Linking Earth Systems Models to Social Population Agent Based Models Through Geography

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Presentation prepared for the First Workshop on Understanding Climate Change Through Data at the University of Minnesota in Minneapolis, August 15-16, 2011.

Outline

- The goal
- Earth Systems Models
- Epidemiologists and computer scientists
- Agent modelers
- Lynch’s event algebra for idea possession and transfer
- Shared-idea networks
- Example of idea transfer
- Mechanisms for acting upon new ideas
- Data needs for linked model

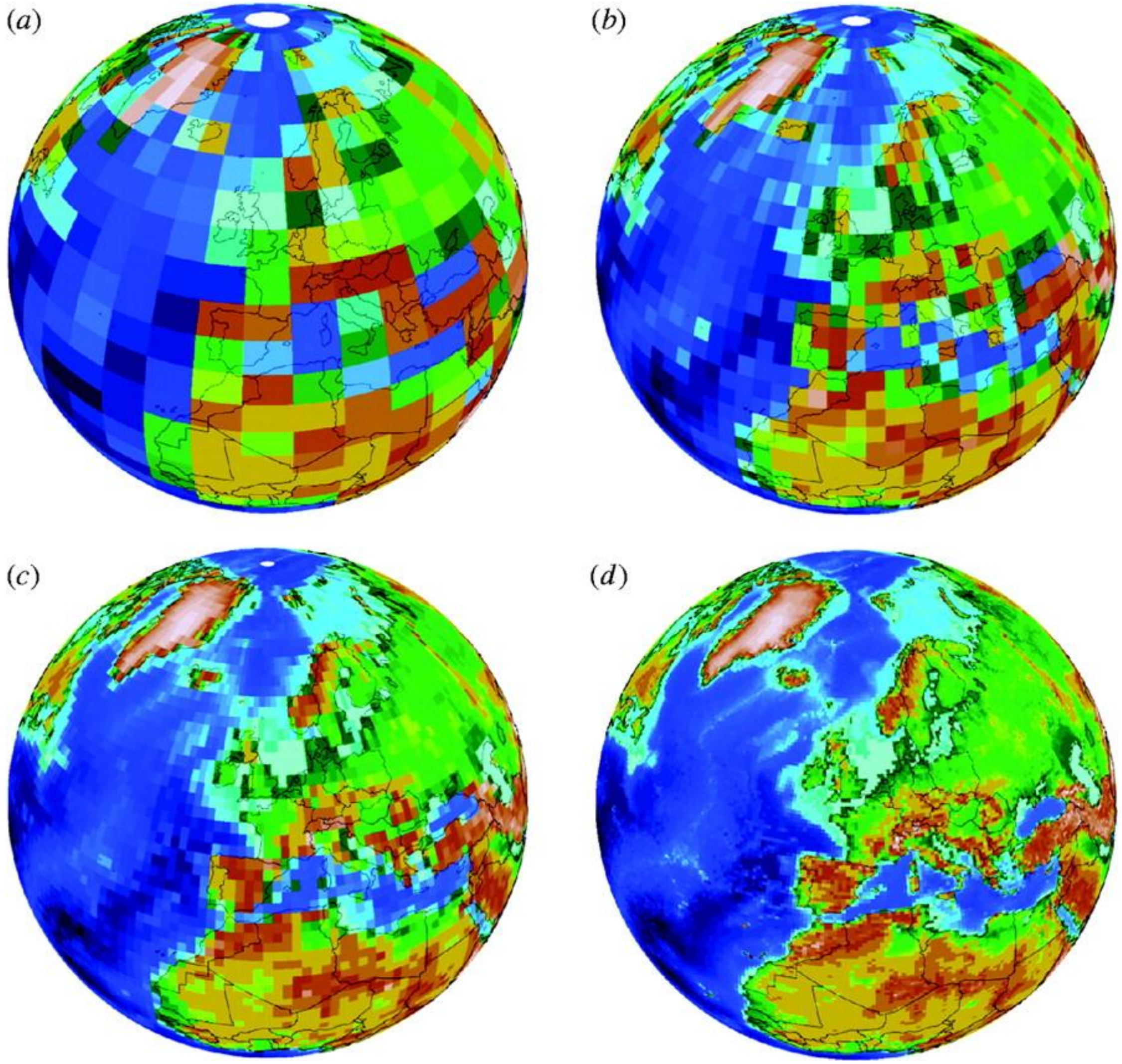
The Goal

- The goal should be to build a global-scale computational model that simulates the interplay between changes to the biophysical environment and the human populations affected by them
- To do that the computational model must link biophysical processes to social processes through populations “living” in geographic locations
- The goal thus should be to link an earth systems model with a high degree of geographic detail with a parallel social population model (agent-based) containing a geographically distributed population that “experiences” the changing environment and responds to the changes

What Have the Earth Systems Scientists Done?

