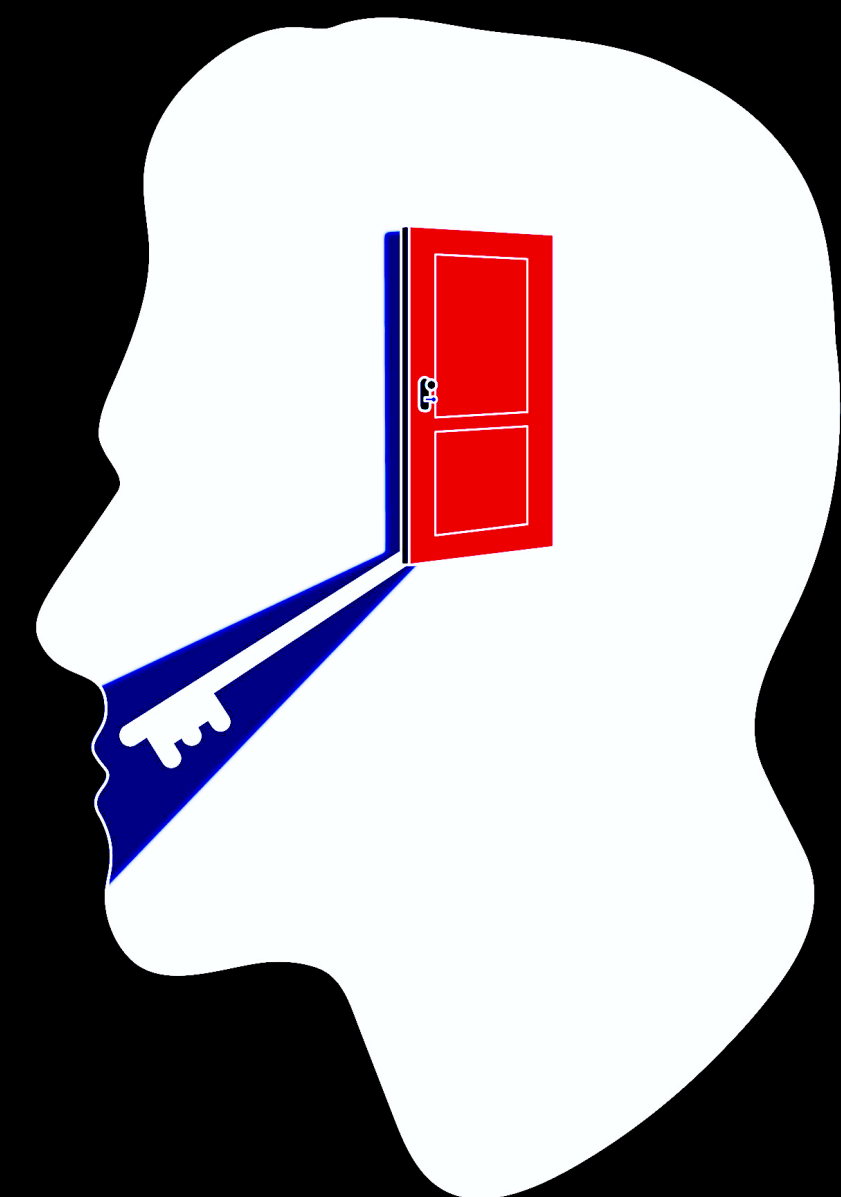
no assumptions;  
all worlds are possible



**private assumptions:** what the speaker assumes to be true

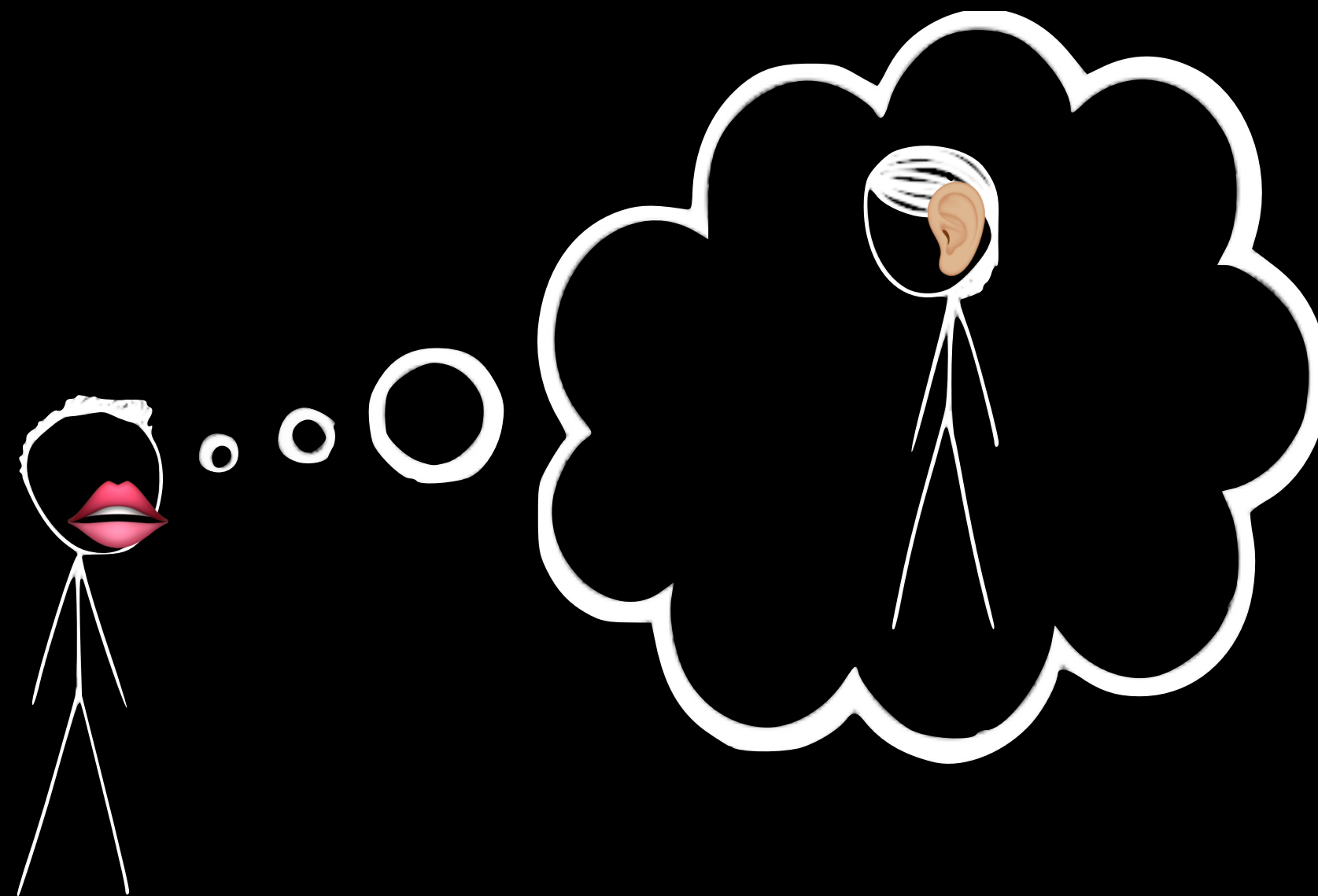
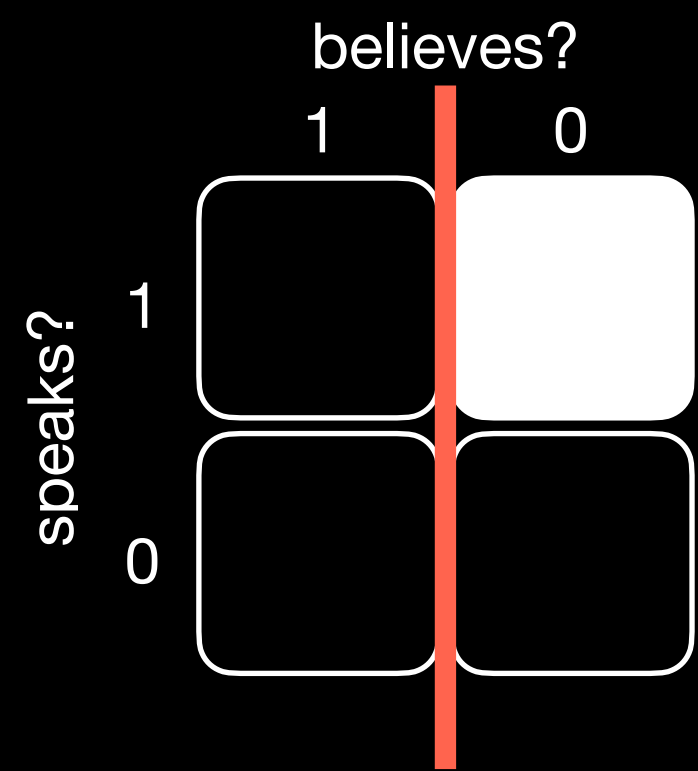


