

# Modelling Memory Retrieval Processes with Drift Diffusion

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## Memory Retrieval Mechanisms

Speed-accuracy trade-off designs have provided a critical empirical cornerstone in our understanding of the architecture of memory retrieval in sentence processing.

- Much of the evidence in this domain comes from Multiple Response SAT (MR-SAT), a methodology that disassociates memory access from retrieval speed and availability;
- If there is a retrieval process → *availability* should be reduced as distance increases;
- If via direct access → *retrieval speed* should **not** be affected as distance increases.
- If via serial search → *retrieval speed* should be slowed as distance increases.
- MR-SAT has been key in arguing that sentence processing is mainly subserved by **cue-based, direct access** retrieval mechanism (Foraker & McElree, 2006; Martin & McElree, 2008, 2011).
- However, MR-SAT is a **time consuming** and **resource intensive** methodology, leading to fewer opportunities to replicate previous results and extend our understanding to new phenomena.

## Drift Diffusion Modelling

Alternative methodology, Drift Diffusion Modelling (DDM):

- DDM has been used to analyse two alternative forced choice experimental designs (Ratcliff 1978; Ratcliff, et al., 2016; McElree & Doshier 1989).
- Modelling memory retrieval processes with DDM may have advantages in requiring fewer response time measurements to recover meaningful parameters.

DDM jointly models accuracy and response time distributions with parameters that reflect distinct underlying memory retrieval processes.

- $\tau$ , *nondecision time*, the encoding and motor response time (similar to the SAT intercept);
- $\alpha$ , *boundary separation*, the distance between the two possible forced choice alternative responses (with larger numbers indicating higher accuracy; similar to the SAT rate);
- $\delta$ , *drift rate*, the tendency of the diffusion process to drift towards one response alternative other the other (with positive values drifting upwards; similar to the SAT asymptote);
- $\beta$ , *response bias*, which is held constant in the modelling of these studies.

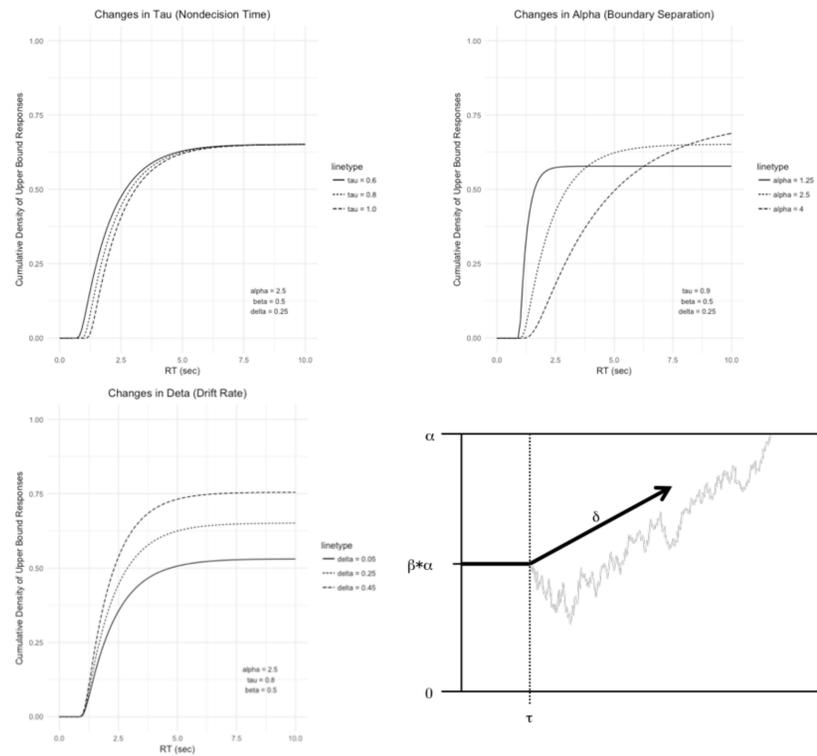


Fig. 1: Hypothetical cumulative density curves for drift diffusion models that differ by each parameter

## Methods

Speeded acceptability judgement (N = 64) on MTurk

- An experimenter-paced, phrase-by-phrase sentence reading task RSVP presentation.
- Followed by an end of sentence acceptability judgment with binary choices.

DDM analysis:

- We used the RWeiner package in R to fit a Weiner drift diffusion model for each condition for our participants (Wabersich & Vandekerckhove, 2014).
- Responses were coded for accuracy, permitting us to hold  $\beta$  constant at 0.5.
- The by-participant parameter fits were submitted for analysis using mixed-effects modelling with maximal random intercepts and slopes by participant.

## Experiment 1: Sluicing

Martin & McElree (2011):

- Distance had *no effect* on the time for memory access in the processing of sluicing constructions.
- Antecedents are retrieved via a *cue-based direct-access* mechanism.

We replicated this study by manipulating Distance and Acceptability of sluicing constructions:

- Near-Grammatical Michael slept and studied, but he didn't tell me what.
- Far-Grammatical Michael studied and slept, but he didn't tell me what.
- Near-Ungrammatical \* Michael slept and studied, but he didn't tell me which.
- Far-Ungrammatical \* Michael studied and slept, but he didn't tell me which.

