Modelling Performance in the Sustained Attention to Response Task

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The Sustained Attention to Response Task (SART)

- Digits 1–9 presented in random order, one every 1.15 s
- Each digit shown for 250 ms followed by 900 ms mask
- Participants must click the mouse in response to each digit
- Must withhold response when they see the number 3
- Total of 225 trials (25 $\times$ 9 digits), lasting approx. 4.3 min
- 18 practice trials (2 $\times$ 9 digits)
- Instructions: "Press for each digit as quickly as possible with the exception of the digit 3. Try and press as quickly as possible while making as few errors (pressing for a 3) as possible"
- Measures:
  - errors of commission (EOC; mouse clicks to number 3)
  - response time for each trial

Previous studies

- Devised by Manly and Robertson (1997) studying patients with frontal lobe injury – region previously associated with sustained attention
- SART performance:
  - normal = 6.36 (25%) EOC
  - diminishes following injury to frontal lobes
  - correlates with some other measures of sustained attention (e.g., cognitive failures questionnaire)

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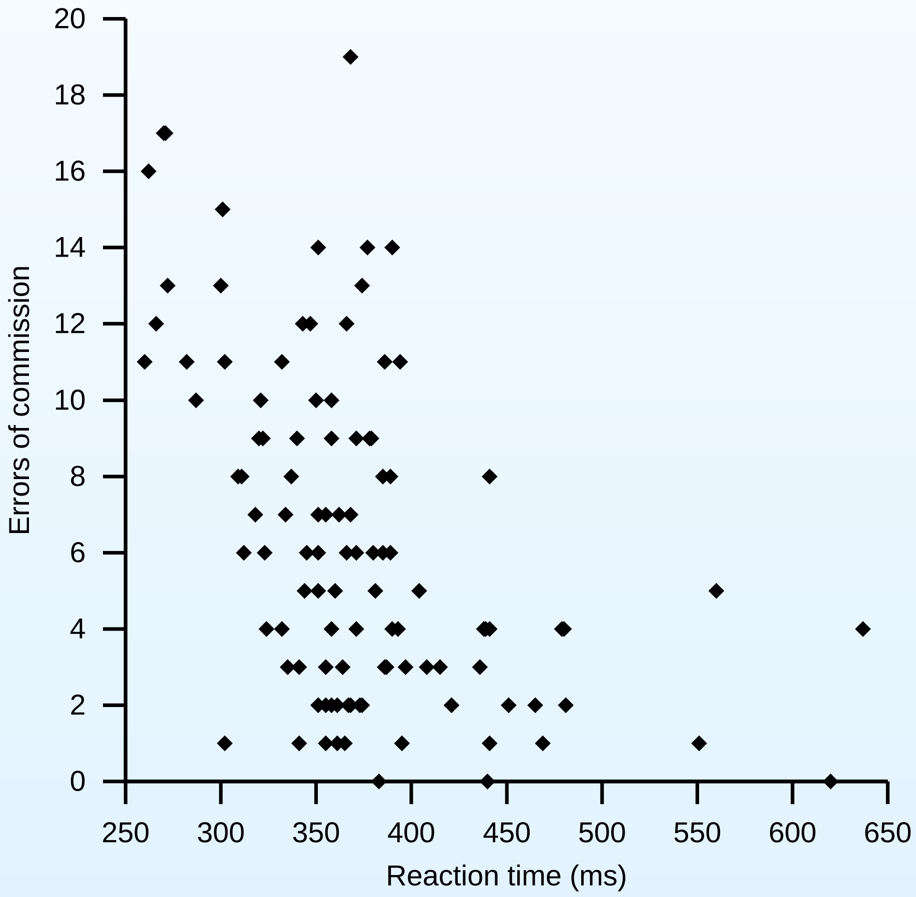
- SART performance reflects the ability to sustain attention:
  - continuous performance over 225 trials
  - long and unpredictable intervals between targets
  - response to non-target trials becomes automatic
  - vigilant monitoring required to withhold response on infrequent target trials

