

NTS:  $P(s_c | \bar{V}) > P(s_q | \bar{V})$   
 [deaccented "has" is a cue for competitor]

$$\Leftrightarrow r_c q_{\bar{V}} > r_q p_{\bar{V}}$$

$$\Leftrightarrow \frac{q_{\bar{V}}}{p_{\bar{V}}} > \frac{r_q}{r_c}$$

any bias towards competitor must be counterbalanced by the evidence  $\frac{q_{\bar{V}}}{p_{\bar{V}}} > 1$ .

[we could naturally expect this to be the case] even if  $r_q \neq r_c$  because of  $[q_{\bar{V}} > p_{\bar{V}}]$

So assume:  
 $r_q = r_c + \epsilon_r$   
 $q_{\bar{V}} = p_{\bar{V}} + \epsilon_{\bar{V}}$   
 with  $0 \leq \epsilon_r < \epsilon_{\bar{V}}$

Then:

$$\frac{p_{\bar{V}} + \epsilon_{\bar{V}}}{p_{\bar{V}}} > \frac{r_c + \epsilon_r}{r_c}$$

$$\Leftrightarrow (p_{\bar{V}} + \epsilon_{\bar{V}}) \cdot r_c > p_{\bar{V}} (r_c + \epsilon_r)$$

$$\Leftrightarrow p_{\bar{V}} r_c + \epsilon_{\bar{V}} r_c > p_{\bar{V}} r_c + p_{\bar{V}} \epsilon_r$$

$$\Leftrightarrow \epsilon_{\bar{V}} r_c > p_{\bar{V}} \epsilon_r$$

$$\Leftrightarrow \frac{\epsilon_{\bar{V}}}{\epsilon_r} > \frac{p_{\bar{V}}}{r_c}$$

true if  $\epsilon_r < \epsilon_{\bar{V}}$  &  $p_{\bar{V}} < r_c$   
 both are natural assumptions  
 also assumed here:  $q_{\bar{V}} > p_{\bar{V}}$  &  $r_q \geq r_c$  ✓

maybe assume that:  $r_q = r_c + \epsilon_r$   
 with  $0 \leq \epsilon_r$  small &  $p_{\bar{V}} + \epsilon_{\bar{V}} = q_{\bar{V}}$   
 with  $0 \leq \epsilon_r < \epsilon_{\bar{V}}$ .

NTS:  $P(s_q | V) > P(s_c | \bar{V})$   
 [proof exists (?) for flat prior  $r_q = r_c$  and identical string likelihood  $p_{\bar{V}} = q_{\bar{V}}$ ]

$$\Leftrightarrow \frac{r_q p_V}{r_q p_V + r_c q_V} > \frac{r_c q_{\bar{V}}}{r_q p_{\bar{V}} + r_c q_{\bar{V}}}$$

$$\Leftrightarrow \frac{r_q p_V}{r_q p_V + r_c q_V} > \frac{r_c (1 - q_V - q_{\bar{V}})}{r_q (1 - p_V - p_{\bar{V}}) + r_c (1 - q_V - q_{\bar{V}})}$$

$$\Leftrightarrow \dots > \frac{r_c - r_c q_V - r_c q_{\bar{V}}}{r_q - r_q p_V - r_q p_{\bar{V}} + r_c - r_c q_V - r_c q_{\bar{V}}}$$

$$\Leftrightarrow r_q p_V (r_q - r_q p_V - r_q p_{\bar{V}} + r_c - r_c q_V - r_c q_{\bar{V}}) > (r_c - r_c q_V - r_c q_{\bar{V}}) \cdot (r_q p_V + r_c q_V)$$

$$\Leftrightarrow r_q^2 p_V - r_q^2 p_V^2 - r_q^2 p_V p_{\bar{V}} + r_q r_c p_V - r_q r_c p_V q_V - r_q r_c p_V q_{\bar{V}} > r_q r_c p_V + r_q r_c q_V - r_q r_c p_V q_V - r_c^2 q_V^2 - r_q r_c p_V q_{\bar{V}} - r_c^2 q_V q_{\bar{V}}$$

$$\Leftrightarrow r_q^2 p_V - r_q^2 p_V^2 - r_q^2 p_V p_{\bar{V}} > r_q r_c p_V - r_c^2 q_V^2 - r_c^2 q_V q_{\bar{V}}$$

$$\Leftrightarrow (r_q^2 - r_q r_c) p_V - r_q^2 p_V^2 - r_q^2 p_V p_{\bar{V}} > -r_c^2 q_V^2 - r_c^2 q_V q_{\bar{V}}$$

$$\Leftrightarrow (r_q^2 - r_q (r_q - \epsilon_r)) p_V - r_q^2 p_V^2 - r_q^2 p_V p_{\bar{V}} > -(r_q - \epsilon_r)^2 q_V^2 - (r_q - \epsilon_r)^2 q_V q_{\bar{V}}$$

$$\Leftrightarrow (r_q^2 - r_q^2 + r_q \epsilon_r) p_V - r_q^2 p_V^2 - r_q^2 p_V p_{\bar{V}} > -(r_q^2 - 2r_q \epsilon_r + \epsilon_r^2) (q_V^2 - q_V q_{\bar{V}})$$

$$\Leftrightarrow r_q \epsilon_r p_V - r_q^2 p_V^2 - r_q^2 p_V p_{\bar{V}} > \dots$$

show, it is clear that any prior bias for  $s_q$  will pull does towards  $s_q$ ; show that, by mere likelihood, the same result is expected; no net:  $\epsilon_r = 0$

