

NTS: $P(s_q | \bar{V}) > P(s_c | \bar{V})$

[deaccented "has" is a cue for competitor]

$$\Leftrightarrow \tau_q q_{\bar{V}} > \tau_q p_{\bar{V}}$$

$$\Leftrightarrow \frac{q_{\bar{V}}}{p_{\bar{V}}} > \frac{\tau_q}{\tau_c}$$

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 $\tau_q \approx \tau_c$ because of $q_{\bar{V}} > p_{\bar{V}}$]

so assume:

$$\begin{cases} \tau_q = \tau_c + \epsilon_q \\ q_{\bar{V}} = p_{\bar{V}} + \epsilon_{\bar{V}} \end{cases} \text{ with } 0 \leq \epsilon_q < \epsilon_{\bar{V}}$$

Then:

$$\frac{p_{\bar{V}} + \epsilon_{\bar{V}}}{p_{\bar{V}}} > \frac{\tau_c + \epsilon_q}{\tau_c}$$

$$\Leftrightarrow (p_{\bar{V}} + \epsilon_{\bar{V}}) \cdot \tau_c > p_{\bar{V}} (\tau_c + \epsilon_q)$$

$$\Leftrightarrow p_{\bar{V}} \tau_c + \epsilon_{\bar{V}} \tau_c > p_{\bar{V}} \tau_c + p_{\bar{V}} \epsilon_q$$

$$\Leftrightarrow \epsilon_{\bar{V}} \tau_c > p_{\bar{V}} \epsilon_q$$

$$\Leftrightarrow \frac{\epsilon_{\bar{V}}}{\epsilon_q} > \frac{p_{\bar{V}}}{\tau_c}$$

true if $\epsilon_q < \epsilon_{\bar{V}}$ & $p_{\bar{V}} < \tau_c$

both are natural assumptions

also assumed here: $q_{\bar{V}} > p_{\bar{V}}$ &

$$\tau_q > \tau_c \quad \checkmark$$

maybe assume that: $\tau_q = \tau_c + \epsilon_q$
with $0 \leq \epsilon_q$ small & $p_{\bar{V}} + \epsilon_{\bar{V}} = q_{\bar{V}}$
with $0 \leq \epsilon_q < \epsilon_{\bar{V}}$.

NTS: $P(s_q | V) > P(s_c | V)$

[proof exists (*) for flat prior $\tau_q = \tau_c$ and initial string likelihood $P_n = q_n$]

$$\Leftrightarrow \frac{\tau_q p_V}{\tau_q p_V + \tau_c q_V} > \frac{\tau_c q_V}{\tau_q p_V + \tau_c q_V}$$

$$\Leftrightarrow \frac{\tau_q p_V}{\tau_q p_V + \tau_c q_V} > \frac{\tau_c (1 - q_V - q_n)}{\tau_q (1 - p_V - p_n) + \tau_c (1 - q_V - q_n)}$$

$$\Leftrightarrow \dots > \frac{\tau_c - \tau_c q_V - \tau_c q_n}{\tau_q - \tau_q p_V - \tau_q p_n + \tau_c - \tau_c q_V - \tau_c q_n}$$

$$\Leftrightarrow \tau_q p_V (\tau_q - \tau_q p_V - \tau_q p_n + \tau_c - \tau_c q_V - \tau_c q_n) > (\tau_c - \tau_c q_V - \tau_c q_n) \cdot (\tau_q p_V + \tau_c q_V)$$

$$\Leftrightarrow \tau_q^2 p_V - \tau_q^2 p_V^2 - \tau_q^2 p_n p_V + \tau_q \tau_c p_V - \tau_q \tau_c p_V q_V - \tau_q \tau_c p_V q_n > \tau_q \tau_c p_V + \tau_q \tau_c q_V - \tau_q \tau_c p_V q_V - \tau_c^2 q_V^2 - \tau_q \tau_c p_V q_n - \tau_c^2 q_V q_n$$

$$\Leftrightarrow \tau_q^2 p_V - \tau_q^2 p_V^2 - \tau_q^2 p_n p_V >$$

$$\tau_q \tau_c p_V - \tau_c^2 q_V^2 - \tau_c^2 q_V q_n$$

$$\Leftrightarrow (\tau_q^2 - \tau_q \tau_c) p_V - \tau_q^2 p_V^2 - \tau_q^2 p_n p_V >$$

$$- \tau_c^2 q_V^2 - \tau_c^2 q_V q_n$$

$$\Leftrightarrow (\tau_q^2 - \tau_q (\tau_q - \epsilon_q)) p_V - \tau_q^2 p_V^2 - \tau_q^2 p_n p_V > -(\tau_q - \epsilon_q)^2 q_V^2 - (\tau_q - \epsilon_q)^2 q_V q_n$$

$$\Leftrightarrow (\tau_q^2 - \tau_q^2 + \tau_q \epsilon_q) p_V - \tau_q^2 p_V^2 - \tau_q^2 p_n p_V > -(\tau_q^2 - 2\tau_q \epsilon_q + \epsilon_q^2) (q_V^2 - q_V q_n)$$

$$\Leftrightarrow \tau_q \epsilon_q p_V - \tau_q^2 p_V^2 - \tau_q^2 p_n p_V > \dots$$

• okay, it is clear that any prior bias for s_q will pull closer to s_q ; shows that, by more likelihood, the same result is expected; so set: $\epsilon_q = 0$ (4)

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

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

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

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

assume:

$$q_{\bar{V}} = q_V + \epsilon_q \quad \epsilon_q > \epsilon_p$$

$$p_V = p_{\bar{V}} + \epsilon_p$$

[producing V when adequate is less likely than producing \bar{V} when adequate] $p_V > q_{\bar{V}}$

[producing V when inadequate is less likely than producing \bar{V} when inadequate] $p_{\bar{V}} > q_V$

