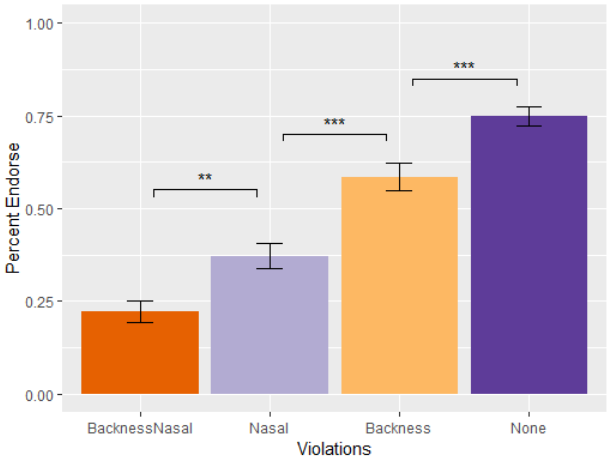
Gang effects are the norm: evidence from artificial grammar learning studies

Introduction: An ongoing debate in phonology concerns whether the grammar is better characterized by frameworks which use strictly-ranked constraints (Optimality Theory (OT) (Prince & Smolensky 1993/2004) and related theories) or weighted constraints (Harmonic Grammar (HG) (Legendre et al. 1990) and related theories). In this paper, I examine a theoretical point where OT and HG make different empirical predictions: *cumulative constraint interactions* (Jaeger & Rosenbach 2006), or, more commonly, "gang effects". OT doesn't allow gang effects by default, while HG permits ganging automatically. Using a series of artificial grammar learning experiments, I show that learners exhibit spontaneously emerging ganging behavior when presented with ambiguous learning data, providing experimental data supporting weighted-constraint theories of phonological grammar.

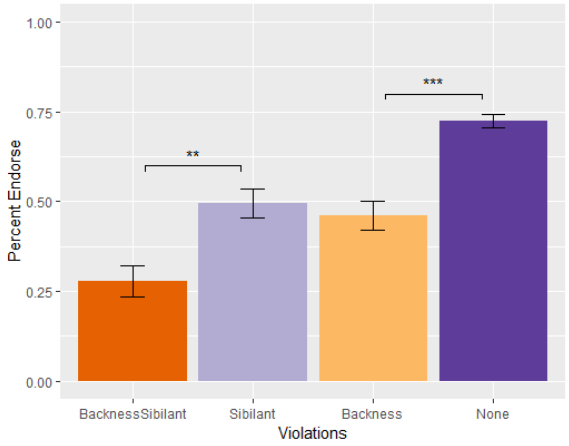
Gang effects are contexts where multiple simultaneous constraint violations result in a different outcome than each of those violations independently. For example, in Kaska (Athabaskan), /ɛ/ → [a] when preceding coda [h] with a following nucleus [a] (data from Lionnet 2016), but not when these conditions are met individually. The same effect obtains in static phonotactic well-formedness judgments: multiple marked elements together determine the well-formedness of the word as a whole: [plag] > {[tlag], [plavb]} > [tlavb] ('>' = '*more acceptable than*') (Pizzo 2015).

Research plan: In each of four experiments, participants were taught a language conforming to two static phonotactic constraints, then asked to make well-formedness judgements about novel words violating neither, one, or both of the constraints. All experiments gathered both *lexical decision* data ("Could this word belong to your language?") and *continuous ratings data* ("How good does this word sound in your language on a 0 (bad) – 100 (good) scale?") to capture both threshold-based and gradient measures of acceptability. Only lexical decision data are displayed here for the sake of space; ratings data are qualitatively and quantitatively similar. All comparisons indicated graphically via '*''s are significant.

Experiment 1 assessed whether learners inferred a gang effect between two constraints faced with only positive evidence. Participants (n=33) learned a language where all 32 CVCV training words obeyed nasal consonant harmony (consonants from {p, t} or {m, n}) and vowel harmony (vowels from {i, e} or {u, o}). Subjects were trained with similar-sounding blocks of words grouped together: ex., first words with front vowels and nasals, then back vowels with nasals, then front vowels with voiceless stops, etc. After passing a verification stage to ensure they had learned each phonotactic independently, subjects completed a lexical decision task on 64 novel items, 32 of which violated neither phonotactic, 8 of which violated only the vowel harmony phonotactic, 8 of which violated only the consonant harmony phonotactic, and 8 of which violated both phonotactics. Results from the lexical decision task (shown above) indicated that participants endorsed nasal harmony-violating and backness harmony-violating forms with significantly greater likelihood than doubly-violating forms – that is, they exhibited a gang effect in acceptability between phonotactic constraint violations.



Experiment 2 sought to verify the generality of the findings of Experiment 1 by replicating the finding using a different combination of phonotactic constraints. Participants (n=34) completed an experiment identical to Experiment 1, except that the nasal consonant harmony constraint was replaced by a sibilant harmony constraint (consonants from {s, z} or {ʃ, ʒ}) to test the generality of the gang effect observed in Experiment 1. Results (right) indicate that participants endorsed words violating either sibilant or backness harmony with significantly greater likelihood than doubly-violating forms.



Experiment 3 sought to investigate the robustness of the effects found in experiments 1 and 2 under training conditions more similar to natural language acquisition. Participants (n=66) completed an experiment identical to Experiment 1, except that training took place using a passive exposure learning paradigm: participants were instructed to listen to a speech stream contained 20 repetitions of each of the 32 training words in a random order. The training paradigm was altered to more closely mimic natural language acquisition. Statistical analysis indicated that participants endorsed nasal harmony-violating and backness harmony-violating forms with significantly greater likelihood than doubly-violating forms.

Experiment 4 asked whether participants inferred both *counting cumulativity* (two violations of the same constraint are worse than one, all else equal) and *ganging cumulativity* (two violations of different constraints are worse than each individually, all else equal). Participant (n=52) had a training phase identical to Experiment 1, and in generalization tested participants on a selection of CVCVCVCV words which crossed 0, 1, or 2 violations of one harmony constraint with 0, 1, or 2 violations of the other. Statistical analysis revealed that participants inferred counting cumulativity and ganging cumulativity robustly for both phonotactic constraints.

Discussion: As OT and HG make divergent predictions about gang effects, these experimental findings bear on debates about the suitability of strict-ranking vs. weighted-constraint phonological frameworks as models of speaker behavior. Across experiments, tasks, and patterns, participants judge forms violating both phonotactics worse than those violating only one phonotactic, constituting strong evidence that human beings naturally respond in a HG-like way to ambiguous data. Learners also robustly infer both *gang effects* and *count effects*, as predicted by weighted-constraint theories. Further ongoing work in this vein applies the same approach to phonological alternations, and finds evidence that learners also infer ganging.

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