$$\frac{p_V}{p_V + q_V} > \frac{q_{\bar{V}}}{p_{\bar{V}} + q_{\bar{V}}}$$

$$\Leftrightarrow p_V p_{\bar{V}} + p_V q_{\bar{V}} > p_V q_V + q_V q_{\bar{V}}$$

$$\Leftrightarrow p_V p_{\bar{V}} > q_V q_{\bar{V}}$$

$$\Leftrightarrow \frac{p_{\bar{V}}}{q_V} > \frac{q_{\bar{V}}}{p_V}$$

$$(p_{\bar{V}} + \epsilon_p) p_{\bar{V}} > q_V (q_V + \epsilon_q)$$

$$p_{\bar{V}}^2 + \epsilon_p p_{\bar{V}} > q_V^2 + \epsilon_q q_V$$

$$p_{\bar{V}}^2 + \epsilon_p p_{\bar{V}} > q_V^2 + \epsilon_q q_V + \epsilon_p q_V$$

assume:  
 $q_{\bar{V}} = q_V + \epsilon_q$   $\epsilon_q > \epsilon_p$   
 $p_V = p_{\bar{V}} + \epsilon_p$   
 [producing  $V$  is less likely than producing  $\bar{V}$  when adequate]  $p_V < q_{\bar{V}}$   
 [producing  $V$  is less likely than producing  $\bar{V}$  when inadequate]  $p_{\bar{V}} > q_V$

# Computational Pragmatics

Michael Franke



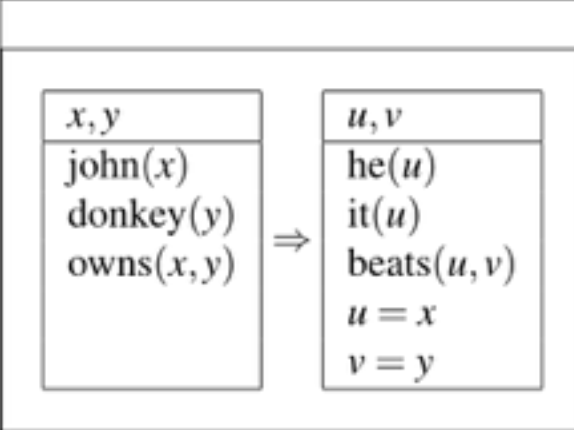
# Two views of language

ወንጌያውያን እና የሌሎች ጸሎት ገጽ

እርሷ ለእርሷ ወንጌያውያን እና የሌሎች ጸሎት ገጽ

እርሷ ለእርሷ ወንጌያውያን እና የሌሎች ጸሎት ገጽ

እርሷ ለእርሷ ወንጌያውያን እና የሌሎች ጸሎት ገጽ



**sentence** | 'sentns |  
 noun  
 1 a set of words that is complete in itself, typically containing a subject and predicate, conveying a statement, question, exclamation, or command, and consisting of a main clause and sometimes one or more subordinate clauses.  
 • Logic a series of signs or symbols expressing a proposition in an artificial or logical language.  
 2 the punishment assigned to a defendant found guilty by a court, or fixed by law for a particular offense: *her husband is **serving** a three-year **sentence** for fraud | slander of an official carried an eight-year prison sentence.*  
 verb [with obj.]  
 declare the punishment decided for (an offender): *ten army officers were **sentenced** to death.*

structure



disambiguated by pragmatic reasoning



function

# Language use & pragmatic inference



“If I say to any one, ‘**I saw some of your children to-day**’, he might be justified in inferring that I did not see them all, not because the words mean it, but because, if I had seen them all, it is most likely that I should have said so.”

(Mill 1867)