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

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

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

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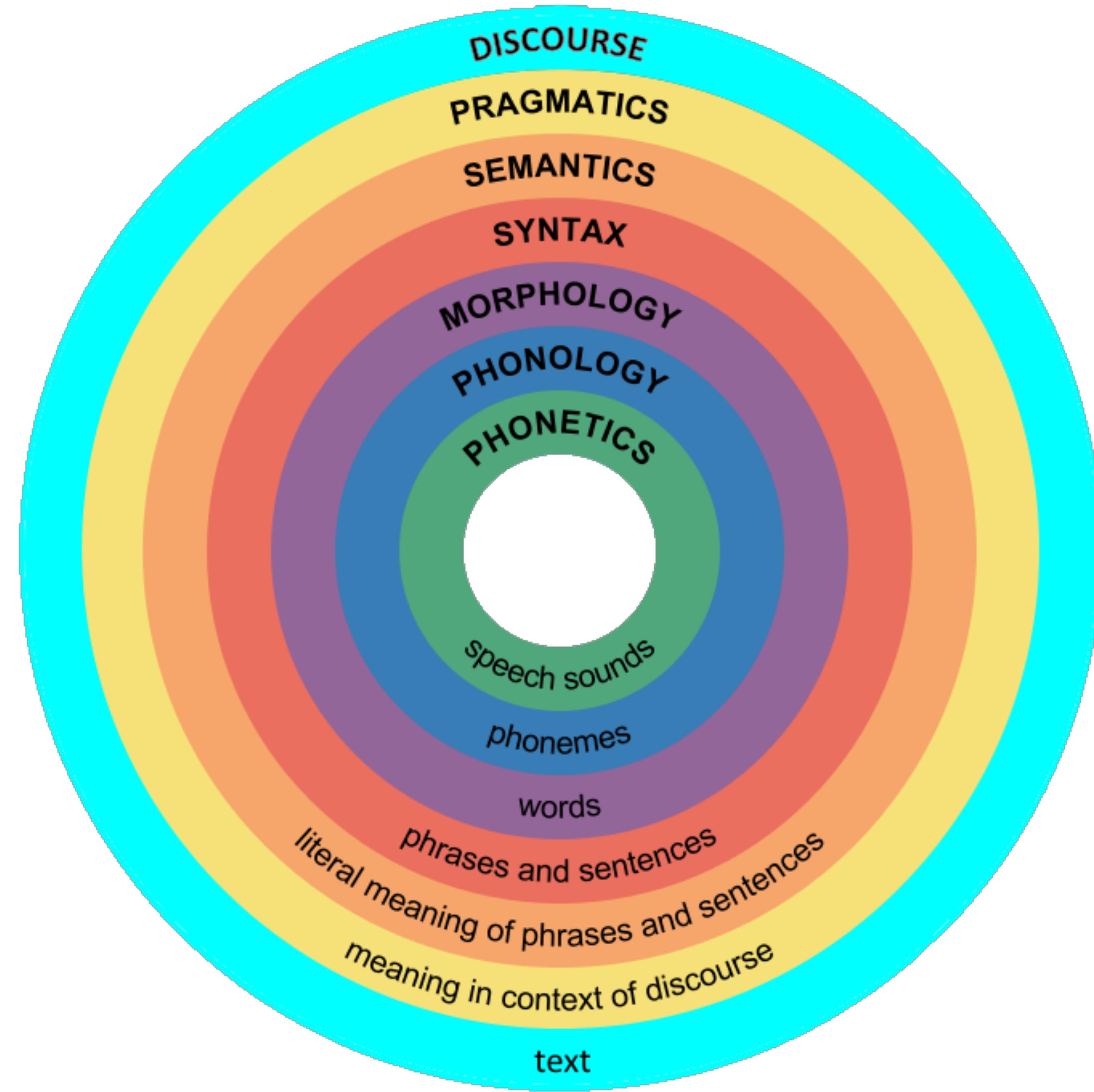
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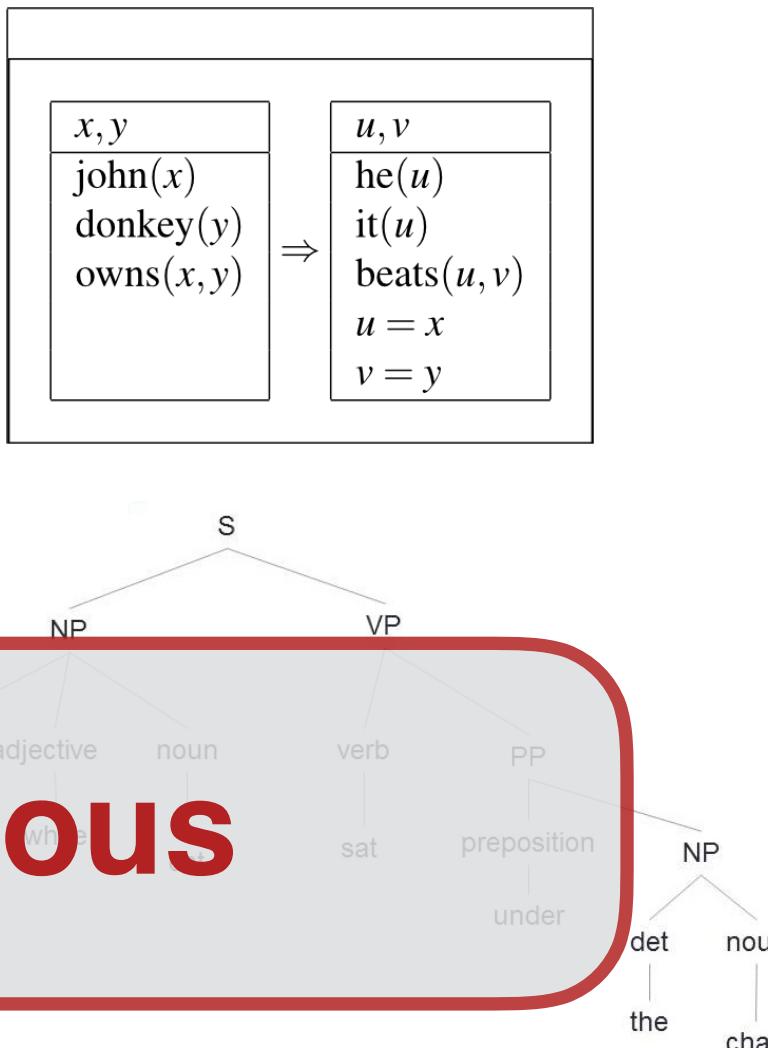
The biggest collection of paper clips is in Spaarnwoude, Nordholland.



Whiskey!

Two views of language

ପ୍ରେତପାଦଙ୍କାରୀରାମାଧ୍ୟବିନ୍ଦୁ ॥ ଗନ୍ଧା
ଶ୍ଵରାଜାରୀରାମାଧ୍ୟବିନ୍ଦୁ ॥ ଶ୍ରୀରାମାଧ୍ୟବିନ୍ଦୁ
ଶ୍ରୀରାମାଧ୍ୟବିନ୍ଦୁ ॥ ଶ୍ରୀରାମାଧ୍ୟବିନ୍ଦୁ ॥ ଶ୍ରୀରାମାଧ୍ୟବିନ୍ଦୁ ॥
ଶ୍ରୀରାମାଧ୍ୟବିନ୍ଦୁ ॥ ଶ୍ରୀରାମାଧ୍ୟବିନ୍ଦୁ ॥



ambiguous

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



Semantics^{logical}

BUT FOR THAT TO HAPPEN, LOGIC
WOULD HAVE TO BECOME AN EXACT
SCIENCE!

