Production Compilation

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- Some examples
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- Implementation in 5.0
- Introduction of production compilation raises some issues

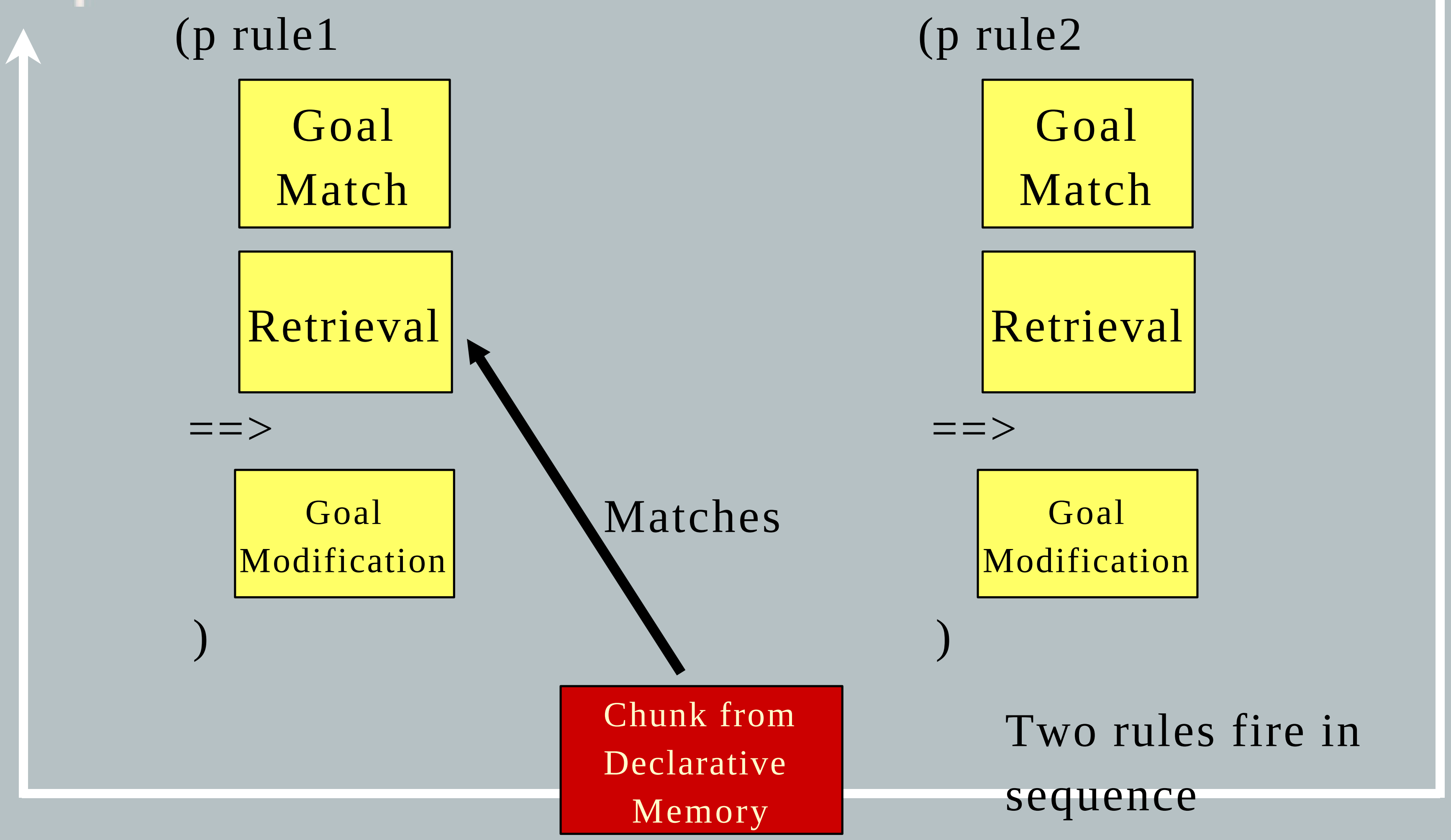
Goals of production compilation

- Gradual speedup as declarative knowledge is compiled into procedural knowledge
- Discontinuous learning: “sudden jumps”

Production compilation: specialization and combination

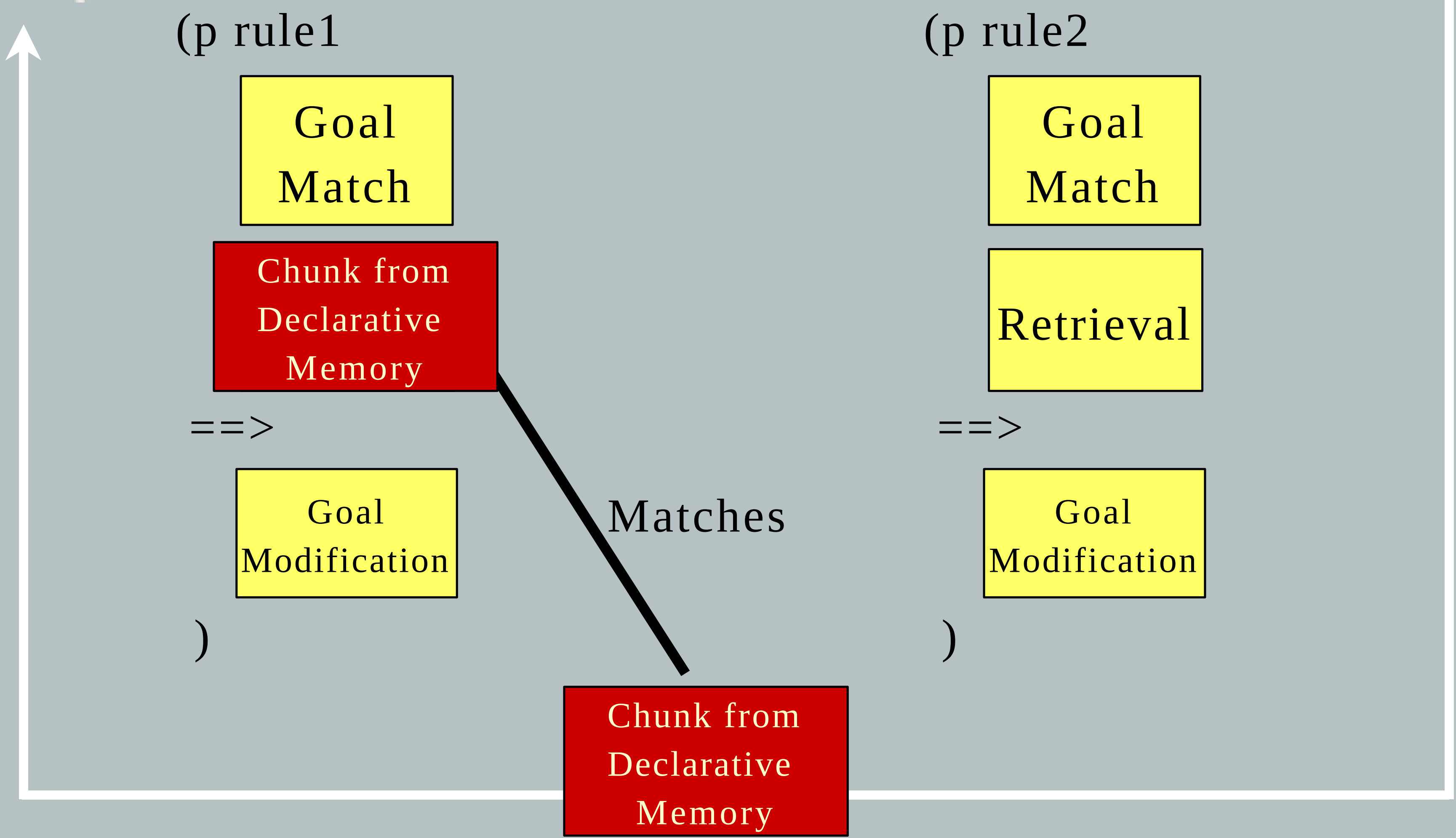
- General idea: two rules that fire in sequence are combined into one
- Production rules are specialized by substituting the retrieval into the rule (or, in 5.0, factoring out the retrieval request and retrieval match)
- Production rules are combined by merging two rules into one

Schematic overview (4.0)

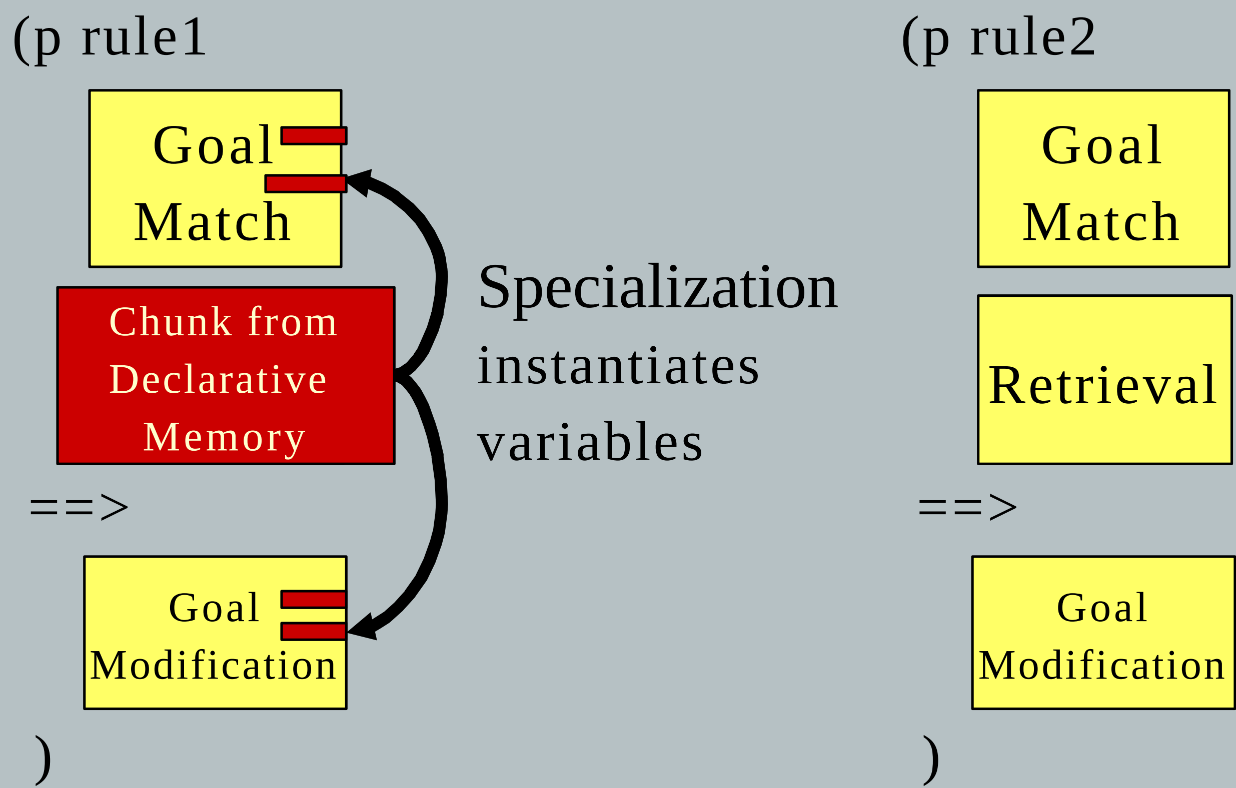


Two rules fire in sequence

Specialization



Specialization



Specialization

(p rule1

Goal
Match

==>

Goal
Modification

)

