It’s all Cantonese to me:
Designing a non-word repetition set for Cantonese

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Abstract

Non-word repetition (NWR) tests have been established as effective tools to screen for specific language impairments (SLI) in children. Their merit lies in removing extraneous influence of lexical knowledge so that NWR performance can be a sensitive marker of phonological processing ability. As standard NWR tests only apply to the specific language for which they are designed, the Universal non-word repetition (UNWR) test (Howell et al., 2016) was designed for use with 20 languages to assess NWR ability in children with diverse language backgrounds. However, it cannot apply to languages with vastly different phonological characteristics from the Indo-European languages for which it was designed. This paper investigates how to fill the gap for testing NWR in tone languages based on the same phonologically informed approach used for UNWR, focussing on Hong Kong Cantonese as a starting point. I propose a Cantonese non-word repetition (CanNWR) set, which requires variation along six parameters: syllable count, syllable structure, initial consonants, final consonants, vowels, and tone. The parameters are grounded in patterns of markedness and child language acquisition, and take into consideration the interface between phonology, morphosyntax, and semantics. I then suggest the set up of a CanNWR test with stimuli selected to minimise extant lexical interference, and fine-tuned to measure phonological skills. CanNWR has implications for extension to other tone or Sinitic languages, and I conclude by outlining the direction of further work in this area.

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1. Introduction

In non-word repetition (NWR) tests, participants are tasked to listen to non-words and repeat each one. The non-words conform to the phonological structure of their native language but do not exist in the lexicon. Since at least Kamhi and Catts (1986), NWR has been used to abstract away from lexical knowledge and study phonological processing difficulties in children who also have syntactic and semantic processing deficits (Dollaghan, Biber & Campbell, 1993). NWR tests are presently used to screen for specific language impairment (SLI)—a disorder that impairs children's acquisition and use of language despite typical development in non-verbal intelligence, hearing sensitivity, oral motor function, and social interaction skills, and the absence of neurological damage (Leonard, 2014). However, Stokes, Wong, Fletcher and Leonard (2006) contended that NWR cannot distinguish children with SLI (CwSLI) from children with normal language development (CwNL) in Cantonese.

To challenge that claim, this paper introduces a phonologically informed Hong Kong Cantonese NWR (CanNWR) set. The present focus is on building a tool to screen for SLI in 4-5 year old children, but CanNWR has much wider application to psycholinguistic experimentation with children and adults too. I begin by discussing the literature on NWR tests in §2. In §3, I synthesise various phonological analyses of Cantonese with reference to closely related Chinese dialects and argue for six markedness parameters determined through typological frequencies and language acquisition patterns. In §4, I select nonce syllables based on phonemic lexicons, phonotactic restrictions, and syllable-likeness, then demonstrate the set-up of a CanNWR test. Before concluding, I suggest directions for further work on and extension of CanNWR in §5.

2. NWR tests

NWR taps into phonological processing skills, cognitive skills, and memory (Coady & Evans, 2008; Snowling, Chiat & Hulme, 1991)—it demands accurate perception, underlying phonological representations that are sufficiently robust to encode the novel string, working memory to analyse and temporarily store the string, phonological assembly of speech units, motor planning, and articulation. NWR tests have gained traction as a screening tool for various language disorders, consistently differentiating CwSLI from CwNL (Coady & Evans, 2008; Estes, Evans & Else-Quest, 2007).

2.1 Motivation for NWR

Pinpointing what NWR measures has been an issue of debate—whether phonological working memory (e.g., Gathercole, 1995) or phonological sensitivity (e.g., Metsala, 1999) (breaking down non-words into component units (Coady & Evans, 2008)), or an underlying phonological processing ability, of which phonological working memory and phonological sensitivity are indistinct surface manifestations (Bowey, 1996). Regardless of whether they are separate constructs (Baddeley, 2003) or not (MacDonald & Christiansen, 2002), phonological working memory and phonological sensitivity certainly function interdependently. Both clearly support NWR because performance correlates with digit span as well as prosodic structure and neighbourhood density (the proximity of non-words to real words differing in a single segment or tone (Luce, 1986)) of the non-words (Coady & Evans, 2008; Roy & Chiat, 2004). They cannot be disentangled from the other processing and cognitive skills involved either, as SLI may impair one or multiple components.

For this paper, it suffices to put this debate aside and acknowledge that NWR tests are effective identifiers of phonological deficits. Crucially, NWR removes extraneous lexical influence. Coady and Evans (2008) pointed out that CwSLI have smaller lexicons than age-matched CwNL. Even if their lexicon size is matched to that of younger CwNL, they may contain different words. And even if lexicon content is identical, they are likely to store underlying lexical and phonological units with lower levels of specificity. Such lexical knowledge facilitates NWR fluency and accuracy through redintegration, a cognitive process through which non-word traces are reconstructed through high lexical and phonotactic probabilities of phonemic sequences in the ambient language (Gathercole, 1999; Munson, 2001; Munson, Kurtz & Windsor, 2005). However, NWR tests are sensitive to lexicon size, lexicon content, and organisation of underlying phonological representations, hence can control factors of word frequency and familiarity that would inherently disadvantage CwSLI (Coady & Evans, 2008; Lee, Chiu & van Hasselt, 2002).

Compare for instance the Children's Test of Nonword Repetition (CNRep; Gathercole, Willis, Baddeley & Emslie, 1994) and the Nonword Repetition Test (NRT; Dollaghan & Campbell, 1998). English words and affixes are embedded in CNRep tokens, and both CwSLI and CwNL demonstrate greater accuracy for high over low word-like tokens, and for non-words containing real syllables (Dollaghan, Biber & Campbell, 1993, 1995). In contrast, the NRT excludes embedded real words to reduce word-likeness, so its group effects can be largely attributed to phonological skills. The merit of NWR is in manipulating the word-likeness of stimuli to minimise extant lexical interference and in fine-tuning tests to measure phonological skills (Gathercole, 1995).

2.2 UNWR

Unlike standard NWR tests, the Universal non-word repetition (UNWR) test (Howell et al., 2016) was designed for not one but 20 languages, assessing NWR in heterogeneous language samples. Although children learning a foreign language may experience word-finding difficulty (WFD) and repeat whole monosyllabic words, this problem lies with vocabulary rather than fluency, and does not impair NWR (Howell et al., 2016). Since UNWR is not biased to a specific language, it dissociates fluency difficulty from WFD in non-native speech.

Crucially, UNWR was informed by developments in phonological theory and advances in descriptions of syllable, metrical, consonant-system, and vowel-system typology. Its non-words are phonologically wellformed and conform to the syllabic phonotactic constraints of the 20 languages, and have additionally been controlled for lexical effects.

Despite its diverse application, UNWR remains limited to Indo-European languages. Languages with vastly different syllable structure—such as Japanese, in which coda consonants are restricted to the initial position of partial or full geminates (Kawagoe, 2015)—present challenges for it, as do languages with contrastive tone like Cantonese. The logical next step is to explore extension of UNWR. The rigorous approach to its design sets the benchmark for future NWR tests for other language families.

2.3 Tone languages

The question now is whether the UNWR concept works with tone languages, and if so, how it should deal with tones. This paper focusses on Cantonese as a starting point. Suprasegmentals like stress are not included in the parameters used by UNWR (Howell et al., 2016). However, tone is a major lexical property in Cantonese (So & Leung, 2004) and cannot be omitted from the parameter set. Its functional load in distinguishing minimal pairs is especially heavy (Pye, Ingram & List, 1987; Yip, 2002) given the language's limited syllable structure (So & Dodd, 1995). I argue for the development of a CanNWR set that includes tones.

2.4 Existing Cantonese tests

NWR has yet to be adopted for screening SLI in Hong Kong. Speech skills tests have included the Hong Kong Children's Articulation Test (HKCAT; Cheung, Ng & To, 2006) and Cantonese Segmental Phonology Test (CSPT; So, 1993). In the HKCAT, children are presented with pictures to elicit target words, then scored on production accuracy for consonants, vowels, and tones (To, Cheung & McLeod, 2013) to measure their vocabulary and assess speech-sound disorders (Klee, Wong, Stokes, Fletcher & Leonard, 2009; Wong, Leung, Siu, Lam & Chan, 2011). In the CSPT, children are required to name pictures and tell a story, testing production of consonants, vowels and tones at word and discourse level to identify phonological and articulation difficulties (So & Leung, 2004). Of greater interest to this paper, however, is an initial Cantonese NWR test (Stokes et al., 2006) that examined prosodic and lexical effects.

