Identifying Dual-Task Executive Process Knowledge Using EPIC-Soar

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PRESENTATION OUTLINE

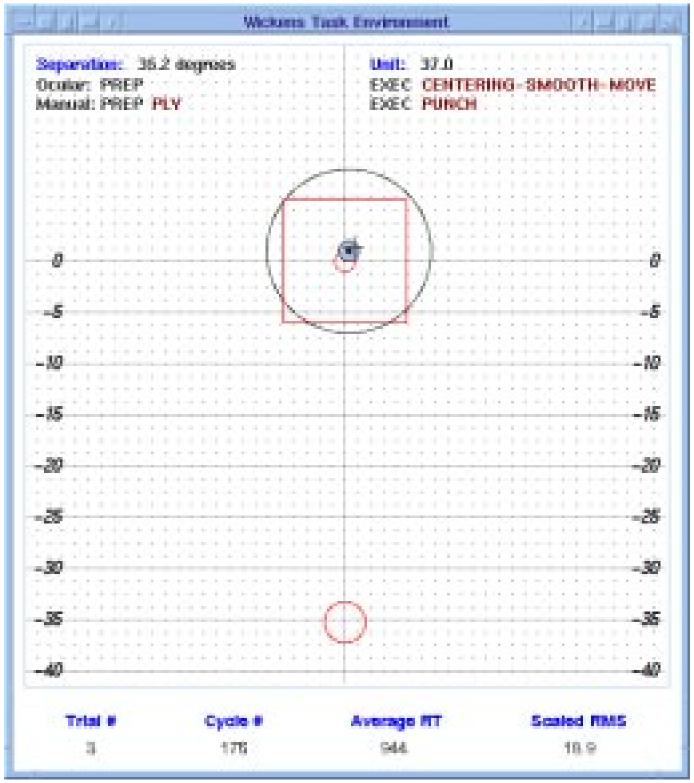
- **Introduction**
- **The Wickens’ Task**
- **EPIC**
- **EPIC-Soar**
- **Current Work**
- **Future Work**

INTRODUCTION

- **People encounter many activities that require the performance of more than one task at a time**
  - *Nuclear plant controller monitoring plant parameters*
  - *Pilot landing a passenger airplane in inclement weather*
  - *F1 driver down-shifting, steering, braking, and planning strategy*
  - *Grad students playing DOOM*
- **How do people learn to perform these kinds of tasks?**
- **What do people learn when becoming proficient at these kinds of tasks?**

THE WICKENS' TASK

- **A study by Martin-Emerson & Wickens (1992)**
- **Consists of a tracking task and a choice-reaction time task**
- **Vertical separation and tracking difficulty are manipulated**
- **Study the effect of vertical separation on tracking and choice task performance**
- **Results of this study apply to the design of heads-up displays**
- **Vertical separation and tracking difficulty are manipulated**



Separation: 36.2 degrees
Ocular: PREP
Manual: PREP PLY

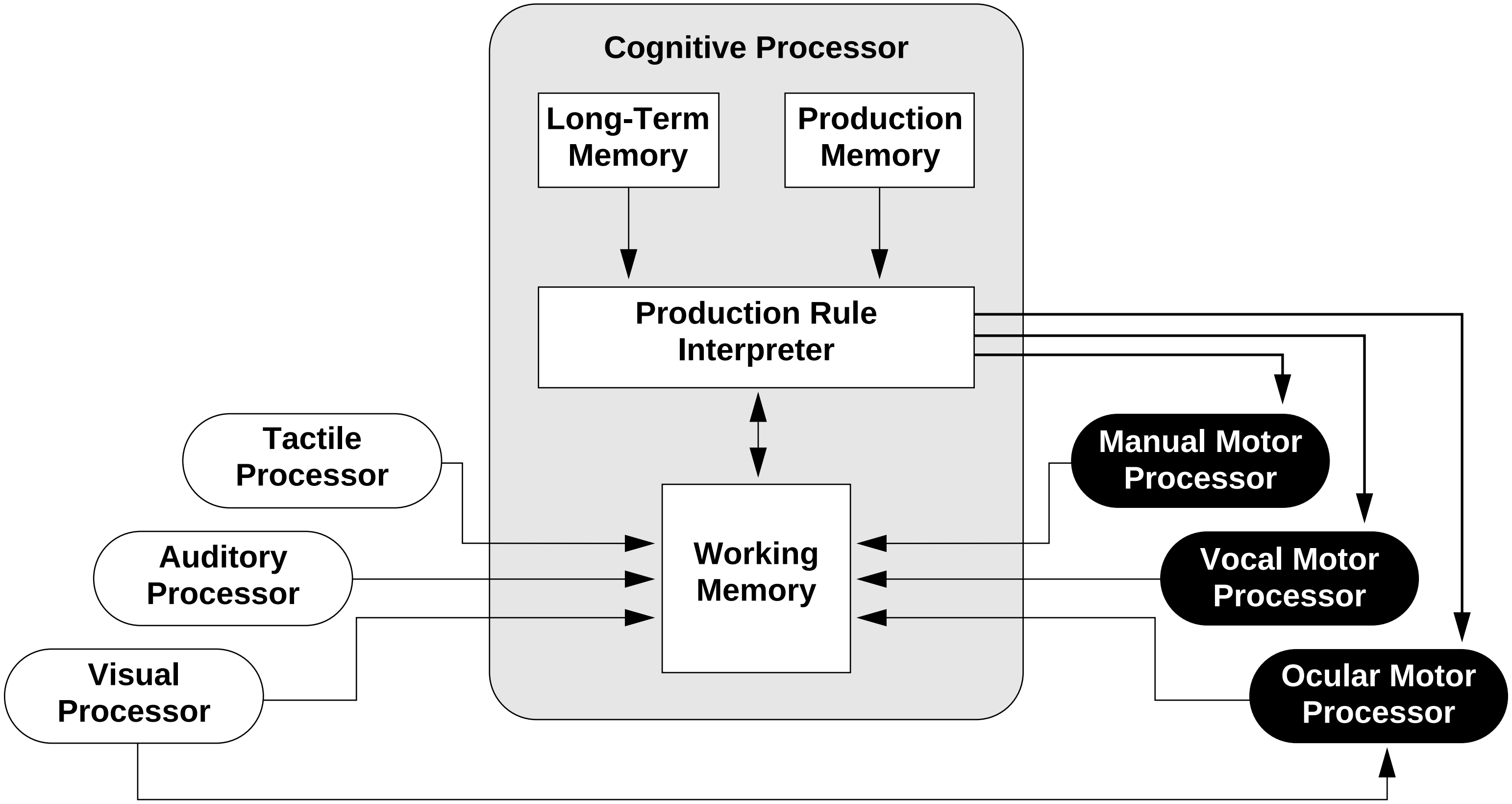
Unit: 37.0
EXEC CENTERING-SMOOTH-MOVE
EXEC PUNCH

