A Symbolic Model of Human Attentional Networks

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Abstract

Attention is a complex, multi-component, multilevel cognitive faculty. The dominant computational modeling approaches to attention have often focused on one specific type of attention at one specific level. In particular, various connectionist modeling techniques at the subsymbolic level have been widely adopted. In this talk I will report a symbolic computational model of the Attentional Network Test (ANT), which simultaneously involves three attentional networks (alerting, orienting, and executive control). The model was developed in Act-R, a rule-based cognitive architecture. The results show that the model, by sequentially firing rules at a rate of about one every 40-50 ms, was able to capture the effect of each attentional network. The model implies that while the attentional networks can be distinguished at both neuroanatomical and behavioral levels, different attentional networks may adopt similar computational operations at least at a symbolic rule level. The implications of the model for modeling various attentional disorders will be discussed.

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A Symbolic Model of Attention

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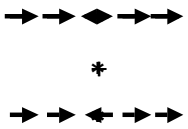
Health Informatics

What is attention?

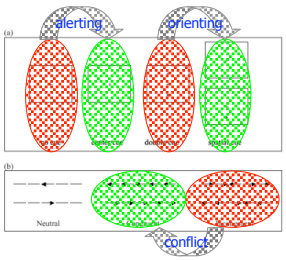
- "Everyone knows what attention is.".
  – William James, 1890
- "On attention itself, it is needless to discourse at length; its nature and conditions are familiar to every thoughtful student".
  – Munsell, 1873

ANT

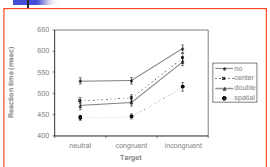


(Fan et al, 2002)

ANT Effects

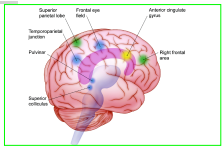


ANT Results



- Alerting = 47ms +- 18ms
- Oriention = 51ms +- 21ms
- Conflict = 84ms +- 25ms

(Fan et al, 2002)

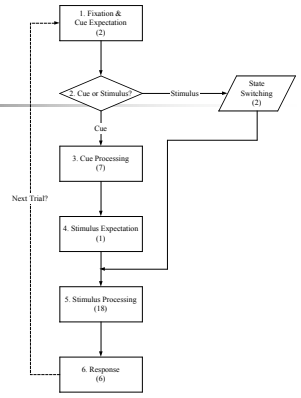


- Variables
  - Genetics
  - Early development
  - Pathology
    - ADHD
    - Schizophrenia
    - Borderline Personality

Modeling Attention

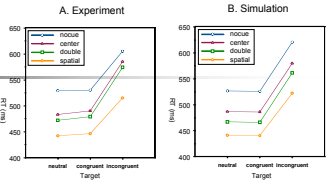
- The dominant computational modeling approach to attention is connectionism (e.g., Cohen et al, 1990).
- One question is, can attention be modeled symbolically? That is, can we summarize these kinds of feelings such as conflict, alerting, orienting through symbolic structures, such as rules or chunks?
- Attention in Act-R/PM
  - Mainly a function of the visual module
  - Explicitly speaking: orienting attention only
    - Bottom-up: attention capture
    - Top-down: "move-attention", ~185ms
- It's interesting to see how ANT can be modeled on Act-R/PM.

ANT on Act-R/PM



- Task analysis
- Mapping the task components to 36 production rules
- Demo?

Model Results



- Fan et al (2002) design
- 100 simulated subjects
- r = 0.99

Effects (ms) (mean±stddev)	Attentional Networks		
	Alerting	Orienting	Executive Control
Experiment	47 ± 18	51 ± 21	84 ± 25
Simulation	55 ± 7.4	45 ± 7.0	86 ± 7.4

One Key Manipulation

- 40 ms cost / rule
  - At least 1 move-attention (85ms) + 1 press-key (210ms) + 4-8 rule firings
  - Practice effect?

Three Attentional Effects

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;;;Alerting (nocue-doublecue):
   ;; exp: 47+-18ms, model: 55+-7ms.
   ;; There is one rule, called not-cue-so-switch-state-and-shift-attention, that
   fires in the no-cue condition but not in any other cued condition. This rule
   summarizes the cost associated with the preparatory state change (from
   expecting either a cue or a stimulus to specifically expecting a stimulus) and
   is responsible for a major part of the alerting effect.

;;;orienting (centercue-spatialcue):
   ;; exp: 51+-21ms, model: 45+-7ms.
   ;; We assume that in the spatial-cue condition attention has already been
   allocated to the correct spatial location before the stimulus is to appear,
   whereas in the center-cue condition the firing of this additional production
   rule is necessary to bring the system to a comparable level of stimulus
   processing. This additional step, through a rule called notice-stimulus-with-
   centercue-and-shift, costs 40 ms and is the major source of the orienting
   effect.

;;;executive control (incongruent-congruent):
   ;; exp: 84+-25ms, model: 86+-7ms
   ;; The result of move-attention is not perfect. When attention is directed to
   one location, an object nearby may be selected, especially when the scene is
   crowded or the objects are similar. This kind of imprecision is one
   fundamental reason for the flanker effect.
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Symbolic Diffusion?

- 10ms effect: doublecue condition is 10ms less the the center cue condition.
  - the center-cue induces the participant to focus attention on the fixation location while the double-cue makes the participant diffuse attention at both the top and bottom locations so that each location receives a little priming.
  - A challenge to symbolic modeling: How can attention be diffused symbolically when we only have in hand a *move-attention* command, which presumably shifts the *focus* of attention to a pre-specified spatial location?
  - Instead of using a neurally plausible diffused attention mechanism, we assume that attention is moved twice, each time to one of the two cues. This is like a betting strategy.
  - 19 +- 8 ms.

Issues

1. How far can we go with symbolic modeling of attention?
   - While attention is often modeled in connectionist frameworks, rules and strategies summarize nicely the associated psychological reality.
   - Minimum symbolic time scale?
2. Relations with subsymbolic modeling
   - Different mechnisms (e.g., serial & parallel)
   - Multilevel modeling and cross-validation
3. How to evaluate the model?
   - Pathology & development: rule missing & rule tuning?
   - What do they mean?
4. 40ms/rule issue?