assumption that  
Charley speaks Spanish



# speaker behavior

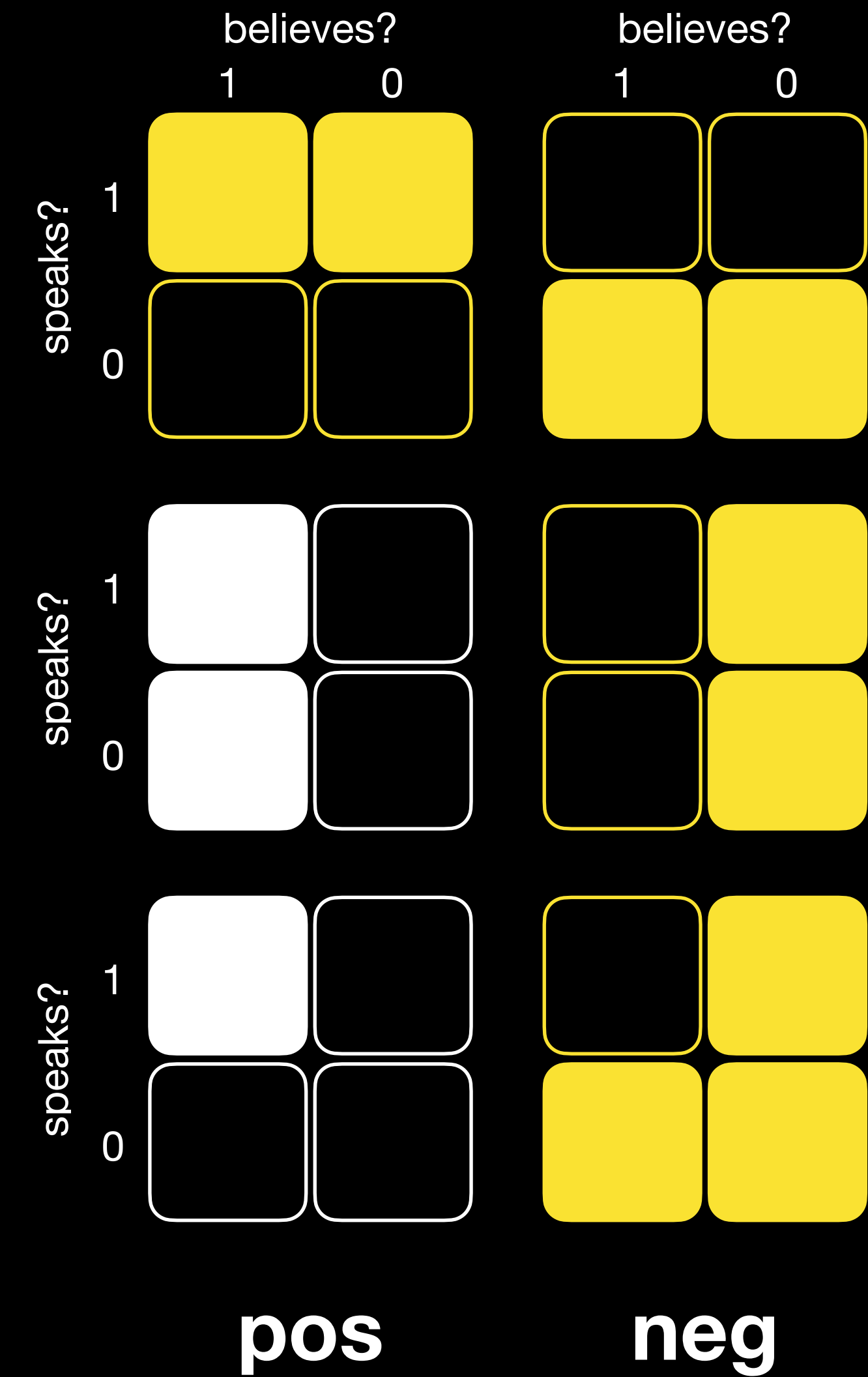
*neg-know* not particularly informative



**simple**

**think**

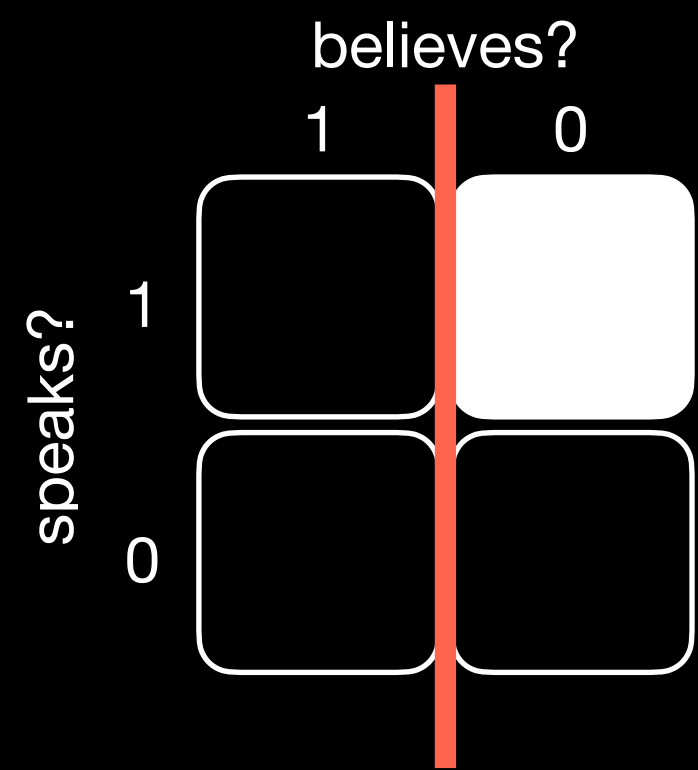
**know**



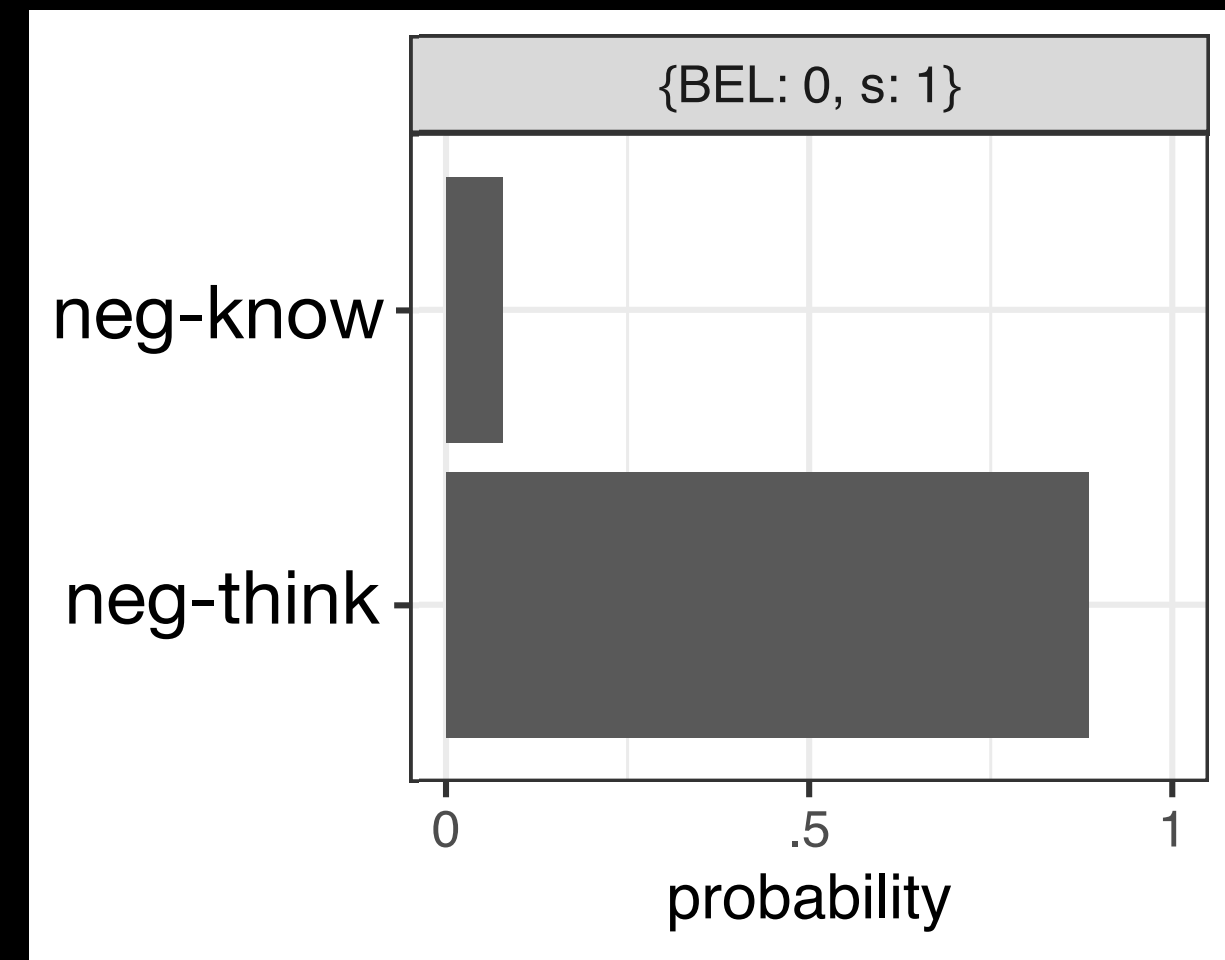
**does Cole believe?**

# speaker behavior

*neg-know* not particularly informative



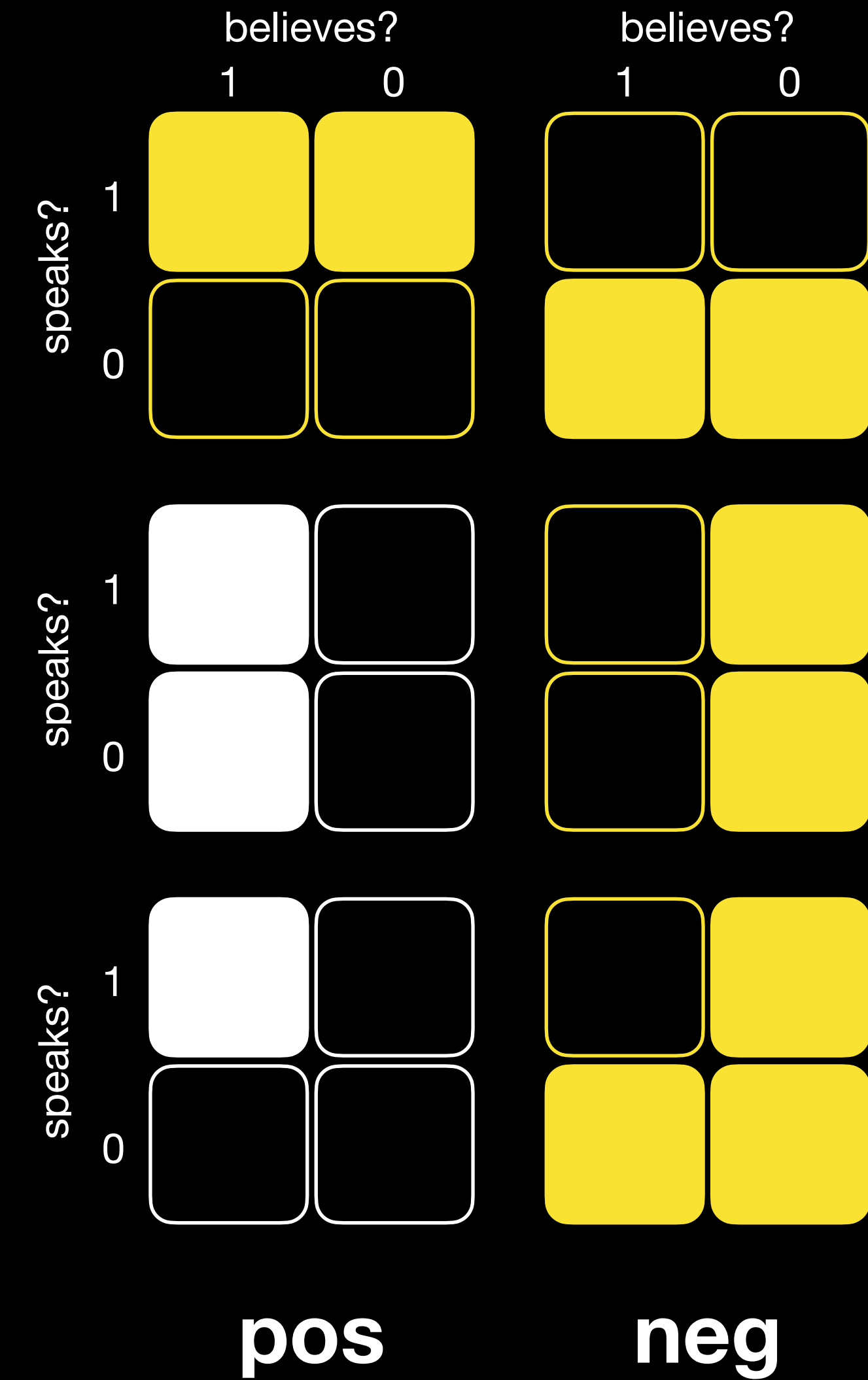
*does Cole believe?*



**simple**

***think***

***know***

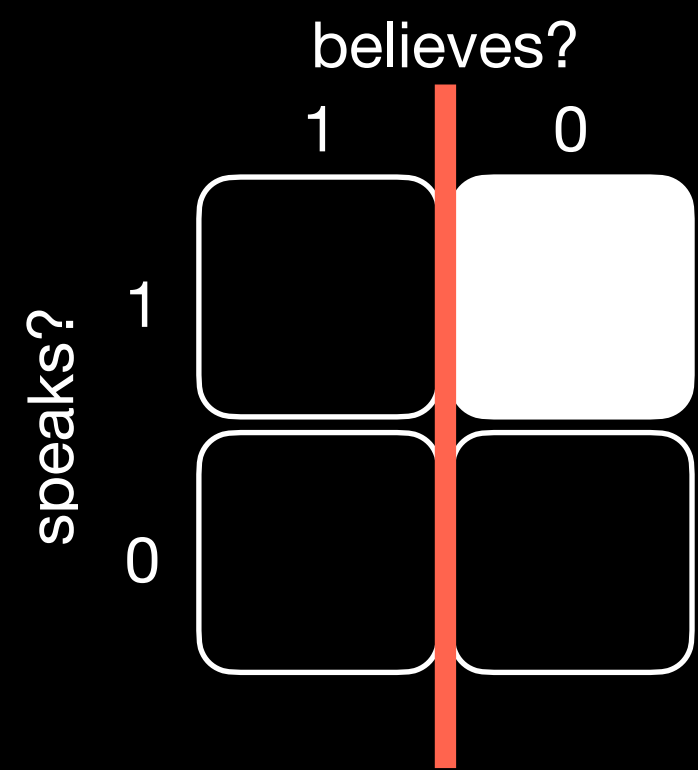


**pos**

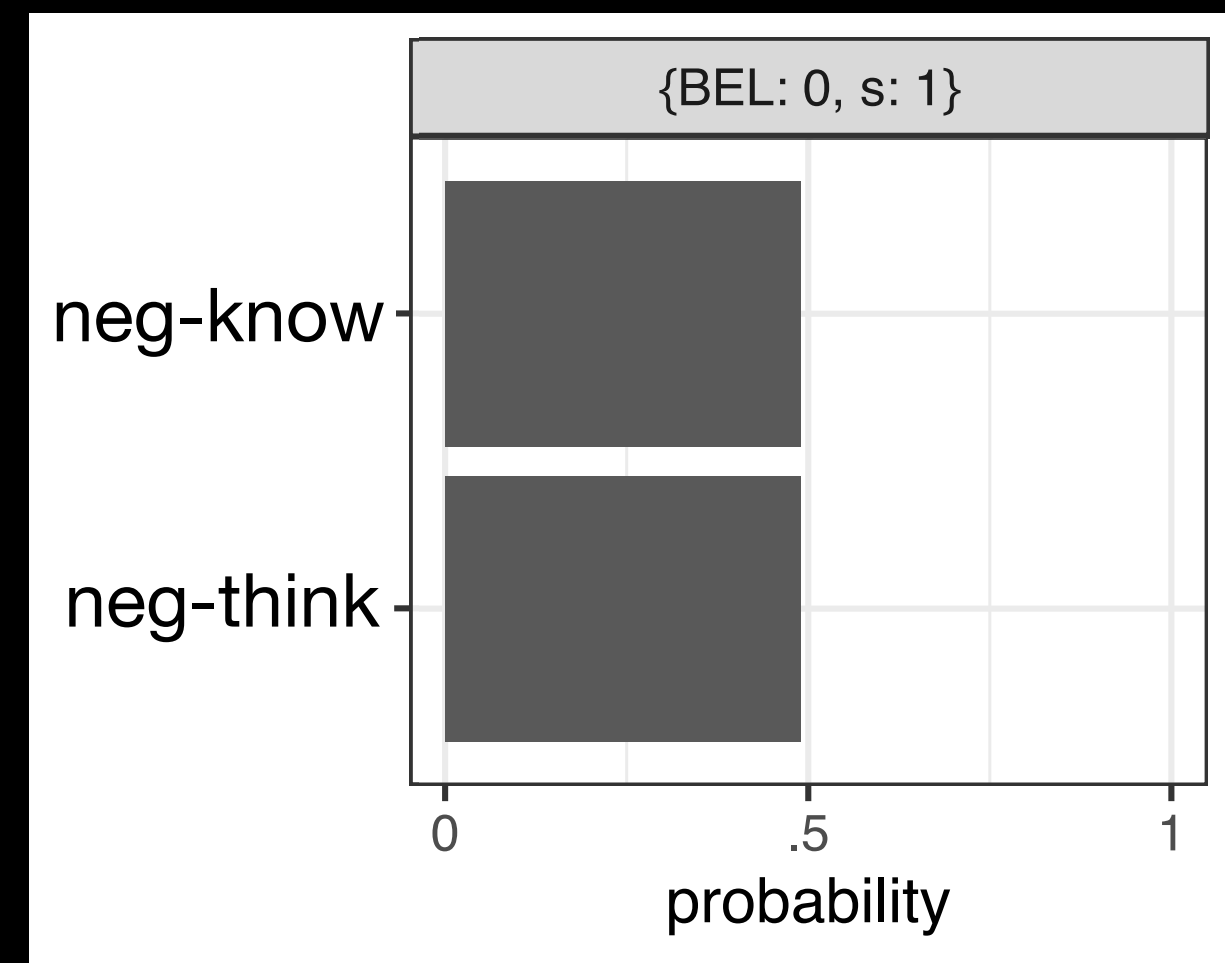
**neg**

# speaker behavior

*neg-know* is more informative if the speaker already assumes that Charley speaks Spanish



