Cognitive Constraints in Dual-Task Performance: Implications of the ACT-R Architecture

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Motivation

- **Two models of dual task performance where for both models one task is Argus Prime, other task is not**
- **Tracking Task -- perceptual-motor intensive**
  - **Model switches at unit task boundaries**
  - **Good account of performance in both tasks**
  - **Bad account of number of task switches**
- **Alphabet Task (“alpha”) -- auditory-cognitive intensive**
  - **Model switches at unit task boundaries & driven by “onset recognition” from bottom-up**
  - **Good account for performance in both tasks**
  - **Better account for number of task switches**

Motivation

- How did the models implement task switching??
- We cheated!!
- Do not have a high-fidelity, cognitively plausible account for how to switch to and how to switch back
- So -- what, if any, constraints does the ACT-R Architecture impose on task switching in the dual task case?

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Overview

- **Cognitive Constraints -- hints from the architecture**
- **Description of Argus Prime and dual tasks**
- **Where subjects switch**
- **Current thinking**
- **Next steps**

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Cognitive Constraints on Dual-Task Performance: Switching from & Switching back

- **Switching *from* -- Knowing/deciding when to switch**
  - **Deliberate or deciding to process a stimulus**
  - **Opportunity to rehearse current goal**
  - **(more on switching from at CogSci talk)**
- **Switching back -- Recovery**
  - **Retrieve the most active goal of target task**
  - **Which goals are bad bets or good bets for task resumption**
    - **(goal --> subgoal --> subsubgoal --> subsubsubgoal??) -- which one is "most useful"??**
  - **Altmann & Trafton**
    - **Similarities and differences**

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Cognitive Constraints

- **What is the most transitory but needed information in an ACT-R 5 model?**
- **Information currently contained in the buffers!**
- **During task performance, next step is determined by current goal + other buffer information**
- **This *other buffer* information would be lost and unavailable even if the suspended goal were well encoded and easily retrievable**

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Typical “working”productions

```
(p typical-production
=goal>
      isa classification-task
      step looking
=visual-location>
      isa visual-location
      attended nil
      kind text
=visual-state>
      isa module-state
      modality free
==>
+visual>
      screen-pos =visual-location
=goal>
      step  attending)
```

```
(p another-production
=goal>
      isa classification-task
      step get-track-number
=retrieval>
      isa   target
      track-number =tn
==>
+goal>
     step find-target)
```

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Cognitive Constraints: Implications of our analysis

- **Perhaps the loss of buffer information imposes a preferred switch pattern on the cognitive system**
- **At what level of analysis does buffer information become (generally) less important?**
- **Unit task!!**
- **In our models, the steps required within a unit task tend to depend on information in retrieval buffer, motor buffer, or visual buffer**
- **Initiating the NEXT unit task after completing one unit task does not depend on buffer information**

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Cognitive Constraints: Implications of our analysis

- **Is this an issue for our models? Or is this a general constraint imposed by the architecture?**
- **Do unit task boundaries have a privileged status in dual task, task switching?**
  - **Is this part of what makes a unit task a unit task?**
  - **CMN: Unit task is a control construct, not a task construct**

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Working Hypothesis

- **Top-Down monitoring and switching aligned with the unit task structure of the tasks**
- **People most likely to monitor and/or switch AFTER completing one unit task and before initiating the next unit task**

