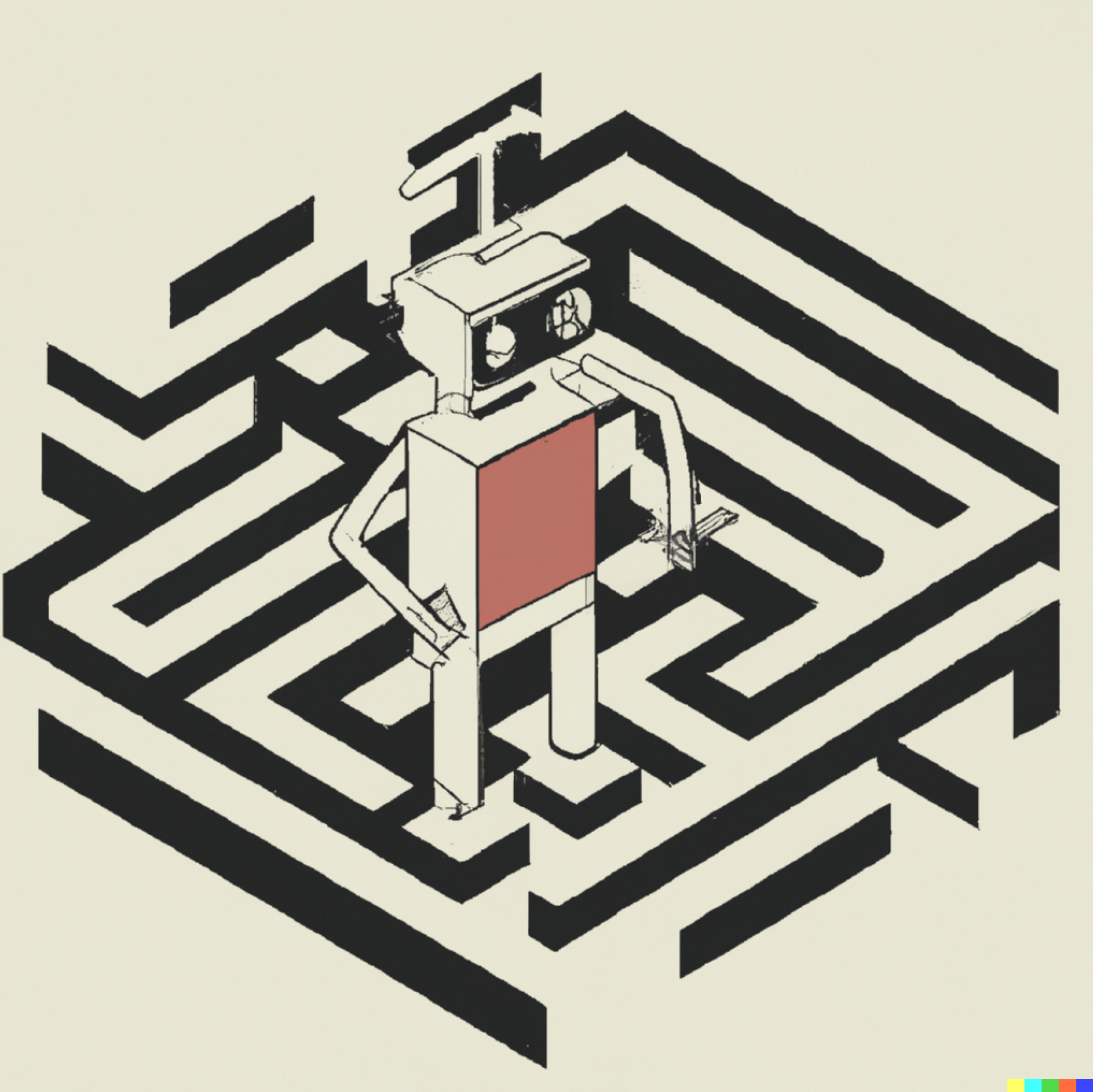


Seminar in Cognitive Modelling

Lecture 4 - Processes

Neil Bramley

On the speed of mental processes -(originally published in 1868)

"Will it ever be possible for the function of the mind to be included in the chain of transforming forces?" (p413)

- Franciscus Donders notes other sciences aim to describe causal mechanisms underpinning law-like relations, could psychology do the same
- Seems hard (especially in 1860s)
- How can we measure processes?

On the speed of mental processes -(originally published in 1868)

"…Would it not be possible to determine the time required for shaping a concept or expressing one's will? For years this question intrigued me…" (p417)

Using Time?

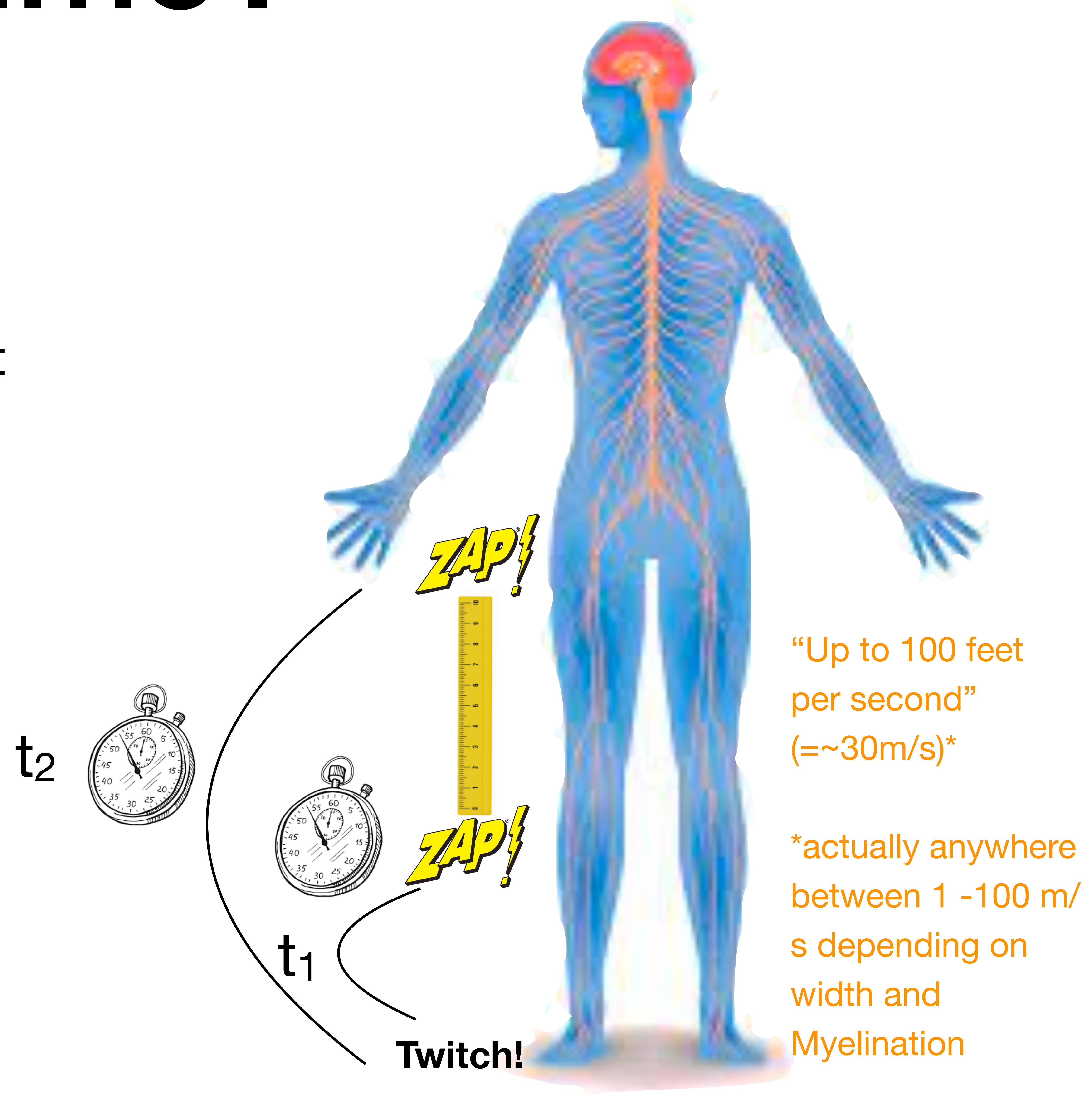
- Scientists like Hermann Helmholtz had developed a subtraction method to estimate speed of nerve signals signals around the body

- E.g. measure time between stimulation and reflex at two points

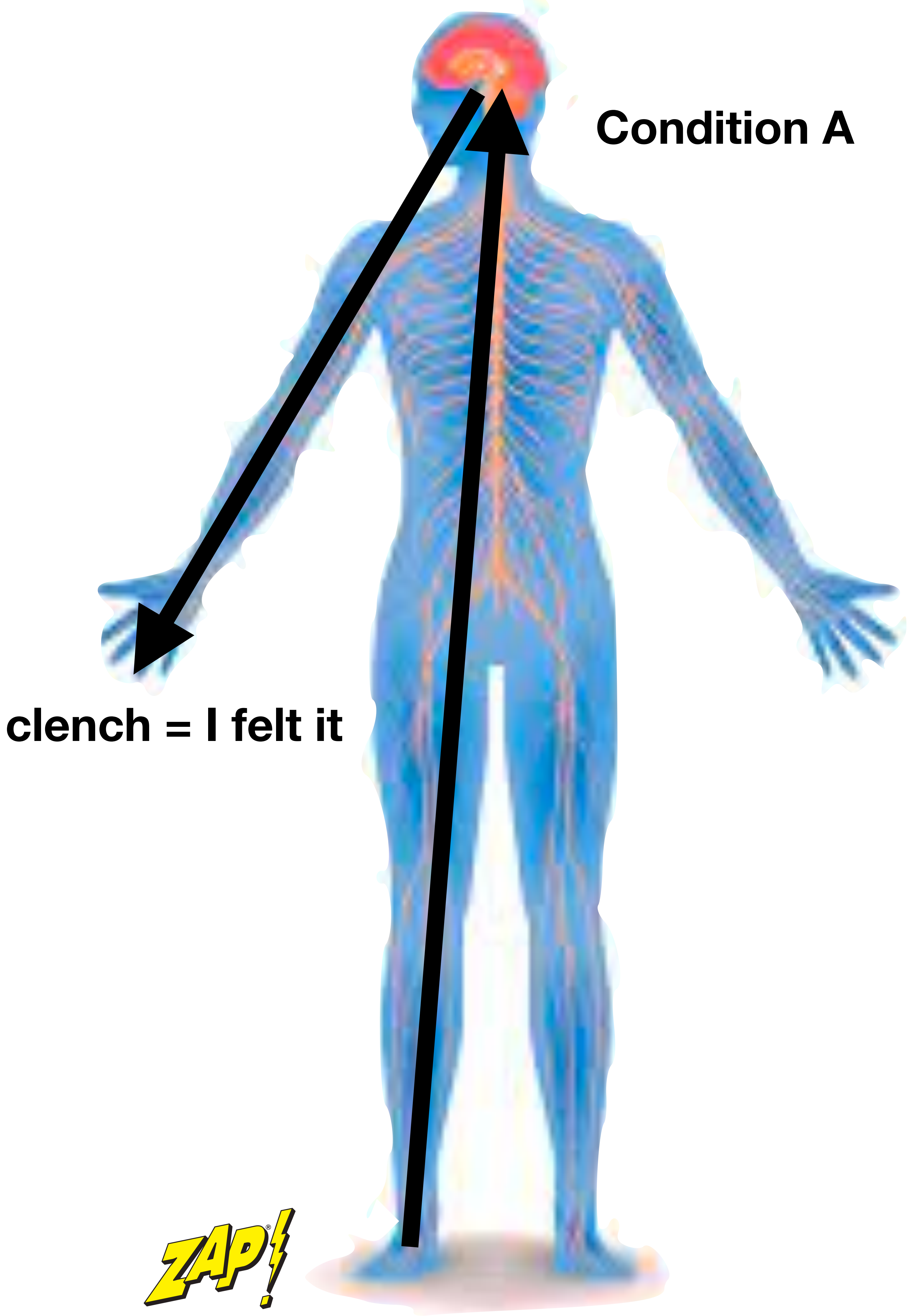
  - mean(t_1-t_2) = statistical estimate of signal speed allowing for measurement errors

  - min(t_1-t_2) = *potential* signal speed

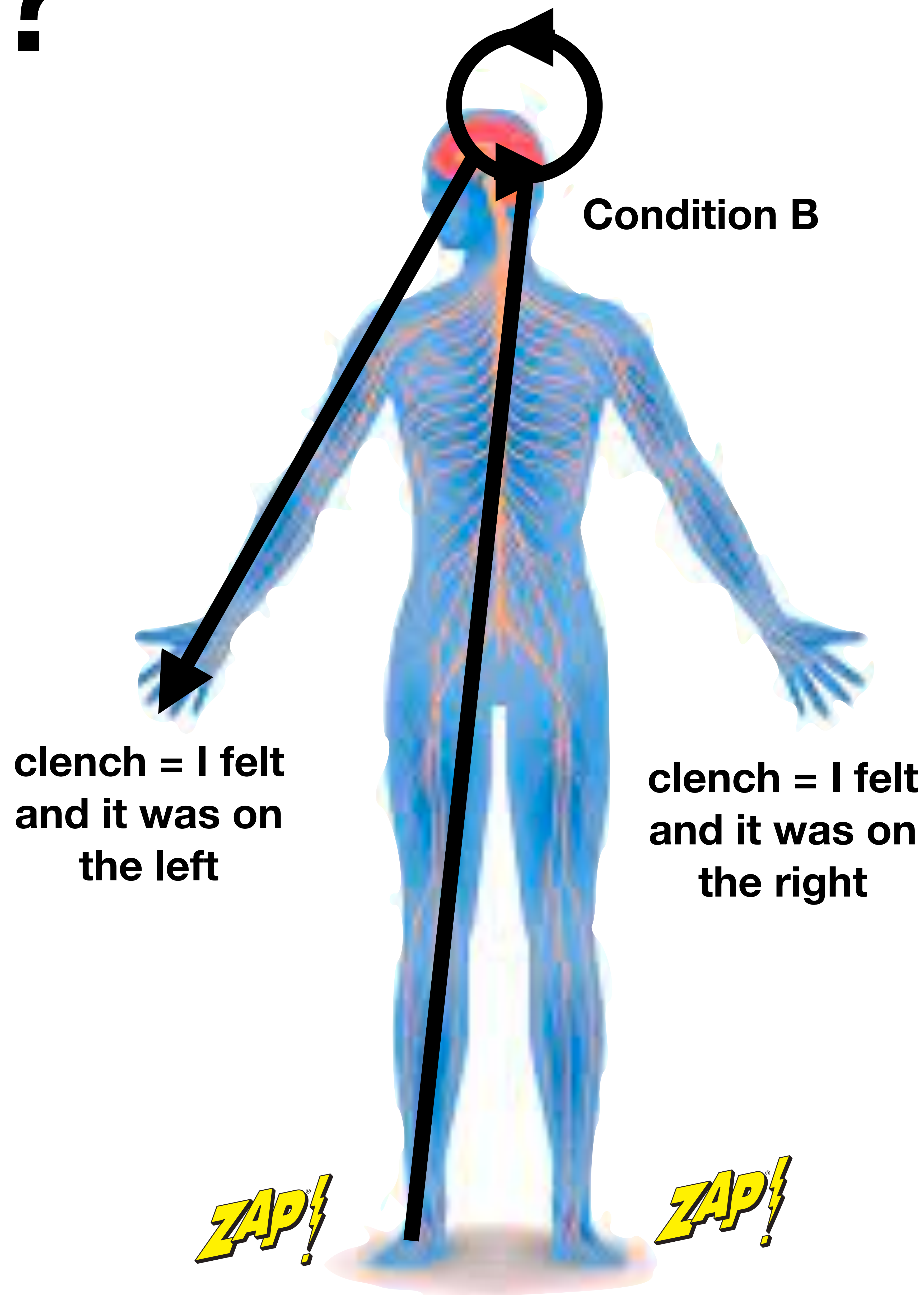
- Donders first to explore reaction time **"RT"** via subtraction method as way to measure cognitive processes



Using Time?



