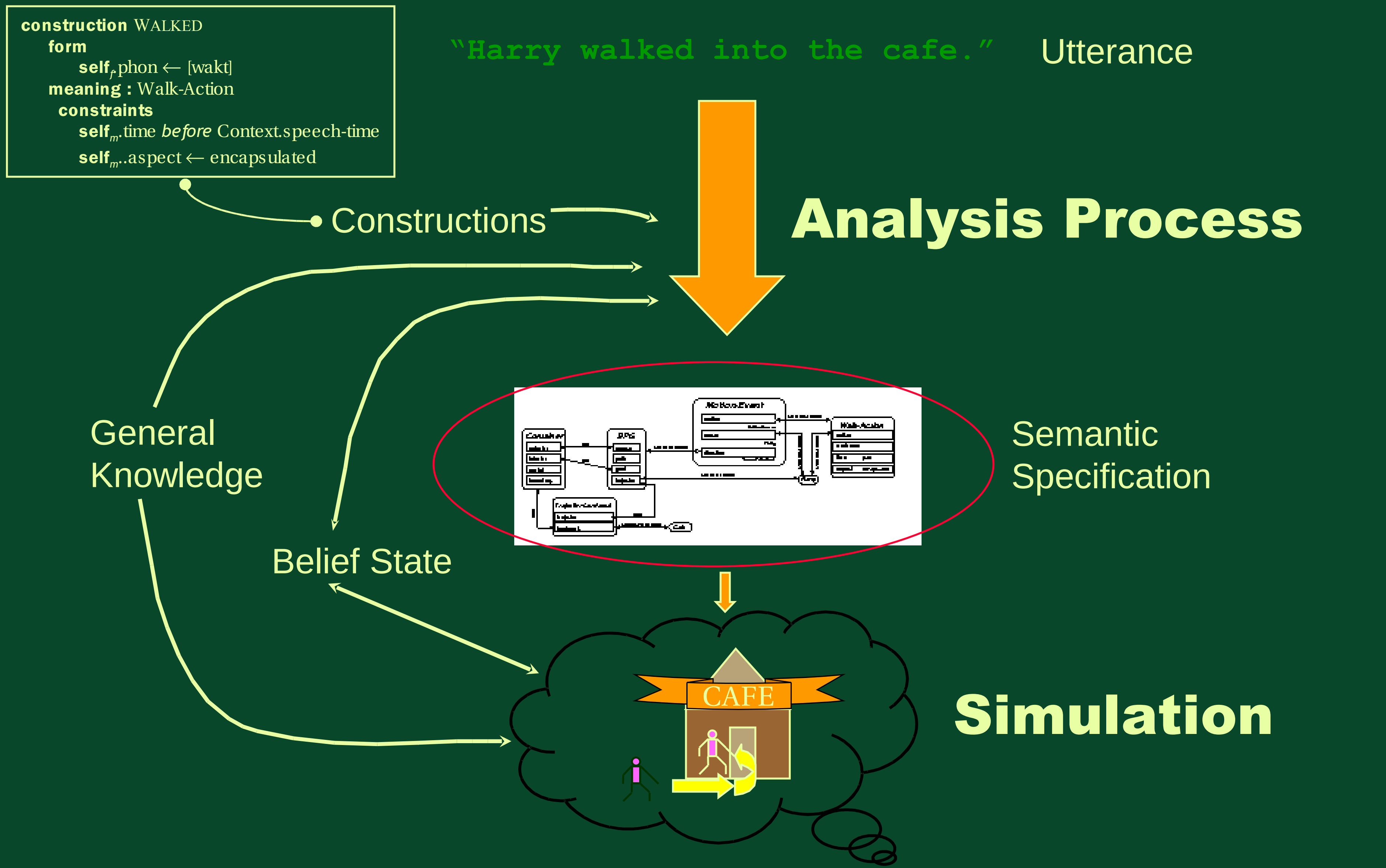
Lecture Overview

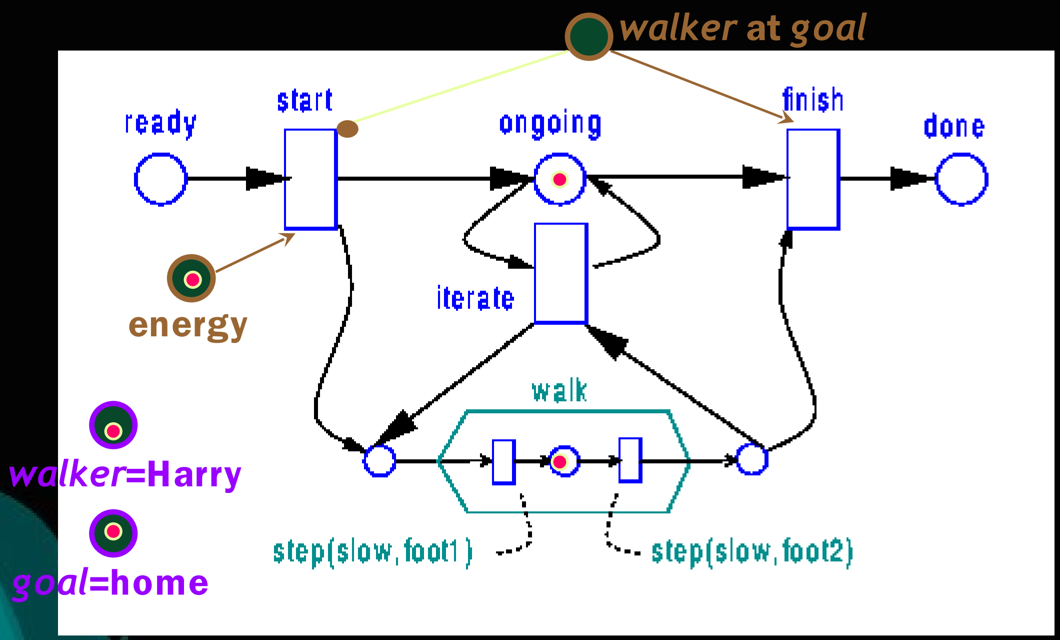
- Event Structure in Language
- Aspect
- X-schemas and Event Structure
- Controller x-schema and Aspect
- A Simulation Framework for Event Structure
- Compositional structure

Simulation-based language understanding



Active representations

- Many inferences about actions derive from what we know about executing them
- Representation based on stochastic Petri nets captures dynamic, parameterized nature of actions



Walking:

bound to a specific *walker* with a direction or *goal*

consumes resources (e.g., energy)

may have termination condition (e.g., *walker* at *goal*)

ongoing, iterative action

X-Schema Extensions to Petri Nets

- Parameterization
  - x-schemas take parameter values (speed, force)
    - Walk(speed = slow, dest = store1)
- Dynamic Binding
  - X-schemas allow run-time binding to different objects/entities
    - Grasp(cup1), push(cart1)
- Hierarchical control and durative transitions
  - Walk is composed of steps which are composed of stance and swing phases
- Stochasticity and Inhibition
  - Uncertainties in world evolution and in action selection

Event Structure for semantic QA

Srini Narayanan

- Reasoning about dynamics
  - Complex event structure
    - Multiple stages, interruptions, resources, framing
  - Evolving events
    - Conditional events, presuppositions.
  - Nested temporal and aspectual references
    - Past, future event references
  - Metaphoric references
    - Use of motion domain to describe complex events.
- Reasoning with Uncertainty
  - Combining Evidence from Multiple, unreliable sources
  - Non-monotonic inference
    - Retracting previous assertions
    - Conditioning on partial evidence

Event Structure in Language

- Fine-grained
- Rich Notion of Contingency Relationships.
  - Phenomena: Aspect, Tense, Force-dynamics, Modals, Counterfactuals
- Event Structure Metaphor:
  - Phenomena: Abstract Actions are conceptualized in Motion and Manipulation terms.
  - Schematic Inferences are preserved.

Aspect

- Aspect is the name given to the ways languages describe the structure of events using a variety of lexical and grammatical devices.
  - Viewpoints
    - is walking, walk
  - Phases of events
    - Starting to walk, walking, finish walking
  - Inherent Aspect
    - run vs cough vs. rub
  - Composition with
    - Temporal modifiers, tense..
    - Noun Phrases (count vs. mass) etc..

A Precise Notion of Contingency Relations

Activation:

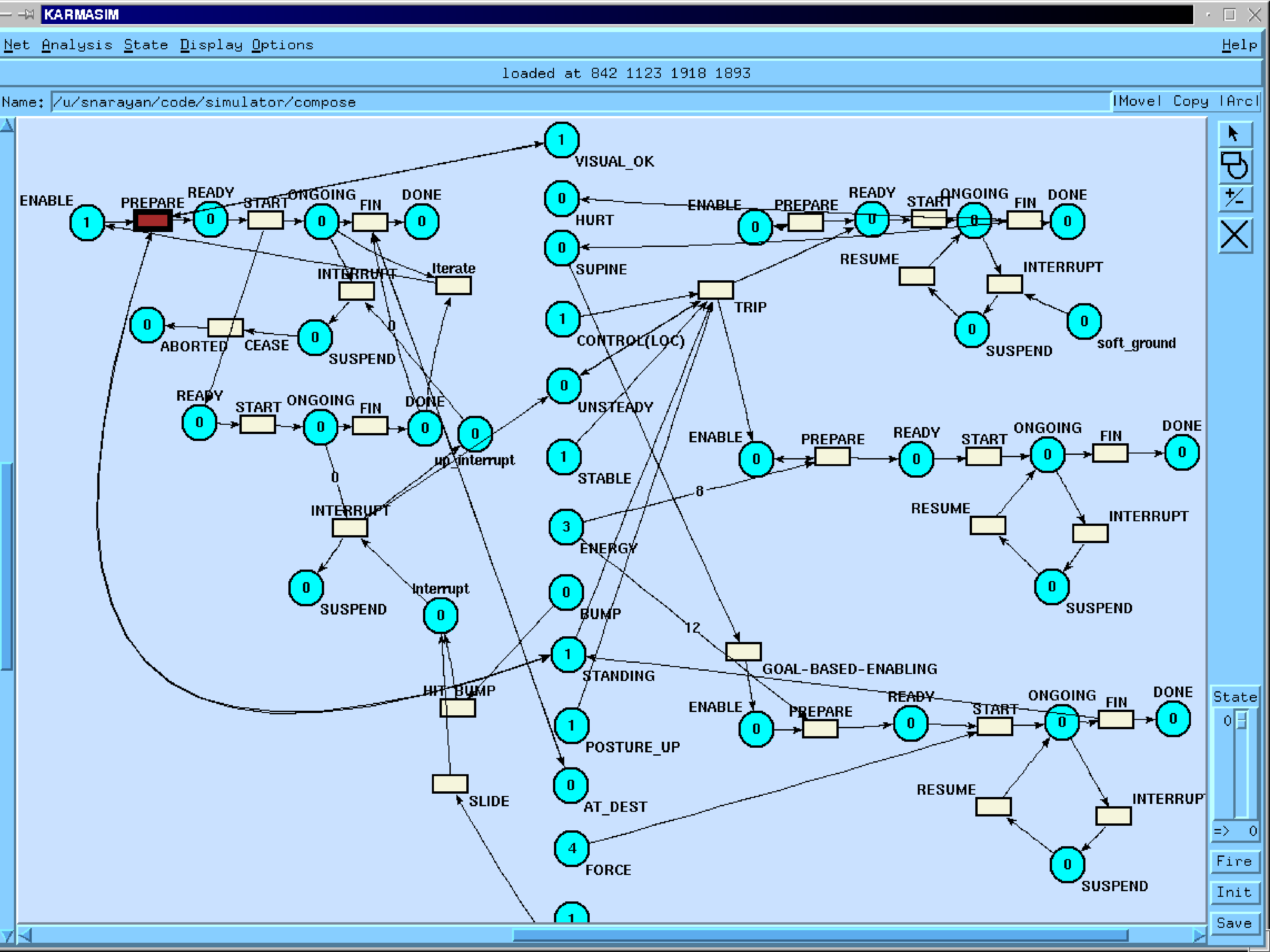
Executing one schema causes the enabling, start or continued execution of another schema. Concurrent and sequential activation.