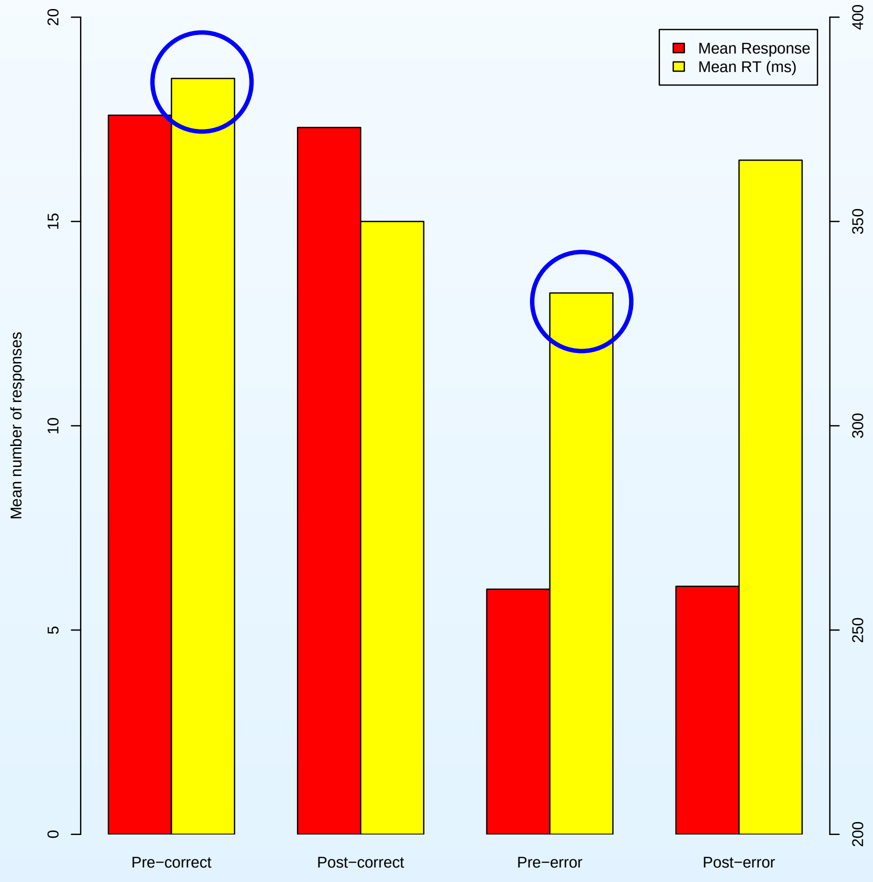
Speed-accuracy trade-off

- Mean RT (over all go trials) significantly predictive of number of errors made ($r = -0.49$)



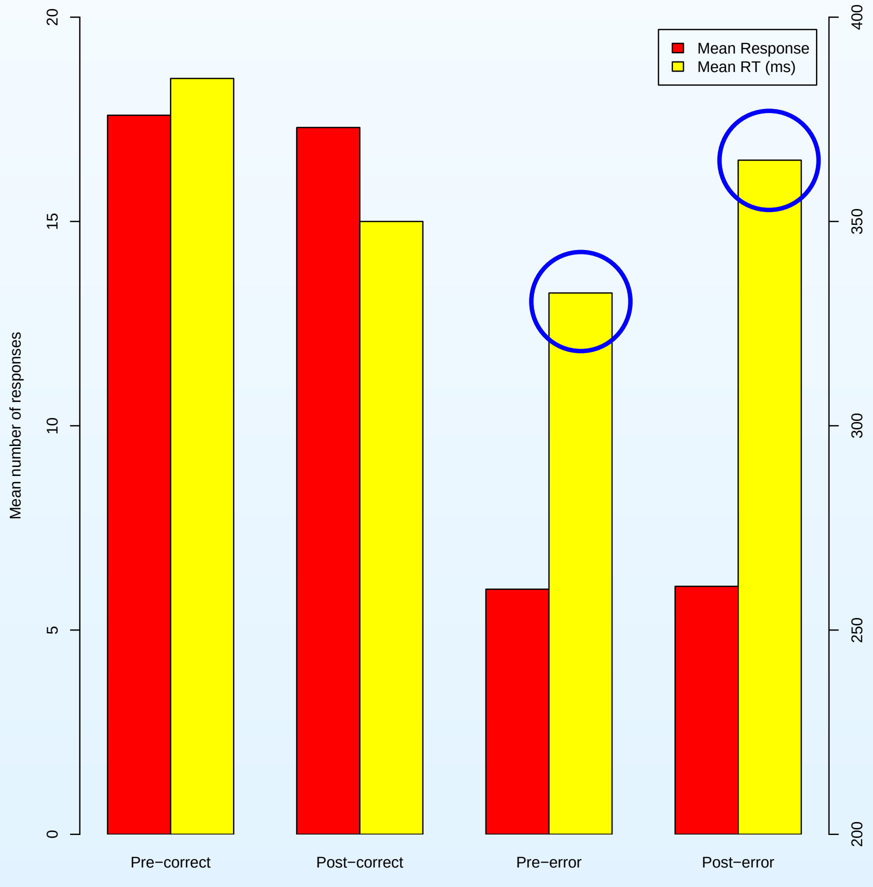
Speed-accuracy trade-off

- Trials immediately prior to EOC significantly faster (51 ms) than trials prior to correctly withheld response