Trial #	Cycle #	Average RT	Scaled RMS
3	176	944	18.9

- **Reation time computed as the time from stimulus onset to response**

EPIC

- **An architecture for modeling human performance**
- **Especially well studied for modeling multiple-task performance**

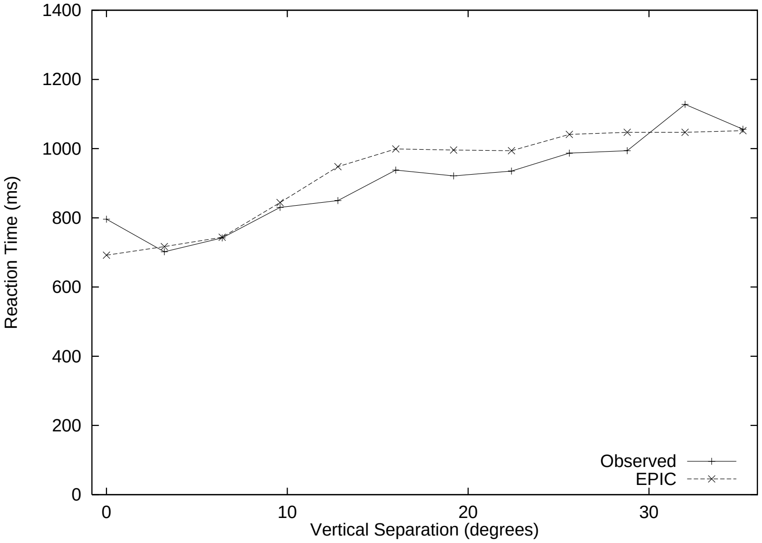


THE EPIC MODEL OF THE WICKENS’ TASK

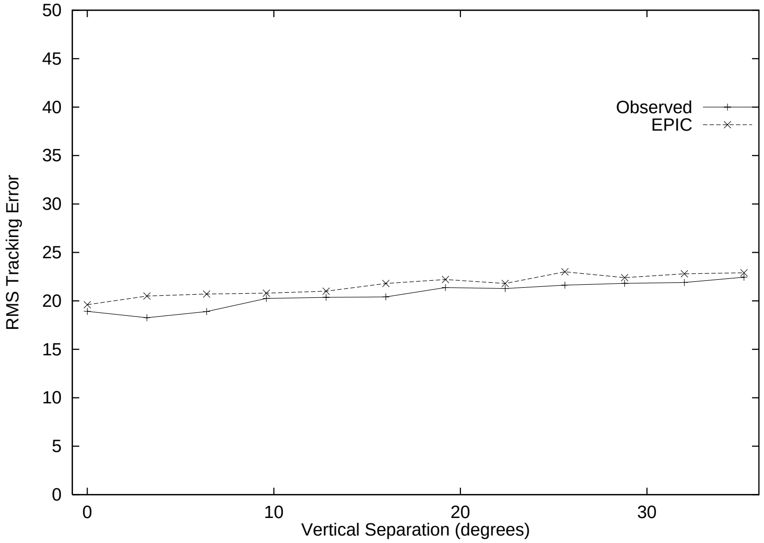
- **The executive process in the EPIC model uses explicit control of task components to produce performance**

- **Kieras (1994) found that a concurrent, tightly interleaved performance strategy was needed to achieve this level of match**

