The Transmission of Vowel Harmony and Vowel Disharmony: An Iterated Learning Study

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1 Introduction

During phonological acquisition, learners may better acquire certain patterns over others due to cognitive predispositions, i.e., inductive biases (Moreton, 2008). Inductive biases are believed to affect phonological acquisition both in natural language and in laboratory settings (Finley, 2021; Martin & Peperkamp, 2020; Moreton & Pater, 2012a; Wilson, 2006). Among inductive biases, structural bias and substantive bias have been main research foci in the study of phonological learning. Structural bias refers to the preference towards simpler patterns, which involve fewer numbers of features or more straightforward relations among them. For instance, the alternation between [f] and [v] is learned better than the mapping between [s] and [b], as the rule for the former pair involves only one feature, voicing, while the other pair requires changes in both voicing and place of articulation (Moreton & Pater, 2012a). Substantive bias refers to a tendency that learners may more readily acquire phonetically motivated patterns than those without a clear phonetic motivation (Moreton & Pater, 2012a). Studies constantly provided evidence for the structural bias (Finley & Badecker, 2009; Kuo, 2009; Warker et al., 2008), whereas the effect of the substantive bias has not always been detected (bias found: Glewwe, 2019; Kimper, 2016; Martin & White, 2021; bias not found: Lysvik, 2020, Experiment 1; Pycha et al., 2003; Wilson, 2006, Experiment 1). For instance, Myers and Padgett (2014) measured the participant's ability to generalize phonological rules of a natural pattern, word-final devoicing, and its unnatural counterpart, word-final voicing. In their experiment, participants who learned devoicing pattern showed a higher accuracy than those learning voicing pattern; they were also more capable of applying the devoicing rule to novel places such as the utterance medial position. Contrary to this, Glewwe et al. (2019) found better learning of the theoretically dispreferred voicing process, against the substantive bias hypothesis.

The asymmetry of vowel harmony and disharmony, the case study of the current study, has also been actively examined to test the role of substantive bias in phonological learning. The complexity levels of harmony rule and its counterpart disharmony rule are similar (Martin & Peperkamp, 2020; Martin & White, 2021). But, vowel harmony is attested in many languages such as Turkish and Hungarian, while disharmony is considerably uncommon, only seen in two languages out of 100 in WALS (Gordon, 2016). In terms of phonetic substance, harmony is perceptually better motivated than vowel disharmony, as it lengthens the exposure to a vowel feature, e.g., roundness, allowing higher accuracy in perception of that specific feature (Kaun, 2004). Accordingly, if the substantive bias affects learning, the two patterns are expected to show fundamentally different learnability in lab-based experiments. With the assumption that a successful acquisition of a general rule should allow extrapolation with limited training, one study (Martin & White, 2021) taught participants to create plural or diminutive forms with a single suffix but further tested them with plural-diminutive forms with two suffixes. The results showed significant difference between the learning outcomes of natural and unnatural patterns: learners in the harmonic condition inferred a general harmony pattern and extended it to address new suffixal forms, while the group of disharmony condition failed to apply the disharmonic rule in the double-suffix test. Along with the evidence from adults' phonological learning, the effect of substantive bias was also found to play a role in children's learning of phonology (Do & Mooney, 2021): Children trained on languages with dominant harmonic or disharmonic patterns both preferred to reproduce languages with more harmonic patterns. In the disharmony condition, harmony became a dominant pattern in their production, reversing the input frequencies. On the other hand, Pycha et al. (2003) discovered that listeners did not find natural patterns more cognitively accessible than unnatural ones. Skoruppa and Peperkamp (2011) found no bias effect

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either in perceptual learning: participants did equally well in acquiring novel accents with harmony or disharmony.