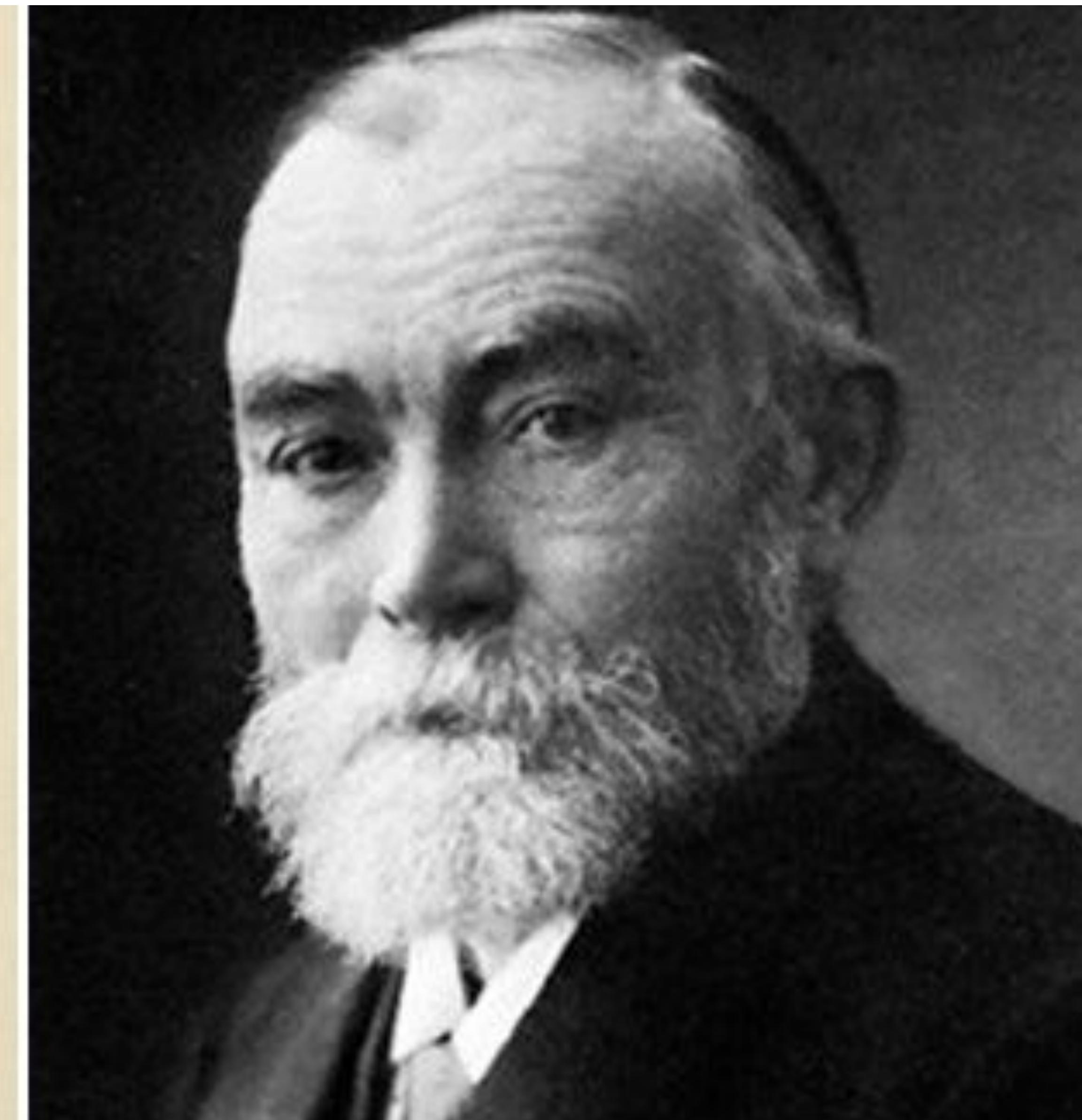
THE
STRUGGLE
HAS JUST
BEGUN...

BEGRIFFSSCHRIFT,
EINE DER ARITHMETISCHEN NACHGEBILDETE
FORMELSPRACHE
DES REINEN DENKENS.

VON

DR. GOTTLÖB FREGE.

PRIVATDOCENTEN DER MATHEMATIK AN DER UNIVERSITÄT JENA.



expression
“robot”