- They are building a very good and powerful forecasting capability
- A sizable set (~20) of sophisticated computer simulation models
  - Significant evidence supports the way the models represent and thus simulate different processes
  - Models can generate a wide range of forecast trajectories depending upon different input trajectories and assumptions
  - Different models are both compatible and varied
  - Similar results from different models adds to confidence in the forecasts
- Policies and procedures for coordinating the activities of independent modeling teams
  - Enables the "ensemble" forecasts used by the IPCC
- A process for a back-and-forth exchange between data gatherers, data analysts, theoreticians, and computational modelers
  - Empowers the development of more and ever better process models that form the simulations

Horizontal resolution of the contemporary atmospheric and ocean climate model components



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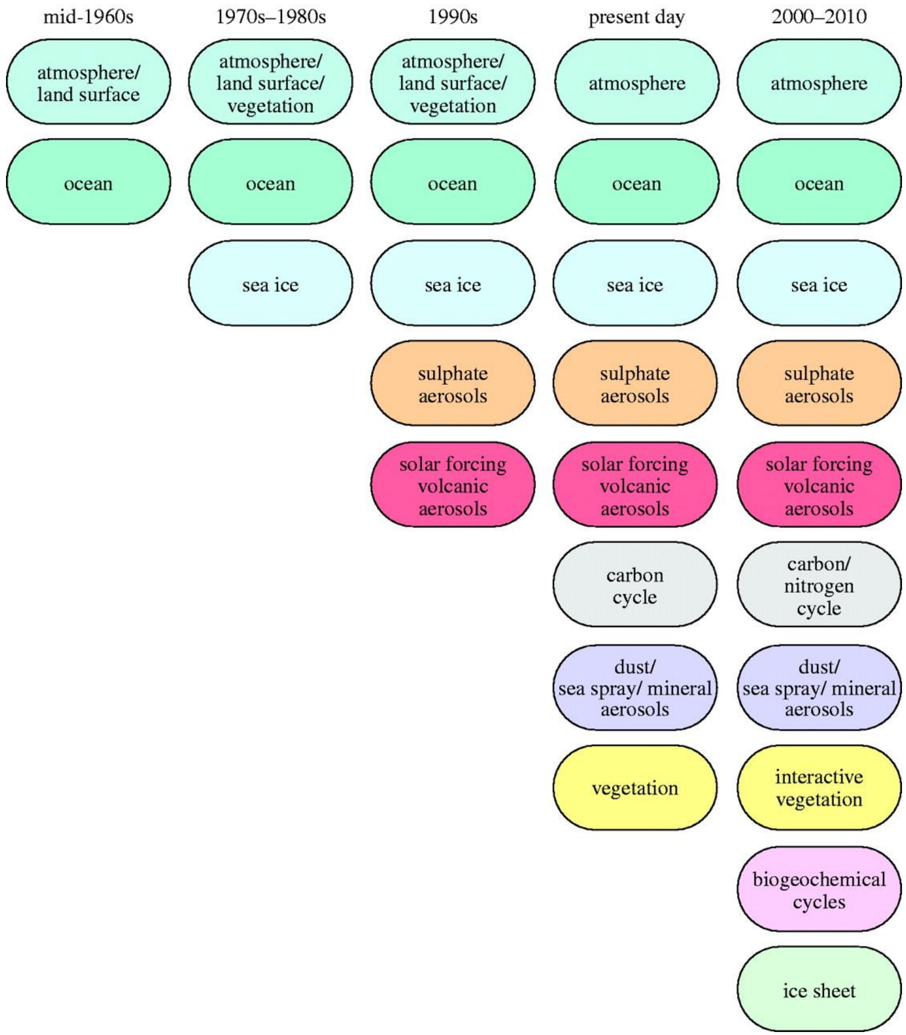
Progress in Terms of Integration