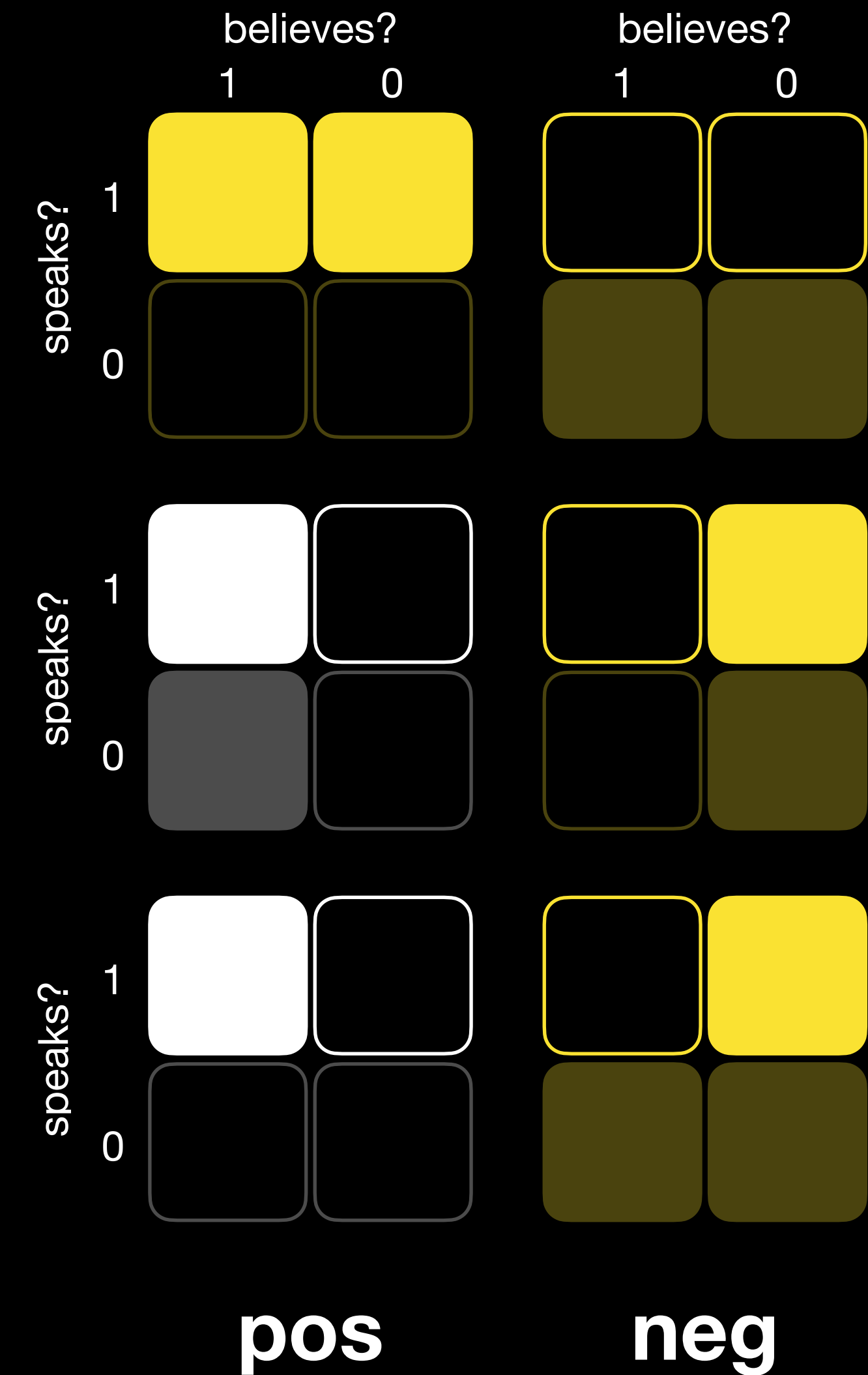
*does Cole believe?*



**simple**

***think***

***know***

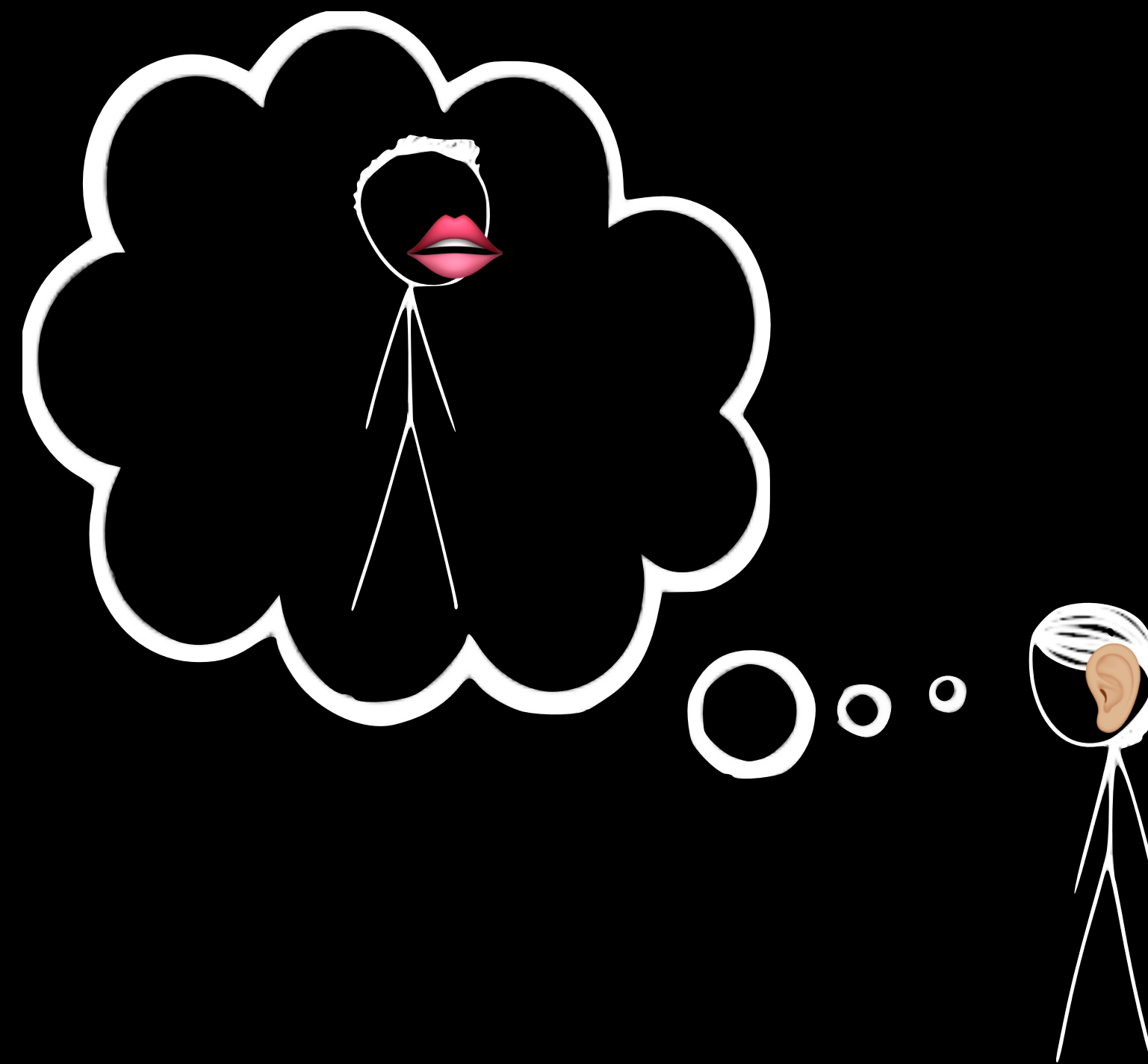


**pos**

**neg**

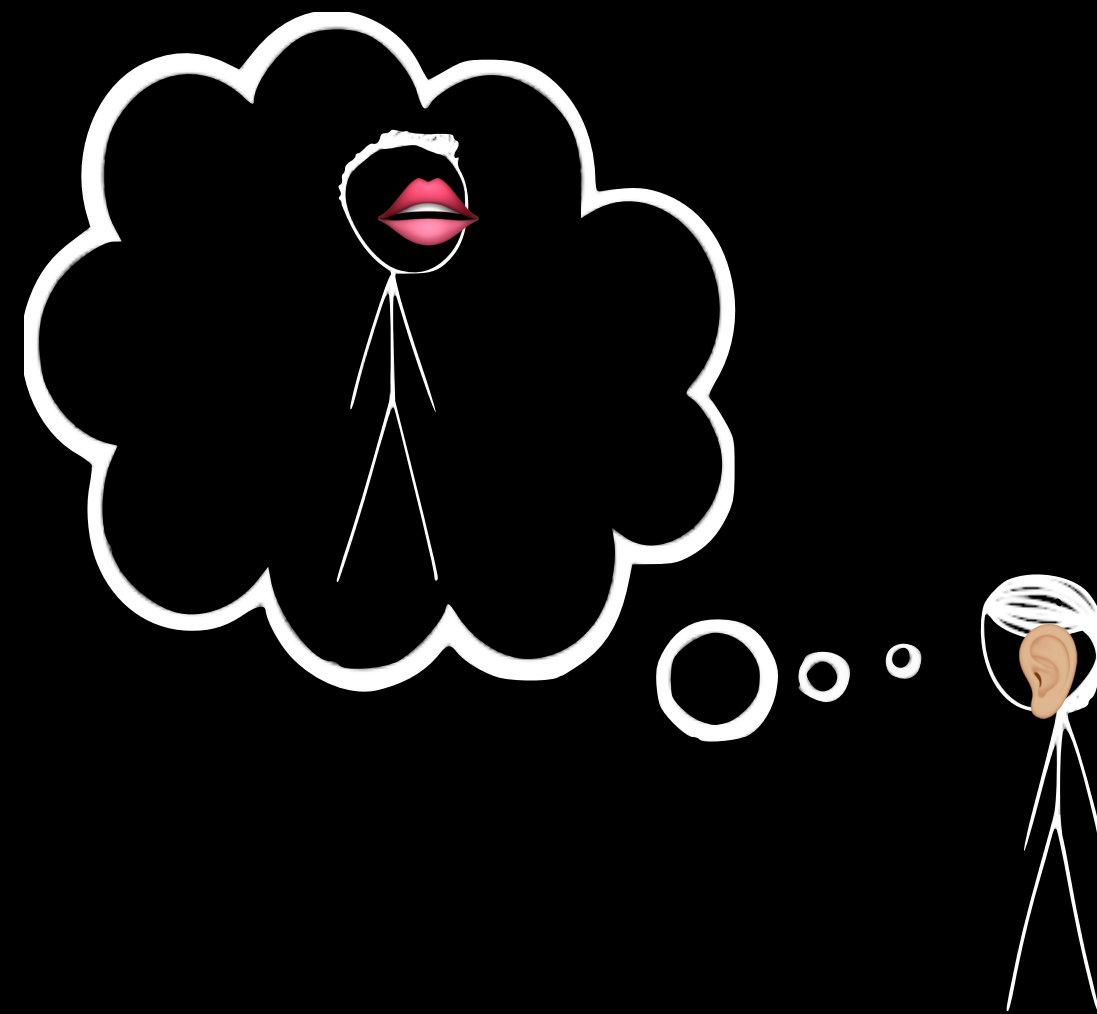
# basic model intuition

listeners interpret utterances by **reasoning about** what would have led **a speaker** to produce the utterance in the first place



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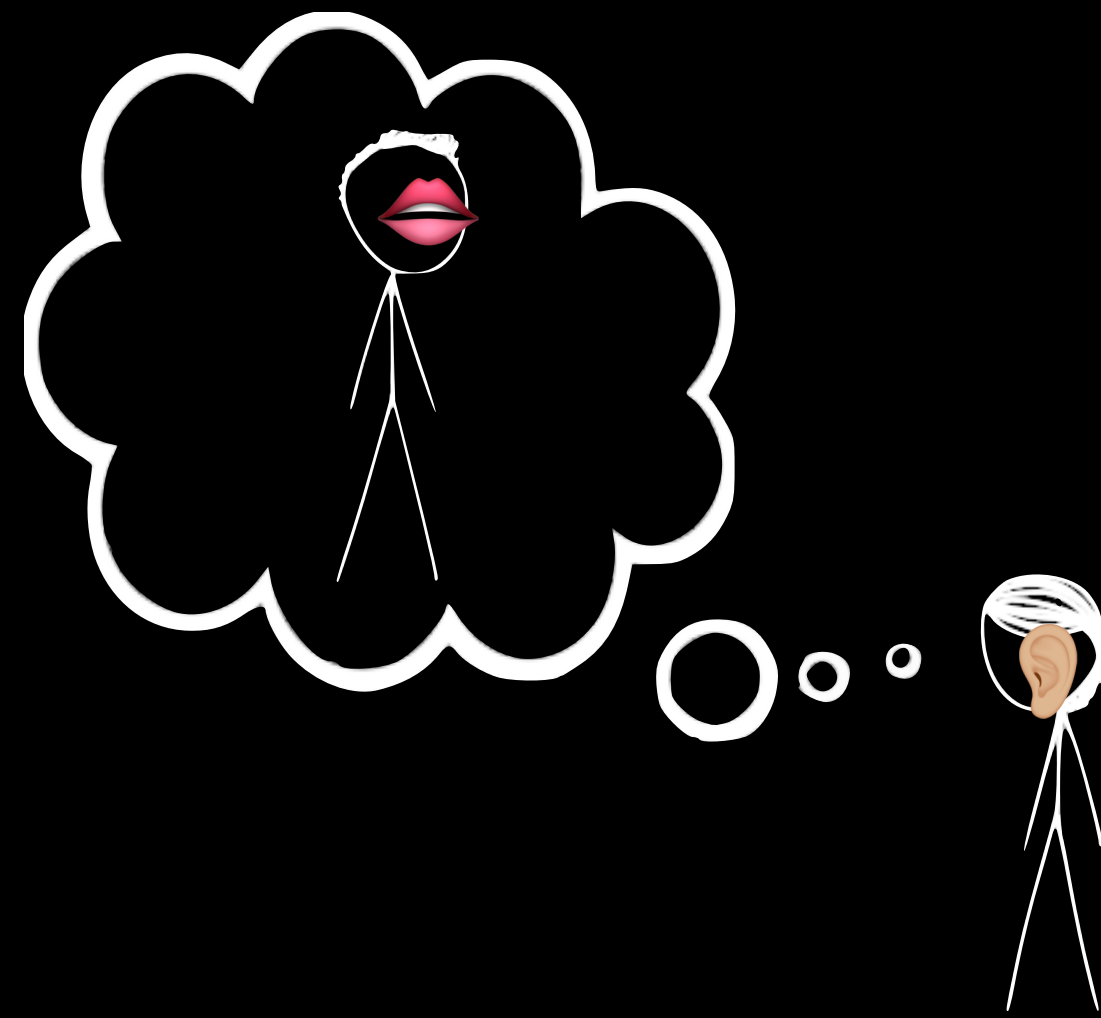


when the listener hears “Cole doesn’t know...” they are likely to infer that the speaker assumes that Charley speaks Spanish



# basic model intuition

listeners interpret utterances by **reasoning about** what would have led  
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**projection!!!**

when the listener hears “Cole doesn’t know...” they are likely to infer  
that the **speaker assumes that Charley speaks Spanish**

Cole doesn't *think/know* that Charley speaks Spanish.