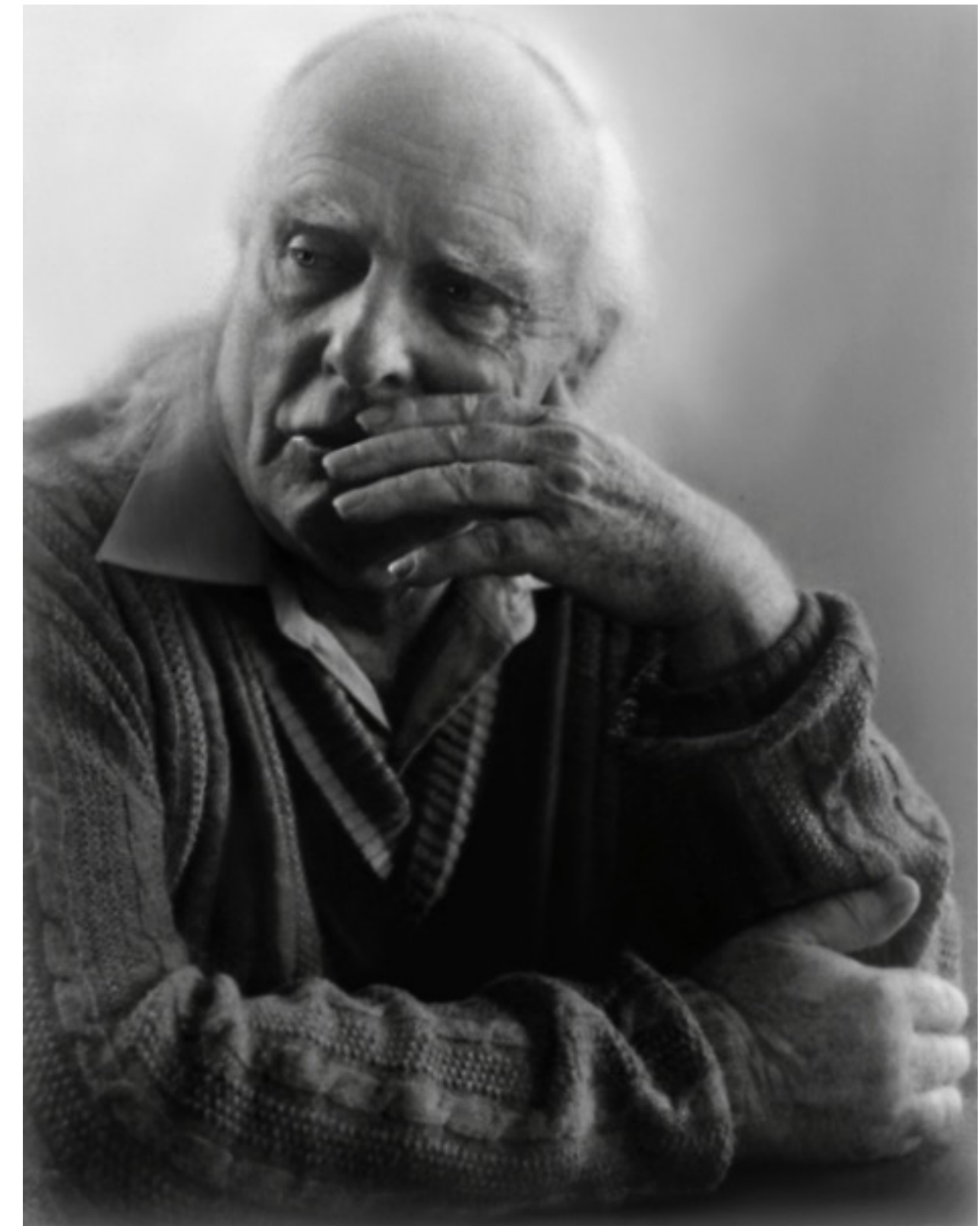
# Language use & pragmatic inference

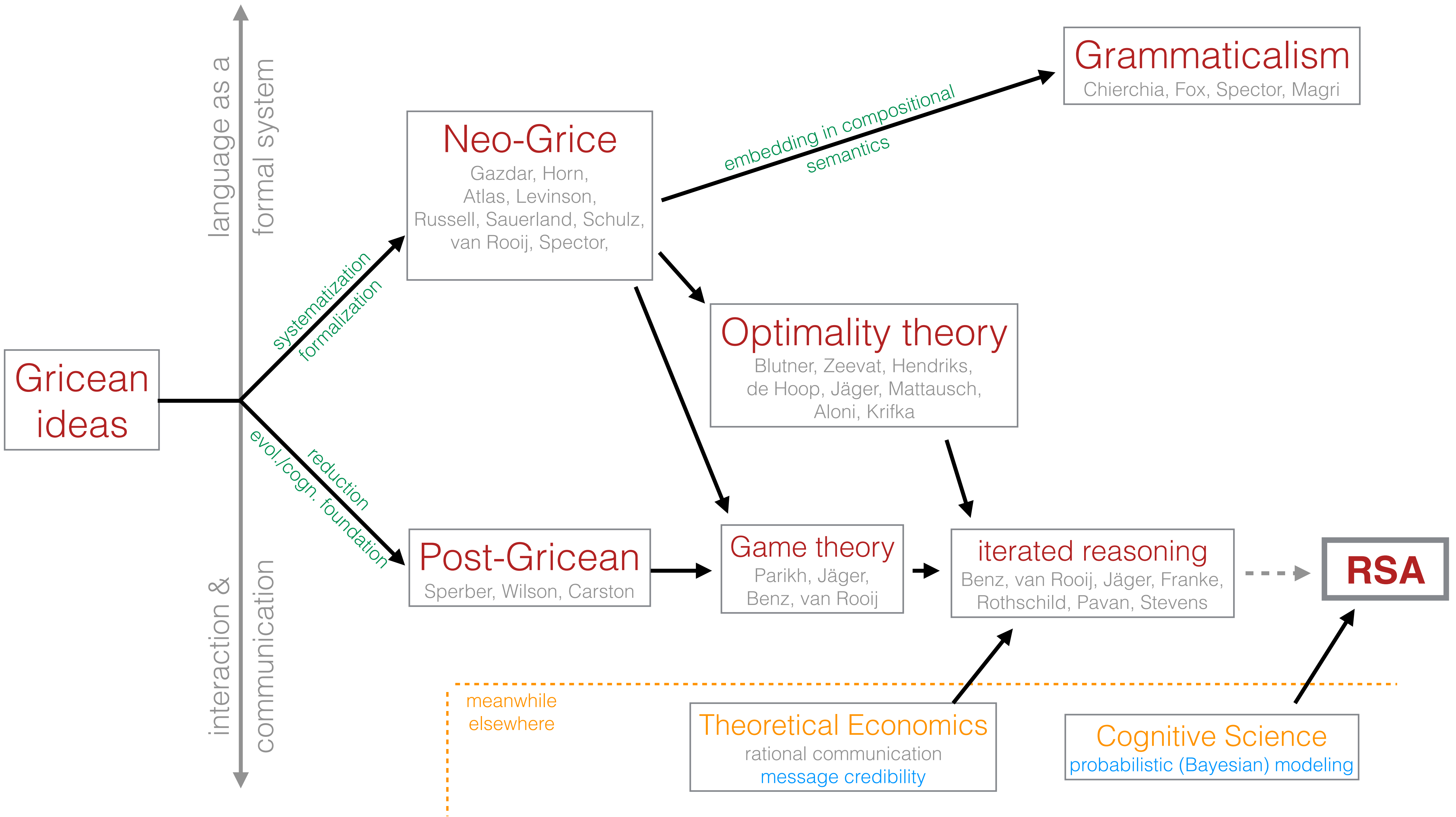
## Maxims of Conversation

Be truthful, informative, relevant, brief, clear ...