Choice Task

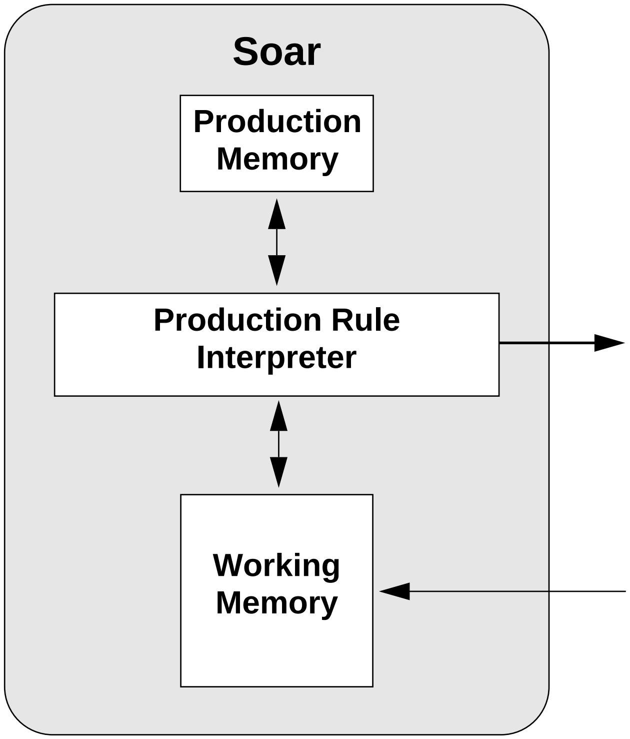


Tracking Task



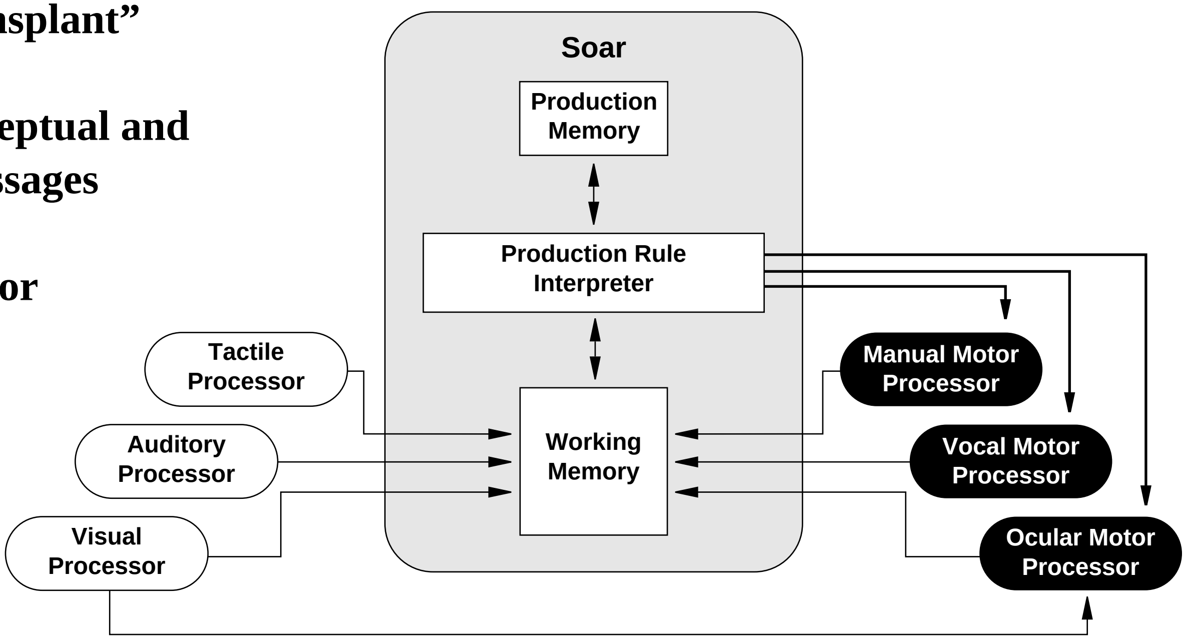
SOAR

- **An architecture for modeling human cognition**
- **Single learning mechanism called *chunking***
- **Soar has demonstrated many human capabilities such as: planning, problem solving, various forms of learning (induction, compilation, analogic, instruction), and natural language**



EPIC-SOAR

- **Soar has a proven learning mechanism, but no psychologically-plausible mechanisms for perception and action**
- **EPIC has psychologically-plausible mechanisms for perception and action, but no learning capability**
- **Orthogonal systems imply potential for a synergistic hybrid architecture**
- **Did a “mind transplant”**
- **EPIC sends perceptual and motor status messages**
- **Soar returns motor commands**



CURRENT WORK

- **Identify and classify the knowledge that is needed to transition from novice to expert performance**

- **Posit possible explanations for acquiring this knowledge**

- **Our modeling approach:**

  - *viewed novice-to-expert transition as a continuum*
  - *started with a novice model of individual Wickens' tasks*
  - *sequential: mutually-exclusive performance of tracking and choice*
  - *concurrent: steps of individual tasks are interleaved with one another*
  - *incrementally elaborated the model to progress through the continuum*
  - *relied on the EPIC model to guide the construction of our model*
  - *parsimoniously added knowledge*
  - *needed an acquisition procedure for each piece of added knowledge*

- **The rest of the talk presents the models developed using this approach**

LEARNING INDIVIDUAL TASKS

- **Novice model**

```
tracking-task          choice-task
  track-target           recognize-stimulus
  watch-cursor           verify-stimulus
                         find-response
                         respond-to-stimulus
```