Early studies had found prosodic effects in English (e.g., Bortolini & Leonard, 2000; Marshall, Ebbels, Harris & van der Lely, 2002) and Swedish NWR (e.g., Sahlén, Reuterskiöld-Wagner, Nettelbladt & Radeborg, 1999), supposedly due to "complex phonotactic structures, variable stress patterns, and difficult-to-articulate consonants" in both languages (Stokes et al., 2006, p. 221). Stokes et al. assumed that Cantonese prosody is uncomplicated because of its relatively smaller consonant inventory, simple syllable structure, absence of word stress, and early acquired tones. Thus, they argued that their test isolates NWR performance from prosodic effects. Finding no significant difference between age-matched CwSLI and CwNL, they attributed previous findings to prosodic effects that CwSLI struggle with and concluded that NWR is ineffective for screening Cantonese CwSLI. However, their claims and conclusion seem far too hasty.

2.5 A new Cantonese NWR test

Van der Lely and Harris' (1999) Test of Phonological Structure (TOPhS) varies syllabic and metrical complexity along the five binary phonological parameters in Table 1. Although metrical-stress parameters are not relevant to Cantonese, syllabic parameters that establish rime and word-end markedness are applicable. Where the CNRep failed to account for prosodic factors (Gallon, Harris & van der Lely, 2007), UNWR remedied this through insight into syllabic and metrical factors. Building on the design of UNWR, CanNWR takes on board developments in prosodic theory and assigns categories of markedness determined through typological frequencies and language acquisition patterns (Rice, 2007). Even though acquisition patterns vary widely, systematicity is still found in the acquisition of natural classes in ascending order of complexity (Lee, 2005; Stokes & To, 2002).

Stokes et al. (2006) compared NWR accuracy for attested versus unattested initial CV biphones. The former may be achieved through redintegration, but the latter are absent from existing lexical forms, so must be achieved through true repetition. Relative to age-matched CwNL, CwSLI had poorer performance for attested forms and equal performance for unattested forms. These findings also feed into the design of CanNWR.

Table 1. Syllabic and metrical parameters in TOPhS
(Gallon et al., 2007, p. 440)

Parameter		**Setting**	**Description**	**Real Word**	**Non-word**
Syllabic	**Onset**	Unmarked	No consonant cluster	***ci***.*ty*	***pí***.*fi*
		Marked	Consonant cluster	***pre***.*tty*	***prí***.*fi*
	Rhyme	Unmarked	Open syllable	*c**i**.ty*	*p**í**.fi*
		Marked	Closed syllable	*f**il**.ter*	*p**íl**.fi*
	Word-end	Unmarked	Vowel-final	*ci.**ty***	*pí.**fi***
		Marked	Consonant-final	*s**it***	*pɪ**f***
Metrical	**Left adjunction**	Unmarked	No initial unfooted syllable	*ci.ty*	*kɛ́.tə*
		Marked	Initial unfooted syllable	***ba***.*na.na*	***fə***.*kɛ́.tə*
	Right adjunction	Unmarked	No final unfooted syllable	*ci.ty*	*kɛ́.tə*
		Marked	Final unfooted syllable	*Ca.na.**da***	*kɛ́.tə.**lə***

3. CanNWR set

3.1 Design requirements

The CanNWR set is generated through markedness categories in six parameters: syllable count, syllable structure, initial consonants, final consonants, vowels, and tones. Where relevant, they take into consideration the interface between phonology, morphosyntax, and semantics. This is especially pertinent for Cantonese, in which each monosyllabic morpheme is arguably associated with a lexical or functional meaning, hence can be a word in itself, and a monosyllabic word is recognised as the primary phonological isolate (Cheung, 1986). The construction of a polysyllabic non-word in Cantonese is therefore subject to many challenges (Chan, Skehan & Gong, 2011).

In this section, I defend the notion that the NWR paradigm is applicable to Cantonese and address various issues surrounding it. Like most NWR tests, CanNWR uses auditory stimuli, so I discuss how allophonic variations and current sound changes should inform the production of natural sounding tokens.

3.2 CanNWR parameters

3.2.1 Syllable count

Following Stokes et al. (2006), CanNWR ranges from one to four syllables. Since most syllables in Cantonese can be considered free morphemes (Tsang, Chambers & Mozuraitis, 2017; Wong, Chan & Beckman, 2005) and morphemes are generally monosyllables (Duanmu, 1990; Pulleyblank, 1997), the lower threshold is set at one syllable (cf. two syllables in UNWR).

As higher syllable counts increase working memory load, one might assume a direct relation between syllable count and level of markedness. However, Gathercole and Baddeley (1989) found a systematic decline in NWR accuracy as syllable count increased from two to four, but better performance for disyllables than monosyllables. Compounds comprising two or more syllables also account for 90.79% of Cantonese words (Tang, 2017), so monosyllables should not be deemed less marked than disyllables. Hence, the CanNWR set uses the binary parameter in (1) instead of a scale.

(1) Syllable count parameter

Less marked		More marked
1, 2	vs	3, 4
e.g., /saː33-wɐŋ22/		e.g., /saː33-wɐŋ22-hɔː23/

3.2.1.1 Polysyllabic words

Compounding is highly productive in Cantonese, with polysyllabic words built up from smaller words (Wu, Tsang, Wong & Chen, 2017). Similar to other dialects (see Chen & Chen, 2000), the polysyllables in (2) are semantically classified as compounds with their meaning transparently derived from constituent morphemes.

(2) Transparent compounds (Lee, Chen, Luke & Shen, 2002, p. 1)

	Example	Characters	Overall Gloss
a.	[fat3-kun55] rules-officer	法官	‘judge’
b.	[tsɪk2-sɪŋ55-kej55] straight-ascend-machine	直升機	‘helicopter’
c.	[sej33-tʰʊŋ55-pat3-tat2] four-through-eight-arrive	四通八達	‘accessible’

Yet precisely because each monosyllable can be analysed as an “isolatable citation form” (Cheung, 1986, p. 231), it is unclear how speakers interpret polysyllabic sequences syntactically and prosodically. A trisyllabic sequence, for instance, could be parsed in one of the following four ways. Since these are all possible options, the nature of polysyllabic non-words and speakers' interpretation of them must be taken into account.

(3) Trisyllabic sequences

	Parse	Example	Characters	Overall Gloss
a.	Three monosyllables	[how35 sɪk2 a:55] good eat PARTICLE	好 食 啊	‘nice to eat’
b.	Monosyllable + disyllable	[sɐn55 tsy:21-si:55] new kitchen-master	新 廚師	‘new chef’
c.	Disyllable + monosyllable	[sɐn55-sɪn55 tsɔj33] new-fresh vegetables	新鮮 菜	‘fresh vegetables’
d.	Trisyllable	[ta:35-bin55-low21] hit-edge-stove	打邊爐	‘hotpot’

Parsing of polysyllabic sequences is complicated by the absence of prosodic cues from stress patterns and tone sandhi. This contrasts with English where *black bird* bears primary phrasal stress on the second word but *blackbird* bears primary compound stress on its first syllable (Giegerich, 1992). Furthermore, in the Suzhou Wu dialect, tone sandhi is used as a cue for compounds and "tonal domains correspond to polysyllabic compounds" (Chen, 1991, in Lee, 2002, p. 62), but neither is available in Cantonese.

Still, other properties provide compound-level prosodic cues in Cantonese. Depending on its position within the compound, a syllable varies in rime duration, fundamental frequency relative to a homotonic syllable, and intensity level (Lee, Chen, Luke & Shen, 2002). Thus, there remains the potential for speakers to parse polysyllabic non-words as single syntactic and prosodic units. Instances of opaque compounds in (4) further justify this, because speakers interpret them as compounds rather than phrases.

(4) Opaque compounds (Matthews & Yip, 2011, pp. 59-60)

	Example	**Characters**	**Overall Gloss**
a.	[hap3-tsow33] sip-vinegar	呷醋	'jealous'
b.	[jɐw21-kɔn55-søɥ35] swim-dry-water	游乾水	'play mahjong'
c.	[sɪk2-kʷɔː33-jɛː22-tsʊk5] eat-across-night-congee	食過夜粥	'to have studied martial arts'

3.2.1.2 Polysyllabic non-words

Chan et al. (2011) assumed that Cantonese speakers define words not in terms of sounds but in terms of syllables that correspond to meaningful orthographic characters, hence suggested that polysyllabic non-words should comprise real syllables in novel combinations. However, the activation of orthographic forms is irrelevant for the present focus on children with limited orthographic awareness. Although it is of concern when testing literate subjects, using real syllables would defeat the fundamental purpose of NWR tests—to remove lexical effects from real words and sequences. If subjects could map real constituent syllables onto orthographic representations, phonological forms, or morphemic meanings in their lexicon (Zhou, Marslen-Wilson, Taft & Shu, 1999), they could construe polysyllabic non-words as separate syntactic and prosodic non-words regardless of prosodic cues. Therefore, CanNWR uses only nonce syllables.