- Two forms of integration
- Integration of different processes within a computational model
  - How you encompass and define chains of causation
  - Allows for feedback loops that may range far afield from a particular process
- Integration of the results of the models
  - Coordination of the teams’ activities so that they generate comparable results
    - Protocols for data exchange and the nature of scenario experiments
  - Allows for tests of scenarios that are implemented with different representations of physical, chemical, geological, or biological processes at different geographical locations
  - Consistent results from a set of independently developed models have more “weight” than results from one model

The time history of the climate model components and coupled climate model development (past, present and future)



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Coordination of Data

- The coordination of data formats is done by the scientific and modeling communities
- They wish to be able to bridge between climate data and the data streams generated by the computational models
  - So that models can be compared against historical data
- They wish to be able to link the data from different domains and models
  - Atmosphere, surface, ocean
- They have adopted a format that locates data by time-space and sometimes as a function of other variables
- Coordination is achieved by use of Net CDF, a set of software interfaces, libraries, and machine-independent data formats that allows programmers to have different data analysis, data visualization, and simulation programs able to read and write data to a common standard

What Exists With Respect to a Parallel Social Population Model?

- Parallel in that the population is geographically distributed in the same way that the bio-physical processes in the earth systems models are geographically distributed
- There are a number of research threads that can be brought together to make such a model

What We Found From Epidemiologists

- Epidemiologists working with computer scientists have developed very large agent-based computational models with synthetic populations the size of the United States in which the social agents are:
  - Geographically distributed in a manner consistent with the population being emulated
  - Given attributes consistent with the (sub)populations where the social agents are located
  - Connected to (and “mix” with) each other through social networks of both close and casual contacts that have been identified through social network studies
  - Going about daily activities identified from the social network studies, including moving from place to place as the computational model steps through simulated time

The Representation of an Emotion: Fear

- Epstein and colleagues (2008) extended the epidemiological models by adding to the agents' set of characteristics the ability for the agents to possess an important binary condition:
  – Did the agents "feel" fear because of knowledge of a disease outbreak or did they not have that fear?
- If the agents possessed the characteristic of feeling fear (a variable switched to On), they would behave differently.
  – They would be more likely to stay home thereby changing the progression of the disease

Agents as Individuals

- Two other research threads have developed large populations of sophisticated agents that operate and interact within a computational model
  - Evolutionary economists
  - Artificial society simulators
- The goal is to create societies that have as their foundation populations of individuals–in the computer
  - To do that they try to represent individuals in significant detail
- Two projects deserve mention

Linking the Physical With the Social

- Silverman and colleagues have imbued social agents with
  - Physiology (nourishment, injury level, sleep need, etc.)
  - Stress and coping style
  - Value “trees” with respect to goals, standards, and preferences
  - Social roles and relationships
  - Differences in how decisions are made across agents
  - Perception and inferential modeling of others
  - Existence within social factions consisting of leaders and followers
- Chaturvedi and colleagues have provided their agents with
  - Traits (demographics, religion, nationalism, etc.)
  - Sensors (communications from media or other agents)
  - Perception and short and long-term memory
  - Expectations and predispositions
  - Existence within a social environment consisting of governments, media, infrastructure, institutions, and organizations

Extending the Social Population Models by Adding Ideas

- Combined capabilities of agent-based models include
  - Agents correctly geographically located
  - Many social and demographic variables describing agents and their situations
  - Embryonic representations of agents both:
    - Possessing sensors and bio-physical responses
    - Internal mechanisms for responding to changing environments
    - Operating within broader societies including groups, tribes, governments, and institutions
    - Having a particular emotion or not
- A logical next step is to give the agents the capability to possess, share, and act upon ideas

Aaron Lynch and Mnemons

- In "Units, Events, and Dynamics in Memetic Evolution" (1998), Aaron Lynch set the foundations for representing social actors possessing and sharing ideas
- He argued that ideas could be thought of as memory constructs and that those memory constructs could be abstracted into the concept of a mnemon (neemon)
  - An idea is a memory construct is a mnemon
- Lynch showed how to work with mnemons such that we can describe idea possession and transfer events
- The transfer of memory constructs (embodied in data structures) is thus a way to simulate the transfer of an idea from one social agent (individual) to another