- **Ran this model to build “expert” chunks of the individual tasks**

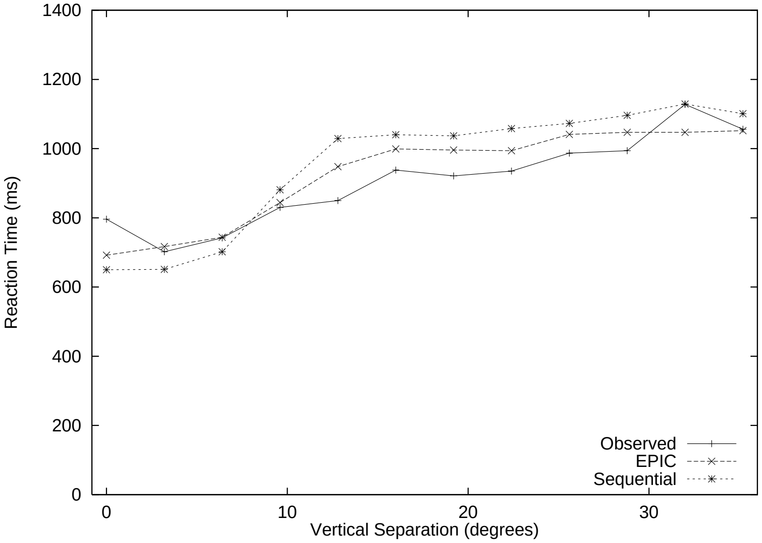
- **This state represents a subject who can perform the tracking task and the choice task individually at an expert level**

- **Subsequent models are built upon this foundation**

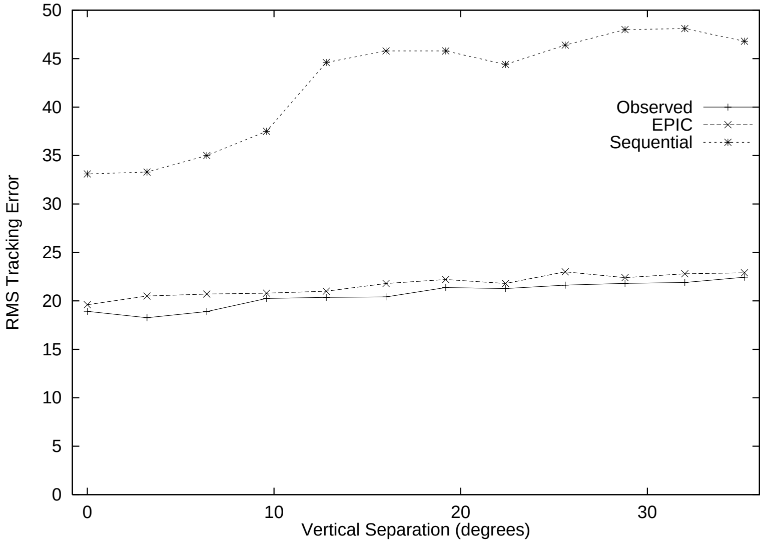
■ MODEL: SEQUENTIAL

- **Added operator preference knowledge**
- **Added a `fixate-on-stimulus` rule**

Choice Task



Tracking Task



■ OPPORTUNISTIC PREPARATION

- **EPIC model had a rule to prepare the eye to look at the stimulus**

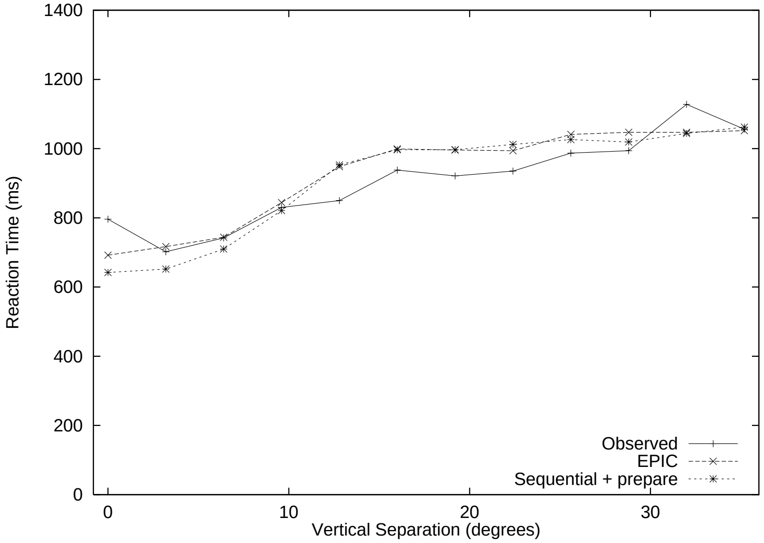
- **EPIC motor processors process commands in two consecutive phases, preparation then execution, each phase taking time**