Inhibition:

Inhibitory links prevent execution of the inhibited x-schema by activating an inhibitory arc. The model distinguishes between concurrent and sequential inhibition, mutual inhibition and aperiodicity.

Modification:

The modifying x-schema results in control transition of the modified xschema. The execution of the modifying x-schema could result in the interruption, termination, resumption of the modified x-schema.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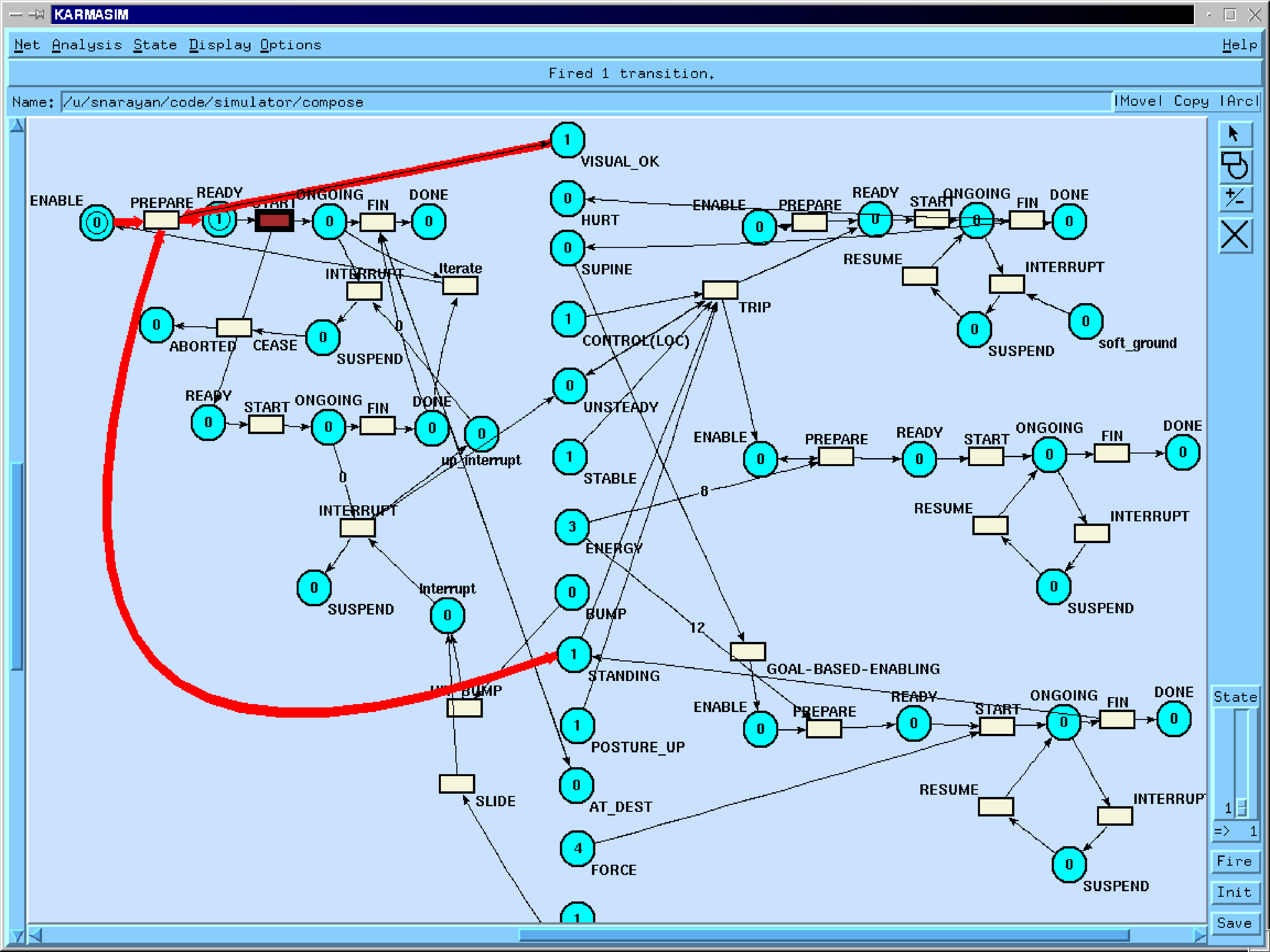
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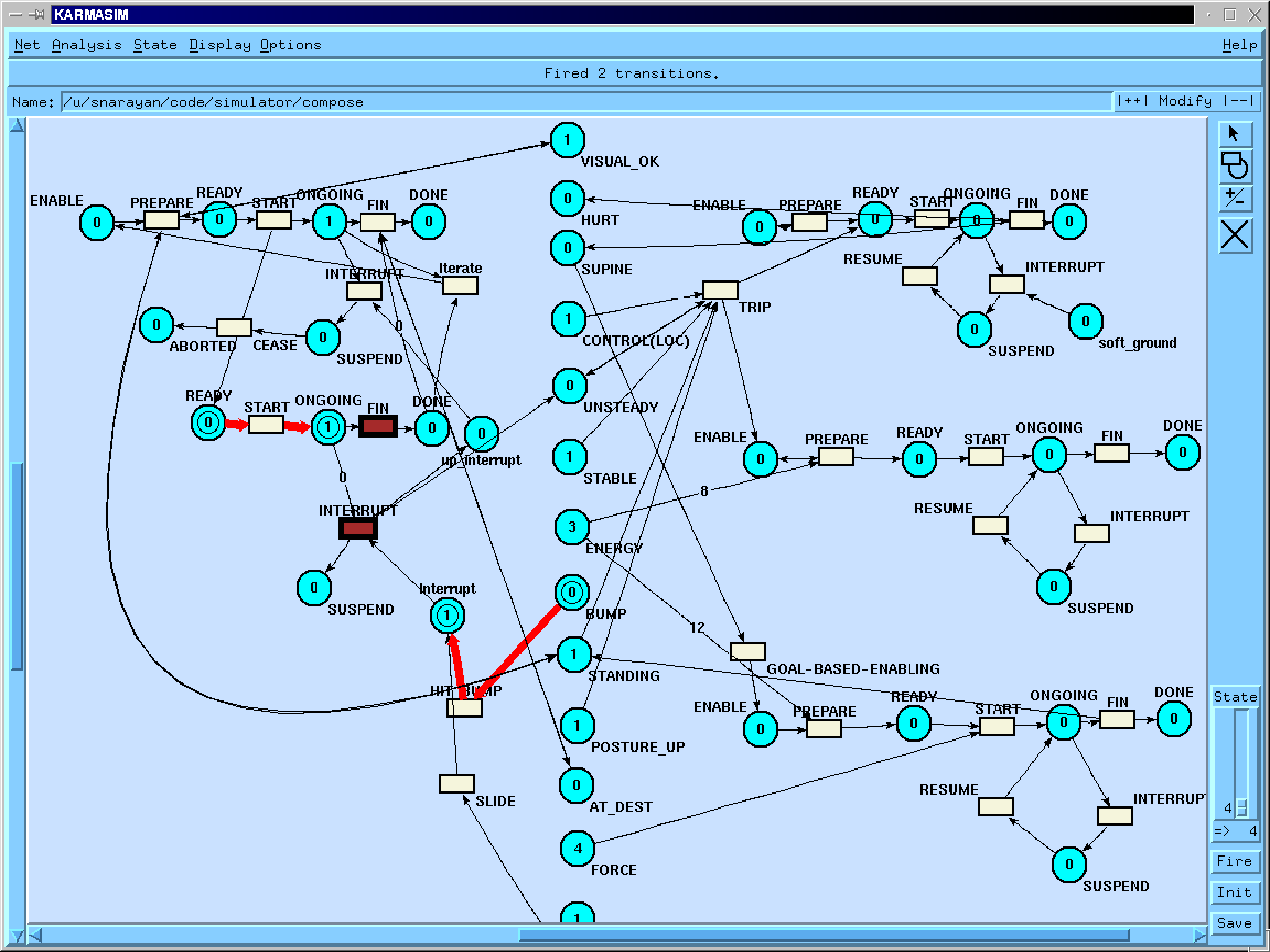
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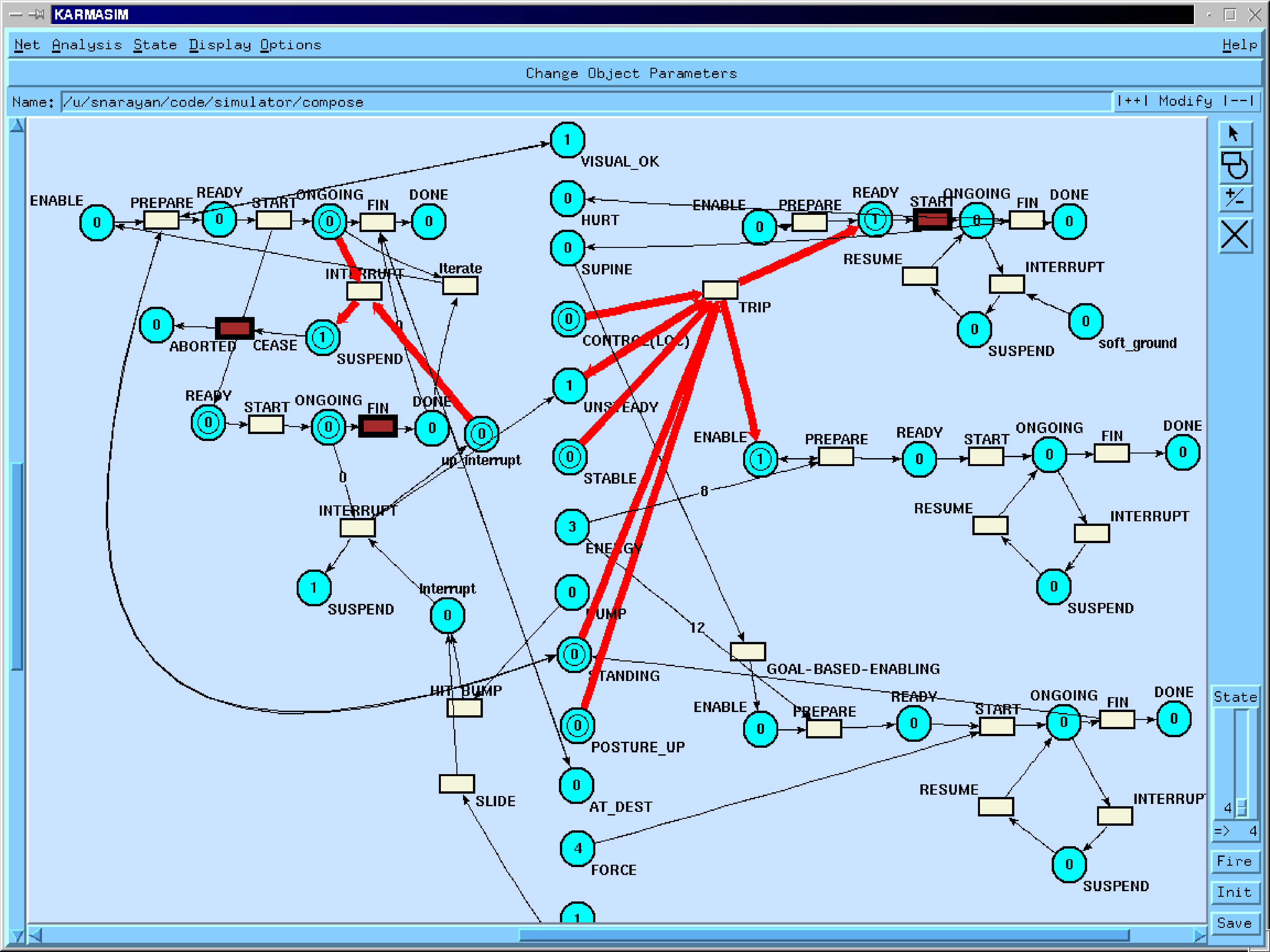
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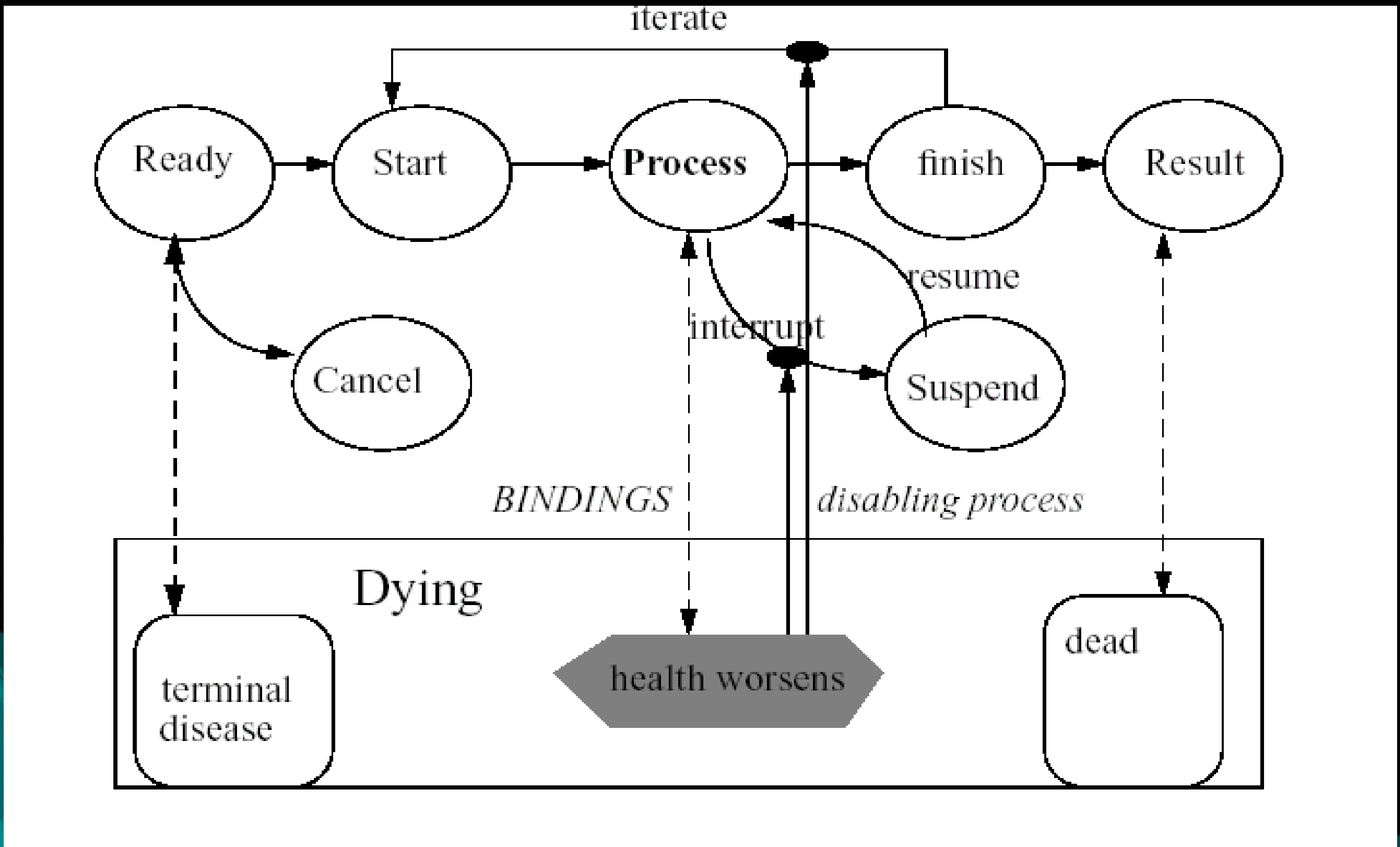
Init
Save