HAS A

sense

```
myself: ( lambda n: ( ( lambda cond: lambda t: lambda f:  
    lambda t: lambda f: t(( lambda x: x))))(n))( lambda  
    lambda _: ( lambda n: lambda m: n(lambda x: ( lambda n:  
        lambda x: x))(n)( myself(myself)(( (lambda n: lambda  
            lambda myself: ( lambda n: ( ( lambda cond: lambda  
                lambda x: x))))( lambda t: lambda f: t(( lambda x: x))))(  
                    lambda _: ( lambda n: lambda m: n(lambda x:  
                        ( lambda f: lambda x: x))(n)( myself(myself)(( (lambda  
                            lambda u))(n)) )))))  
            lambda n: lambda f: lambda x: f( n(f)(x ))(( lambda n: lam  
                lambda n: lambda f: lambda x: f( n(f)(x ))(( lambda n: lam  
                    lambda f: lambda x: x))))))))
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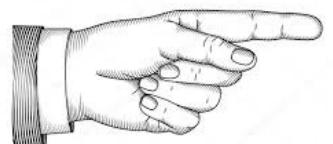
DETERMINES

reference



Frege

On Sense & Reference



Sense (Sinn) :: intension :: manner of presentation (Art des Gegebenseins) :: way of singling out parts in a world to which the expression applies

Reference (Bedeutung) :: extension :: set of positive instances in a given world / truth-value for saturated

φ	ψ	\parallel	$\varphi \wedge \psi$	$\varphi \vee \psi$	$\varphi \rightarrow \psi$
1	1		1	1	1
1	0		0	1	0
0	1		0	1	1
0	0		0	0	1

- (1) a. They got married and had kids.