3.2.2 Syllable structure

Under traditional analyses of Cantonese, the syllable ranges from a monophthong or syllabic nasal to a maximum of four segments CGVX where "C is a consonant, G is a glide, and VX is a diphthong, or a short vowel plus a consonant, or a long vowel" (Duanmu, 2014, p. 423). In what follows, I challenge this view, propose a canonical (C)VX syllable structure where X is a consonant, and establish the syllable structure parameter settings in (5).

(5) Syllable structure parameter

Less marked		More marked
Onset	vs	Empty onset
e.g., /sɐŋ22/		e.g., /ɐŋ22/
Sonorant-final	vs	Obstruent-final
(C)VV, (C)VG, (C)VN		(C)VO
e.g., /sɐŋ22/		e.g., /sɐk2/

(6) gives examples of syllabic nasals. [m̩] is only found underlyingly in one word, and [ŋ̍] only occurs with [-upper] register tones (Bauer, 1982). However, a contemporary sound change has resulted in an almost complete replacement of [ŋ̍] with [m̩] (Bauer & Benedict, 1997). Since it is unclear whether non-occurring combinations of syllabic nasals with [+upper] tones constitute accidental (phonotactically possible) or systematic (phonotactically impossible) gaps, CanNWR excludes them, thereby also maintaining the (C)VX syllable structure with an obligatory vowel.

(6) Syllabic nasals (Barrie, 2003, p. 2; Bauer & Benedict, 1997, p. 26)

a. [m̩21] 唔 NEG

b. [ŋ̍21] 吳 'Ng (surname)'

c. [ŋ̍23] 五 'five'

d. [ŋ̍22] 誤 'mistake'

The initial consonant is optional since there exist vowel-initial syllables with empty onsets, e.g., (7). Cheung (1986) suggested that an epenthetic [ʔ] fills the empty onset—a process that is common cross-linguistically (Uffmann, 2007)—but vowel-initial interjections, particles, and the proper noun prefix never have onsets (Chao, 1947).

(7) Syllables with empty onsets

a.	[ɔː23]	哦 'oh (interjection)'
b.	[aː21]	呀 (interrogative particle)
c.	[aː33]	啊 (proper noun prefix)
d.	[ap3]	鴨 'duck'
e.	[ʊk5]	屋 'house'
f.	[an33]	晏 'afternoon'
g.	[ɔn55]	安 'peace'
h.	[ow55]	歐 'Au (surname)'
i.	[ɐj35]	矮 'short'

Languages with onsetless syllables also have syllables with onsets (Féry & van de Vijver, 2003), complying with basic principles of syllable structure wellformedness (Ito, 1989; Prince & Smolensky, 2004). The CanNWR set adopts the cross-linguistic markedness parameter in which syllables with onsets are unmarked, whereas syllables with empty onsets are marked.

Now, I return to the CGVX analysis to determine where G belongs in syllable structure out of the following four possibilities.

(8) Proposed affiliations of G in CGVX (Duanmu, 2014, p. 424)

a.	[C [GVX]]	(Xu, 1980, p. 80)
b.	[C [G [VX]]]	(Cheng, 1966, p. 136)
c.	[[CG] [VX]]	(Bao, Shi & Xu, 1997, p. 87)
d.	[C^G [VX]]	(Duanmu, 1990; 2007; Ao, 1992, 1993)

(8a) is rejected as G does not form a constituent with VX for rhyming, so cannot be part of the rime (Duanmu, 1999). (8b) is ruled out because a zero consonant only occurs in the onset slot, yet its allophone [ʔ] never combines with G, and thus G must belong to the onset (Duanmu, 1999). Since G only appears independently in the absence of an initial C (Duanmu, 2014), this eliminates

(8c). When C and G are both filled, the segments behave phonologically as a single contour segment C^G, as in (8d), where G is the secondary articulation of C (Duanmu, 1999, 2011) (see §3.2.3 for discussion). Hence, the Chinese syllable can be simplified to [(C) [VX]] with an optional initial consonant. This structure is assumed here.

Next is the issue of Cantonese 'diphthongs'. Contrary to the view that these are vowel + vowel sequences (Wong, 1941/2001), I analyse them as vowel + glide sequences with the glide being the final consonant (Bauer & Benedict, 1997; Chao, 1968; Cheung, 1986; Hashimoto, 1972; Kao, 1971; Matthews & Yip, 2011; Tse, 1991). This simplifies syllable structure by maintaining a single nuclear peak (Kao, 1971). Furthermore, true diphthongs would be expected to combine with final nasals and obstruents, yet such combinations are not found, and glides are in contrastive distribution with nasals and obstruents word-finally (Kao, 1971). 'Diphthongs' are therefore vowel + glide sequences with the latter occupying the syllable's X slot.

Depending on what occupies X, Cantonese rimes have the structure VV (long monophthong), VG (glide), VN (nasal) or VO (obstruent). This parameter distinguishes between sonorant-final and obstruent-final syllables. Sonorant-final syllables pattern together in carrying all six lexical tones (Yip, 2002) but obstruent-final syllables only carry three checked level allotones (So & Dodd, 1995). As Figure 1 shows, the former also has higher lexical (type) and usage (token) frequencies. Thus, obstruent-final syllables are more marked than sonorant-final syllables.

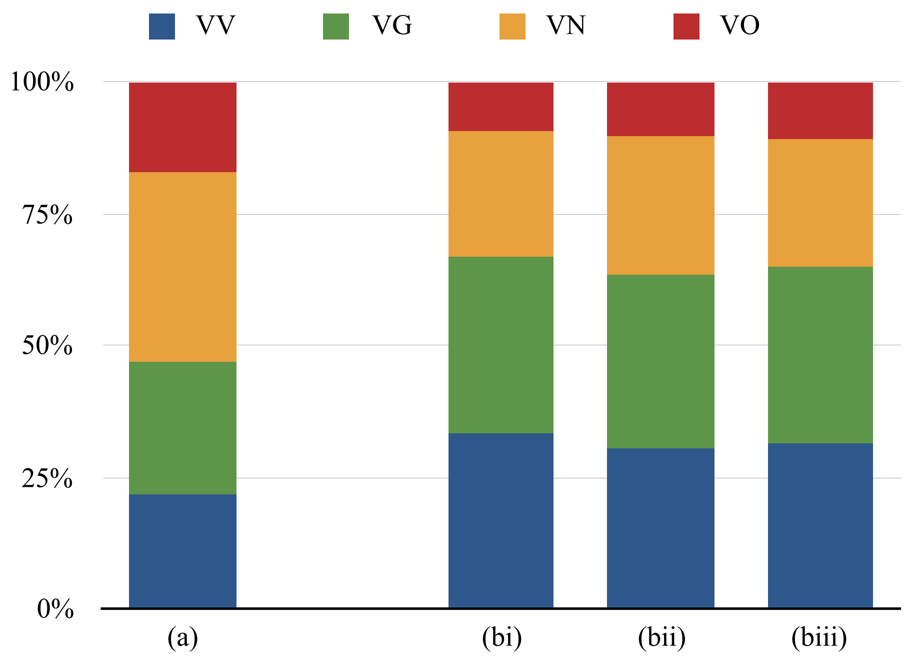

Figure 1. Frequencies of Cantonese rimes by (a) type and (b) token
Data from (a) Leung, Law and Fung (2004); (bi) Leung et al. (2004); (bii) Ng and Kwok (2004); (biii) Fok (1979)

Syllables with final consonants are universally marked, because languages with consonant-final syllables always also have vowel-final syllables, while other languages lack consonant-final syllables altogether, and phonological processes commonly avoid final consonants (Kager, 1999). As Cantonese children acquire VV and VG sequences alongside each other (To et al., 2013), they are not separated here. §3.2.4 discusses the relative markedness of VG and VN.

3.2.3 Initial consonants

This paper assumes the initial consonant inventory in Table 2.