Slow down after error

- Trials immediately after EOC significantly slower (31 ms) than trials immediately prior to error



My own experience of using SART

- Collaborative project with *Institute of Medical and Social Care Research*, University of Wales, Bangor, UK
- Mindfulness training for patients with anxiety and depression, chronic pain, binge eating disorder, fibromyalgia, etc.
- Clinical evidence that mindfulness:
  - increases overall psychological wellbeing
  - helps people to more effectively manage some disorders
- Mindfulness involves increased awareness and attention to everyday actions and mental events
- I used SART and STT to investigate effect of eight-week course of mindfulness training on sustained attention

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- Observing people doing SART:
  - subjects approach the task in different ways
  - emphasise either speed or accuracy
  - many deliberately slow down after an EOC
- Hypothesis: performance largely determined by an individual's strategy when satisfying competing task instructions to minimise both RT and error
- Question: would an ACT-R model of the SART produce the same pattern of behaviour found by Manly & Robertson?

An ACT-R model of the SART

- ACT-R 5.0 using perceptual-motor components
- Interacts with SART through the same interface as the human participants (reads text on screen and clicks mouse)
- Consists of 11 production rules

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- Two competing strategies:
  - simply click mouse after detecting stimulus – faster but more errors
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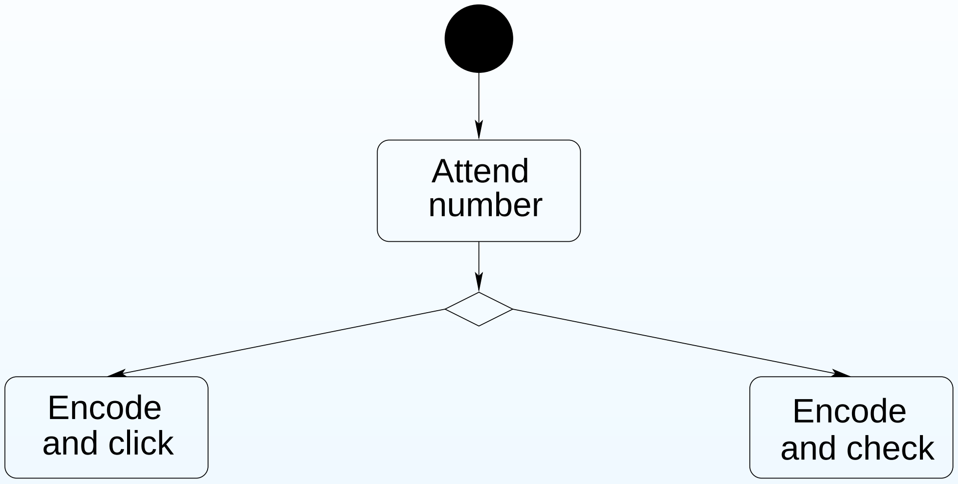
- Two responses to EOC:
  - don't change strategy – just keep clicking
  - decide to use checking strategy on the next trial