Inherent Aspect Selects/Disables Controller Transitions



Other Transitions in the Controller may be coded

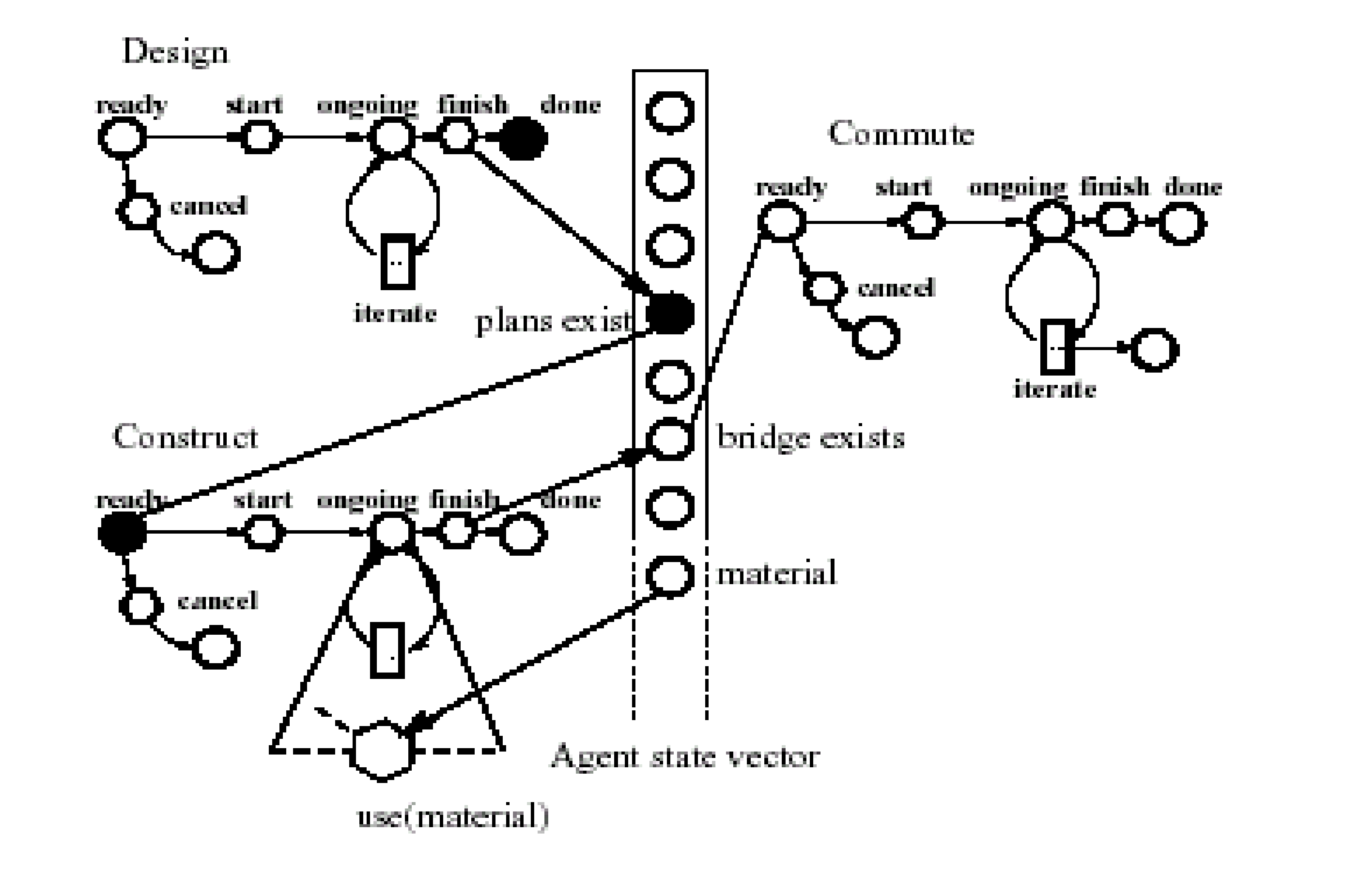
- Lexical items may code interrupts
  - Stumble is an interrupt to an ongoing walk
- A combination of grammatical and aktionsart (inherent aspect) results in the interpretation
  - Ready to walk : Prospective
  - Resuming his run: Resumptive
  - Has been running: Embedded progressive
  - About to Finish the painting: Embedded Completive.
  - Canceling the meeting vs. Aborting the meeting.

Combination with “temporal” connectives

- Temporal Connectives are often causal.
  - I bought stock when the market crashed.
  - The market crashed when I bought stock.

- Interpretations of these connectives may depend on the controller and the specific process x-schemas
  - When they built the 39th Street bridge...
    - a local architect drew up the plans.
    - they used the best materials.
    - they solved most of their traffic problems.

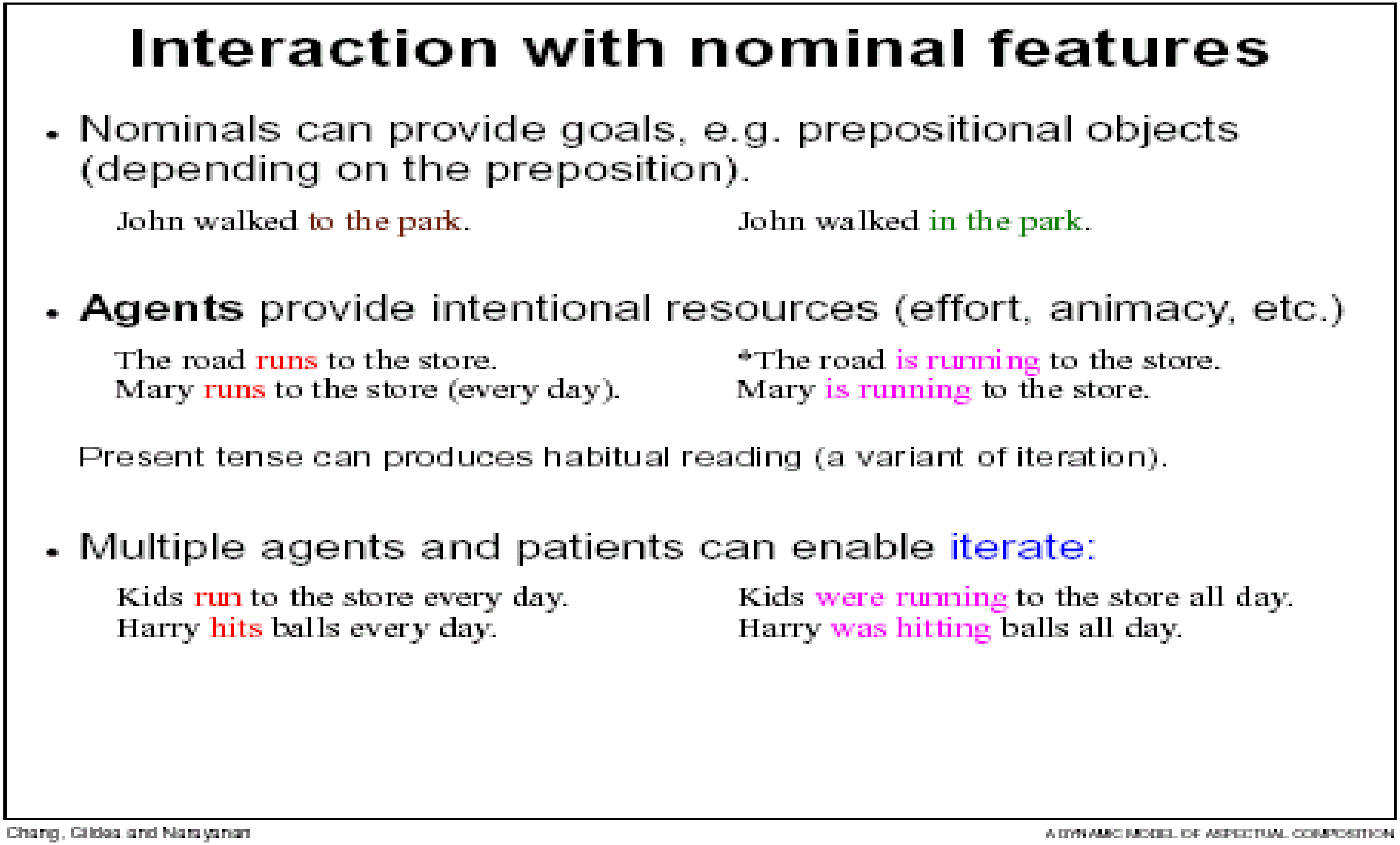
Inter-Schema relations



Levels of Granularity

- Events can be construed at different levels of granularity based on various contextual factors.
  - In 1991, McEnroe injured his knee while playing tennis.
  - This morning, I injured my knee while playing tennis.
  - He is coughing (normal time scale vs. slow-motion film time scale).