→ Charley speaks Spanish

empirical targets

*know* projects more than *think*

(e.g., Kiparsky & Kiparsky 1970; Degen & Tonhauser 2022)

**prior beliefs** modulate projection

(e.g., Mahler 2020, 2022; Degen & Tonhauser 2021)

**QUDs** modulate projection

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## testing the empirical targets

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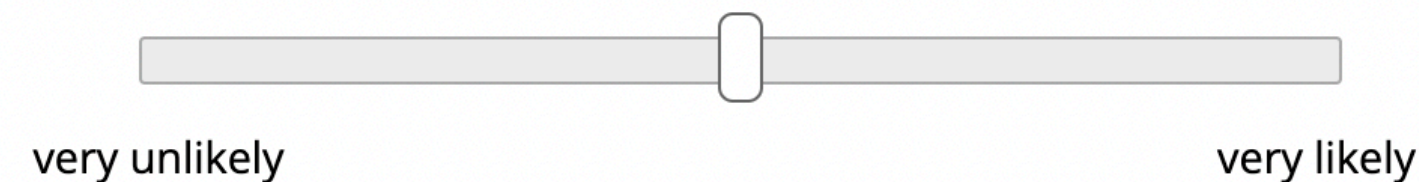
# experiment 1

n=833

Please read this text:

**Sue runs a company that connects language learners with remote teachers who live all over the world. She's trying to figure out how well her assistant, Cole, knows her remote teachers. Sue's business partner tells her what Cole said about Charley, who lives in Korea: *"Cole knows that Charley speaks Spanish."***

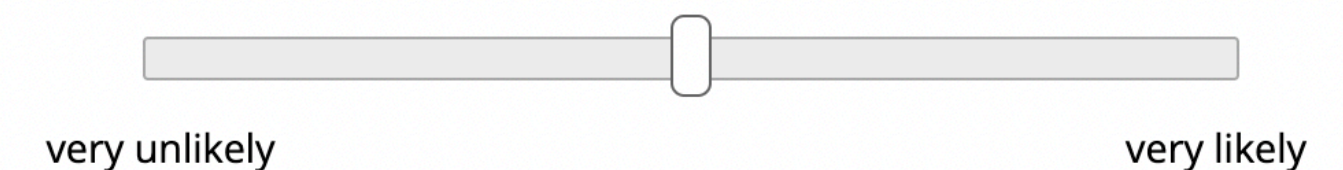
Given what you have read above, how likely is it that Charley speaks Spanish?



Please read this text:

**Sue runs a company that connects language learners with remote teachers who live all over the world. She's putting together a list of the languages spoken by the remote teachers. After consulting her assistant, Cole, who knows the teachers and the languages they speak better than she does, Sue is currently working through the list of teachers to identify who speaks Spanish. When she gets to Charley, who lives in Mexico, Sue says to her business partner: *"Cole doesn't think that Charley speaks Spanish."***

Given what you have read above, how likely is it that Charley speaks Spanish?



read a story context, rate the probability of target content



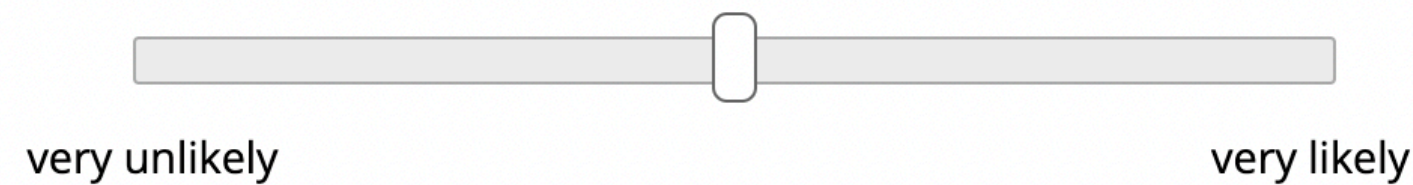
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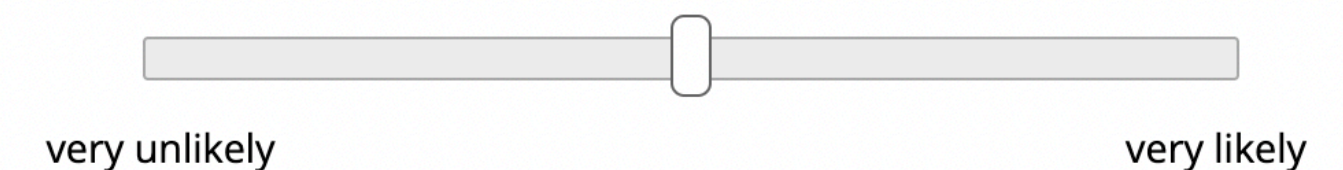
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prior manipulation



# experiment 2

n=333

Sue runs a language school. She's trying to figure out how well her five assistants Kate, Tom, Cole, Tatiana, and Riccardo know her remote teacher Charley. Sue keeps track on this list:

Assistants	Believes that Charley speaks Spanish?
Kate	yes
Tom	no
Cole	
Tatiana	
Riccardo	

Next up, she wants to record in her list whether **COLE** believes that Charley speaks Spanish. Her business partner tells her: "*Cole thinks that Charley speaks Spanish.*"

Given what you have read above, how likely is it that Charley speaks Spanish?



very unlikely

very likely

Sue runs a language school. She's currently working through a list of her teachers — Kate, Tom, Charley, Tatiana, and Riccardo — to identify who speaks Spanish. She occasionally consults Cole, who knows some teachers better. Sue keeps track on this list:

Teachers	Speaks Spanish?
Kate	yes
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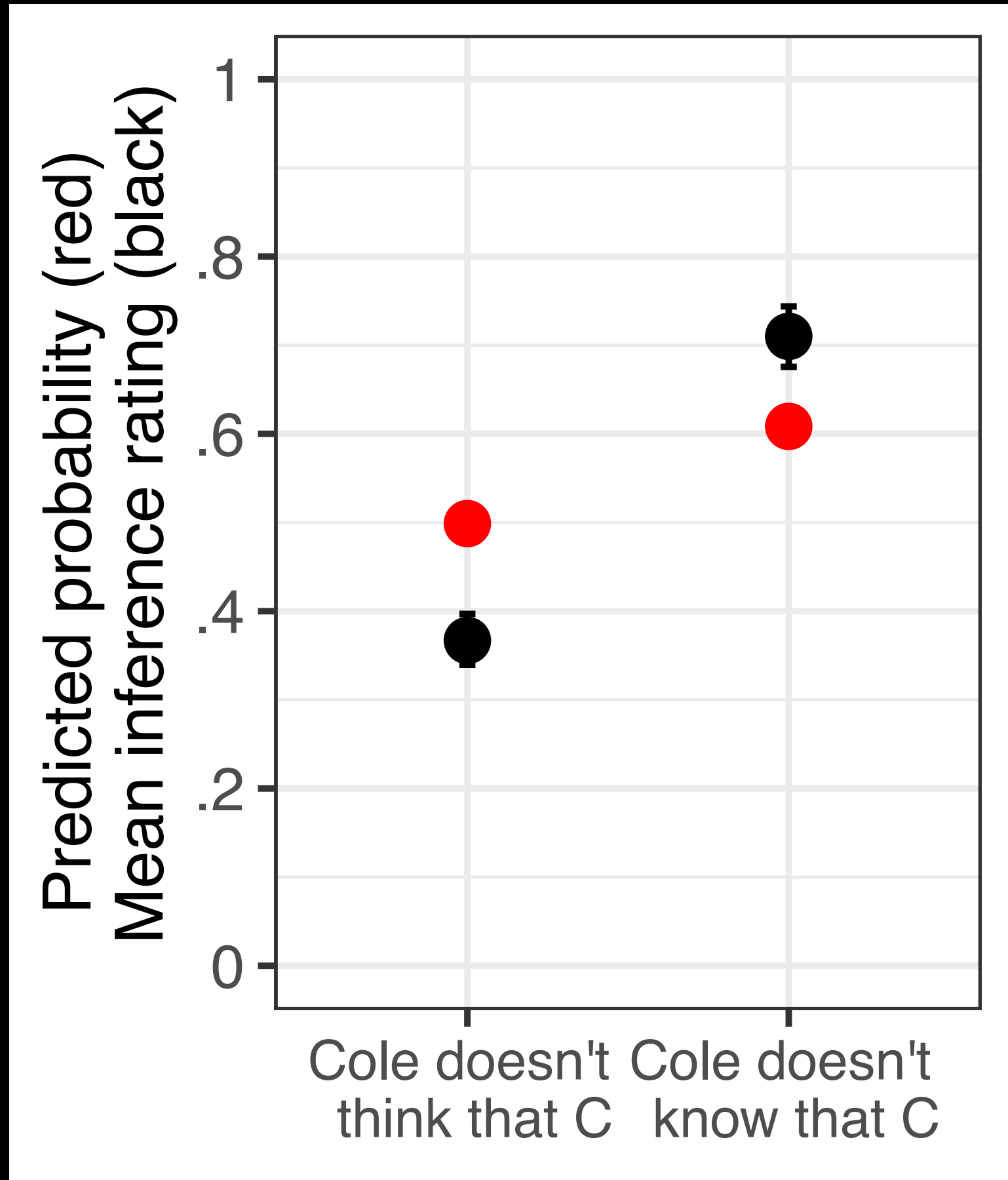
very unlikely