(p rule2

Goal
Match

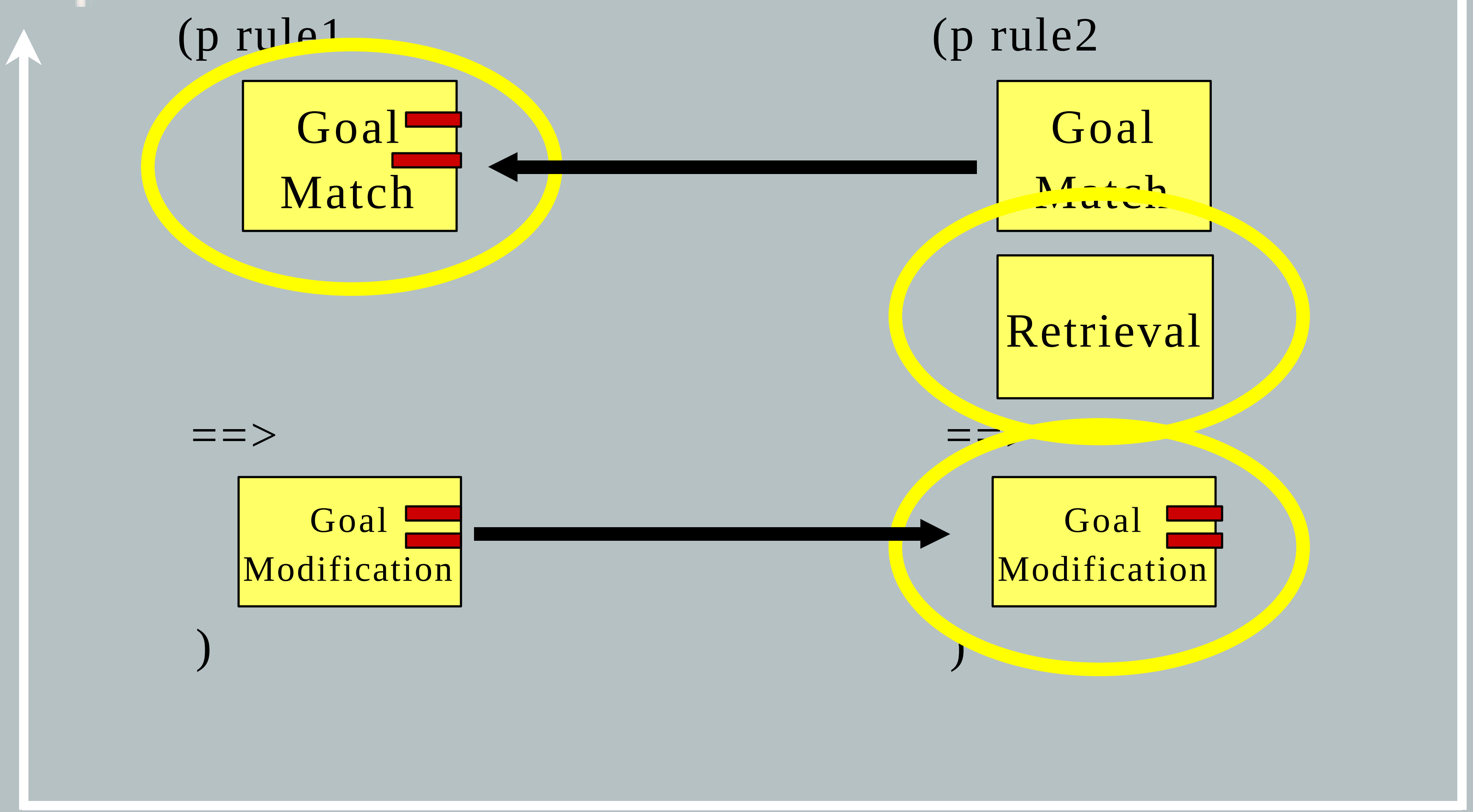
Retrieval

==>

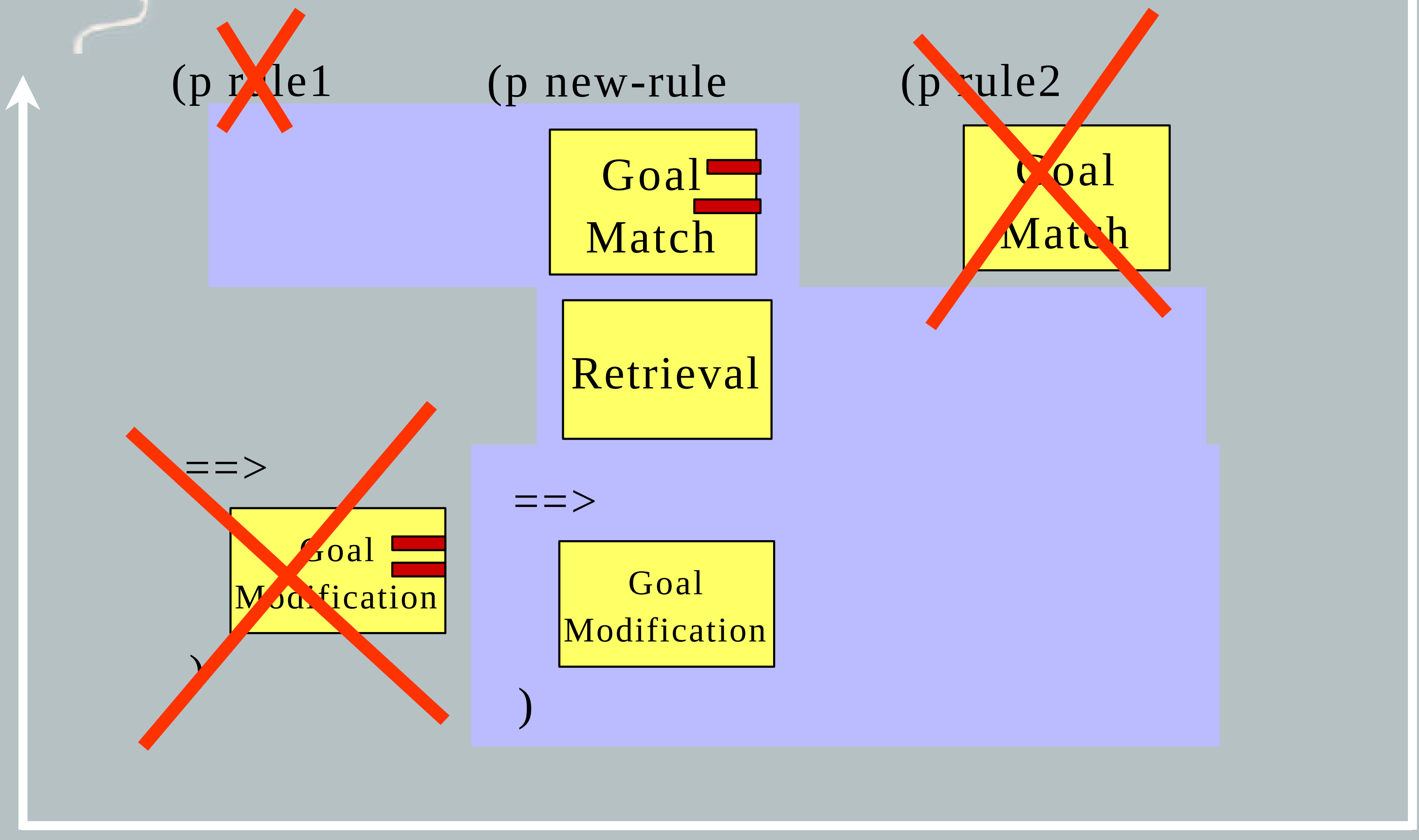
Goal
Modification

)

Combination



Combination



The new rule

(p new-rule

Goal Match

Retrieval

==>

Goal Modification

)

How are rules introduced?

- Rule learning only occurs if parent rules have sufficient experience (!)
- New rule inherits parameters from parents, except for the number of initial experiences
- New rule receives an initial penalty on expected gain to ensure gradual introduction

Properties of the new compilation

- It is implicit
- It supports a transition from declarative to procedural knowledge
- Doesn't produce illegal or short-circuiting rules because all new rules are specializations of existing rules

Support for gradual speedup

- By factoring out retrievals
  - Speedup because retrievals are no longer needed
  - It reduces errors (retrieval errors)
  - Frees up "working memory" by reducing interference (example in KA-ATC model)

Discontinuous learning

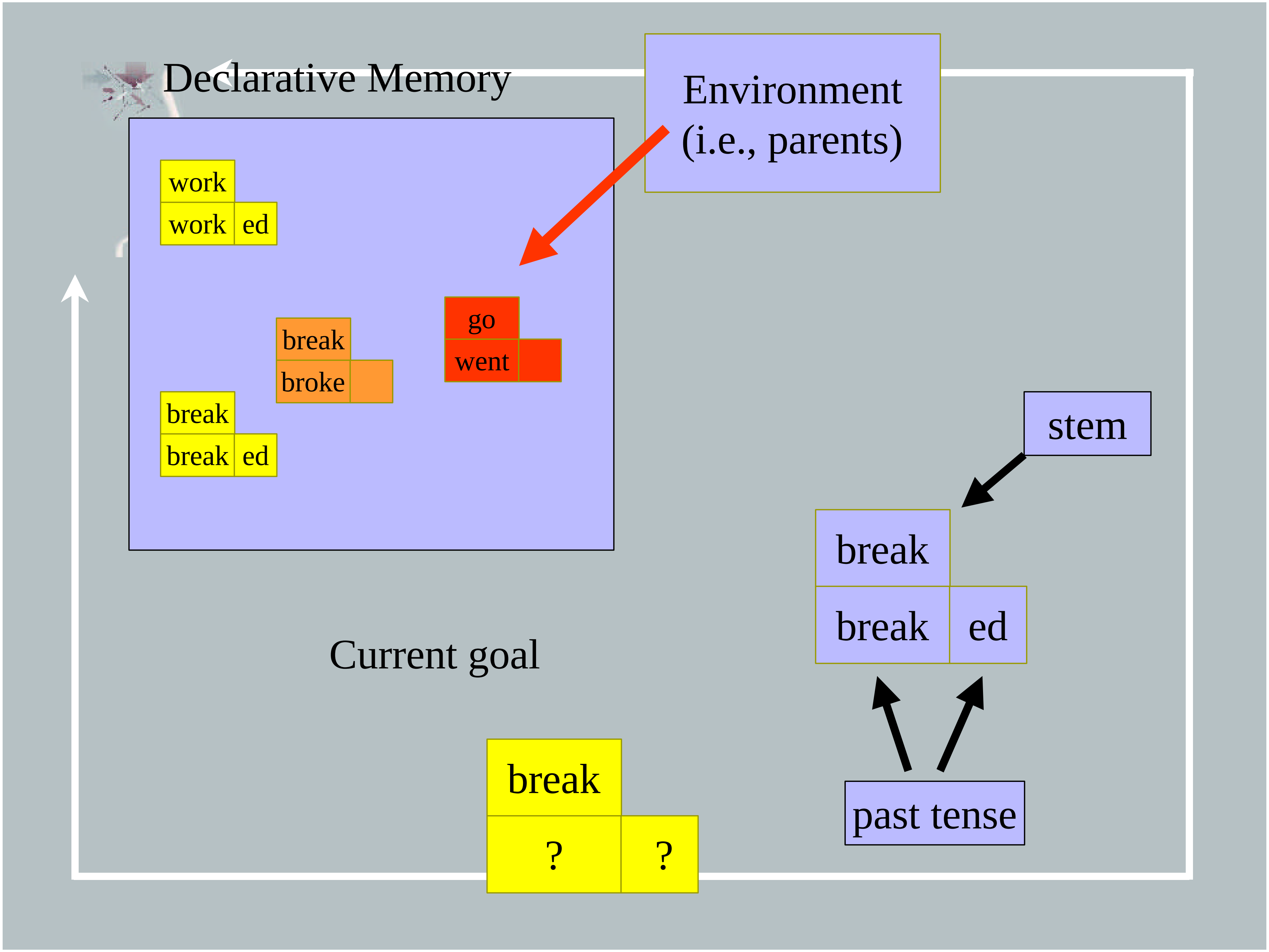
- In declarative memory, ***activation*** (how often is a chunk used) determines its success
- In procedural memory, ***expected gain*** (how efficient is the use of knowledge) determines its success
- A shift from declarative to procedural may produce transition effects: for example, U-shaped learning