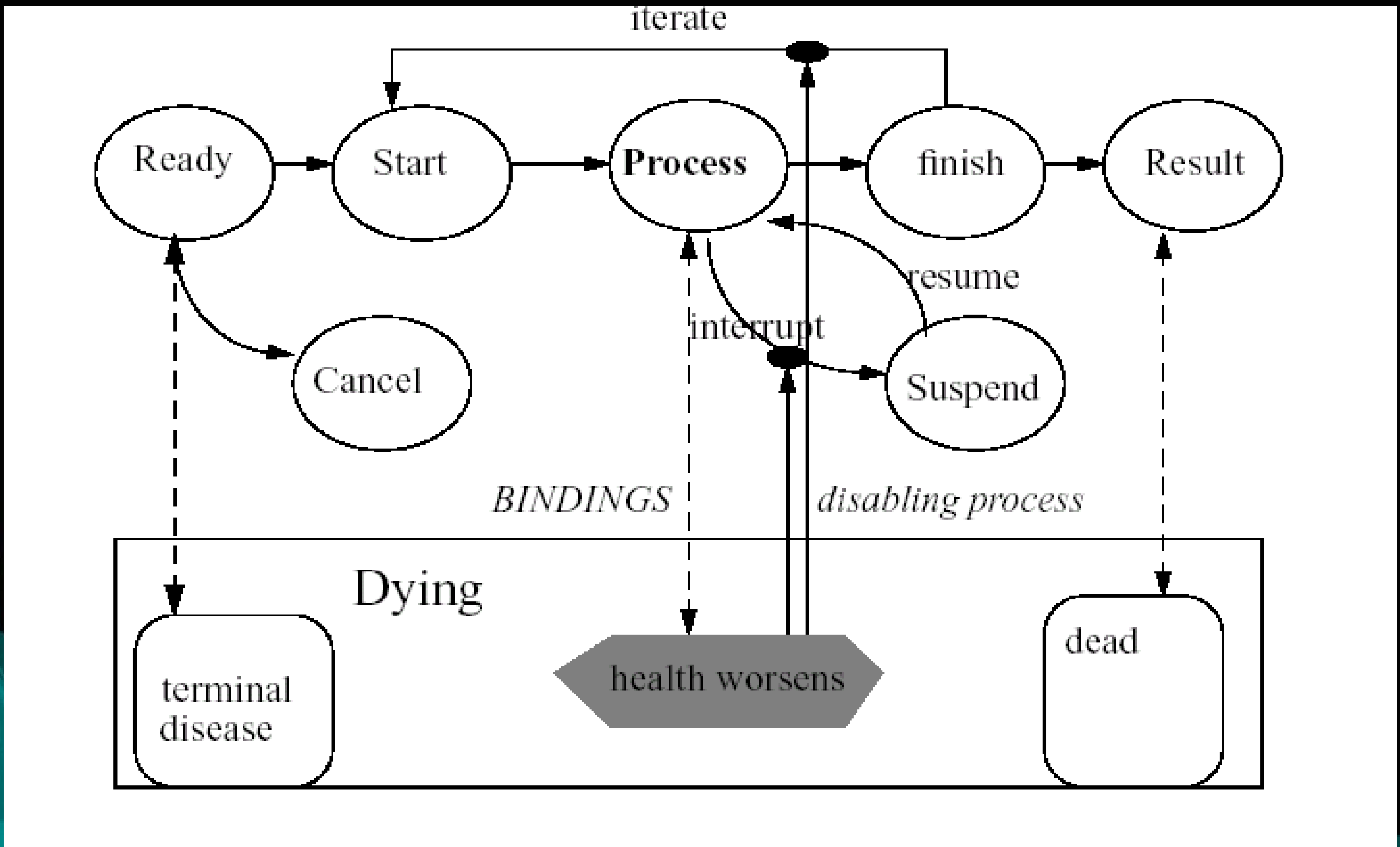
Composition with nominals



Combination with “temporal” primitives

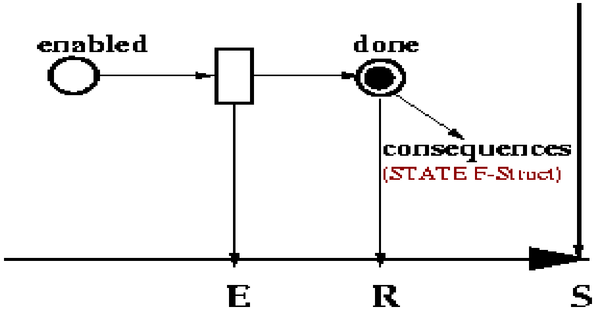
- When the built the bridge,
  - they lost the plans.
  - they forgot to give the commuting public adequate warning.
  - they ran out of materials
  - they had a great opening event.
  - they solved the traffic problem.
- When they were building the bridge ….

Inherent Aspect Selects/Disables Controller Transitions

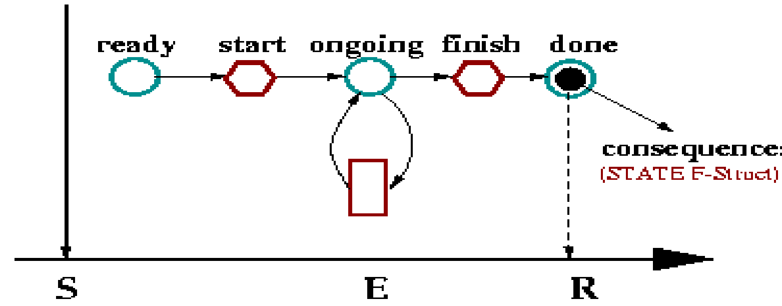


Interaction of Aspect with Tense

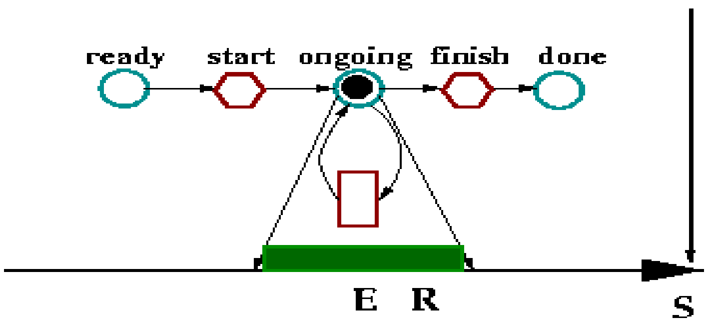
- Reichenbach's system uses three pointers
  - Speech Time (S)
  - Reference Time (R)
  - Event Time (E)
- Tense is a partial ordering relation between the pointers
  - Simple Past E < R, E < S
  - Perfect E < R < S



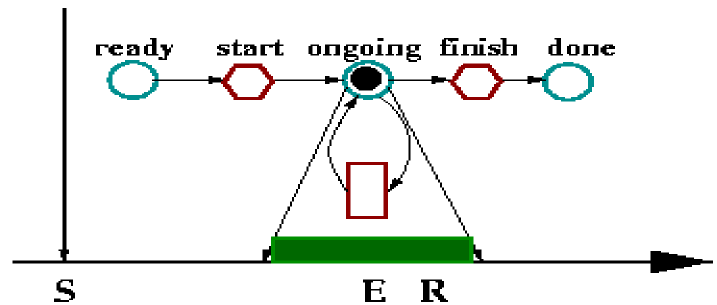
a) John had lost his keys



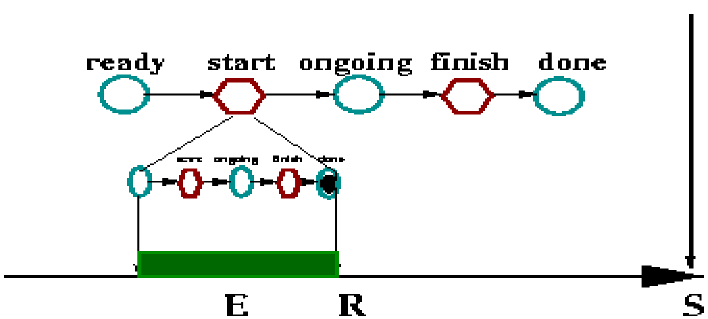
b) John will have walked to the store



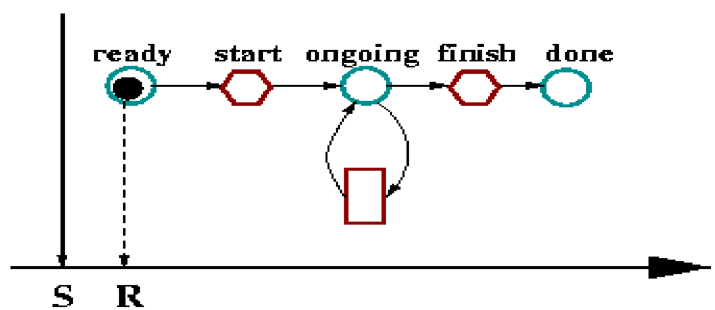
c) John was walking to the store



d) John will be walking to the store



e) John had started eating

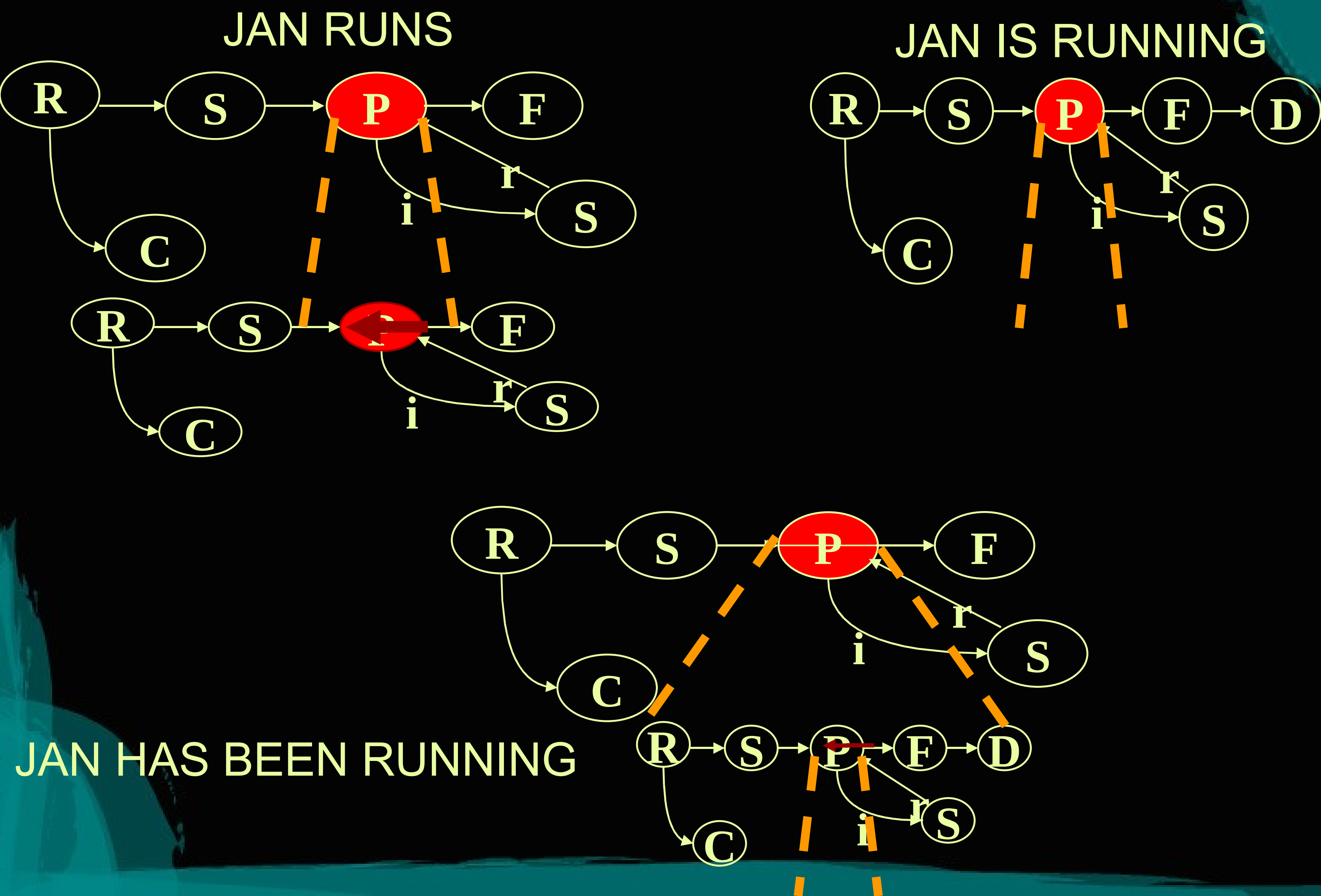


f) John will be ready to eat

The Present Tense

- Habitual and generic readings of iterated-event sentences, e.g., *She smokes, Oil floats on water*
- ‘Progressive-style’ readings of event sentences in languages other than English, e.g., French: *Eh bien, à present, je me sens mieux. Le morale **revient**.* ‘Now I’m feeling better. My morale is coming back.’ (Binet, *Bidochon* 8: 42)
- ‘Perfect-style’ readings of state-phase sentences in languages other than English, e.g., *Ca fait dix minutes qu’elle nous **parle** de la moquette!* ‘She’s been telling us about the carpet for 10 minutes.’ (Binet, *Bidochon* 10:17)