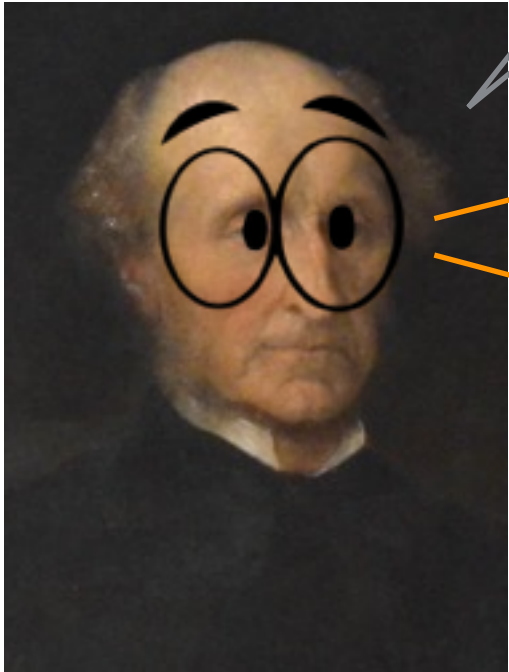
“[O]ne of my avowed aims is to see talking as a special case or variety of purposive, indeed rational, behaviour.”

(Grice 1975)



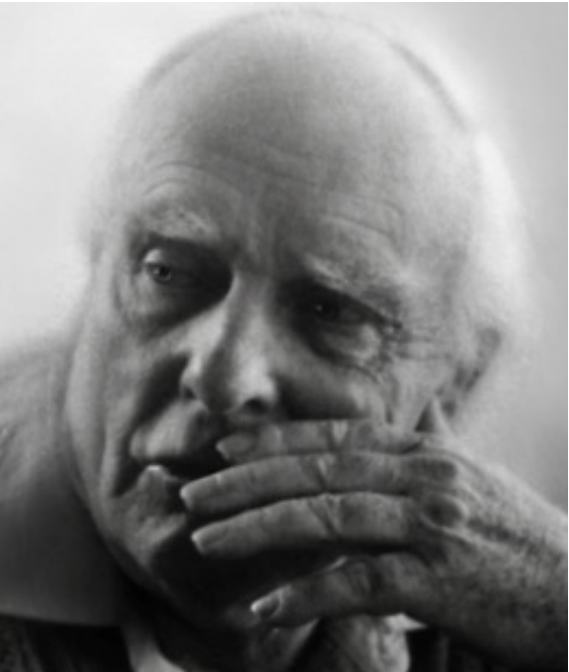
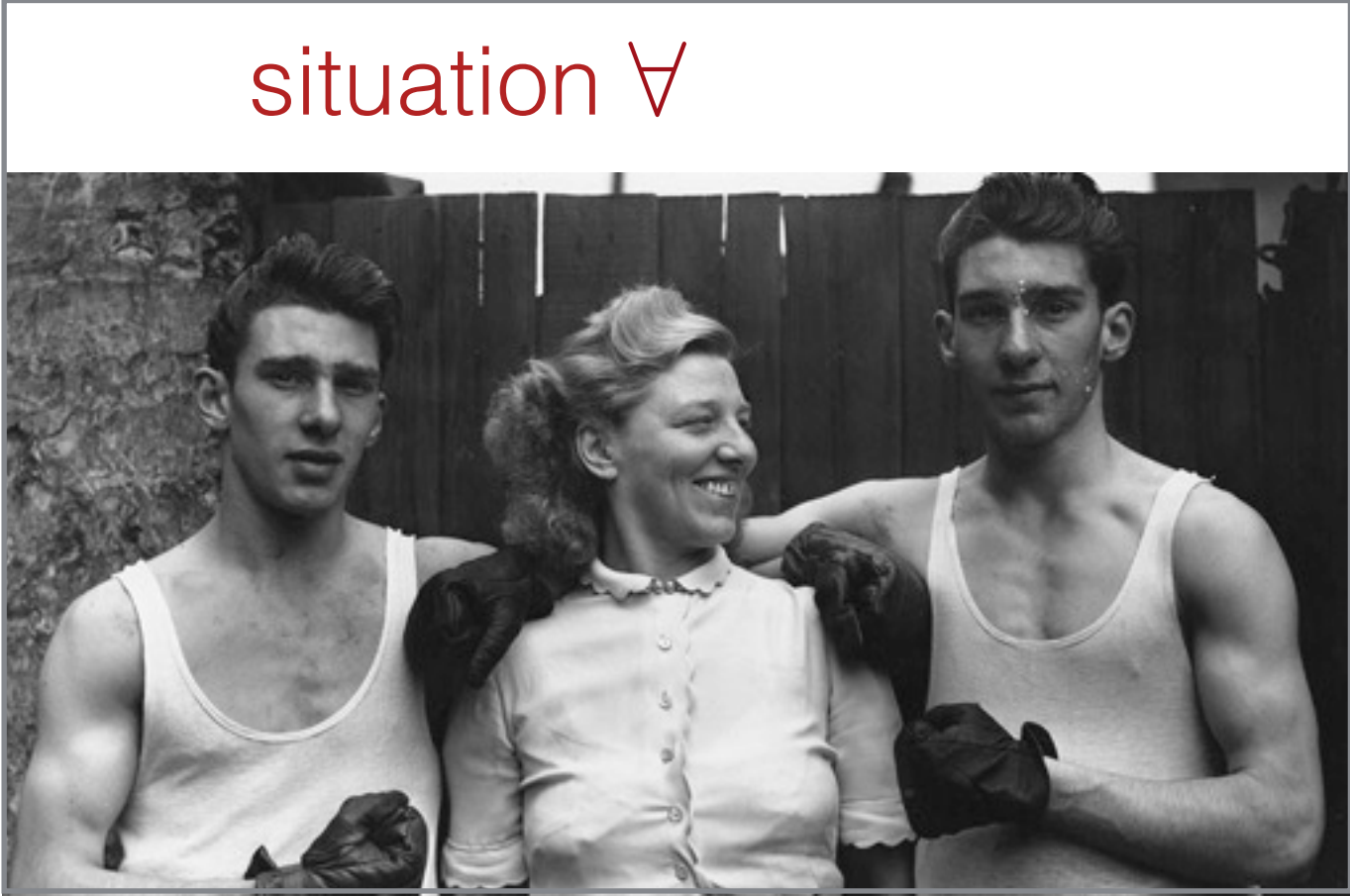