A state chart of the model



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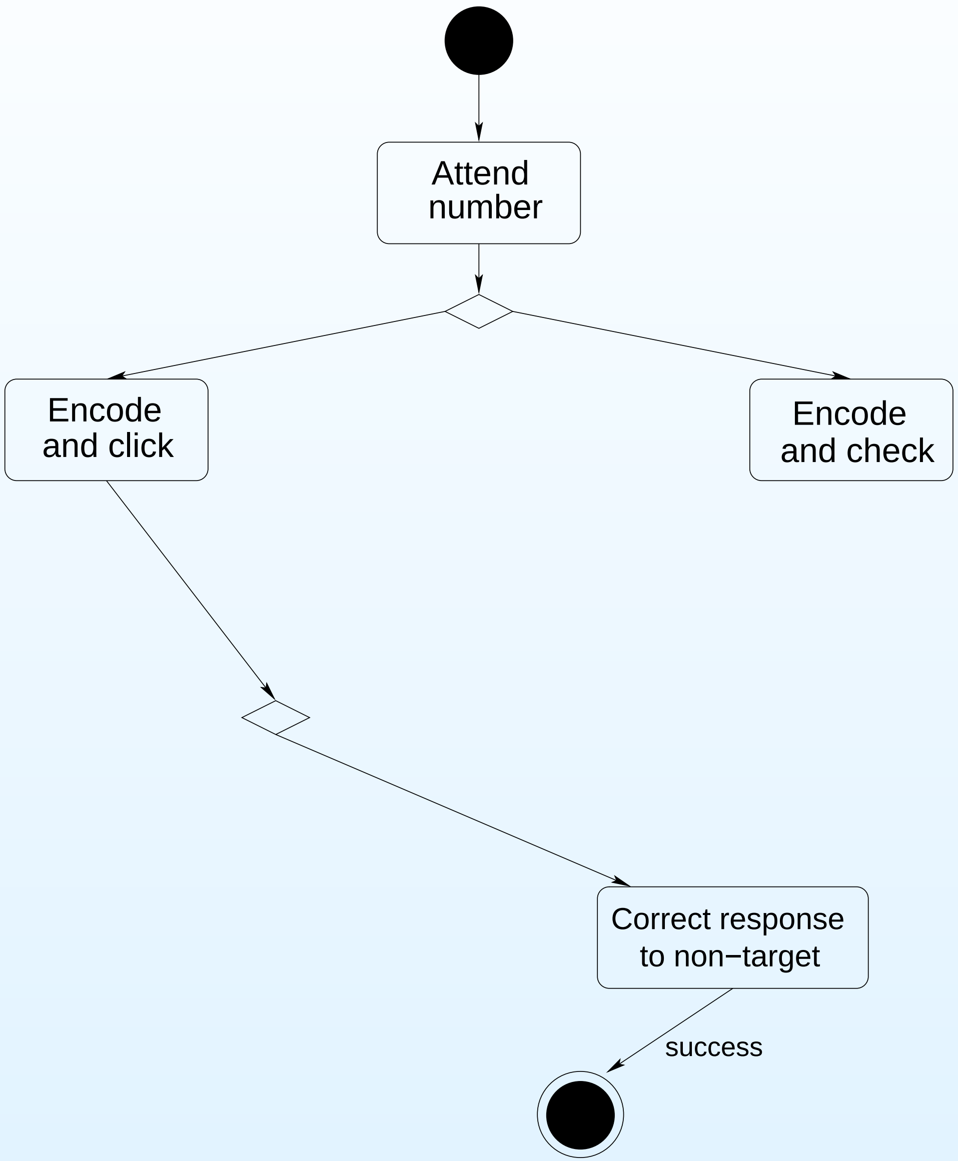

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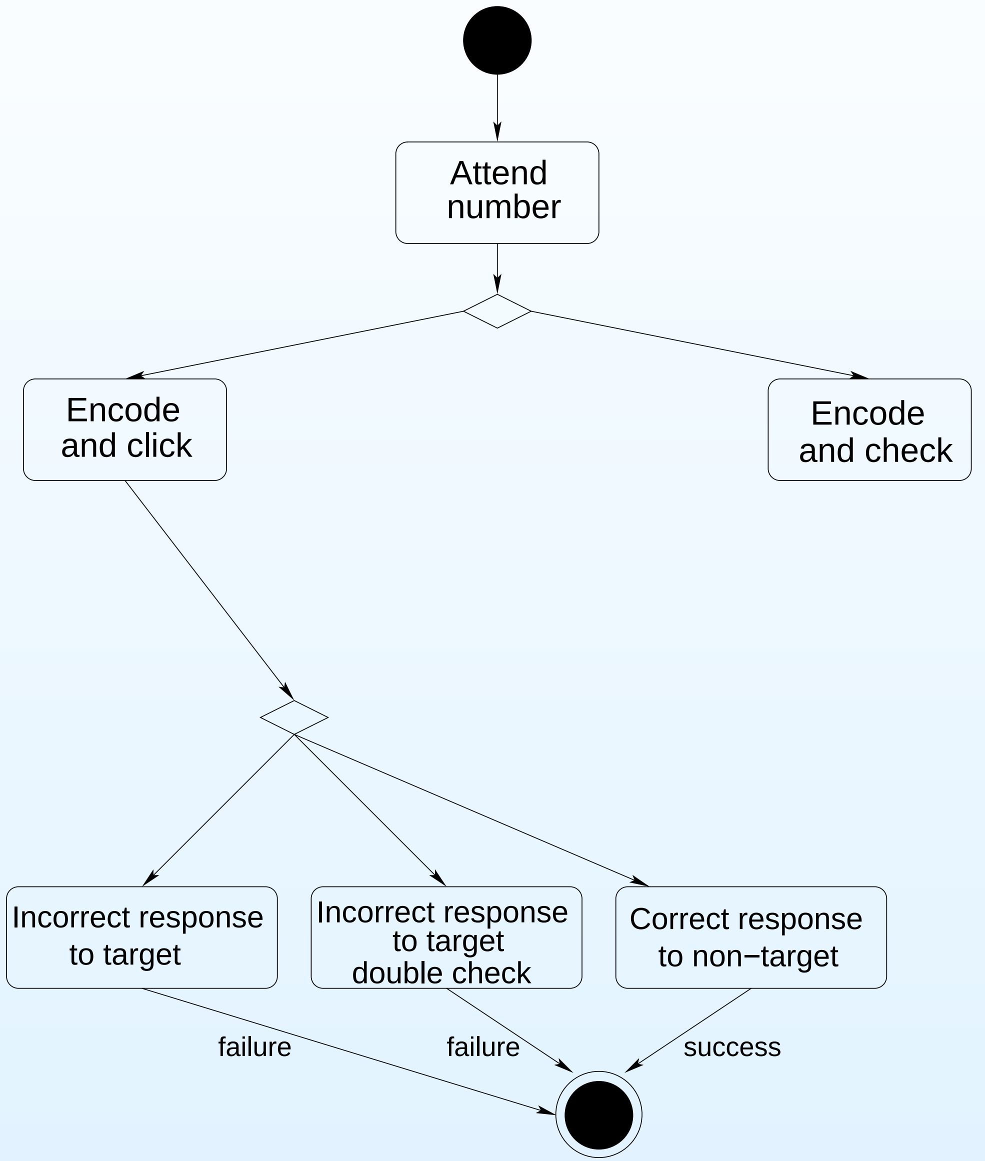