Only [w] appears in the G position when C is filled (Duanmu, 2011, 2014), so a single-slot C^G analysis of the onset increases the consonant inventory by two sounds [k^w-] and [k^{wh}-]. This seems a worthwhile trade-off for simplifying syllable structure (Ao, 1992, 1993). However, it is uneconomical for dialects like Mandarin, in which the consonant inventory would have to be trebled for the full set of initial consonants occurring with [w] and [j] (Chan, 1985 in Duanmu, 1990). Duanmu's (1990, 2000) solution is that C^G is a contour segment of C and G. There are multiple advantages to this. One, it fits in with the phonetic description of /k^w, k^{wh}/ having simultaneous lip rounding and velar closure (Duanmu, 2002; Kao, 1971). Two, it maintains a simple syllable structure and small phoneme inventory (Duanmu, 2014). Three, it accounts for the distributional pattern where /k^w-, k^{wh}-/ but not /k-, k^h-/ have restricted co-occurrence with labial consonants and rounded vowels (Bauer & Benedict, 1997; Hashimoto, 1972; Kao, 1971) (see §4.1.2.3 for discussion). Finally, it aligns /k^w-, k^{wh}-/ with /ts- ts^h-/ in being underlying contour units (Duanmu, 2002; Kao, 1971). These four segments are more marked given their complexity and late

Table 2. Initial consonant inventory of Cantonese

	Labial	Alveolar	Palatal	Velar	Glottal	Labial-velar
Stop						
Unaspirated	p	t		k		k^w
Aspirated	p^h	t^h		k^h		k^{wh}
Nasal	m	n		ŋ		
Fricative	f	s			h	
Affricate						
Unaspirated		ts				
Aspirated		ts^h				
Approximant		l	j			w

acquisition by Cantonese children[1] (So & Dodd, 1995; So & Leung, 2004; To et al., 2013) and cross-linguistically (Jakobson, 1941, in Edwards, Beckman & Munson, 2015).

Among the simple segments, fricatives /f-, s-, h-/ form a natural class (Cheung, 1986) and are treated as more marked. They too are acquired later than the remaining consonants (So & Dodd, 1995; So & Leung, 2004; To et al., 2013). Furthermore, stopping errors, which cause fricatives and affricates to be realised as plosives, affect children up to a later age than other errors like velar fronting, both in Cantonese and other languages (Bowen, 1998; Grunwell, 1987; So & Dodd, 1995; So & Leung, 2004).

Laryngeal contrasts in Cantonese stops are based on aspiration rather than voicing. Unaspirated stops /p-, t-, k-/ have short lag voice onset time (VOT) and their aspirated counterparts /p^h-, t^h-, k^h-/ have long lag VOT (Clumeck, Barton, Macken & Huntington, 1981). The markedness of aspirated stops, produced with spread glottis, is reflected in later acquisition, errors with deaspiration (So & Dodd, 1995; So & Leung, 2004), and lower token frequency (Leung et al., 2004; Ng & Kwok, 2004).

This parameter does not distinguish among unaspirated stops, nasals, and glides, nor their places of articulation. These segments are all acquired early (So & Dodd, 1995; So & Leung, 2004), and although /k-/ is late acquired in line with universal tendencies (Tse, 1991), it has the highest token frequency (Leung et al., 2004; Ng & Kwok, 2004).

Next, allophonic variations conditioned by phonological environment must be accounted for. Glides occur before non-high vowels and homorganic high vowels (see §4.1.2.5), and /j-/ is realised as the labialised [ɥ-] in assimilation with following front rounded vowels /y, œ/ (Cheung, 1986; Hashimoto, 1972). Additionally, /s-, ts-, ts^h-/ are realised as the palatalised [ʃ-, tʃ-, $tʃ^h$-] respectively before /y, œ/ (Barrie, 2003; Leung et al., 2004). CanNWR must include instructions to use accurate allophonic realisations for the presentation of natural sounding tokens.

(9) lists sociolinguistic variations reflecting current sound changes. Acceptable variants must be recognised and differentiated from actual speech errors (To, McLeod & Cheung, 2015). The CanNWR set has no minimal pairs contrasting them, and subjects should be scored correctly for either production.

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[1] In fronting errors, children tended to substitute /$k^{(h)}$/ with [$t^{(h)}$] but /$k^{w(h)}$/ with [$p^{(h)}$], suggesting that they took into account the labial place of [w] (So & Dodd, 1995; To et al., 2013).

(9) Current sound changes affecting initial consonants (adapted from Cheung, 1986; Whelpton, 1999; To et al., 2015, p. 336)

	Variation	Example	Character	Gloss	Frequency (Adults)	Frequency (Children)
a.	/n-/ ➝ [l-]	/nam21/ ➝ [lam21]	男	‘boy’	94.6%	92.6%
b.	/ŋ-/ ➝ ∅-	/ŋɐw21/ ➝ [nɐw21]	牛	‘cow'	37.5%	71.9%
c.	∅- ➝ [ŋ-]	/ʊk5/ ➝ [ŋʊk5]	屋	‘house'	31.3%	7.1%
d.	/kʷ⁽ʰ⁾/ ➝ [k⁽ʰ⁾-]/ [+back, +round]	/kʷɔ:35/ ➝ [kɔ:35]	果	‘fruit'	50.9%	42.0%

The acquisition of /l-/ is inconsistently reported across studies (e.g., So & Dodd, 1995; So & Leung, 2004; To et al., 2013), and despite the widespread occurrence of (9a) children sometimes nasalise /l-/ to [n-] (To et al., 2013). Thus, /l-/ is excluded from the parameter settings for initial consonants in (10).

(10) Initial consonants parameter

Less marked		More marked
Simple	vs	Complex
stops, nasals, glides, fricatives		/ts- tsʰ-, kʷ-, kʷʰ-/
e.g., /wi:21/		e.g., /tsi:21/
Others	vs	Fricatives
stops, nasals, glides		/f, s, h/
e.g., /ŋi:21/		e.g., /fi:21/
Others	vs	Spread glottis
unaspirated stops, nasals, glides		/pʰ-, tʰ-, kʰ-/
e.g., /ki:21/		e.g., /kʰi:21/

3.2.4 Final consonants

Table 3. Final consonant inventory of Cantonese

	Labial	Alveolar	Palatal	Velar	Glottal	Labial-velar
Stop	p	t		k		
Nasal	m	n		ŋ		
Approximant			j			w

Final consonants are separately parameterised due to the imbalance between the 19 initial consonants and the eight final glides, nasals, and unreleased stops, as in Table 3. Initial and final consonants should even be treated as constituting independent systems since they have different realisations and variation patterns (Cheung, 1986), and the acquisition of final consonants follows the reverse sequence to that of initial consonants for both manner and place of articulation (To et al., 2013; Tse, 1991).

Although word-initial oral stops have a laryngeal contrast, this distinction is neutralised in word-final unreleased [p̚-, t̚-, k̚-] (Kao, 1971). Despite the lack of clarity on the acquisition sequence of stops versus nasals, Figure 2 shows that stops have far lower lexical and usage frequencies than both glides and nasals, so are classified as more marked using the binary feature [±son]. This supports the relative markedness of obstruent-final syllables as established in §3.2.2.

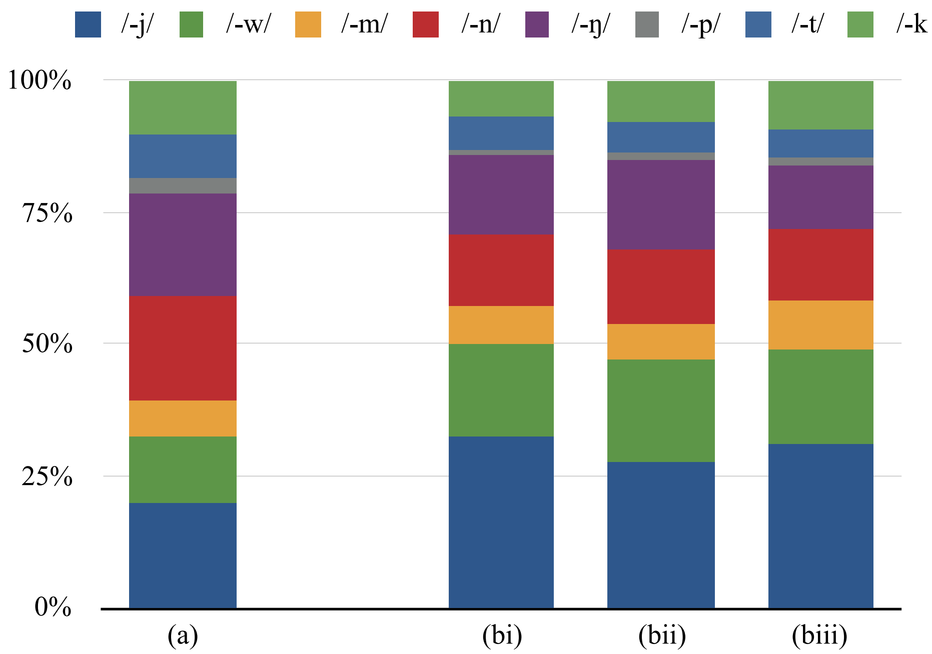


Figure 2. Frequencies of Cantonese final consonants by (a) type and (b) token
Data from (a) Leung, Law and Fung (2004); (bi) Leung et al. (2004); (bii) Ng and Kwok (2004); (biii) Fok (1979)

Glides are the earliest acquired word-final segments (To et al., 2013; Tse, 1991) and have higher token frequencies than nasals (see Figure 2), hence are less marked. The binary feature [±cont] captures this.