- **Performance can be improved by preparing for an upcoming command**

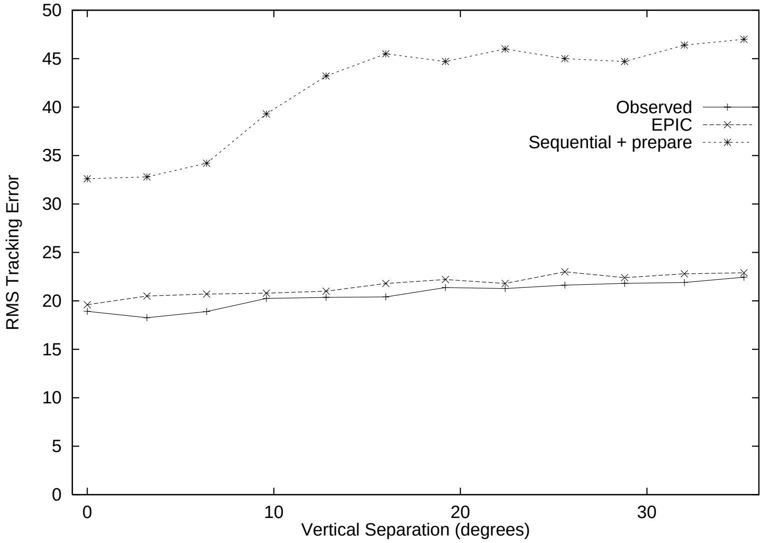
MODEL: SEQUENTIAL + PREPARE

- **Added a** `prepare-for-stimulus` **rule**

Choice Task



Tracking Task



DEALING WITH COMMAND COLLISIONS

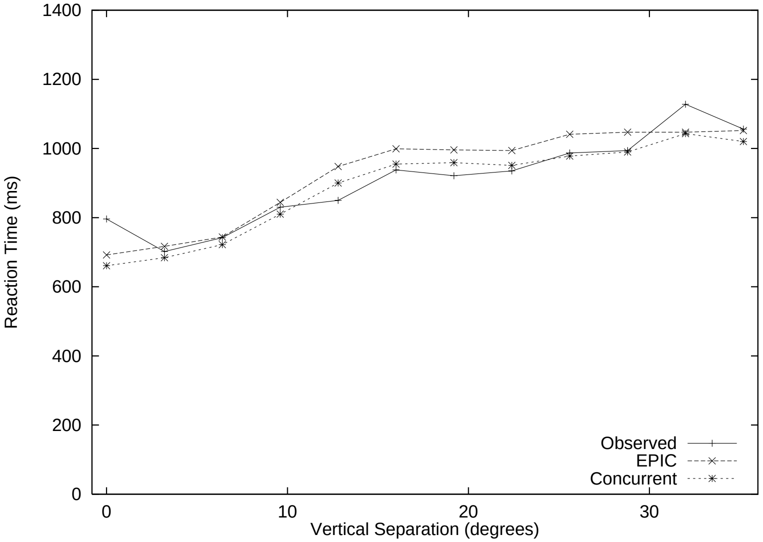
- **Concurrent behavior creates opportunities for motor command collisions**
- **EPIC “jams” and ignores the commands**
- **Devised a task-independent** `jam-repair` **procedure**
  - *reconstructs the jamming situation*
  - *uses task knowledge to identify the preferred command*
  - *learns a* `jam-avoidance` *chunk*
  - `jam-avoidance` *chunk is immediately used to recover from jam*
  - *in future similar situations, the* `jam-avoidance` *chunk will prevent jam*
- **In cases where there is no applicable task knowledge, one of the jamming commands is arbitrarily selected and sent to EPIC**
- `jam-repair` **created all the** `jam-avoidance` **chunks needed for this task**

MODEL: CONCURRENT

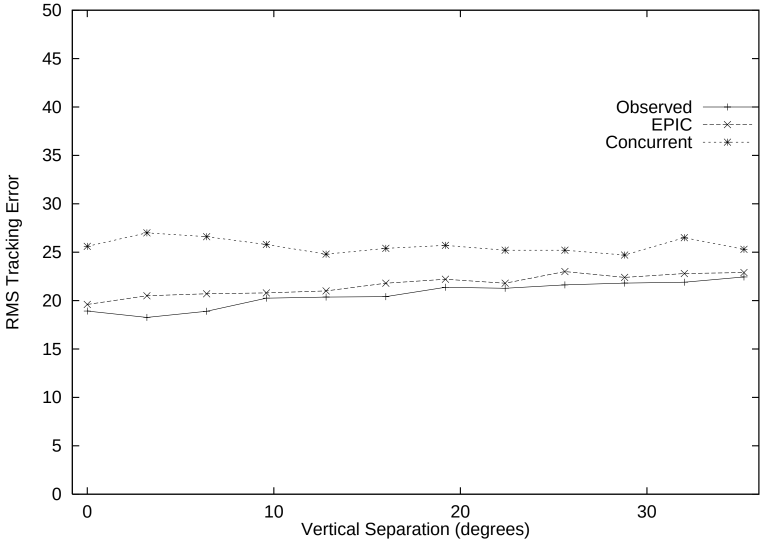
- **Replaced operator preference knowledge (used to implement the sequential strategy) with a simple operator composition mechanism** *(Covrigaru, 1992)* **that enables the individual task to execute concurrently**