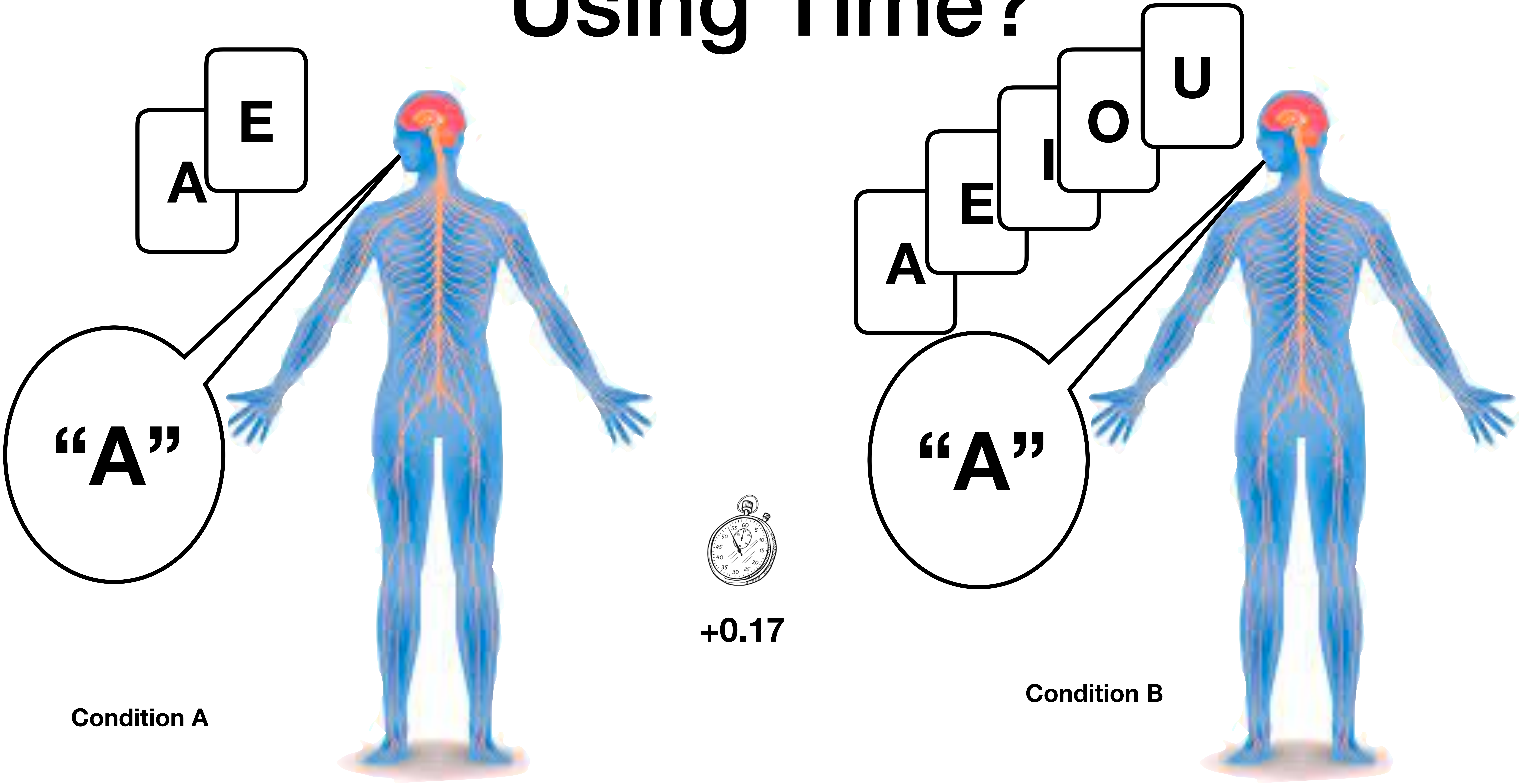
+0.067



Using Time?

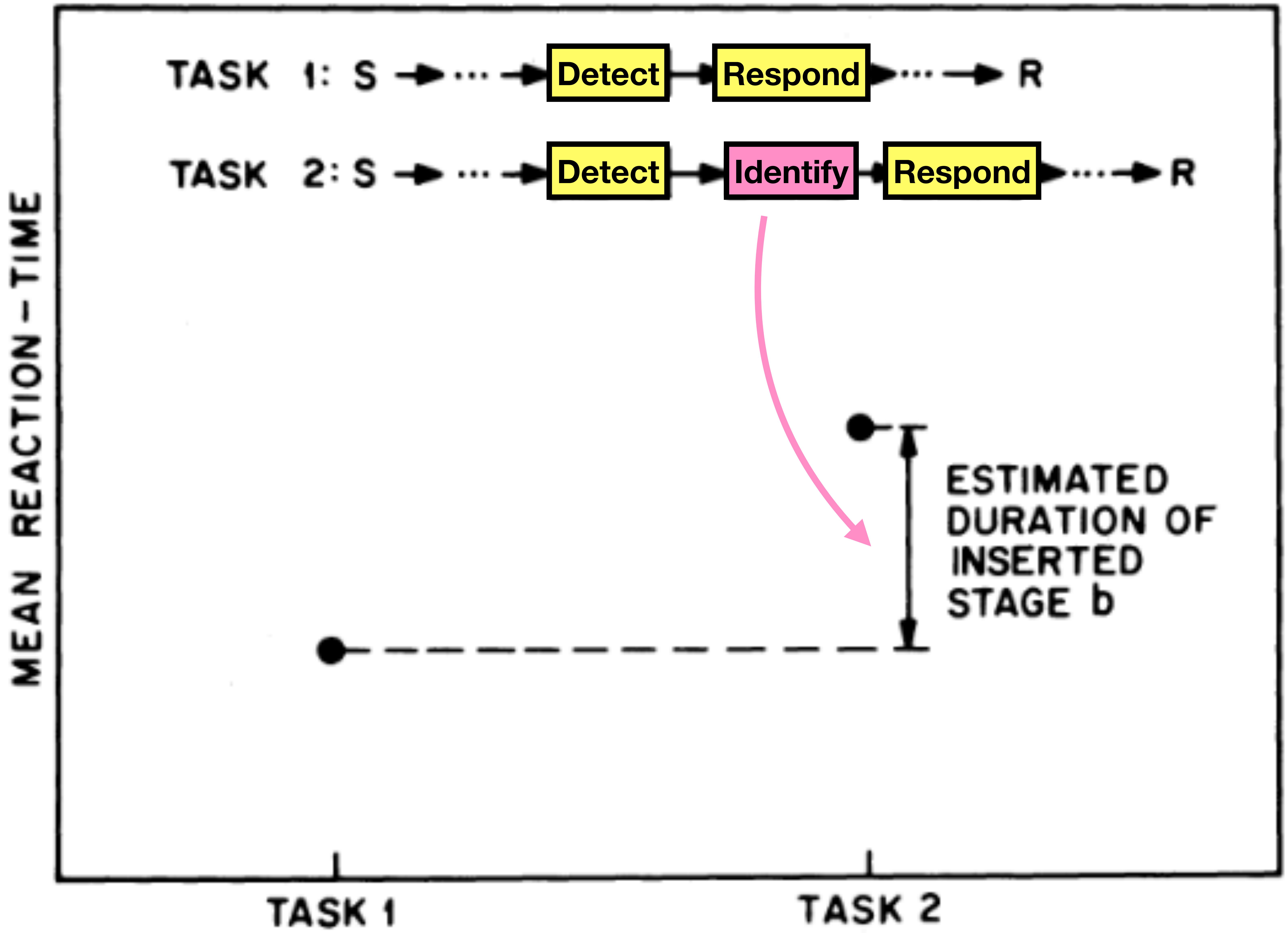

Condition A
clench = I saw it
?
Condition B
clench = I saw and it was red
clench = I saw and it was white
+0.154

Using Time?



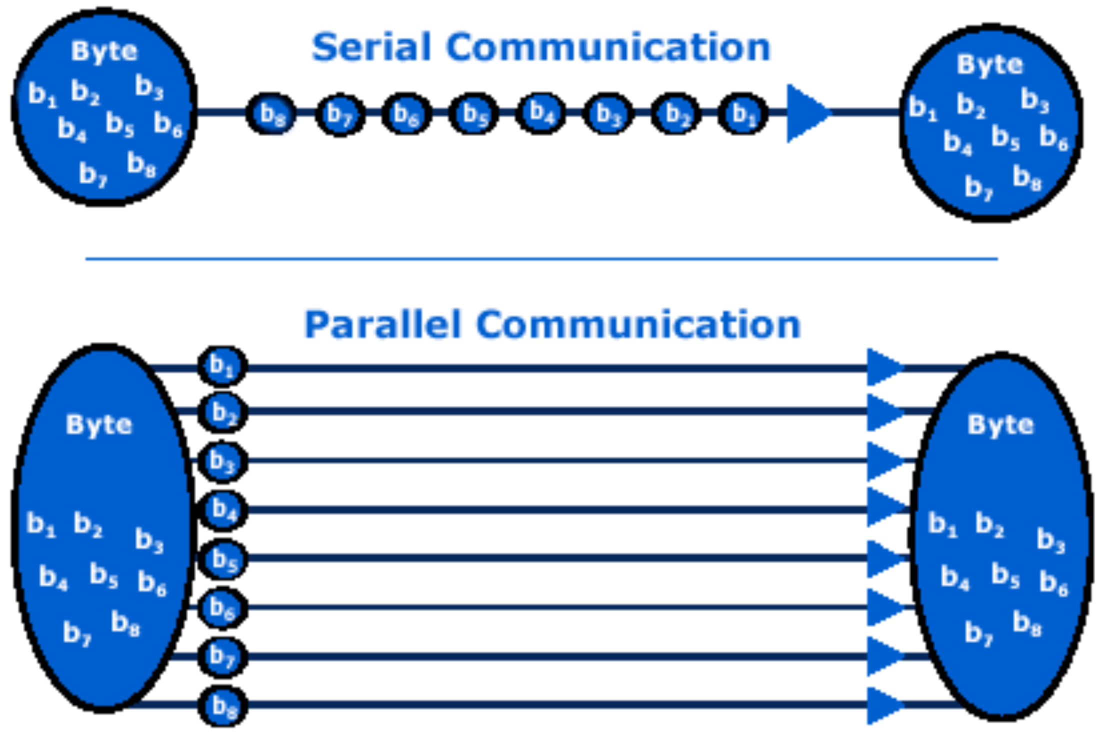
- From a modern viewpoint, these experiments flawed (and underpowered) but a new method is born…
- 100 years later… Sternberg, (1969). Memory-scanning: Mental processes revealed by reaction-time experiments. *American Scientist*
- Paper starts highlighting conceptual problems with earlier work using reaction times
  - e.g. Willhelm Wundt, who succeeded Donders
- And approach that had come to be called “Stage theory”

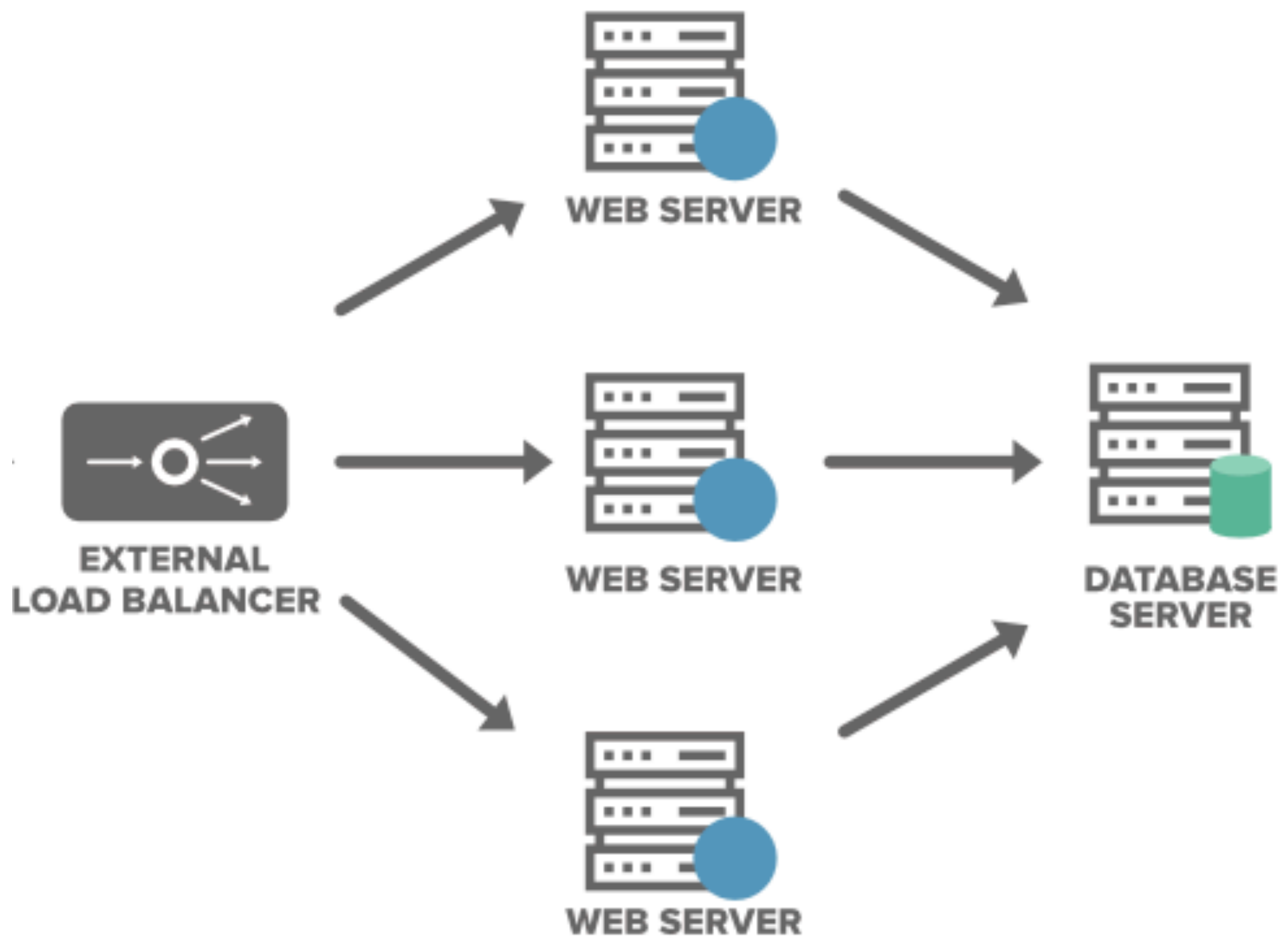
Stage theory (too simple)



