

ESLLI2015 Advanced Course on Computational Models of Grounding in Dialogue

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What is Grounding?

- Not electrical grounding
- Not postponing space rocket flights
- Not crashing a ship onto land
- Not symbol-grounding
- **Establishing common ground (Clark & Wilkes-Gibbs '86)**

Computational Models of Dialogue (Grounding)

- **Formal Models of Human interaction**
 - Automated recognition/classification
 - Prediction
- **Generative/Participation models**
 - Human-computer (spoken) dialogue system
 - Robot
 - Virtual Human



Purposes for Artificial Agents

- Applications
 - As intelligent/natural social interface to Computers and Information (e.g. Siri)
 - As virtual role-player (e.g. for training doctor-patient interviews, teamwork, cross-cultural negotiation,...)
- Cognitive/Social Science Research
 - Stimulus for Social Interaction experiments (virtual confederate)
 - Reification of Pragmatics Theory

Virtual humans:

What are they?

- Intelligent agents that support meaningful social interactions with human users in virtual reality
 - Play the role of teachers, peers, adversaries
- “Avatars” with a computer brain
 - Communicate through speech & gesture
 - Reason about environment
 - Understand and express emotion



What can they do?



- Portable, low-cost approach to supplement face-to-face interaction
- People respond “as if” they were human
 - Social facilitation (Hayes et al. 2010)
 - Impression management (Krämer et al. 2003)
 - Stereotype bias (Lok et al. 2008)
- Training control and consistency
 - Ensure consistency across trainees
 - Systematic manipulations
 - Incorporate “involuntary” behaviors
- Evaluate formal behavior models
 - Through perception studies
 - In context of interaction
 - Find gaps in interaction





Outline of Course (covered today)

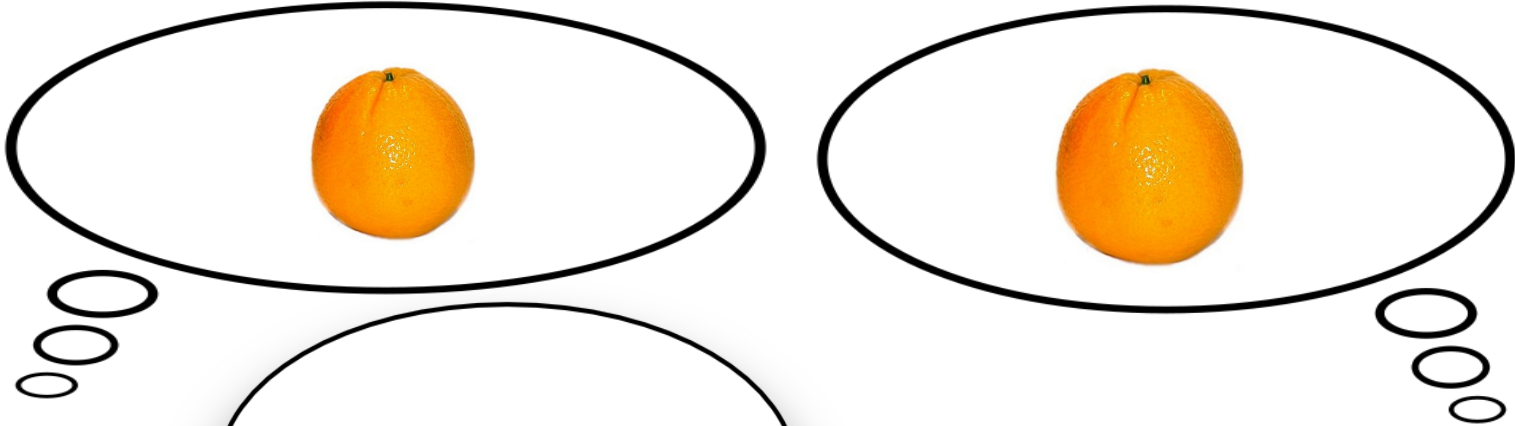
- Preliminaries: representation, agency, communication
- Common Ground: How it is modeled and achieved
- Clark and Schaefer's Model of Grounding
- Feedback and Error-handling in Spoken Dialogue Systems
- Early Computational Models of Grounding
- Miscommunication: The Good, the Bad, and the Ugly
- Multi-functionality of Utterances
- Multi-modal Grounding
- Degrees of Grounding
- Multiparty Grounding
- Incremental Grounding

PRELIMINARIES: REPRESENTATION, AGENCY & COMMUNICATION

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Linguistic Communication



Logic & Reasoning: Representation



Orange(O1)

$\exists x: \text{Orange}(x)$

$\neg \exists y: \text{Orange-Juice}(Y)$

Logic & Reasoning



$\neg \exists x: \text{Orange}(x)$

Orange-Juice(O2)

$\exists y: \text{Orange-Juice}(y)$

Logic & Reasoning: Action



- Make-OJ(O1,O2)



Logic & Reasoning: Plan

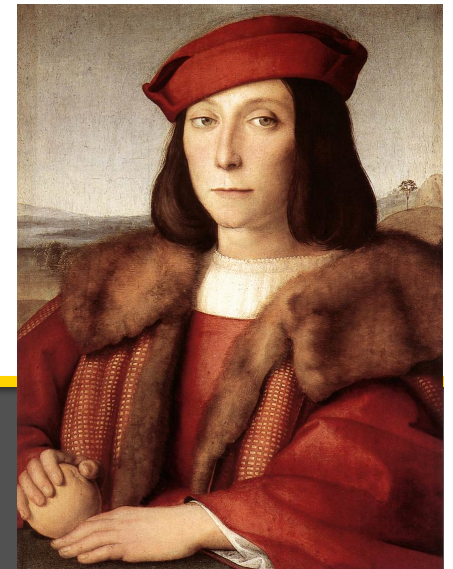
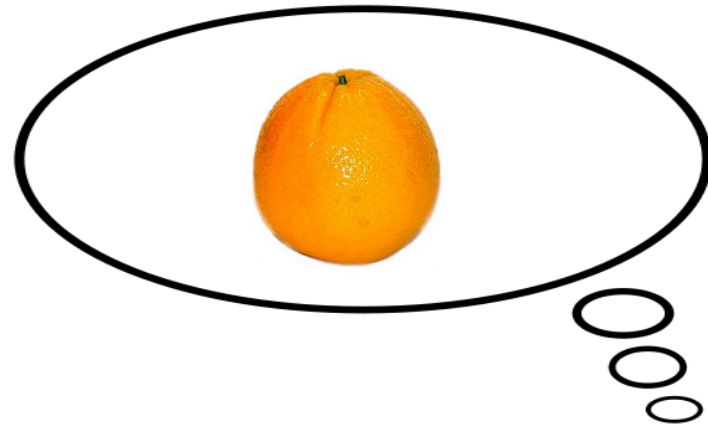


- Operator: Make-OJ
- Pre-condition: Orange(O1)
- Action: Make-OJ(O1,O2)
- Effects:
 - Delete: (Orange(O1))
 - Add: (Orange-Juice(O2))

Belief



Believe (M,Orange(O1))