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Argus Prime

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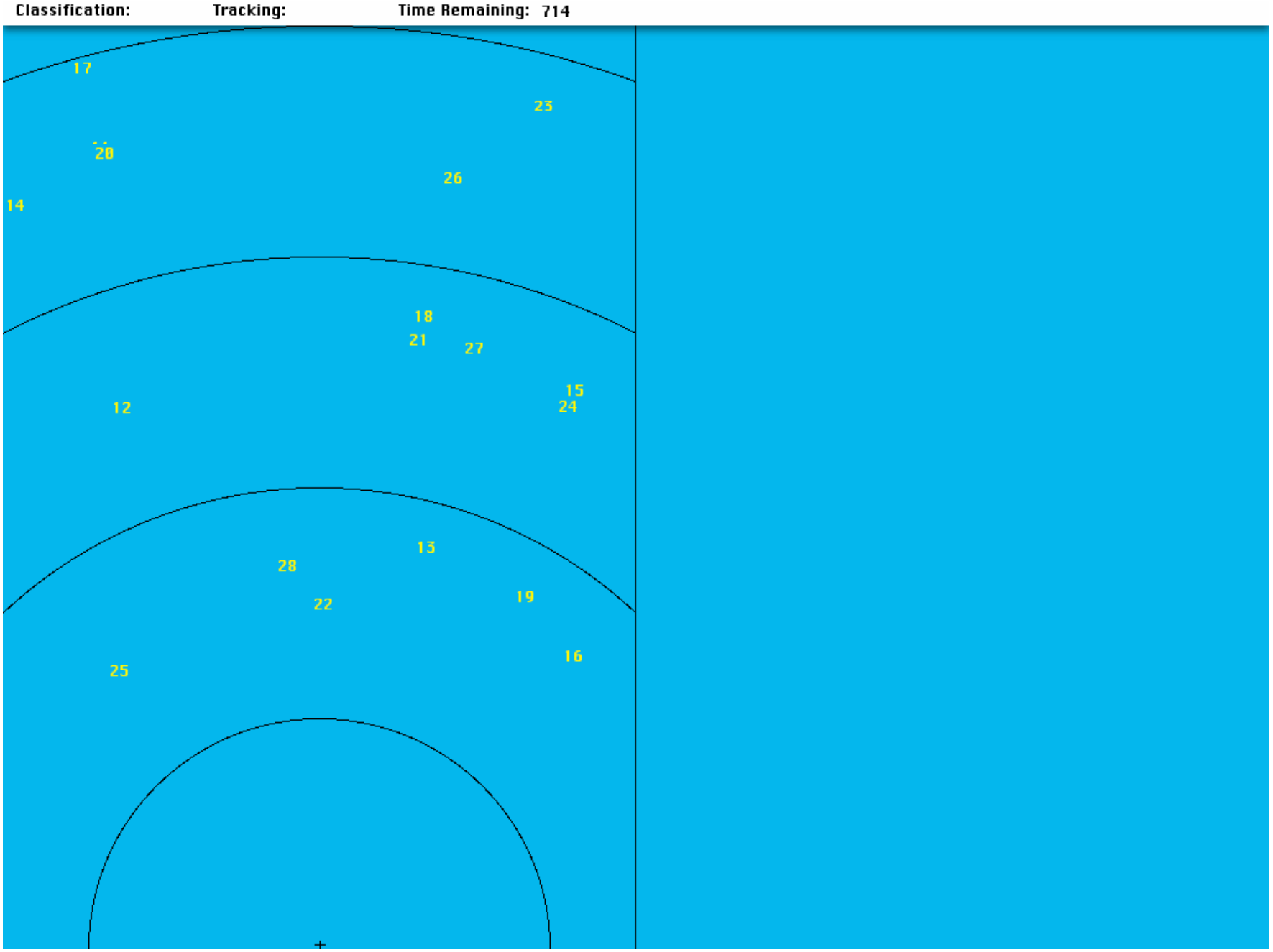