Problems with stage theory

- Cognition likely to involve both serial and parallel processes
  - + tasks might share or compete for same cognitive resources
- Besides, goal is to reveal processing *structure*, reductive assumption of seriality prohibits this
- Stage theory does leaves major inter-individual and intra-individual variance unexplained
  - Suggestive of heterogeneous processing strategies and/or involvement of stochastic processes?
  - Mean or min? What about error trials?





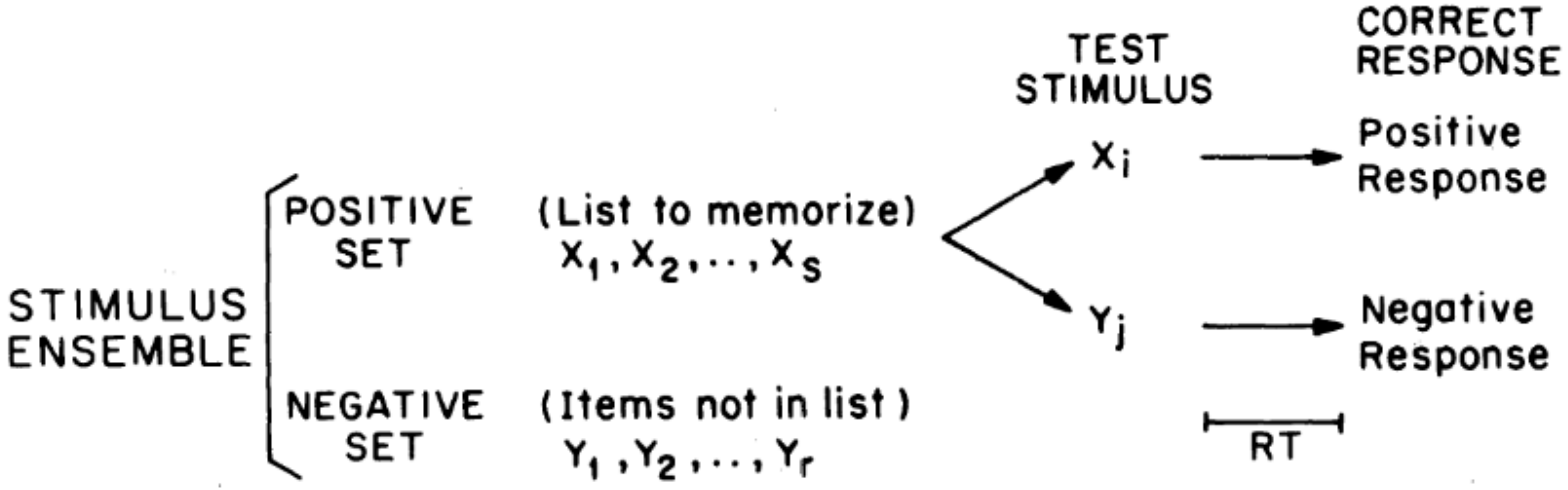
Memory scanning

- Sternberg describes series of more recent studies on *information retrieval from memory* on somewhat better footing
- Rather than inserting tasks wholesale, focuses scaling same task, i.e. *Varied Set Procedure*
    - E.g. varying the dimensions/demands of tasks to see how RT scales
    - Still sets aside question of what happens in error trials by focusing on correct responding
    - And still extremely small sample sizes

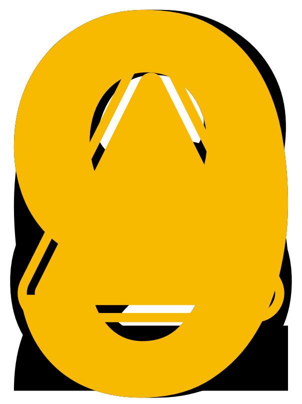
Item recognition task

- Participants repeatedly memorize a list of 1—6 digits and then are asked if a test digit was in the set

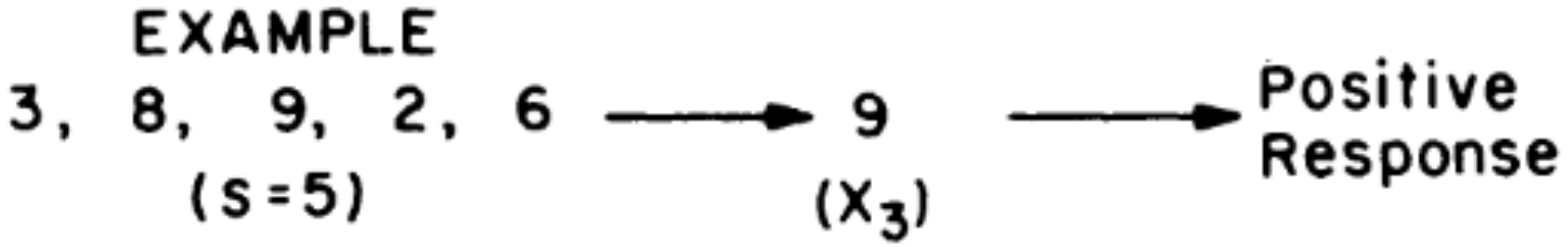
- It is actually in the set 50% of the time

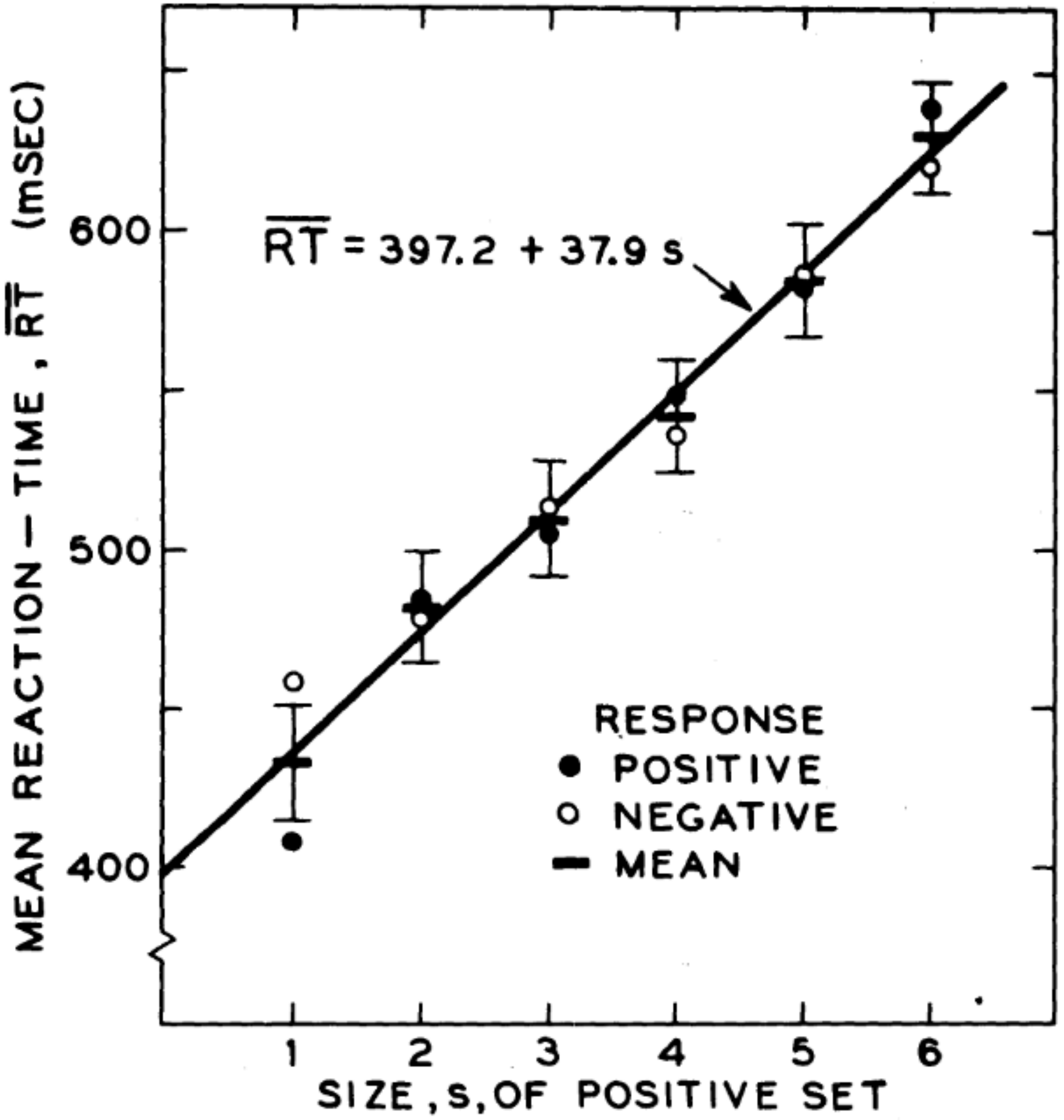


Item recognition task



And now try to recall the set in order…



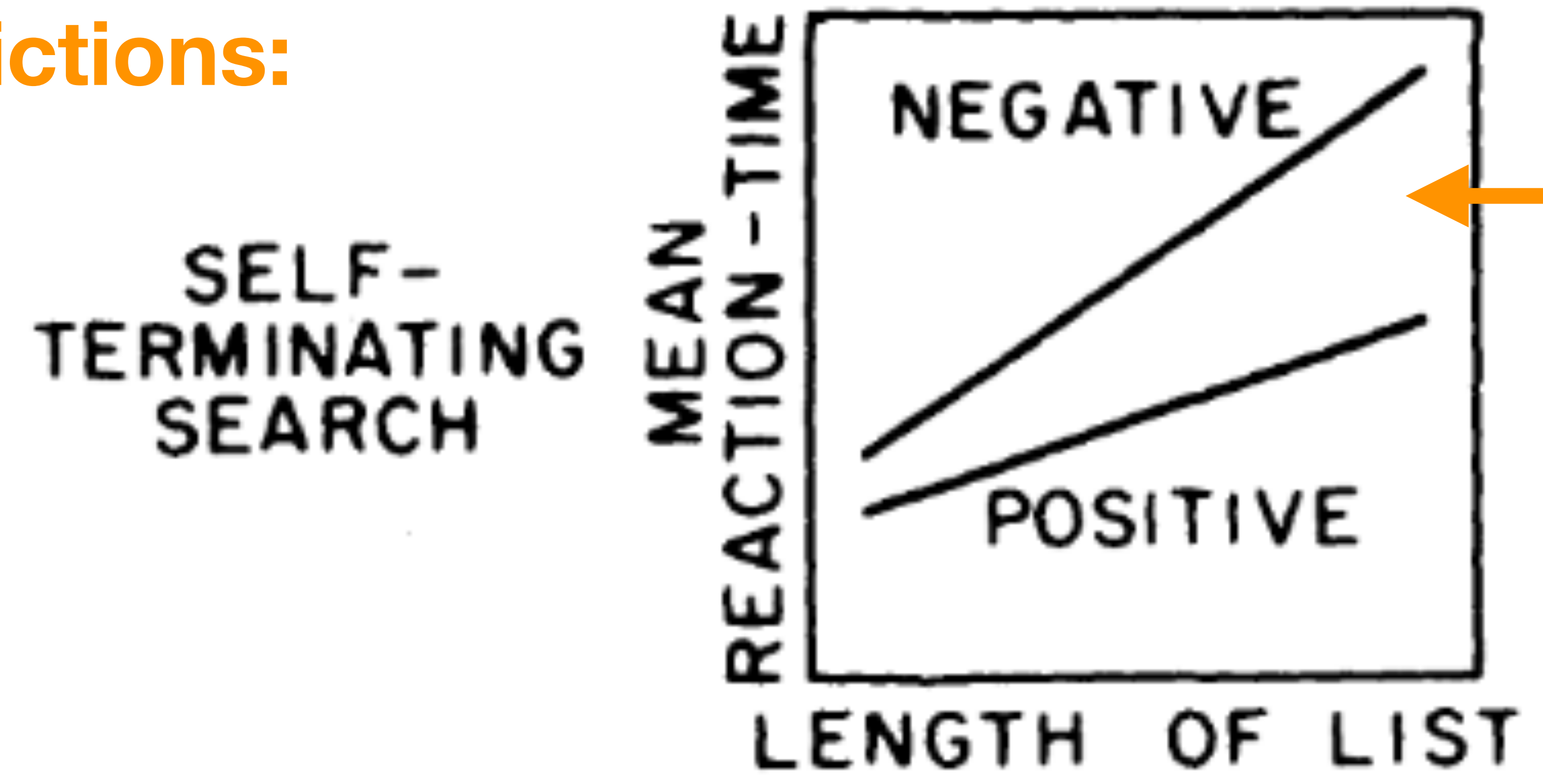


- Reaction time (RT) increases linearly with set size
- But do we search short term memory via a **self terminating search** or **exhaustive search**?
- E.g. self terminating:
  Compare; check; compare; check; compare; check…
  OR exhaustive:
  Compare; compare; …, compare; Check

