

## Comparing the Learnability of Different Modal Systems in an Artificial Language

Across languages, modal words (like English *must* or *might*) vary along two dimensions: force (necessity vs. possibility) and flavor (the type of necessity/possibility expressed, e.g., deontic vs epistemic)<sup>[1,2]</sup>. There is significant cross-linguistic variation in how these two axes are lexicalized<sup>[3,4]</sup>. Some languages distinguish mainly force (e.g., English<sup>[5]</sup>), others mainly flavor (e.g., St’át’imcets<sup>[6]</sup>), some encode both (e.g., Javanese Paciran<sup>[7]</sup>), and others neither (e.g., Washo<sup>[8]</sup>). However, this variation is constrained: no known language allows a single form to express two combinations of flavor and force (e.g., deontic possibility and epistemic necessity) without also expressing the other two. We explore the hypothesis that the absence of this type of system results from a cognitive bias against homophony between semantically unrelated meanings (see [9] for a similar idea in the person and number domain). Modal systems that use the same form for meanings that share neither force nor flavor are thus expected to be less common because cognitively less natural for speakers. Here, we aim to test this idea by operationalizing ‘naturalness’ as ‘ease of learning’. Specifically, modal systems based on force or flavor should be easier to learn than their alternatives, which would in turn explain the typology. We tested this by conducting an experiment where English participants learned an artificial language featuring one of three modal systems: (i) a force system distinguishing necessity vs. possibility (as in English); (ii) a flavor system distinguishing epistemic vs. deontic (as in St’át’imcets); and (iii) a mixed system combining flavor and force (one modal for epistemic necessity and deontic possibility, another for epistemic possibility and deontic necessity, Fig. 1). We expected the mixed system to be more difficult to learn than the other two.

	(a) Force		(b) Flavour		(c) Mixed	
	Poss	Nec	Poss	Nec	Poss	Nec
Epi	sig	dup	sig	dup	sig	dup
Deo	sig	dup	sig	dup	dup	sig

Fig 1. Experimental conditions.

**Method** 180 English-speakers were recruited on Prolific. They were told that they would learn the meaning of two words in a novel language called Tak Pisan, which resembles English. The two novel words used as modals were randomly selected amongst *gleeb*, *sig*, *dup*, and *frimp*, and they had the syntactic distribution of English auxiliaries. The remaining words were borrowed from Tok Pisin (an English-based creole). Participants were presented a picture and a sentence with a blank describing the picture (e.g. “Mina \_\_\_ haid rabbit in hat blu.”), and asked to complete the sentence with one of the two novel words. They were given feedback on their answers. Pictures could depict one of four meanings: epistemic possibility, deontic possibility, epistemic necessity, and deontic necessity, Fig. 2). There were 8 different items (sentence-picture combination) for each flavor, i.e. 16 different pictures overall. Participants were randomly assigned to one of the three conditions (60 per condition): force,

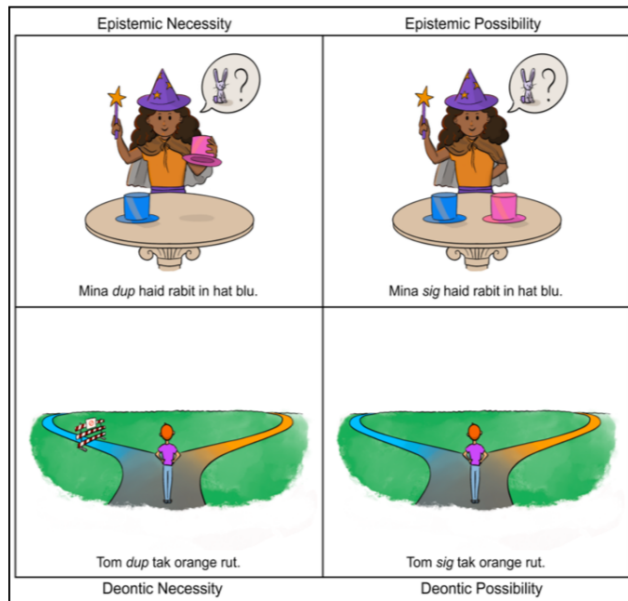
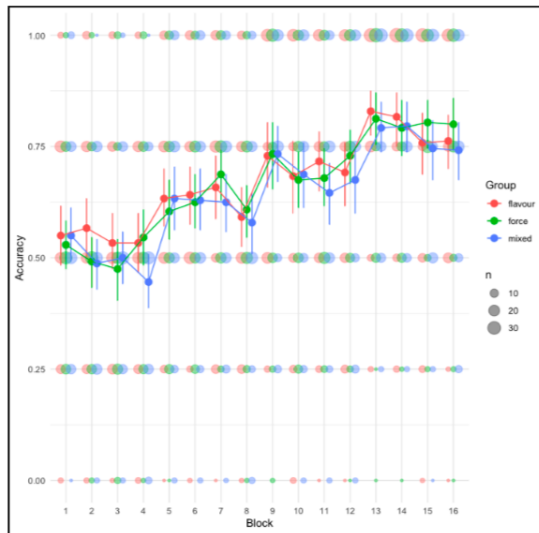


Fig 2. Illustration of situations for each force x flavour combination together with sentences in Tak Pisan.

flavor and mixed, which differ on the specific form-to-meaning mapping (Fig. 1). The experiment consisted of 16 blocks of 4 items, one for each force–flavor combination.