The common ground of the aforementioned experiments, no matter whether they support the substantive bias or not, is that they depict the learning outcomes of one or multiple populations, which could be seen as synchronic data in a short period. The typology, however, inevitably reflects diachronic language changes as well. What the current study aims to explore is the role of a substantive bias during the course of language transmission. Research on general language development proves the necessity and feasibility to explore language transmission in a laboratory setting. First, it is possible to simulate the emergence of language structures through laboratory work. For example, Verhoef et al. (2016) created acoustic signals with a slide whistle and included only 12 signals in the training material, and participants still tended to re-use the blocking units more frequently and systematically. Generally, along the transmission, entropy decreased and learnability increased. Second, certain language phenomena, which may not occur at the beginning, take time to develop. Some very young sign languages such as Nicaraguan Sign Language (NSL) --which is under 50 years old-- demonstrate gradual changes in signers' spatial modulations. In laboratory work using an artificial language transmission (Motamedi et al., 2021), researchers found descending iconicity of gestures and more conventional spatial contrastive modulations over generations matching typological data, suggesting importance to involve transmission to account for the typological development. Also, with the discovery of the substantive bias effect in learning, it is worth testing how the bias effect is passed down and reshapes language towards natural patterns throughout the course of transmission. The speculation is that, during language change, substantive bias could cause the more natural patterns to accumulate and increase their distribution in a language system (Moreton & Pater, 2012a). Some historical data is germane to this hypothesis. For example, unstressed vowel reduction is a natural phenomenon (Lehiste, 1970), and through diachronic changes in Galeata Romagnolo, unstressed word-final vowels (except /a/) were eliminated at a certain stage (Baroni, 2001). Furthermore, although the substantive bias is not found in some acquisition studies, it is possible that the bias could surface through transmission. Previous experiments involving transmission proved that populations could perform distinctively from individuals (Reali & Griffiths, 2009; Smith & Wonnacott, 2010). Reali and Griffiths revealed the strong effect of weak biases at a community level. Their Experiment 2 contained repeated episodes, where participants learned the associations between a single object and two words. The frequencies of words varied among different conditions and over generations. Compared with Experiment 1 with only one generation, Experiment 2 presented a more consistent transformation from probability matching (copying the frequency in the input) to regularization (linking one object with one word).

A way to explore language transmission in a laboratory setting is by using the iterated learning paradigm. As Kirby et al. (2008) defined, one or multiple participants in an iterative chain represent one generation, who are asked to learn and replicate the target behavior from the predecessor (see Figure 1). The output of a generation will be used as the input for the next generation, and the learning procedure stays the same for every iteration. The artificial language learning paradigm can provide the target behavior and the repeated procedure for iterated learning experiments (Hudson Kam & Newport, 2005; S. Kirby et al., 2008). For example, Kirby and colleagues trained participants with random pairs of pictures and written syllables. As the picture-string pairs were passed down, the mapping between the visual stimuli and their written labels became more transmissible and structured.

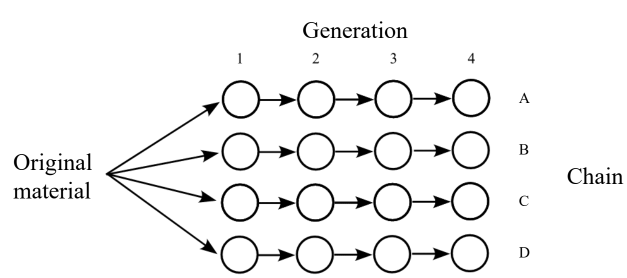


Figure 1: Transmission chains in iterated learning paradigm (Mesoudi, 2007, p. 39).

Explicitly focusing on phonological asymmetries, Evjen (2021) fed artificial languages with final devoicing (natural pattern) and final voicing (less natural pattern) to the diffusion chains. For the beginning generation, the training material involved no variability between the two patterns, and the test result became the input of the successive generation. Participants learned the two patterns equally well, showing no preference of the more natural pattern, final devoicing. No substantive bias effect through transmission was attributed to its competition against other biases and the experiment setting. While the phonetic motivation might increase the learnability of final devoicing, the paradigm uniformity bias disfavors consonant alternations (Do, 2018; Lysvik, 2020), resulting in a language with a few voicing or devoicing phenomena in both conditions. In addition, the author suggested that with longer chains with more iterations, the experiment could provide stronger evidence regarding the influence of the substantive bias. Another transmission study on inductive biases aimed at explaining the mismatch between typological patterns and experimental learning outcomes. Many languages tend to avoid repetition of consonants with some identical features (Gordon, 2016), but both consonant and vowel repetitions are preferred by learners in experiment context (Ota & Skarabela, 2016, 2018). In a followed-up experiment, Ota et al. (2021) introduced interaction into the iterated learning paradigm. The results showed the increase of both forms of repetitions and more use of the vowel repetition. The larger likelihood of adding vowel repetitions was attributed to learners' inherent preference for similar adjacent vowels. To the best of our knowledge, no other studies compared the transmission of phonetically grounded vs. ungrounded patterns.

The current study aims to investigate whether and how the substantive bias acts on phonological transmission and leads to an imbalanced distribution of natural and unnatural patterns, corresponding to the typological asymmetry. We hypothesize that the substantive bias will lead to better transmission of the phonetically natural pattern, i.e., vowel harmony, resulting in its predominance in the language. If the hypothesis holds true, vowel harmonic patterns will be maintained or increase in the language over multiple iterations, whereas the proportion of less natural disharmonic patterns will decrease. In contrast, if the bias has no effect on language transmission, both patterns will show a similar changing tendency.