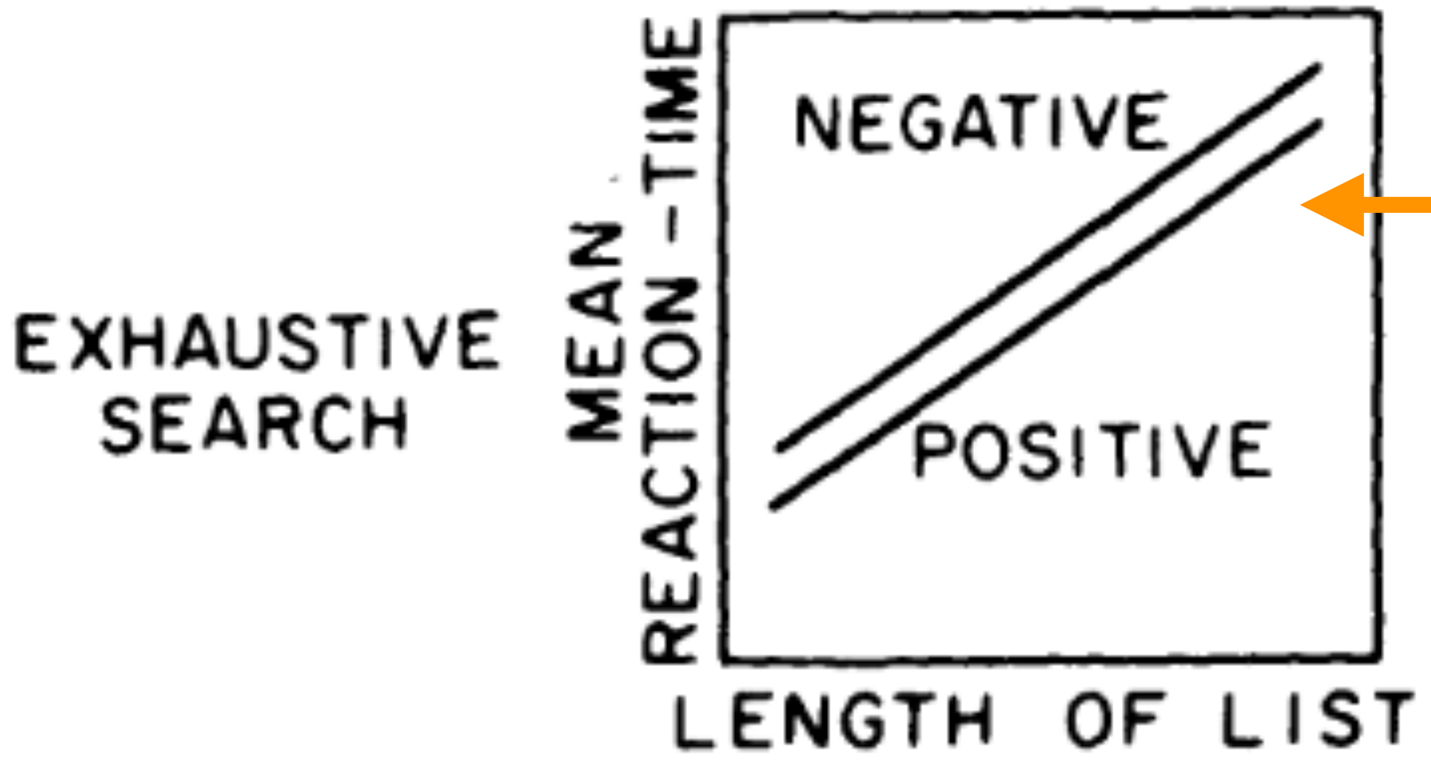
- Do we include an if *match* then *break* statement in our memory scanning process?

- **Intuition**: Self terminating search might be quicker *if* match discovered early but might be slower *if* no match found, or found only near the end, since more computations performed in total

Theoretical predictions:

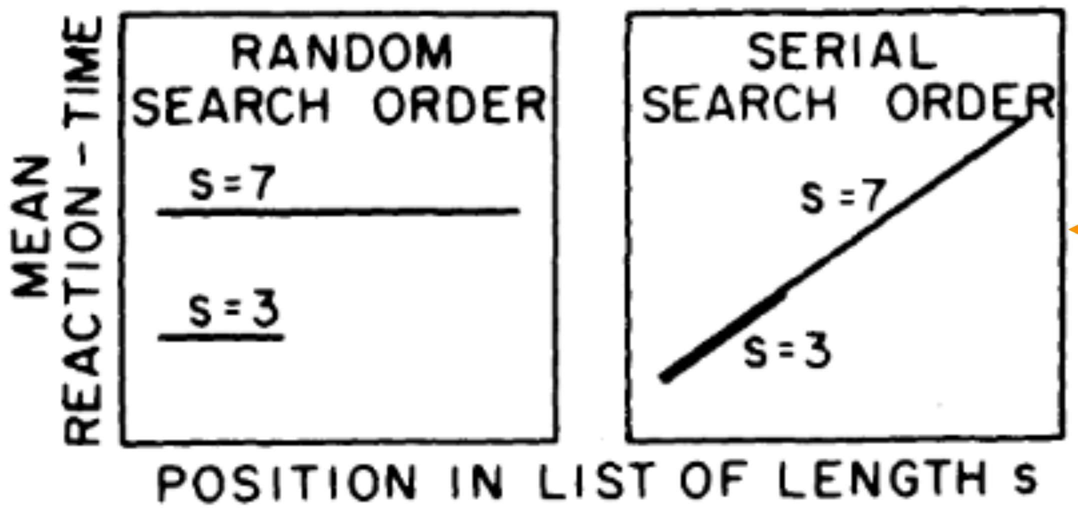


Because successful searches will end early

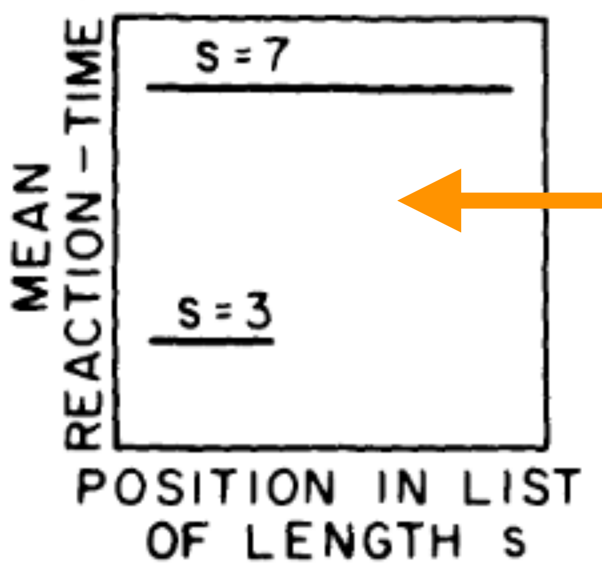


Doesn't matter much if search was successful, just how long the list was

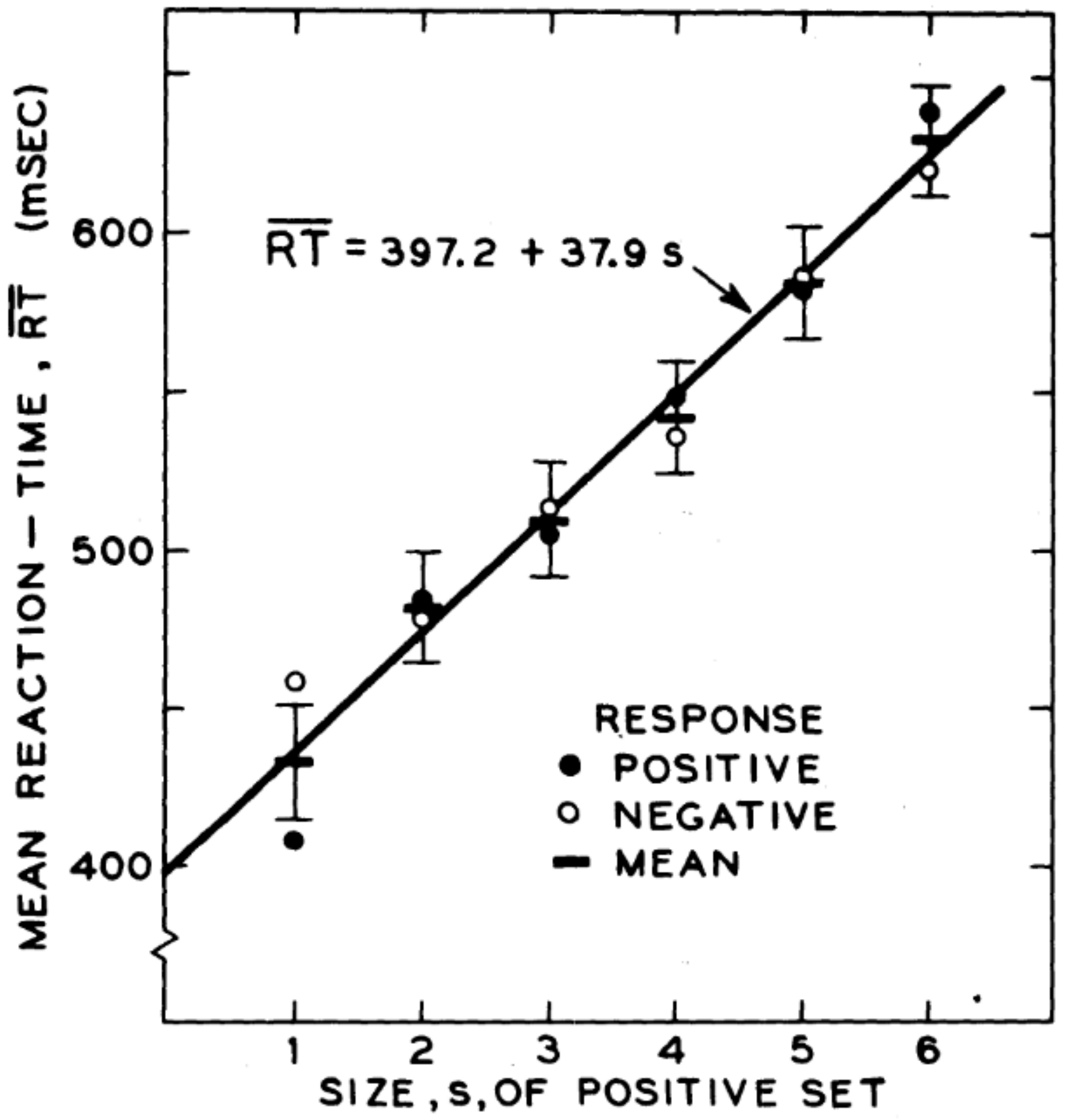
RT variable but unpredictable (depends on search order)



RT shaped by serial position

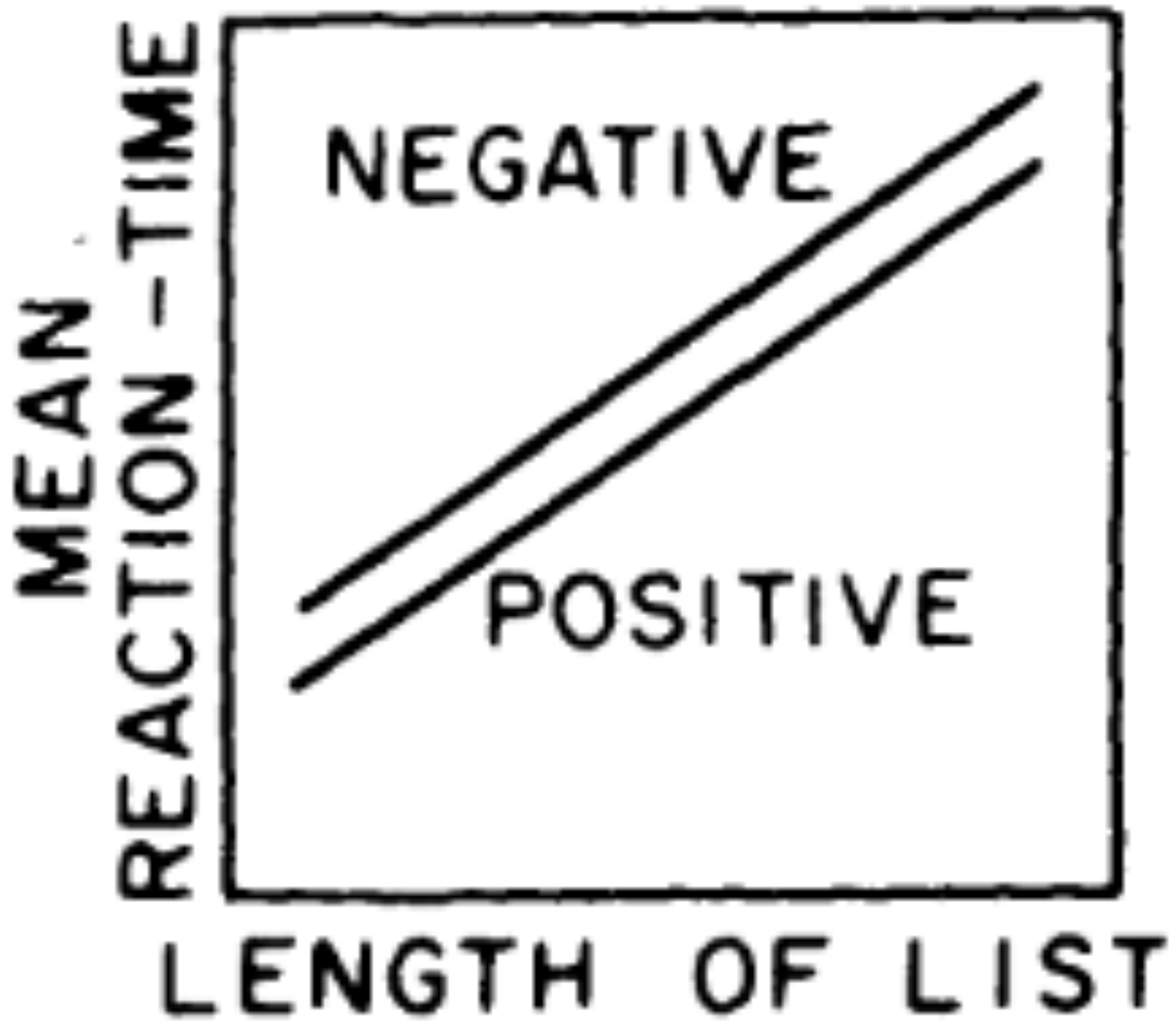


RT insensitive to serial position



(+ Serial position also had no effect)

