Efficient Compression in Locomotion Verbs Across Languages

Thomas A. Langlois[1,2], Roger Levy[1], Nidhi Seethapathi[1], Noga Zaslavsky[2]

[1]Massachusetts Institute of Technology (MIT) Brain and Cognitive Sciences Department (BCS) [2]New York University (NYU) Department of Psychology

Background

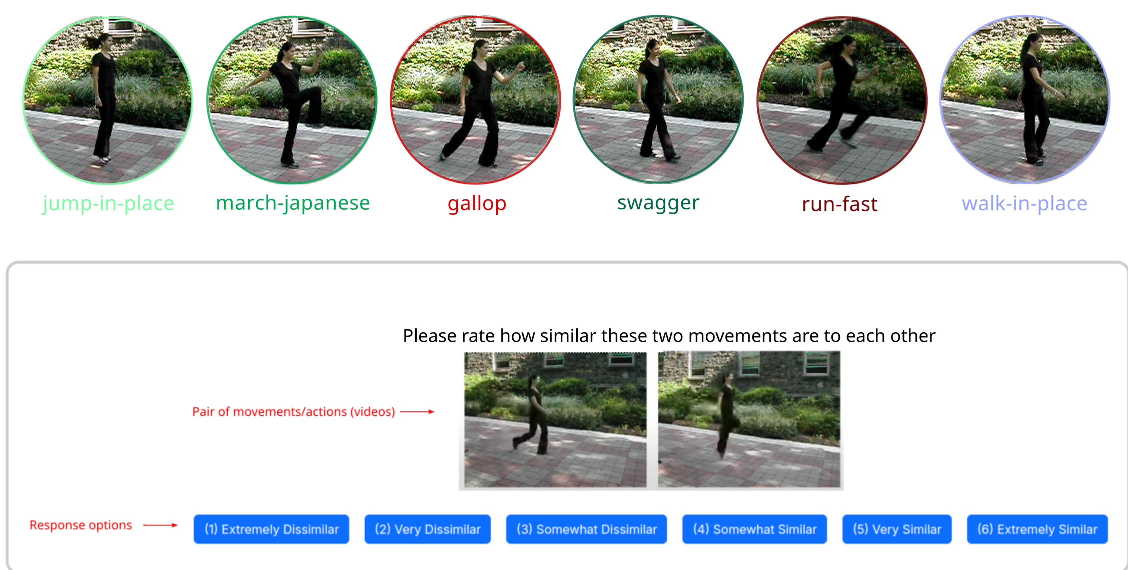
- Languages shaped by a drive for efficient communication[1]
- Locomotion & verbs not examined in terms of efficiency
- Locomotion & verbs correspond to time-varying stimuli

Question:
Do locomotion verbs show a pressure for efficiency?