2 Method

2.1 *Participants* The experiment recruited 326 participants at the authors' institute through bulk email invitations, and 163 participants finished the experiment. All of them were self-reported adult Hong Kong Cantonese native speakers. Many of them can speak Mandarin and/or English among other languages, but none of them reported that they have knowledge on any languages with vowel harmony. 35 participants failed the focus check questions (see section 2.3), and thus they were excluded from the transmission chain immediately, yielding 128 valid participants into the data analysis. 66% of the participants were females and 33% were males, with one participant preferring not to declare. The majority (78%) were aged between 18 and 30, and 22% were beyond 30 years old.

2.2 *Stimuli* The experiment contained two conditions, the natural condition where participants learnt vowel harmony patterns and the unnatural condition exhibiting vowel disharmony patterns. For each language, the stimuli consisted of 24 $C_1V_1C_2V_2$ items. Participants were exposed to these items during training and testing (see section 2.3 for details). The stimuli were equally divided into three groups, A, B, and C. The stimuli design for each of the three groups was the same. In each group, stem consonants were chosen from {p, p^h, t, t^h, k, k^h, m, n}, all of which are attested phonemes in Hong Kong Cantonese. Every consonant occurred twice in each position of C_1 and C_2. The positional frequencies of phonemes were balanced so that no specific consonant appeared especially frequently in any specific pre-vocalic contexts. Stem vowels included back rounded vowels {ɔ, u} and front unrounded vowels {i, ɛ}. The vowels within each stem exhibited harmony or disharmony according to the condition. In the harmony condition, the 4 vowels yielded 8 vowel combinations, each occurring once in a group. For the disharmony condition, the second vowel in the stem was changed to another vowel with the opposite rounding feature (e.g., /p^hik^hɛ/ to /p^hik^hɔ/). The consonants stayed the same so that the stimuli from the same group in the two conditions only differed in the second vowel.

In the training session, the stimuli were formed with 16 items from two groups out of A, B and C. Participants learned a pair of a singular and a plural form for every word stem. An image of a single alien accompanied each stem, and the corresponding suffixal form was paired with three of the same aliens, as shown in Figure 2. All alien images were downloaded from Sporepedia (*Sporepedia*, 2022). The plural suffix /mi/ contains a front unrounded vowel, and the other /mu/ contains a back rounded vowel. Both /mu/ and /mi/ are not used sound sequences Hong Kong Cantonese[1]. Therefore, the participants should have a similar low familiarity with both syllables and show no preference. The second vowel in the stem always triggered harmony or disharmony across the morpheme boundary. For the first generation, both conditions presented 100% of harmony and disharmony. For instance, in the harmony condition, /mi/ was only assigned to words ending with {i, ɛ}. Examples of training items in group A for both languages were listed in Table 1.

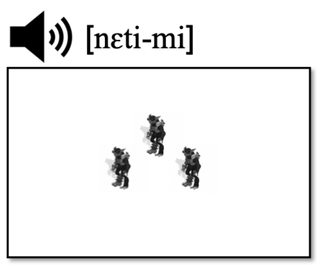


Figure 2: Participants learnt the word, i.e., the suffixal form, to call three aliens.

Harmony stem	Harmony suffix	Disharmony stem	Disharmony suffix
p^{h}ik^{h}ɛ	p^{h}ik^{h}ɛ-mi	p^{h}ik^{h}ɔ	p^{h}ik^{h}ɔ-mi
tukɔ	tukɔ-mu	tukɛ	tukɛ-mu

Table 1: Training items from group A for harmonic and disharmonic languages used in the first generation.

In the testing session, 16 stimuli contained 8 items from the training material and 8 new items. For example, if generation *n* used A and B as the training material, the testing set would contain B and C. Participants heard both old and new items in the test. The new items could reflect whether participants had learned the harmony rule and could apply it to a novel environment (Finley, 2021), as an indicator of phonological generalization. The test consisted of two-way forced choice questions, and the two answers were the same word stem with suffix /mi/ or /mu/. The test results were the input for the next generation. In the example above, stems from B and C became the training materials for generation *n+1*. See Table 2 for a list of stimuli sets for the first three generations. The harmonic patterns for the original harmony and disharmony items varied over generations. For example, in the harmony condition, if a participant chose /mu/ for the stem /p^{h}ik^{h}ɛ/ in the test, this pair of /p^{h}ik^{h}ɛ/ and /p^{h}ik^{h}ɛmu/ was passed down to the next generation. The stem part stayed the same and the harmony feature was still determined by the second vowel and the suffixal vowel: in the harmony condition, words like /p^{h}ik^{h}ɛmu/ were defined as a disharmonic item, while in the disharmony condition, words like /p^{h}ik^{h}ɔmu/ were defined as a harmonic item.