EXHAUSTIVE SEARCH



- So, **looks like we search short term memory exhaustively**

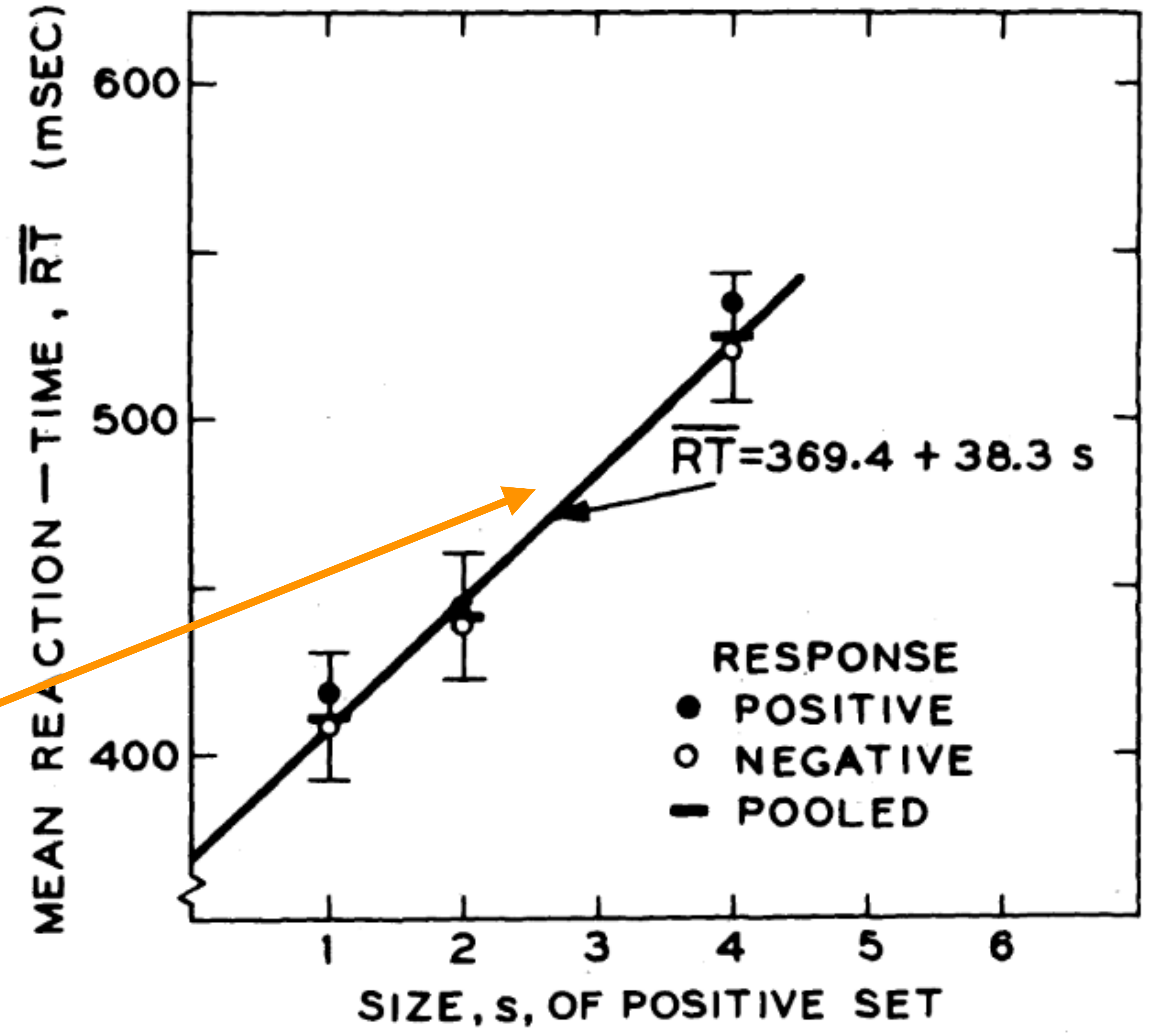
What about in long term memory?

- In “fixed set” task variant, participants learn a stable set over many trials, to point where they can recall it days later
  - i.e. scanning information from *long term* memory not just current content of working memory

- People repeatedly tested on whether test items are in the learned set

- RT is still linear + positive and negative RT still coincides

- **So: looks like we also search long term stored items exhaustively too**

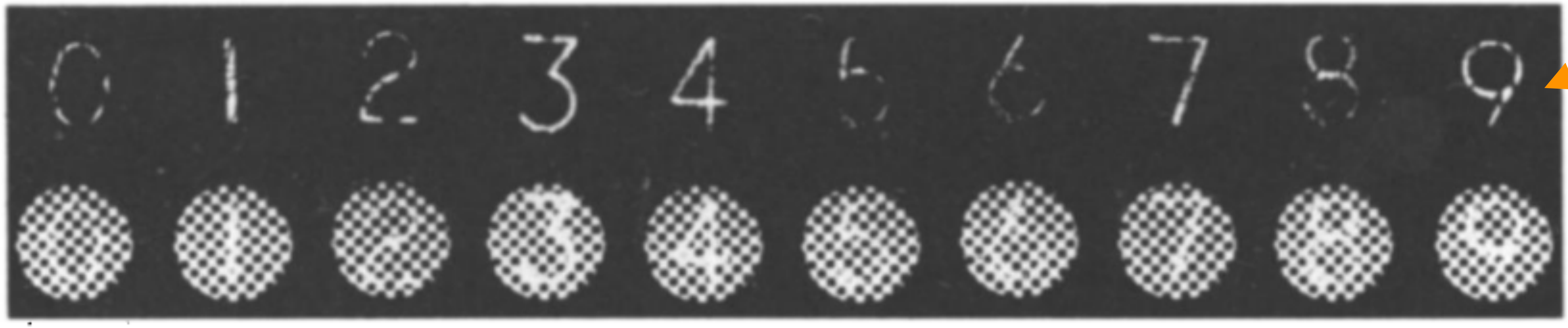


Effects of simulus quality?

- What is the nature of the representations that can be compared at such high speed?
- I.e. Do we compare raw sensory inputs to memory trace (cf Representation) vs. Preprocess abstract/symbolic meanings then compare?
- Can probe this by comparing recognition of intact vs degraded stimuli

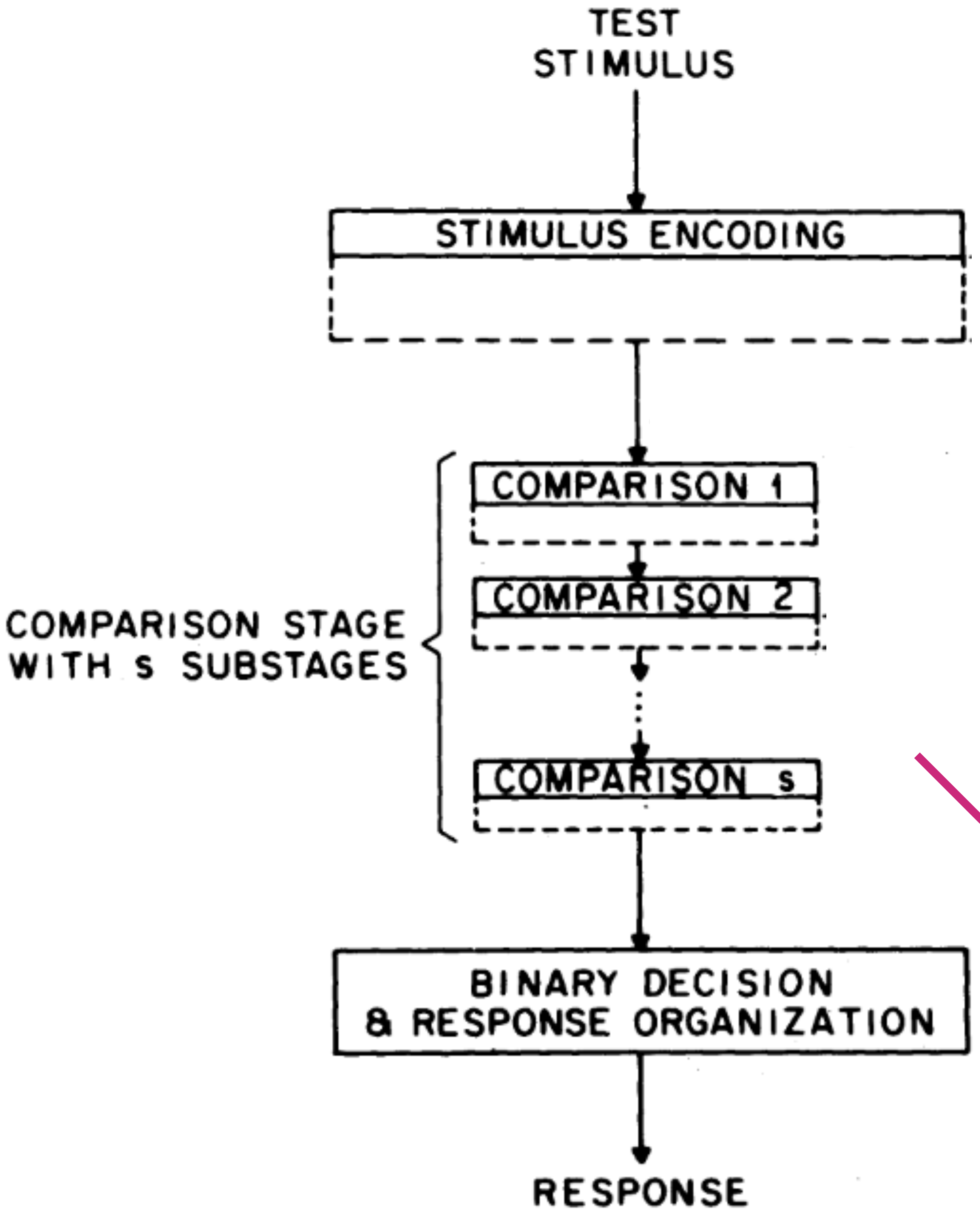
Intact:

Degraded:



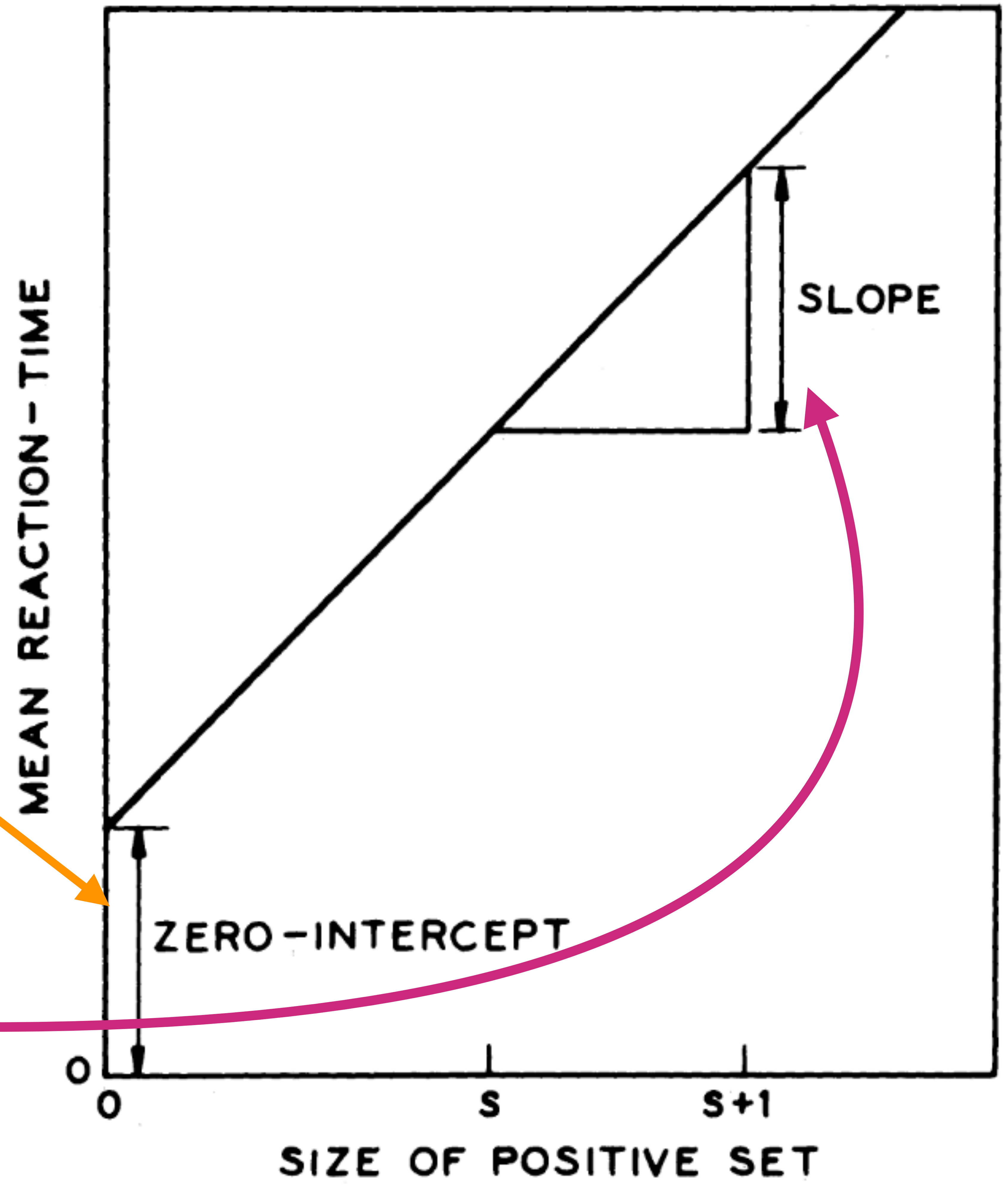
Presumably more intact than this at the time😂

Reformatting question into model predictions:



If we entirely preprocess the stimuli it should increase RT by a constant

If we work with the raw stimulus, it should affect every comparison, increasing the set-size slope