very likely

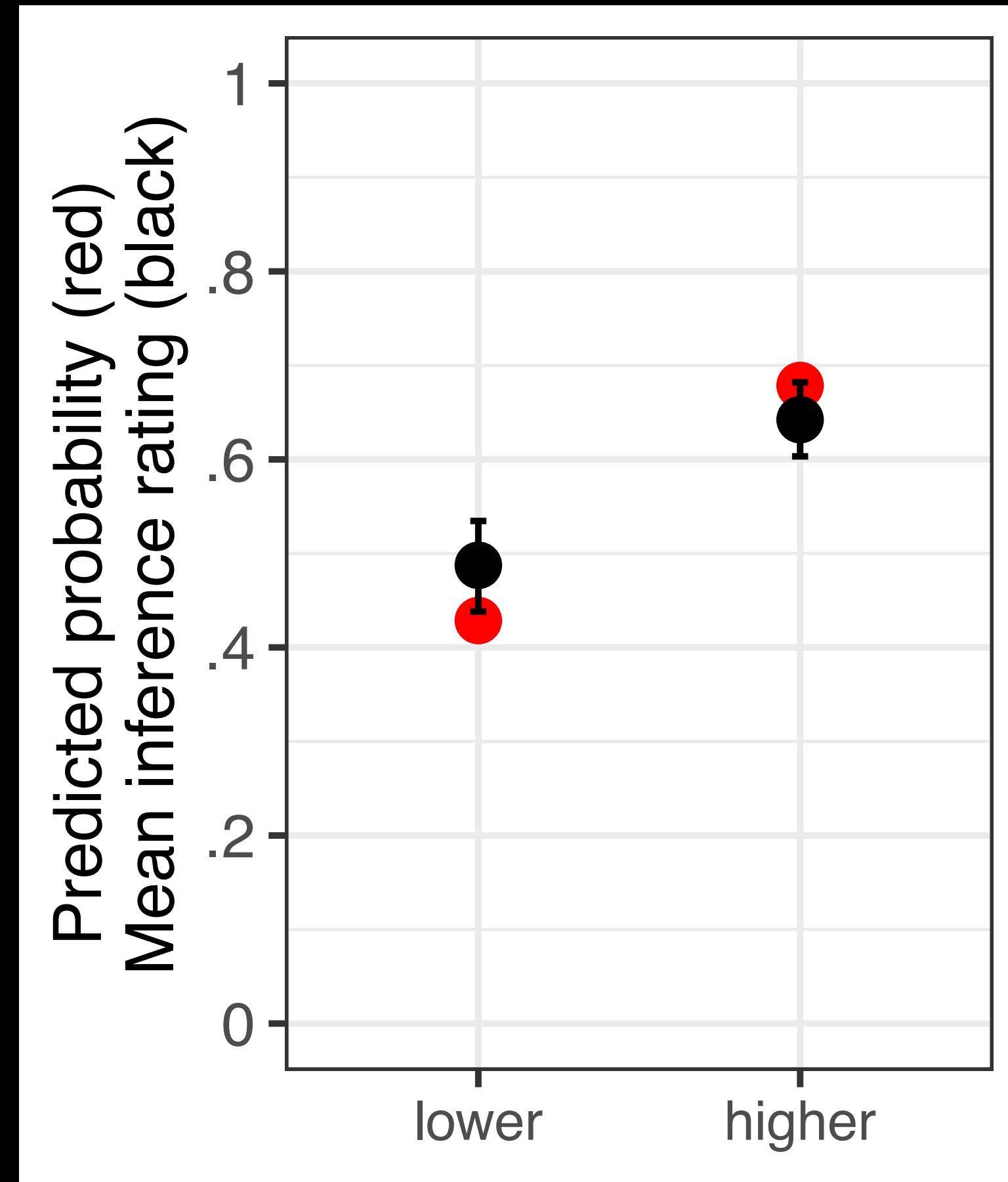
QUD manipulation



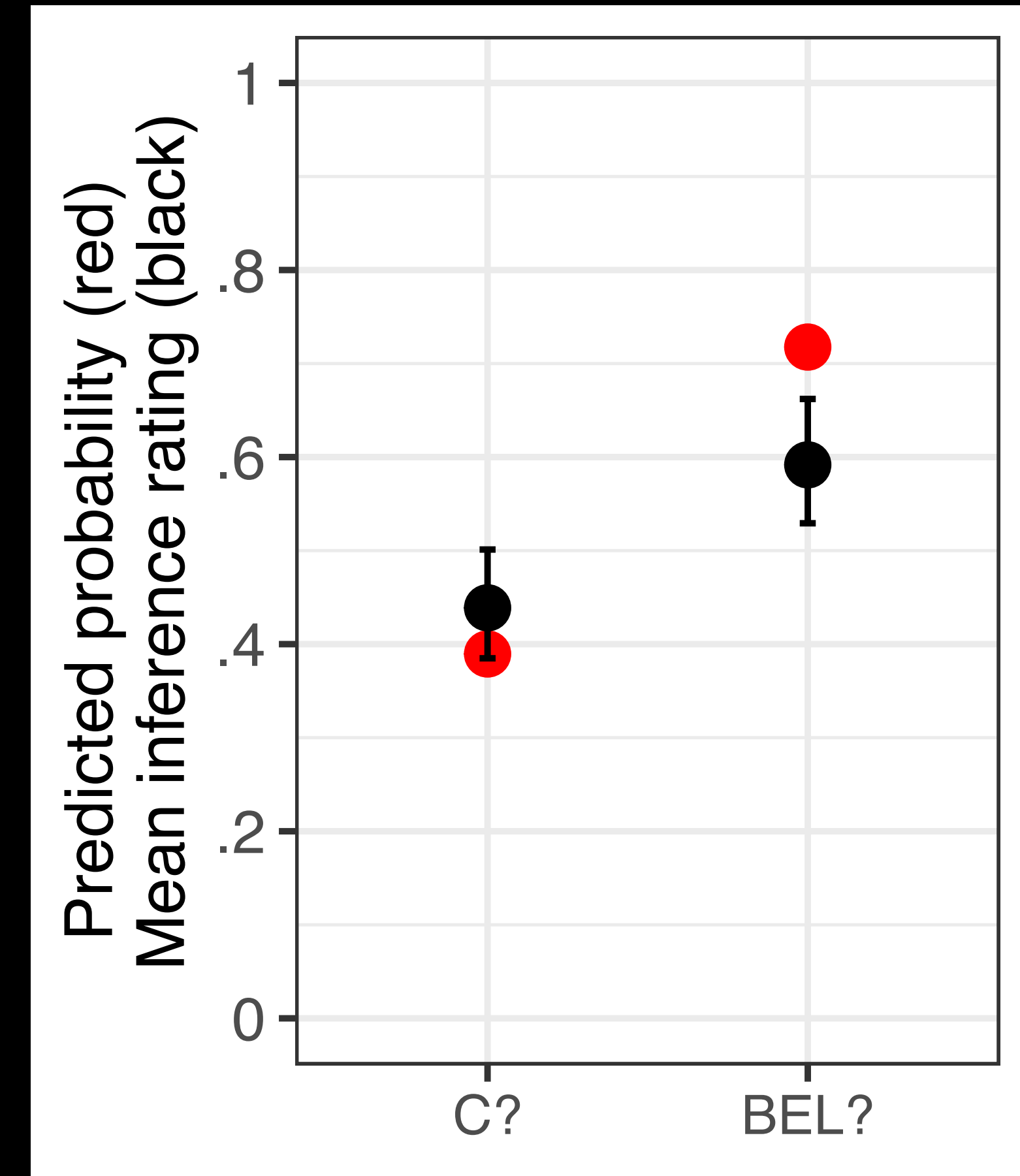
# model predictions and human data



*know* projects more than *think*



priors beliefs modulate projection



QUDs modulate projection

Cole doesn't *think/know* that Charley speaks Spanish.

empirical targets

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Cole doesn't *think/know* that Charley speaks Spanish.

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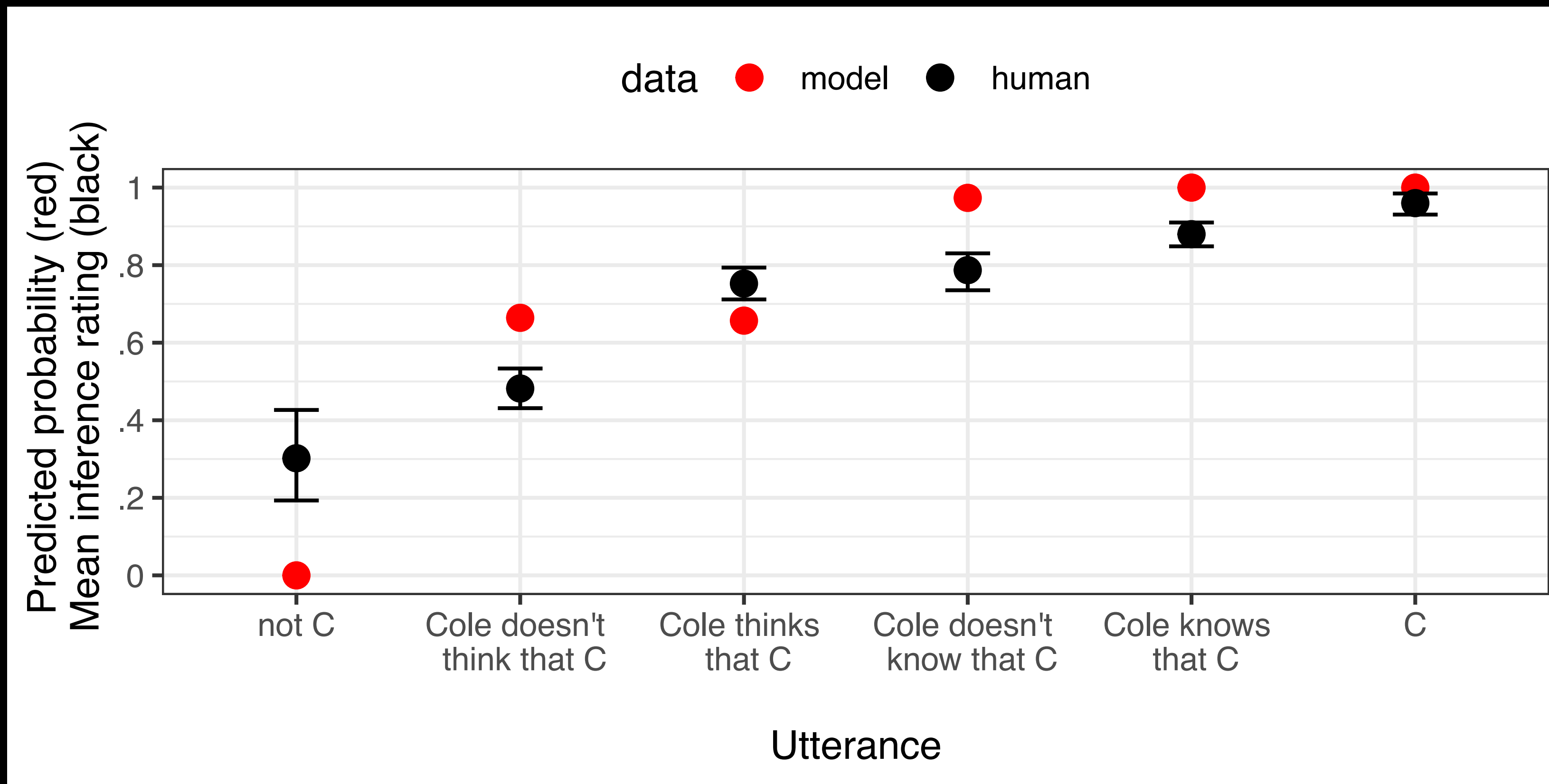
	Heim 1983 vd Sandt 1992	Djärv & Bacovcin 2020	Abrusán 2011 Simons et al 2017	Schlenker 2021	Our analysis
<i>know</i> projects more than <i>think</i>	✓	✓	✓	✓	✓
prior beliefs modulate projection	✗	✗	✗	✓	✓
QUDs modulate projection	✗	✓	✓	✗	✓



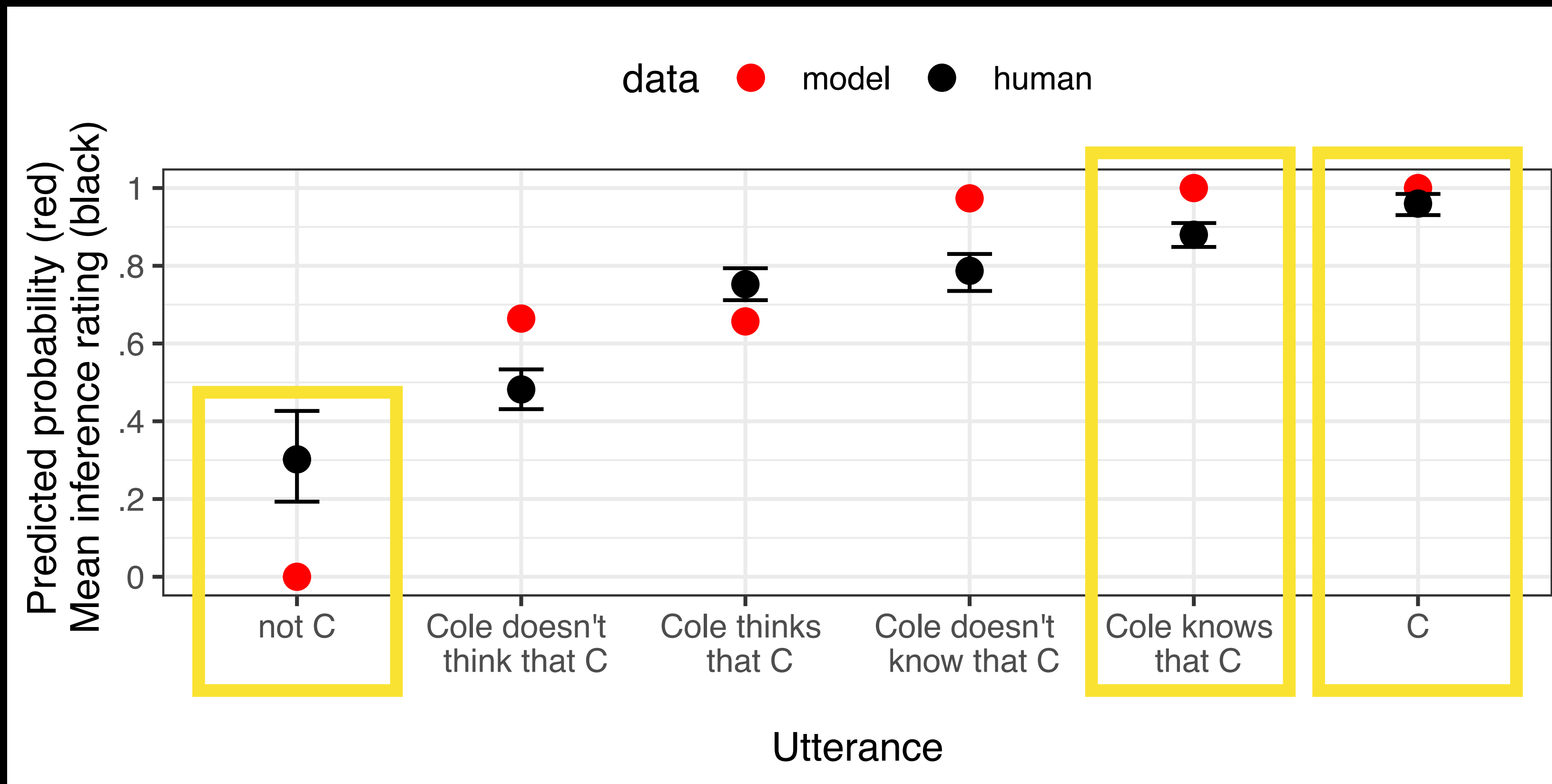


instead of developing analyses tailored to informative presuppositions,  
we **can** and **should** develop more general analyses that make predictions about  
inferences drawn from utterances