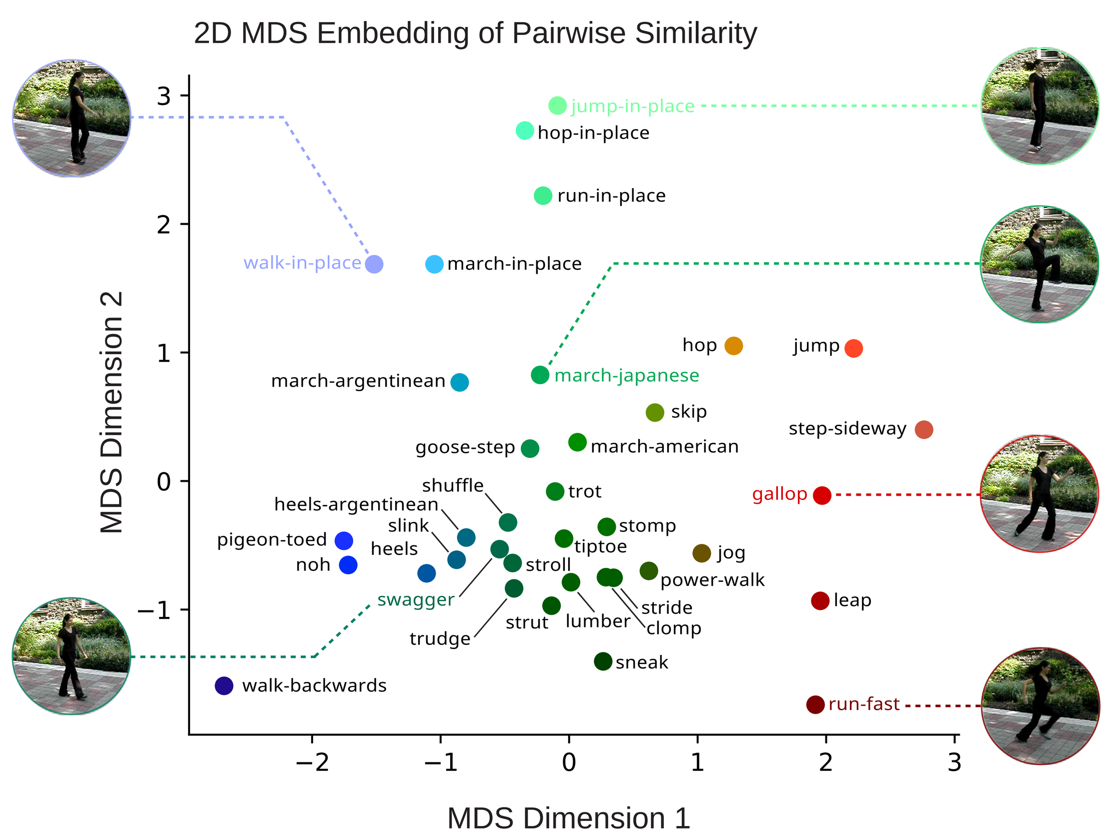
Similarity data

- Estimating a psychological locomotion similarity space

Motion Similarity Task



Locomotion Space U (MDS)



Naming data

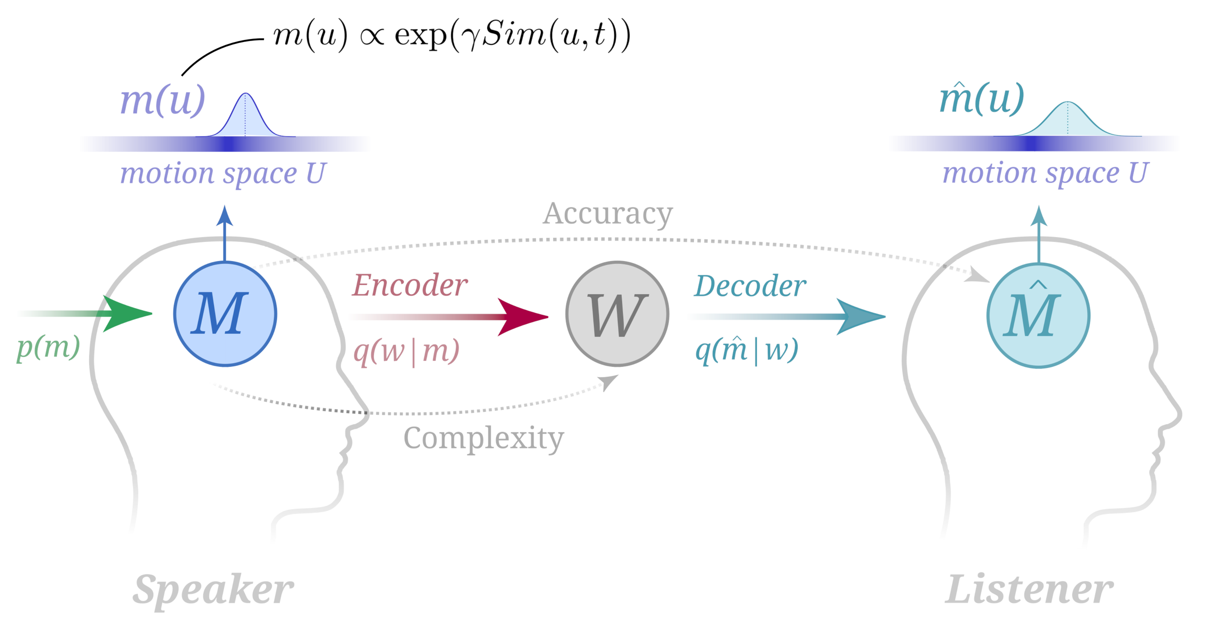
- Verb meanings evaluated using existing verb annotations[2]
- English, Spanish, Dutch, Japanese verbs (Malt et al. 2008)