The back-to-front acquisition of final consonants (To et al., 2013) aligns with cross-linguistic patterns (Ingram, 1974) and correlates with the higher token frequency of velars than bilabials for both final stops and nasals in Cantonese. However, place distinctions are not made in the parameter settings in (11).

(11) Final consonants parameter

Less marked		More marked
[+son]	vs	[-son]
/-j, -w, -m, -n, -ŋ/		/-p, -t, -k/
e.g., /pɛn33/		e.g., /pɛt3/
[+son, +cont]	vs	[+son, -cont]
/-j, -w/		/-m, -n, -ŋ/
e.g., /pɛw33/		e.g., /pɛn33/

Final /-j/ is also realised as [-ɥ] after [œ] (Cheung, 1986), and this must be reflected in the presentation of test stimuli. Minimal pairs contrasting sociolinguistic variants of final consonants in (12) are excluded, and subjects should be scored correctly for either production.

(12) Current sound changes affecting final consonants (adapted from To et al., 2015, p. 336)

	Variation	Example	Character	Gloss	Frequency (Adults)	Frequency (Children)
a.	/-n/ → [-ŋ]	/hœŋ55/ → [hœn55]	香	‘fragrant’	24.1%	29.7%
b.	/-ŋ/ → [-n]	/kɔn55/ → [kɔŋ55]	乾	‘dry'	0.8%	5.0%
c.	/-t/ → [-k]	/kœk3/ → [kœt3]	腳	‘foot'	2.6%	2.8%
d.	/k-/ → [-t]	/hɔt3/ → [hɔk3]	渴	‘thirsty'	8.0%	14.5%

3.2.5 Vowels

The representation of Cantonese vowels is a controversial topic. In this sub-section, I present the vowel system (see Figure 3) and rime combinations (see Table 4) adopted here and assign vowel parameter settings.

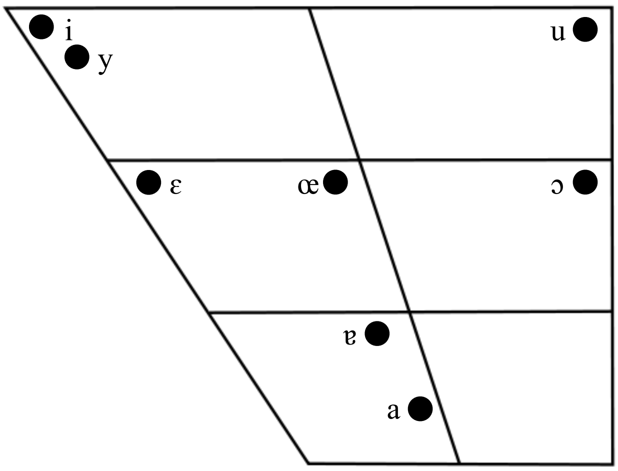


Figure 3. Vowel system of Cantonese
(adapted from Stokes & Wong, 2002, p.601)

Table 4. Rime combinations in Cantonese
(compiled and adapted from Barrie, 2003, p. 5; Bauer, 1985, pp. 101-102; Cheung, 1986, pp. 31-38; Hashimoto, 1972, p. 90)

	∅	**/-j/**	**/-w/**	**/-m/**	**/-n/**	**/-! /**	**/-p/**	**/-t/**	**/-k/**
/i/	[iː]		[iw]	[im]	[in]		[ip]	[it]	
['\]						[ɪŋ]			[ɪk]
/y/	[yː]				[yn]			[yt]	
/u/	[uː]	[uj]			[un]			[ut]	
[#]						[ʊŋ]			[ʊk]
/$/	[ɛː]		[ɛw]	[ɛm]	[ɛn]	[ɛŋ]	[ɛp]	[ɛt]	[ɛk]
[e]		[ej]							
/œ/	[œː]			[œm]		[œŋ]			[œk]
[ø]		[øɥ]			[øn]			[øt]	
/%	[ɔː]	[ɔj]			[ɔn]	[ɔŋ]		[ɔt]	[ɔk]
[o]			[ow]	[om]			[op]		
/a/	[aː]	[aj]	[aw]	[am]	[an]	[aŋ]	[ap]	[at]	[ak]
/&		[ɐj]	[ɐw]	[ɐm]	[ɐn]	[ɐŋ]	[ɐp]	[ɐt]	[ɐk]

The eight vowel phonemes in Cantonese combine with different final consonants, and all except /ɐ/ can appear independently in a CVV syllable. Previous analyses have taken vowel length to be contrastive within each pair (e.g., Lee, 1983). Encoding this length contrast complicates the simple canonical (C)VX structure by introducing superheavy CVVC syllables. However, Table 4 shows the restricted occurrence of 'long' vowels in complementary distribution with 'short' vowels. Length is thus phonologically predictable, and the allophonic difference is better characterised as a tense-lax dichotomy in quality (Duanmu, 2009, 2011; Hashimoto, 1972). Only the pair /a, ɐ/ must be recognised as separate underlying phonemes (Zee, 2003; in Duanmu, 2009) because they contrast in all positions except where /ɐ/ cannot appear independently. Like Mandarin then, Cantonese vowel length is prosodically conditioned to satisfy bimoraicity requirements and allow association with contour tones (Duanmu, 1990, 1999, 2014; Gordon, 2006; Yip, 1997, 2002).

In considering whether /y/ is a true phoneme or an allophone of /u/, Cheung (1986) claimed that there are no minimal pairs as [u] only occurs with labial initials while [y] appears elsewhere. Bauer and Benedict (1997) refuted this by pointing out contrasts after velar stops, e.g., (13).

(13) Contrastivity of /u/ and /y/ (adapted from Bauer & Benedict, 1997, p. 82)

	/u/			**/y/**		
	Example	**Character**	**Gloss**	**Example**	**Character**	**Gloss**
a.	/kun55/	官	'officer'	/kyn55/	捐	'donate'
b.	/kun35/	館	'public building'	/kyn35/	捲	'roll up'
c.	/k^{h}ut3/	括	'include'	/k^{h}yt3/	缺	'lack'
d.	/kut1/	嗗	'gulp'	/kyt1/	橛	'section'

Although the CanNWR parameters are only concerned with the eight underlying vowel phonemes, test stimuli must be presented with the correct allophones.

Element Theory is a useful framework for establishing vowel parameter settings. Each basic element |**I**, **A**, **U**| can be phonetically realised independently, namely as [i, a, u] (Backley, 2011). These three vowels occur in all languages, are the exact vowels found in a three-vowel system, and are the "extreme points in the acoustic vowel space" with "maximally distinct acoustic properties" (Backley & Nusakawa, 2009, p. 52; Backley, 2011, p. 20). Furthermore, they are acquired early cross-linguistically, including in Cantonese[2] (Cheung, 2000; Lindblom, 1986). Element Theory is advantageous in straightforwardly capturing these unique properties of the three universally unmarked vowels—each is represented as a simplex unit with a single element, contra other vowels that require elements to combine in compound expressions, so are complex and more marked (Backley, 2011).

The front rounded vowels /œ, y/ are most marked universally. They combine the elements |**I**, **U**|, whose acoustic properties conflict because |**I**| increases F2, whereas |**U**| decreases F2 (Backley, 2011). They are also found in less than 7% of the world's languages (Backley, 2011) and are the last vowels acquired by Cantonese children (To et al., 2013).[3]

Vowel parameter settings are given in (14).

(14) Vowels parameter

Less marked		More marked
Others	vs	Front rounded
/i, a, u, ɛ, ɔ, ɐ/		/œ, y/
e.g., /tɔː33/		e.g., /tyː33/
Simplex	vs	Complex
/i, a, u/		/ɛ, ɔ, ɐ/
e.g., /taː33/		e.g., /tɔː33/

3.2.6 Tones

Of the six lexical tones (see Table 5), three are level tones on sonorant-final syllables with phonetically similar checked allotones on obstruent-final syllables (Barrie, 2007). The remaining three are contour tones carried only by sonorant-final syllables, most likely because the sonorous portion of the rime in CVO syllables is too short to associate with contour tones (Gordon, 2006).