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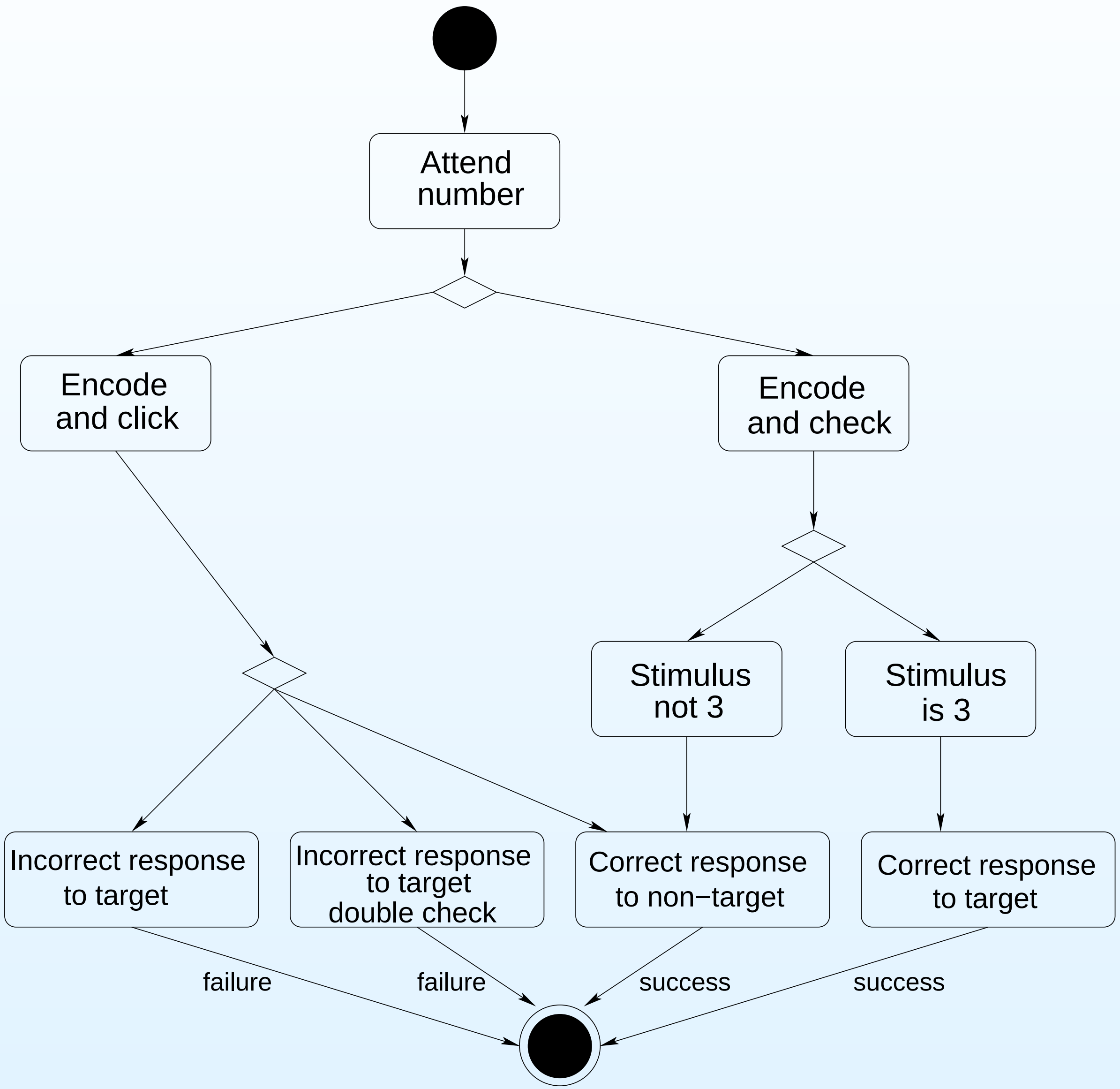