# Pragmatics from rational social reasoning



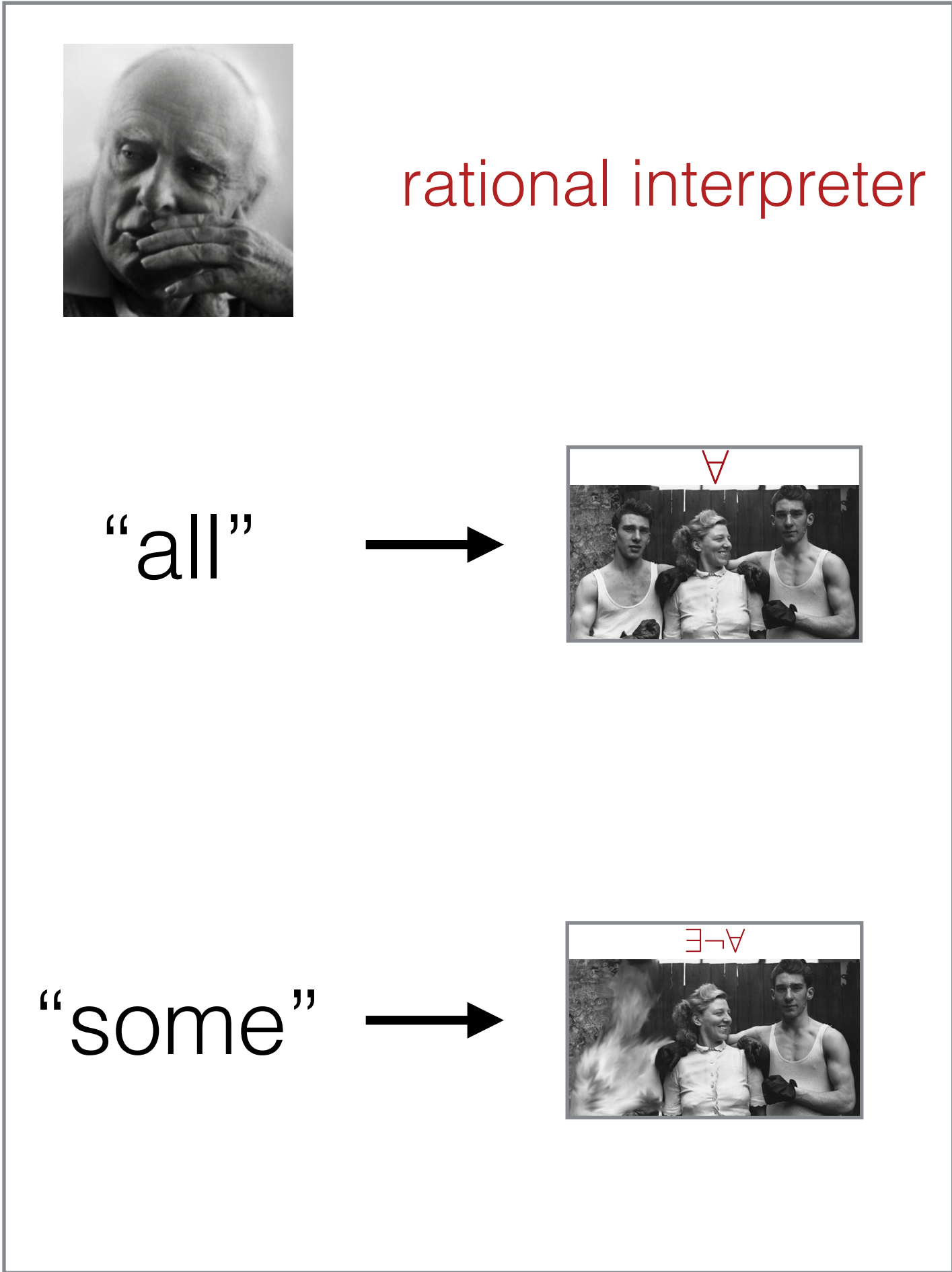