Example: Learning the past tense

- At some point during language development, children discover and use the regular rule of past tense inflection:

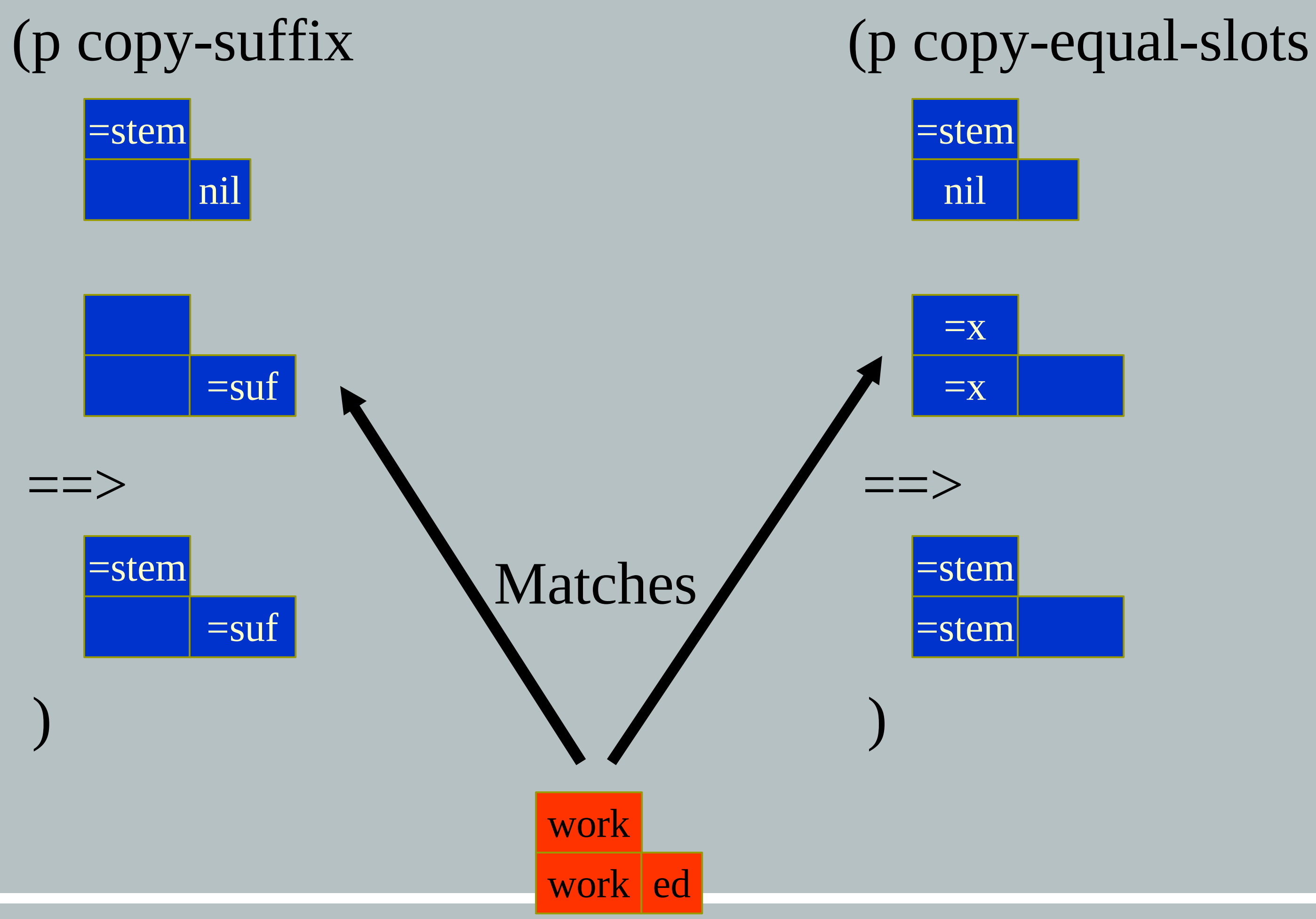
To get the past tense of a verb, add –ed to it.

- The regular rule can be learned by applying production compilation to two productions that implement analogy

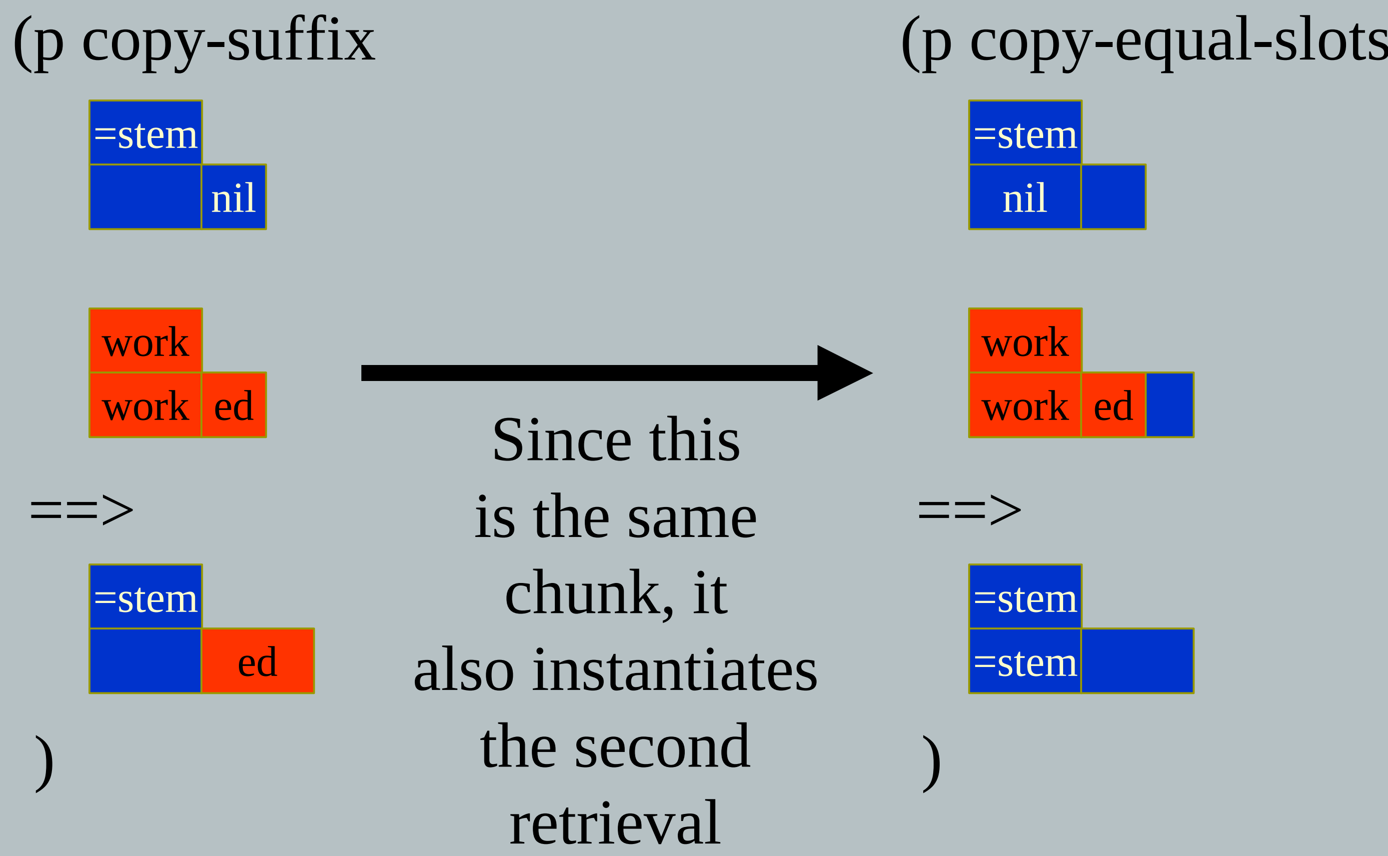


Declarative Memory
Environment
(i.e., parents)
work
work ed
break
broke
go
went
break
break ed
stem
break
break ed
Current goal
break
? ?
past tense

Regular rule is learned by specializing Analogy



Regular rule is learned by specializing Analogy



Regular rule is learned by specializing Analogy

(p learned-regular-rule

=stem	
nil	nil

==>

=stem	
=stem	ed

)

U-shaped learning

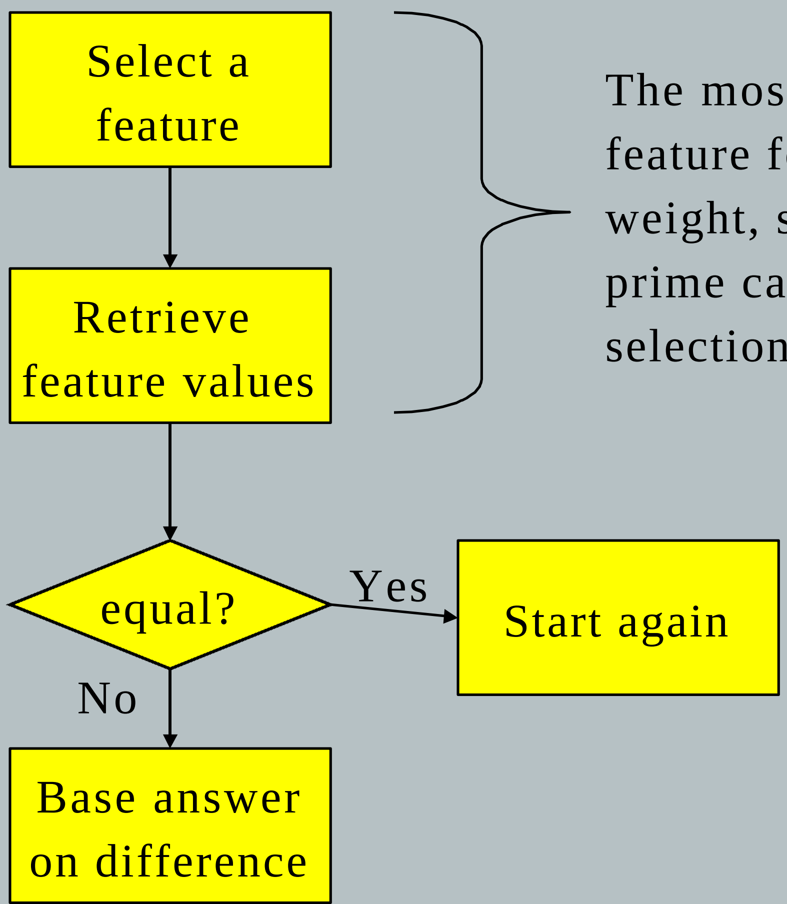
Important aspect of past tense

- In the "base-level activation" domain, using -ed examples is ***rare***, because they have low activations (regular verbs are low-frequent)
- In the "expected gain" domain, using -ed is ***frequent***, because it is an efficient strategy (you can add -ed to any verb you want)