## Experiment 2: Reflexives in Picture NPs

Reflexives have stood out as one case where memory retrieval may be guided by structural search (Dillon, et al., 2014).

- Previous experimental work showed that reflexives can be bound from outside a picture noun phrase (PNP), even if there is a possessor in the PNP (Asudeh & Keller, 2001).
- These binding possibilities may be explained by the comprehenders initially *searching* for a possible binder inside the PNP, and only later attempting to search outside the PNP.

We manipulated Distance and Gender of the PNP reflexive dependency:

- Near-Different Gender The guild worried that Sally heard about John's picture of himself.
- Far-Different Gender (\*) The guild worried that John heard about Sally's picture of himself.
- Near-Same Gender The guild worried that Bill heard about John's picture of himself.
- Far-Same Gender \* The guild worried that Sally heard about Mary's picture of himself.

## Experiment 3: Anaphoric Trigger too

What about anaphoric presupposition triggers?

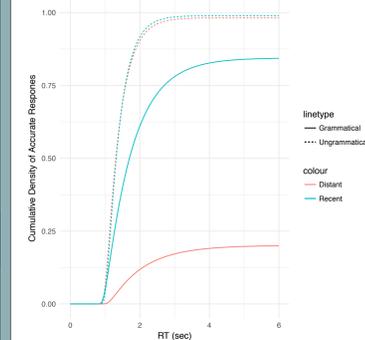
- Triggers like *again* and *also* have been shown to be rapidly sensitive to presupposition violation and are used incrementally during online comprehension to predict upcoming linguistic content (Tiemann et al, 2011; Schwarz & Tiemann, 2012; Romoli et al, 2014)
  - The fact that retrieval processes occurs so rapidly is consistent with the hypothesis that parsers have direct access to presupposed content.
- Meanwhile, Kim (2014) reported in a visual world eye-tracking experiment that participants preferred satisfying the presupposition of *also* using material that was linearly and hierarchically closer to the trigger in the discourse.
  - Such locality biases in processing potentially point toward a search-based retrieval mechanism that grants local targets a temporal advantage.

We manipulated Distance and Acceptability of the presupposition dependency:

- Near-Acceptable If the editor resigned, then the critics resigned too.
- Far-Acceptable If the editor resigned, then everyone at the publishing house would be shocked to hear that the critics resigned too.
- Near-Unacceptable \* If the editor plagiarized, then the critics resigned too.
- Far-Unacceptable \* If the editor plagiarized, then everyone at the publishing house would be shocked to hear that the critics resigned too.

## Results & DDM Analysis

Experiment 1: Model estimates of effects on DDM parameters for Sluicing

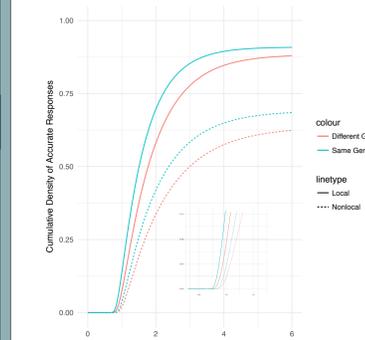


	$\tau$	$\alpha$	$\delta$
Distance	1.150	1.051	-0.266
Grammaticality	-0.700	0.521	3.361**
Interaction	-1.338	1.097	3.509***

DDM Analysis:

- No effect on  $\tau$  or  $\alpha$ , suggesting that memory access during the processing of sluicing constructions is not a serial search mechanism
- In line with Martin & McElree's (2011) findings

Experiment 2: Model estimates of effects on DDM parameters for Reflexives in PNPs

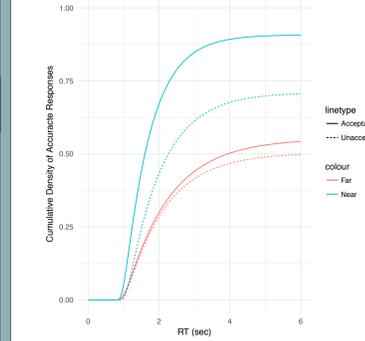


	$\tau$	$\alpha$	$\delta$
Distance	2.344*	-0.174	5.535***
Context	-0.387	-1.742	-1.572
Interaction	0.234	0.110	-0.378

DDM Analysis:

- DDM revealed a Distance effect on  $\tau$ , suggesting that memory access for a distance antecedent is delayed.
- This is consistent with a *serial search* model of memory retrieval.

Experiment 3: Model estimates of effects on DDM parameters for Anaphoric trigger too



	$\tau$	$\alpha$	$\delta$
Distance	1.691	0.863	-1.725
Context	2.100*	0.821	4.261***
Interaction	0.941	-0.051	-0.310

DDM Analysis:

- DDM revealed no effect of Distance on  $\tau$  or  $\alpha$ , suggesting no significant effects of Distance in terms of speed of retrieval.
- This is consistent with a *cue-based direct access* model of memory retrieval.

## Discussion

Advantage of using DDM:

- We have shown that modeling memory retrieval processes with DDM (1) provides convergent evidence to SAT, and (2) may have advantages in requiring fewer response time measurements to recover meaningful parameters.
- This gives us more opportunities to extend our understanding to new phenomena.
  - Our findings of a serial search process for Reflexives in PNPs (Exp 2) suggests that we need to take a more careful look at the memory process underlying this particular type of dependency.

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## QR Code

