Effects of foil processing, decision-making, and initial attention in the Maze task

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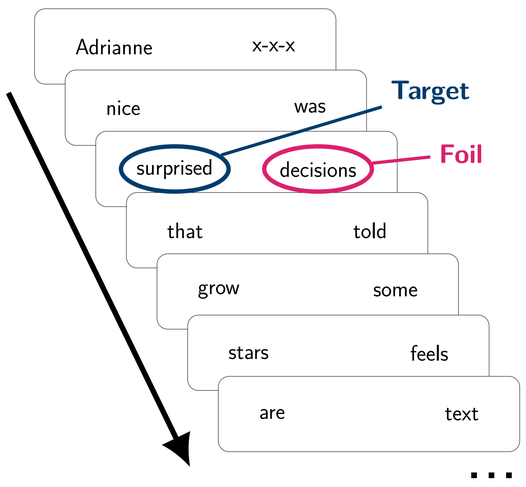
(PDF and materials)

Understanding the Maze task

- How do comprehenders approach Maze decisions?
- To what extent are measurements sensitive to Foil properties?

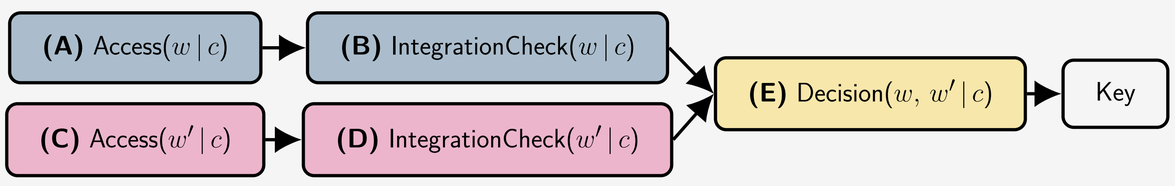


The Maze task [1, 5]

- Sequence of forced-choice decisions between suitable continuations (**Targets**) vs. inappropriate **Foils**.
- Foils often high-surprisal continuations from a language model [1].
- Choosing a Foil terminates the trial.
- Decision latencies for Target correlate with other reading measures for Target, without spill-over effects [1, 2, 5, 12].

A basic model of Maze latencies

Assume the latency of a correct Maze decision between Target w and Foil w' in context c is dependent on the duration of five processes:



- Target processing (A-B):
  - Only portion shared with typical reading processes
  - To use the Maze as a proxy for reading, experiments should aim to isolate differences here
- Foil processing (C-D):
  - Relative contributions are largely unknown, foils often controlled across conditions
- Decision-making (E):
  - By assumption, participants decide based on how easily each word integrates in c
  - Correct decisions would be slower when evidence is more balanced [7]
  - Initial evidence: Primed foils produce slower decisions [6]

Testing the model

Linking assumptions:

- Language model estimates of Surprisal($w \mid c$) are proportional to both difficulty of comprehending w [10] and the human plausibility of w as a continuation
- Access($w \mid c$), IntegrationCheck($w \mid c$) would be slower for higher Surprisal($w \mid c$)
- Decision(w, w') would be slower as Surprisal($w' \mid c$) − Surprisal($w \mid c$) approaches 0

Prediction: Effects of **Foil surp.** and **surp. diff.**, beyond effects of **Target surp.**

Methods

Data come from two large experiments in [4] using [1]'s method for high-surprisal Foils.

Surprisals for analysis were estimated (in bits) from GPT-2 [9] via `minicons` [8].

To make the strongest argument for the contribution of non-Target processes, we:

- fit initial, minimal regressions on odd trials only,
- used the minimal regression to extract residuals for even trials,
- then probed for the effect of other variables in regressions over those residuals.

Regressions were fit in `brms` [3] using weakly-constrained priors, centered linear predictors, and dummy-coded binary predictors.

❶
```
RT ~ Position * Trial + TargetSurp +
    (1 + Position * Trial + TargetSurp | Subject) + (1 | Item)
```

❷
```
Residual RT ~ (FoilSurp + SurpDiff) * TargetPosition * SideRepeat +
    (0 + (FoilSurp + SurpDiff) * TargetPosition * SideRepeat | Subject)
```

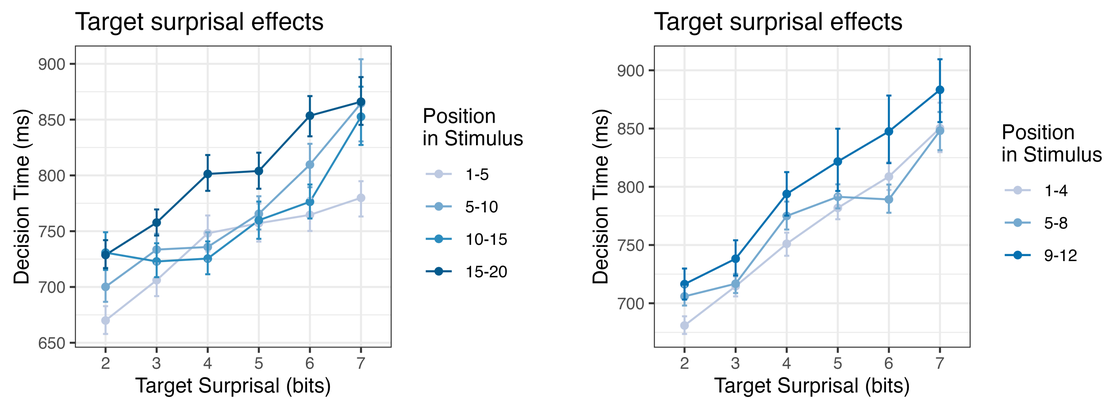
A more complex alternative (considering visual attention)