informative presuppositions are just one kind of inference

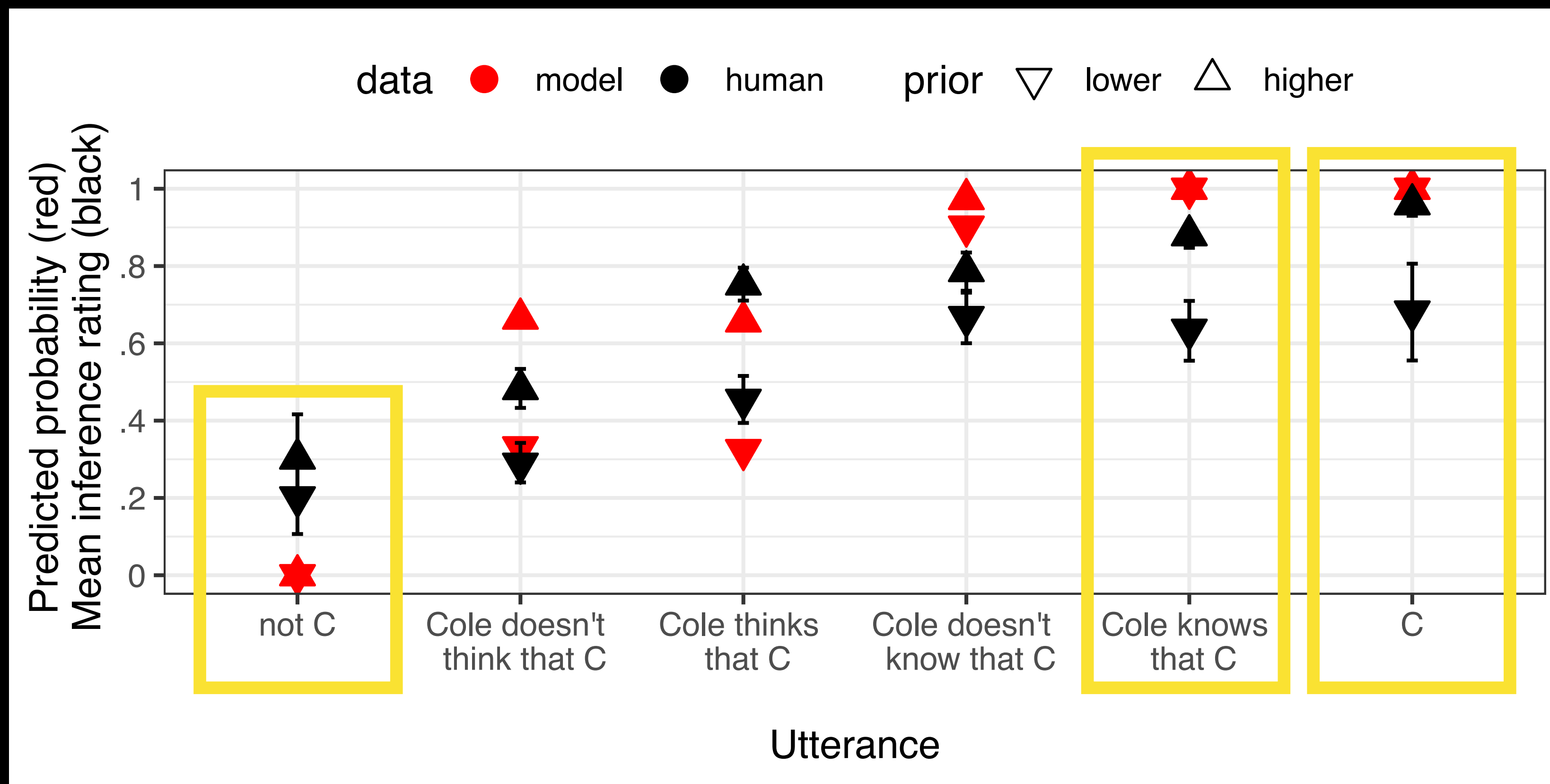


informative presuppositions are just one kind of inference

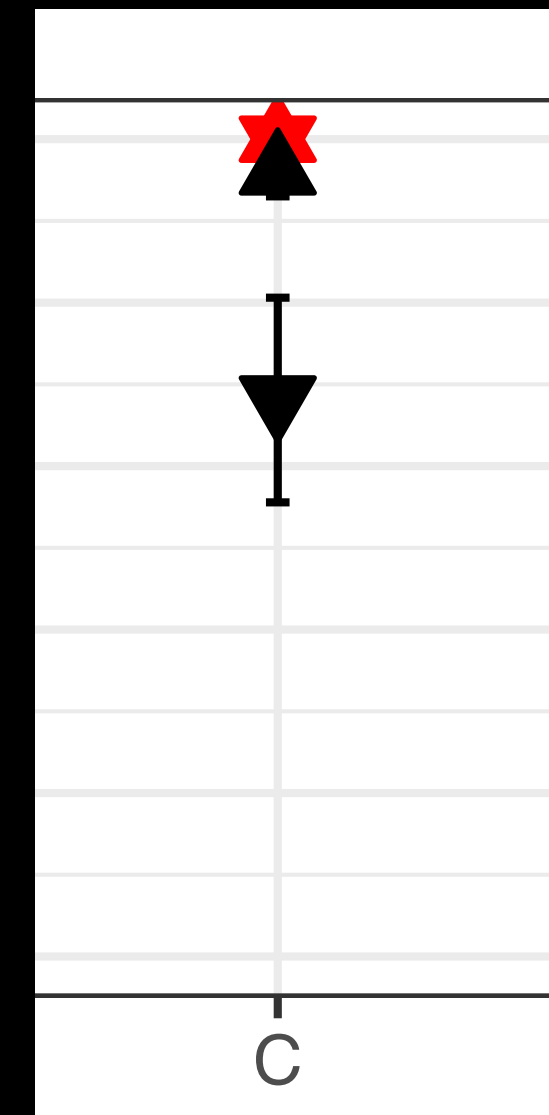


**problem:** too much reliance on literal semantics

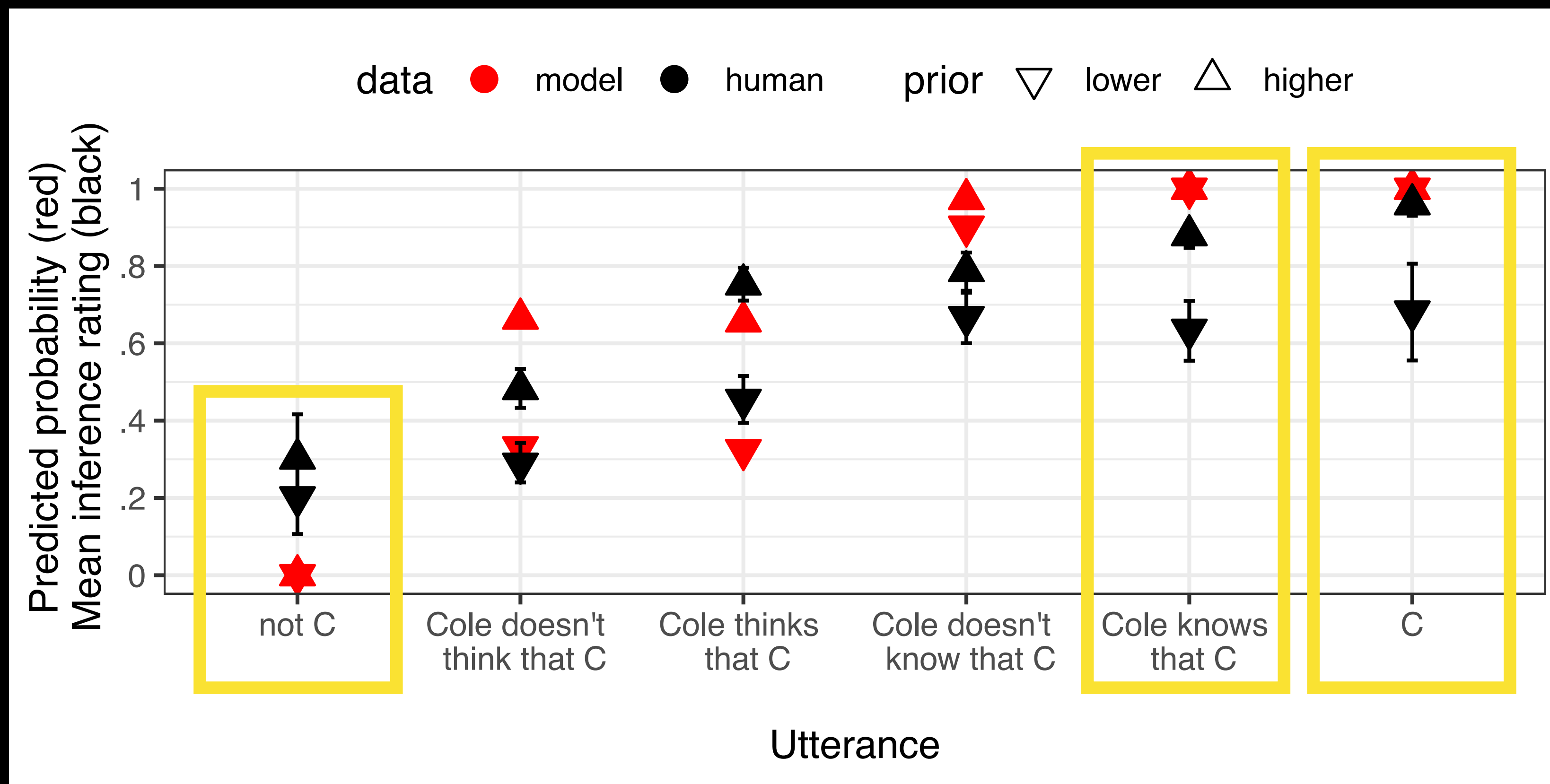




**problem: no sensitivity to the prior**



**problem:** no sensitivity to the prior



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we need to relax the predictions of the model





**we need to relax the predictions of the model**

option 1  
relax the semantics

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**option 1**  
**relax the semantics**

**option 2**  
**relax the speaker**

**we need to relax the predictions of the model**

option 1  
relax the semantics

option 2  
relax the speaker

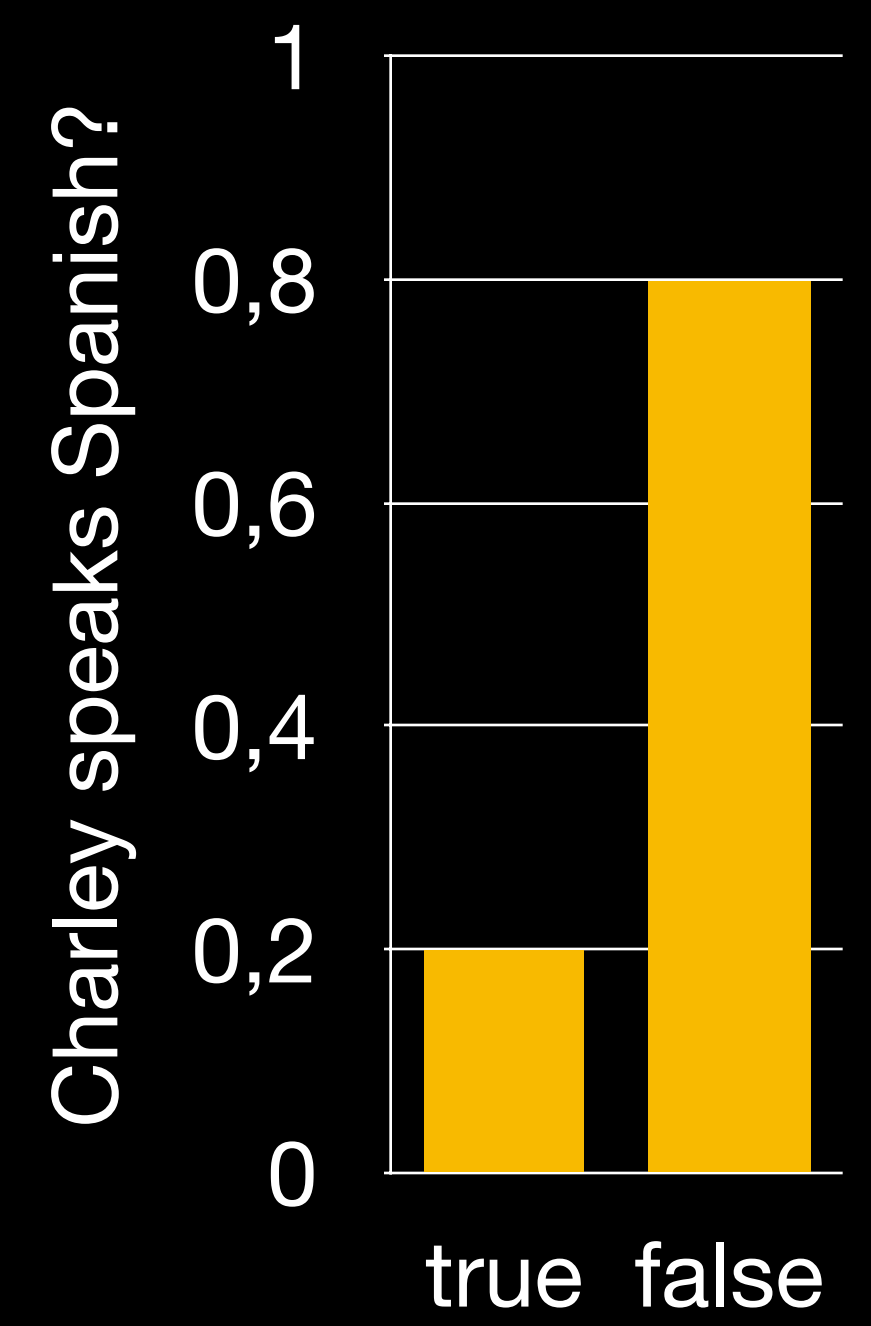
option 3  
relax the listener



relax the listener

**fact:**  
Charley lives in Korea

prior belief



relax the listener

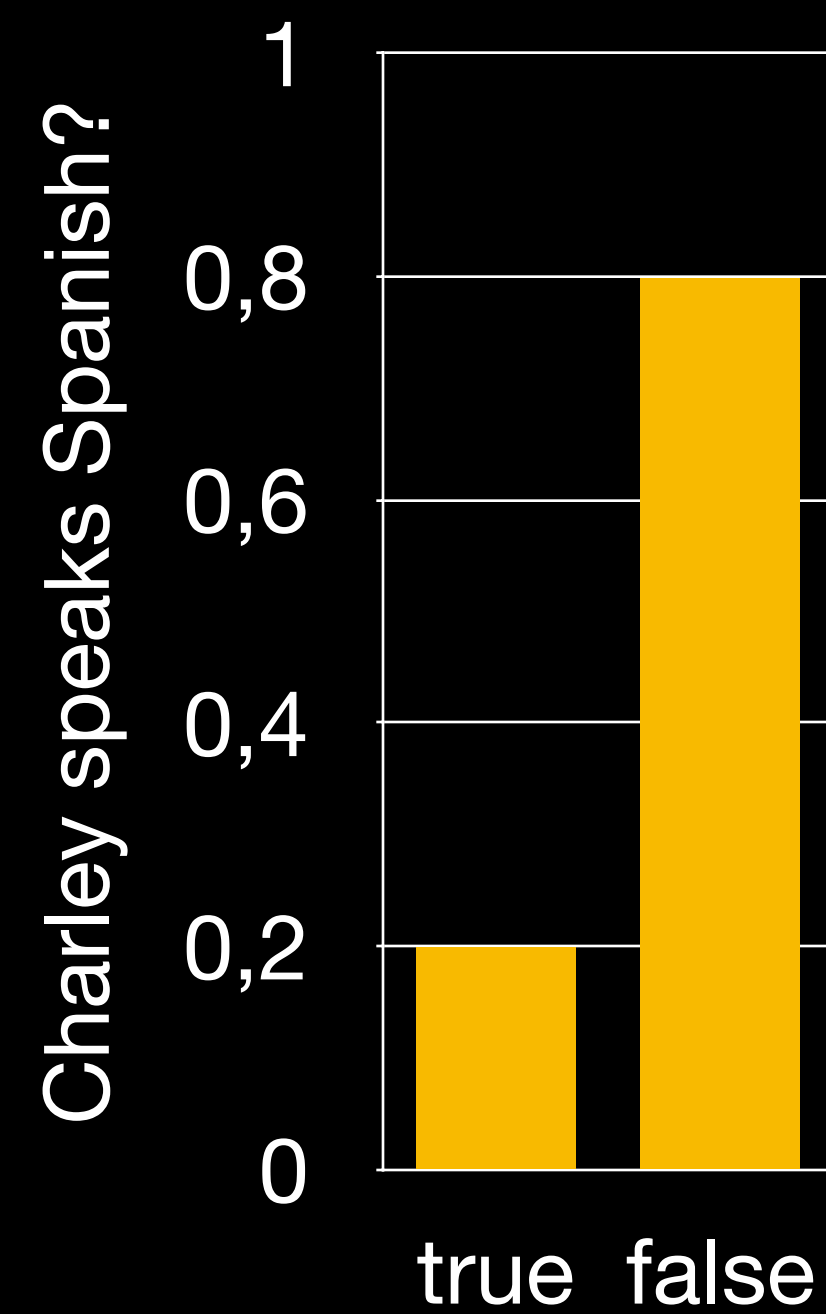
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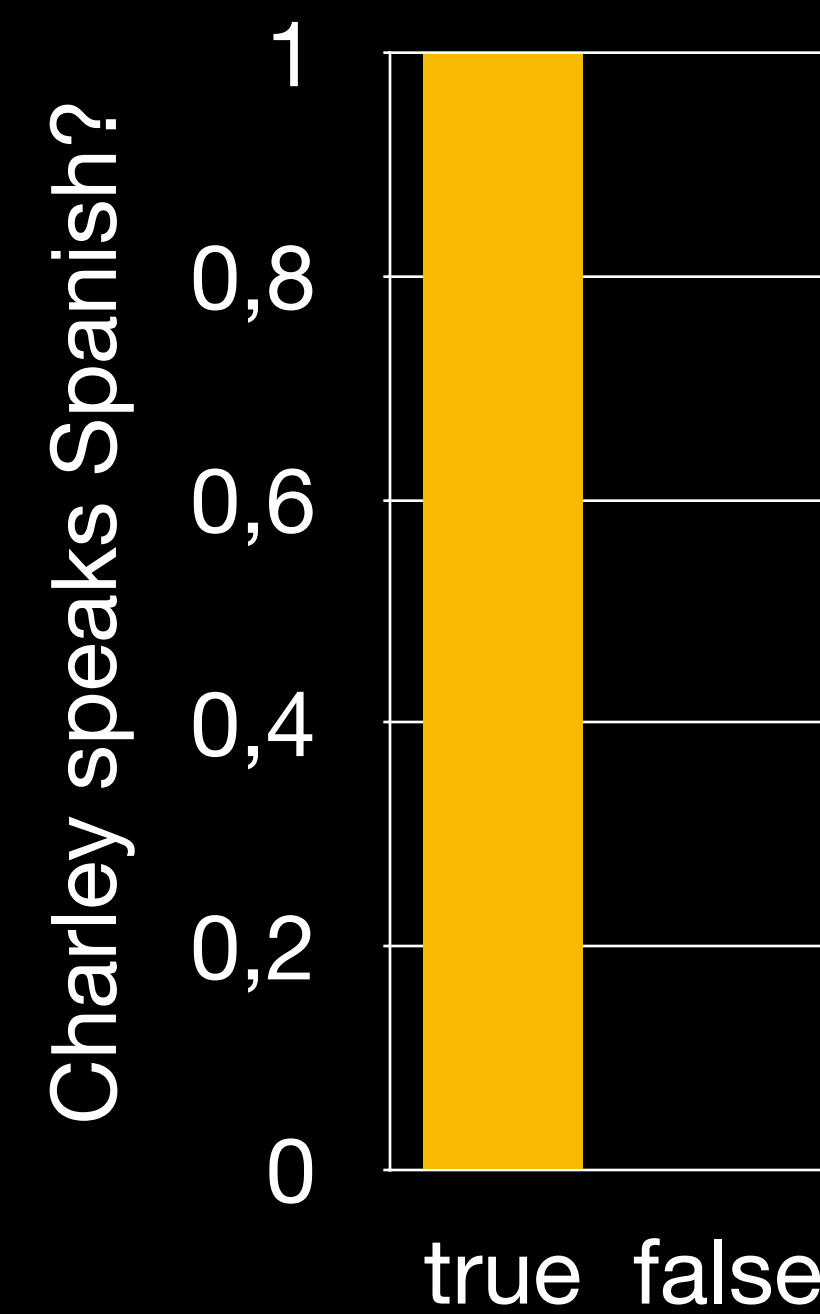
**utterance:**