Example: Balanced Beam (work by Hedderik van Rijn)

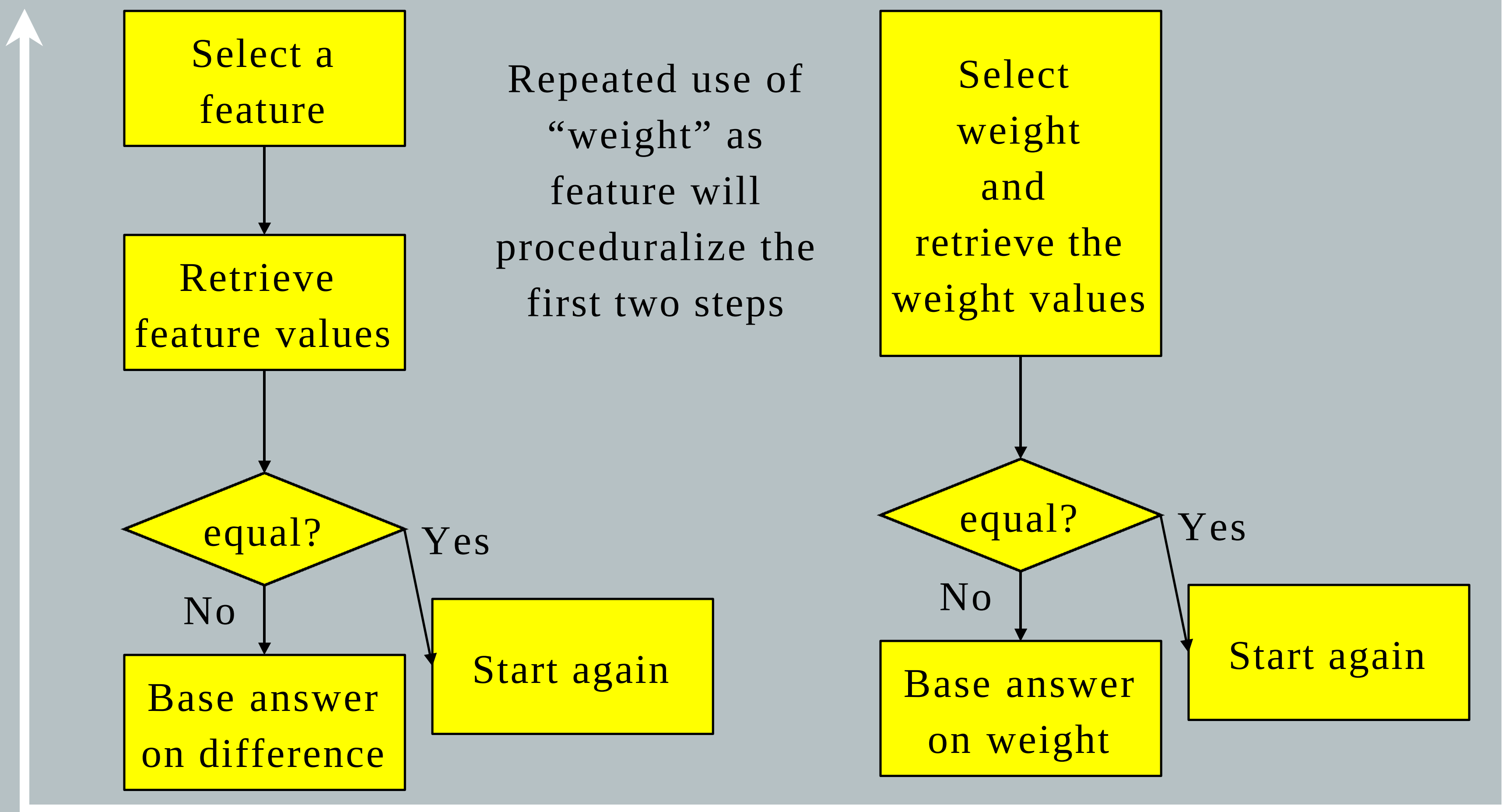
- Stage 1: Only look at weights
- Stage 2: Look at weights, and if they are equal, look at distance

Pre-stage 1 strategy

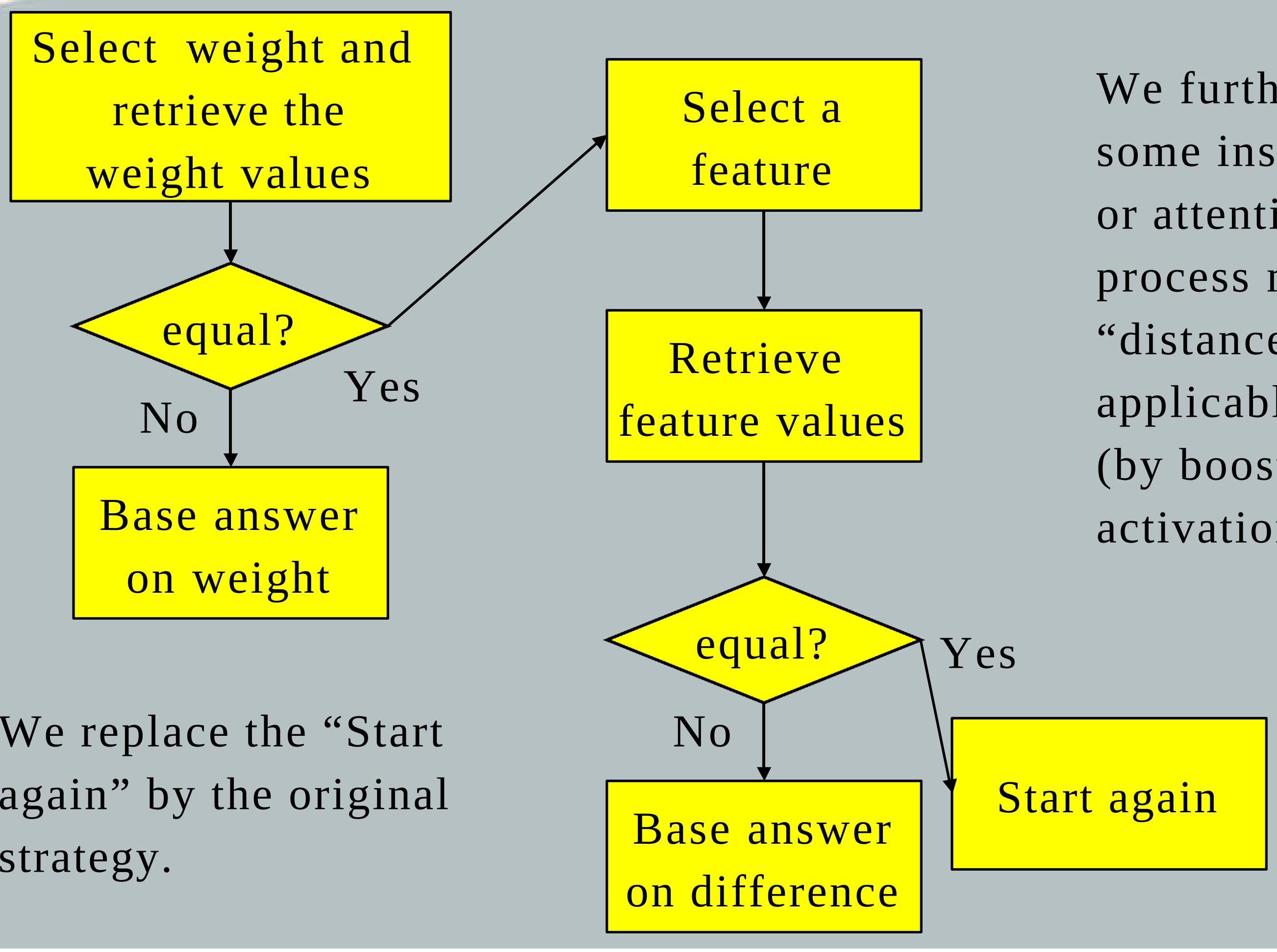


The most promising feature for a beam is weight, so weight is a prime candidate for selection

Stage 1 strategy



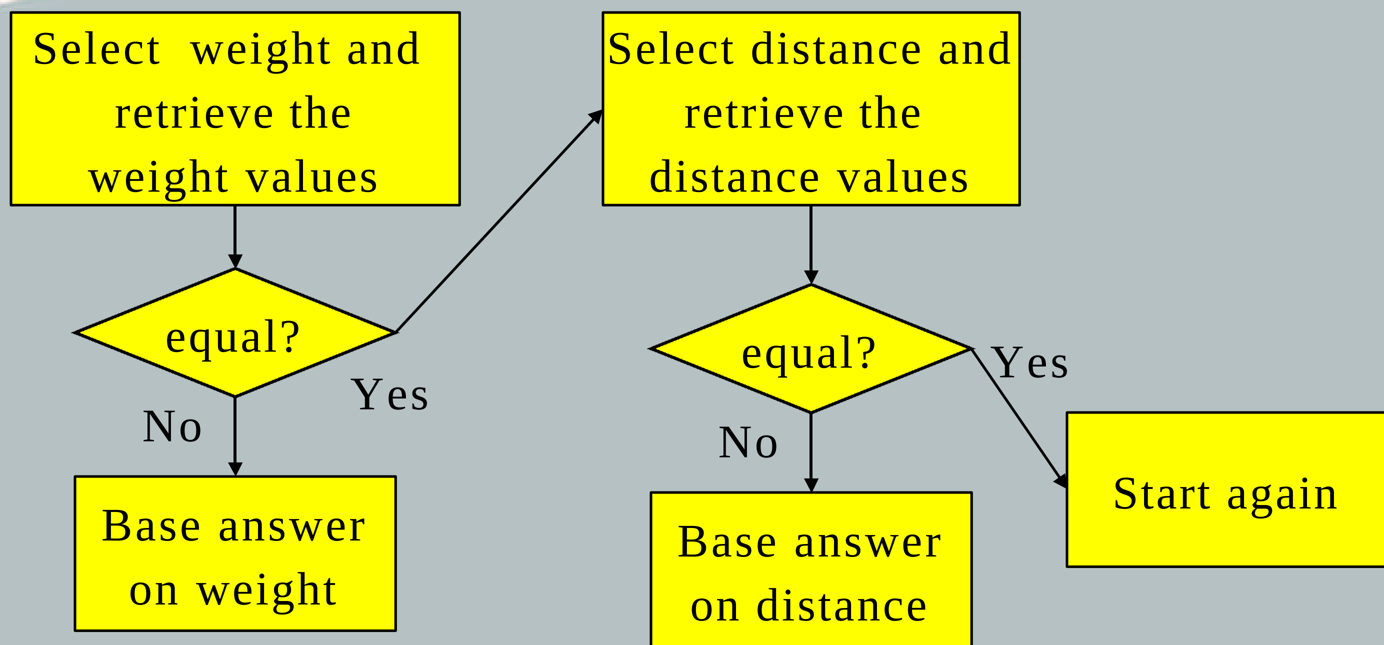
Stage 1 --> Stage 2



We further assume some instructional or attentional process marks “distance” as an applicable feature (by boosting activation)

We replace the “Start again” by the original strategy.