The Present Triumvirate



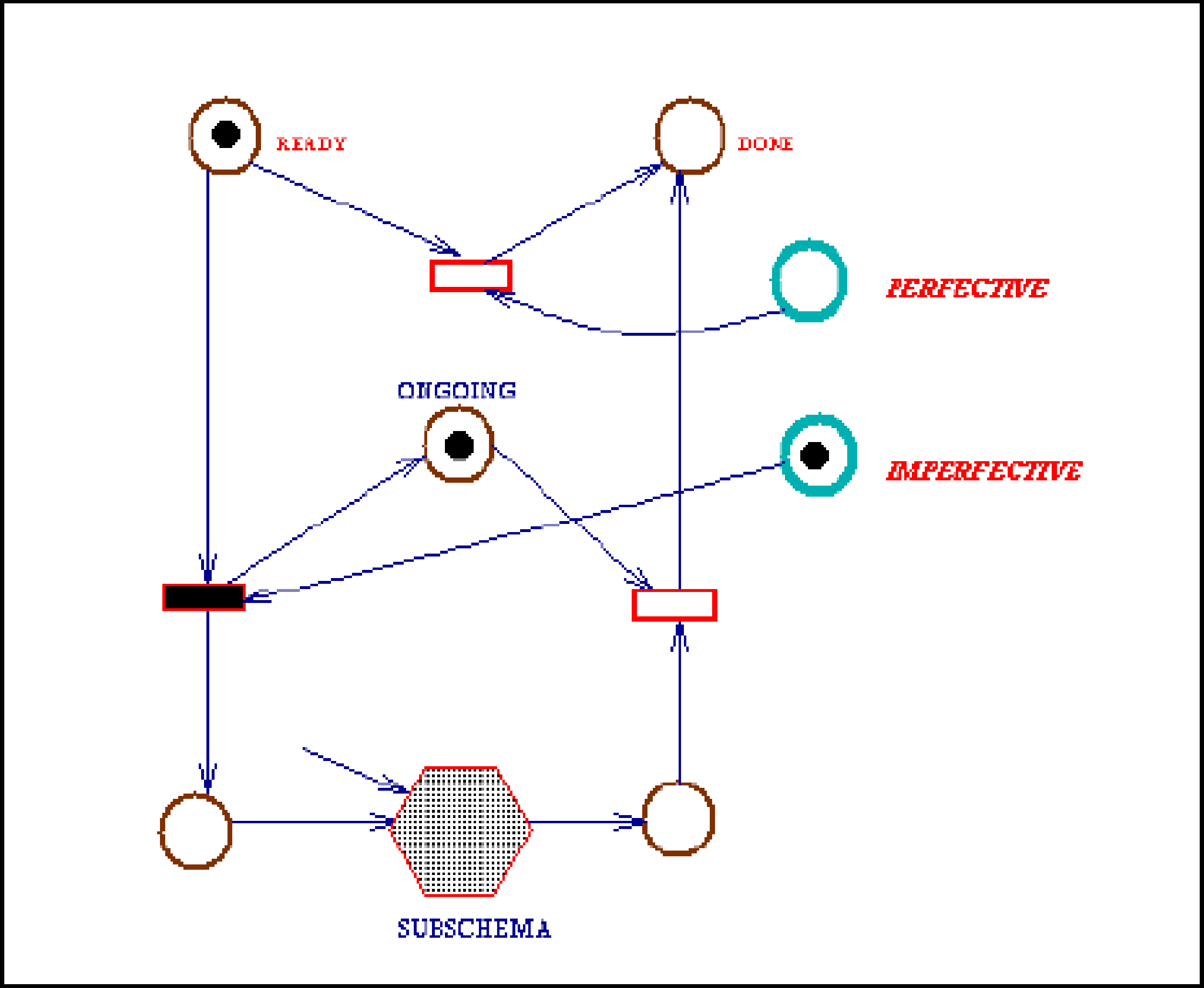
Present Tense Embedding

- Of course, we can extend through embedding ANY of the available states in the CONTROLLER.
  - John is starting his run.
  - John starts his run (every morning).
  - John stops his run after 3 miles. (He never achieves his goal of running 5).
  - John has been canceling his run.
  - John cancels his run (twice a week).
  - We have been restarting this Harley for the last 5 mins.
  - The meeting is about to resume.
  - My morale is returning (Michaelis 02).
- Question: Do (which) languages have constructions for these states?

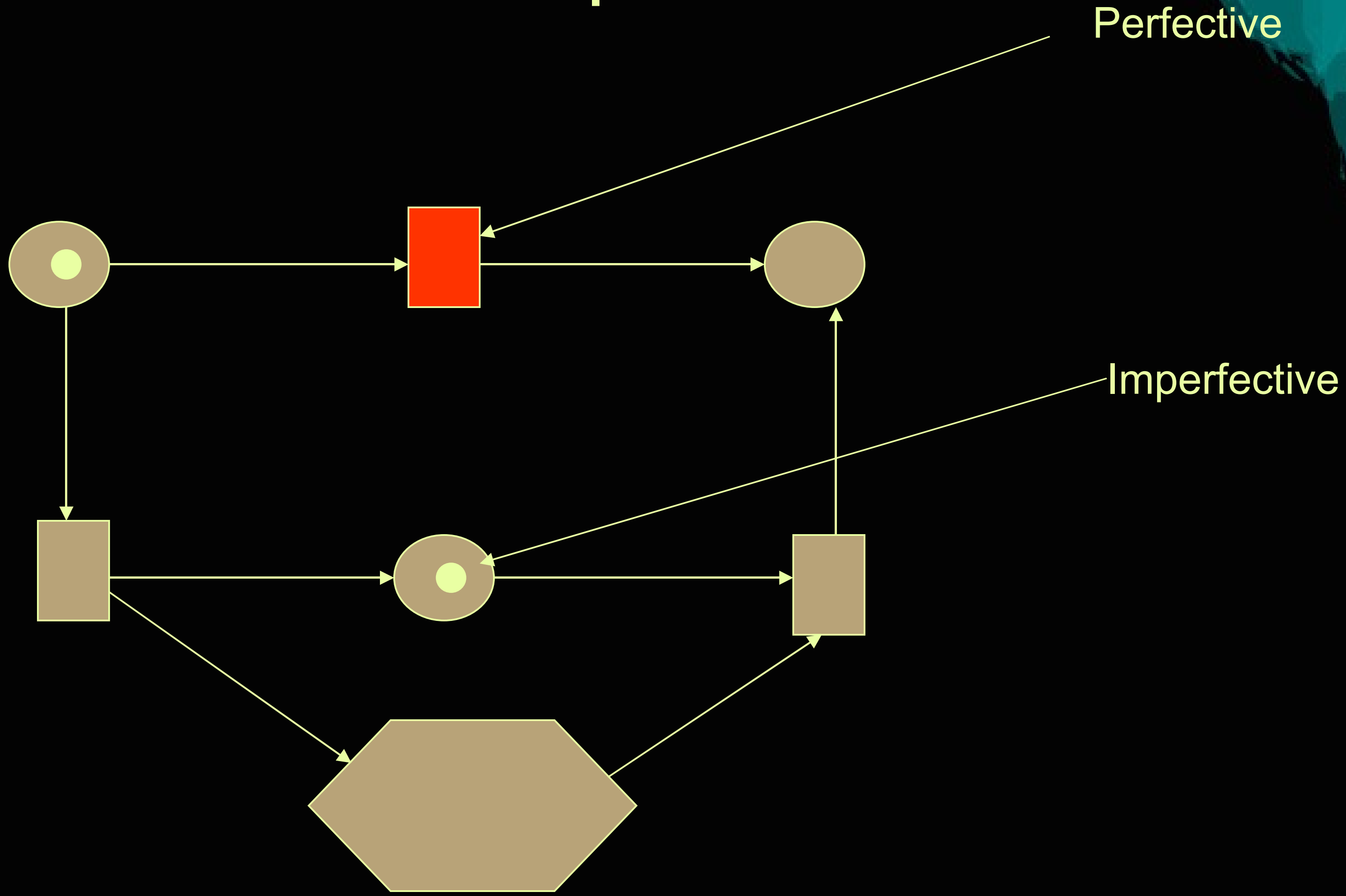
Two types of past tense

- Two types of past tense
  - Imperfective
    - Selects a state.
      - States contain their reference interval
  - Perfective
    - Selects an whole event
      - Events are contained within their reference interval

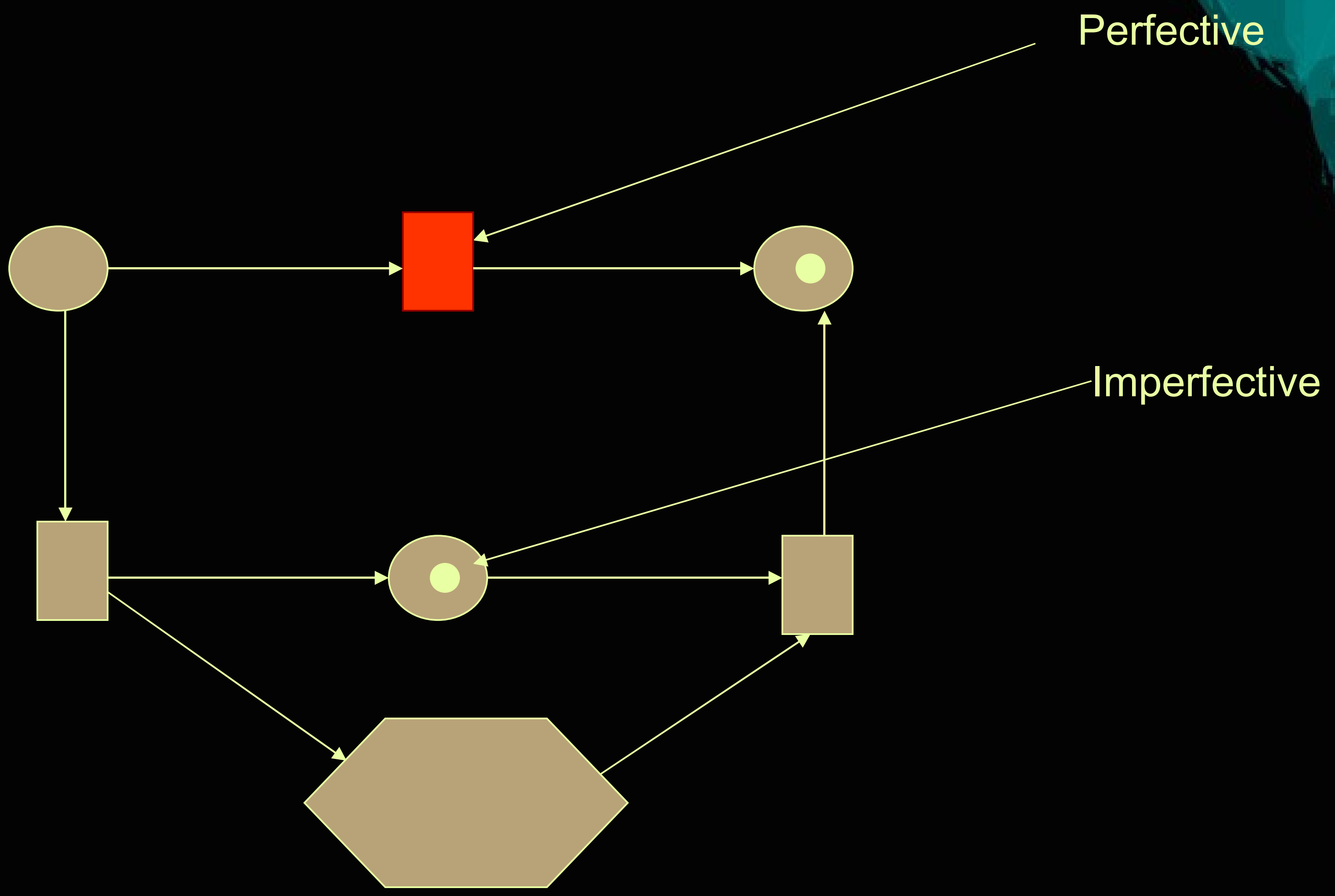
Viewpoint Aspect (Perfective/Imperfective)