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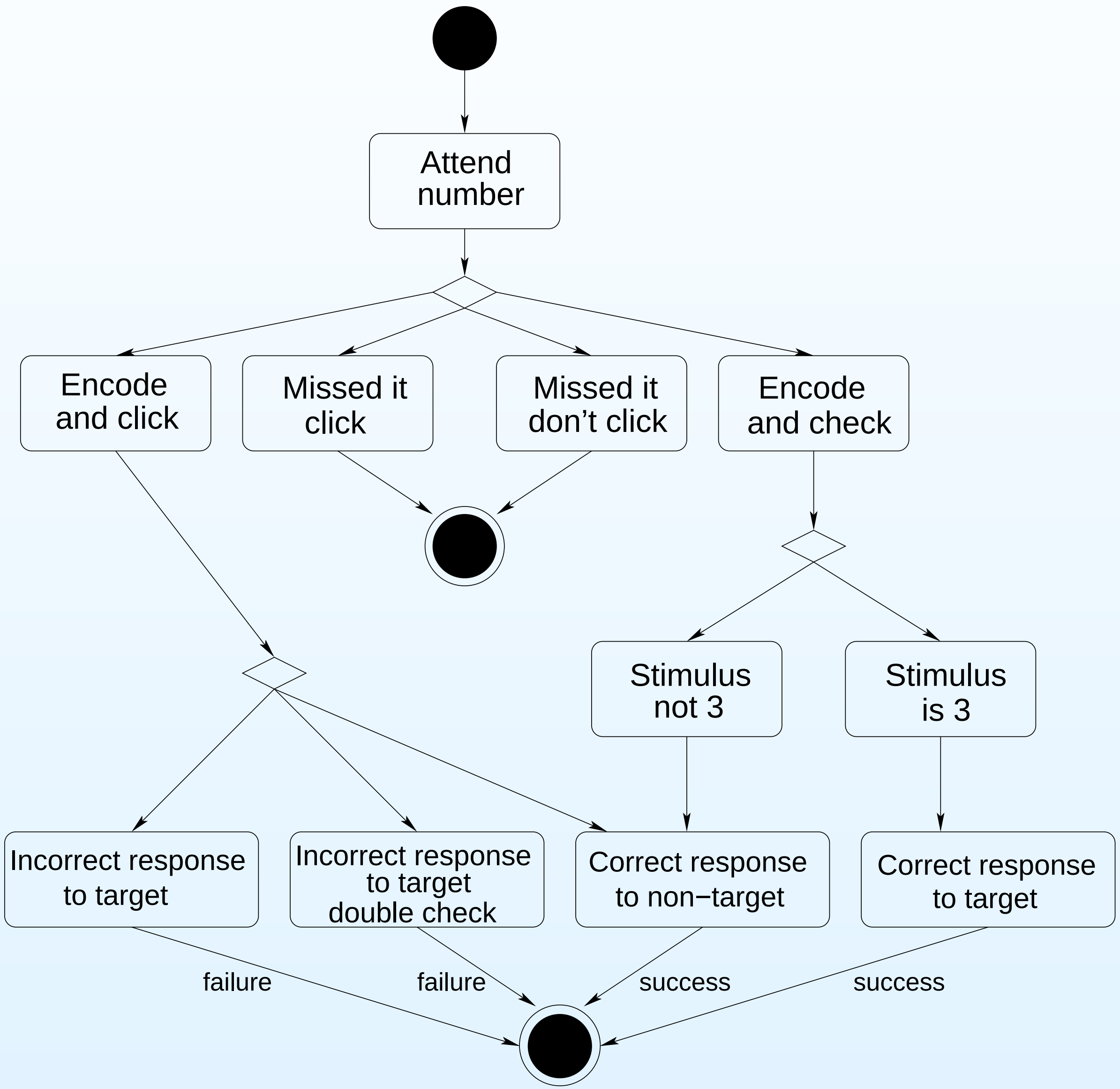


Choosing a strategy

- On each trial, the model has to choose between fast-but-inaccurate and slow-but-accurate productions
- ACT-R's *conflict resolution* mechanism selects production with highest utility, U_i, defined as

$$U_i = P_i G - C_i + \sigma$$

  - $P_i =$ probability of successfully achieving goal if production i fires (reflects history of success and failure for production i)
  - $C_i =$ cost (in time) associated with using production i until goal achieved
  - $G =$ value of current goal
  - $\sigma =$ noise