**Results and Discussion** Fig. 3a shows the proportion of correct responses across blocks per condition. To evaluate whether there was a difference in learning as a function of the group, we fit a Bayesian logistic regression predicting accuracy as a function of condition, block, and their

interaction. The model revealed moderate evidence that participants in the mixed group performed worse than those in the flavor group ( $\beta=-0.17$ ,  $CI=[-0.4, 0.05]$ ,  $P<0=0.89$ ). In contrast, the force group did not differ from the flavor group ( $\beta=-0.05$ ,  $CI=[-0.28, 0.18]$ ,  $P<0=0.37$ ). There was no evidence for differences in learning trajectories between conditions. These results suggest that a mixed modal system is more difficult to learn than force and flavor-based systems. This supports the hypothesis that learners prefer systems where



**Fig 3a.** Mean accuracy by block per condition. Error bars indicate bootstrapped confidence intervals. Small dots represent participants' performance.

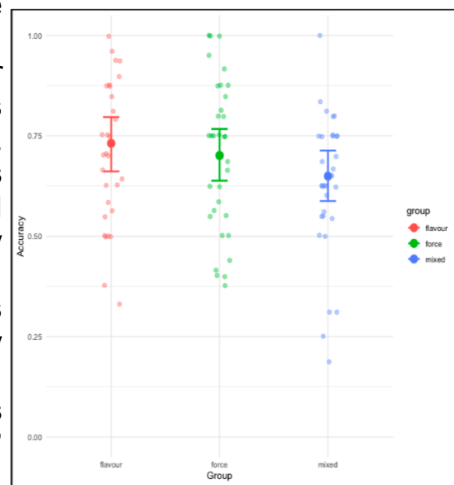
Specifically, the former may have relied on a force- or flavor-based rule (which could be easier to retain), whereas the latter might have learned on a case-by-case basis.

**Summary** We investigated the existence of a cognitive bias in favor of semantically-based homophony in the modal domain. We found that modal systems featuring homophony that is not semantically motivated were harder to learn and memorize than those in which the homophony is semantically motivated. This evidence, however, was only moderate, as all systems tested turned out to be learnable. Future work will employ other paradigms to magnify this effect.

**References** [1] Kratzer, A. (1977) What 'must' and 'can' must and can mean. *Linguistics and Philosophy*. [2] Hacquard, V. (2010) On the event relativity of modal auxiliaries. *Natural Language Semantics*. [3] Nauze, F. D. (2008) *Modality in typological perspective*. Universiteit van Amsterdam. [4] Steinert-Threlkeld, S., Nathaniel, I. & Qingxia, G. (2023). A semantic universal for modality. *Semantics and Pragmatics*. [5] Van Der Auwera, J. & Plungian V. (1998) Modality's semantic map. *Linguistic Typology* [6] Rullmann, H, Matthewson, L. & Davis, H (2008). Modals as distributive indefinites. *Natural Language Semantics*. [7] Vander Klok, J. (2012). *Tense, aspect, and modal markers in Paciran Javanese*. McGill University. [8] Bochnak, M. R. (2015a). Underspecified modality in Washo. *Proceedings of the Workshop on Structure and Constituency in Languages of the Americas*. Bochnak, M. R. (2015b). Variable force modality in Washo. *North-East Linguistic Society*. [9] Saldana, C, Borja H, Bicke, B. (2022) More or Less Unnatural: Semantic Similarity Shapes the Learnability and Cross-Linguistic Distribution of Unnatural Syncretism in Morphological Paradigms. *Open Mind*.

homophony is based on semantic similarity. However, this conclusion is supported only by moderate evidence (e.g.,  $P>0 = 0.89$ ). To assess whether participants in different groups differed in their learning strategy (i.e., whether they memorized items on a case-by-case basis or inferred a general rule based on semantic similarity), we ran a follow-up study a few days later. In this follow-up, participants who had successfully learned the modals in the original experiment ( $n \approx 30$  per group) completed six additional blocks. Fig. 3b shows the overall proportion of correct responses for the participants who completed the study. Results show that, when recalling what they had learned three days earlier, participants in the mixed group performed worse than those in the flavor and force groups (estimate =

$-0.42$ , 90% CI  $[-0.83, 0.01]$ ,  $P>0 = 0.95$ ). This suggests that the initial learning strategy of participants in the force and flavor groups differed from that in the mixed group.



**Fig 3b.** Overall proportion of correct responses 3 days later.