Perfective/Imperfective

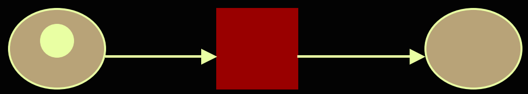


Simulation and Reference Interval

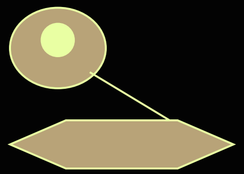


Events and Past tense coercions

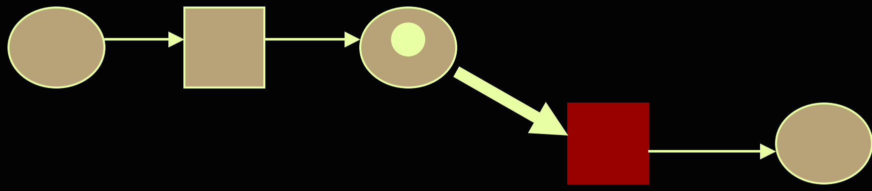
- John ran [yesterday].
  - Episodic



- I glanced at her. [she didn’t notice]. She looked elated.
  - Stative



- [When the bookie came to collect], John ran [away].
  - Inceptive.



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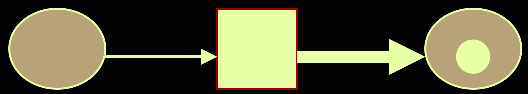

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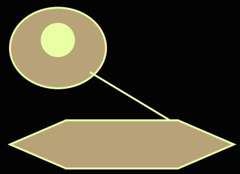

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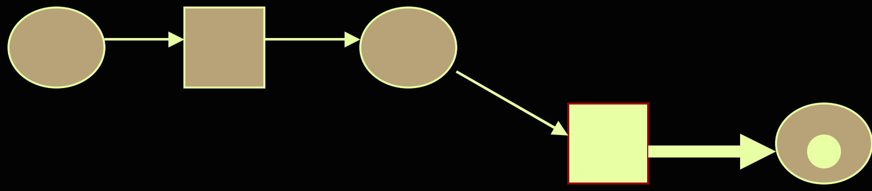
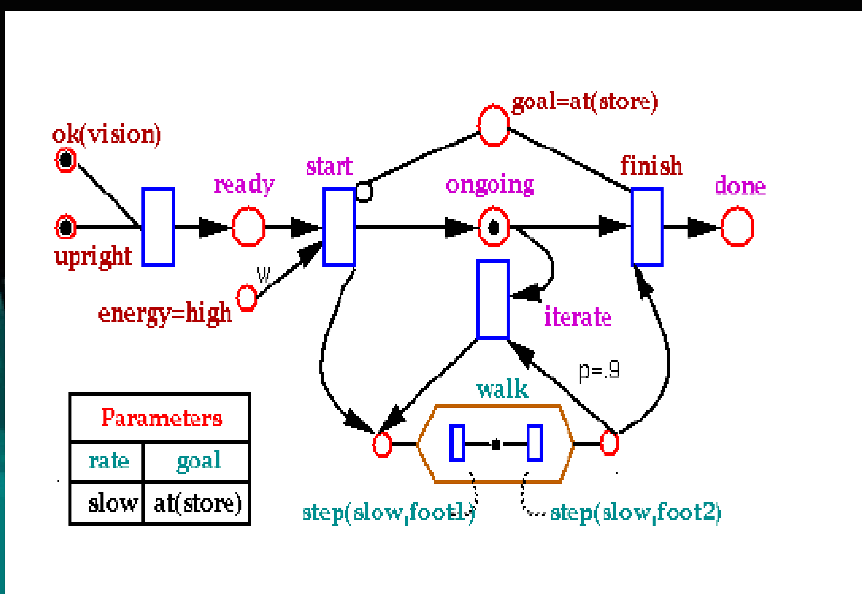


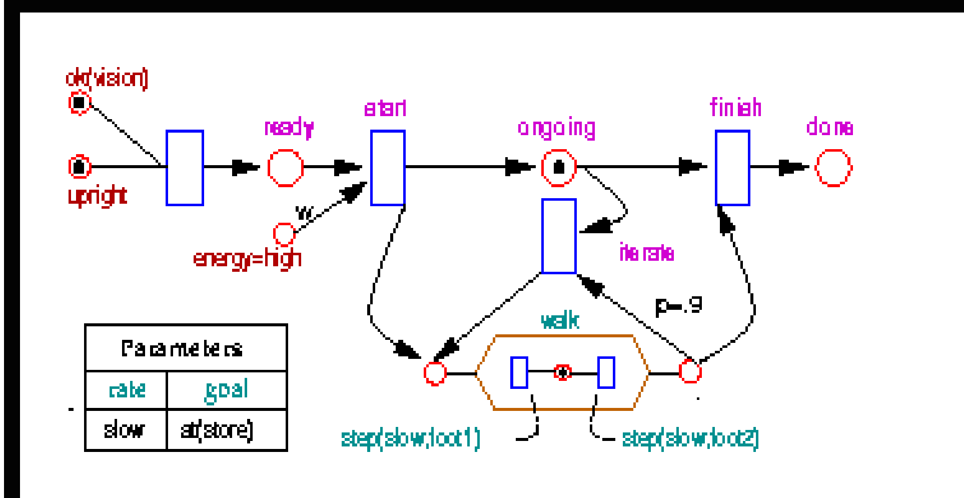
Inference using the Controller

Different Bindings give rise to different interpretations.

Dowty's Imperfective Paradox

He was walking to the store.	**He was walking.**
does not imply	***does imply***
He walked to the store.	**He walked.**





Features of Representation

- Inherently action based, with fine grained distinctions in resource usage, and temporal evolutions.
- Can deal with concurrent actions, durations, hierarchical action sets, and stochastic actions (selection and effects).
- Highly responsive to a changing environment with uncertain evolutions.
- Can model complex domain constraints in a factorized representation that can compute complex ramifications as well as prior beliefs and possible predictions.

Summary of Aspect Results

- Controller mediates between linguistic markings and individual event/verbal x-schemas (Cogsci99)
  - Captures regular event structure; inspired by biological control theory
  - Flexible: specific events may require only a subset of controller; interaction of underlying x-schemas, linguistic markers and hierarchical abstraction/ decomposition of controller accounts for wide range of aspectual phenomena.
- Important aspectual distinctions, both traditional and novel, can be precisely specified in terms of the interaction of x-schemas with the controller (Cogsci97,98, AAAI99,CogSci2002):
  - stative/dynamic, durative/punctual: natural in x-schemas
  - telic processes: depletion of resources
  - continuous processes: consumption of resources
  - temporary/effortful states; habituals
  - dynamic interactions with tense, nominals, temporal modifiers
  - incorporation of world knowledge, pragmatics

Logical Action Theories

- Connection to ARD *(or other Action Languages)*:
  - The representation can be used to encode a *causal model* for a domain description D (in the Syntax of ARD) in that it satisfies all the *causal laws* in D. Furthermore, a *value proposition* of the form C *after* A is entailed by D iff all the terms in C are in *S*i; the state that results after running the *projection algorithm* on the action set A. (IJCAI 99)
- Executing representation,
  - frame axioms are encoded in the topology of the network and transition firing rules respect them.
- Planning as backward reachability or computing downward closure (IJCAI 99, WWW2002)
- Links to linear logic. Perhaps a model of stochastic linear logic? (SRI CSL TR 2001).

Current Work

- How does analysis provide the right reference interval properties for simulation?
  - Aspectually sensitive tenses
  - Granularity
  - Temporal Connectives
- Hypothesis:
  - A simulation/enactment framework with rich inter-event relations (through activation, inhibition, interruption, termination, etc.) provides the right framework.

Connectionist Implementation

- x- schemas have been implemented in a connectionist network.
- Two main issues arise in the implementation.
  - 1) Dynamic Binding.
  - 2) Belief Propagation
- Dynamic binding is modeled through temporal synchrony in SHRUTI.

Purely local belief propagation requires restricting the topology of the domain models?

Experimental Verification of the Simulation Hypothesis

- Behavioral – Image First
  - Does shared effector slow negative response?
    - Pilot results (Bergen and Shweta Narayan)
- Imaging – Simple sentence using verb first
  - Does verb evoke activity in pre-motor effector area?
    - Collaborators at Parma and Milan have obtained preliminary results.
    - Berkeley Experiment under way
- Metaphor follow-on experiment
  - Will “kick the idea around” evoke motor activity?
- Investigate the finer details of the simulation hypothesis.

Lecture Overview

- Event Structure in Language
  - Compositional Structure and Contingency Relationships
  - Metaphor
    - Primary Metaphor
    - Complex Metaphors

Conclusions

Embodiment can provide crucial insights for NLU

- Non-trivial action and interaction requires representations of events, states and domain relations.
- Representation of events based on motor control and imaginative simulation

- Substantial Progress in exploiting results in NLU
  - We have built a pilot system that uses some of the key technologies in a proof of concept implementation.
- We are currently extending the pilot system to
  - Use richer probabilistic representation and inference techniques that are able to scale to large domains and ontologies.
  - Formalize and employ a compositional set of embodied conceptual primitives and grammatical constructions.
  - Perform both behavioral and fMRI imaging experiments to test the predictions of the simulation hypothesis

Conceptual Metaphor Provides Embodied Reasoning For Abstract Concepts

Virtually all abstract concepts (if not *all*) have conventional metaphorical conceptualizations — normal everyday ways of using concrete concepts to reason systematically about abstract concepts.

Most abstract reasoning makes use of embodied reasoning via *metaphorical mappings from concrete to abstract domains*

What Are Conceptual Metaphors?

In NTL, conceptual metaphors are structured connectionist “maps” — circuits linking concrete source domains to abstract target domains.

In the fit of NTL to Neuroscience, such metaphorical maps would be neural circuits in the brain linking sensory-motor regions to other regions.

We claim therefore that, in such cases, the sensory-motor system is **directly engaged** in abstract reasoning.

Metaphorical Grasping

There is a conceptual metaphor, *Understanding Is Grasping,* according to which one can *grasp ideas.*

One can begin to grasp an idea, but not quite get a hold of it.

If you fail to grasp an idea, it can go right by you — or over your head!

If you grasp it, you can turn it over in your mind.

You can't hold onto an idea before having grasped it.

In short, reasoning patterns about physical grasping can be mapped by conceptual metaphor onto abstract reasoning patterns.

We use metaphors everyday

- The council *attacked every weak point* of his proposal.
- I don't know how to *put my thoughts into words*.
- I've been feeling quite *depressed* of late.
- "*Washington* remains stuck in talks with Russia and France over the failure to secure a second U.N. resolution"
- My summer plans are still *up in the air*.
- I *see* what you mean.
- Something *smells fishy*, but I can't quite *put my finger on it*.

What is the basis for metaphors?