Choosing a strategy

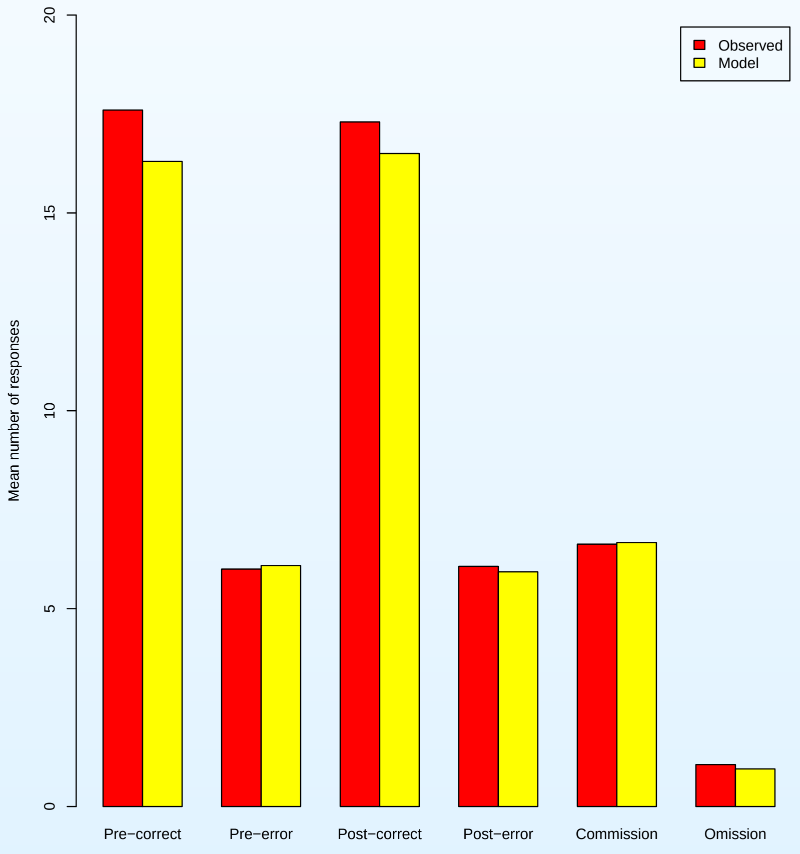
- Utility learning — if a production leads to a successfully achieved goal, likelihood of it being used again increases
- Model's preference changes from trial to trial:
  - P and C values of productions adjusted
  - history of success and failure
  - time taken to produce success or failure
- Both strategies lead to a majority of successful trials
  - so if model starts to prefer a strategy, will generally continue with it
  - but this affects number of errors and mean RT
- However: Explicit production for adopting encode-and-check strategy after error produces bias

Simulation

- Model run 150 times (simulating 150 participants)
- Utility values of the two strategy productions set equal – likelihood of choosing either strategy equal at start of task
- Two parameters which control the learning of production utilities were adjusted:
  - s – adjusts the amount of the variance in the noise added to the calculations – set to a low value (.01).
  - G – the value of the goal in utility equation – set to 0.45 s to reflect very short trial duration
- EOC and RT for each trial recorded

