The acquisition of Cantonese phonotactics

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This work investigates infants' learning mechanisms for Cantonese phonotactics, and whether their learning trajectory of phonological structures can be predicted by structural complexity and naturalness of phonotactic constraints. Structural complexity can be defined by the factors of distance (i.e. local vs long-distance) and the window size of restricted sequences of sounds. Window size can be thought of as *n*-gram, the larger the window size, the longer the sequence, and the more complex it is. For example, English phonotactics allows the sequences of birgrams such as *st*- and trigrams *str*- which has window size of 2 and 3 sounds respectively; but not **sr*- or **ftr*-. Cantonese syllables are simpler than those in English, only (C)V(C) structures are legal, and a number of phonotactic gaps were identified [1] (shown in (1) – (4) below). These gaps allow us to compare the acquisition of syllables that are of different structural complexity.

<u>Low structural complexity</u>:

1) [bigram, local] Labial onsets cannot be followed by a front rounded vowel (e.g. */byu/)
2) [bigram, local] Coronal onsets cannot be followed by /uː/ (e.g. */tu/)

<u>Higher structural complexity</u>:

3) [trigram, non-local] Labial onset cannot co-occur with labial coda (e.g. */bab/)
4) [trigram, local] /ɔː uː/ cannot occur between coronal onsets and codas (e.g. */tot/)

The first 2 phonotactic rules are considered to be less complex because they are local dependencies with the window size of 2. (4) is considered more complex even though it is a local dependency but its window size is 3. (3) is regarded more complex because it is a non-adjacent dependency that restricts the cooccurrence of the onset and coda of the syllable while the vowel in the medial position is variable.

Obligatory Contour Principle (OCP) is a commonly found restriction for natural languages, which prevents homorganic sounds from occurring in sequence. For example, word-likeness results show that the violation of root consonant cluster in Arabic led to lower word likeness ratings [2]. (1), (3) and (4) violate OCP. (1) can be viewed as a violation because of sharing a [+labial] feature, while (3) and (4) violate OCP at the consonant tier, because the initial and final consonant share the same place of articulation. (2), on the other hand, violates a less natural phonotactic constraint, because it is more natural for coronal onsets to be followed by front vowels; violation of (2) would therefore lead to a more marked structure [3, 4].

The coronal-labial contrast in the Cantonese phonotactic gaps may also contribute to the results. This is because the backness of the vowel is influenced by the coronal onset, whereas they are not affected by labial onsets [3]. Moreover, in an examination of coronal and labial onset frequencies using Cifu [5], a Cantonese frequency lexicon, among all the monosyllabic word frequencies, coronal onsets have 328,132 occurrences, while labial onsets only have 104,041. This shows that Cantonese-learning infants have more exposure to the legal structure involving coronal onsets.

As for the learning trajectory of structural patterns, infants as young as 5 months old show evidence for rule learning when there are multimodal cues [6]. 7-month-olds can track patterns equivalent to the complexity of trigrams: for example, they can distinguish ABB patterns from ABA [7]. Headturn experiment results show that both 7- and 9-month-old age groups can segment words based on local transitional probability (TP) and stress cues respectively [8]. Infants' ability to detect non-adjacent dependency emerges at around 12 months old [9]. Yet, in another study the 12-month-old group failed to learn non-adjacent dependencies like *aXc*, while 15-month-olds succeeded [10]. Thus, to examine the learning trajectory of Cantonese phonotactic rules, which involve both local and non-local dependencies at different window sizes, we tested Cantonese-learning infants in 5 cross-sectional age groups (5, 7, 9, 12, 14 months) ($N = 150$).

We tested the infants on a head-turn preference paradigm. 32 pseudowords corresponding to the four Cantonese phonotactic gaps were created, four legal-illegal word pairs for each phonotactic gap. The factors of *locality* and *window size* were tested within-subject. Each trial contains four exemplars of the same type (e.g. *Labial bigram – legal*), making there 8 trials in total. Each trial was set to have a maximum looking time at 80s. The order of the trials were counterbalanced. The infants' looking time were recorded for analysis.

A linear model was built with the fixed factors *Age* (5 levels: 5, 7, 9, 12 &14m), *Legality* (2 levels: legal *vs* illegal), *Window size* (2 levels: bigram *vs* trigram), and *Place* (2 levels: coronal and labial), and logged looking time as dependent variable. There is a significant effect for *Place* $F(1, 1015) = 3.974$, $p = .046$) and *Age* ($F(4, 145) = 2.649$, $p = .036$), also an interaction between *Legality* and *Place* ($F(1, 1015) =$

12.279, p = .0005). Post-hoc pairwise comparisons reveal significant looking time differences for coronal gaps at 9-month-olds (*bigram*: est = .463, se = .224, t = 2.063, p = .039) and 7-month-olds (*trigram*: est = .45, se = .224, t = 2.008, p = .045). There were also looking time differences for the trigram labial gap at 5- (est = -0.433, se = .224, t = -1.93, p = .054) and 9-month-olds (est = -0.423, se = .224, t = .1.89, p = .060).

Since looking time results show different preferences for legality for coronal and labial gaps, separate models were built for the two types of gaps. For both models, *Legality*, *Age*, and *Window size* were used as fixed factors. In the coronal model, significant effect for Legality was found (F(1, 435) = 4.954; p = .027). Infants show novelty preference for the coronal gaps, and according to the familiarization model by Hunter & Ames (1988), novelty preference signifies a more mature stage of learning than familiarity preferences (as cited in [11]). For labial gaps items, significant *Legality* (F(1, 435) = 6.961; p = .009) and *Window size* (F(1, 435) = 6.301; p = .012) effects were found. There were also a marginal effect for *Age* (F(1, 145) = 2.30, p = .062) and a three-way interaction for *Legality x Age x Window size* (F(4, 435) = 2.032, p = .089). Post-hoc pairwise comparisons reveal marginal looking time differences for trigram at 5- (est = -.432, SE = .225, t = 1.921, p = .055) and 9-month-olds (est = -.428, SE = .225, t = 1877, p = .061). Infants showed a familiarity preference towards legal stimuli for the labial trigram gap. With reference to Hunter & Ames' (1988) familiarization model, this may reflect that the structure learned is still considered complex relative to age.

The opposite direction of preferences for coronal and labial gaps may represent the different learning trajectory for coronal and labial rules, while these differences in learning trajectory can possibly be attributed to the complexity differences. The successful acquisition of the gaps with trigrams labial gap may indicate that window size is outweighed by other factors, as bigram restrictions are not necessarily learned earlier than trigrams. Overall, no looking time difference was found for the bigram labial gap. Even though this pattern violates OCP, infants' looking time data does not show legality contrasts. On the other hand, infants successfully distinguish patterns that violate OCP at the consonant tier level (i.e. trigram labial, trigram coronal). This may indicate the gradient nature of OCP violations. The opposite direction of looking preferences between the two trigram gaps may reflect the differential encoding for true local trigram patterns and non-local patterns (i.e. aXb, where X is variable). Finally, the data does not rule out frequency effect for coronal gaps. It is possible that the accumulative effect of local dependency and OCP violation makes infant notice the trigram coronal gaps at 7 months old, while violation at local dependency alone (bigram coronal gap) is more recognizable than solely tier-based OCP violation (trigram labial gap).

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