Stage 2


Select weight and retrieve the weight values
equal?
Yes
No
Base answer on weight
Select distance and retrieve the distance values
equal?
Yes
No
Base answer on distance
Start again

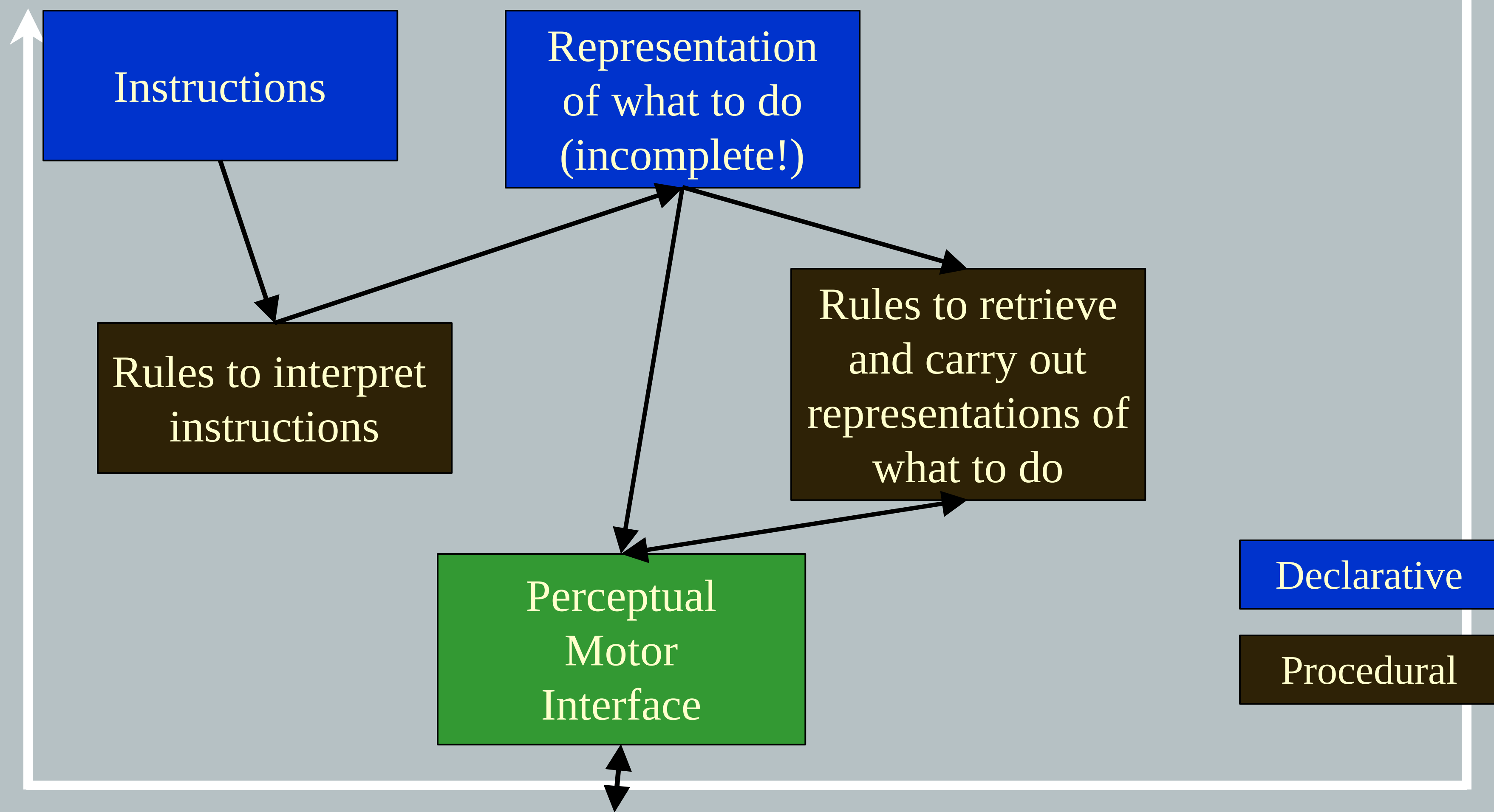
Learning from instructions

- If the chunk that is specialized is an instruction, we can have general task-independent productions that interpret task-specific chunks.
- We therefore need retrieve and interpret instructions
- More on this in the instruction session

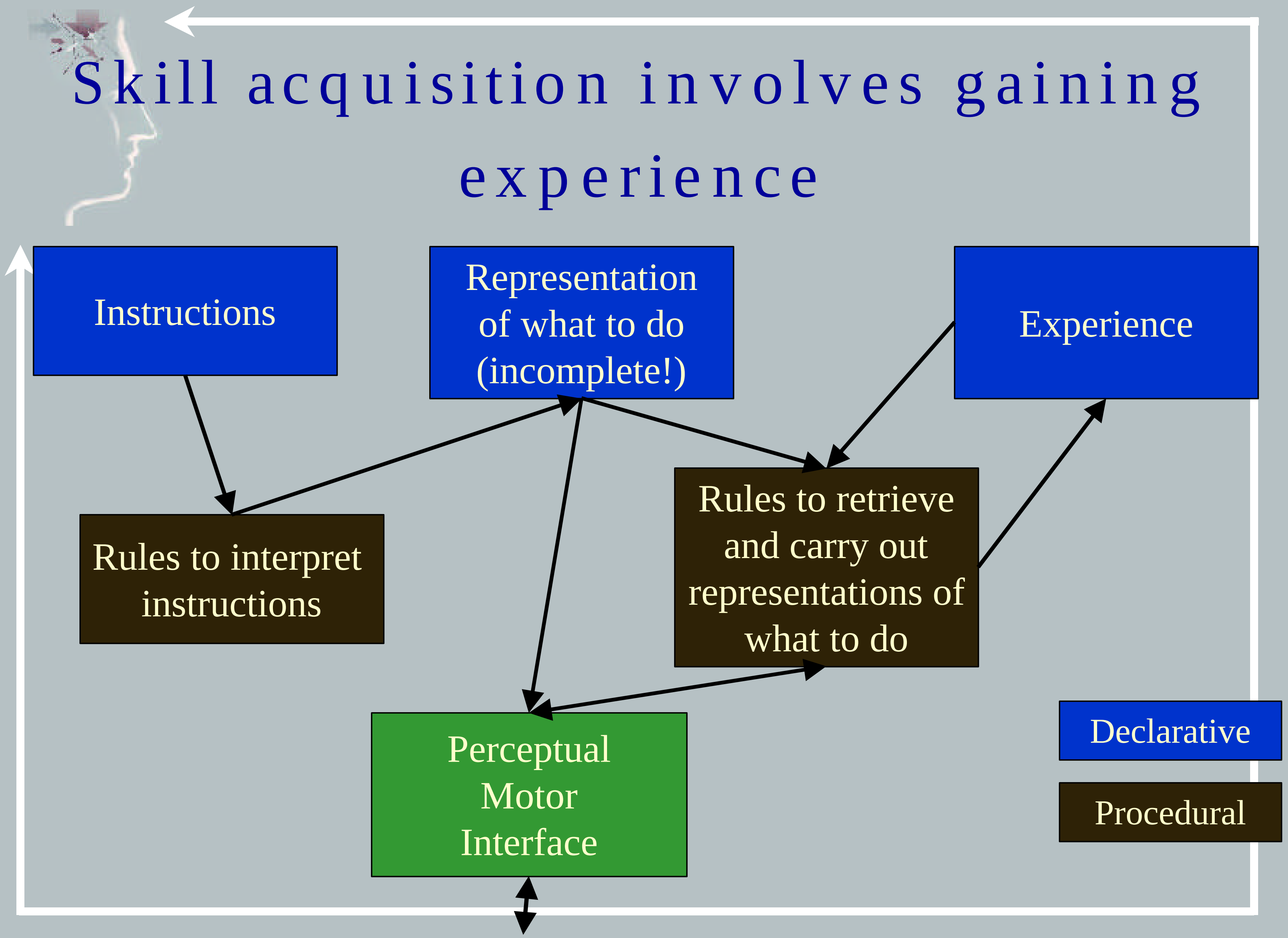
Skill acquisition

- Learning from instructions is the first step in the acquisition of new skills
- Preview of ICCM talk: model of the KA-ATC task