Lynch’s Mathematical Foundation

- Lynch created a proto-algebra for mnemon (idea) transfer that enables representation of:
  - States and change of state of mnemon possession
  - Multiple mnemons and mnemon configurations
  - Mnemon transfers that generate memes and those that do not
  - Complementary or competing mnemons in terms of creating a meme
  - Multi-stage transitions of an individual from one mnemon state to another
  - Network size threshold effect regarding mnemon transfer
  - Mass media transfer of mnemons
  - Categories or groups of social agents
  - Location and situation dependence of mnemon transfer
  - Deception

Basic Idea Transfer Events

- $A*{\sim}B + {\sim}A*B \Longrightarrow A*{\sim}B + A*B$
- “Person with one mnemon transferring it to another person with a different mnemon” event

- $A*{\sim}B + {\sim}A*B \Longrightarrow A*B + A*B$ *(or $2A*B$)*
- “Two individuals transfer a mnemon to each other” event

- $(A*B*C) + {\sim}A*{\sim}B*{\sim}C \Longrightarrow 2A*B*C$
- “Combination of three mnemons enabling transfer of each mnemon” event

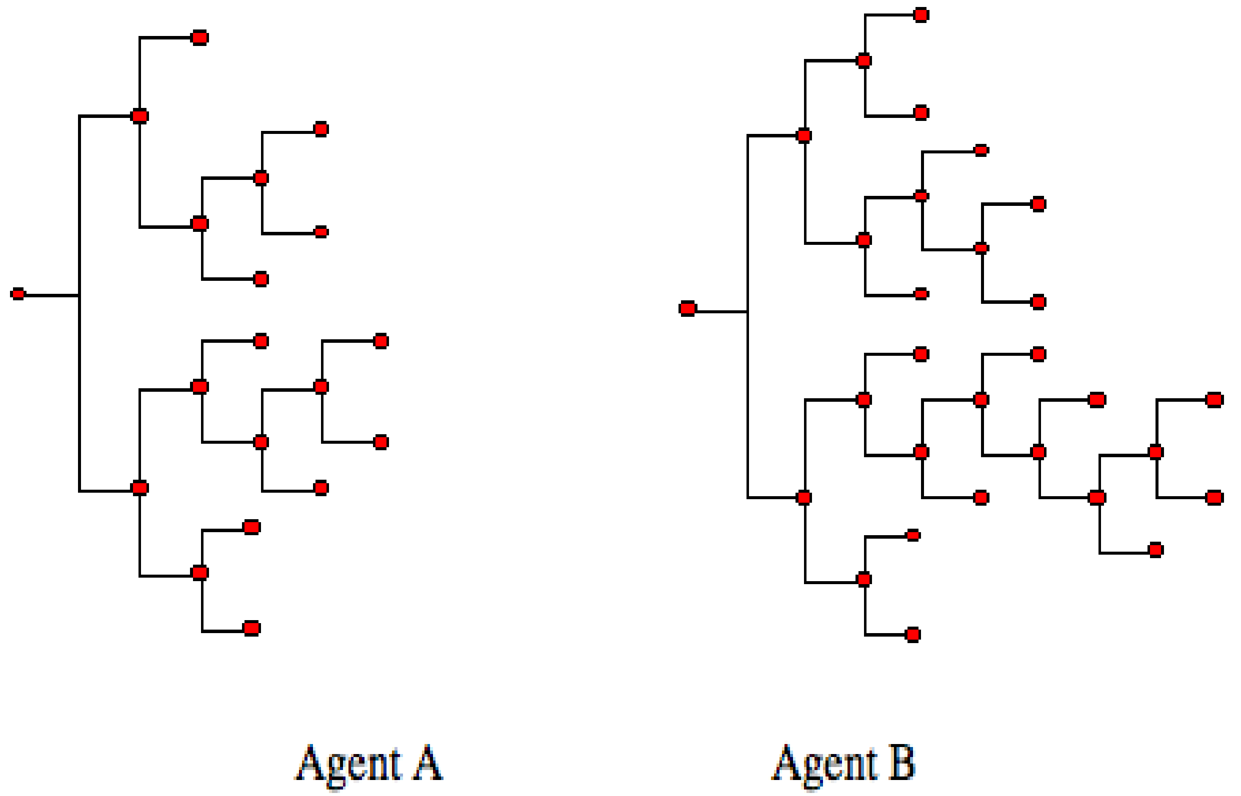
Shared-idea Networks

- When a mnemon gets transferred from one host to another agent (that agent now becoming a host), the two hosts form a shared-idea network
- As a mnemon continues to get transferred to additional agents, the shared-idea network grows
- A shared-idea network is unique to a mnemon
  - It is possible for a mnemon to be a fuzzy concept, which would allow for larger shared-idea networks
- More precisely, a set of hosts possessing the same (or perhaps very similar) mnemon defines a shared-idea network, individuals linked in that they possess the same idea (mnemon)
- A meme is a shared-idea network that grows rapidly to a large size