- **Added** `jam-repair` **procedure**

Choice Task



Tracking Task



■ PIPELINING MOTOR COMMANDS

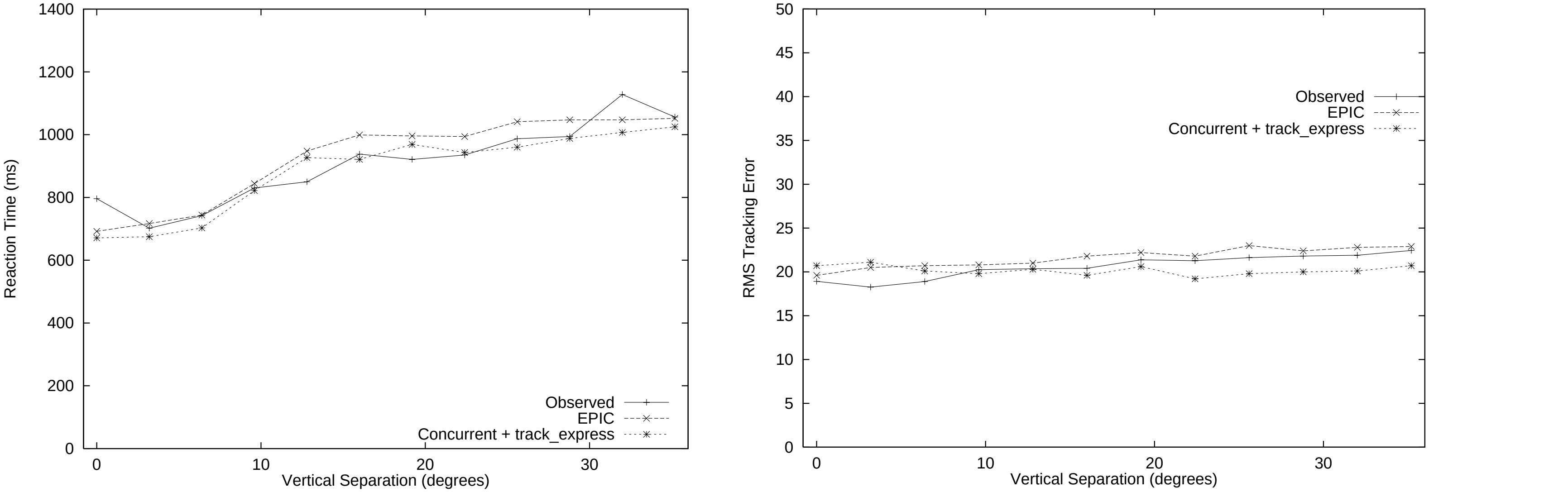
- **EPIC model had a rule that performs a track command immediately after the choice response as been sent**
- **This track rule differs from the normal track rule in that it pipelines the track on the “tail” of the choice response command**
- **EPIC motor processors process commands in two consecutive phases, preparation then execution, each phase taking time**
- **Pipelining allows the overlapping of the preparation and execution of two different commands**
- **Performance can be greatly improved by pipelining commands into the motor processors**

■ MODEL: CONCURRENT + TRACK-EXPRESS

- **Added** `track-express` **rule**

Choice Task

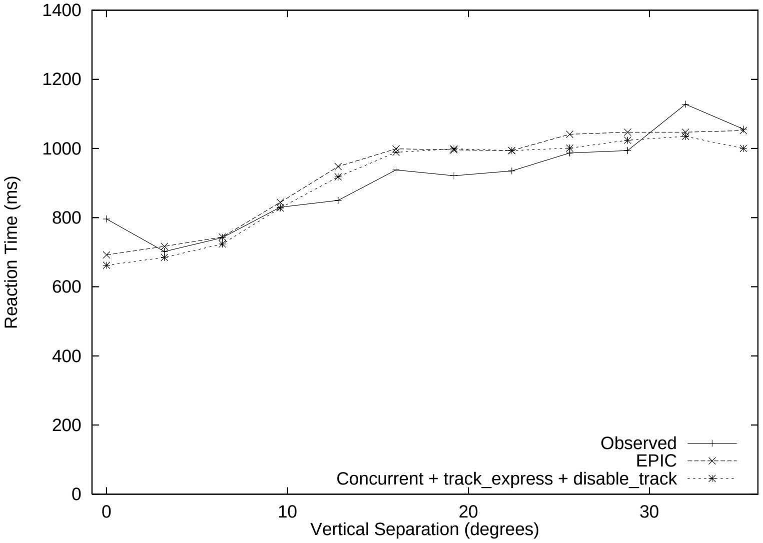
Tracking Task



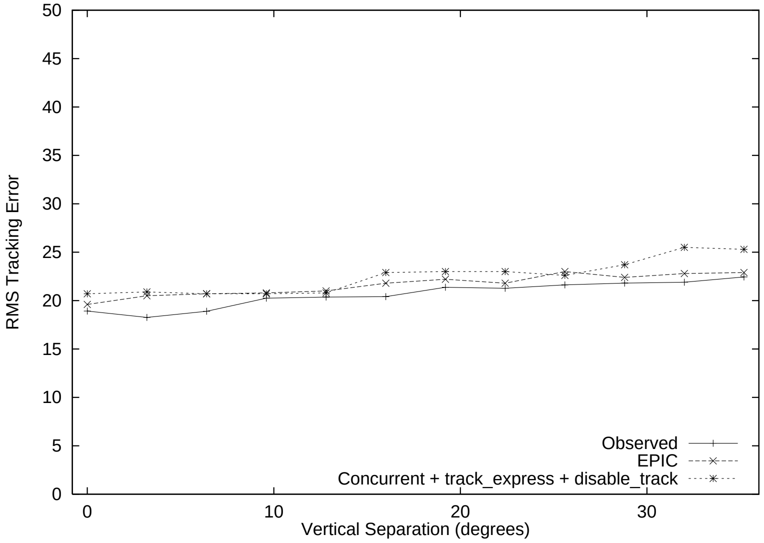
MODEL: CONCURRENT + TRACK-EXPRESS + DISABLE-TRACK