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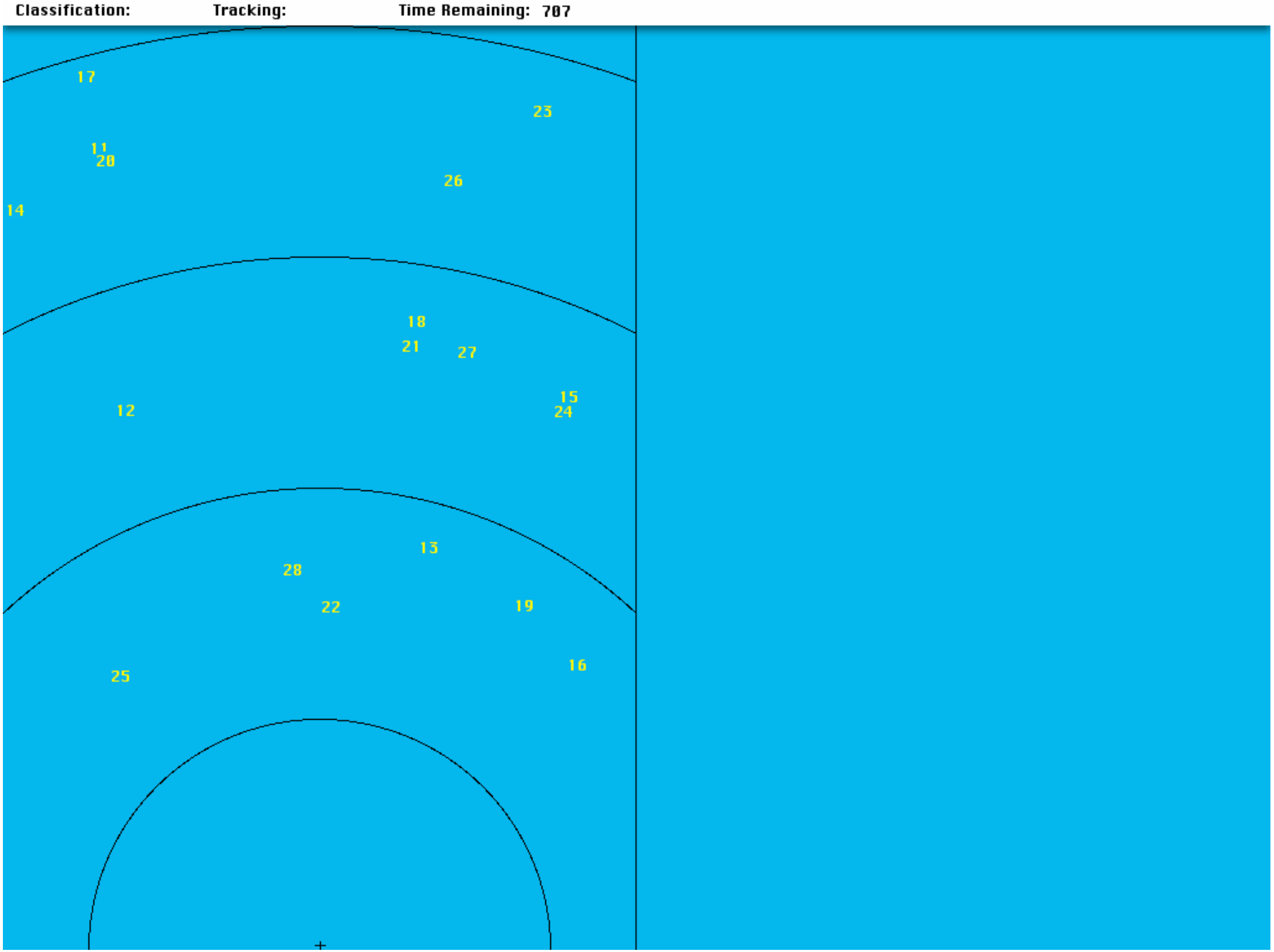