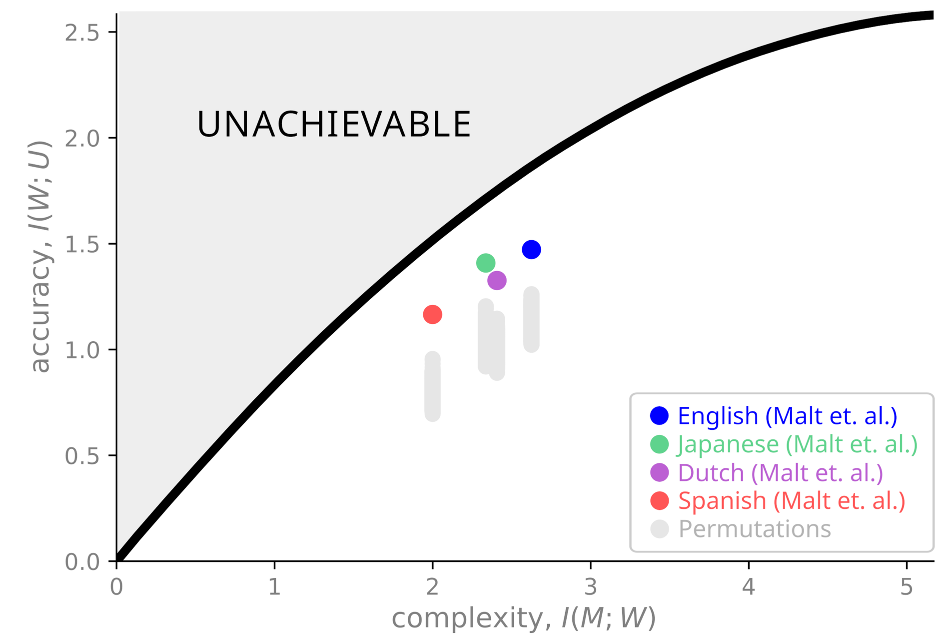
[1]Zaslavsky, N., Kemp, C., Regier, T., & Tishby, N. (2018). Efficient compression in color naming and its evolution. *Proceedings of the National Academy of Sciences*, 115(31), 7937–7942

[2]Malt, B. C., Gennari, S., Imai, M., Ameel, E., Tsuda, N., & Majid, A. (2008). Talking about walking: Biomechanics and the language of locomotion. Psychological science, 19(3), 232–240.

Communication model & Efficiency analysis

- Verb meanings across multiple languages show a pressure for efficiency





Theoretical Model (IB)