- **EPIC model had rules to disable tracking when the eye was busy**
- **Modified `track-target` and `watch-cursor` operators**
- **These changes further elaborate the tracking task and as a result are not considered part of the knowledge needed for concurrent behavior**

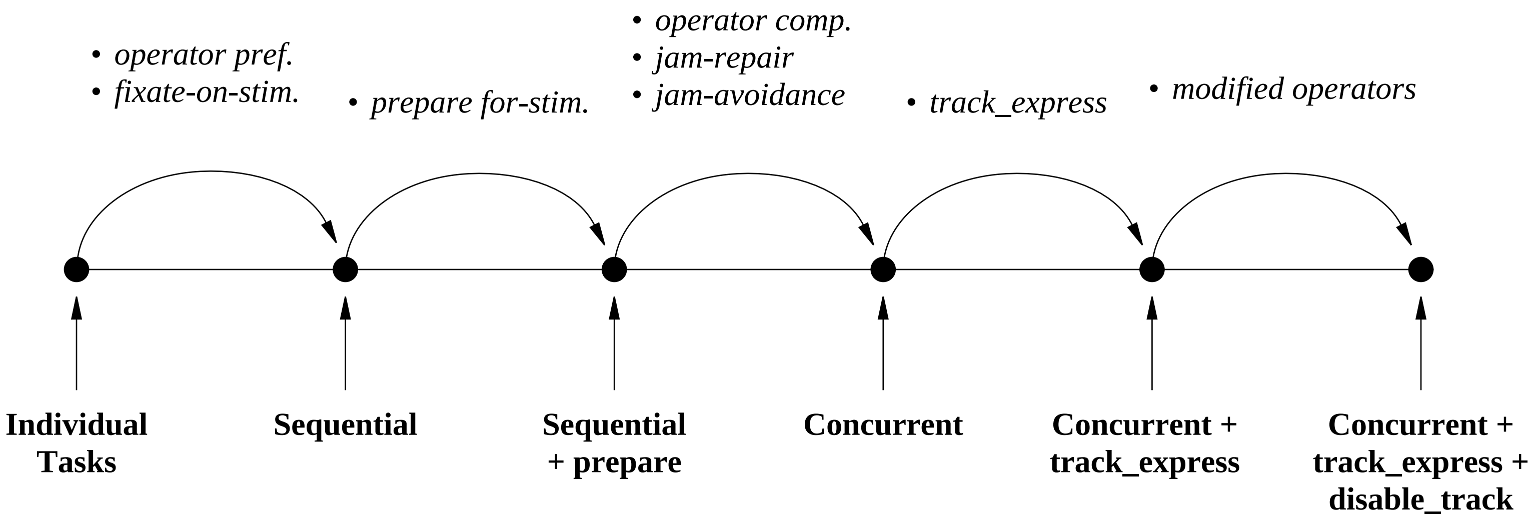
Choice Task



Tracking Task



RECAP: LINEAGE OF MODELS



Individual Tasks

- *operator pref.*
- *fixate-on-stim.*

Sequential

- *prepare for-stim.*

Sequential + prepare

- *operator comp.*
- *jam-repair*
- *jam-avoidance*

Concurrent

- *track_express*

Concurrent + track_express

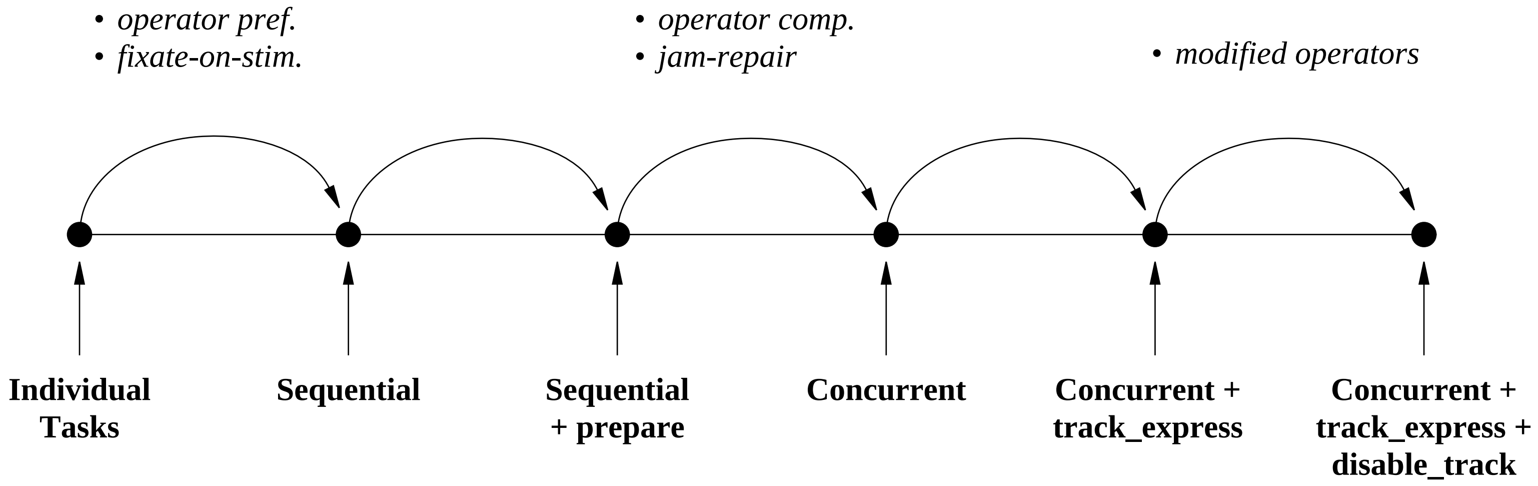
- *modified operators*

Concurrent + track_express + disable_track

ANALYSIS OF THE ADDED KNOWLEDGE

- **Task knowledge**
  - *acquired from verbal or written task instructions and subject to interpretation bias*
  - *this learning mechanism is a thesis in itself (Huffman, 1994)*

- **Innate knowledge**
  - `jam-repair` *procedure*



- *operator pref.*
- *fixate-on-stim.*

- *operator comp.*
- *jam-repair*

- *modified operators*

Individual Tasks

Sequential

Sequential + prepare

Concurrent

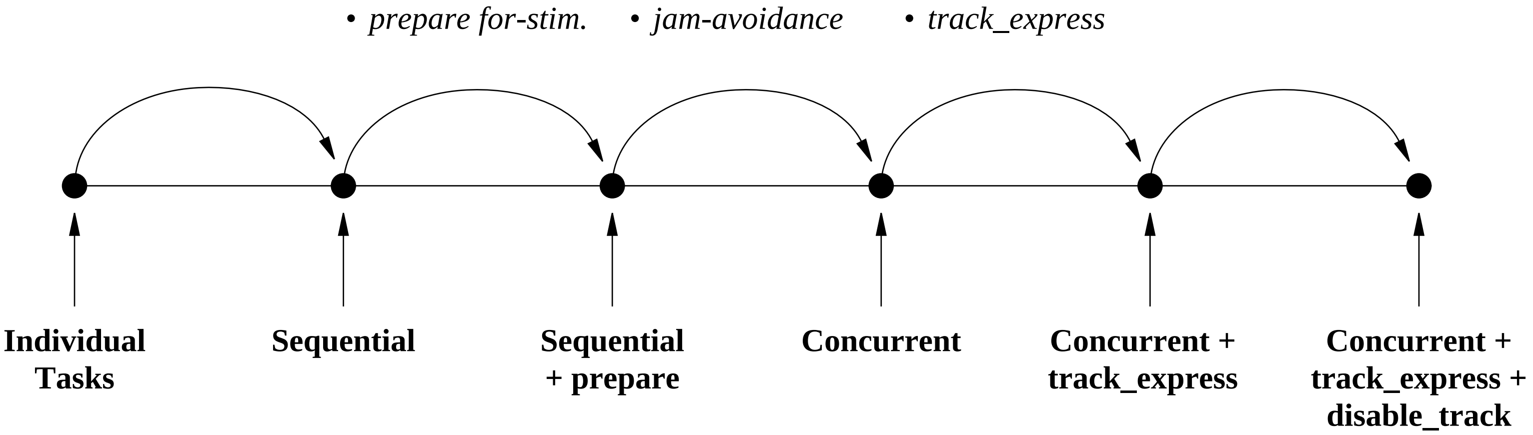
Concurrent + track_express

Concurrent + track_express + disable_track

ANALYSIS OF THE ADDED KNOWLEDGE

- **Experiential knowledge**
  - `jam-avoidance` *chunks learned from the* `jam-repair` *procedure`*

- **Strategy knowledge**
