Reconciling opposite neighborhood frequency effects in lexical decision: Evidence from a novel probabilistic model of visual word recognition

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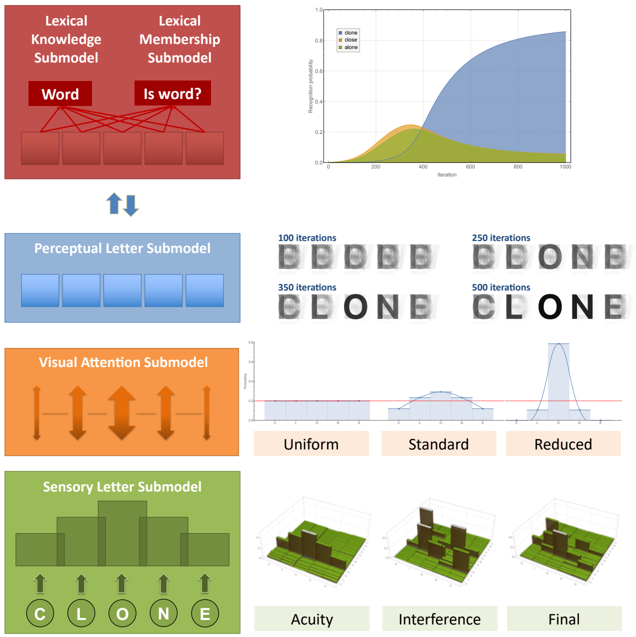
BRAID Bayesian Word Recognition with Attention Interference and Dynamics

The general structure of the BRAID model relies on three levels of processing as featured in most previous word recognition models.

1. The **letter sensory submodel** implements low-level visual mechanisms involved in letter identification and letter position coding. Feature extraction is parallel over the input string, an acuity gradient is implemented symmetrically around fixation and location is distributed over adjacent letter positions, implementing lateral interference between letters.
2. The **letter perceptual submodel** implements how information extracted from the sensory input accumulates gradually over time to create a percept, i.e. an internal representation of the input letter string.
3. The **lexical knowledge submodel** implements knowledge about the 40.481 English words of the British Lexicon Project. The probability to recognize a word is modulated by its frequency. This level is enriched by a module, called the **lexical membership submodel**, that implements a mechanism to decide whether or not the input letter-string is a known word. This submodel is critical to simulate lexical decision.

One major originality of BRAID is to assume the existence of a fourth level:

4. The **visual attentional submodel** implements an attentional filtering mechanism between the letter sensory submodel and the letter perceptual submodel. Transfer of information between these two submodels is modulated by the amount of attention allocated to each letter position.



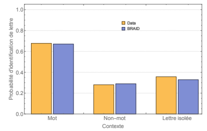
Behavioral Task Simulations: Probabilistic Questions

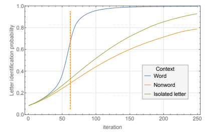
- **Letter identification with lexical knowledge**

$$Q'^{T}_{P_n} = P(P_n^T \mid s_{1:N}^{1:T}\ [\lambda_{L}{}_{1:N}^{1:T} = 1]\ [\lambda_{P}{}_{1:N}^{1:T} = 1]\ \mu_A^{1:T}\ \sigma_A^{1:T}\ g^{1:T})$$

Behavioral experiment: Johnston (1978, experiment 2) showed that letters are recognized significantly more often when they are presented in a word context rather than in isolation and when they are presented in isolation rather than in a non-word context.

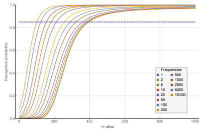
Simulation: BRAID reproduces behavioral results (e.g., after 62 iterations). The mean time course of letter identification shows that the word effect over isolated letter and non-word is a strong effect and that the advantage of isolated letters over a non-word context, significant from iteration 43, is durable.