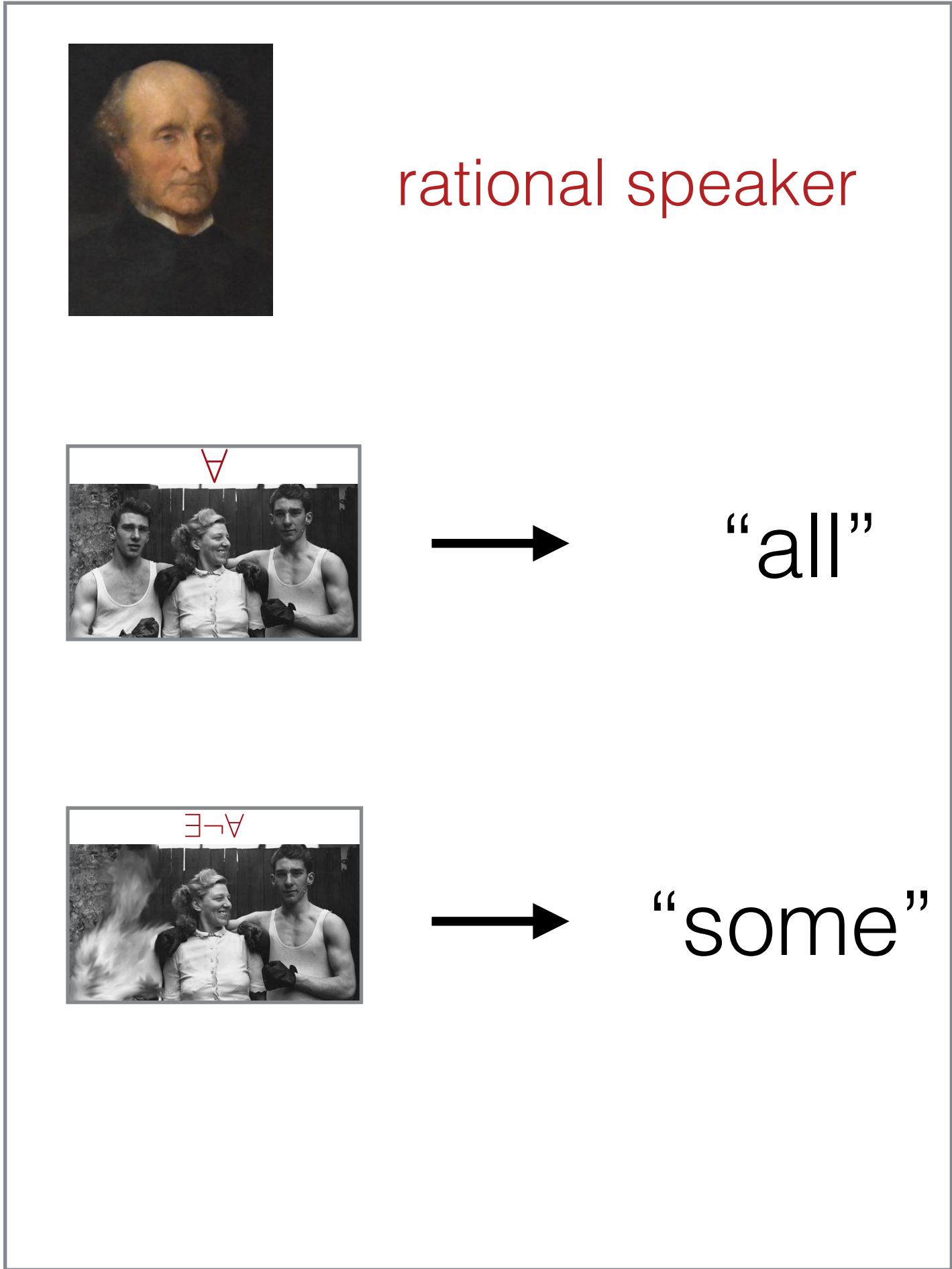
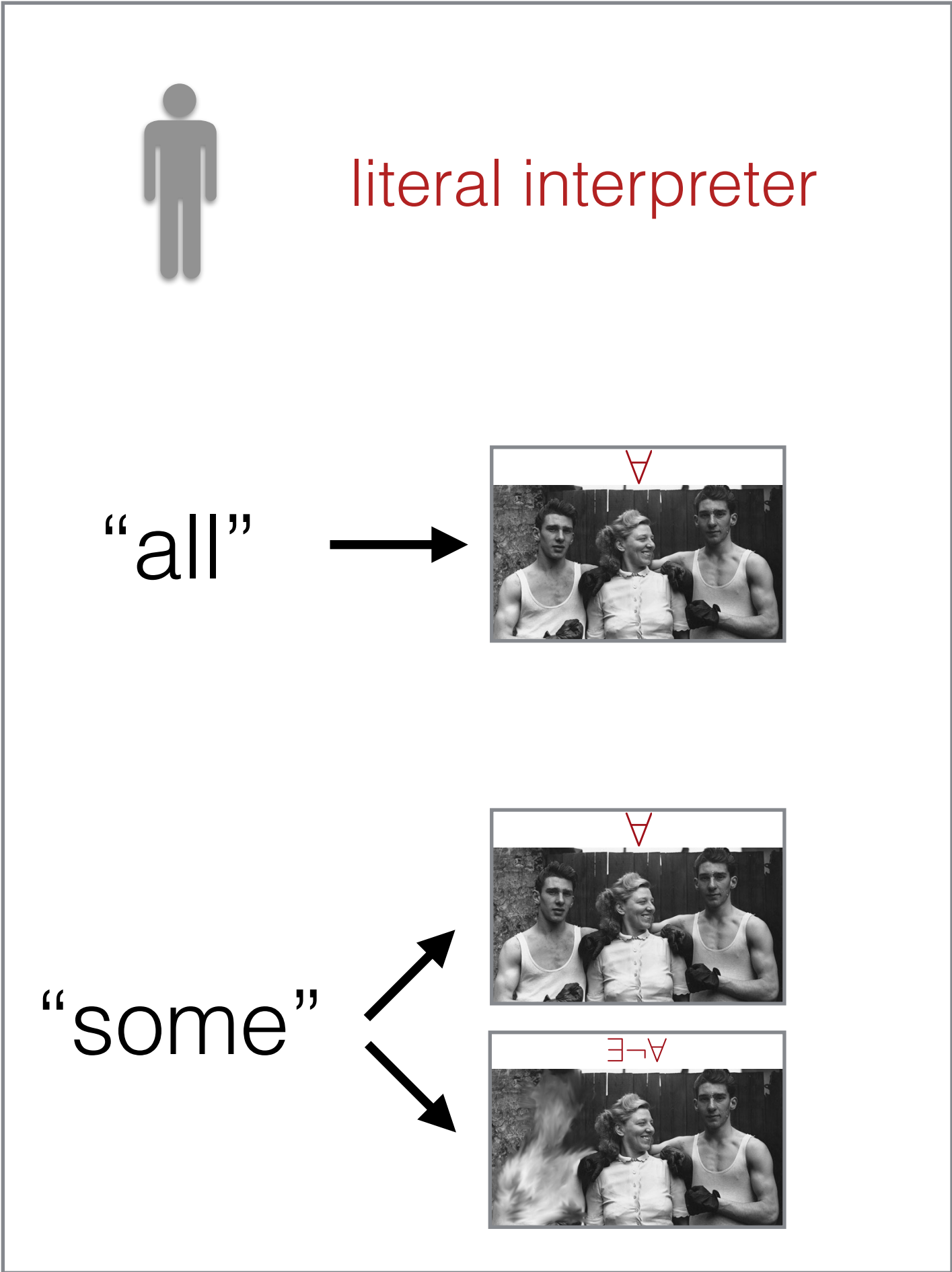
"I saw some of your children today."