Generation	Training set	Testing set
1	A + B	B + C
2	B + C	A + B
3	A + B	B + C

Table 2: Training and testing materials for the first three generations.

The stimuli were recorded in a sound-proof booth by an adult male speaker native in American English and bilingual in Hong Kong Cantonese. The speaker assigned the stress on the first syllables of all items. Onyx Blackjack 2x2 in 24bit format was used for the recording, and the sampling rate was 44.1Hz. The

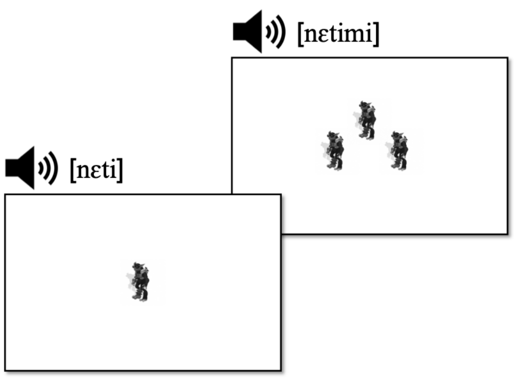
[1] /mu/ is unattested in Hong Kong Cantonese; /mi/ is a variant pronunciation for a pair of homophones, but according to native Hong Kong Cantonese speakers, it is never used in conversations.

original audio files were normalized in Praat to realize an average intensity of 70dB and transformed to MP3 format with ffmpeg for online compatibility.

2.3 *Procedure* The experiment was built in PsychoPy2 (Peirce et al., 2019) and released via Pavlovia (Bridges et al., 2020). In each transmission chain, the routine for every participant included two blocks, training and testing blocks. Instructions and practice trials were provided in both blocks to familiarize participants with the layout and operation mechanism.

Participants were guided to learn an alien language at the beginning. In the first block, the training for the artificial language contained 16 unique words with 3 times of repetitions, totaling up to 48 items. In one trial, the audio of a stem item was played with a single alien image appearing at the center of a page. After 2 seconds, the corresponding plural form was played, and three of the same aliens occurred in a pyramid configuration, replacing the original one. The group of aliens stayed for another 2 seconds. There was a one-second eye-fixing session between every two trials with a small cross in the center of the screen. A presentation example of an item is visualized in Figure 3. The training session contained visual and auditory stimuli, so the participants were asked to focus on both images and sounds.

The second block was a testing phase, and it involved 16 two-way forced choice questions. When a test started, as in the training phase, a single alien was presented, with the audio of the word stem played simultaneously. After 2 seconds, three of the same aliens showed up, and soon after 1 second, the two choices for different plural forms occurred successively with an interval of 1.5 seconds. Together with the audio for each choice, a selecting circle and a player button appeared on the screen, as shown in Figure 4. Participants were required to listen to all auditory stimuli before selection, because all the buttons were not activated until the second sound was played. They could click the replay button to listen to the sounds for multiple times and make choices by clicking on the selection circle. The circle turned black to indicate their choice. Once the participants had clicked on either circle, the NEXT button popped up, and they could continue.



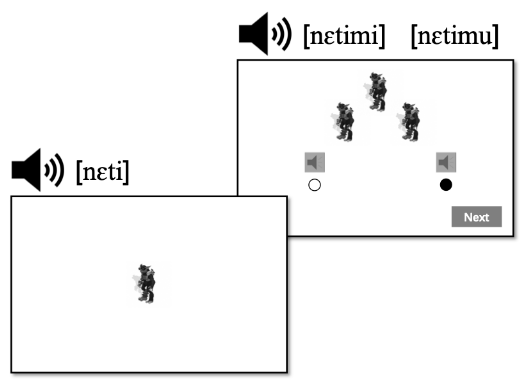


Figure 3 (left): Screens shown in the training block; **Figure 4** (right): Screens shown in the testing block.

The testing phase contained three focus-check questions as well, each inserted after every 4 formal trials. The question had the same format as other formal trials, starting with an initial word and two following options. Instead of artificial items, it played three real English words, including a pair of synonyms and a color word (e.g., *quick*, *fast* and *blue*). One of the synonyms was the initial word (e.g., *quick*) and the other two words (e.g., *fast*, *blue*) were the two options. Participants were explicitly asked to choose the color word at the beginning of the test, and there were also instructions on the attention-check trial page. Participants who failed any one of the three focus questions were excluded from the transmission chain and data analysis.