Results

Two possible predictions

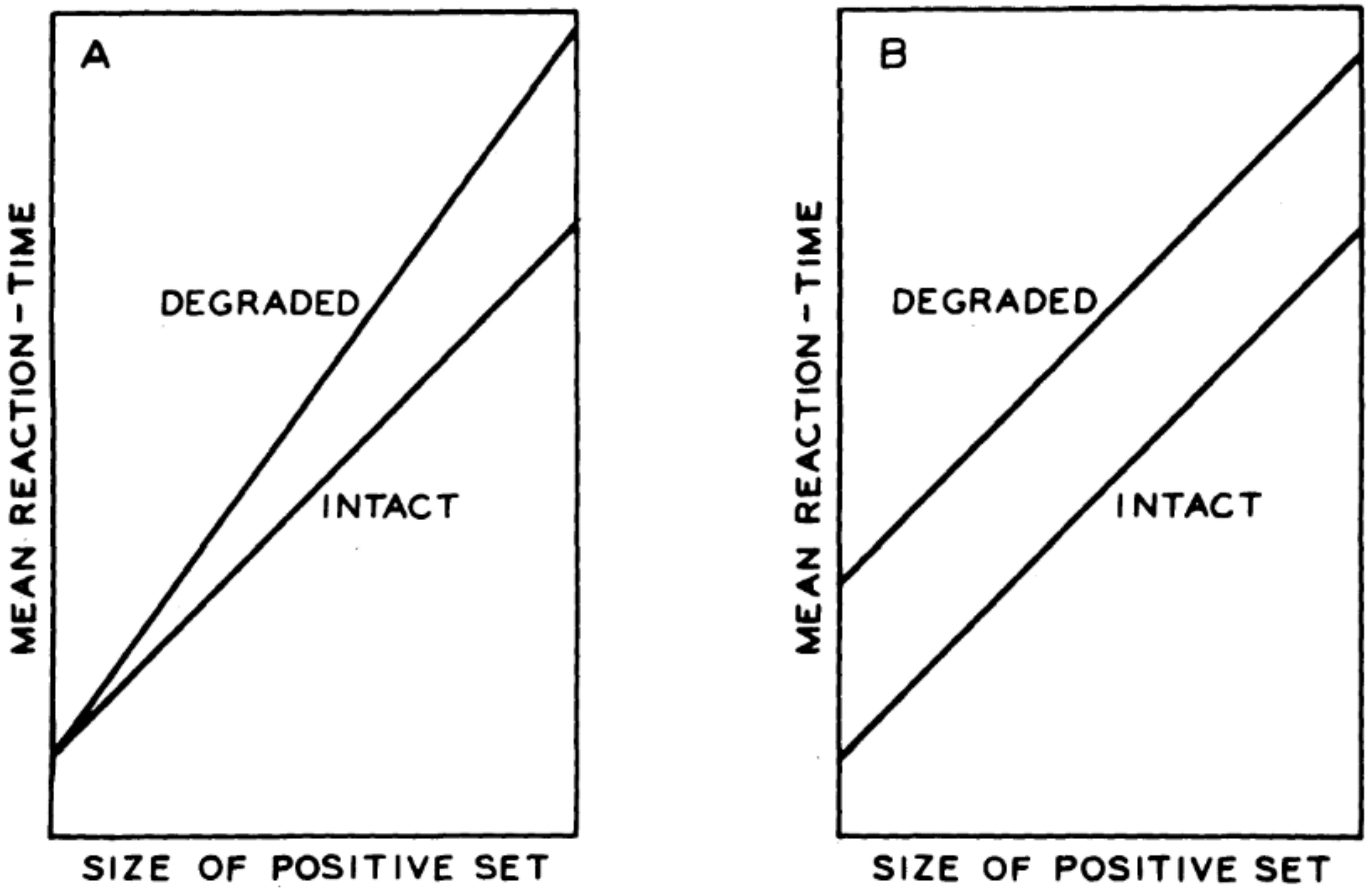
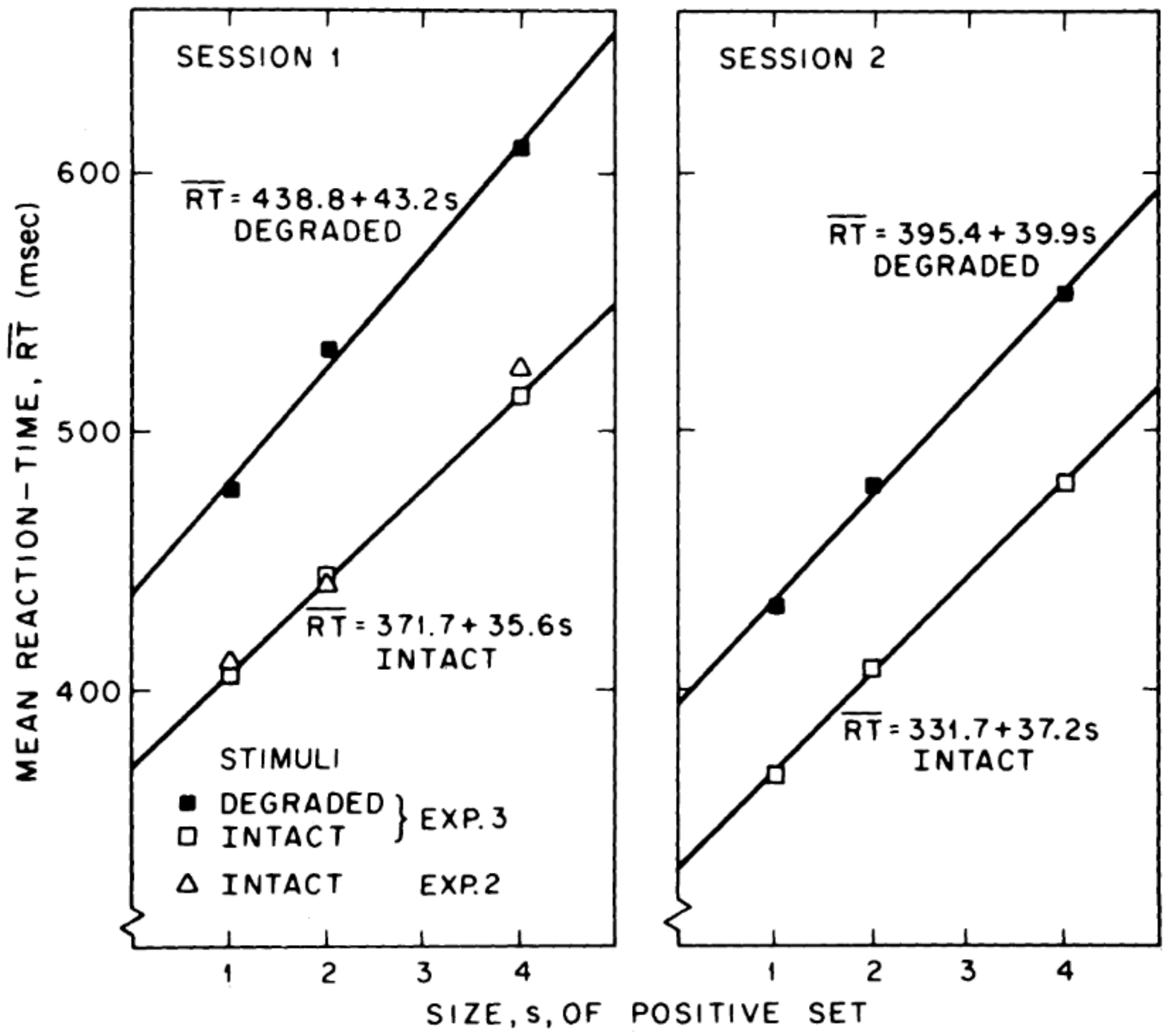


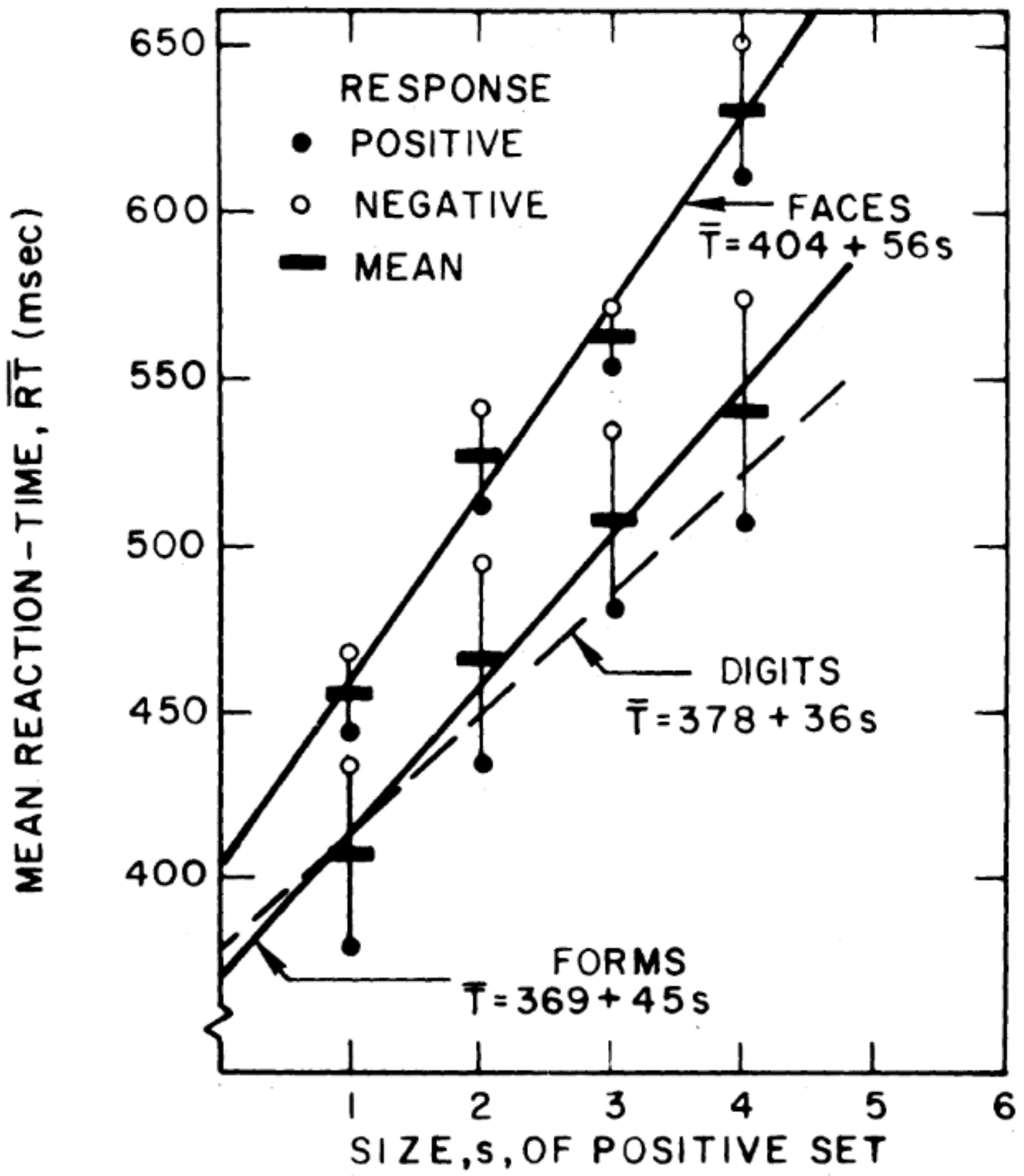
FIG. 9. Two possibilities for the effect of test-stimulus quality on the RT-function. A: Quality influences comparison stage only. B: Quality influences encoding stage only.

What was found



- **Degradation clearly increases preprocessing time**
- **But still seems to influence comparison processes a little, at least initially!**

Is exhaustive scanning true for other types of memories than symbolic digits?

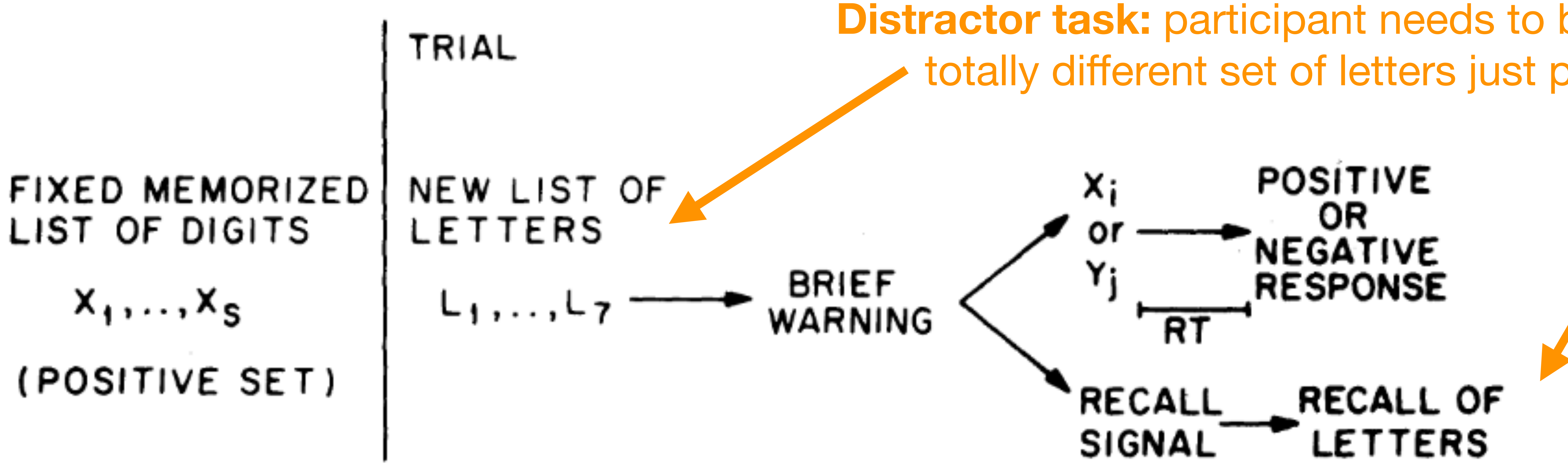


- **Yes**
- At least: Recognition of digits, ‘nonsense forms’ and faces all show similar linear effects of set size & similar slope for positive and negative cases.