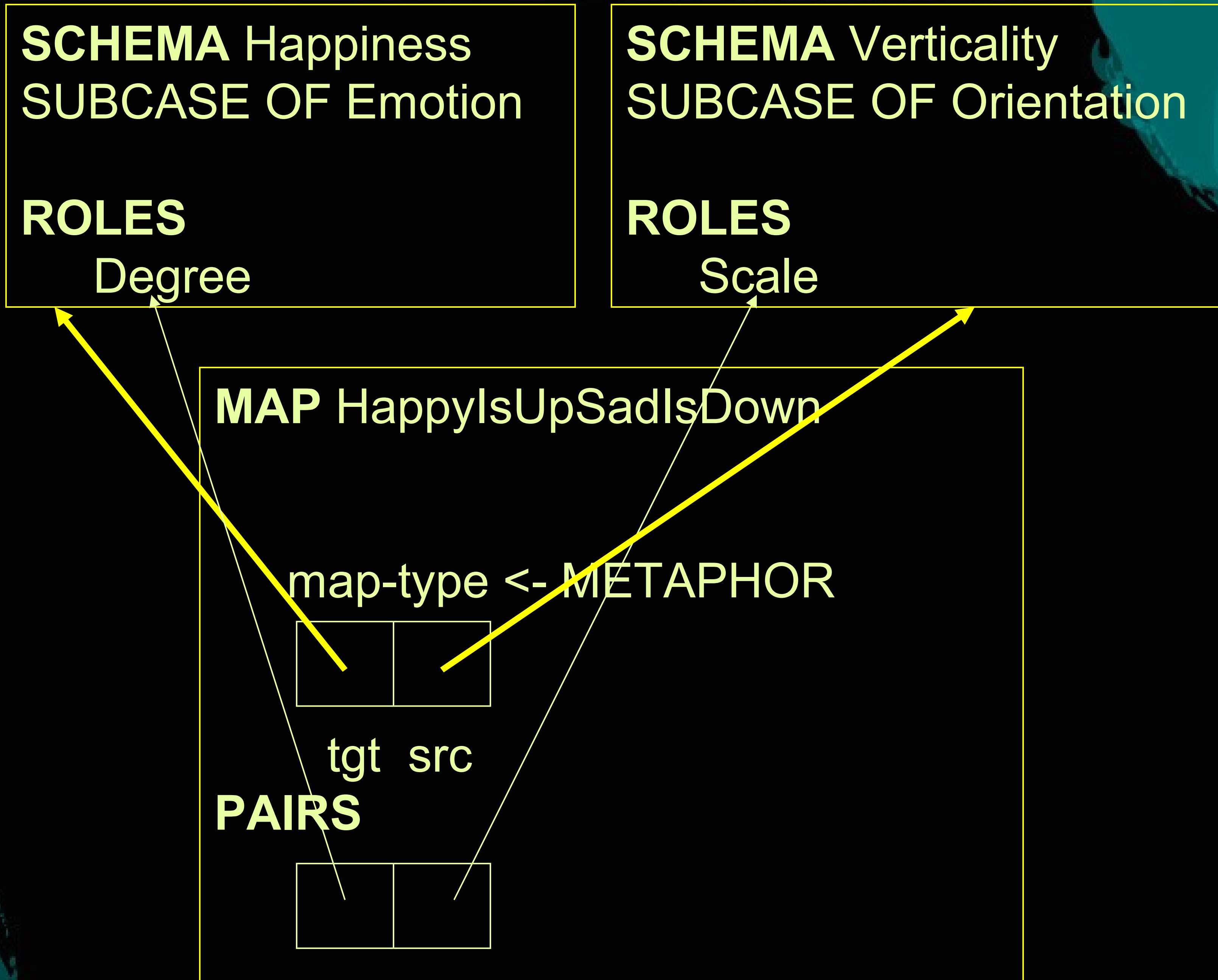
- metaphor is understanding one thing in terms of another
- specifically, we reason about abstract concepts through our sensory-motor experience.
- that means we have:
  - correlation
  - inference

Metaphors, defined

- Formally, metaphors are *mappings* from a *source domain* to a *target domain*
- both the source and target domains are structured by schemas and frames
- Take a simple example:

  I've been feeling quite *depressed* of late.

  (Happy is Up; Sad is Down)


SCHEMA Happiness
SUBCASE OF Emotion
ROLES
Degree
SCHEMA Verticality
SUBCASE OF Orientation
ROLES
Scale
MAP HappyIsUpSadIsDown
map-type <- METAPHOR
tgt src
PAIRS

How are these metaphors developed?

- Conflation Hypothesis:
  Children hypothesize an early meaning for a source domain word that *conflates* meanings in both the literal and metaphorical senses
  - experiencing warmth and affection when being held as a child
  - observing a higher water level when there's more water in a cup

A few primary metaphors

- The conflation hypothesis works for metaphors that have an experiential basis, i.e. primary metaphors
  - Affection Is Warmth
  - Important is Big
  - Categories are Containers
  - Knowing is Seeing
  - Time Is Motion

Affection is Warmth

- Subjective Judgment: Affection
- Sensory-Motor Domain: Temperature
- Example: They greeted me *warmly*.
- Primary Experience: Feeling warm while being held affectionately.

Important is Big

- Subjective Judgment: Importance
- Sensory-Motor Domain: Size
- Example: Tomorrow is a *big* day.
- Primary experience: As a child, important things in your environment are often big, e.g., parents, but also large things that exert a force on you

Categories are Containers

- Subjective Judgment: Perception of Kinds
- Sensory-Motor Domain: Space
- Example: Are tomatoes *in* the fruit or vegetable category?
- Primary Experience: Things that go together tend to be in the same bounded region

Knowing is Seeing

- Subjective Judgment: Knowledge
- Sensory-Motor Domain: Vision
- Example: I *see* what you mean.
- Primary Experience: Getting information through vision

Chris Johnson's Thesis

- Predicts 3 stages of acquisition:
  - source domain word within the source domain
  - constructions that have double-meaning
  - constructions that are specific to the target domain
- e.g.

  “Can you see what’s in here?” (stage 2)

  “I see what you mean” (stage 3)

Time is Motion

- Subjective Judgment: The passage of time
- Sensory-Motor Domain: Motion
- Example: Time *flies*.
- Primary Experience: Experiencing the passage of time as one moves or observes motion

Dual Metaphors for Time

1. Time is stationary and we move thru it
   - The finals are *just around the corner*.
   - Don't look *back* on what you have done.
2. Time is a moving object
   - My spring break *went by* so quickly.
   - *Come* what may.

Time expressions in English

- In English, we predominantly use front/back terms to talk about time.
- We can talk about the good times *ahead* of us or the hardships *behind* us.
- We can move meetings *forward*, push deadlines *back*.
- On the whole, the terms used to order events are the same as those used to describe asymmetric horizontal spatial relations
  - (e.g., ‘‘he took three steps *forward*’’ or ‘‘the dumpster is *behind* the store’’).

Mandarin time expressions

- In Mandarin, front/back spatial metaphors for time are also common(Scott, 1989).
- Mandarin speakers use the spatial morphemes *qia´n* (‘‘front’’) and *ho`u* (‘‘back’’) to talk about time.
- Mandarin speakers also systematically use vertical metaphors to talk about time (Scott, 1989). The spatial morphemes *sha`ng* (‘‘up’’) and *xia`* (‘‘down’’) are frequently used to talk about the order of events, weeks, months, semesters, and more.
- Earlier events are said to be *sha`ng* or ‘‘up,’’ and later events are said to be *xia`* or ‘‘down.’’

Question

- So, do the differences between the English and Mandarin ways of *talking* about time lead to differences in how their speakers *think* about time?
- This question can be expanded into
  - Does using spatial language to talk about time have implications for on-line processing?

Lera Boroditsky's experiment

- Mandarin and English speakers were asked to answer a spatial priming question followed by a target question about time.
- The spatial primes were either about horizontal spatial relations between two objects or about vertical relations.
- After solving a set of two primes, participants answered a TRUE/FALSE target question about time.
  - Is March *earlier* than April

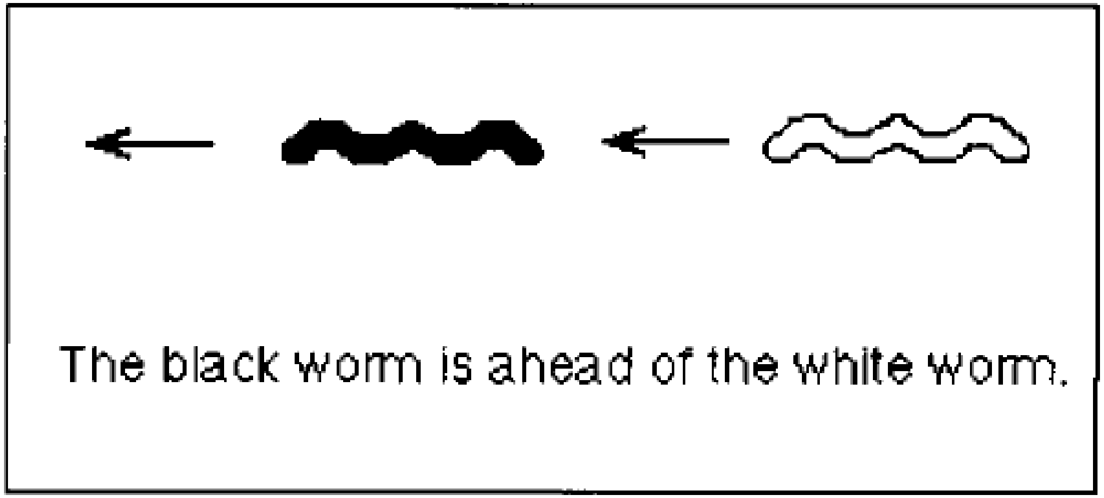


FIG. 3a. Example of a horizontal spatial prime used in Experiments 1 and 3.

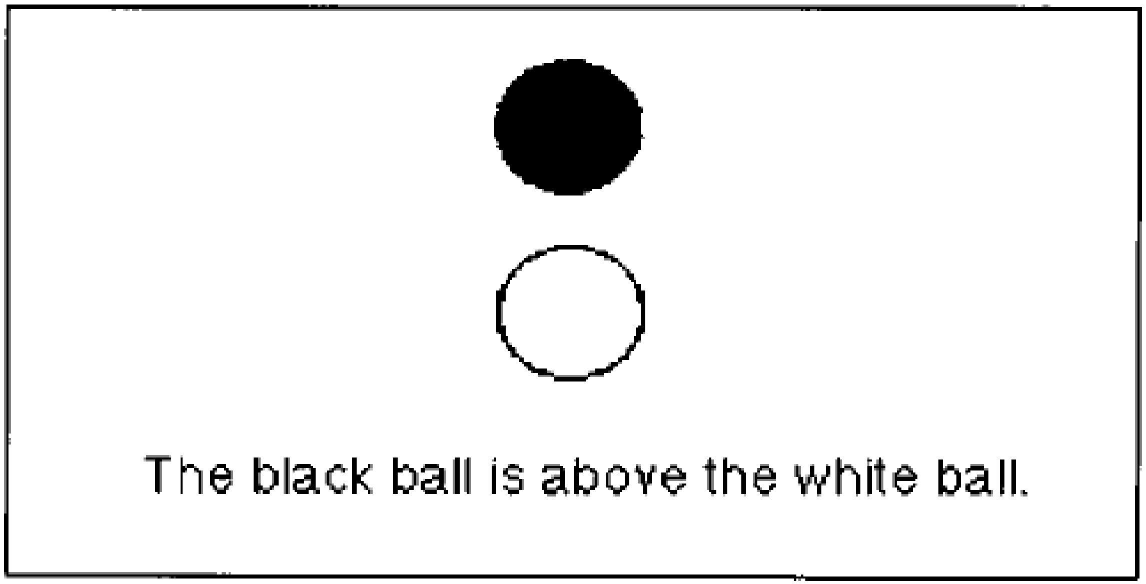


FIG. 3b. Example of a vertical spatial prime used in Experiments 1 and 3.

