Error-driven Learning in DFT: A case study of structural priming



Zhenghao Herbert Zhou Yale University LSA Annual Meeting Jan 10, 2025

Part of the Symposium Talk Series:



Dynamic Field Theory for unifying discrete and continuous aspects of linguistic representations

Structural Priming

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- DO: Alice sent Bob a letter.
- PD: Alice sent a letter to Bob.

E.g. [Bock 1986, Chang 2012]

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Carl <u>gave</u> Danis a letter.

Carl <u>showed</u> Danis a letter.

Alice <u>gave</u> Bob a book.

TARGET

PRIME

E.g. [Pickering & Branigan 1998]

Inverse Frequency Effect: the less preferred (lower frequency) syntactic structure causes a stronger priming effect than the more preferred (higher frequency) structural alternative.

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Verb Bias: promise is biased towards DO design is biased towards PD

Inverse Frequency Effect: the less preferred (lower frequency) syntactic structure causes a stronger priming effect than the more preferred (higher frequency) structural alternative.



A professor designed a student a letter. <u>The secretary drew the card for the boss.</u>

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E.g. [Jaeger & Snider 2007]

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Prime Verb

Promised Buy Find Keep Design





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[E.g. Chang 2012]



- e: to-field coupling, Gaussian stimuli;
- e: to-node coupling, activation stimuli;
- -: excitatory coupling;
- - -: inhibitive coupling





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| Prime Verb | <u>Verb PD Bias</u> |
|------------|---------------------|
| Bring | 0.23 |
| Buy | 0.27 |
| Find | 0.41 |
| Draw | 0.52 |
| Design | 0.77 |

- Verb Bias Field [hosting both prediction and production]: probabilistic information of producing one structure over the other;
- **Contrastive Field** [hosting error signal computation]: a space for computing the difference between expected and actual information;
 - e: to-field coupling, Gaussian stimuli;
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Processing Steps in DFT

Incrementally perceiving or processing the prime sentence:

• (i) perceiving the prime verb only;



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- (iii) perceiving the structure of the sentence;



Error-signal computation:

• (iv) compare the expectation of the probabilities of DO and PD versus the actual perceived prime structure.



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> ***The magnitude of this difference is proportional to the final priming strength.



Producing the target sentence, as is affected by the prime:

• (v) generating an expected relative frequency between DO and PD according to the target verb's verb bias;



Producing the target sentence, as is affected by the prime:

- (v) generating an expected relative frequency between DO and PD according to the target verb's verb bias;
- (vi) shifting the relative frequency towards the direction of the prime structure;



Capturing the Inverse Frequency Effect





Capturing the Lexical Boost Effect



Small IFE: prime_{vb} = 95

Large IFE: prime_{vb} = 55







Simulation Results

| Prime Condition | Prime Verb Bias | Target Production Position | Priming Effect |
|---------------------|--------------------|-------------------------------|----------------|
| Extremely DO-biased | 55 (-20) | 81 | (+6) |
| Slightly DO-biased | 65 (-10) | 79 | (+4) |
| No bias | 75 (0) | 78 | (+3) |
| Slightly PD-biased | 85 (+10) | 77 | (+2) |
| Extremely PD-baised | 95 (+20) | 76 | (+1) |

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- **Future**: explicitly modeling the *"learning"* process by adding memory traces.

Thanks for Listening!



Appendix: Parameters

| Parameter | Value |
|------------|-----------|
| au | 20 |
| h | -5 |
| eta | 4 |
| q | 0.1 |
| range | [-10, 10] |
| resolution | 0.05 |
| c_{11} | 6 |
| c_{21} | -3 |

(a) Parameter values for a node.

| Parameter | Value |
|----------------|-------|
| c_{exc} | 20 |
| c_{inh} | 5 |
| c_{alob} | 0.9 |
| σ_{exc} | 5 |
| σ_{inh} | 15 |

(a) Parameters for the selection kernel (used for the **[Verb Bias]** field.

| Parameter | Value |
|-----------|-------|
| au | 20 |
| h | -5 |
| eta | 4 |
| q | 1 |
| size | 150 |

(b) Parameter values for a DNF.

| Parameter | Value |
|----------------|-------|
| c_{exc} | 17.5 |
| c_{inh} | 15 |
| c_{glob} | 0 |
| σ_{exc} | 5 |
| σ_{inh} | 10 |

(b) Parameters for the selection kernel (used for the **[Contrastive]** field.