 b. They had kids and got married.
- (2) One more ukulele song and I'm out.
- (3) Jon had no coin or he would have given it to him.
- (4) If you pour sugar in your coffee, it tastes great.
 But if you pour sugar and gasoline in your coffee,
 it tastes awful.
- (5) **A:** Do you speak Portuguese?
B: My wife does.

φ	ψ	$\varphi \wedge \psi$	$\varphi \vee \psi$	$\varphi \rightarrow \psi$
1	1	1	1	1
1	0	0	1	0
0	1	0	1	1
0	0	0	0	1



Pragmatics

Gricean

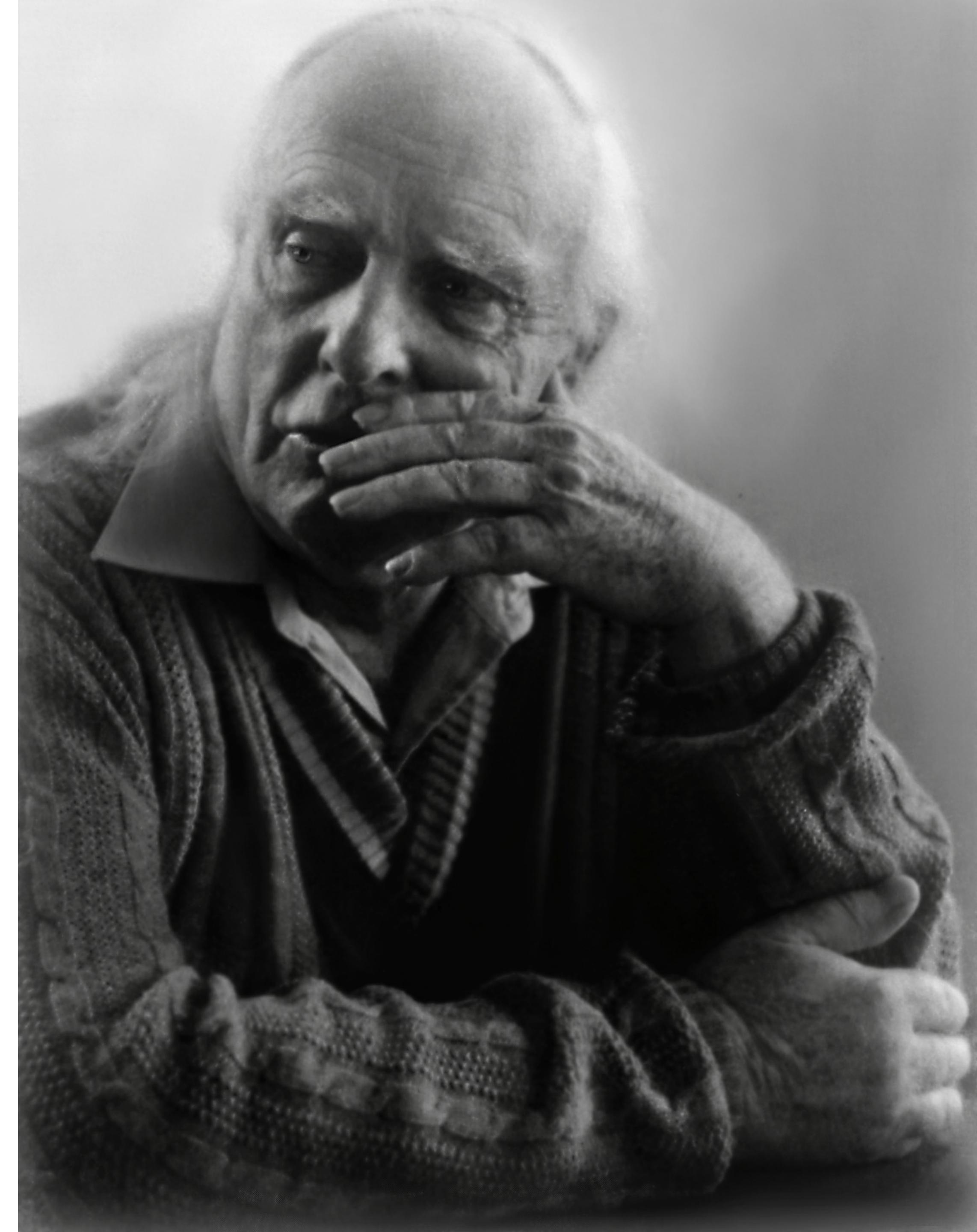


“If I say to any one, ‘**I saw some of your children to-day**’, he might be justified in inferring that I did not see them all, not because the words mean it, but because, if I had seen them all, it is most likely that I should have said so.”

(Mill 1867)

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

(Grice 1975)



Maxim of Quality

Try to make your contribution one that is true.

- (i) Do not say what you believe to be false.
- (ii) Do not say that for which you lack adequate evidence.

Maxim of Quantity

- (i) Make your contribution as informative as is required for the current purposes of the exchange.
- (ii) Do not make your contribution more informative than is required.

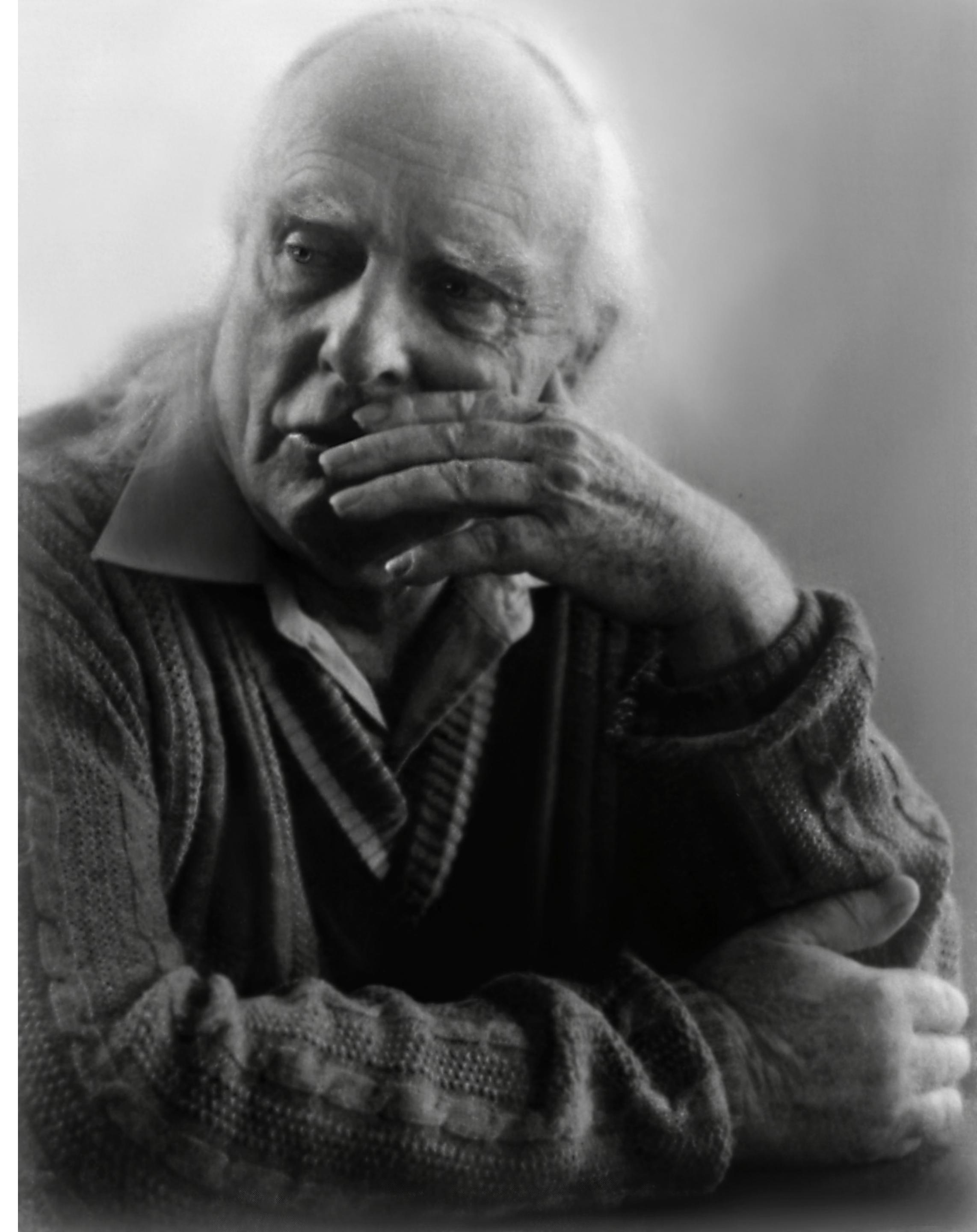
Maxim of Relation

- (i) Be relevant.

Maxim of Manner

Be perspicuous.

- (i) Avoid obscurity of expression.
- (ii) Avoid ambiguity.