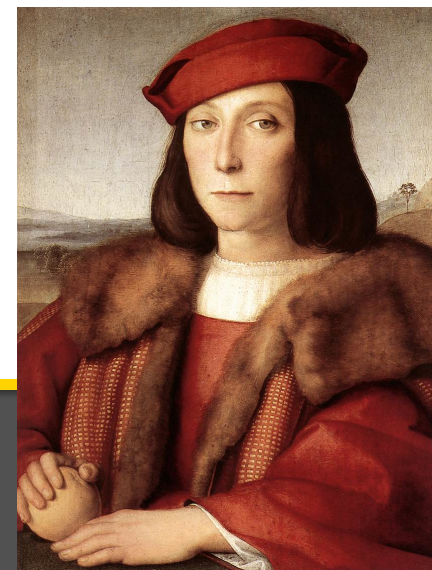
Rational Agency (BDI)

Believe (M, Orange(O1))

Desire (M, $\exists y$: Orange-Juice(y))

Intend (M, Make-OJ(O1,O2))

Want Orange-Juice(Y)
 $\neg \exists y$: Orange-Juice(Y)
Orange(O1)





Rational Agency

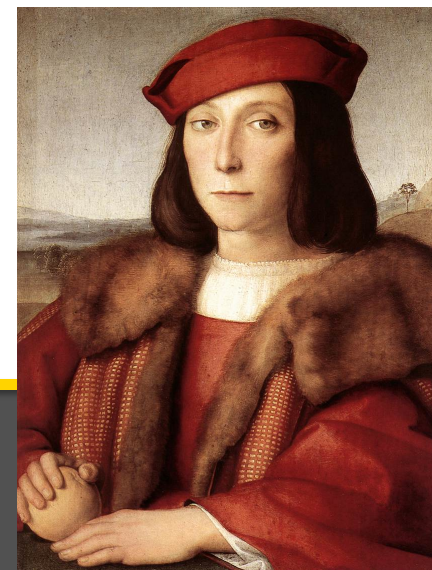
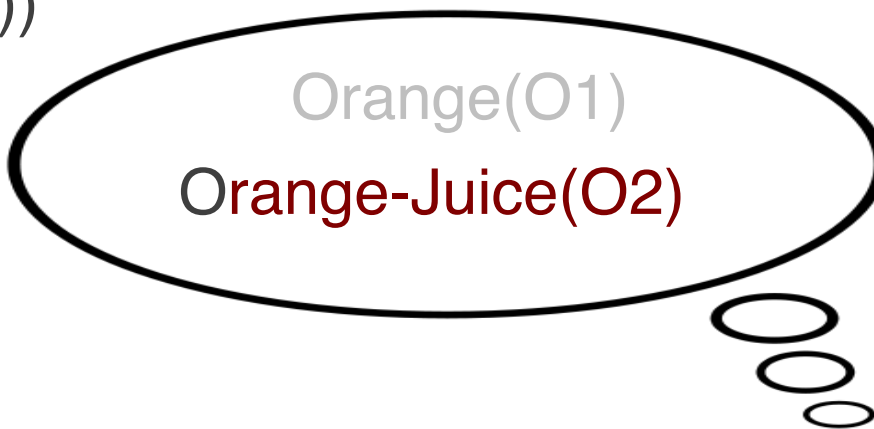
Believe Orange(O1)

Desire (M, $\exists y$: Orange-Juice(y))

Intend(M, Make-OJ(O1,O2))

Perform(M, Make-OJ(O1,O2))

Orange-Juice(O2)



Rational Agency

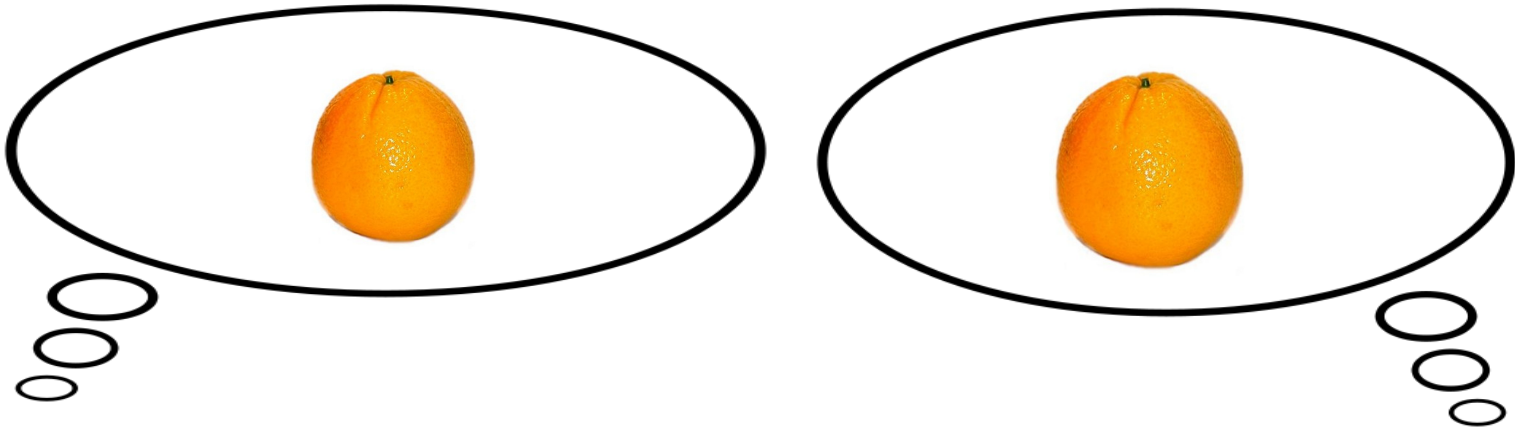


Desire (M, $\exists y$: Orange-Juice(y))
Believe Orange-Juice(O2)

$\neg \exists x$: Orange(x)
Orange-Juice(O2)



Same Belief



Individual And Joint Attitudes

Individual Attitudes

- **Belief**
- **Desire**
- **Plan**
- **Intention**

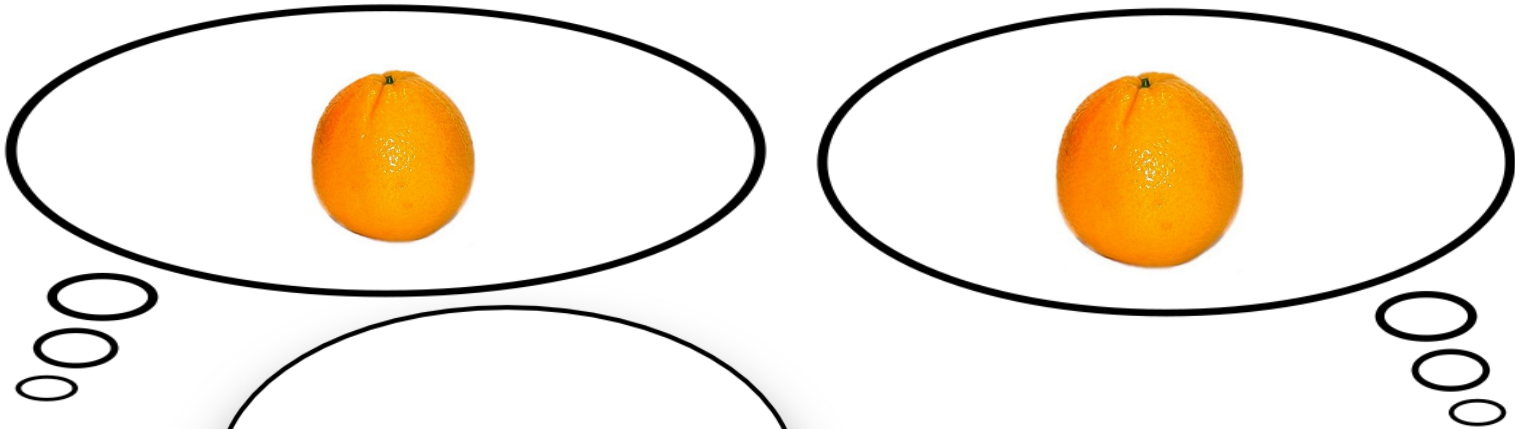
Multiparty (asymmetric) Attitudes

- **Social Commitment**
- **Obligation**

Joint Attitudes

- **Mutual Belief**
- **Joint Intention**
- **Shared Plan**

Communication



An orange



COMMON GROUND: HOW IS IT MODELED AND ACHIEVED?