[2] The rime combinations [iw, uj] comprising the unmarked /i, u/ are acquired later than other 'diphthongs' (To et al., 2013), perhaps due to the lack of agreement in roundness and frontness. However, both are still acquired early by age 3;6.

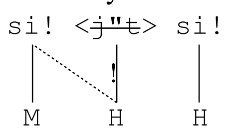
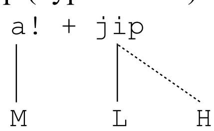
[3] Interestingly, [øɥ] is acquired significantly earlier than underlying /œ/. I thank Florian Breit for his suggestion that the presence of rounding through both its segments could make it more perceptually salient than [œ] alone.

Table 5. Tonal inventory of Cantonese[4]
(adapted from Chow, Belyk, Tran & Brown, 2015, p. 58)

Jyutping (description)	**Register**	**Unchecked Tones**			**Checked Allotones**		
		Example	**Character**	**Gloss**	**Example**	**Character**	**Gloss**
1 (high level)	[+upper]	/si:55/	詩	‘poem'	/sik5/	色	‘colour’
2 (high rising)		/si:35/	史	‘history'			
3 (mid level)		/si:33/	試	‘to try’			
4 (low falling)	[-upper]	/si:21/	時	‘time’	/sik3/	舌	‘tongue’
5 (low rising)		/si:23/	市	‘city’			
6 (low level)		/si:22/	事	‘affair’	/sik2/	食	‘to eat’

A historical seventh tone [53] has merged with [55] and is no longer contrastive in Hong Kong Cantonese, hence is excluded here (Barrie, 2007; Yip, 2002). Consequently, the purported tone sandhi of [53] to [55] before another high tone is no longer active (Tse, 1978). Except for two sub-regularities, Cantonese tones do not change in concatenated words or connected speech (Chen, 2000; Matthews & Yip, 2011; Yip, 2002). Firstly, syllable elision may result in reassociation of the stranded tone to a preceding host, e.g., (15a). Secondly, morphologically conditioned alternations may change the meaning of lexical items, e.g., (15b) or attach a floating high tone hypocoristic suffix, e.g., (15c). Since none of these cases are phonologically conditioned (Tse, 1978), nonce syllables can be freely combined without concern for tone sandhi.

(15) Tone changes (adapted from Chen, 2000, p. 34, 60; Yip, 2002, p. 177)

	Underlying Representation	**Characters**	**Surface Form**	**Overall Gloss**
a.	/si:33 <jɐt5> si:33/ try ASP try	試一試	[si:35 si:33]	‘give it a try’ 
b.	/tʰɔŋ21/ sugar	糖	[tʰɔŋ35]	‘candy’
c.	/jip2/ Yip (surname)	葉	[a:33 jip25]	‘Yip (hypocoristic)’ 

[4] Numerical tone values use Chao’s (1930) scale system and are not phonetic transcriptions.

Contour tones are more marked than level tones (Yip, 2002) following from the implicational universal that languages with contour tones also have level tones (Zhang, 2002). Furthermore, children acquire level tones before contour tones (Tse, 1978) while people with aphasia lose contour tones before level tones (Yip, 1980).

The feature *register* divides the pitch range into [±upper] (Kao, 1971; Yip, 1980), distinguishing the more marked [22] from the less marked [55, 33] ([2] versus [5, 3] for checked allotones) due to the greater perceptual salience and earlier acquisition of [+upper] tones (Fok, 1974; Tse, 1991).

Tone parameter settings are given in (16).

(16) Tones parameter

Unchecked Tones		
Less marked		**More marked**
Level	vs	Contour
[55, 33, 22]		[35, 21, 23]
e.g., /pʰim55/		e.g., /pʰim35/
[+upper]	vs	[-upper]
[55, 33]		[22]
e.g., /pʰim55/		e.g., /pʰim22/
Checked Allotones		
Less marked		**More marked**
[+upper]	vs	[-upper]
[5, 3]		[2]
e.g., /jɛt5/		e.g., /jɛt2/

4. CanNWR test

A sample set of CanNWR test stimuli is provided in the Appendix, using only nonce syllables and avoiding duplication to prevent syllables from being interpreted as individual words. A multi-step process was used to generate and select stimuli, taking into account phonemic lexicons, phonotactic restrictions, syllable-likeness, and cumulative markedness scores.

4.1 Nonce syllable selection

4.1.1 Phonemic lexicons

Tang (2017) compiled a novel-based written corpus of Cantonese. A unified pronunciation dictionary, obtained through pre-processing and unification of multiple open-source pronunciation dictionaries, was used as a base lexicon for segmentation with the Viterbi algorithm and transcription. The corpus consists of 11.4 million word tokens and 80,896 word types. Some words had to be removed due to unavailable pronunciations or if they contained only Latin letters and were not in the dictionary. Word types found in fewer than three documents were also deleted to remove noise. Monosyllabic English words or syllables that cannot be matched to a single Cantonese character were further filtered out, producing 16.3 million syllable tokens and 1,791 syllable types. Permutations of all (C)VX syllables were generated, and real syllables were removed by checks against the corpus.

4.1.2 Phonotactic restrictions

Nonce syllables fill either accidental or systematic gaps. The former conform to the language's phonotactic restrictions, so are permissible but simply non-occurring sequences. The latter violate phonotactic restrictions, so are impossible sequences (Bauer & Benedict, 1997; Kirby & Yu, 2007). In what follows, I consider seven reported co-occurrence restrictions (CRs) to identify systematic gaps, which are excluded to ensure phonotactic wellformedness.[5]

[5] Analyses of CRs are beyond the scope of this paper but include obligatory contour principle type effects (Cheng, 1991; Yip, 1988), locality conditions and planar V/C segregation (Yip, 1997), and feature merger and percolation (Duanmu, 1990).

4.1.2.1 Velar consonants

The CR blocking velar finals after /i, y, u/ follows from an analysis of /e/ and /o/ as underlying phonemes with the allophones [ɪ] and [ʊ, ø] respectively (Cheung, 1986; Kenstowicz, 2012; Yip, 1997). Under my analysis, [ɪ, ʊ] are allophones of /i, u/, so only */-yk, -yŋ/ are systematic gaps.

4.1.2.2 Anterior consonants

An alleged CR on [ɛ, e, œ, ø, o] before labial and coronal finals ([ɛ, ɪ, œ, ø, ʊ] under my vowel system) (Kenstowicz, 2012) overlooks the occurrence of [-ɛw, -ɛm, -ɛp, -ɛn, -ɛt, -œm, -øn, -øt] in colloquial, onomatopoeic, borrowed, and even non-colloquial words (Bauer, 1985; Bauer & Benedict, 1997; Cheung, 1986) like (17a-h). Under my analysis, [ɪ, ø, ʊ] are allophones of /i, œ, u/ respectively. Since combinations of /i/ with anterior consonants are attested, only (17i-m) constitute systematic gaps.

(17) Vowels with final anterior consonants (Bauer, 1985, p. 107; Bauer & Benedict, 1997, pp. 61, 70-71, 76-78; Cheung, 1986, pp. 33-34; Tang, 2017)

a.	[tɛw22]	□ ‘throw’	□ characters without orthographic forms
b.	[lɛm35]	舐 ‘lick’	
c.	[kɛp5-tøn35]	喼嗵 ‘captain’	
d.	[fɛn55]	□ ‘friend’	
e.	[kɛt5]	□ ‘giggling sound’	
f.	[tʰœm55]	□ ‘term’	
g.	[tøn55]	敦 ‘honest’	
h.	[søt5]	恤 ‘shirt’	
i.	*/-œw/		
j.	*/-œp/		
k.	*/-uw/		
l.	*/-um/		
m.	*/-up/		

4.1.2.3 Labial consonants

The co-occurrence of labial initial and final consonants was thought to be entirely prohibited, with exceptions in colloquial, onomatopoeic, and borrowed words (Hashimoto, 1972; Kao, 1971; Yip, 1988), e.g., (18a-g). However, these gaps are readily filled, so it is problematic to posit a phonotactic constraint that categorically bans such combinations (Bauer, 1985; Cheng, 1991; Yu, in press). In fact, labial-labial co-occurrence is found even in non-colloquial words (Bauer & Benedict, 1997), e.g., (18h-j), and thus (18k-l) are simply historical-accidental gaps (Duanmu, 1990). Meanwhile, (18m) is the only known instance where /$k^{w(h)}$-/ co-occurs with a labial final, so the status of other gaps with labial-velars is unclear, and the CanNWR set excludes them for now.