?

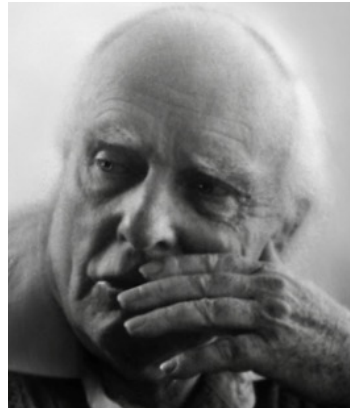




# Pragmatics from rational social reasoning



# Pragmatics from rational social reasoning



rational interpreter



rational speaker



literal interpreter



# Pragmatics from rational social reasoning



rational interpreter

	$\forall$	$\exists \rightarrow \forall$
<b>“all”</b>	1	0
<b>“some”</b>	0	1



rational speaker

	<b>“all”</b>	<b>“some”</b>
$\forall$	1	0
$\exists \rightarrow \forall$	0	1



literal interpreter

	$\forall$	$\exists \rightarrow \forall$
<b>“all”</b>	1	0
<b>“some”</b>	.5	.5

# Pragmatics from rational social reasoning



rational interpreter

	$\forall$	$\exists \neg \forall$
<b>“all”</b>	.9	.1
<b>“some”</b>	.1	.9



approximately rational speaker

	<b>“all”</b>	<b>“some”</b>
$\forall$	.9	.1
$\exists \neg \forall$	.1	.9



literal interpreter

	$\forall$	$\exists \neg \forall$
<b>“all”</b>	1	0
<b>“some”</b>	.5	.5

# Pragmatics from rational social reasoning



rational interpreter

	$\forall$	$\exists \neg \forall$
<b>“all”</b>	.9	.1
<b>“some”</b>	.1	.9



approximately rational speaker

	<b>“all”</b>	<b>“some”</b>
$\forall$	.9	.1
$\exists \neg \forall$	.1	.9



literal interpreter

	$\forall$	$\exists \neg \forall$
<b>“all”</b>	1	0
<b>“some”</b>	.5	.5

**listener behavior**

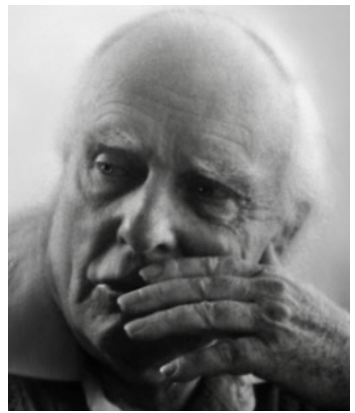
$$U \rightarrow \Delta(S)$$

**speaker behavior**

$$S \rightarrow \Delta(U)$$



# Rational Speech Act model



pragmatic listener

$L_1$

$$P_{L_1}(s | u) \propto P_{S_1}(u | s) \cdot P(s)$$



pragmatic speaker

$S_1$

$$P_{S_1}(u | s) = \exp(\underbrace{\alpha(\log P_{L_0}(s | u) - \text{Cost}(u))}_{\text{Exp. Utility}(u|s)})$$

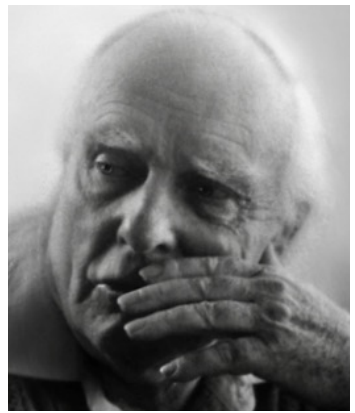


literal listener

$L_0$

$$P_{L_0}(s | u) = P(s | \llbracket u \rrbracket)$$

# Rational Speech Act model



pragmatic listener

$L_1$

$$P_{L_1}(s | u) \propto P_{S_1}(u | s) \cdot P(s)$$



pragmatic speaker

$S_1$

$$P_{S_1}(u | s) = \exp(\underbrace{\alpha(\log P_{L_0}(s | u) - \text{Cost}(u))}_{\text{Exp. Utility}(u|s)})$$