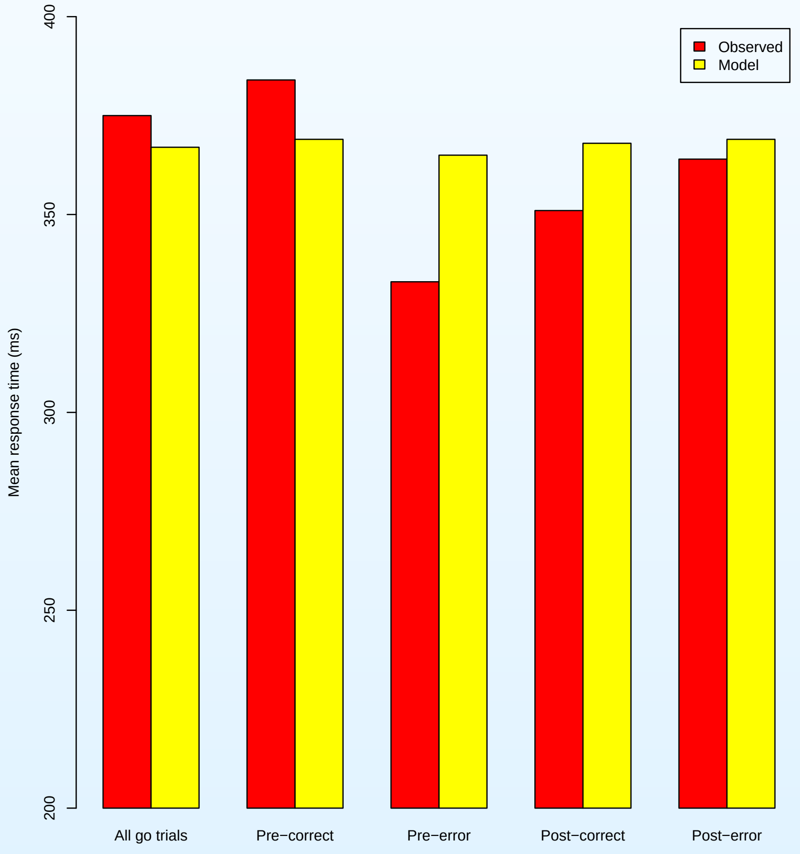
Comparing the response data

- Very close fit to observed pattern of responses
- $R^2 = .998$ (*RMSE* $= .756$). Mean model EOC $= 6.67$



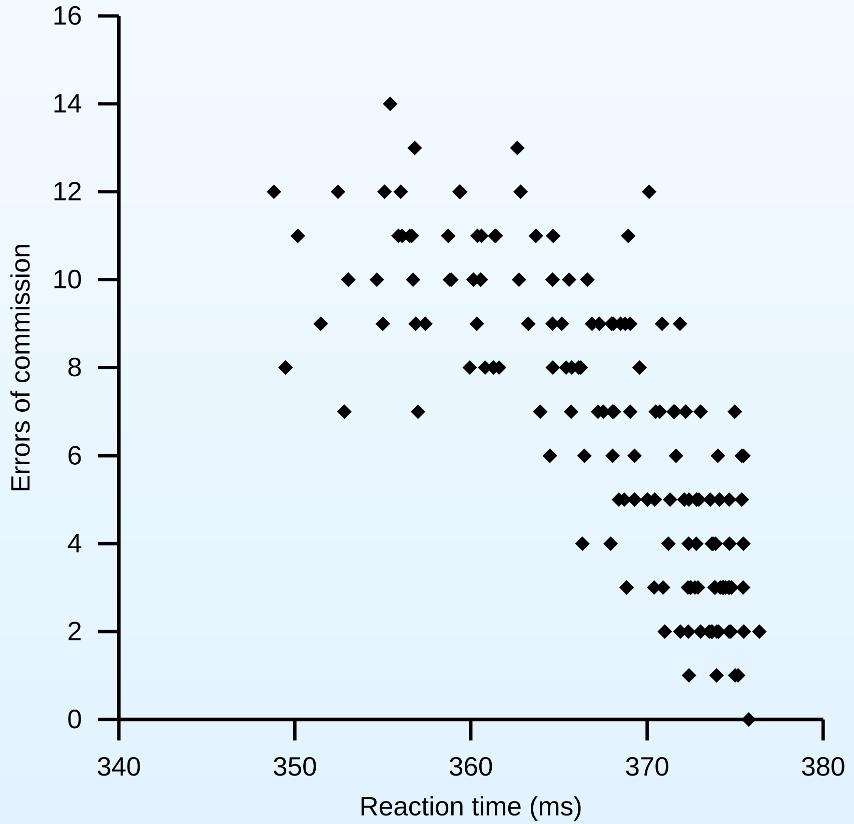
Comparing the RT data

- Reasonable fit to RT data. $R^2 = .665$ (*RMSE* $= 19.933$)
- Mean model RT for go trials $= 367$ ms (observed $= 375$ ms)



Speed-accuracy trade-off in ACT-R

- Range of RTs produced by model smaller than observed
- Significant correlation between mean RT on go trials and the number of EOC ($r = -0.788$, $p < .01$).



Conclusions

- Simulation
  - model shows that much of performance in SART can be explained by strategy choice in speed-accuracy trade-off
  - instructions to "...[t]ry and press as quickly as possible while making as few errors (pressing for a 3) as possible"
  - subject's have to satisfy conflicting task demands
- Speed-accuracy trade-off in ACT-R
  - typically addressed by manipulating G parameter – lower G reduces emphasis on accuracy
  - model accounts for a range of speed-accuracy behaviour in SART using utility learning mechanism with fixed G.

Conclusions

- Sustained Attention
  - model questions explanatory role of sustained attention in the SART
  - issue about vigilance in repetitive, automated tasks (e.g., driving, monitoring ATC display, washing dishes)
  - people *disengage* attention from task to engage in other mental activities (daydreaming, guided thinking etc.)
- ACT-R
  - has one attention mechanism (W parameter) – determines how activation from current goal used to retrieve knowledge in declarative memory
  - SART model involves no declarative retrievals
  - currently no mechanism in ACT-R to allow for multiple concurrent tasks that affect allocation of attention