After recruitment, for each condition, participants were divided into 8 groups, and an individual represented one generation. The link to the experiment was sent out according to the generation successively. Participants in the first generation learnt the seed input, the categorical language exhibiting either harmony or disharmony. After their completion, the test results were directly fed to a new experiment version, which was delivered to the next generation, and the process repeated for the rest of the chain (see Figure 5 for an illustration of the first four generations).

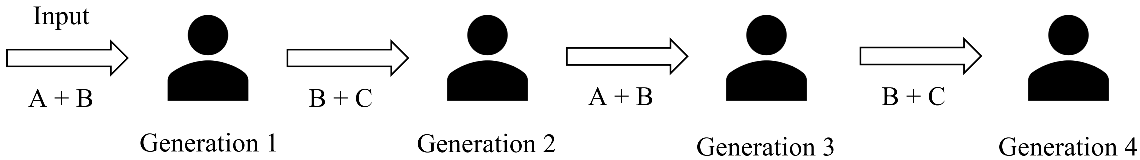
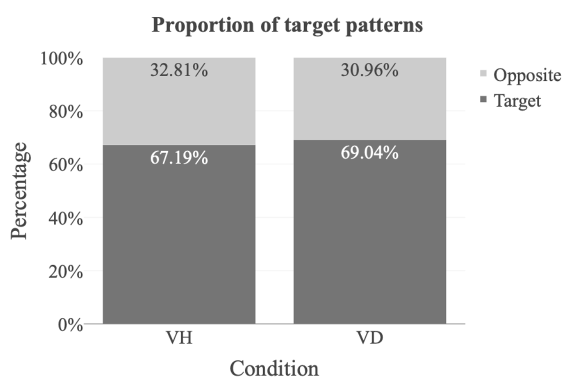


Figure 5: First four generations in one transmission chain.

3 Results

Participants who failed in any of the three focus-check questions were immediately eliminated from the transmission chain (N = 35). Thus, in total, 128 participants were included in the analysis. In this section, the data is analyzed both from a general perspective and individual perspective, leading to four major findings regarding conditional and generational differences.

Recall that the experiment aimed to investigate the transmission of VH and VD patterns, and there were two potential influencing factors, condition and generation. When the outcomes of the natural and unnatural conditions were compared, we found no general or transmission difference between the two conditions. By seeing multiple chains as a big pool of phonological learning, Figure 6 plots the proportion of VH and VD patterns in the testing phase. In the harmony condition, the target pattern VH took up 67.19% in all trials, and in the disharmony condition, VD patterns took up 69.04%. The target patterns were dominant in both conditions, showing no significant different ($p = 0.37$, $t(2046) = -0.9$).



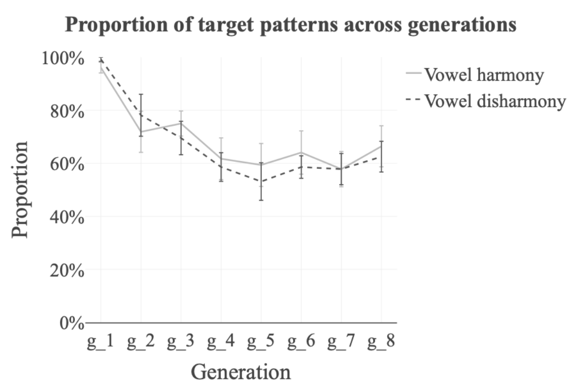


Figure 6 (left): Proportion of target patterns (i.e., harmonic patterns in the VH condition) and opposite patterns (i.e., disharmonic patterns in the VD condition) in the two conditions; **Figure 7** (right): Proportion of target patterns in every iteration.

Figure 7 plots the proportion of target patterns in every iteration. The two lines present a similar changing tendency, and there is no significant difference between the two conditions in every generation from the beginning to the end, e.g., in the final generation, $M_{\text{VH}} = 0.664$, $M_{\text{VD}} = 0.625$, $p = 0.52$, $t(254) = -0.65$. The shared decreasing trend is our second finding. With input data being a categorical language, the first generation learned both patterns equally well, showing more than 95% of the target patterns. At later stage, the proportion gradually decreased to around 60% at the fourth generation and stayed at this level for the rest part. We found significant difference between the first generation and every later one (e.g., in the VH condition, $M_{\text{g\_1}} = 0.961$, $M_{\text{g\_2}} = 0.719$, $p < 0.001$, $t(173) = 5.57$), while starting from the second generation, every two adjacent generations showed no difference. This might suggest that the variation introduced by the second generation into the original categorical language has been maintained throughout the whole transmission