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Common Ground needed for

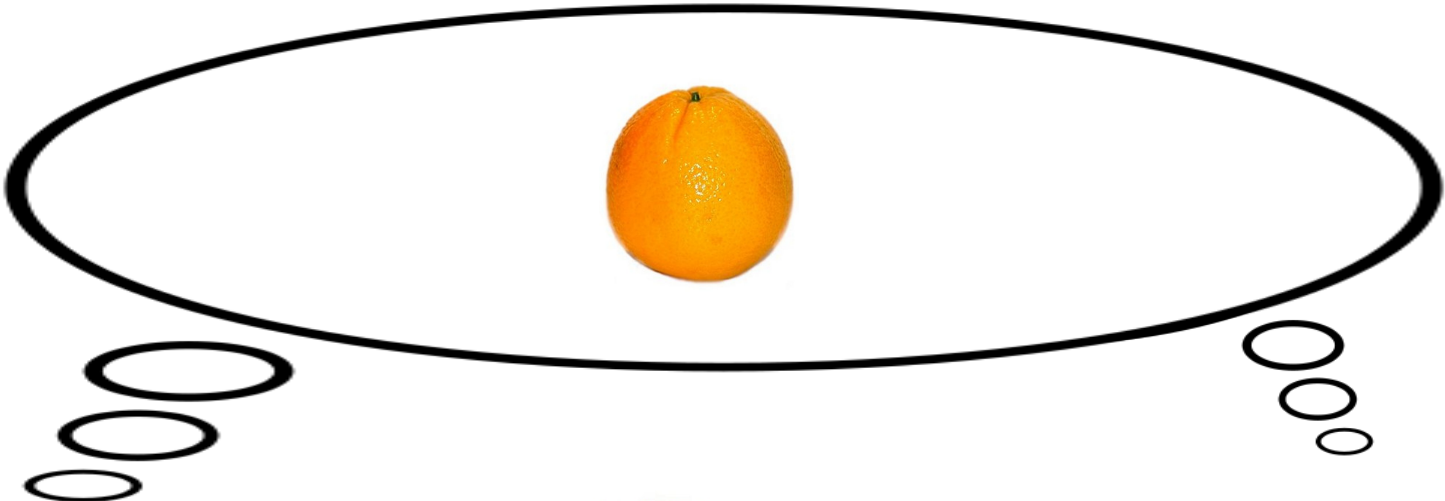


- Concepts (objects, actions, plans,...)
 - Sound -> language Phoneme
 - Phonology
 - Morphology
 - Concept -> word
 - Syntax
 - Semantics
 - Pragmatics
- Coordination
 - Convention
 - Which side of the street to drive on?
 - “Dagen H”
5am on Sunday, 3 September 1967

Models of Common Ground (MK, MB,...)

- **Primitive Attitude**

Mutual Belief

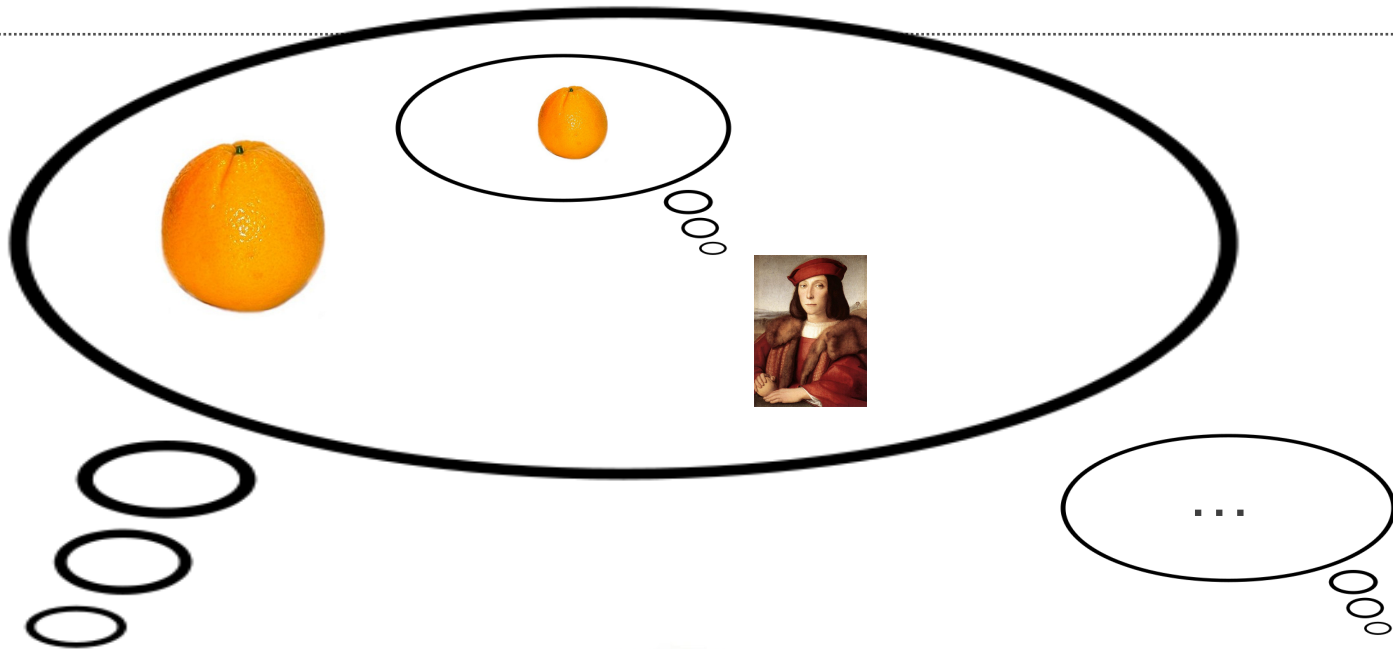


Models of Common Ground (MK, MB,...)