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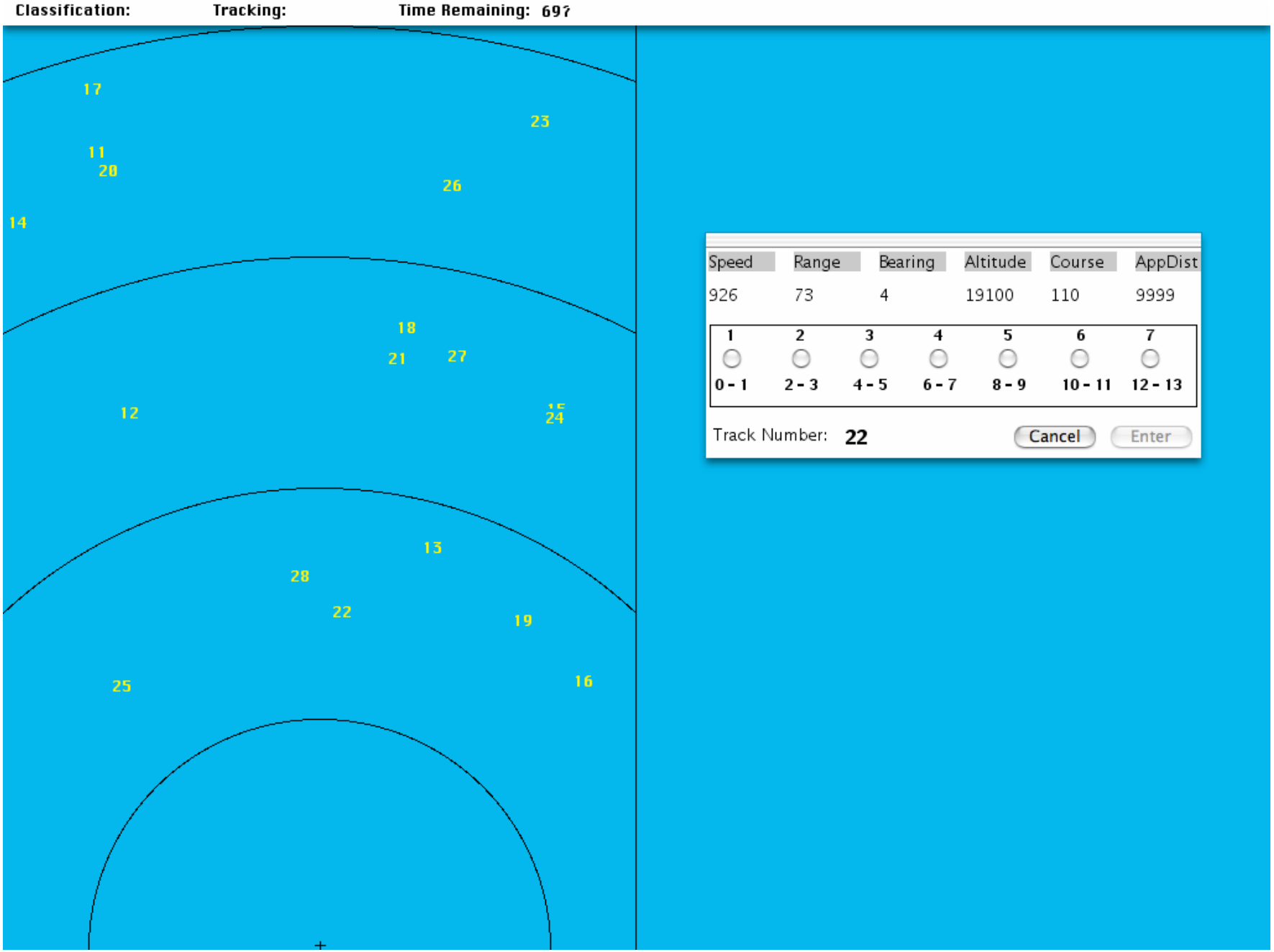

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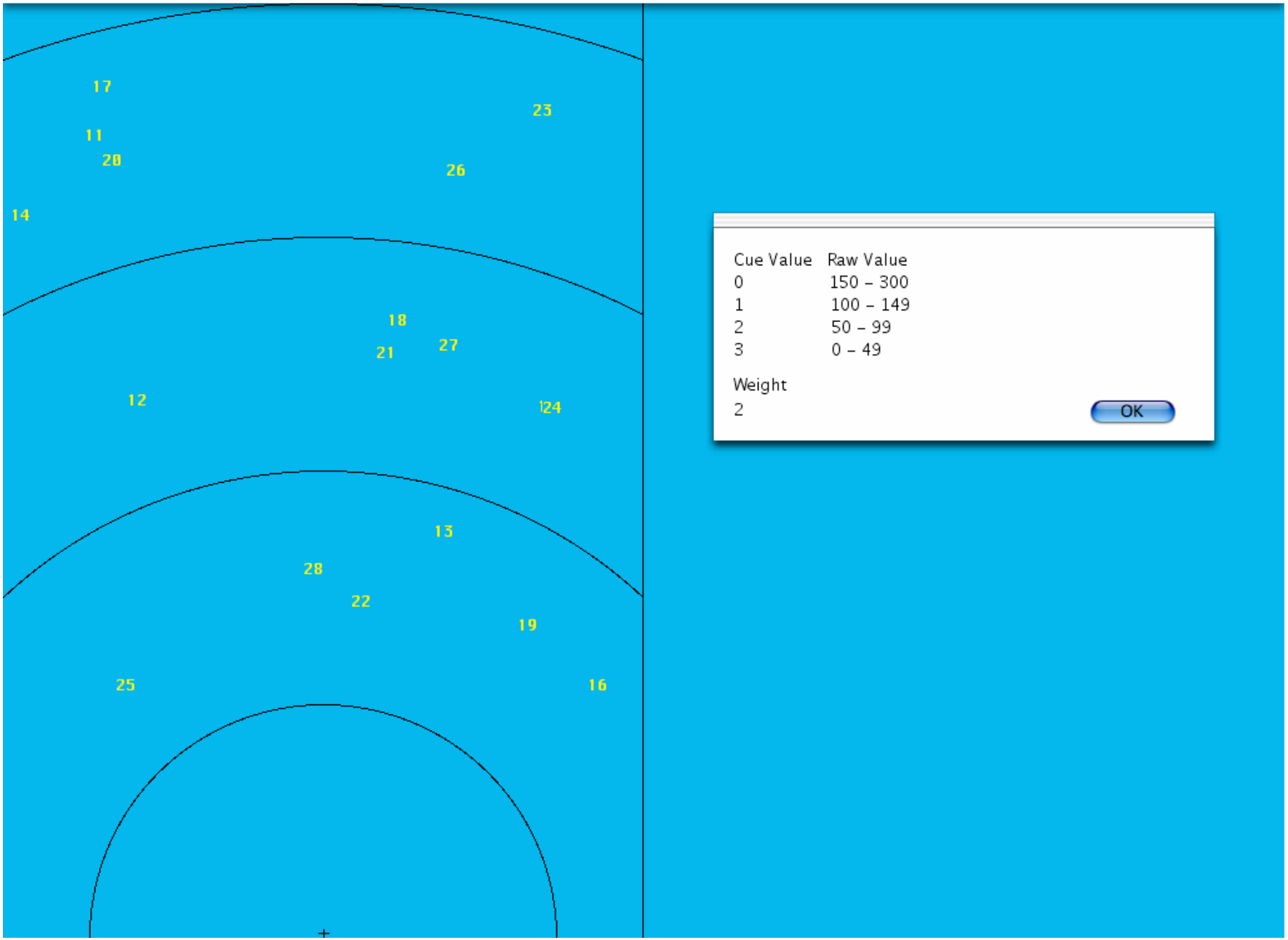