“Charley speaks Spanish.”

prior belief



posterior inference

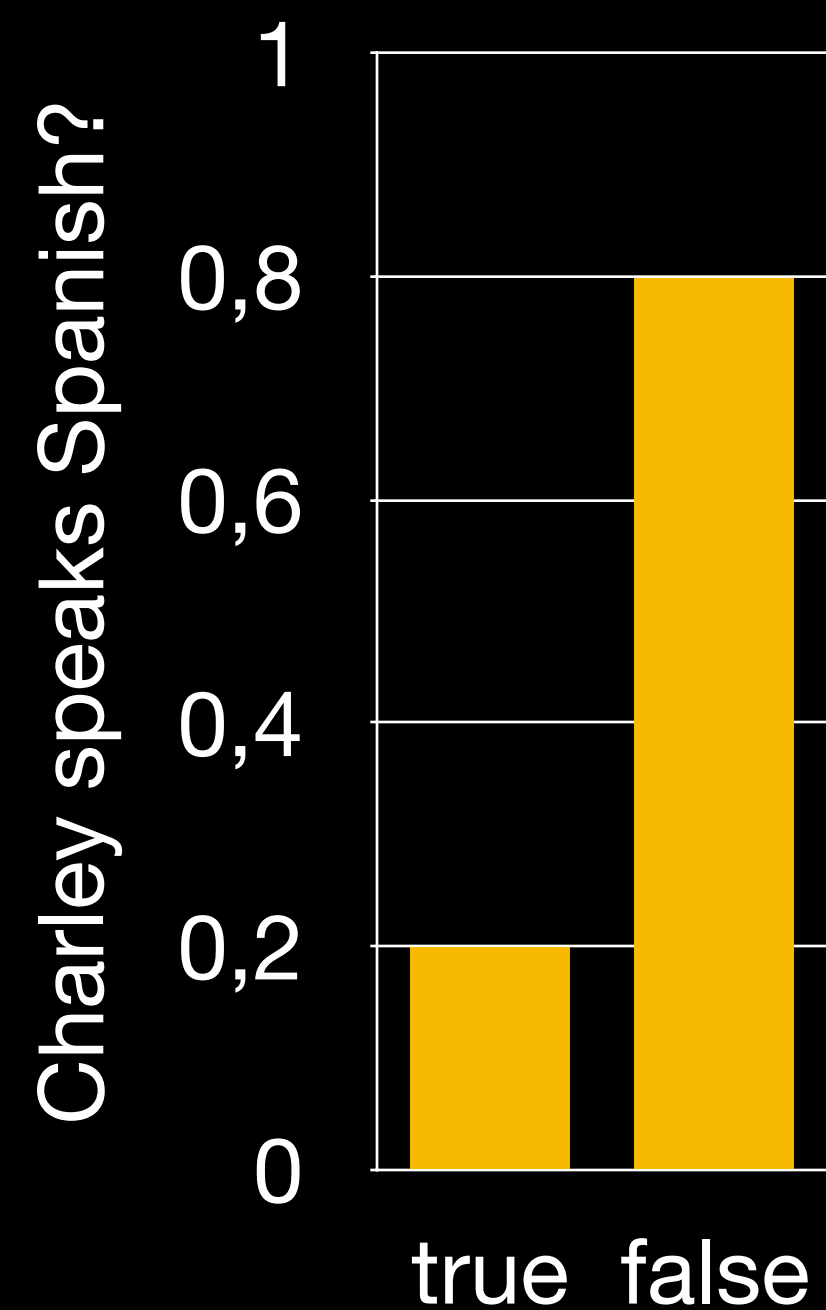


relax the listener

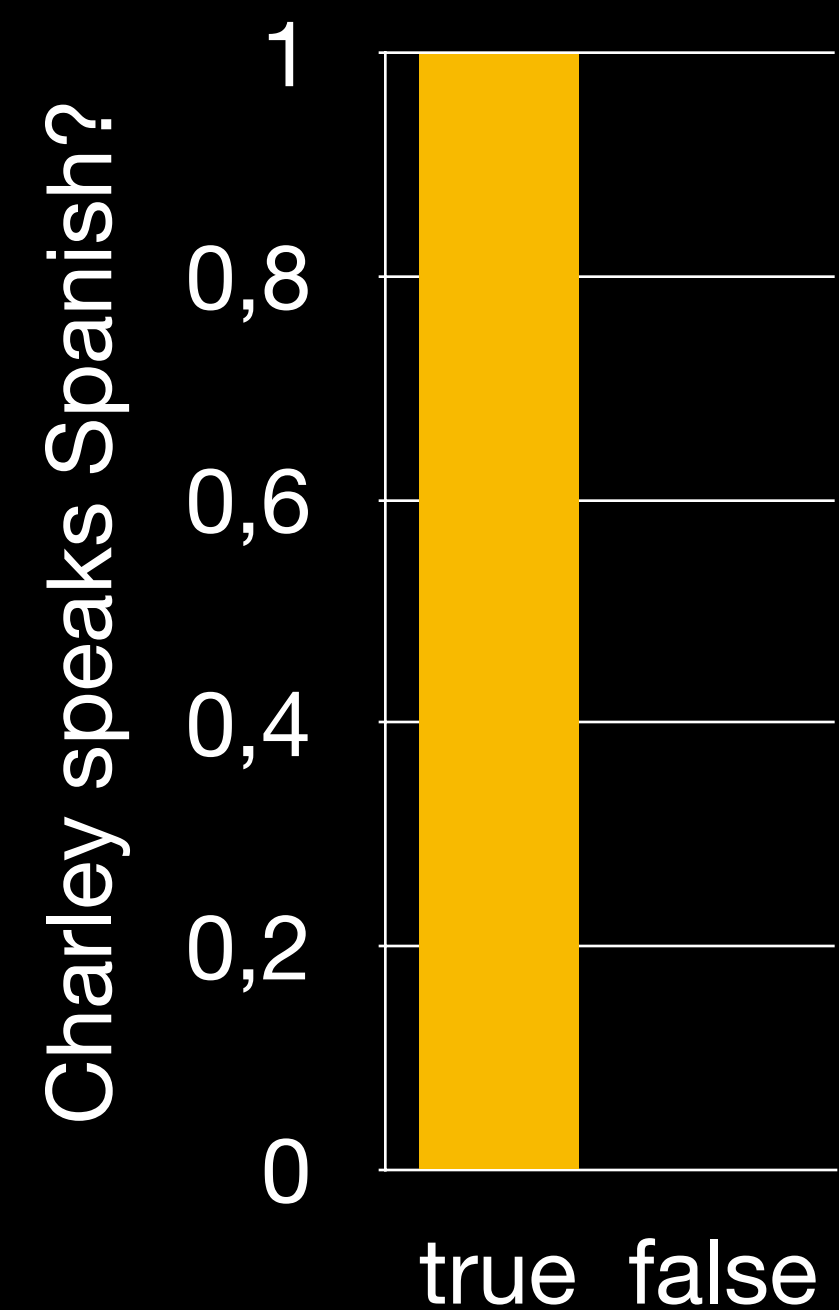
**fact:**  
Charley lives in Korea

**utterance:**  
“Charley speaks Spanish.”

prior belief



posterior inference



← Kullback-Leibler (KL) divergence →

↓

probability with which the listener returns a sample from their prior

# relax the listener

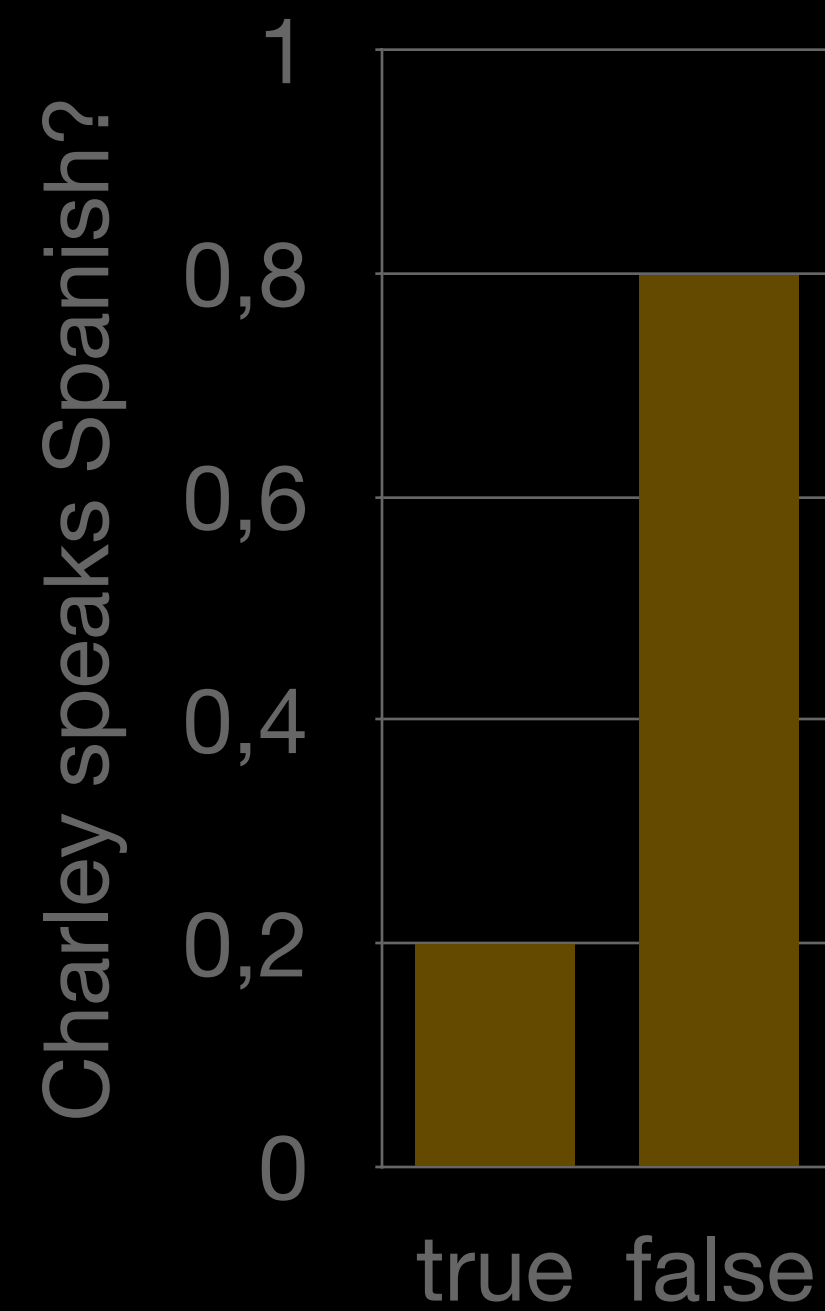
**fact:**

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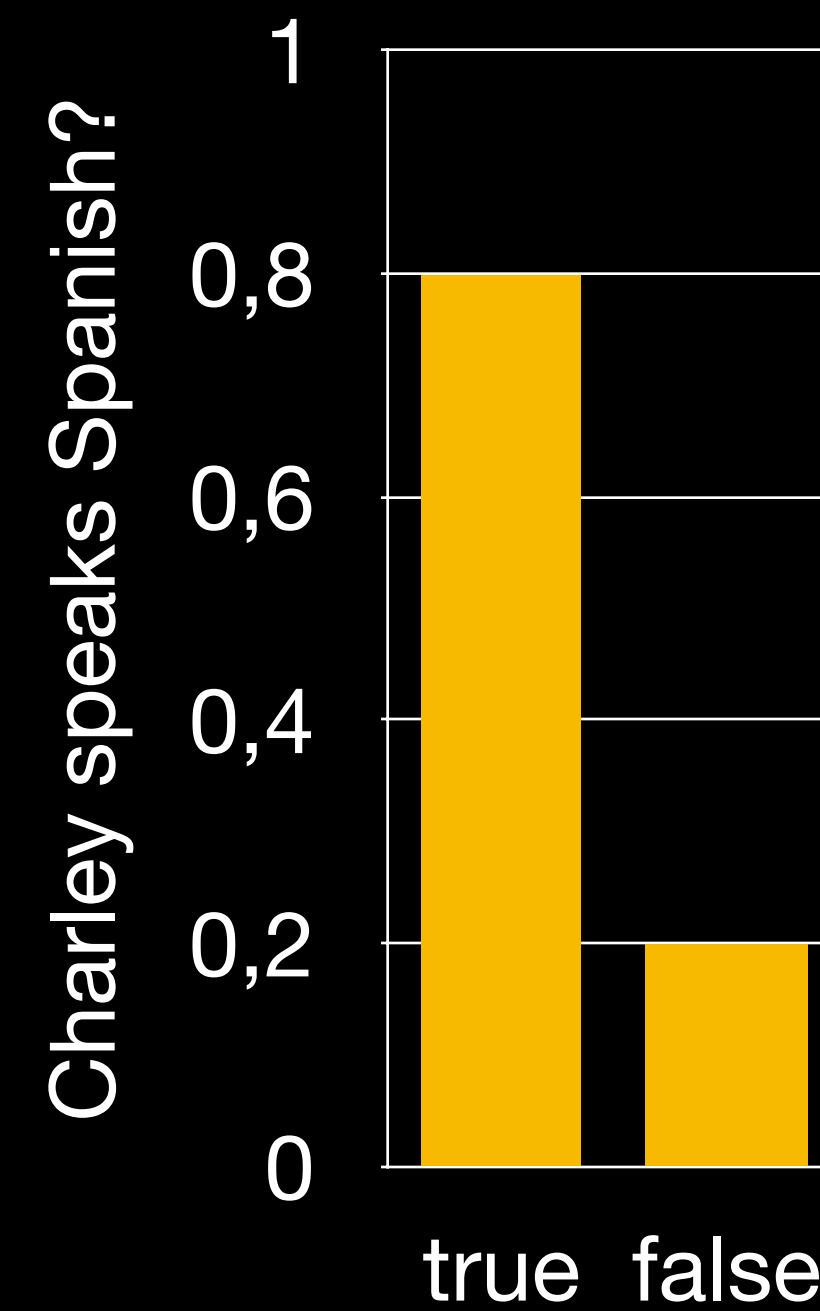
**utterance:**

“Charley speaks Spanish.”