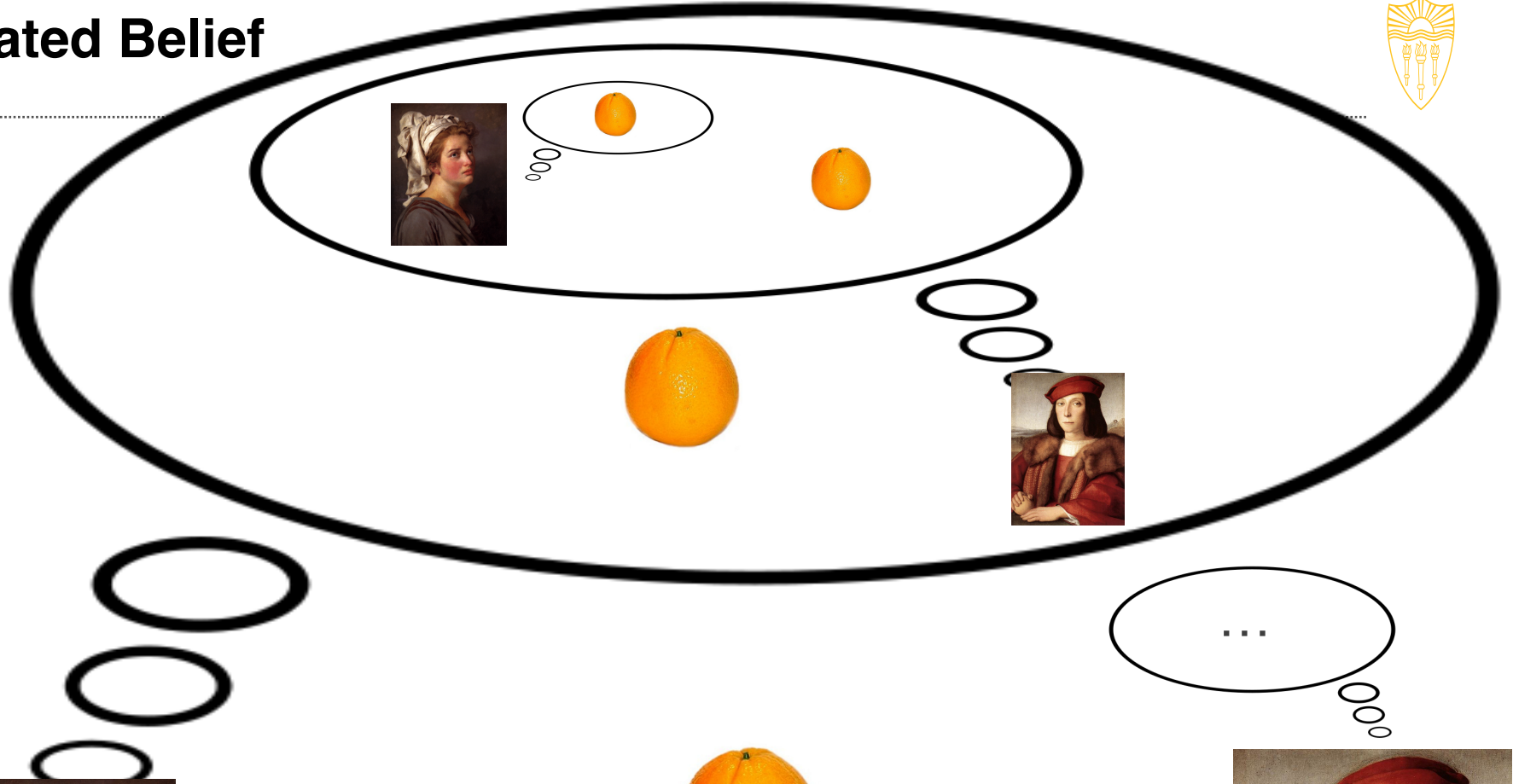
- **Iterated (Schiffer 72)**

- $K_{sp} \wedge K_{Ap} \wedge K_S K_{Ap} \wedge K_A K_{sp} \wedge K_S K_A K_{sp} \wedge \dots$

2nd level Iterated Belief



3rd level Iterated Belief



gies

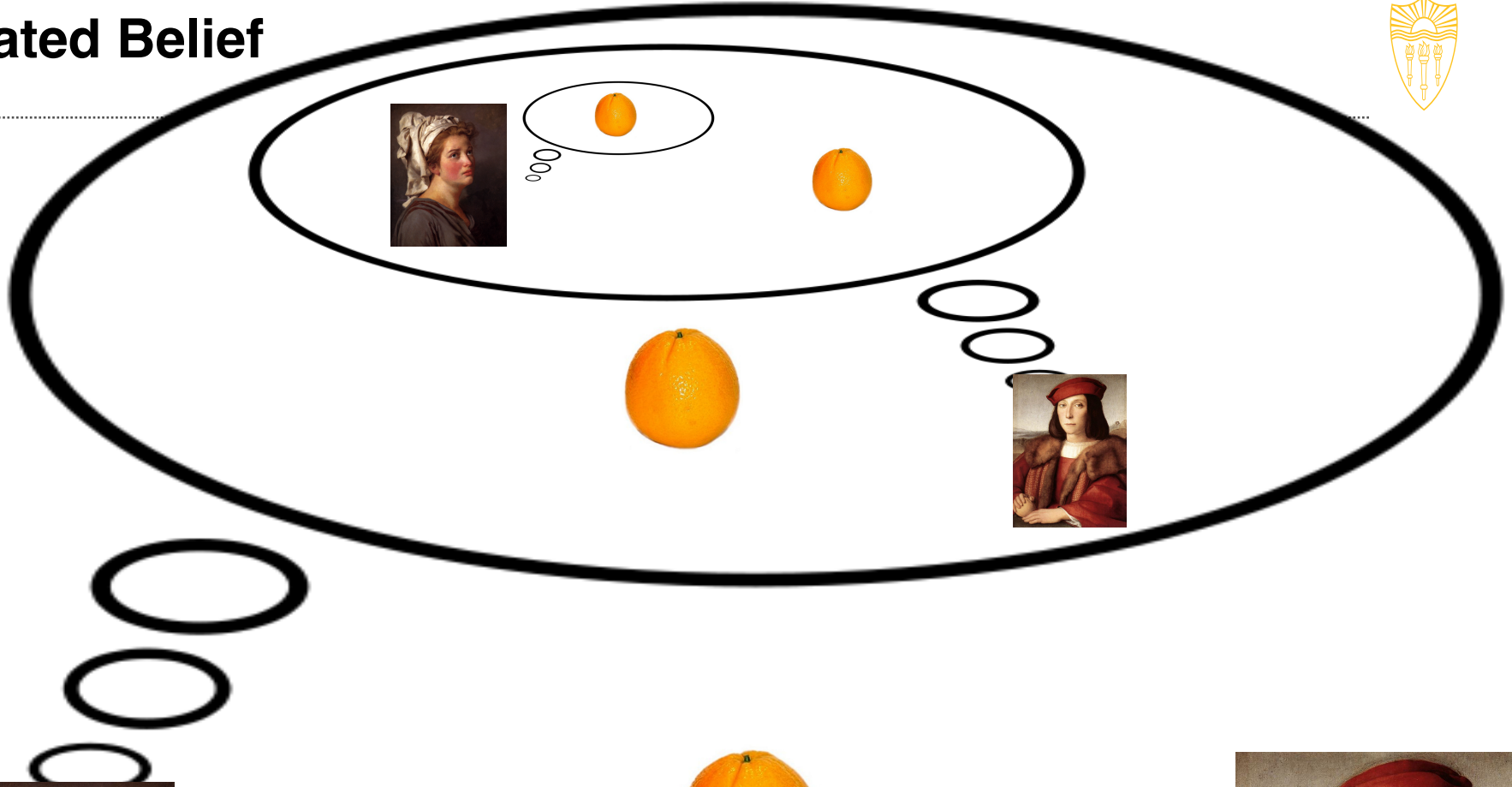


Univer

Models of Common Ground (MK, MB,...)