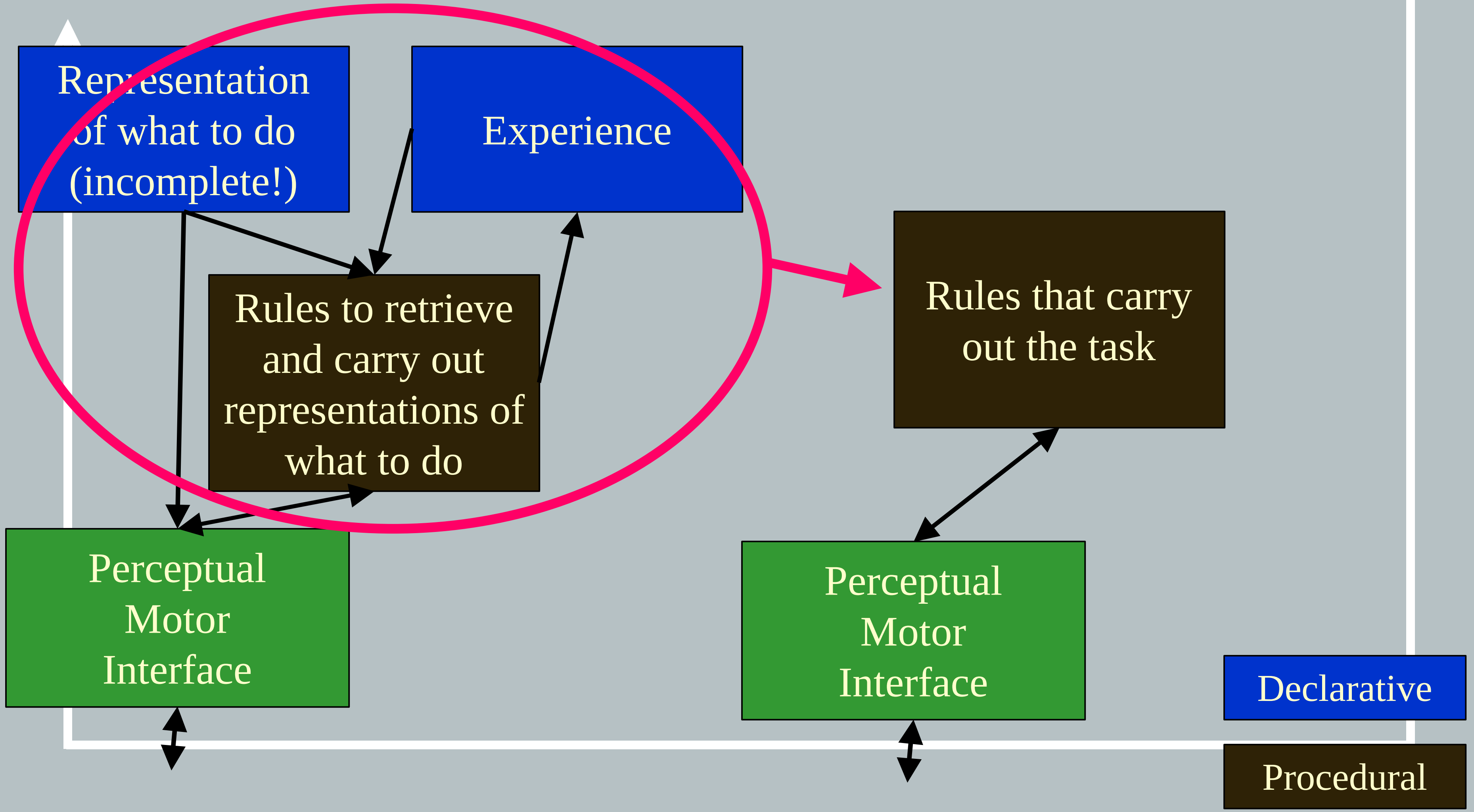
The present model



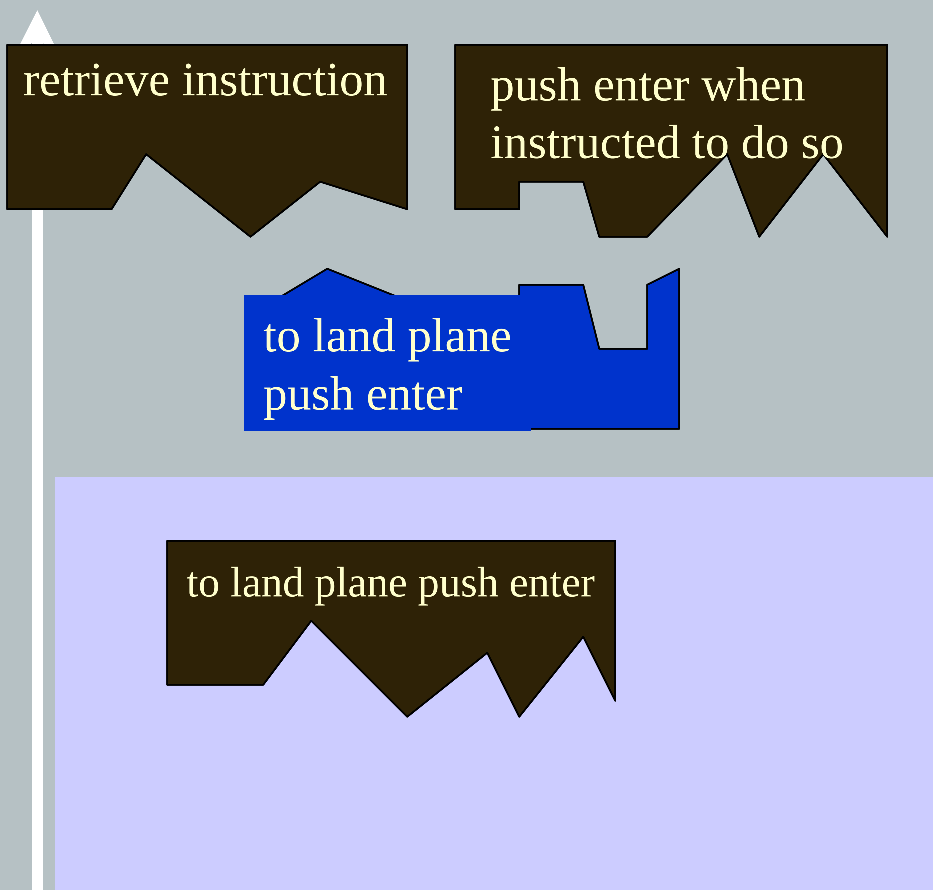
Skill acquisition involves gaining experience



Skill acquisition also involves learning new rules



Production compilation



- Merge two rules into one
- While substituting the retrieved chunk into the new rule

Procedural

Declarative

Production compilation based on experience

Retrieve an successful experience to land the current plane type given the current runway condition on a certain runway

Decide to land the plane on the runway from the retrieved experience

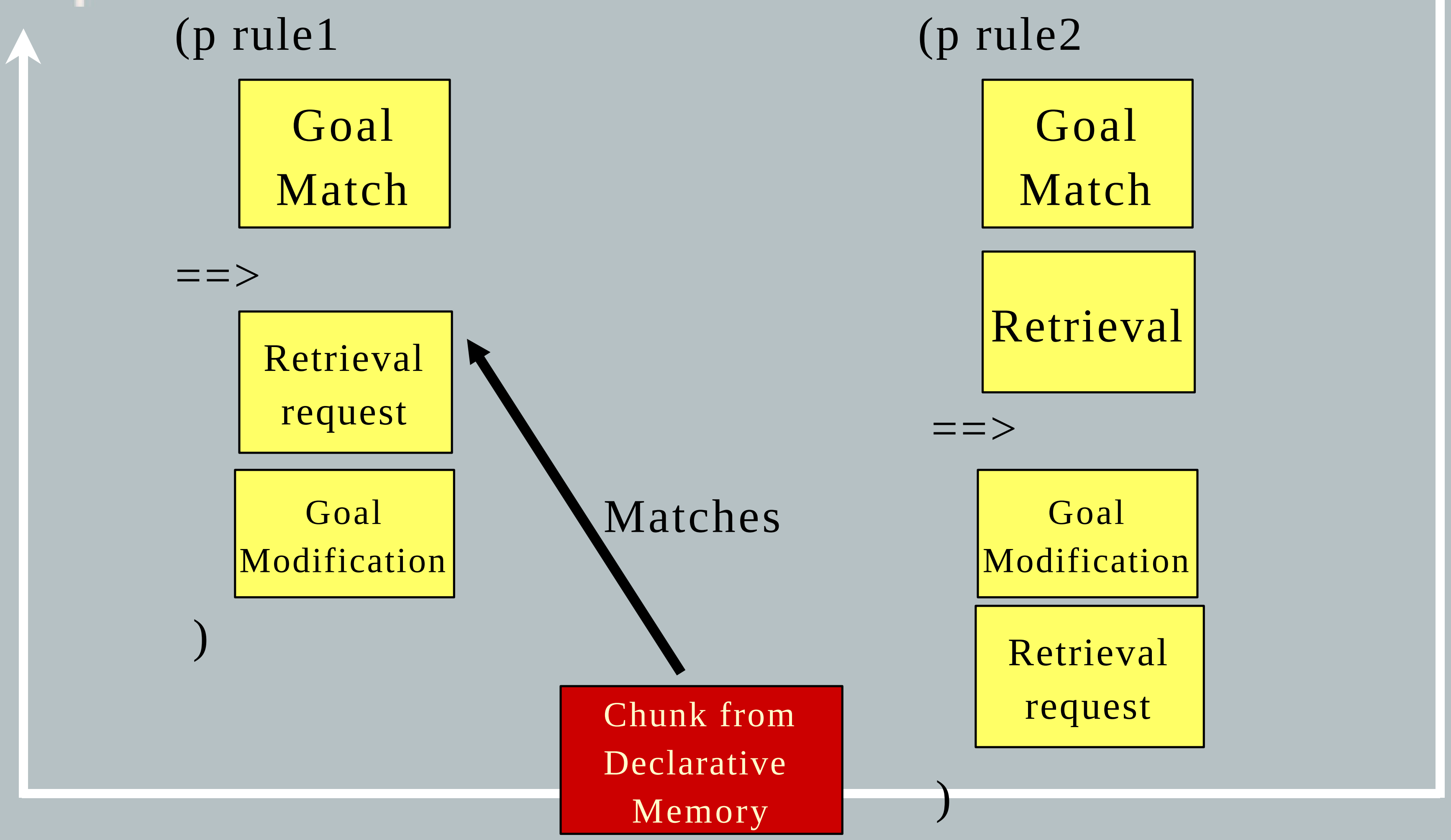
Landing a DC10 when the runways were DRY was successful on the short runway

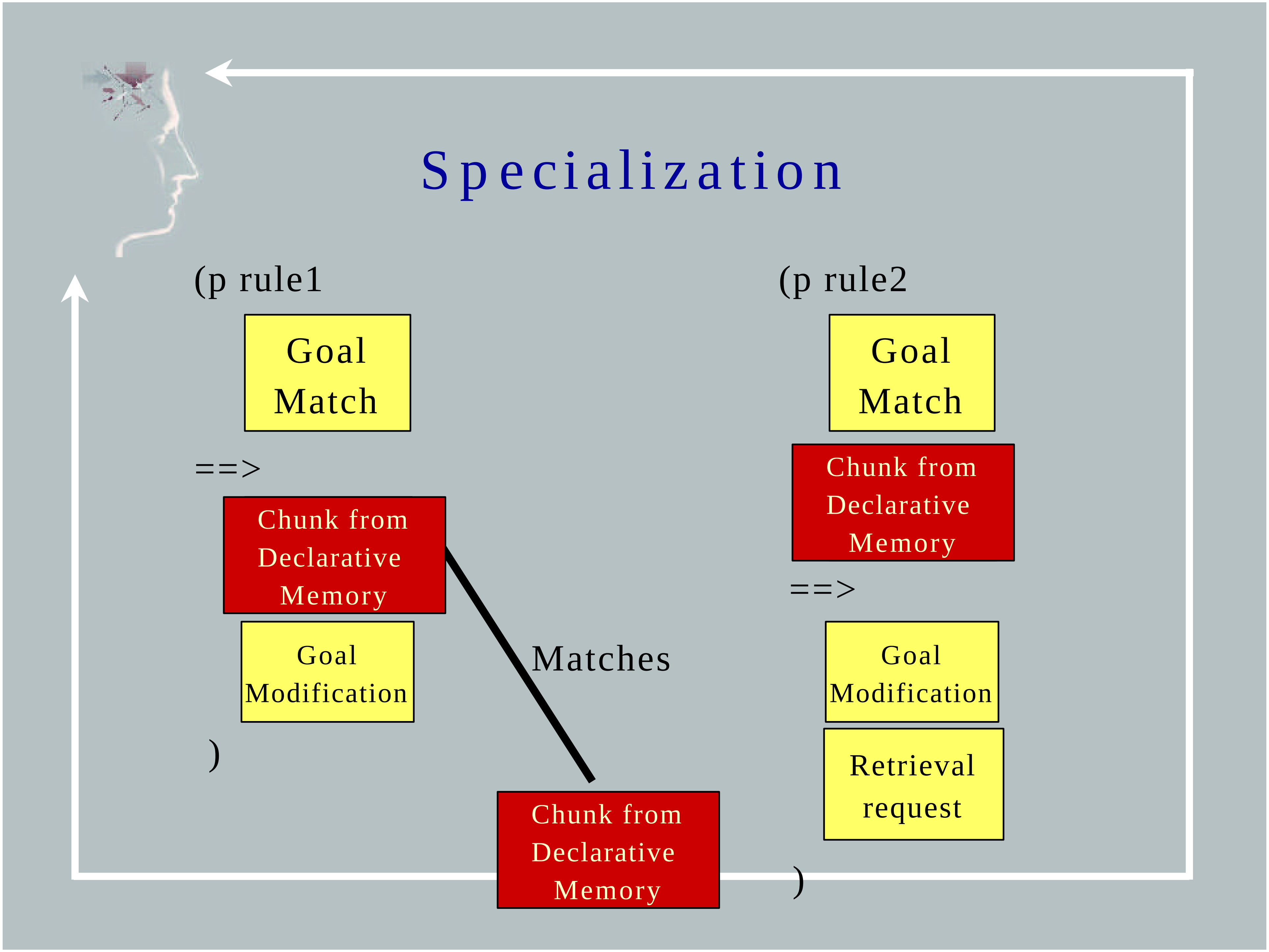
If the plane is a DC10 and the runway is DRY, take the short runway

Procedural

Declarative

Schematic overview (5.0)





Specialization
(p rule1
Goal Match
==>
Chunk from Declarative Memory
Goal Modification
)
Matches
Chunk from Declarative Memory
(p rule2
Goal Match
Chunk from Declarative Memory
==>
Goal Modification
Retrieval request
)

Specialization

(p rule1

Goal
Match

==>

Chunk from
Declarative
Memory

Goal
Modification

)

Specialization
instantiates
variables

(p rule2

Goal
Match

Chunk from
Declarative
Memory

==>

Goal
Modification

Retrieval
request

)