- Forced-choice ptcpts. sometimes make an absolute judgment on the first option [11]
- Mazers may pick a high-plausibility Target immediately if they attend it first
- Predicts: Foils matter less when the display drives Target-first reading, e.g.,
  - Target on L if participants default to read L-R, or
  - Target on side opposite previous Target if participants favor alternation

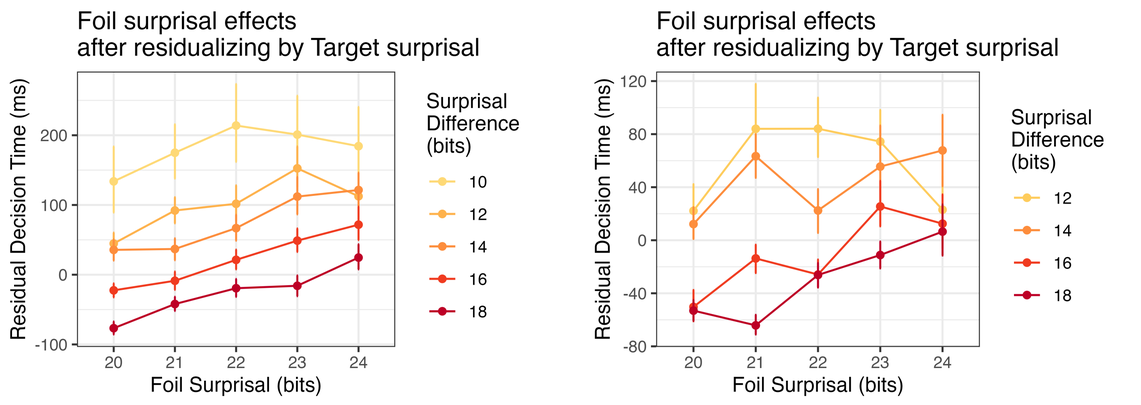
Results

Experiment A				Experiment B			
Ptcpts.	**Items**	**Words/Item**	**Correct RT Obs.**	**Ptcpts.**	**Items**	**Words/Item**	**Correct RT Obs.**
91	440	17–49 (med: 24)	180,309	143	336	5–26 (med: 21)	226,561

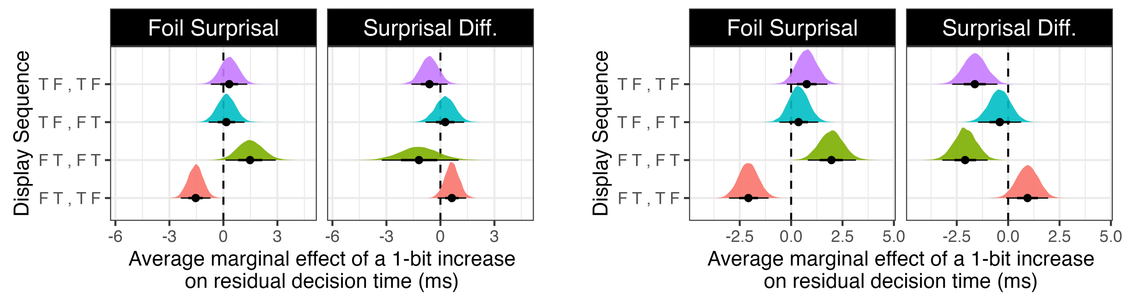
First analyses diagnosed credible **Target surprisal** effects ($\hat{\beta} = 10.08, 13.01$). Acceleration over the expt., but deceleration within the stimulus growing over the expt.



Second analyses diagnosed residual **(+) Foil surprisal and (−) difference effects**.



Foil effects were mediated by display, largest when Foil on L after Target on R (green) ($\hat{\beta}_{\text{Foil}} = 1.49, 1.96$; $\hat{\beta}_{\text{Diff}} = -1.18, -2.09$)



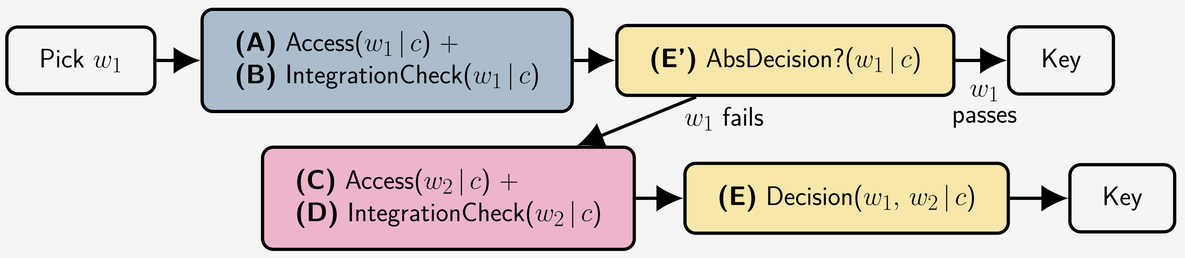
Discussion

Results validate effects of Foil processing and decision-making, but not on all trials.

Mazers appear to make absolute decisions [11] when they attend a good candidate first.

Display effects suggest Mazers distributed attention by L-R and/or alternation strategies.

A more complex model:



Consequences

Maze decision times for unexpected Targets may be inflated by:

- slow reading of appropriately unexpected Foils
- slow decision-making as Targets become harder to distinguish
- but less so in cases where displays allow Mazers to make absolute decisions

Accurate estimates of Target processing may require using Foil properties as covariates.

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