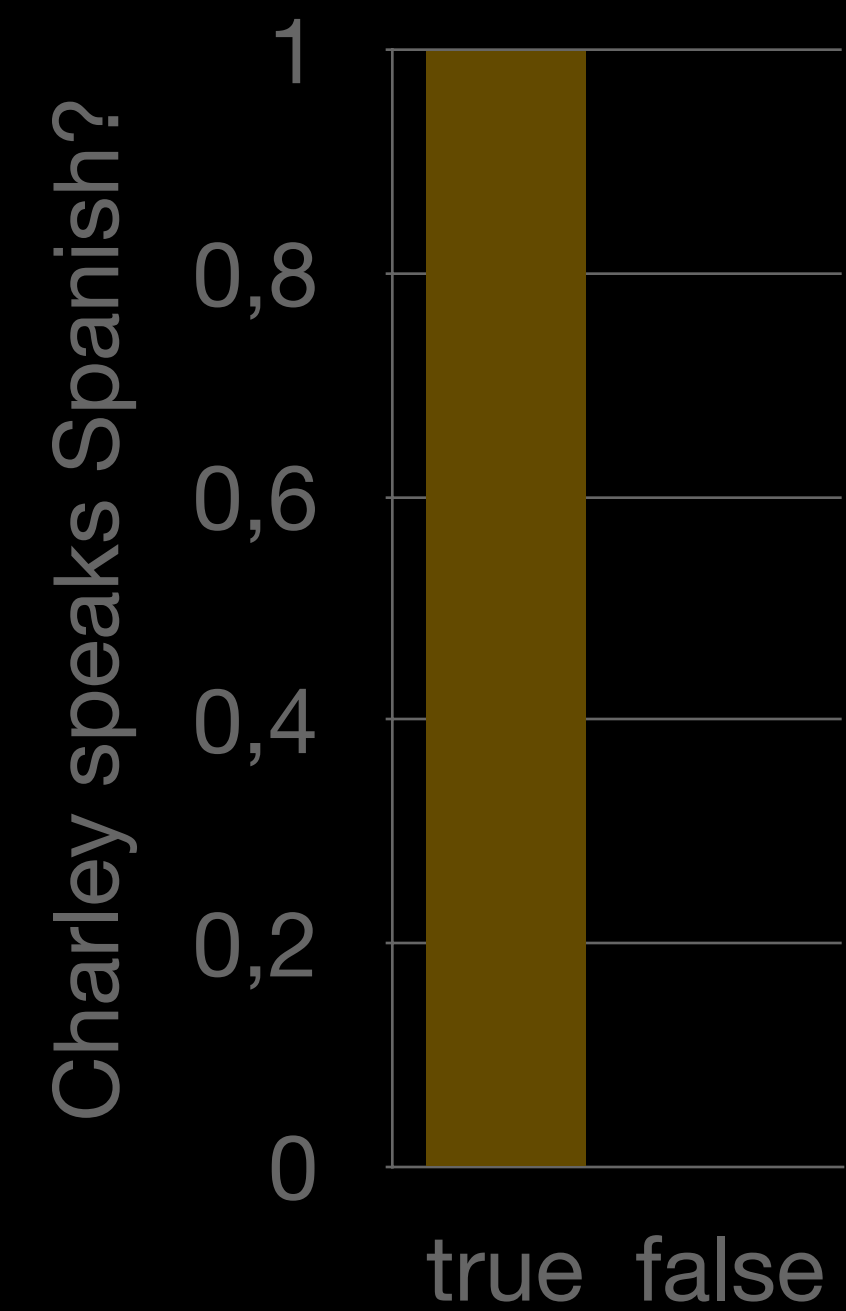
prior belief



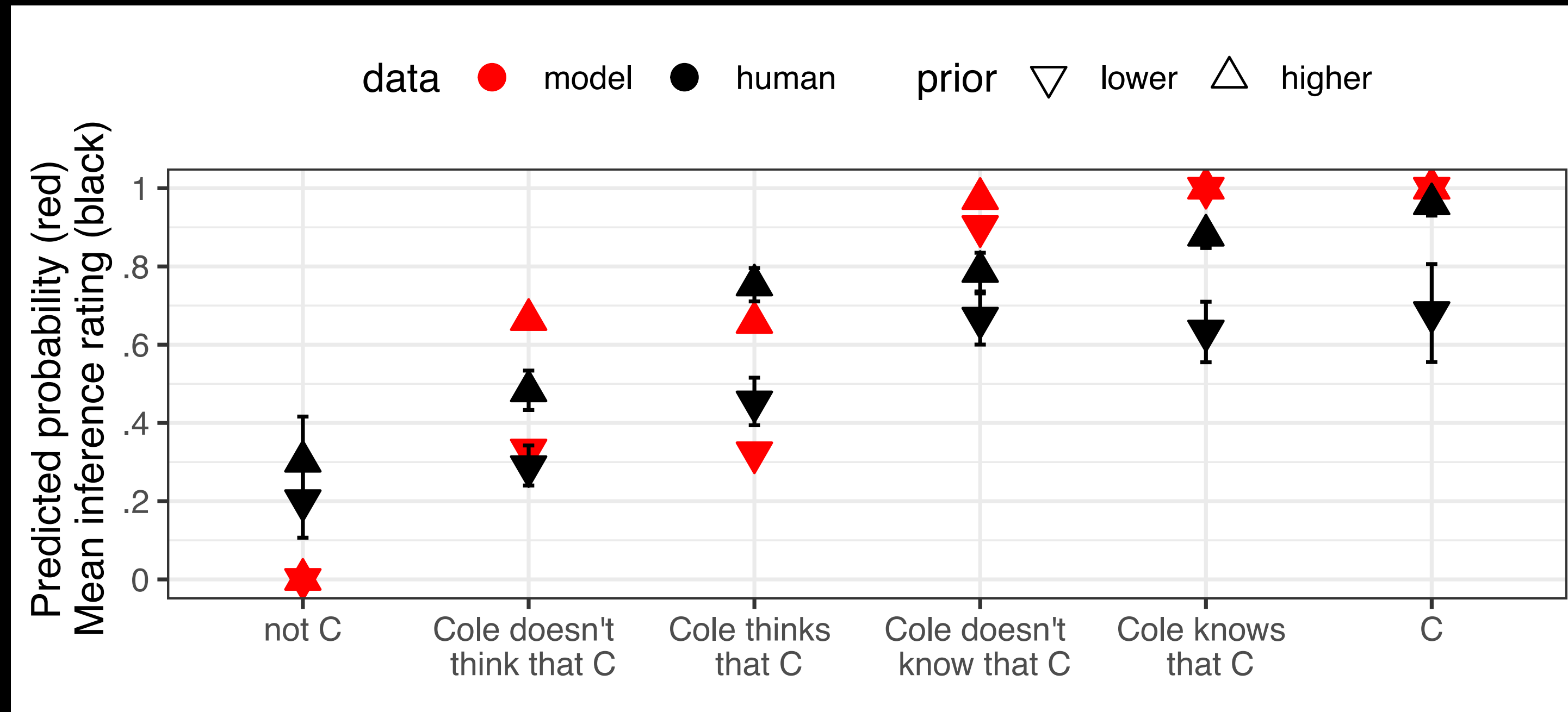
ultimate belief



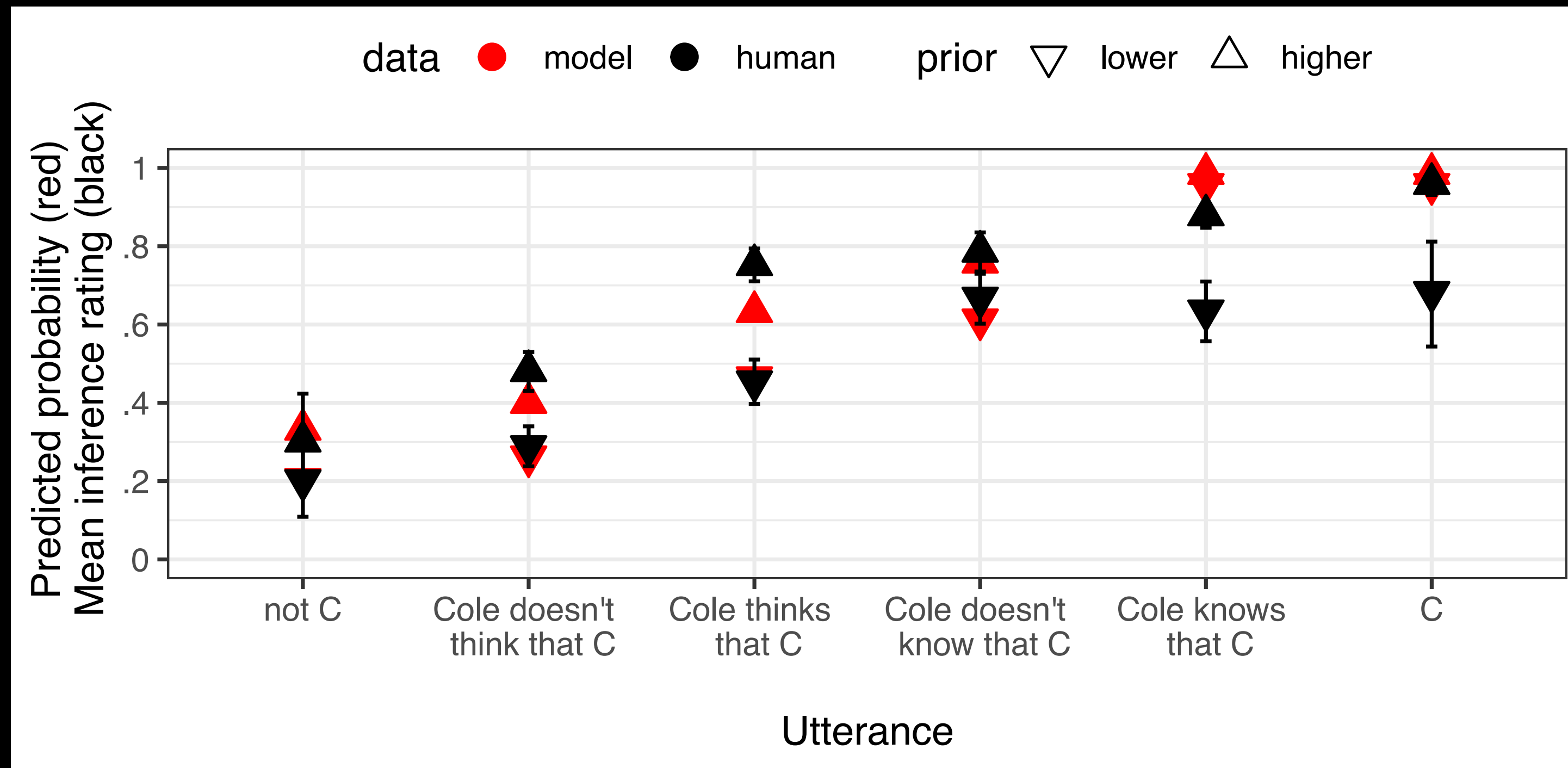
posterior inference



relax the listener



before



after



“The squirrel doesn't **know** that Estonia includes hundreds of islands, small and big.”

→ Estonia includes hundreds of islands

## Projection inferences

- without lexically coded presuppositions
- sensitive to prior beliefs and QUDs

Projection inferences are just one type of inference predicted by the analysis.

Prior beliefs modulate all kinds of inferences, as predicted by our RSA-model.





**thank you!**