- **One-sided (e.g., Cohen '78 BMB)**

One-sided Iterated Belief



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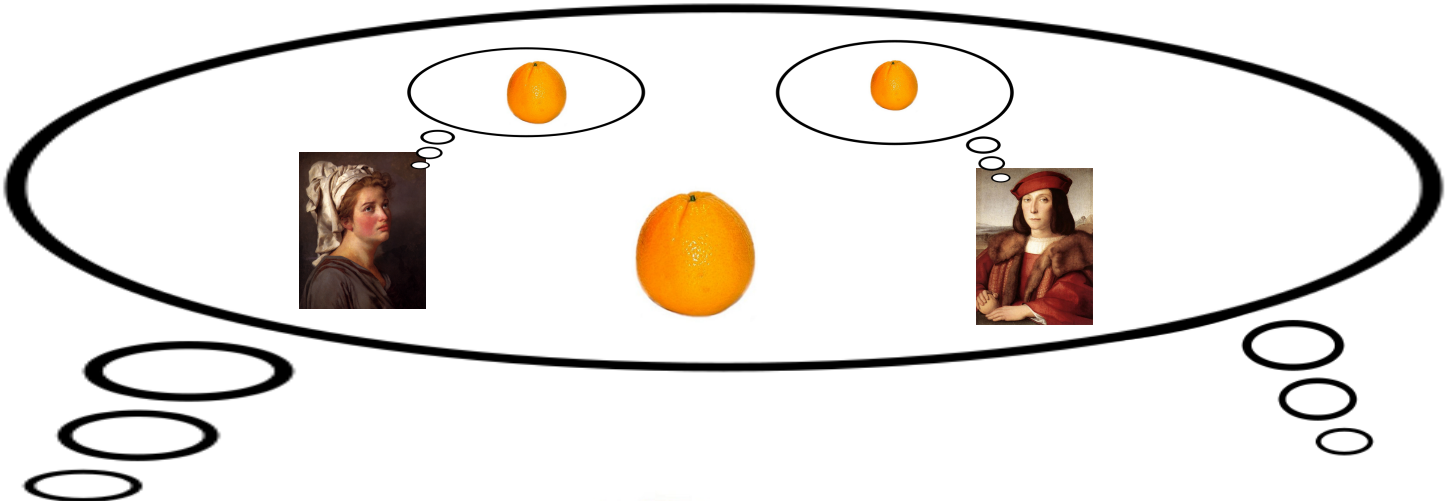


Univer

Models of Common Ground (MK, MB,...)

- **Fixed Point (Harman 77):** “A group of people have mutual knowledge of p if each knows p and we know this, where *this* refers to the whole fact known”
- **Shared Situation (Lewis 69):** Let us say that it is *common knowledge* in a population P that X if and only if some state of affairs A holds such that:
 1. Everyone in P has reason to believe that A holds.
 2. A indicates to everyone in P that everyone in P has reason to believe that A holds.
 3. A indicates to everyone in P that X .

Mutual Belief



Models of Common Ground (MK, MB,...)

- **Primitive Attitude**
- **Iterated (Schiffer 72)**
 - $K_{Sp} \wedge K_{Ap} \wedge K_S K_{Ap} \wedge K_A K_{Sp} \wedge K_S K_A K_{Sp} \wedge \dots$
- **One-sided (e.g., Cohen '78 BMB)**
- **Fixed Point (Harman 77):** “A group of people have mutual knowledge of p if each knows p and we know this, where *this* refers to the whole fact known”
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How is Common Ground Achieved/Assumed?

- **Iterated: proof of individual attitudes**
 - Truncation heuristics
 - Circular pointer in deepest beliefs (Cohen 78)

How is Common Ground Achieved/Assumed?

- **Iterated: proof of individual attitudes**
 - Truncation heuristics – Clark and Marshall '81

VERSION 1: On Wednesday morning Ann reads the early edition of the newspaper which says that *Monkey Business* is playing that night. Later she sees Bob and asks, *Have you ever seen the movie showing at the Roxy tonight?*

$K(A,t \text{ is } R)$

VERSION 2: On Wednesday morning Ann and Bob read the early edition of the newspaper and discuss the fact that it says that *A Day at the Races* is showing that night at the Roxy. Later, after Bob has left, Ann gets the late edition, which prints a correction, which is that it is *Monkey Business* that is actually showing that night. Later, Ann sees Bob and asks, *Have you ever seen the movie showing at the Roxy tonight?*

$K(A,K(B,t \text{ is } R))$

How is Common Ground Achieved/Assumed?

- **Iterated: proof of individual attitudes**
 - Truncation heuristics – Clark and Marshall '81

VERSION 3: On Wednesday morning Ann and Bob read the early edition of the newspaper, and they discuss the fact that it says that *A Day at the Races* is showing that night at the Roxy. When the late edition arrives, Bob reads the movie section, notes that the film has been corrected to *Monkey Business*, and circles it with his red pen. Later, Ann picks up the late edition, notes the correction and recognizes Bob's circle around it. She also realizes that Bob has no way of knowing that she has seen the late edition. Later that day Ann sees Bob and asks, *Have you ever seen the movie showing at the Roxy tonight?*

$K(A, K(B, K(A, t \text{ is } R)))$

VERSION 4: On Wednesday morning Ann and Bob read the early edition of the newspaper and discuss the fact that it says that *A Day at the Races* is playing that night at the Roxy. Later, Ann sees the late edition, notes that the movie has been corrected to *Monkey Business*, and marks it with her blue pencil. Still later, as Ann watches without Bob knowing it, he picks up the late edition and sees Ann's pencil mark. That afternoon, Ann sees Bob and asks, *Have you ever seen the movie showing at the Roxy tonight?*

$K(A, K(B, K(A, K(B, t \text{ is } R))))$

How is Common Ground Achieved/Assumed?

- **Iterated: proof of individual attitudes**
 - Truncation heuristics – Clark and Marshall '81

VERSION 5: On Wednesday morning Ann and Bob read the early edition of the newspaper and discuss the fact that it says that *A Day at the Races* is playing that night at the Roxy. Later, Bob sees the late edition, notices the correction of the movie to *Monkey Business*, and circles it with his red pen. Later, Ann picks up the newspaper, sees the correction, and recognizes Bob's red pen mark. Bob happens to see her notice the correction and his red pen mark. In the mirror Ann sees Bob watch all this, but realizes that Bob hasn't seen that she has noticed him. Later that day, Ann sees Bob and asks, *Have you ever seen the movie showing at the Roxy tonight?*

$$K(A, K(B, K(A, K(B, K(A, t \text{ is } R))))))$$

How is Common Ground Achieved/Assumed?