Third, despite the decreasing trend, target patterns in both conditions were always dominant. As the last five generations seemed to have an arbitrary distribution of the target patterns, we compared the generational mean and the chance level 50% and found significant difference ($M_{\text{VH}} = 0.69$, $p < 0.001$; $M_{\text{VD}} = 0.592$, $p < 0.001$). The two lines also never went below the 50% threshold, meaning that the dominant patterns were never flipped at the population level. The fourth finding is the relatively large gap between the first two generations. Compared with the perfect reduplication by the first generation, the proportion abruptly dropped below 80% at the second generation. The rather longer error bars of g_2 in Figure 7 indicate varied individual learning outcomes. Figure 8 depicts a full picture of all individuals in the harmony condition. Focusing on g_1 and g_2, we saw that the abrupt drop at the population level was caused by certain chains: the successors of participants who did not pass down a categorical language lost the predominant pattern. For example, the first generations in chains vh_1, vh_2 and vh_7 produced around 10% of opposite patterns, and all the next generations produced less than 70% of the VH pattern.

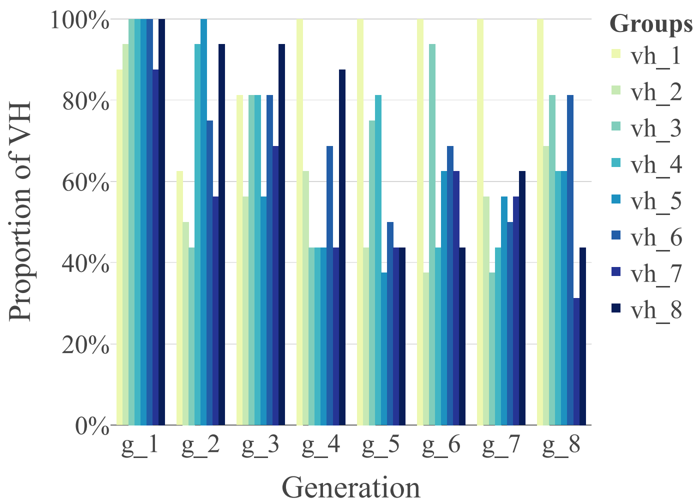


Figure 8: Proportion of target patterns of individuals in VH condition; One bar represents a single participant.

According to the result of a mixed effect generalized linear regression model with condition and generation as fixed factors and participant as a random effect (the first generation of VD condition was set as the reference level), it turned out that every generation significantly affected the proportion of the target pattern (e.g., for generation 2 in VD condition, $\beta = -0.21$, $SE = 0.06$, $p < 0.001$, $R^2 = 0.078$), whereas condition had no effect ($\beta = -0.03$, $SE = 0.06$, $p = 0.58$, $R^2 = 0.078$). However, the two conditions showed difference at the individual level. Although these findings were not supported by statistics, they might reveal some weak effect of the substantive bias on transmission. In the VH condition, one special chain was vh_1, indicated by red bars in Figure 9(a). After a short drop in the first three generations, the proportion of VH increased back to 100% and kept till the end. Such a successful and stable transmission was never found in the VD condition. In VD condition, on the contrary, more individuals flipped the dominant pattern. Many chains involved one or multiple points when the proportion was below 40%, indicated by red bars in Figure 9(b), meaning a reverse of the target pattern. The most extreme low value occurred in the fifth generation in chain vd_6, reaching below 20% of VD. We should not ignore that most of these chains bumped up in the next iteration, but they still signal the loss of a VD language at certain stage. As the last several generations experienced a steady state, with target patterns fluctuating around 60%, the first five generations recorded the decreasing phase and reflected slight difference in the decreasing pathways. According to Figure 10, the decrease was more consistent across groups in VD language, while the transmission chains for VH language fluctuated more often, as exemplified by the two lines.