(18) Labial initials and finals (Bauer, 1985, pp. 101-102; Bauer & Benedict, 1997, pp. 417-418; Cheung, 1986, p. 165; Duanmu, 1990, p. 69; Tang, 2017)

^{n} non-occurring

a.	[pɐm55]	泵 ‘pump’	
b.	[pip5]	□ ‘beep’	
c.	[mɐm55]	餶 ‘food (baby talk)’	
d.	[wɔm55]	□ ‘warm’	
e.	[wɛp5]	□ ‘rap’	
f.	[wow55]	旺 ‘bark’	
g.	[fœm55]	□ ‘firm’	
h.	[p^{h}ow23]	抱 ‘embrace’	
i.	[maw55]	貓 ‘cat’	
j.	[fɐw35]	否 ‘negate’	
k.	^{n}[mVp]		
l.	^{n}[fVp]		
m.	[k^{wh}im55]	□ ‘cream’	
n.	*[k^{w}Vm]		
o.	*[k^{w}Vw]		
p.	*[k^{w}Vp]		
q.	*[k^{wh}Vw]		
r.	*[k^{wh}Vp]		

Rounded vowels have been claimed to be banned before labial finals (Cheng, 1991; Yip, 1988; Yu, in press), but (19-20) show that some combinations are attested.

(19) Labial finals with rounded vowels (Cheng, 1991, p. 109)

*/-yw/	*/-uw/	*/-œw/	/-ɔw/
*/-ym/	*/-um/	/-œm/	/-ɔm/
*/-yp/	*/-up/	*/-œp/	/-ɔp/

(20) Attested labial finals with rounded vowels (Tang, 2017)

a. [tʰœm55] □ 'term'

b. [hɔw35] 好 'good'

c. [fɔm55] □ 'form'

d. [tsɔp5] □ 'job'

Another CR supposedly prohibits labial initials before front rounded vowels but not before back rounded vowels (Cheng, 1991; Duanmu, 1990; Yip, 1988; Yu, in press), e.g., (21). However, labial initials co-occur with front rounded vowels in loanwords (Bauer & Benedict, 1997), e.g., (22a) and in contracted disyllables in connected speech (Cheung, 1986), e.g., (22b-c). Thus, remaining gaps are accidental (Duanmu, 1990), and only combinations of labial-velars before front round vowels constitute systematic gaps (Bauer & Benedict, 1997; Cheung, 1986). (23) provides a summary.

(21) Labial initials with back rounded vowels (Cheng, 1991, p. 109; Duanmu, 1990, p. 69)

a. [pʰun21] 盤 'platter'

b. [mɔː55] 嚤 'slow'

c. [fɔː33] 貨 'goods'

d. [wɔː21] 和 'harmonious'

e. [kʷɔŋː55] 光 'light'

f. [kʷɔk3] 國 'country'

(22) Attested labial initials with front rounded vowels (Bauer & Benedict, 1997, p. 418; Cheung, 1986, p. 243)

	Example		Characters	Overall Gloss
a.	/pʰœ:22 sɛn55/		巴仙	'percent'
	Isolated Citation Form	**Contracted Form**		
b.	/pʰej33 ju:21/	[pʰy:33+21]	譬如	'for example'
c.	/pɐt5 ju:21/	[py:5+21]	不如	'it'd be better'

(23) Labial initials with front rounded vowels

	/p-/	**/pʰ/**	**/m-/**	**/w-/**	**/f-/**	**/kʷ/**	**/kʷʰ/**
/y/	+	+	+	+	+	-	-
/œ/	+	+	+	+	+	-	-

\+ wellformed
\- illformed

4.1.2.4 Coronal consonants

A CR prohibiting coronal initials before /u/ (Kirby & Yu, 2007) is invalidated by the examples in (24). Cheng (1991) suggested that only combinations of /u, ɔ/ with *both* coronal initial and final consonants are truly illformed (contra (25)) but these gaps are also beginning to be filled by loanwords, e.g., (26). Until more is understood about coronal consonant CRs, I maintain that combinations other than [tʰun, sut, sɔt] are systematic gaps.

(24) Coronal initials with /u/ (Bauer & Benedict, 1997, p. 54, 91; Tang, 2017)

a. [tʰʊŋ33] 痛 'painful'

b. [tʊk2] 讀 'to read'

c. [tu:55] □ 'do'

d. [nʊŋ21] 濃 'concentrated'

e. [sʊk2] 熟 'familiar'

f. [tsuj22] 墜 'fall down'

g. [lʊŋ55] 窿 'hole'

h. [ki:55-li:55-ku:55-lu:55] 嘰哩咕嚕 'gibberish'

(25) Coronal initials or finals with back rounded vowels (Bauer & Benedict, 1997, p. 91; Cheng, 1991, p. 110)

a. [tʰɔk3] 托 'to support'

b. [tsɔ:35] 左 'left'

c. [lʊk2] 六 'six'

d. [pʰut33] 潑 'to splash'

e. [mun22] 悶 'bored'

f. [kɔt3] 割 'to cut'

(26) Both coronal initials and finals with back rounded vowels (Tang, 2017)

a. [tʰun55] □ 'tune'

b. [sut5] □ 'suit'

c. [sɔt5] □ 'short'

4.1.2.5 Glides

Initial glides occur before non-high vowels and homorganic high vowels (Bauer & Benedict, 1997), e.g., (27-28). Although the heterorganic combination [wi-] appears in onomatopoeic, colloquial, or borrowed words, e.g., (29a-c), [ju-] is a systematic gap (Bauer & Benedict, 1997), e.g., (29d-f). This CR only applies to tense high vowels since [wɪ-] and [jʊ-] are clearly wellformed, e.g., (29g-j).

(27) Initial glides with non-high vowels (Bauer & Benedict, 1997, pp. 53, 63, 66, 78-80)

a. [jɛ:23] 嘢 'thing'

b. [jɐw55] 休 'rest'

c. [ɥœɥ22] 銳 'sharp'

d. [ɥœn22] 潤 'moist'

e. [wɐn21] 雲 'clouds'

f. [wat2] 滑 'slippery'

(28) Initial glides with homorganic high vowels (Bauer & Benedict, 1997, pp. 52, 54-55, 59, 64, 74-76, 81-82)

a.	[jiː22]	二 'two'
b.	[jiw55]	腰 'waist'
c.	[jin55]	煙 'smoke'
d.	[jit2]	熱 'hot'
e.	[ɥyː23]	雨 'rain'
f.	[ɥyn23]	圓 'round'
g.	[ɥyt2]	月 'month'
h.	[wuː55]	烏 'black'
i.	[wuj22]	會 'society'
j.	[wun35]	碗 'bowl'
k.	[wut2]	活 'alive'

(29) Initial glides with heterorganic high vowels (Bauer & Benedict, 1997, pp. 59, 64, 74-75, 81-82, 85, 91)

a.	[wiw35wiw35sɪŋ55]	□□聲 'police siren squeal'
b.	[wit5]	□ 'creaking'
c.	[win55]	□ 'win'
d.	*[juj]	
e.	*[jun]	
f.	*[jut]	
g.	[wɪŋ23]	永 'forever'
h.	[wɪk2]	域 'area'
i.	[jʊŋ22]	用 'to use'
j.	[jʊk2]	郁 'to move'

Conversely, (30-31) show that final glides cannot share place features with a preceding high vowel (Barrie, 2003; Bauer & Benedict, 1997).

(30) Final glides with homorganic high vowels

a. */-ij/

b. */-yj/

c. */-uw/

(31) Final glides with heterorganic high vowels (Bauer & Benedict, 1997, pp. 59, 64)

a. [kiw33] 叫 'to call'

b. [liw35] 料 'material'

c. [p^huj33] 配 'to match'

d. [muj23] 每 'each'

4.1.2.6 Tones

Two CRs have been claimed to ban [21] with unaspirated initials and [22] with aspirated initials (Kirby & Yu, 2007; Yu, in press). However, there is no apparent phonotactic reasoning for this. Speakers' word-likeness ratings also indicated no dispreference for such non-occurring syllables (Kirby & Yu, 2007). Moreover, (32-33) show that certain combinations are in fact attested. Thus, tone CRs can be dismissed.

(32) Low falling tone [21] with unaspirated initials (Tang, 2017)

a. [pa:21pa:55] 爸爸 'father'

b. [di:21] 哋 *translation unavailable*

c. [ka:21] 㗎 (final particle to express disapproval)

(33) Low level tone [22] with aspirated initials (Tang, 2017)

a. [p^hɔw22] □ 'pro'

b. [k^hɛk2] 劇 'drama'

c. [ts^hak2] 賊 'thief'

4.1.2.7 Consonant clusters

Consonant clusters appear across syllable boundaries but not syllable-internally. The only exceptions arise from contraction (Bauer, 1985; Cheung, 1972, in Cheung, 1986), e.g., (34), but since /l/ is excluded, CanNWR avoids Cl- clusters and preserves the (C)VX syllable structure.