- **Iterated: proof of individual attitudes**
 - Truncation heuristics
 - Example: Vizzini in Princess Bride:



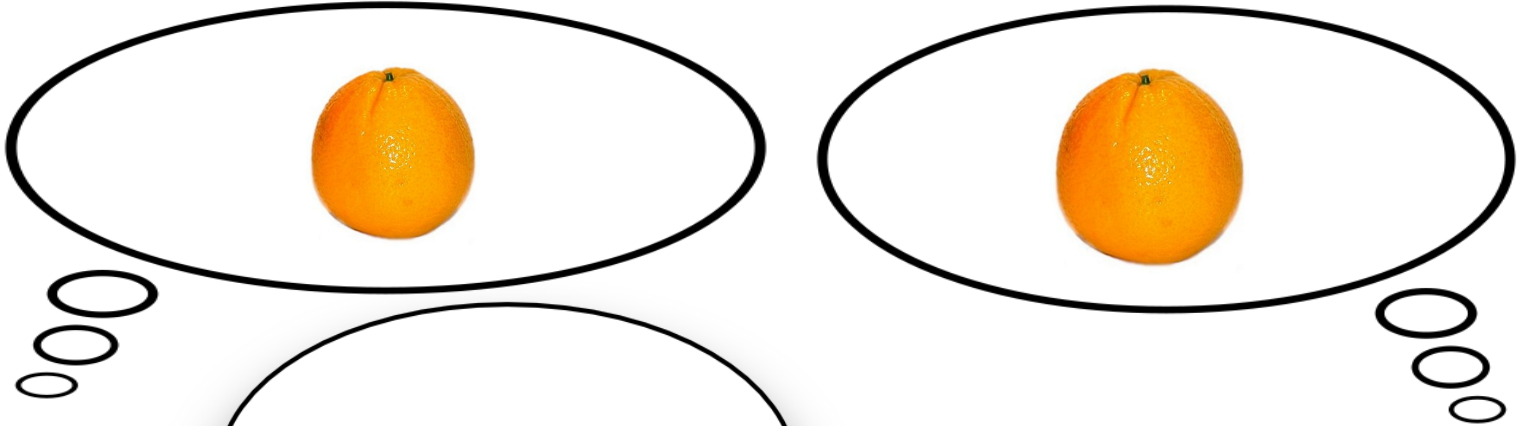
How is Common Ground Achieved/Assumed?

- Shared Situation (Clark & Marshall)
 - Observation of situation. Assumptions of sharedness

Basis for mutual knowledge	Auxiliary assumptions
1. Community membership	Community co-membership, universality of knowledge
2. Physical copresence	
a. Immediate	Simultaneity, attention, rationality
b. Potential	Simultaneity, attention, rationality, locatability
c. Prior	Simultaneity, attention, rationality, recallability
3. Linguistic copresence	
a. Potential	Simultaneity, attention, rationality, locatability, understandability
b. Prior	Simultaneity, attention, rationality, recallability, understandability
4. Indirect copresence	
a. Physical	Simultaneity, attention, rationality (locatability or recallability), associativity
b. Linguistic	Simultaneity, attention, rationality, (locatability or recallability), associativity, understandability

Table 2.1: Clark & Marshall's Methods of Achieving Copresence for Mutual Knowledge

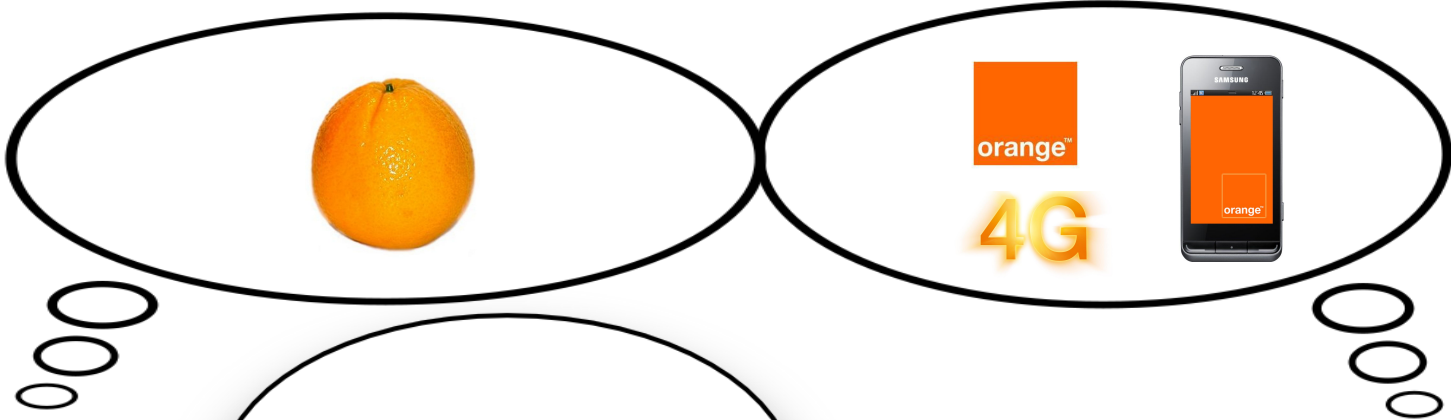
Communication



An orange



Miscommunication



An orange



How is Common Ground Achieved/Assumed?

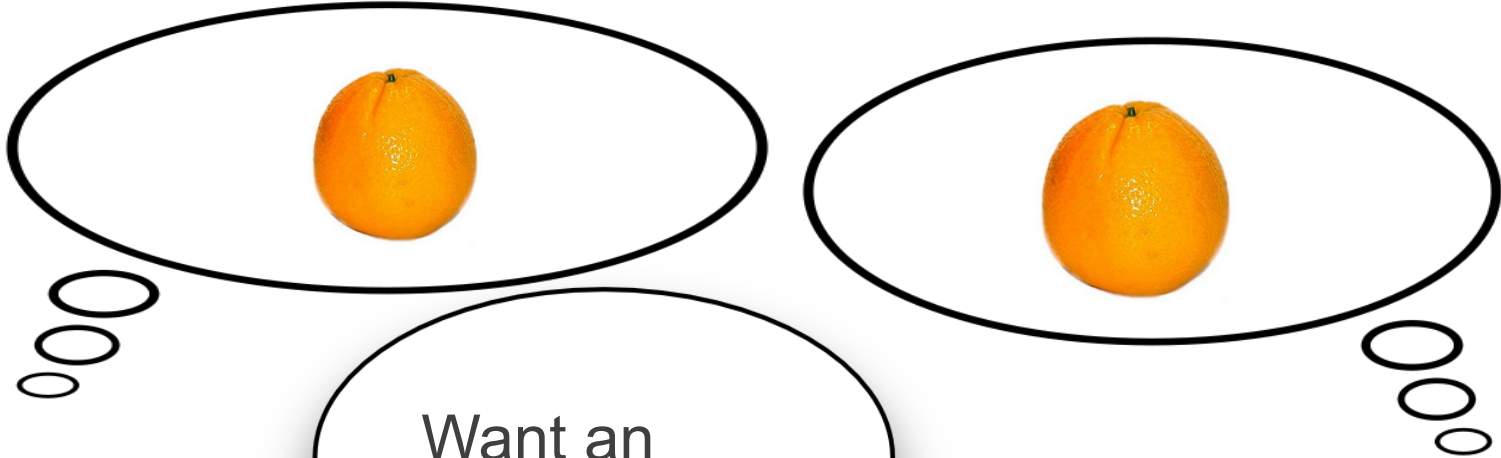
- **Grounding**
 - Feedback process

Clark & Schaefer's contribution model

▪ Contributions to dialogue are collaborative achievements composed of two phases:

- **Presentation Phase:** A presents utterance **u** for B to consider. He does so on the assumption that, if B gives evidence **e** or stronger, he can believe that B understands what A means by **u**
- **Acceptance Phase:** B accepts utterance **u** by giving evidence **e'** that he believes he understands what A means by **u**. He does so on the assumption that, once A registers evidence **e'**, he will also believe that B understands.