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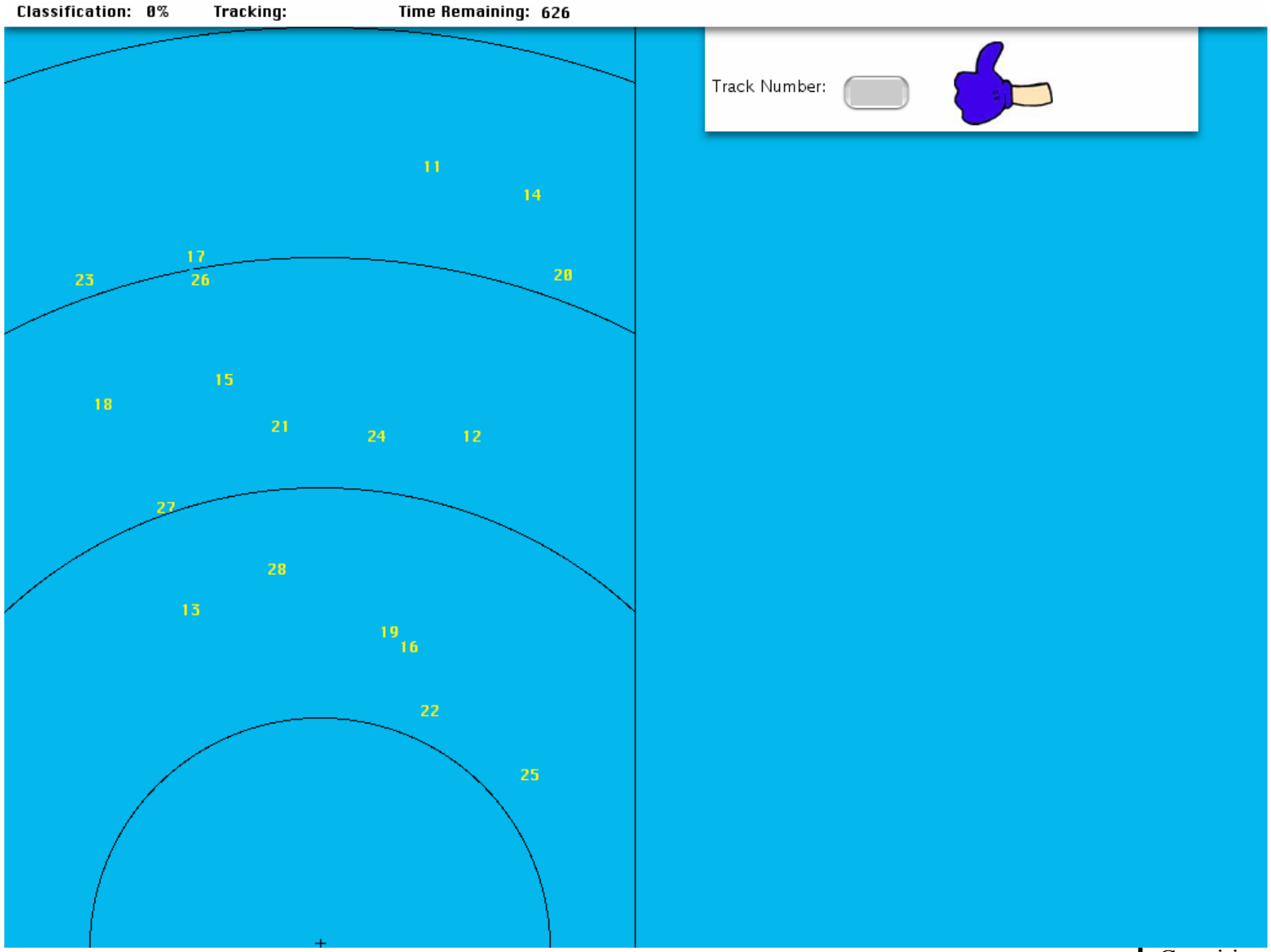