Speaker conveys locomotion $m(u)$ via naming policy $q(w|m)$

Listener infers $\hat{m}(u)$ via decoder $q(\hat{m}|w)$ using Bayes' rule

Theoretical Encoder

Complexity

$$I_q(M;W) = \sum_m \sum_w q(w|m)p(m) \log\left[\frac{q(w|m)}{q(w)}\right]$$

$$\mathcal{F}_\beta\left[q(w|m)\right] = I_q(M;W) - \beta I_q(W;U)$$

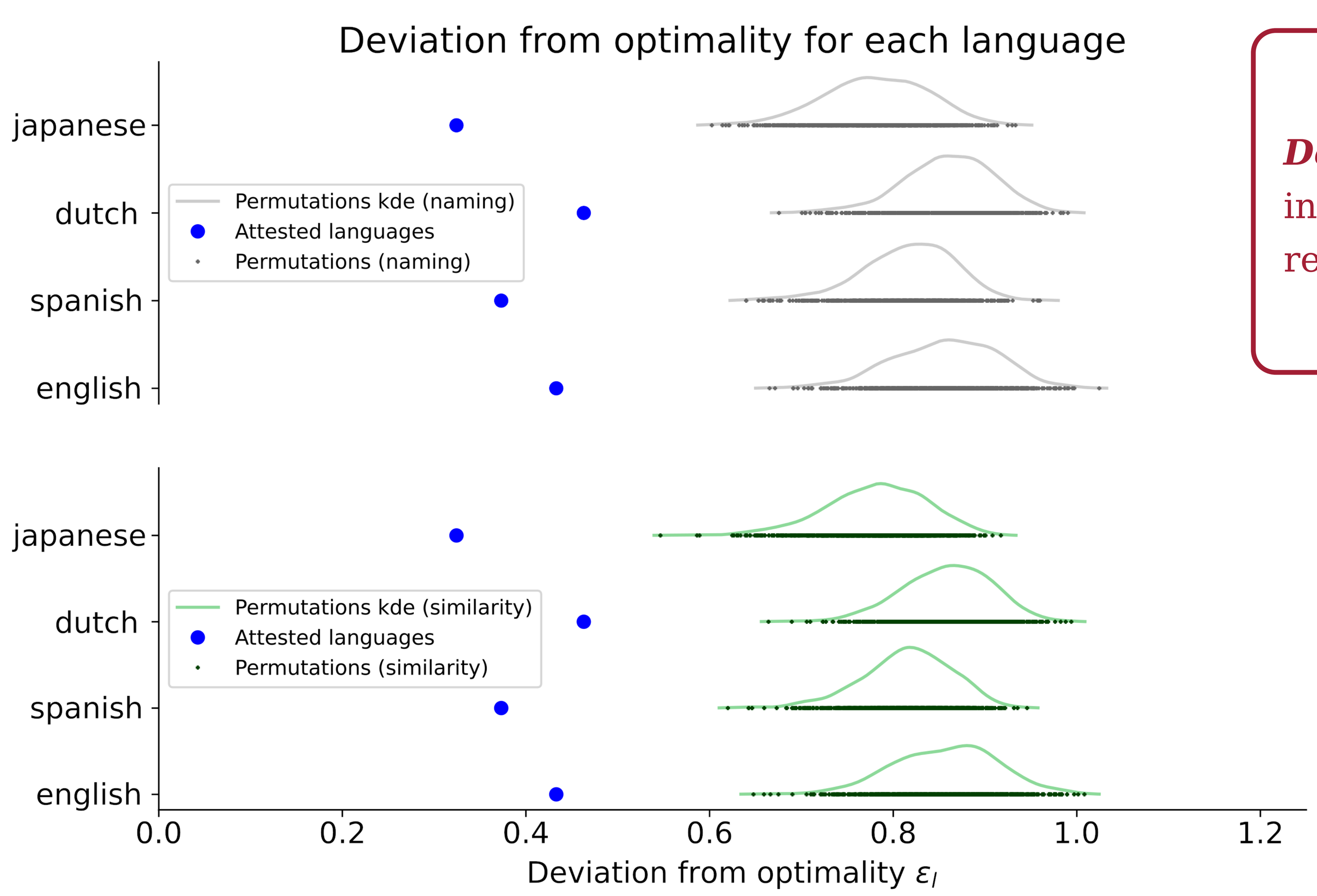
Tradeoff parameter

Accuracy (inversely ~ to distortion)

$$\mathbb{E}_q\left[D[M||\hat{M}]\right] = \mathbb{E}_q\left[\sum_u m(u) \log\frac{m(u)}{\hat{m}(u)}\right]$$

Quantitative analyses

- Permutations of naming data or similarity yield greater deviations from optimality



Quantitative Metric

Deviation from Optimality: measures deviation in IB Objective value between value obtained with real language vs. optimal encoder

Attested System (human data) Optimal IB system

$$\epsilon_l = \frac{1}{\beta_l}\left(\mathcal{F}_{\beta_l}\left[p_l(w|m)\right] - \mathcal{F}^*_{\beta_l}\right)$$