Specialization

(p rule1

Goal
Match

==>

Goal
Modification

)

(p rule2

Goal
Match

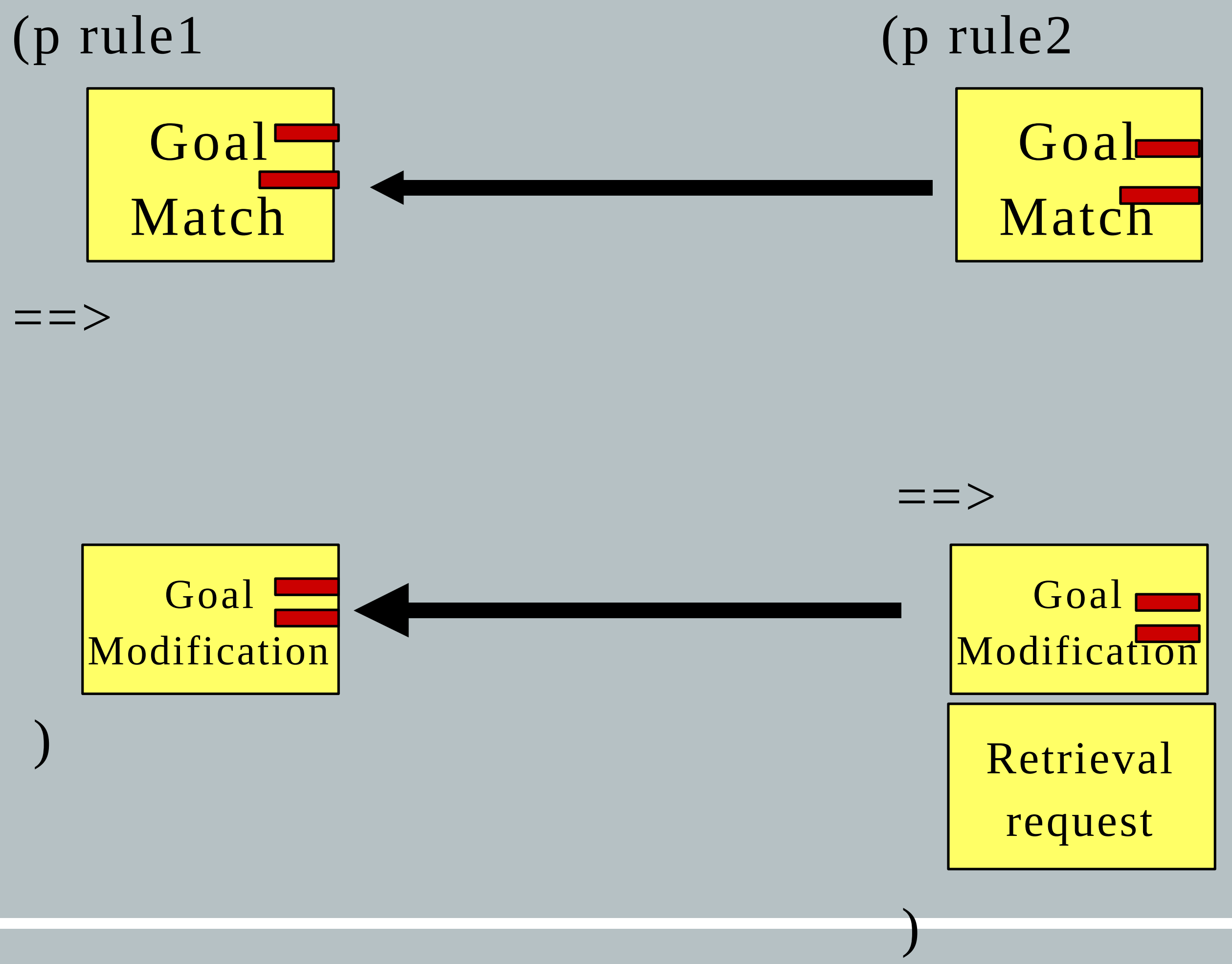
==>

Goal
Modification

Retrieval
request

)

Combination



Combination

(p new-rule

Goal

Match

==>

Retrieval request

Goal Modification

)

Issues in production compilation

- You cannot properly use production compilation without switching on all the other learning mechanisms and expected gain noise. You need at least base-level learning and production parameter learning for it to work at all.

Issues in production compilation

- Production compilation emphasizes the need to work towards models that contain as little task-specific knowledge as possible, except in the form of instructions
  - Declarative instructions
  - General problem solving productions (e.g., retrieval, analogy)

Issues in production compilation

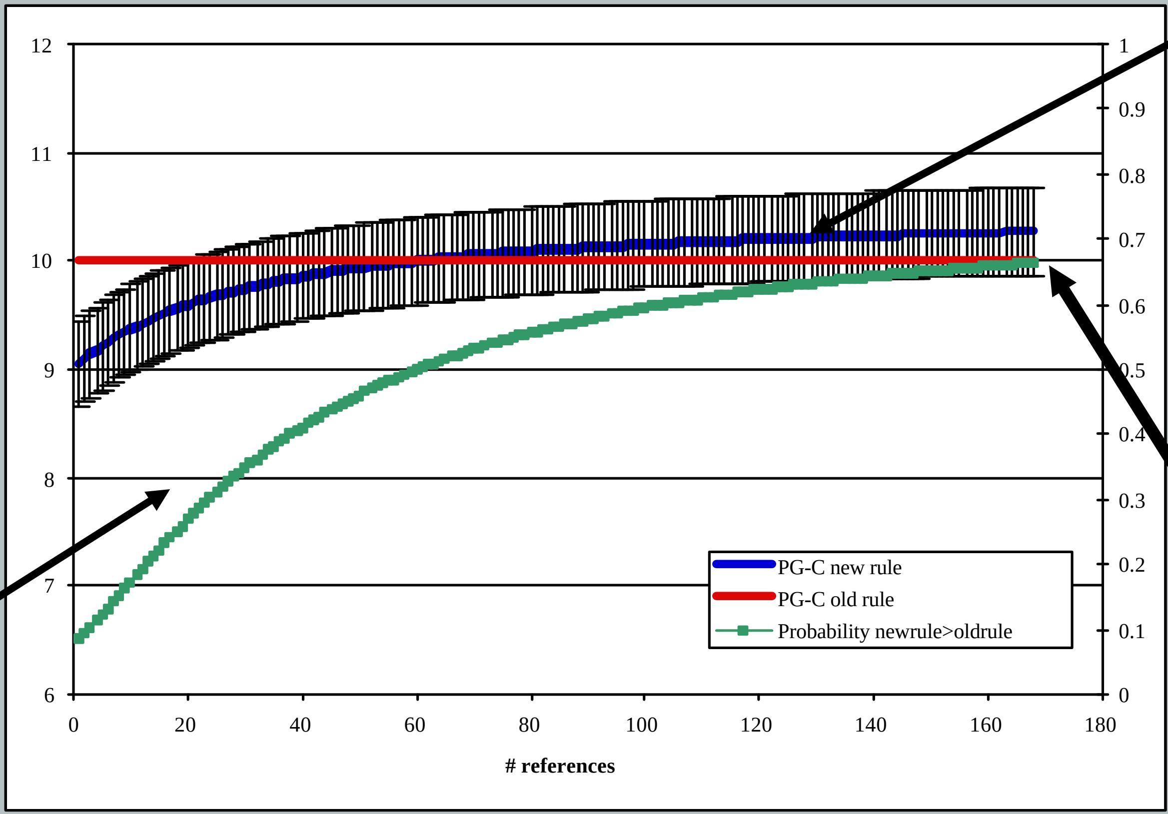
- Interaction with declarative memory
  - Initially, selected of knowledge is based on activation: how often does it occur in the environment, and how often is it retrieved
  - Eventually, selection of knowledge is based on expected gain: how useful is the knowledge.
- Potential evidence: U-shaped learning

Issues in production compilation

- We want the new rule to gradually replace the parent rules, but only if the new rule is better

The case of fixed noise

new rule receives a cost-penalty of 1



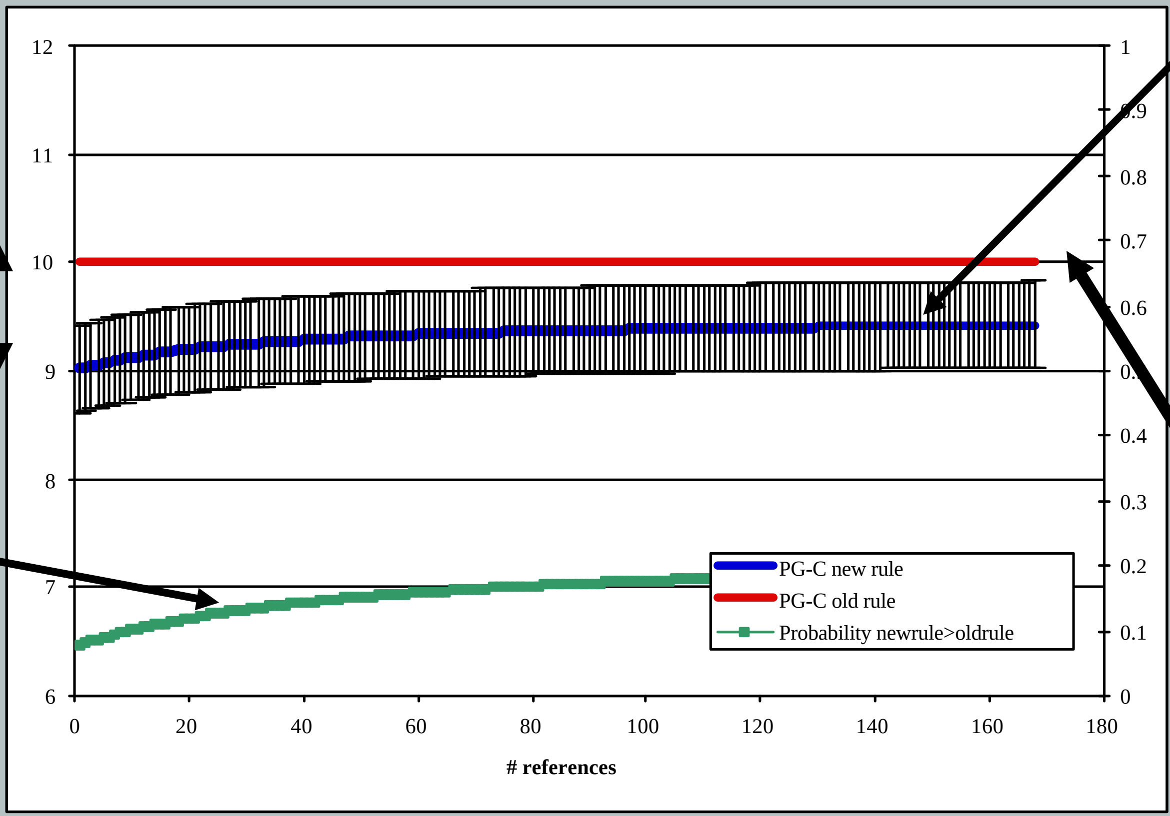
New rule has a eventual PG-C of 10.5

Parent rule (red) has a PG-C of 10.