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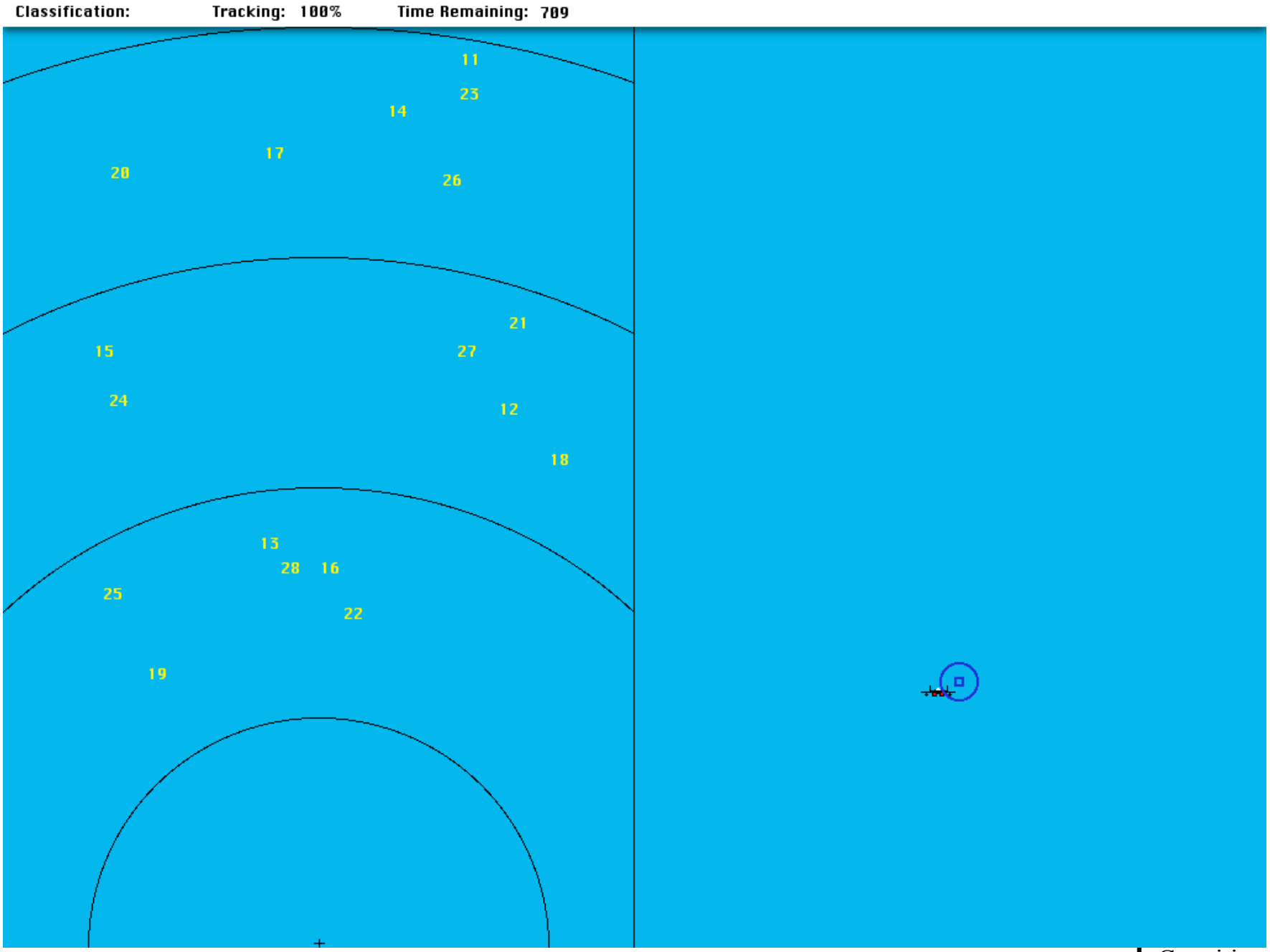