(a) (b)

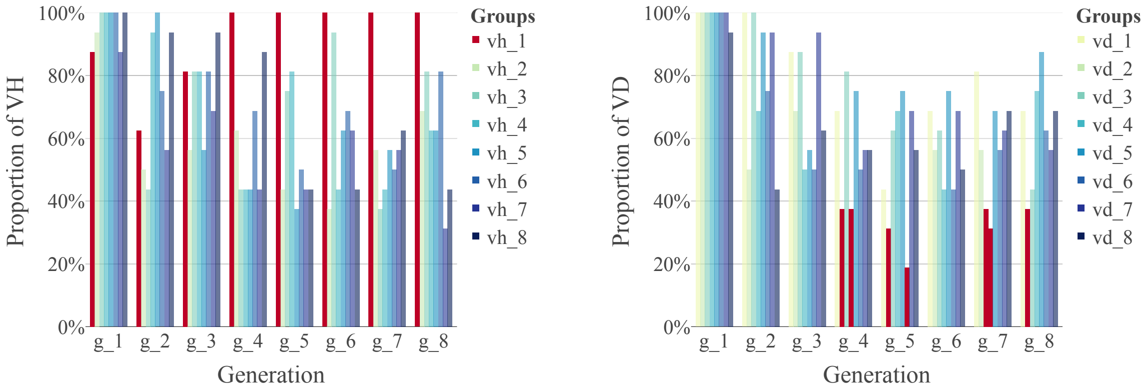


Figure 9: Proportion of target patterns of individuals in VH (a) and VD (b) conditions.

(a) (b)

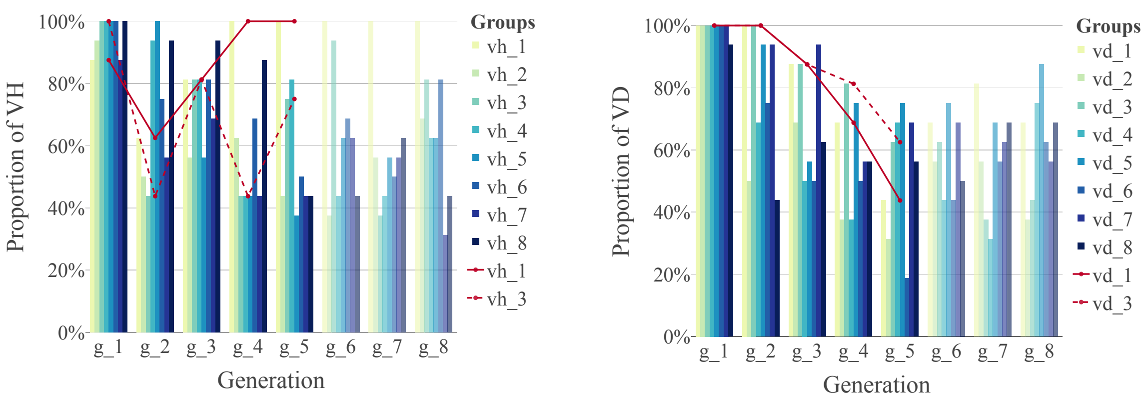


Figure 10: Proportion of target patterns of individuals in VH (a) and VD (b) conditions. Points in lines represent single participant and dotted and solid lines indicate two chains.

4 Discussion

This study has investigated the role of substantive bias in language transmission and found no general difference between the diachronic changes of vowel harmony and vowel disharmony. The similar learning outcomes of both patterns is different from some of the previous reports which observed the naturalness effect (Do & Mooney, 2021; Lysvik, 2020; Martin & White, 2021). However, the current result is in line with some other studies showing no role of phonetic substance in phonological learning (Evjen, 2021; Pycha et al., 2003; Wilson, 2003). The competition between naturalness and complexity might have weakened the bias effect (Moreton & Pater, 2012b). Substantive bias is considered linguistically specific as it is grounded in phonetic substance, but structural bias is also relevant to other domains such as visual pattern learning. Thus, if domain-general mechanism is also activated in ALL tasks, structural bias can be more saliently observed, which could possibly override the effect of the substantive bias (Moreton & Pater, 2012b). In the current experiment, one advantage of testing the learning and transmission of vowel harmony and disharmony is that they share a similar level of structure complexity (Martin & White, 2021). Nonetheless, the similar yet strong structural bias might have blocked the subtle and unstable naturalness difference. In addition, as the categorical language became unpredictable at the later stage of transmission --both languages contained 60% of the target pattern-- the increasing difficulty of generalizing the harmony rule could have further weakened the naturalness bias. Apart from the weakness of the bias, we believe the bias's sensitivity to different methodological choices is also relevant here. For instance, according to Do and Havenhill's review (2021), whether the training in an ALL experiment involved production systematically led to distinctive results: those with production tasks consistently revealed the substantive bias (Moreton, 2012; Wilson, 2006; White, 2014) with one exception from Kosa's study (2010). Although biases could become apparent over repeated episodes of learning (Reali & Griffiths, 2009), the lack of production in our experimental setting might have lead participants to not activate their awareness of phonetic details of the patterns.