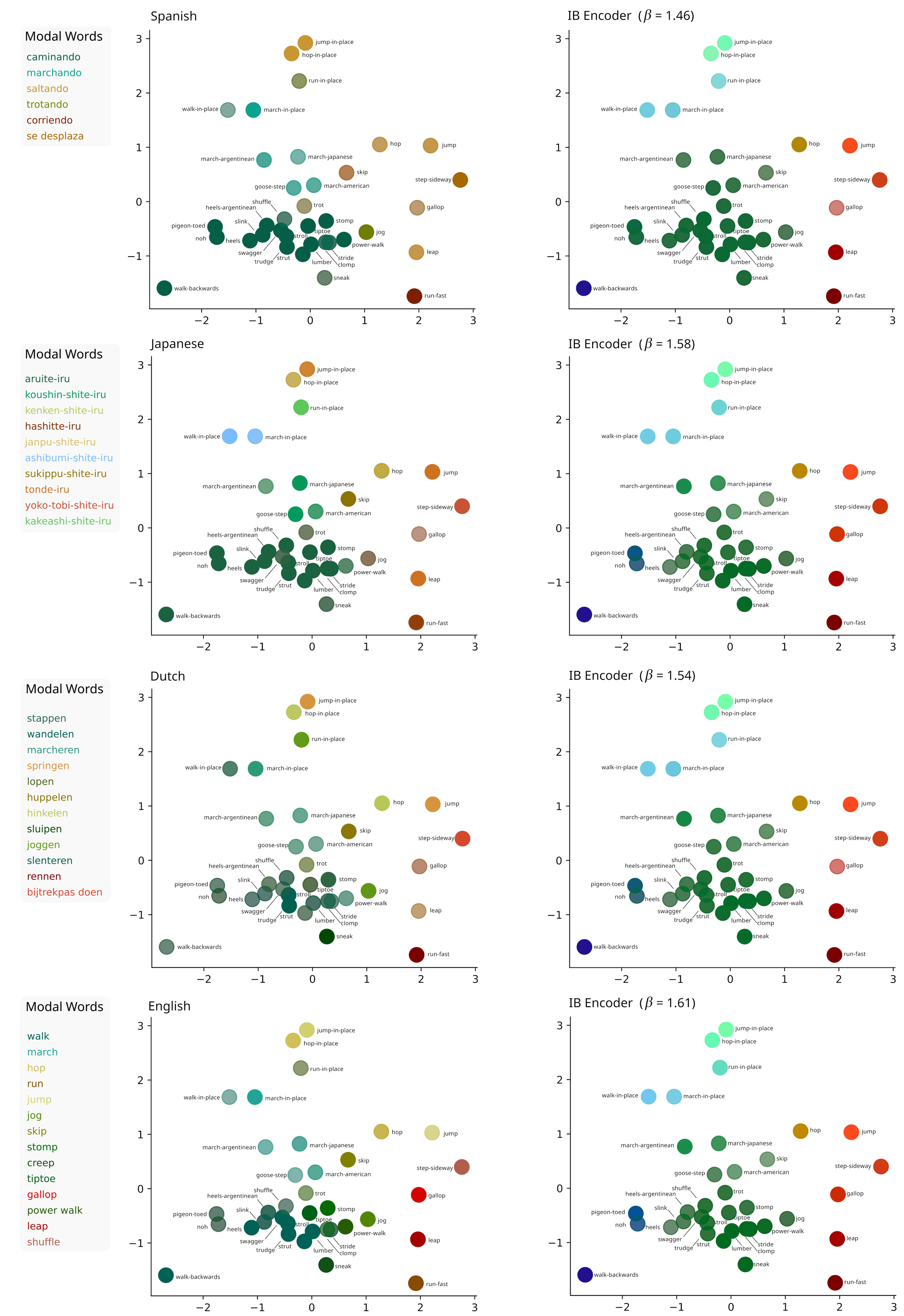
Deviation from optimality

- Naming data permutation analysis indicates that **optimal IB encoders align with attested systems**
- Similarity permutation analysis shows that meaning space reflects **important semantic structure**
- Caveat: gaps remain between optimal IB systems and human languages

Attested & theoretical systems

- Attested systems $p(w|m)$ align with optimal IB encoders $q(w|m)$

Malt et al., (2008) verb meaning annotations (modal words) and closest IB systems



Conclusions

Our results suggest that verb meanings align with theoretical IB predictions and human languages efficiently compress verb meanings

- Future work will expand the stimulus coverage in U and languages l
- Further work is needed to identify the best meaning space and $p(m)$