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Alpha Task

- System says a letter every 4 seconds
- Subject responds by key press
  - “c” if current letter is higher in alphabet than previous letter
  - “x” if lower

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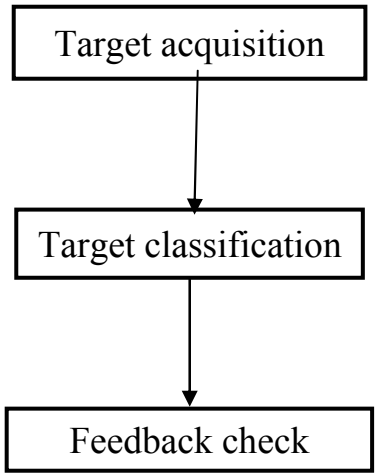
Unit Task Structure



Pacing of tasks is largely under the control of the subjects

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Sentinel Events in Argus Prime

- **7 mouse events that are time stamped and saved to log file**
- **Mark the boundaries of unit tasks or subtasks in Argus Prime**

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Some sentinel events are at unit task boundaries, others are within a given unit task

After which events are subjects more likely to switch?

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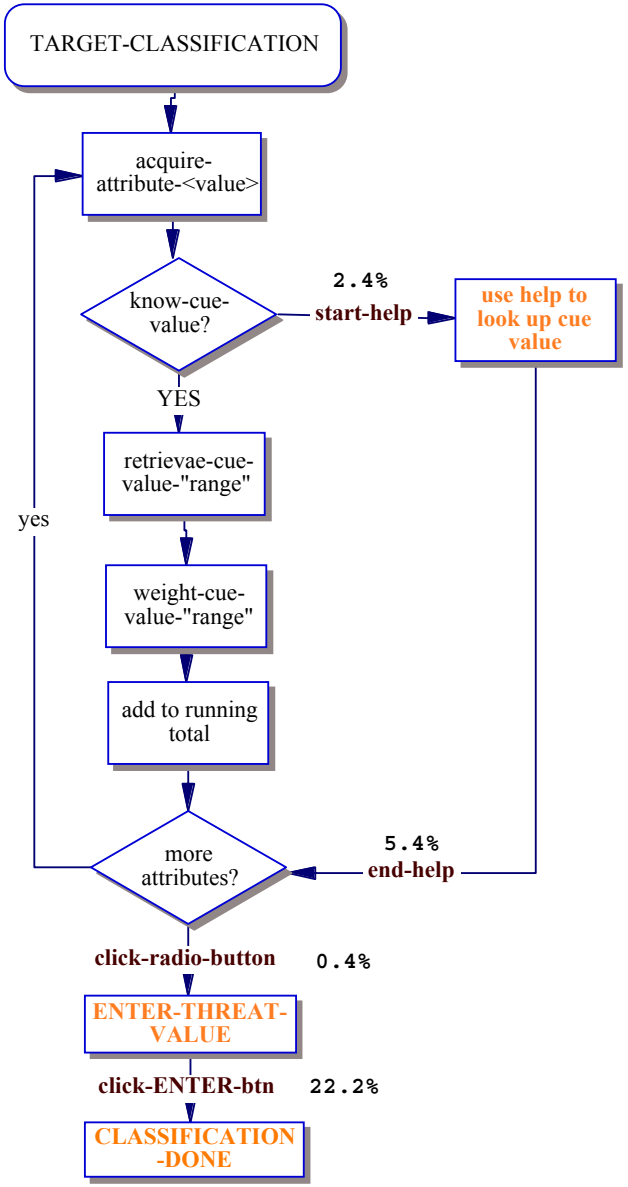
Tracking