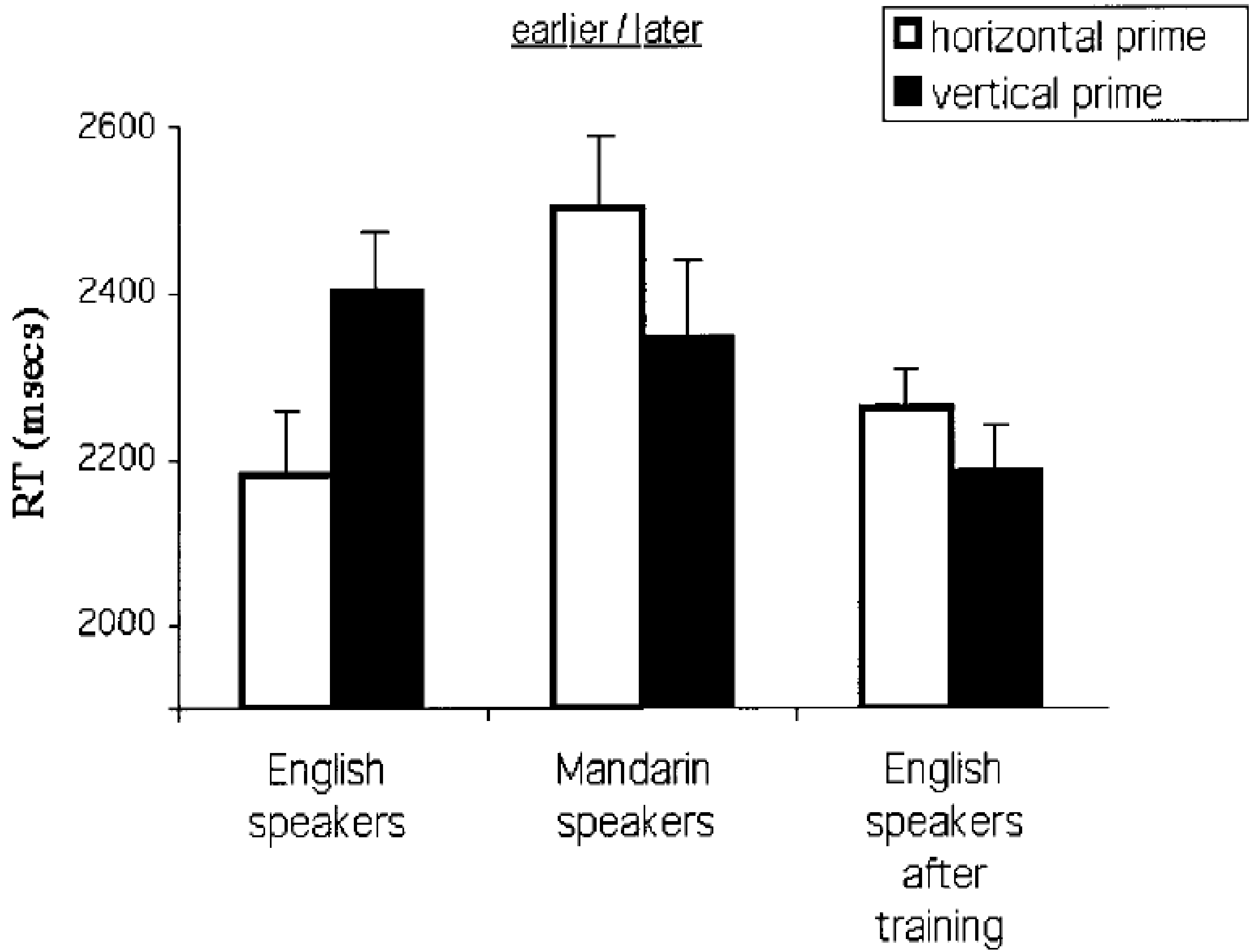


FIG. 4b. Experiments 1 and 3: Response times to purely temporal *earlier/later* questions about time following either a horizontal or a vertical prime are plotted for English speakers, Mandarin speakers, and English speakers who had been trained to talk about time vertically.

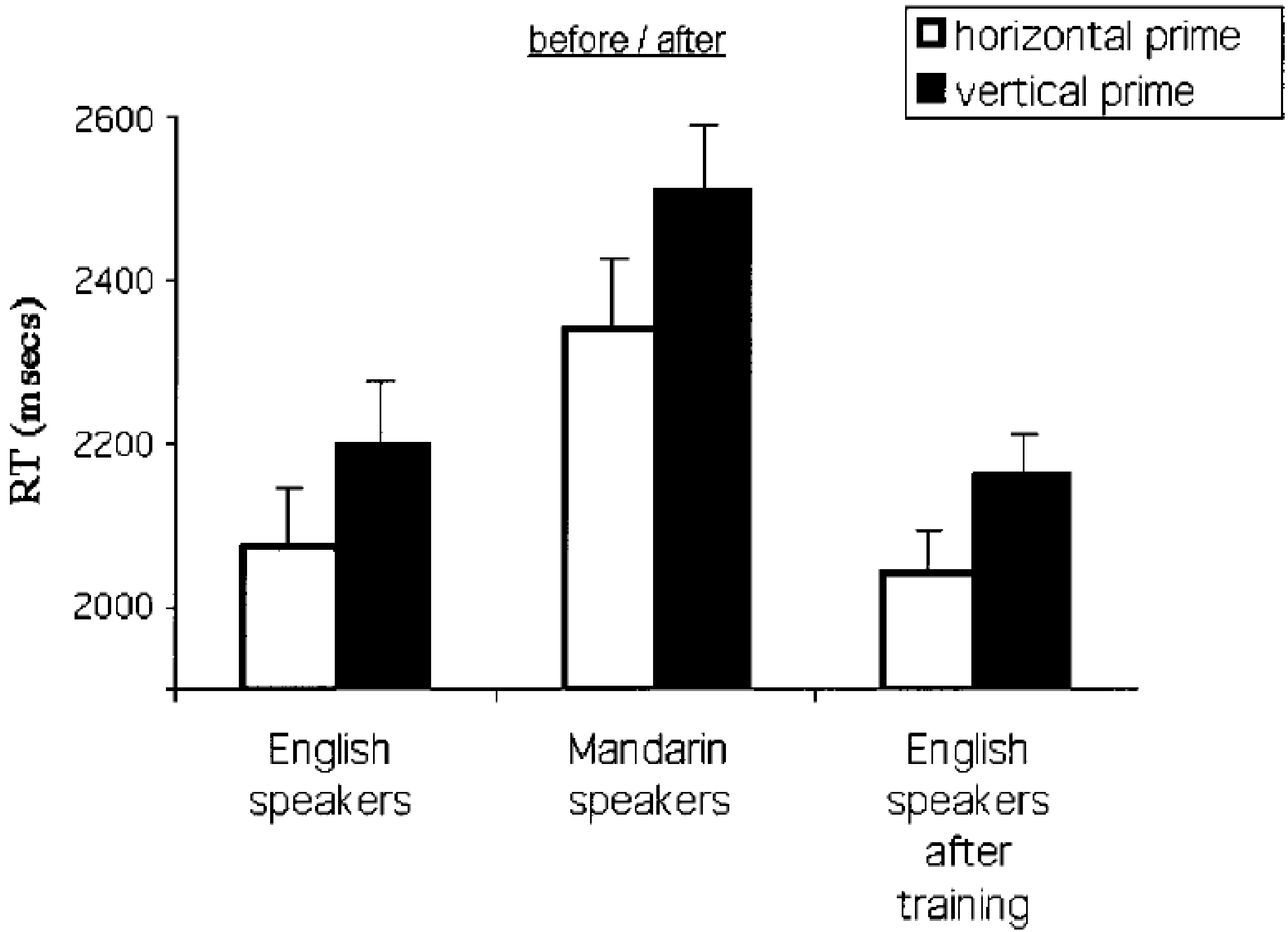


FIG. 4a. Experiments 1 and 3: Response times to spatiotemporal *before/after* questions about time following either a horizontal or a vertical prime are plotted for English speakers, Mandarin speakers, and English speakers who had been trained to talk about time vertically.

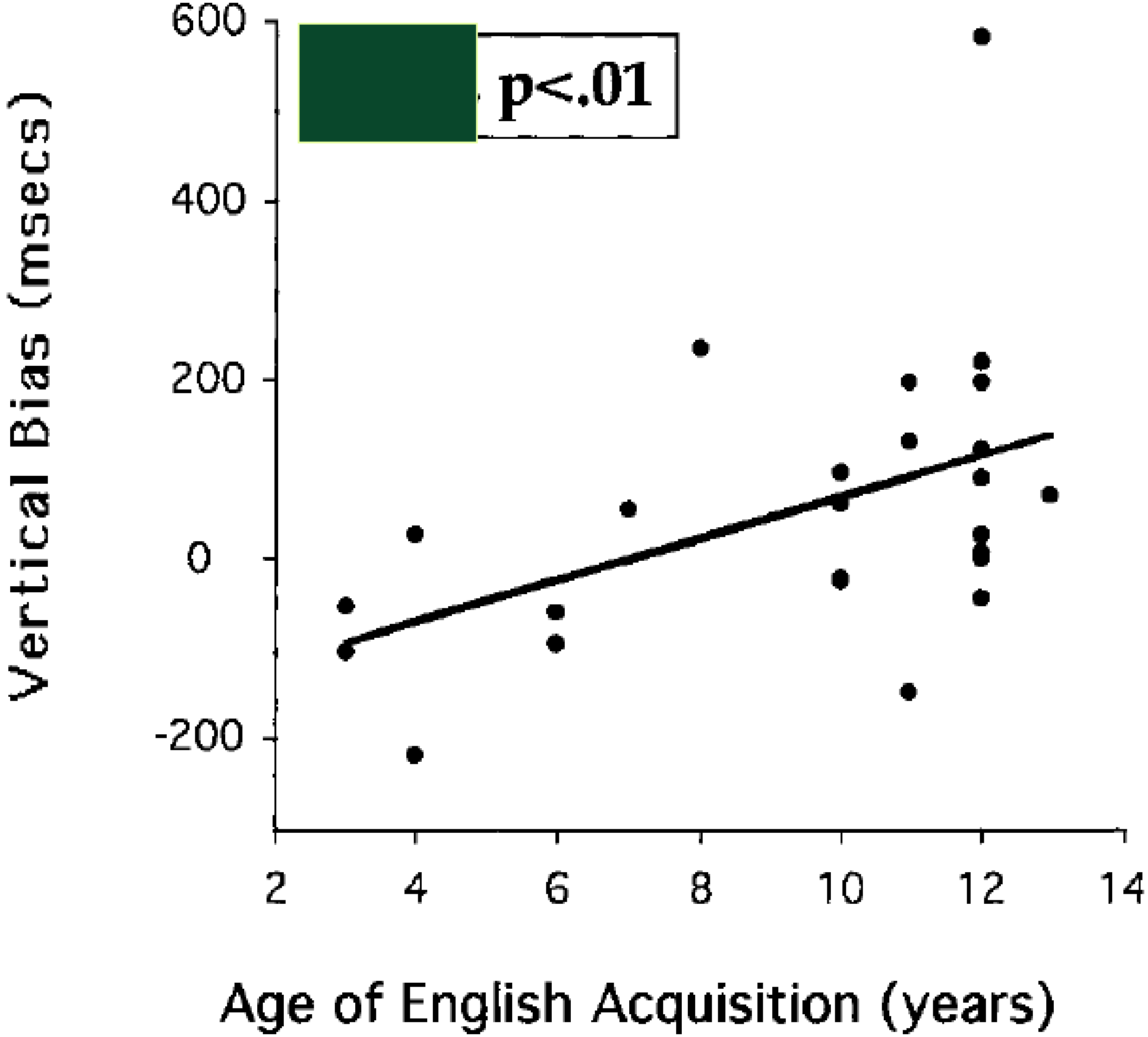


FIG. 6. Experiment 2: Results from 25 Mandarin speakers. Vertical Bias in milliseconds is plotted as a function of Age of Acquisition of English in years. Vertical Bias equals the difference in reaction time between targets following horizontal primes and targets following vertical primes.

Results discussion

- English speakers were faster to verify that ‘‘March comes *earlier* than April’’ after horizontal primes than after vertical primes. This habit of thinking about time horizontally was predicted by the preponderance of horizontal spatial metaphors used to talk about time in English.
- The reverse was true for Mandarin speakers. Mandarin speakers were faster to verify that ‘‘March comes *earlier* than April’’ after vertical primes than after horizontal primes. This habit of thinking about time vertically was predicted by the preponderance of vertical time metaphors in the Mandarin.