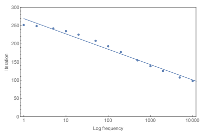




- **Word identification**

$$Q_W{}^T = P(W^T \mid s_{1:N}^{1:T}\ [\lambda_{L}{}_{1:N}^{1:T} = 1]\ [\lambda_{P}{}_{1:N}^{1:T} = 1]\ \mu_A^{1:T}\ \sigma_A^{1:T}\ g^{1:T})$$





Behavioral experiment: A standard finding is that high frequency words are processed faster than low frequency words and that identification time is proportional to log-frequency.

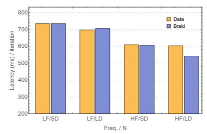
Simulation: To simulate this effect, we reproduce the simulation design first proposed by Norris (2006). The frequency of occurrence of each word rotates in a round-robin manner over all experimental conditions, so that only frequency affects identification time. The BRAID model reproduces the log-frequency effect.

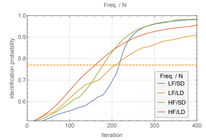
- **Lexical decision**

$$Q_D{}^T = P(D^T \mid s_{1:N}^{1:T}\ [\lambda_{D}{}_{1:N}^{1:T} = 1]\ [\lambda_{P}{}_{1:N}^{1:T} = 1]\ \mu_A^{1:T}\ \sigma_A^{1:T}\ g^{1:T})$$

Behavioral experiment: Andrews (1989, experiment 1 and 3) showed that high density neighborhood slows down letter identification significantly only for low frequency stimuli and has no effect on high frequency stimuli.

Simulation: BRAID reproduces behavioral results with a threshold of YES response at 0.77. More interestingly, it shows that having a high density neighborhood is an advantage at the beginning of the identification process but becomes a drawback when the decision is based on a high level of precision.





References
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Neighborhood Frequency Effects in Lexical Decision

Context

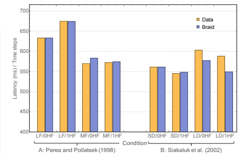
In the lexical decision task, participants have to indicate whether a printed stimulus is a known word (YES response) or not. Among the classical effects related to lexical decision, a poorly understood and highly controversial effect is the neighborhood frequency effect. Latency on YES responses in lexical decision is modulated by the existence of higher frequency orthographic neighbors, namely the existence of at least one word of higher frequency that differs from the target word by a single letter (e.g., *LIKE* is a higher frequency neighbor of the target word *BIKE*).

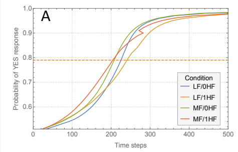
Contradictory behavioral experiments

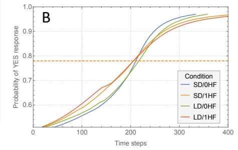
Perea & Pollatsek (1998) Siakaluk, Sears, & Lupker (2002)

Material and procedure:
The two experiments manipulate neighborhood frequency of English words, considering words with one (1HF) or zero (0HF) higher frequency neighbor. Experiment A used small density N and manipulated frequency whereas experiment B manipulated N for low frequency words. Ninety-two lowercase 5-to-6 letter words are used in Experiment A, 60 uppercase 4-to-5 letter words in Experiment B.

Results:
A significant inhibitory neighborhood frequency effect is reported in Experiment A but only for the low frequency words. In contrast, Experiment B reports a significant facilitatory neighborhood frequency effect for low-to-medium frequency words.







Simulation

Material and procedure:
The stimuli used in the simulations are the same as in the behavioral experiments. We first simulate lexical decision in BRAID for 1,000 iterations. Words that did not reach 0.97 identification probability after 1,000 iterations were removed, resulting in an error rate of 1% and 2.5% for the stimuli used in Simulation A and B, respectively.

Results:
The simulated data successfully capture both inhibitory and facilitatory effects of human data, with the same set of parameters. The dynamic curves reveal an inversion of the neighborhood frequency effect with time. The existence of a higher frequency neighbor is facilitatory at the beginning of processing but turns inhibitory over time. In simulation A, the pattern inversion occurs earlier for the low frequency words (iteration 188; threshold value=0.68) than for the medium frequency words (iteration 213; threshold value=0.81), and, in simulation B, earlier for the words that have a small vs. large neighborhood density (iteration 217 vs. 239; threshold value = 0.81 vs. 0.85).