Communication



Want an orange?

An orange sounds yummy, thanks!



How is Common Ground Achieved/Assumed?

- **Iterated: proof of individual attitudes**
 - Truncation heuristics
 - Circular pointer in deepest beliefs (Cohen 78)
- **Shared Situation**
 - Observation of situation
 - Assumptions of sharedness (Clark & Marshall 81)
- **Grounding**
 - Feedback process (Clark & Schaefer 89)

CLARK & SCHAEFER'S CONTRIBUTION MODEL OF GROUNDING

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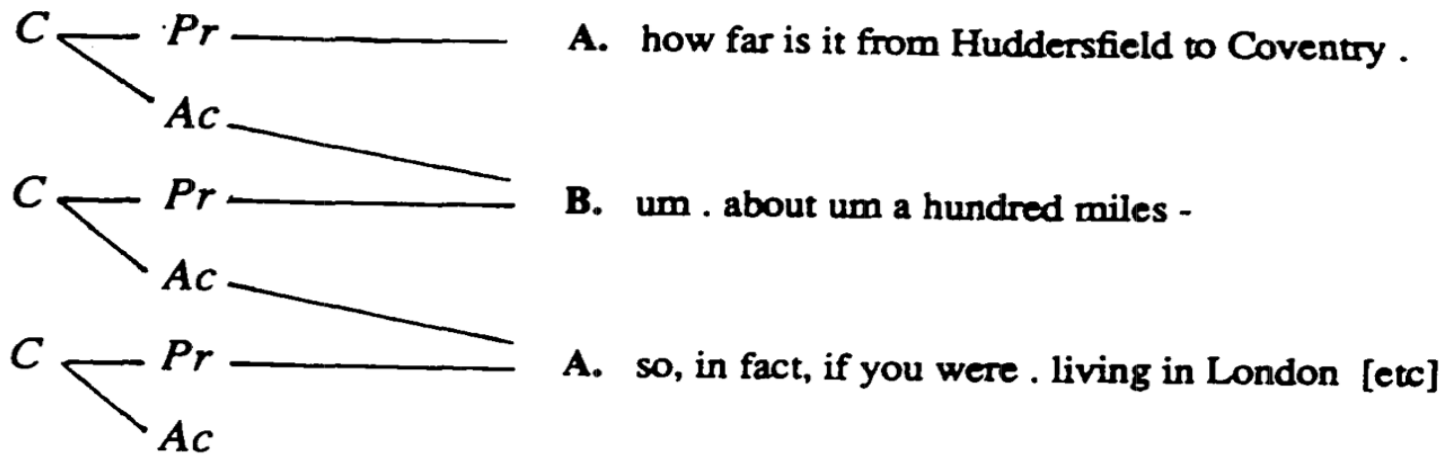


Clark & Schaefer's contribution model

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Serial Contribution Graphs



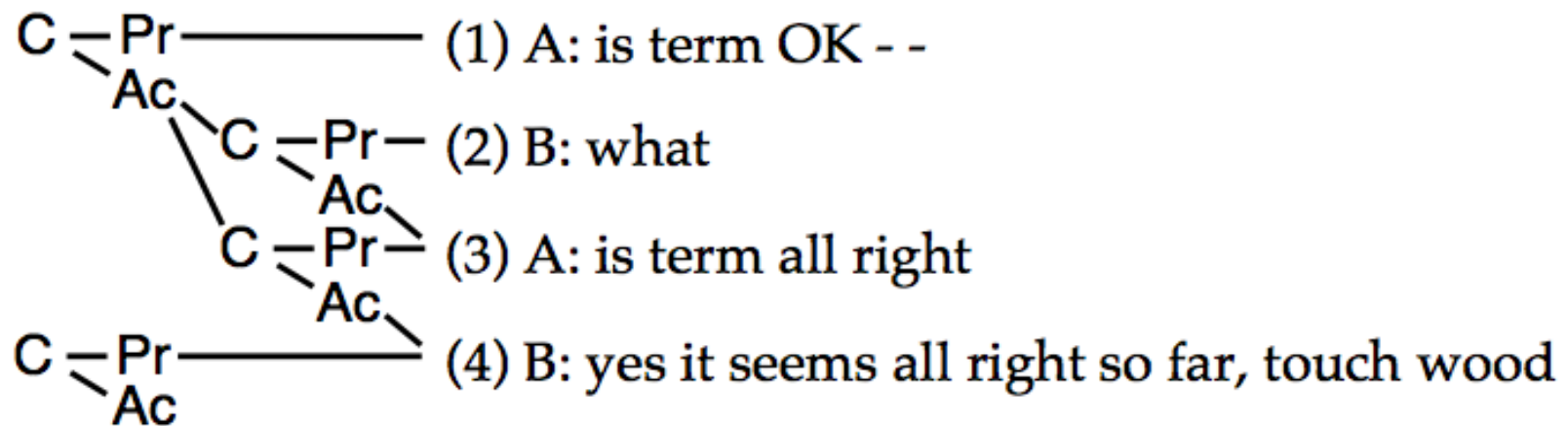
Contribution Model

- **Each signal is also a presentation to be grounded**
 - Recursive model
- **Grounding Criterion:** “The contributor and the partners mutually believe that the partners have understood what the contributor meant to a criterion sufficient for the current purpose”