- (iii) Be brief (avoid unnecessary prolixity).
- (iv) Be orderly.



- (1) a. They got married and had kids.
b. They had kids and got married.

L assumes **S** obeys Maxims

by Manner, **L** assumes **S** to be "orderly"

L expects **S** to present events in chronological order (unless otherwise indicated)

- (5) **A:** Do you speak Portuguese?
B: My wife does.

L assumes **S** obeys Maxims

by Quantity & Relevance, **L** assumes **S** to give all the relevant information **S** is able to

if **S** was able to speak Portuguese, **S** would/should have said so

Q-Implicatures

- (6) I saw some of your children.
↳ I saw some but not all of your children.

- (7) I saw Jack or Jill.
↳ I don't know which.



Levinson

I-Implicatures

- (8) Every ten minutes a man gets mugged in New York City.
↳ Not the same poor fellow every time.

- (8) Every ten minutes a light blinks on the machine.
↳ The same light every time.



Horn

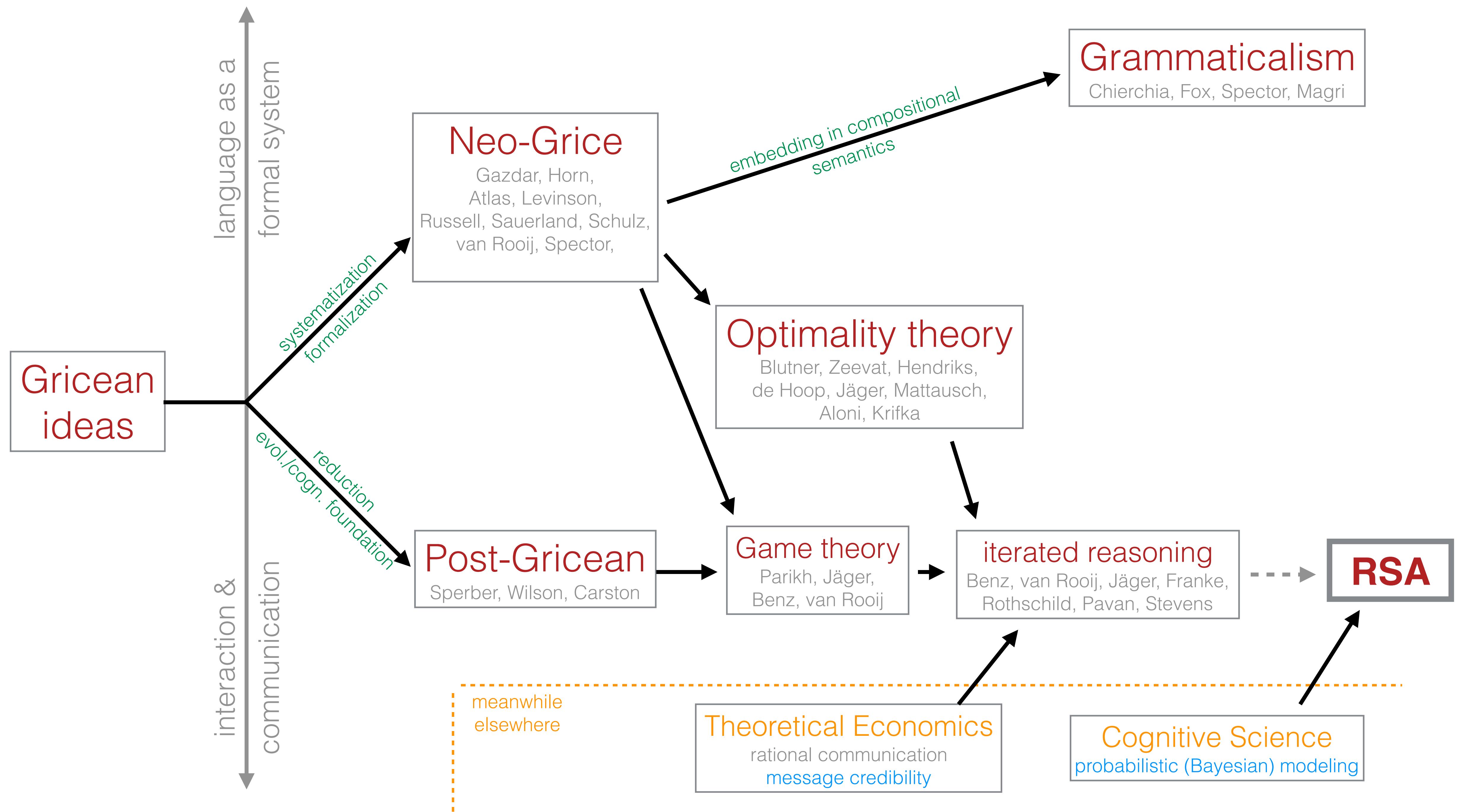
M-Implicatures

- (9) Black Bart caused the sheriff to die.
↳ In some unusual manner, perhaps by accident.



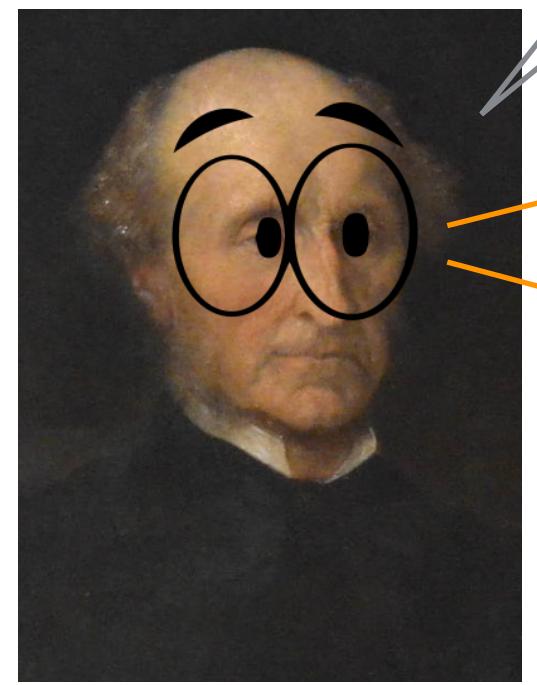
Atlas



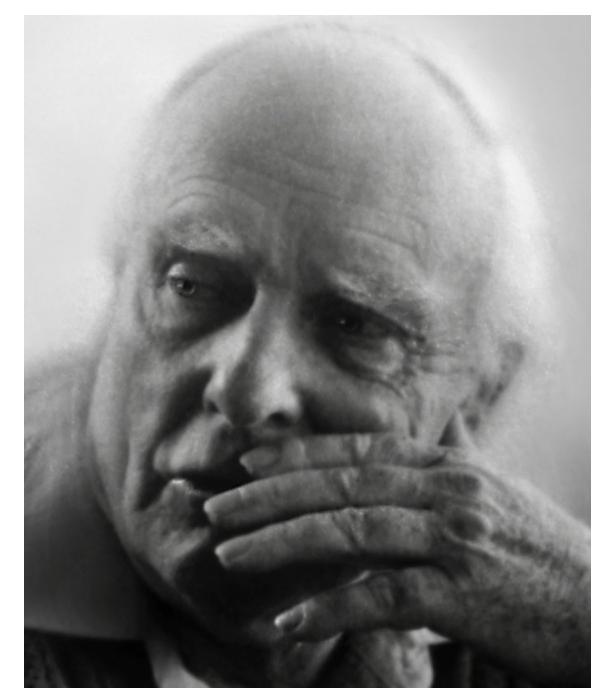
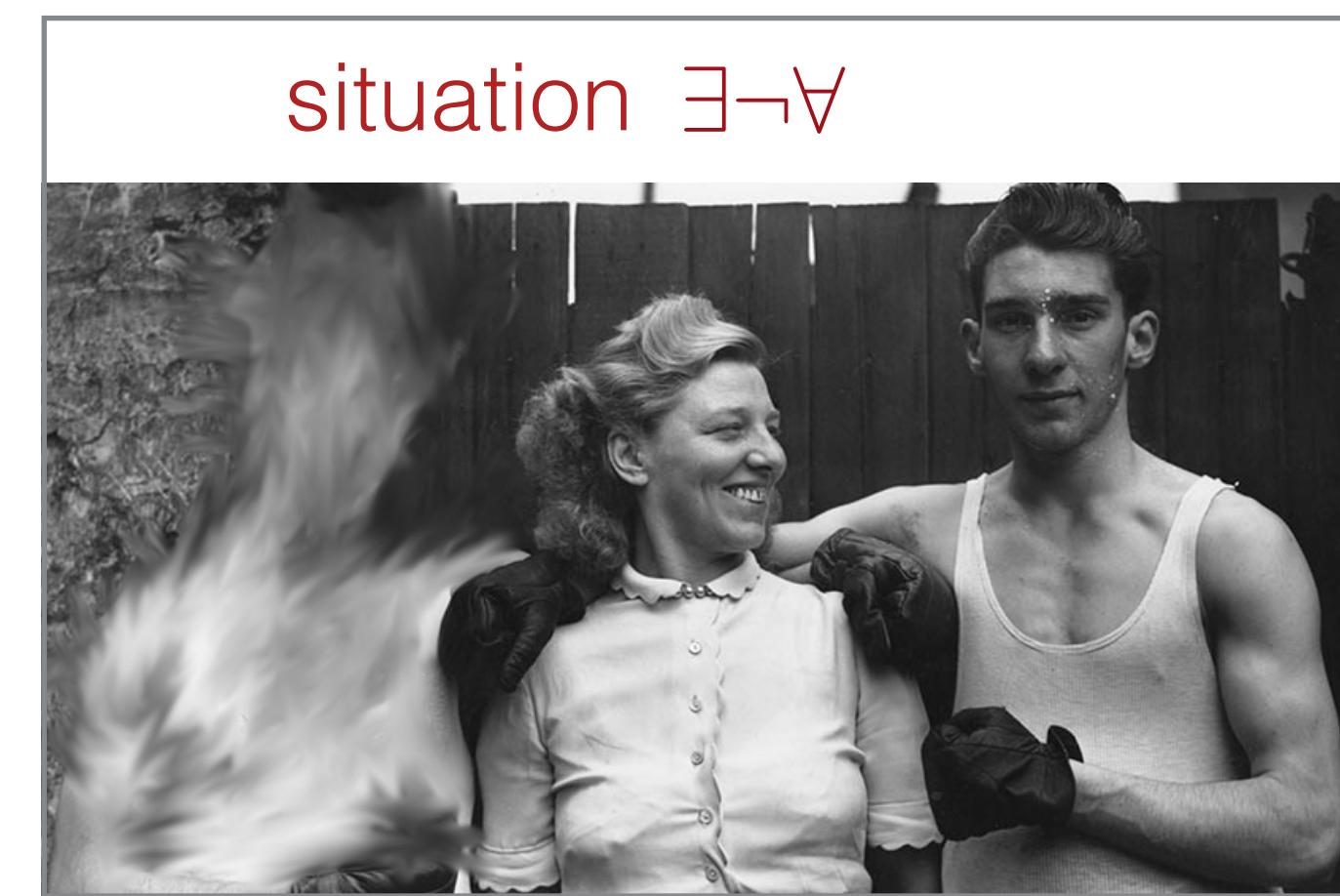
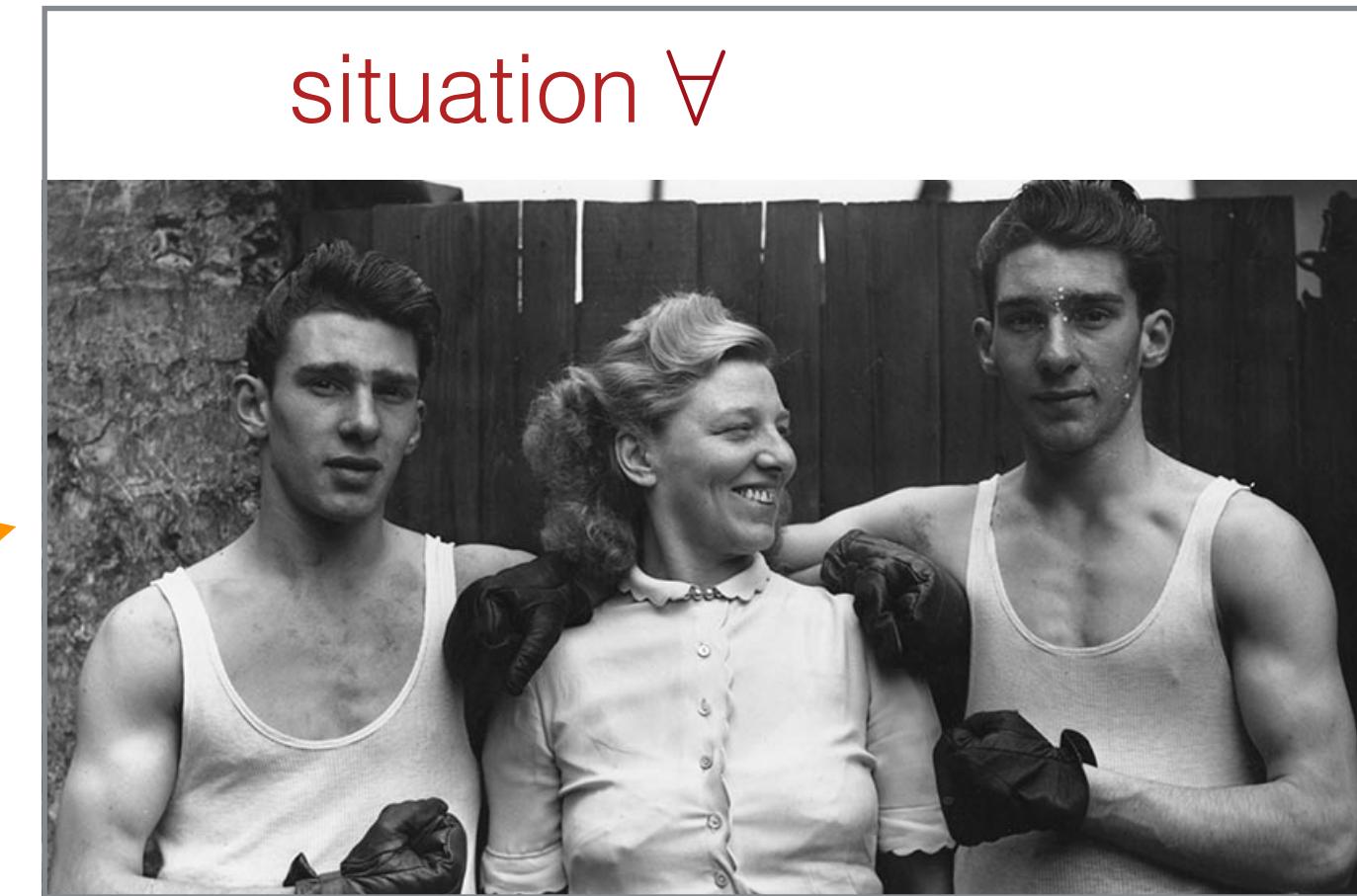




probabilistic **Pragmatics**



“I saw some of
your children
today.”



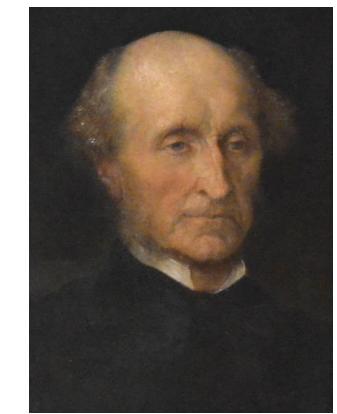