Target-Classification

P(sw) to Tracking task



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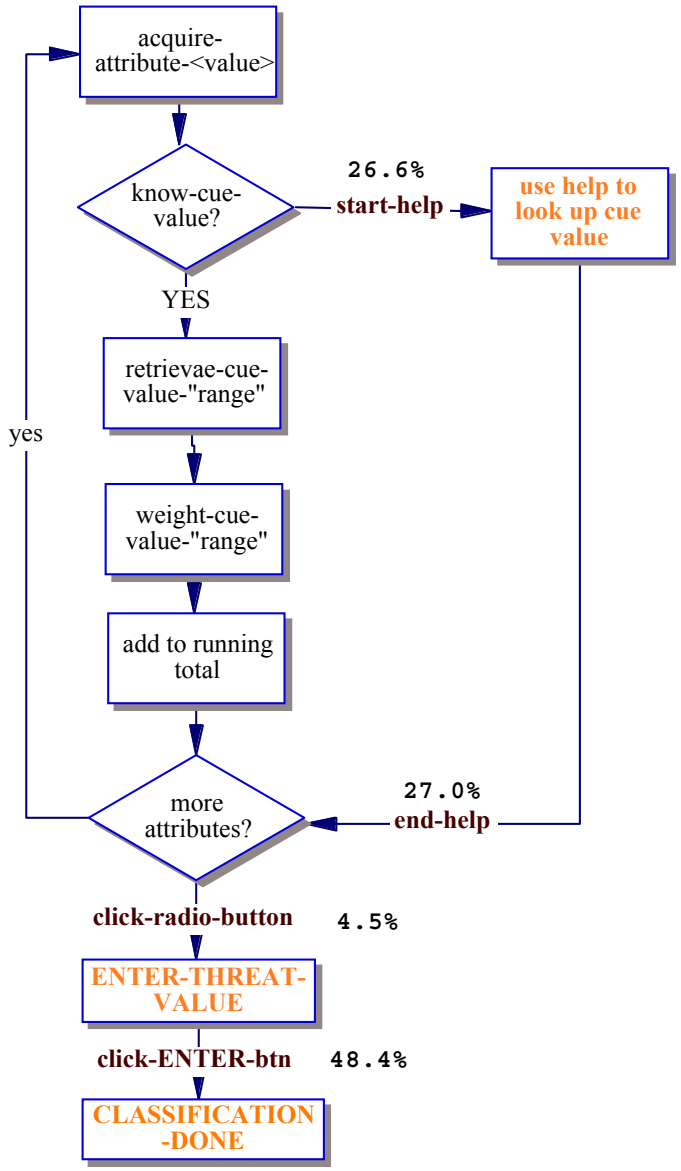
Alpha

Target-Classification

P(sw) to Alpha task

People do switch a lot more



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Unit Task Structure Constraint

- **Buffer information is transitory**
- **Dual tasks use the same buffers**
- **To return to a task:**
  - **Retrieve the most active goal**
  - **To be useful, there must be a production that matches this goal AND not specify any other constraints**
- **This implies a constraint on unit task structure**
  - **Must begin with a "control production"**

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Initial Unit Task Production

```
(p start-unit-task
=goal>
      isa classification-task
      step initial
==>
=goal>
      step start-task)
```

Current Thinking

- **Deliberate (top down) switches are optimal at unit task boundaries because there is no transitory information and cost to return to this point is low**
- **Stimulus driven (bottom-up) switches that interrupt inside a unit task are more costly to recover from**
  - **Because buffer information is lost it is more likely that backing up to the start of the unit task is needed**
  - **Invalid buffer information is a source of error**
- **If can't retrieve a useful goal a strategy to search the environment for cues is needed**
  - **Increase user errors**

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Next Steps

- **Validate that task resumption is to a step that does not rely on transitory data**
  - **Design a dual task that facilitates more precise capturing of where the subjects resume a task**
  - **Design this task to test the implications of the architecture**
- **Collect fine-grained data to determine where subjects resume**
  - **Eye data and mouse data**

Task Buffer Use

	Task		
Buffer	Classification	Tracking	Alpha
Goal	X	X	X
Retrieval	X		X
Visual location	X	X	
Visual	X	X	
Vision state	X	X	
Aural location			X
Aural			X
Aural state			X
Manual	X (for mouse)	X (for mouse)	X (for keyboard)
Manual state	X	X	X