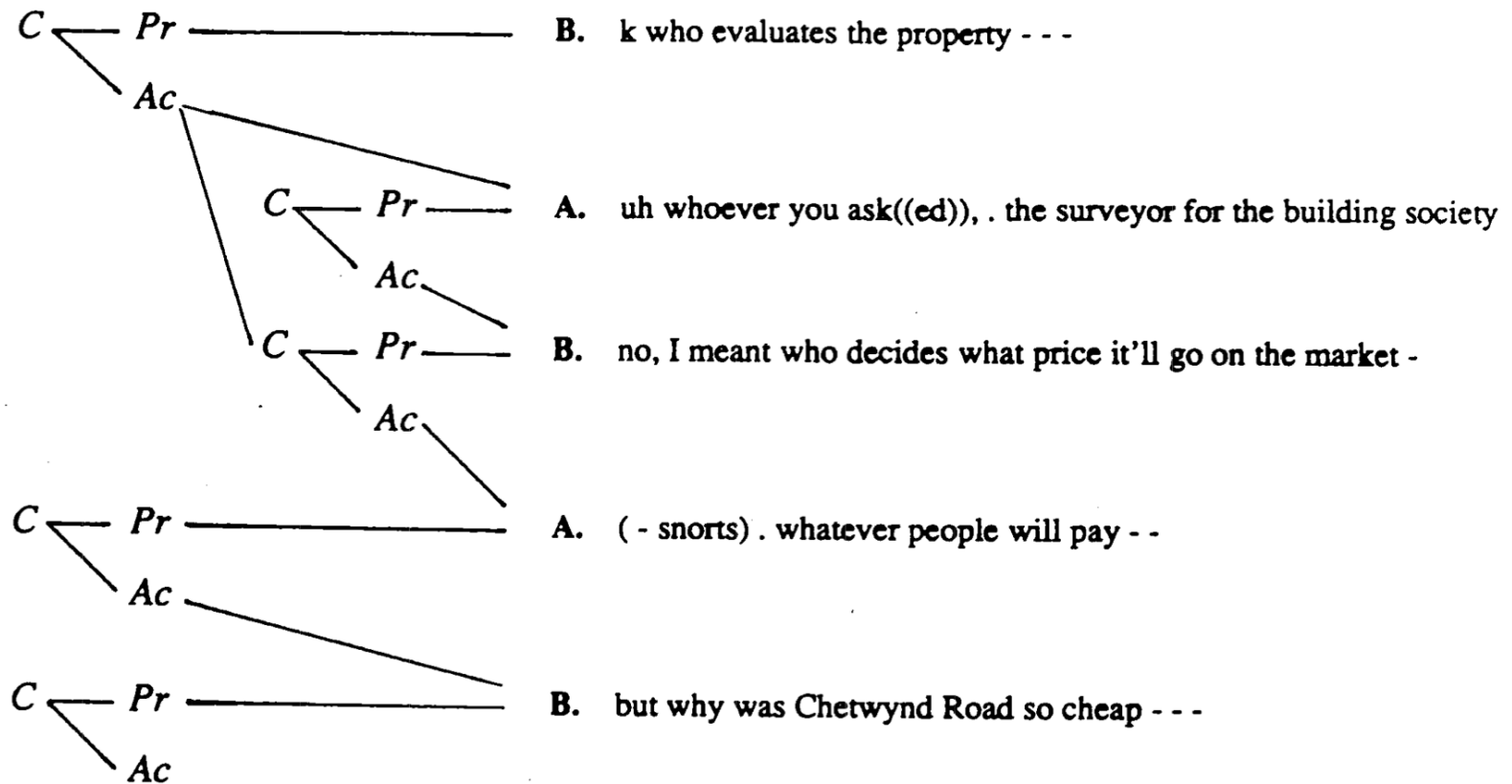
▪ **Graded Evidence:**

1	Display	B displays verbatim all or part of A’s presentation.
2	Demonstration	B demonstrates all or part of what he has understood A to mean.
3	Acknowledgement	B nods or says “uh huh”, “yeah”, or the like.
4	Initiation of relevant next contribution	B starts in on the next contribution that would be relevant at a level as high as the current one.
5	Continued attention	B shows that he is continuing to attend and therefore remains satisfied with A’s presentation.

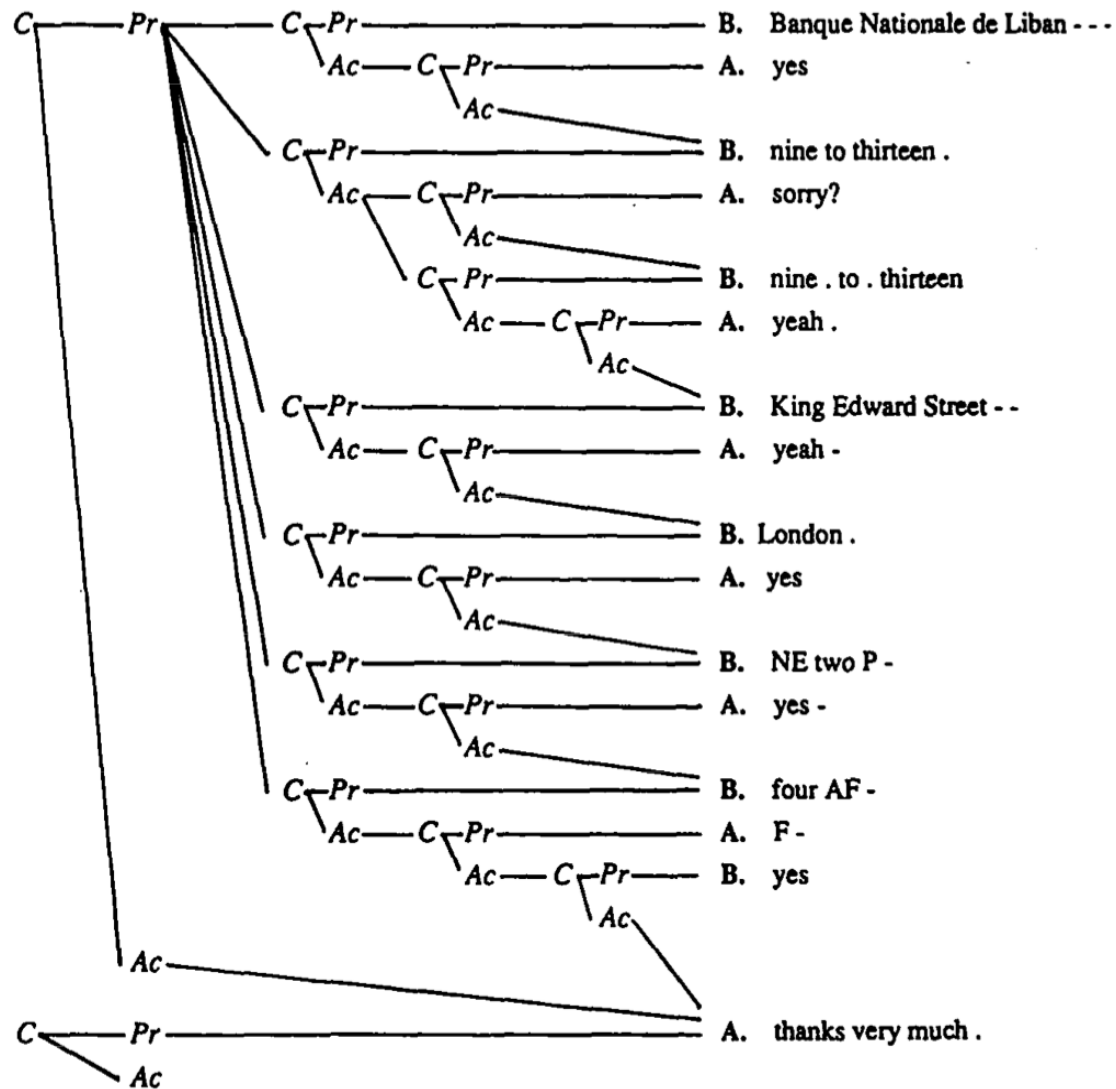
Example of Contribution model – embedded repair request



Contributions with embedded repairs



Contribution with installments



Deficiencies of Contribution Model

- **Off-line model**
 - No way to tell recursion has finished until after the fact
 - No clear specification of moves (for interpretation & generation)
 - Not predictive of next utterances
- **Issues with types of evidence**

Types of Evidence

- **Display: B repeats A' s presentation verbatim** Strongest?
- **Demonstration: B demonstrates what he has understood**
- **Acknowledgement: B makes some sign that he has understood**
- **Initiate Next Contribution: B makes a relevant contribution** Oblivious?
- **Continued Attention: B shows he is satisfied with A' s presentation**



Grounding Gone Wrong



But “Hu” really is on first!