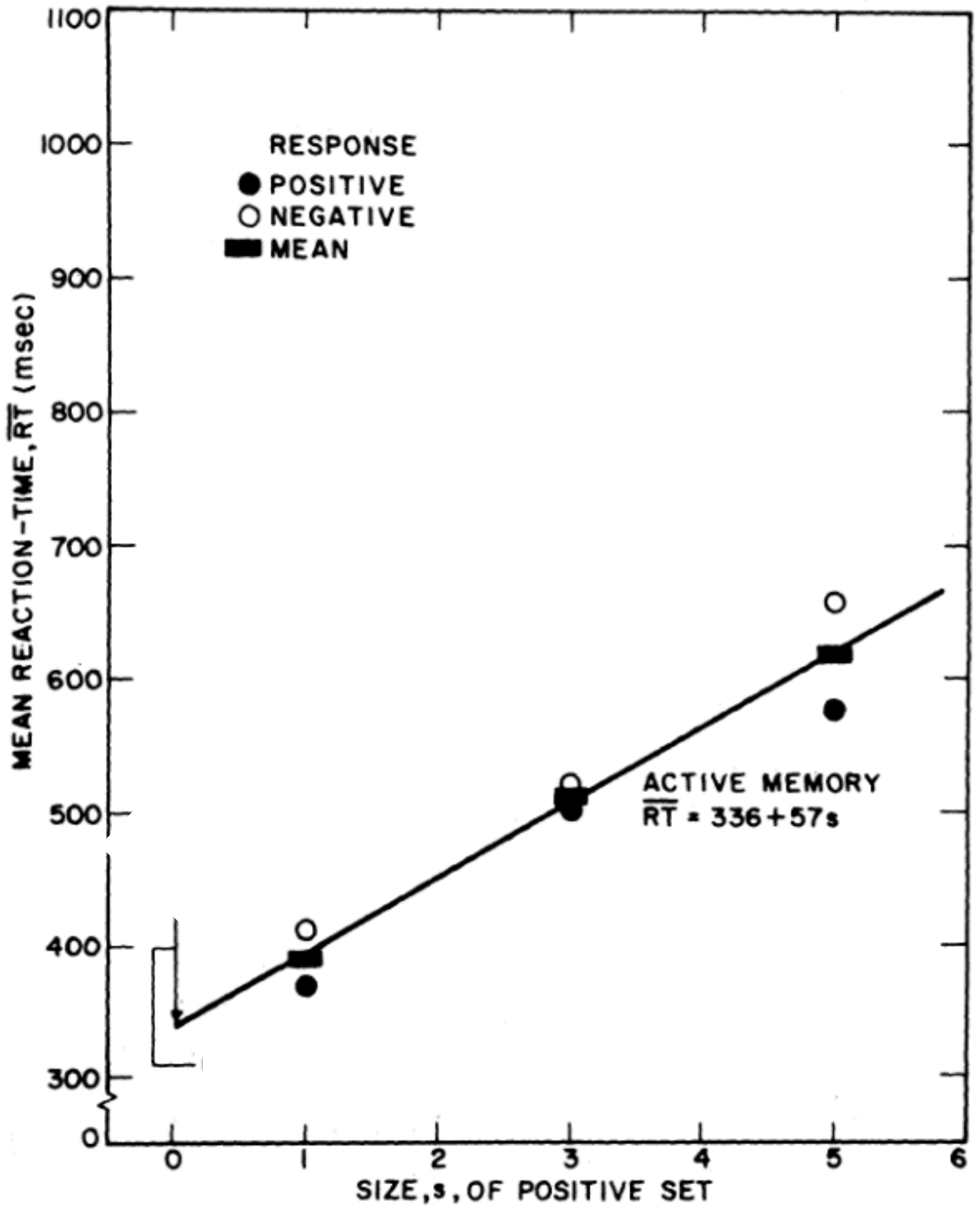
Is the scanning in ‘active memory’?

- Is exhaustive scanning happening in ‘active memory’?
    - i.e. even in fixed-set procedure, participants could be actively “loading” into memory, and rehearsing the set at test
- So what happens if you make them do recall while under load?
    - i.e. what if you make them do something else with their working memory at same time as recognition task?

Distractor task: participant needs to be prepared to recall a totally different set of letters just presented to them



Results of load manipulation



Experimental condition (with distractor task) Much slower and more cost per additional item!

Control condition (no distractor task) RT slope as before

- Adding distractor task has a big effect on the search process (both intercept and slope)
- Active rehearsal (of something unrelated to task) impedes memory search
- Seems like we can't do this 'in the background', attention is needed (cf. Shiffrin and Schneider, 1977)

How could exhaustive search be efficient?

- If you have to check each evaluation before deciding whether to continue you have a kind of serial bottleneck: i.e. need to keep switching task **serially**
    - E.g.: Compare; **check**; compare; **check**; compare; **check**…
- If all you need to do is detect any match with memorised list, this is inherently more **parellisable** / vectorisable:
    - e.g.: $\text{stimulus}_{\text{obj}}$ == $\mathbf{memory}_{\text{array}}$ %>% any()

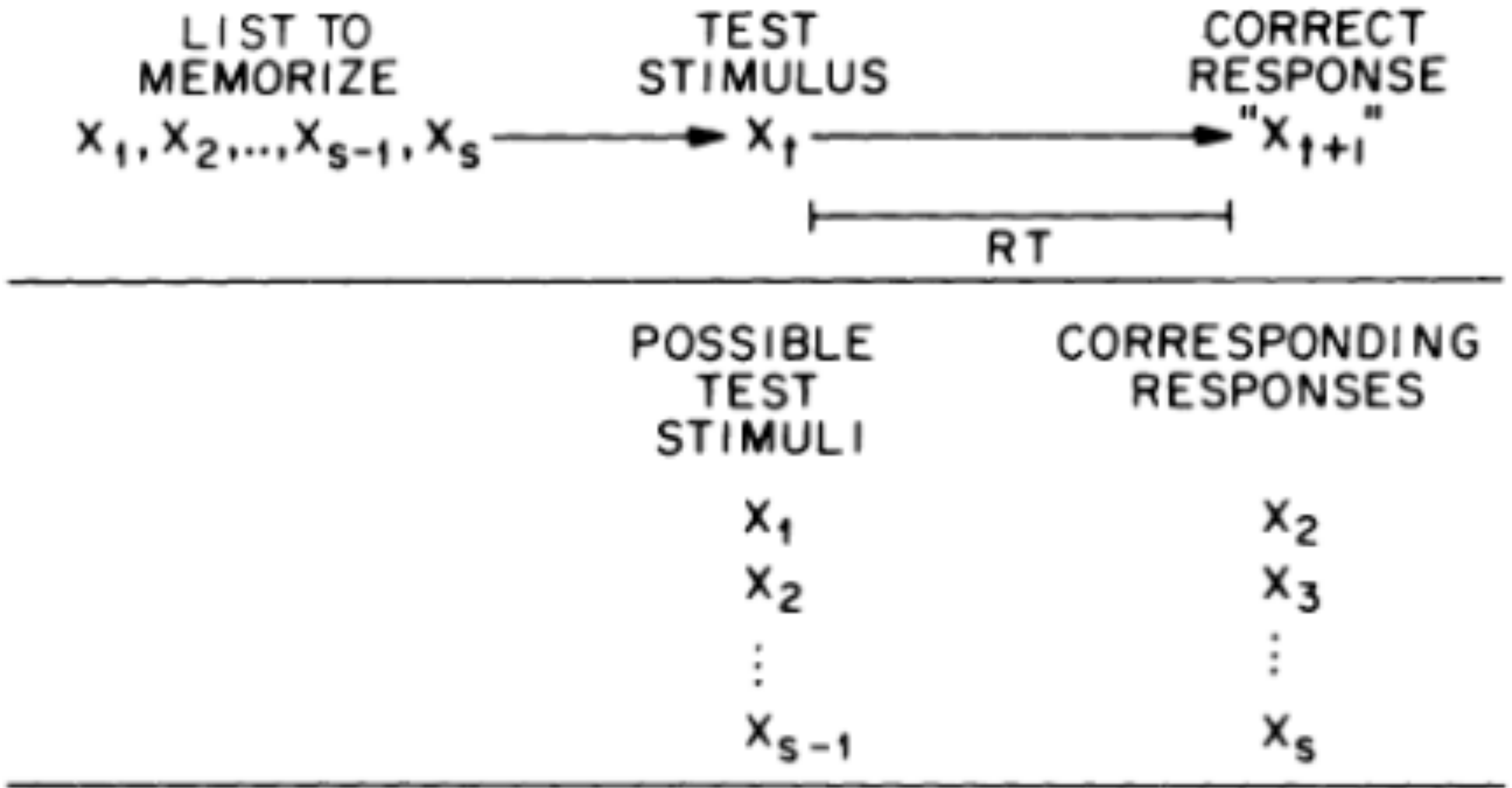
Pipe operator (equiv to nesting LHS in RHS)

- But you are left not knowing where in the array the match was..

Scanning to locate

- So, suggests that tasks other than bare recognition might demand different search process

- I.e. if I show you a number from an ordered set and ask you to tell me the next one in the sequence

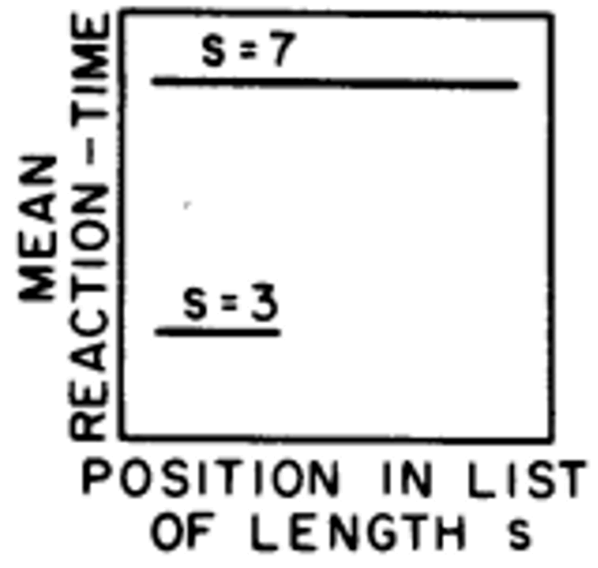


Context recall task

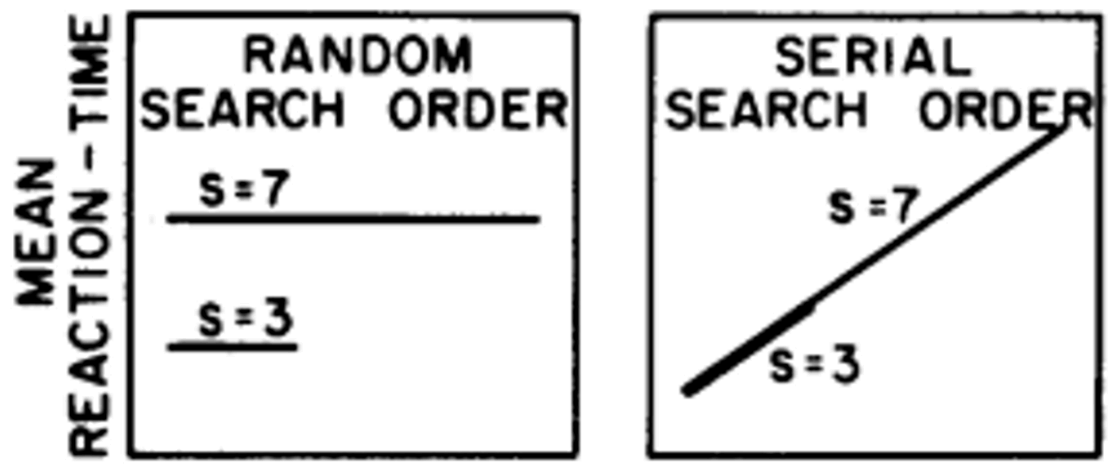
Answer was 8

Results

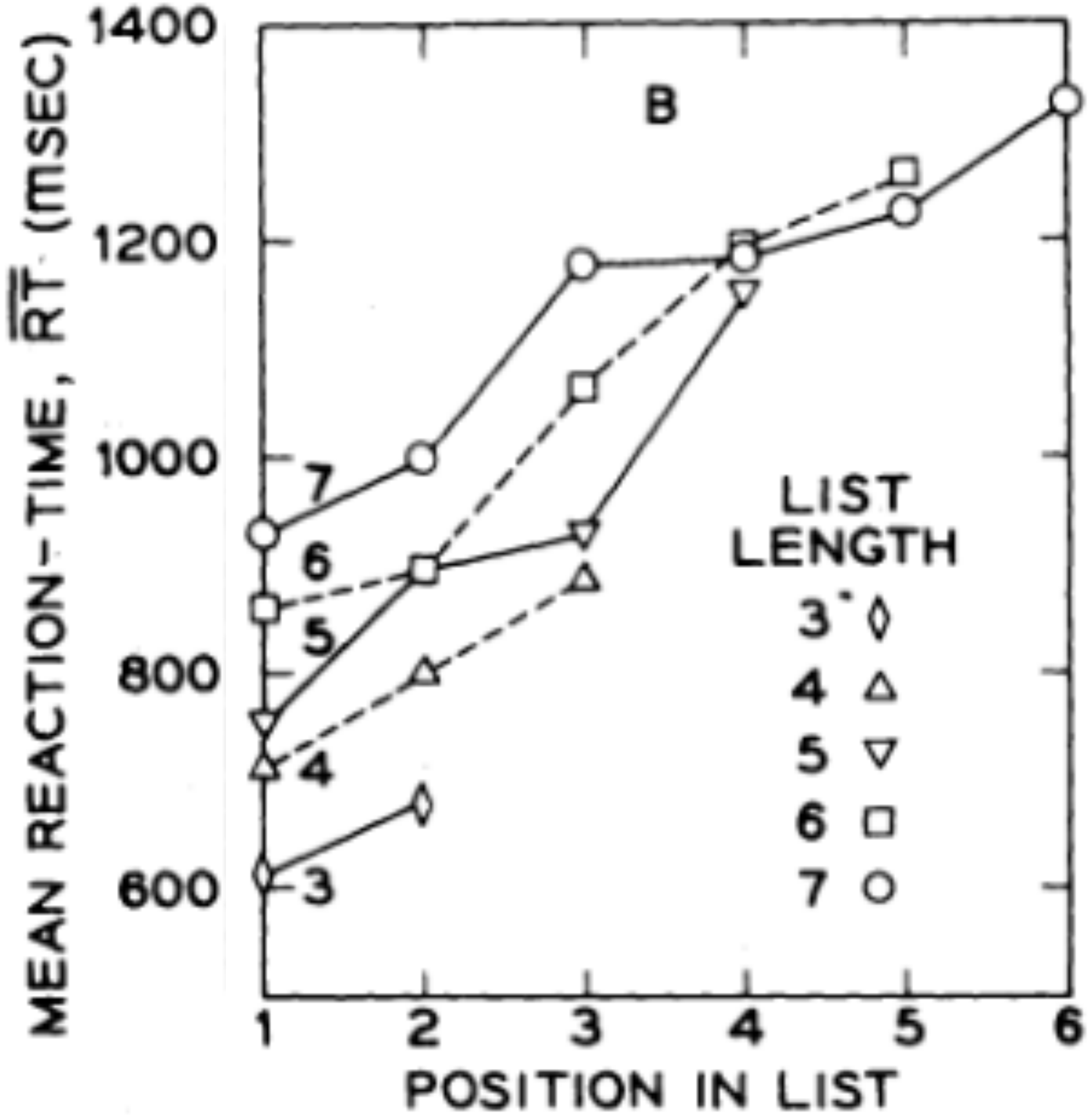
From earlier:



Exhaustive search predicts no RT effect of position in list



Serial self-terminating search predicts effect of position



Position clearly affects RT on average

- **So here we see self-terminating search patterns!**
- Sternberg highlights one subject who shows only effect of list length (indicative of a random search order strategy, or ‘interrupted cyclic rehearsal’) and another with only effect of position (indicative of serial search starting on cue)

- In a final task, participants had to respond one way or other depending on the ordering of the presented pair of stimuli in the original list
- Again, the position in the list affected the RT consistent with self-terminating search

"In some important sense one does not know what is in one's active memory, other than a single item to which attention is currently directed." (p449)

Summing up Sternberg (1969)

- Basic recognition (where the context/position of the memory does not matter) relies on fast exhaustive scan
- But specific recall (where memory must be located exactly in its original context) relies on self-terminating search
- Encoding influences pre-processing but also bleeds over into comparison time, at least initially
- These patterns hold across various stimuli
- The memory scanning process is slowed by cognitive load indicating it requires working memory/attention

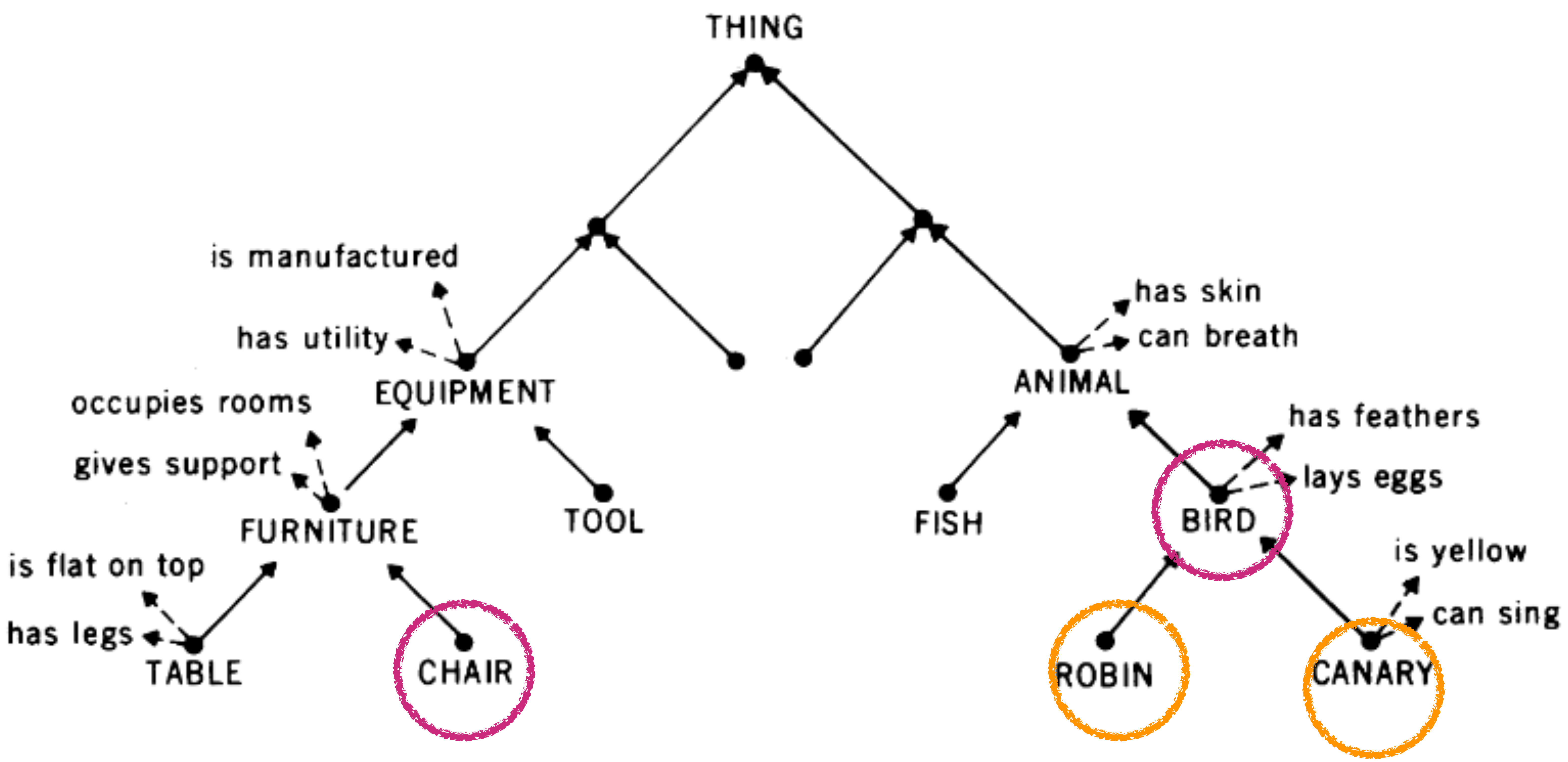
Take homes from Sternberg

- Information must be pulled into working memory for processing
- We have a fast exhaustive search for *recognition*
- We have self-terminating processes for locating/situating memories in context (i.e. for total *recall*)

What about the additional readings?

- Meyer & Schvaneveldt (1976). Meaning, Memory Structure and Mental Processes, *Science* looks at how memory scanning interacts with semantic structure (i.e. with meaningful words rather than arbitrary digits

- So tapping into our **concepts**

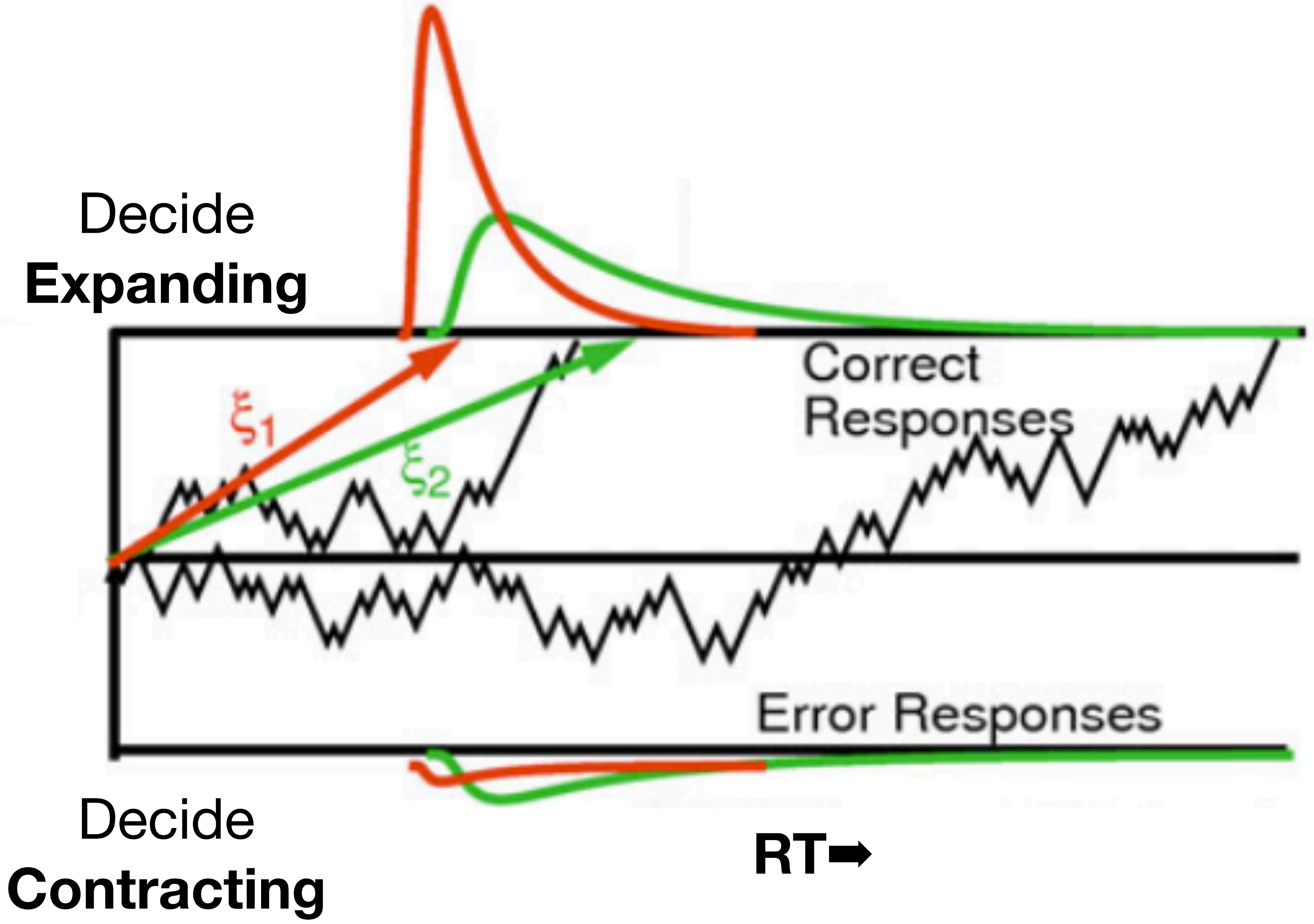


- They show RT for recall of memorized word pairs depends on closeness in natural taxonomy (e.g. **quicker recall**, **slower recall**)

- Suggests semantic memory operates like a spreading wave through a conceptual network

What about the additional readings?

- Smith & Ratcliff (2015). Introduce **Drift Diffusion Models (DDMs)**.
- These model both RT and errors in decision making as resulting from noisy evidence accumulation process



- E.g. Are these dots expanding or contracting?
- Various parameters can be fit to capture distribution of RTs on correct and incorrect discriminations, here shown, predictions under high and low drift rate parameter ξ
- DDMs are flexible and widely studied formalism of choice behaviour, we may meet them again…

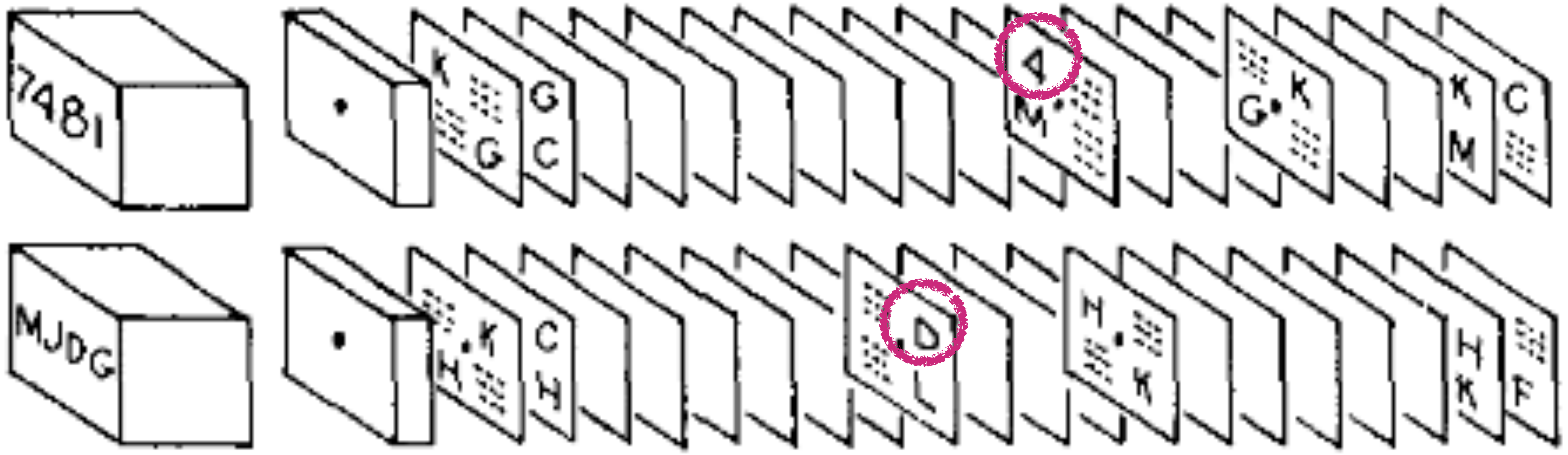
What about the additional readings?

- Shiffrin and Schneider (1977) draw distinction between automatic and controlled processing:

Consistent set procedure

Vs

Variable set procedure



We do this accurately and unaffected by load, i.e. parallel, exhaustive, “in background”

We do this slowly, errorfully, strongly affected by load i.e. demands our sequential attention

- Refinement of Sternberg’s ideas — Controlled processes like self-terminating search are capacity limited because attention cannot be allocated to more than one process at a time.
- Our systems of concepts and categories can aid search: e.g. numerals are saliently different to consonants to us so straightforward to spot
- Their models accounts for learning to search, becoming more efficient with practice & in familiar domains (e.g. look in likely places first when hunting for house keys etc)

References

Donders, F.C. (1898). On the speed of mental processes. *Acta Psychologica*, 30, 412-431.

Sternberg, S. (1966). Memory Scanning: Mental Processes Revealed by Reaction-Time Experiments. *American Scientist*, 57(4), 421-457.

Smith, P.L. & Ratcliff, R. (1995). An Introduction to the Diffusion Model of Decision Making. In *An introduction to model-based cognitive Neuroscience* (pp. 49-70). Springer, New York, NY.

Meyer, D.E. & Schvaneveldt, R. (1976). Meaning, Memory Structure and Mental Processes: People's rapid reactions to words help reveal how stored semantic information is retrieved. *Science*, 192(4234), 27-33

Shiffrin and Schneider (1977). Controlled and Automatic Human Information Processing: II. Perceptual Learning, Automatic Attending, and a General Theory. *Psychological Review*, 84 (2).

Discussion

How can we measure mental processes from behaviours?