Probability of using new rule goes up

Learned rule is worse with fixed noise

new rule receives a cost-penalty of 1



New rule has a eventual PG-C of 9.5

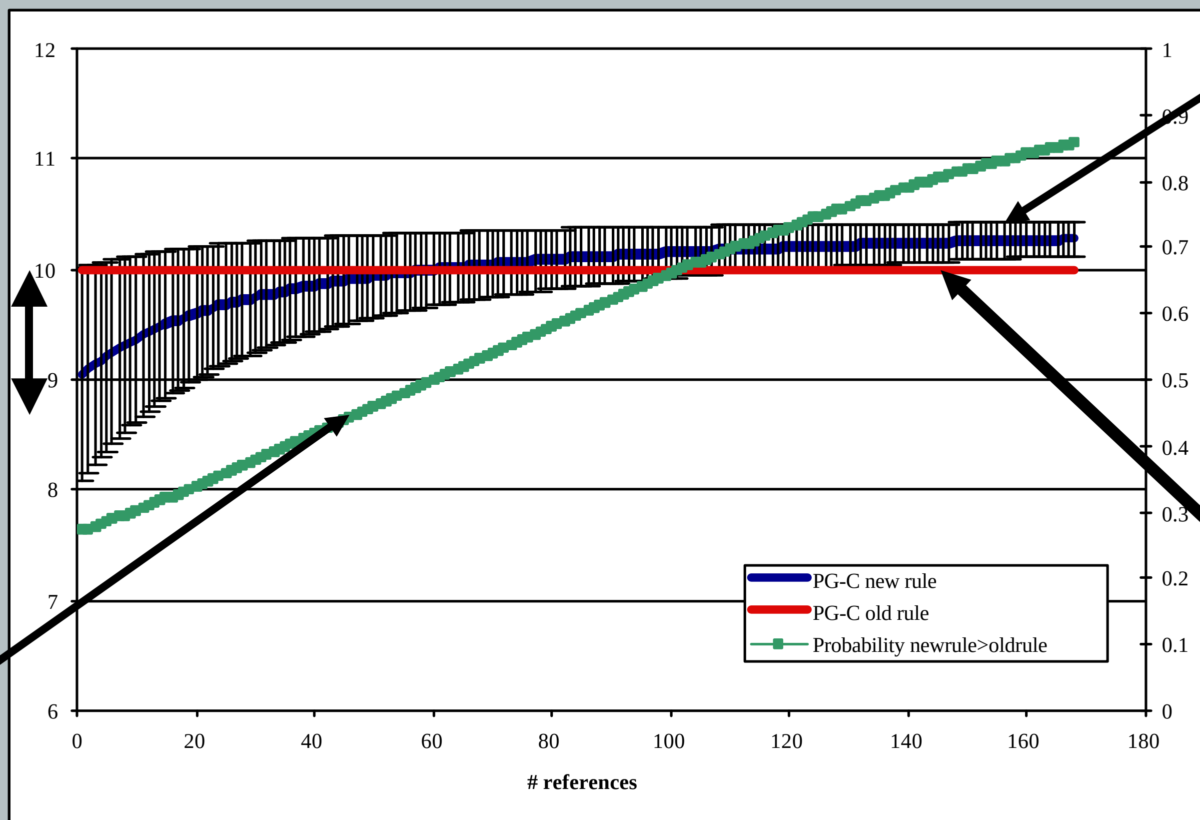
Parent rule (red) has a PG-C of 10.

Probability of using new rule goes up but should go down

One idea: decreasing noise

New rule has a eventual PG-C of 10.5

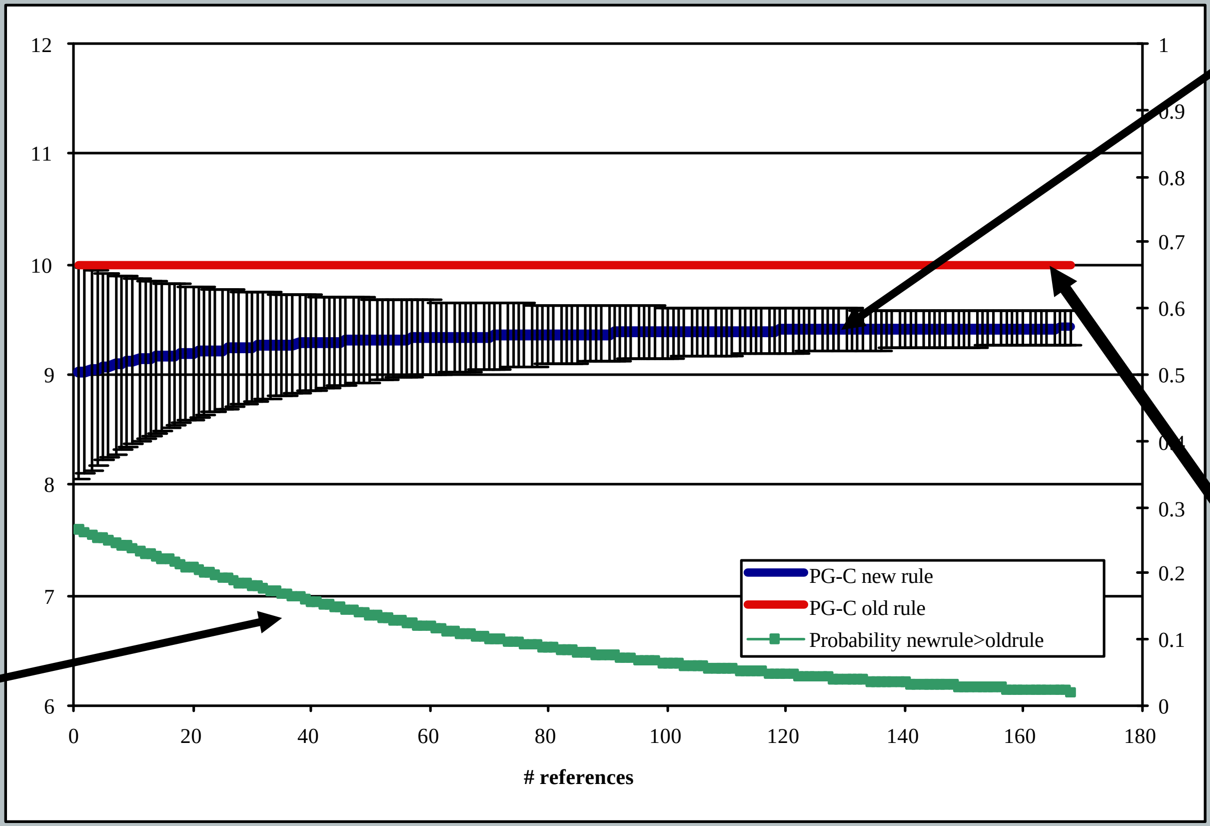
new rule receives a cost-penalty of 1



Parent rule has a PG-C of 10.

Probability of using new rule goes up

If the new rule is worse than the parents...

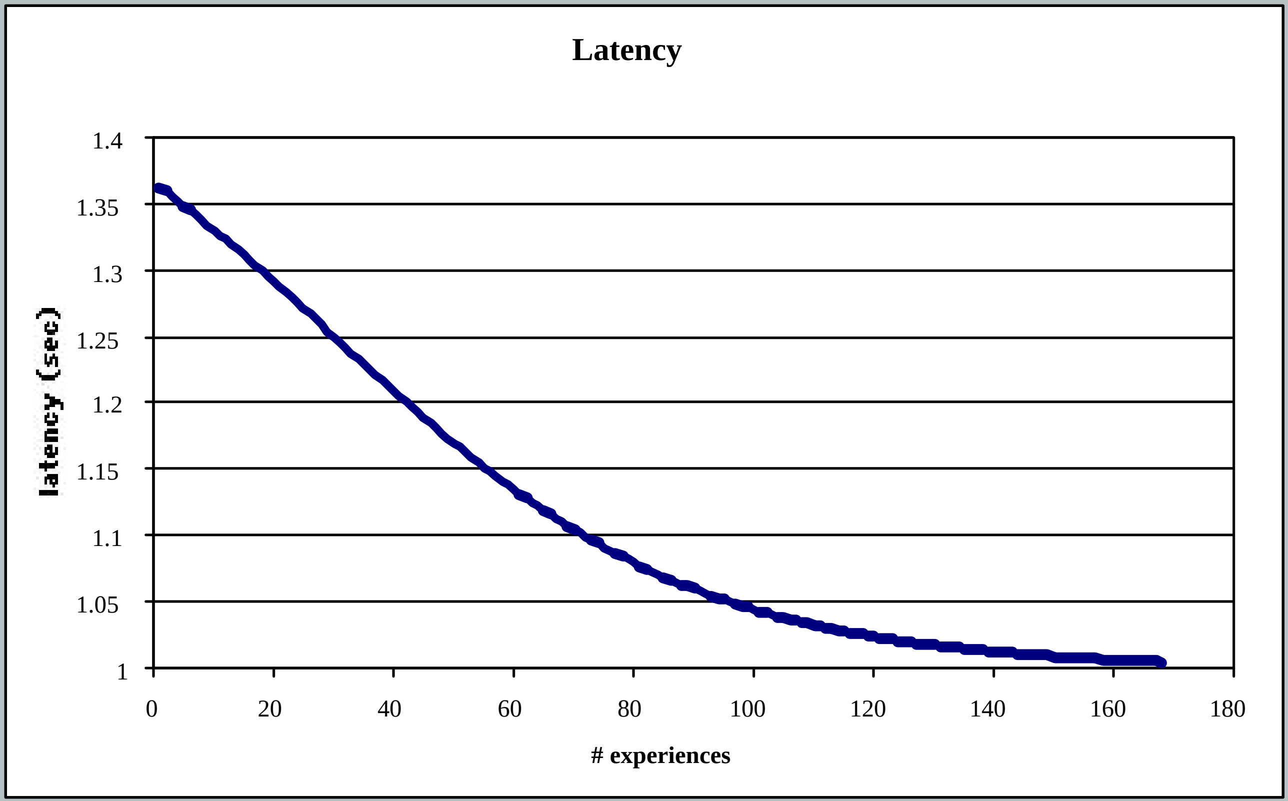


New rule has an eventual PG-C of 9.5

Parent rule has a PG-C of 10.

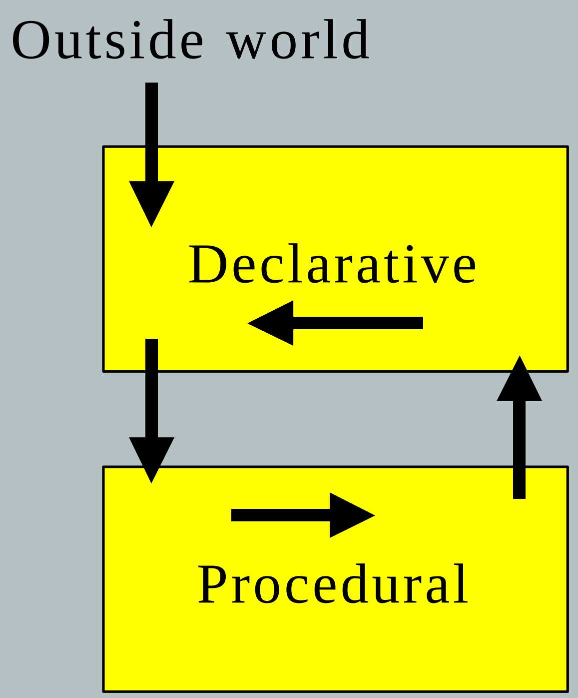
Probability of using new rule goes down

Gradual introduction has the same effect as the discontinued strength learning



Issues in production compilation

- Addition of production compilation closes the learning cycle, with the possibility of more autonomous behavior
- And it raises the bootstrapping question



Some final issues

- May solve the baselevel learning decay problem: is it 0.5 (short-term) or 0.3 (long-term)?
- Retrieval failures proceduralize are hard to proceduralize
- How to learn productions without goals? How does production learning handle other buffers?