What This Means

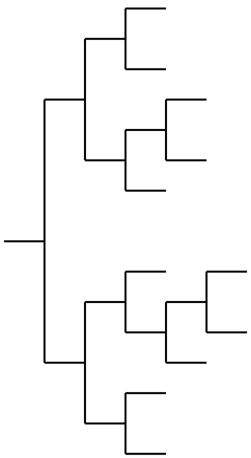
- The Lynch event algebra makes it possible to express the transfer of memory constructs that comprise a mnemon as a set of events
  - The algebraic statements define the algorithms to execute the event
- This enables an agent-based computer simulation in which social agents possess and transfer non-trivial social information, information that can and does change the behavior of the recipient agent(s)
- This makes it possible to simulate different types of ideas emerging from and percolating through a population
  - A population where the potential recipient agents respond differently in the context of different locations, situations, and histories
- This also creates an environment in which models of economic and cultural change at the mass populace level as well as institutional and regime behavior can operate

Memory Constructs for How to do Something Possessed by 2 Agents

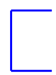


Agent B “knows” more about how to do something than Agent A.
From Morone and Taylor (2004)

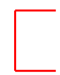
Memory Constructs as Mnemons



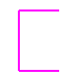
Mnemon A



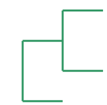
Mnemon B



Mnemon C



Mnemon D



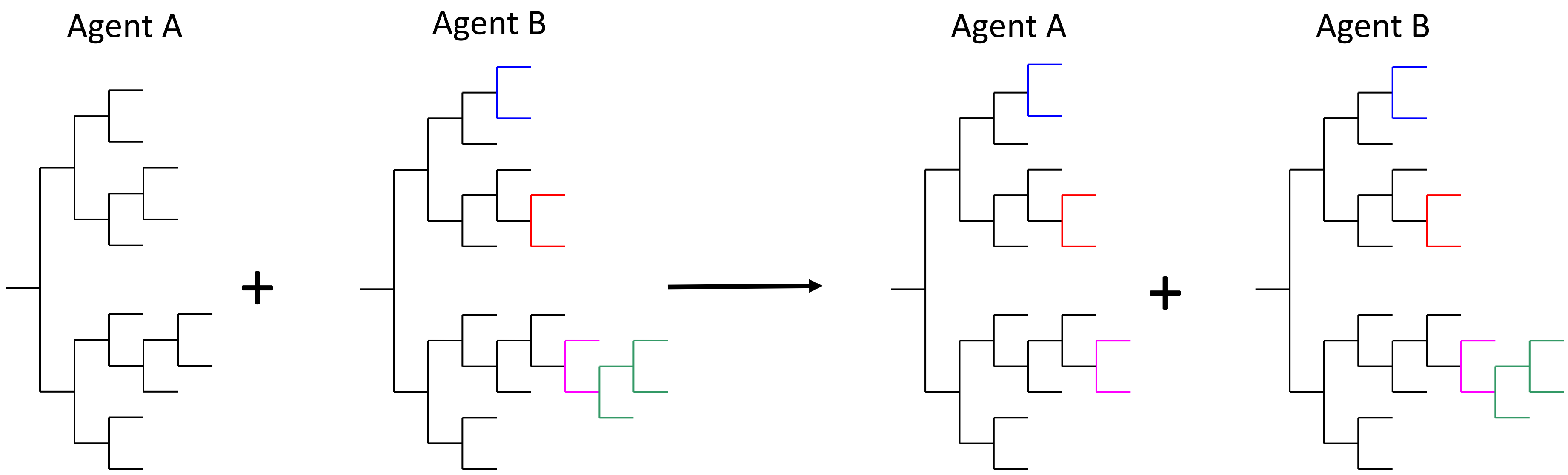
Mnemon E

Agent A possesses mnemon A

Agent B possesses mnemons A,B,C,D,E

Mnemons B,C,D are, for example, instructions in the form of: IF Condition, THEN Do Something; ELSE Do Something Different