  - *pipelined commands:* `track-express` *rule*
  - *opportunistic preparation:* `prepare-for-stimulus` *rule*



■ EXPLANATION OF STRATEGY KNOWLEDGE

- `track-express` **rule**
  - ◆ *attributable to task inducements*
  - ◆ *this rule then comes about from the same mechanisms that create task knowledge*
- `prepare-for-stimulus` **rule**
  - ◆ *after hearing task instructions, the subject forsees this opportunity and creates a this rule*
  - ◆ *prepares are always created whenever a motor command is created*
  - ◆ *preparation is an architectural affordance; therefore there may be a task-independent mechanism which creates prepare rules based on task-knowledge or observed regularities in the environment*

■ SO WHAT?

- **Is this nothing more than recoding EPIC's model within Soar?**
    - *identified knowledge needed to progress from novice to expert*
    - *created a task-independent acquisition procedure that learns how to deal with the problems of concurrent performance*
    - *posited a source for each piece of task knowledge*
    - *the model is situated with a learning framework*
    - *our final model is different from EPIC's model (distributed .vs. central executive process)*
    - *no explicit control of the tasks*

FUTURE WORK

- **Continue refining the model**
- **Fine-grained analysis of the conditions of the strategy rules**
- **Build a task-independent learning mechanism to acquire strategy knowledge**