world knowledge



literal listener

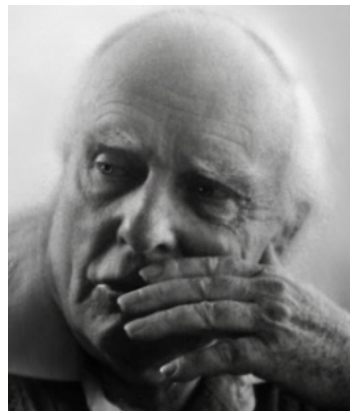
$L_0$

$$P_{L_0}(s | u) = P(s | \llbracket u \rrbracket)$$

semantic meaning



# Rational Speech Act model



pragmatic listener

$$L_1 \quad P_{L_1}(s | u) \propto P_{S_1}(u | s) \cdot P(s)$$

rational choice

linguistic preference

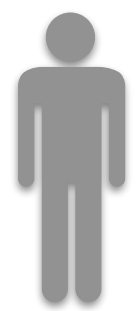


pragmatic speaker

$$S_1 \quad P_{S_1}(u | s) \propto \exp(\alpha(\underbrace{\log P_{L_0}(s | u) - \text{Cost}(u)}_{\text{Exp. Utility}(u|s)}))$$

information flow

Exp. Utility( $u|s$ )

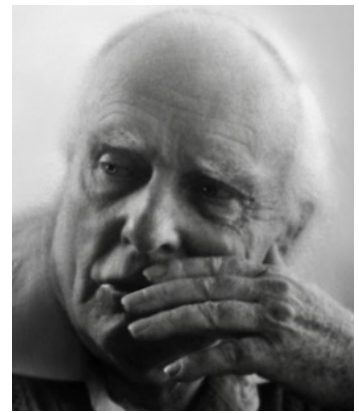


literal listener

$$L_0 \quad P_{L_0}(s | u) = P(s | \llbracket u \rrbracket)$$



# Rational Speech Act model



pragmatic listener

$L_1$

$$P_{L_1}(s | u) \propto P_{S_1}(u | s) \cdot P(s)$$

Bayes rule

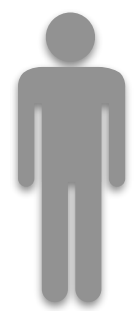
world knowledge



pragmatic speaker

$S_1$

$$P_{S_1}(u | s) = \exp(\alpha(\underbrace{\log P_{L_0}(s | u) - \text{Cost}(u)}_{\text{Exp. Utility}(u|s)}))$$



literal listener

$L_0$

$$P_{L_0}(s | u) = P(s | \llbracket u \rrbracket)$$

speaker model

# This course

## applications

referential communication  
(epistemic) scalar implicatures  
non-literal language use  
vagueness  
politeness  
...

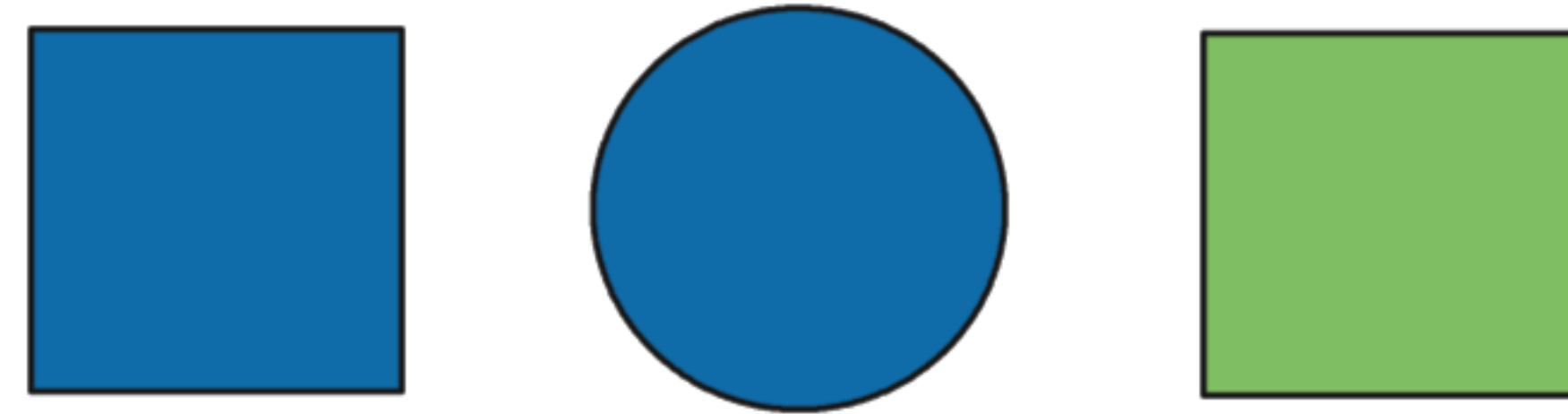
## technicalities

WebPPL  
Bayesian Data Analysis  
...

# referential communication

context

set of objects/referents



utterances

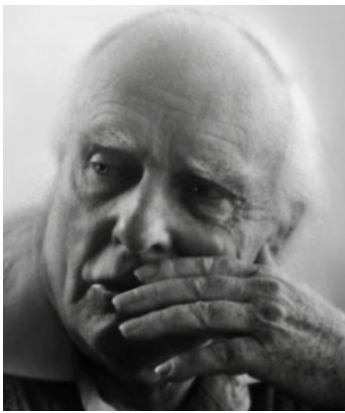
single properties of objects

$$U = \{ \text{"square"}, \text{"circle"}, \text{"green"}, \text{"blue"} \}$$




which object do you think a speaker meant when she selects "blue"?



# RSA for reference games (example)






rational interpreter

			
“square”	.82	0	.18
“circle”	0	1	0
“green”	0	0	1
“blue”	.82	.18	0






rational speaker

	“square”	“circle”	“green”	“blue”
	.5	0	0	.5
	0	.89	0	.11
	.11	0	.89	0



literal interpreter

			
“square”	.5	0	.5
“circle”	0	1	0
“green”	0	0	1
“blue”	.5	.5	0