Transfer of Memory Constructs



In Morone and Taylor example, Agent B gives three instructions to Agent A regarding how to do something, but not a fourth, even more specific instruction

The equivalent event statement using the Lynch algebra is:

A*~B*~C*~D*~E + A*B*C*D*E ==> A*B*C*D*~E + A*B*C*D*E

Mechanisms for Receiving Mnemons

- Castelfranchi (2001) independently created algorithms for three micro-mechanisms that describe how mnemons are adopted by potential hosts
  - Instrumental reasoning
  - Norms-based reasoning
  - Membership-based reasoning
- Castelfranchi and Paglieri (2007) created mechanisms and algorithms for how beliefs of different types shape goal-seeking or even purposive behavior
- Beliefs constrain the goals, intentions, agendas, and plans of social actors and thus their behaviors

Data Needs of the Linked Model

- Geographically distributed data whenever possible so that there is variation in the situations of agents
  - Need to figure out better ways to create variation using the information contained in multiple variables
- Some of these variables will be output variables from the earth systems models for each location
  - Should use existing protocols
- Ways to translate bio-physical data to the situations of social agents (e.g. sea level rise eliminating where agents live, forcing them to migrate)

Basic Mmenon Objects, Signifiers, and Operators

• A, B, C,…	Different mnemons (ideas)
• *	*Resides in same host signifier*
• A*B*C*D…	Multiple mnemons in host possible
• ~	*Does not possess signifier*
• A, ~A	Possesses mnemon or not
• ( )	*Grouping operator*
• ~(A*B*C*D)	Host possesses none of a set of ideas
• [ ]	*Calculation signifier*
• [#+1]	Some number increased by 1

Transition Events

- There are two types of transition events
- Internal transition events
- ---> *Internal transition event operator*
- A ---> ~A "Host of mnemon no longer" event
- ~A ---> A "Generation of mnemon" event
- Internal transition events represent changes describing the state or circumstances of a individual
  - Mnemon configuration, for example
  - Or the location and situation the individual is in

Interaction Plus Transition Events

- Adding the process of interaction brings about the second type of transition event, the transmission event
- A transmission event is a transition in which the mnemon configuration of an agent is changed following an interaction event with another agent
- + *Interaction event operator*
- ==> *Transmission event operator*
- A + ~A ==> 2A “Non-parental conversion” event
- Distinguishing between internal transition events and transmission events is a major change from Lynch, who did not make that distinction

Basic Idea Transfer Events

- A*~B + ~A*B ==> A*~B + A*B

“Person with one mnemon transferring it to another person with a different mnemon” event

- A*~B + ~A*B ==> A*B + A*B *(or 2A*B)*
- “Two individuals transfer a mnemon to each other” event

- (A*B*C) + ~A*~B*~C ==> 2A*B*C
- “Combination of three mnemons enabling transfer of each mnemon” event

Different Mnemon Types

- **A** (bold) *Belief mnemon*
- A *Aware mnemon*
- $\mathbf{A}*B + {\sim}\mathbf{A}*{\sim}B \implies \mathbf{A}*B + \mathbf{A}*B$
- “Change in knowledge and belief in knowledge” event

- $\mathbf{A}*B + {\sim}\mathbf{A}*{\sim}B \implies \mathbf{A}*B + {\sim}\mathbf{A}*B$
- “Change in knowledge but not belief” event

- $\mathbf{A}*B + {\sim}\mathbf{A}*{\sim}B \implies \mathbf{A}*B + {\sim}\mathbf{A}*B \dashrightarrow \mathbf{A}*B + \mathbf{A}*B$
- “Change in knowledge and internal change in belief” events

Addition of Evaluation

- A *Evalution mnemon*
- **A***B*C + ~**A***~B*~C ==> **A***B*C + ~**A***B*C --->
- 2**A***B*C
- “Change in knowledge and reason to accept that new knowledge” event and “change in belief because of that reason” event pair
- Evaluation and belief mnemons accompany awareness mnemons

Alternative Ways to Represent Memory Constructs

- There are
- Frames (names and slots containing attribute-value pairs)
- Scripts (sequences of behaviors)
- Semantic networks (combinations of mnemons and relationships between them)
- Undoubtedly, there are many more that will probably turn out to be necessary to implement