Neural evidence for a new Bayesian model of adjective-noun modification
Sarah Solomon & Sharon Thompson-Schill
Department of Psychology, University of Pennsylvania

How are concepts combined?
We tested whether the uncertainty of a feature (BRIGHTNESS) in a concept (e.g., DIAMOND) affects how that feature is flexibly modulated in combined concepts (“dark diamond”). We used the adjectives “dark” and “light” to modulate the conceptual brightness of 45 noun concepts.

Feature uncertainty was captured using entropy and a predictive Bayesian model.

**PREDICTIVE MODELS**

Additive Model:
\[ B_{\text{COMBO}} = W_{\text{ADJ}} + B_{\text{NOUN}} \]

Bayesian Model: \( \text{optimized } P_{\text{ADJ}, \sigma} \)
\[ B_{\text{COMBO}} = \arg \max f \left( P_{\text{ADJ}} (\mu, \sigma) \cdot P_{\text{NOUN}} (\mu, \sigma) \right) \]

Feature uncertainty is captured in the variance of brightness distributions

**FEATURE MODULATION IN LIFG & LATL**

- Univariate LIFG responses to combined concepts are correlated with ground-truth effects and feature uncertainty.
- Univariate LATL responses are predicted by a Bayesian combinatorial model and multivariate responses are correlated with ground-truth effects.

**EXPRESS RATINGS OF CONCEPTUAL BRIGHTNESS**

Ground-truth effect: The extent to which a noun concept’s conceptual brightness can be modulated by “dark” and “light” adjectives.

Explicit modulation of conceptual brightness is predicted by:

**FEATURE UNCERTAINTY**

- Increased uncertainty in conceptual brightness results in increased modulation of conceptual brightness in “dark” and “light” combinations.
- A Bayesian model which incorporates feature uncertainty outperforms an additive combinatorial model.

**BAYESIAN MODEL**

- Univariate effect: The extent to which mean level of activity was influenced by the dark- and light- combinations relative to the noun
- Multivariate effect: The mean pattern dissimilarity between the noun and its combinations

**ACKNOWLEDGEMENTS:** This research was supported by Grant R01 DC015359 awarded to STS and an NSF Graduate Research Fellowship awarded to SHS.

Entropy
\[ P_{\text{DARK}} \text{ and } P_{\text{LIGHT}} \text{ were derived from a separate survey and transformed into Entropy using the standard equation from information theory:} \]

\[ \text{Entropy} = -P_{\text{DARK}} \log_2(P_{\text{DARK}}) + -P_{\text{LIGHT}} \log_2(P_{\text{LIGHT}}) \]