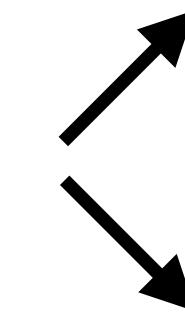


literal interpreter

“all”



“some”



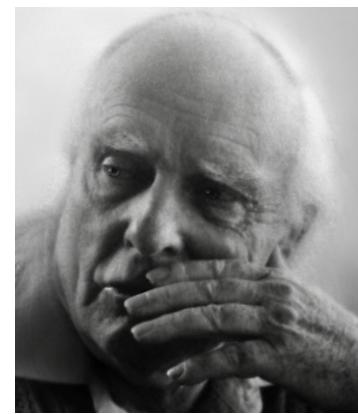
rational speaker



“all”



“some”



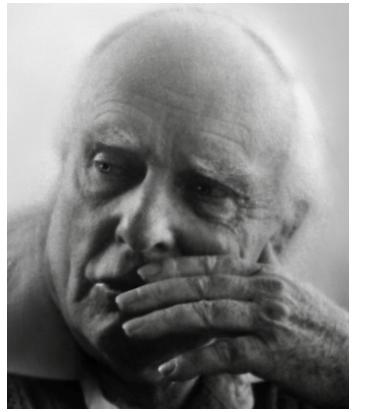
rational interpreter

“all”

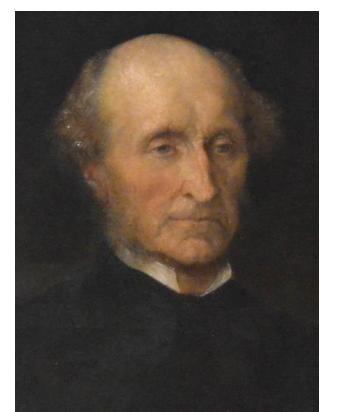


“some”

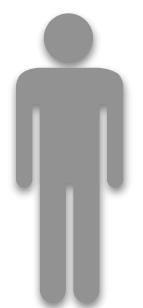




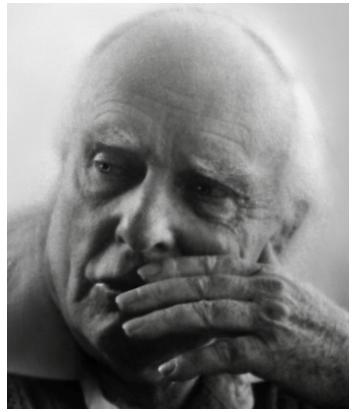
rational interpreter



rational speaker

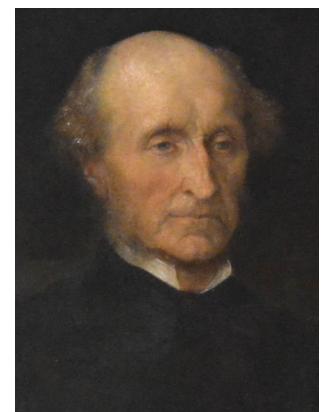


literal interpreter



rational interpreter

	A	$\neg A$
“all”	1	0
“some”	0	1



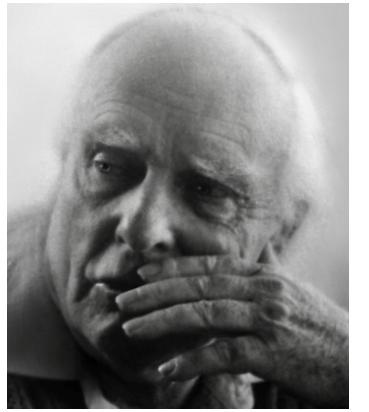
rational speaker

	“all”	“some”
A	1	0
$\neg A$	0	1



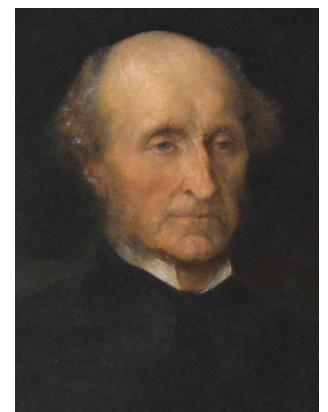
literal interpreter

	A	$\neg A$
“all”	1	0
“some”	.5	.5



rational interpreter

	A	$\neg A$
“all”	.9	.1
“some”	.1	.9



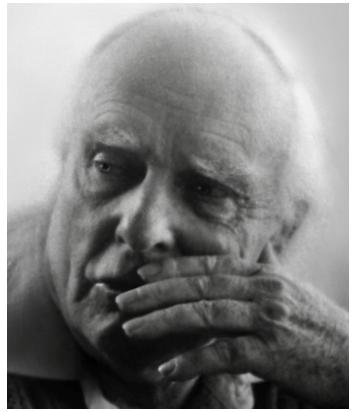
approximately
rational speaker

	“all”	“some”
A	.9	.1
$\neg A$.1	.9



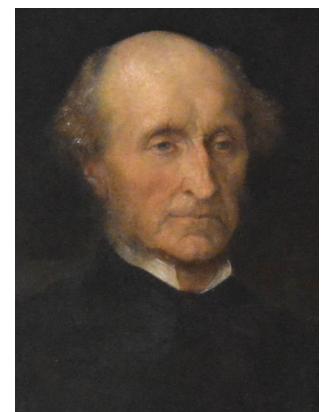
literal interpreter

	A	$\neg A$
“all”	1	0
“some”	.5	.5



rational interpreter

	A	$\neg A$
“all”	.9	.1
“some”	.1	.9



approximately
rational speaker

	“all”	“some”
A	.9	.1
$\neg A$.1	.9



literal interpreter

	A	$\neg A$
“all”	1	0
“some”	.5	.5

listener behavior

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

speaker behavior

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