At the last generation of the transmission, the final distribution of the two patterns misaligned with the synchronic typological distributions of vowel harmony and disharmony (Kaun, 2004). If both patterns are equally able to survive through long-term transmission, then why is vowel harmony much more widely attested than vowel disharmony in natural language? First, it is possible that the asymmetry will occur after longer duration of language transmission, i.e., more generations in iterated learning studies. However, in many iterated learning studies with human participants, eight or fewer generations have been proved to reveal some features of transmission (experiments with five generations: Evjen, 2021; Motamedi et al., 2019, 2021; Ota et al., 2021). Thus, it is not highly likely that no substantive bias effect in this study is due to short length of the chains. In addition, the proportion of target patterns in the current experiment presented stability starting from the fifth generation and did not show particularly different changes for the rest iterations. Accordingly, it is reasonable to expect that the trend will continue even if the chains involve more generations.

The misalignment between the current experiment's results and typological data might also be due to the design of the transmission chain. Recall that the current study employed a paradigm where the transmission solely relied on learning from a single participant in each generation, which is a simplified model of real language change. Another form of the paradigm is the iteration involving both learning and interaction, as illustrated in Figure 11. In such a transmission chain, participants in one generation interact after training, and their communication results are used as the input for the next generation. The language transmitted in this paradigm is under the pressures for effective communication. Kirby and colleagues (2015) employed this paradigm (as illustrated by Figure 11) and compared it to other two paradigms with sole transmission (as the one shown in Figure 1) and sole communication. Among three conditions, only the one with both transmission and interaction showed the emergence of a compositional language. They concluded that the pressures for learning, favoring compressibility, and pressures for communication, favoring expressivity, were both key elements to trigger a structured linguistic system. Though this study targeted on the structure of words and sentences to convey meaning, the proved importance of interaction should also be considered in the transmission of phonological patterns.

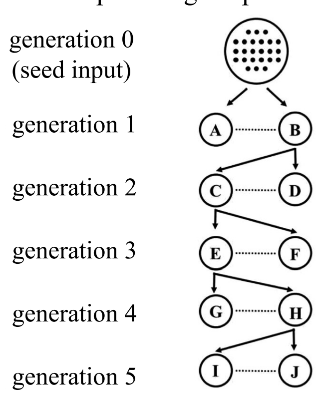


Figure 11: A transmission chain with interaction between two speakers in one generation (Motamedi et al., 2019, p. 4)

The impact of interaction has been proved in other experiments as well (Fehér et al., 2016; Motamedi et al., 2019, 2021; Smith et al., 2017). Ota et al.' s study (2021) on word-internal repetition adopted the transmission-and-communication paradigm. They found increasing use of consonant repetition, which is different from the typological tendency to avoid same consonant within a word. Participant's preference for sound repetition in laboratory settings might result from the high learnability of repeated patterns. The opposite typological generalization suggests that this learning bias only occurs under certain condition. In the communication-only condition of this study, the use of consonant repetition always stayed at a low proportion, suggesting that communication disfavors repetition. Ota et al. then concluded that communicative pressure could override some learning bias during the process of transmission. Fehér et al. (2016) demonstrated that interaction tends to eliminate unpredictable variation. Participants were aware of the communicative function of language and realized the counter-functional nature of unpredictability and thus tended to reduce variability during communication. They designed two situations of communication: the real dyad between human and human, and the pseudo dyad between human and computer, but all participants believed that they were interacting with a real human. Such a belief led to different transmitting results in contrast with the condition without any kind of interaction. These participants showed more regularization in their language during interaction. In the current experiment, the categorical seed languages became increasingly variable over time, and it might be due to the lack of the motivation for the participants to faithfully reproduce the target language. Therefore, as the demand for a more regularized suffixation rule occurs from communication, participants may implicitly rely on phonetic naturalness to achieve regularization. For instance, if two participants need to agree on a fixed suffix /mi/ or /mu/ for all words ending in /ɛ/, the substantive bias may increase the possibility of choosing /mi/ to conform to naturalness. If communication component is included in the current transmission study, we thus predict that the proportion of a more natural pattern such as vowel harmony may increase along the course of language transmission.

This paper contributes to the growing work on substantive bias, by providing a novel perspective from language transmission to compare the diachronic change of phonetically natural and unnatural patterns. The experiment found that both vowel harmony and vowel disharmony became less dominant, leading to increasing variation in the transmitting languages over generations. The results showed that the bias did not impact on language change through iterated learning, at least at the population level. Future work may involve interaction into the experimental paradigm to explore other potential mechanisms through which the substantive bias influences phonological transmission.

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