Rational Speech Act model

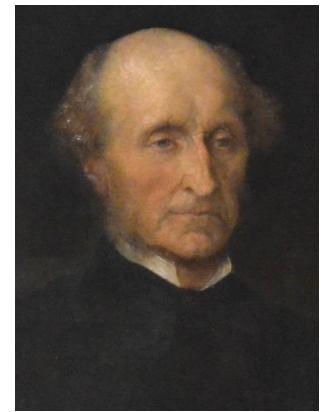


L_0

LITERAL INTERPRETATION STRATEGIC DEPTH 0



$$P_{lit}(s | m) = P(s | [m])$$

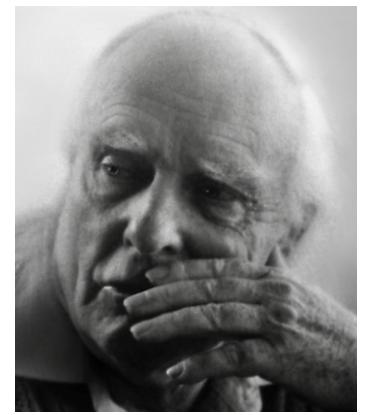


S_1

GRICEAN SPEAKER STRATEGIC DEPTH 1



$$P_S(m | s) \propto \exp \left(\alpha \left(\log P_{lit}(s | m) - C(m) \right) \right)$$



L_1

GRICEAN INTERPRETATION STRATEGIC DEPTH 2



$$P_L(s | m) \propto P(s) P_S(m | s)$$

This course

applications

referential communication

(epistemic) scalar implicatures

non-literal language use

vagueness

politeness

...

technicalities

WebPPL

Bayesian Data Analysis

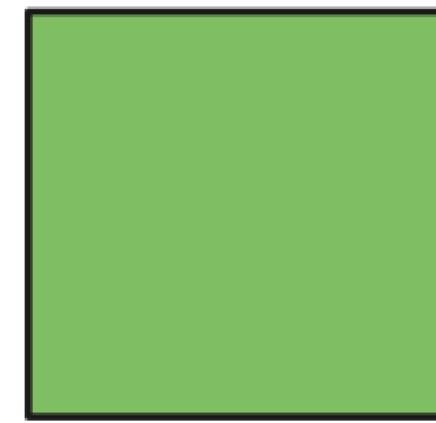
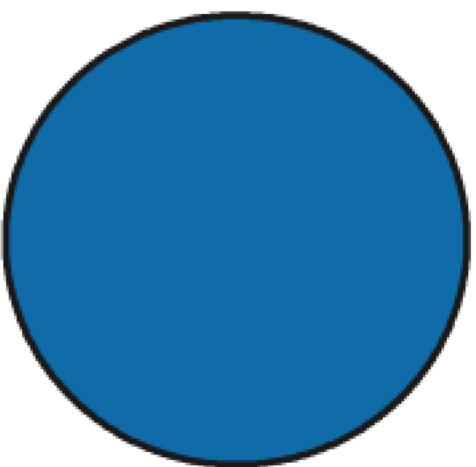
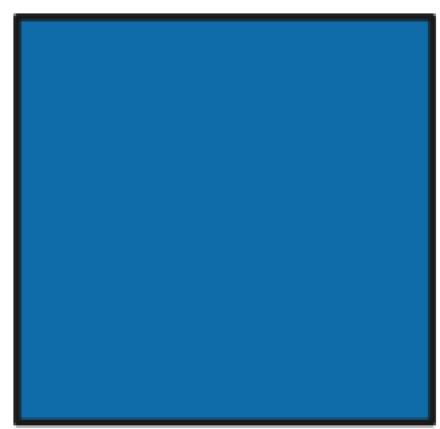
...

Reference Games

referential communication

context

set of objects/referents



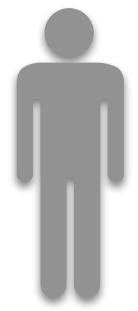
utterances

single properties of objects

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

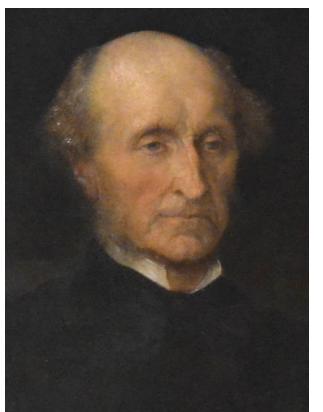
which object do you think a speaker meant when she selects “blue”?

RSA for reference games (example)



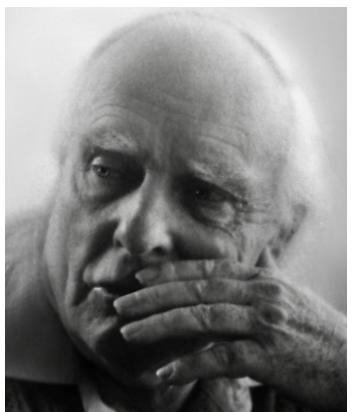
literal interpreter

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



rational speaker

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



rational interpreter

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