(34) Cl- clusters (Bauer, 1985, p. 108; Cheung, 1972, in Cheung, 1986, pp. 112-115)

	Isolated Citation Form	Contracted Form	Characters	Overall Gloss
a.	/hɐm22-ba:22-laŋ22/	[hɐm22 blaŋ22]	冚把呤	‘all’
b.	/fi:21-li:55-fɛt21-lɛt21/	[fli:55 flɛt21]	飛哩□□	‘crying sounds’
c.	/haj55-ka:55-la:55-si:35/	[haj55 kla:55 si:35]	□□□□	‘high class’

Across a syllable boundary, a consonant may undergo progressive or regressive place assimilation to a preceding or following consonant respectively (Cheung, 1986; Leung et al., 2004). Productions showing this effect should not be marked as errors.

4.1.3 Syllable-likeness

Word-likeness is determined by both phonotactic probabilities and lexical neighbourhoods (Bailey & Hahn, 2001). Its influence on NWR accuracy (see §2.1) makes it a crucial consideration in token selection.

Unexpectedly, Kirby and Yu’s (2007) study of Cantonese speakers’ word-likeness judgements found that phonotactic probabilities were weakly correlated with their ratings and in fact negatively correlated with ratings of attested syllables. Contrary to the classical generative phonology model, accidental gaps were not judged to be categorically wellformed and systematic gaps categorically illformed. Instead, ratings of systematic gaps correlated strongly with lexical neighbourhoods, particularly for tone gaps.

Attested initial biphones were not entirely removed from CanNWR because doing so would have drastically limited the available nonce syllable set (cf. Stokes et al. (2006) who treated diphthongs as a single V segment). However, their frequencies were accounted for in syllable-likeness checks. Nonce syllables were sorted according to neighbourhood density and neighbourhood frequency. Density refers to the number of neighbours and frequency refers to their average token frequencies.

Like UNWR, CanNWR tokens have zero neighbours. However, given the limited availability of nonce syllables after filtering out attested syllables and systematic gaps, syllables in polysyllabic tokens have a neighbourhood density of up to seven (homophone neighbourhood density of up to 11) and average neighbourhood frequency of up to 160.

4.2 Token selection

This sub-section demonstrates the implementation of CanNWR in a test.

4.2.1 Cumulative markedness scores

One point is assigned to the more marked item in each sub-parameter, excluding syllable count, to calculate cumulative syllable markedness scores. The CanNWR test has four syllable count levels, with eight steps (tokens) in each. Steps increase in cumulative markedness within a level. Corresponding steps in Levels 2 to 4 have approximately equal mean scores.

Restraint is required in stringing multiple nonce syllables together because concatenating too many 'highly marked' syllables could make the test overly difficult.[6] Initial syllables are never so marked as to impede progress while the position of more marked syllables is randomised across tokens.

Relative weightings of parameters have not been considered at this preliminary stage but should be factored into a final CanNWR test. I also leave open the question of how to integrate syllable count markedness with cumulative markedness scores, which is necessary to ensure a hierarchical order across levels.[7]

(35) recapitulates the full selection process.

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[6] An NWR set should accurately reflect the language's transitional probabilities between syllables (Levelt & Wheeldon, 1994) to provide a more effective test of phonological ability (Chan et al., 2011), but this is not of concern here since Cantonese syllables can be freely concatenated.

[7] I thank Kevin Tang for his input on this in particular.

(35) Selection process

Step 1: Generate all permutations of (C)VX syllables

Step 2: Filter out real syllables through checks against the phonemic lexicon

Step 3: Filter out systematic gaps through examination of phonotactic restrictions

Step 4: Sort by syllable-likeness as measured by neighbourhood density and frequency

Step 5: Further sort by cumulative syllable markedness score

Step 6: Concatenate syllables for each syllable count level, maintaining approximately equal mean markedness scores for corresponding steps in Levels 2 to 4

4.2.2 Operational considerations

For practical reasons, the CanNWR test should be brief and easily administered. Subjects should be tested and audio recorded in a quiet room, with live voice presentation of stimuli to encourage attention, cooperation, and responsiveness (Kirk & Lento, 2000; Roy & Chiat, 2004; Varley & So, 1995). They should be instructed to listen to and repeat the made-up words, taking as much time as required. Stimuli should be presented in the prescribed order with three practice tokens before eight test tokens at each level. Recordings should be transcribed and assessed for intra- and inter-judge reliability. Segmental accuracy could be scored on various features (see, e.g., Edwards, Beckman & Munson, 2004), but vowel productions should not be scored, due to the general variability in vowel quality and specific complexity of the Cantonese vowel system. Variations resulting from current sound changes or phonological alternations should also be ignored. At each level, all stimuli should be tested, but I propose that 75% accuracy could permit progression to the next level for more extensive testing.

5. Future direction

Before concluding, I lay out explicit directions for future work.

Further theoretical investigation of Cantonese phonology and phonotactics should be conducted to clarify areas of discrepancy in the literature, ensure well-defined parameters, and classify accidental and systematic gaps. Gaps that are being filled can be considered accidents, which increases the number of available nonce syllables with zero or low neighbourhood density, but native speaker word-likeness ratings should be obtained for an additional evaluation of their wellformedness. The corpus should be expanded to better reflect colloquial, spoken language (see, e.g., Gimenes & New, 2016) and improve checks against the phonemic lexicon. Syllable count markedness and relative parametrical weightings should be fed into the calculation of cumulative markedness scores, and a pilot study would be advisable to refine operational procedures and scoring methods. Finally, the CanNWR test must be trialled to provide a conclusive response to Stokes et al.'s (2006) claim that NWR cannot screen for SLI in Cantonese children.

CanNWR makes a first step in exploring the extension of UNWR to tone languages. However, the parameters proposed here are significantly different from those appropriate for Indo-European languages. The difference is sufficiently great as to cast doubt on the feasibility of a truly universal version of UNWR. Nevertheless, CanNWR lays strong groundwork for developing a more general NWR set valid for tone or Sinitic languages. Future work should adjust these parameters to account for other types of tonal systems, such as sub-Saharan African languages, which generally only have level tones (Yip, 2002), and languages with tone sandhi, like Beijing Mandarin (Chen, 2000). A Sinitic NWR set would also need to account for languages with restrictions on syllable finals, for instance Mainstream Shanghai, in which all syllables are underlyingly CV with no final X (Duanmu, 1994, 1999).

6. Conclusion

The literature abounds with research on NWR tests, phonological theories of Cantonese words, syllables, phonemes, and tones, language typology, and child language acquisition. Unfortunately, insights to one area have not always fed into the others. This paper has examined design requirements of NWR tests then consolidated and reconciled multiple analyses of Cantonese phonology and phonotactics. Its product is a Cantonese NWR set that is informed by phonological theory, typological descriptions, and acquisition patterns, and further controlled for lexical effects. Herein lies its contribution.

Appendix: Sample CanNWR test stimuli

The tokens are listed with mean cumulative syllable markedness scores.

	Level 1		Level 2	
	Token	**Score**	**Token**	**Score**
Practice 1	/ŋɔm33/	2	/ŋɔj23-wɛt3/	3.5
Practice 2	/pɛw21/	3	/pʰɔm55-kʷɔj23/	4.5
Practice 3	/pœm22/	4	/wœ:23-kʷʰik3/	5
Step 1	/wɛw33/	1	/mɛw33-ŋœ:22/	2
Step 2	/ŋɔp3/	2	/tʰɛw22-wɛn33/	2.5
Step 3	/kɛw23/	3	/ŋuk3-ŋœm55/	3
Step 4	/ŋɔt5/	4	/fɛw33-tɔm23/	3.5
Step 5	/kʰɔm23/	5	/ŋœm33-kɔp2/	4
Step 6	/tsʰɛn22/	6	/pœm55-tsʰɛw23/	4.5
Step 7	/œm23/	7	/kɛn21-tʰɛp2/	5
Step 8	/kʷʰɔt2/	8	/mik3-kʷʰɛt2/	5.5

	Level 3		Level 4	
	Token	**Score**	**Token**	**Score**
Practice 1	/nœ:33-kʰɔm55-fɛm22/	3.33	/kɔm21-mœm33-tɛm21-pœm33/	3.5
Practice 2	/ŋik3-ɛn22-pɔm23/	4	/wɛm22-kʰɛm33-tɐm23-wœt3/	3.75
Practice 3	/ŋɛw35-kɛn23-pʰyt5/	4.33	/ŋaŋ33-pʰɛn22-fɔp2-mɐp3/	4
Step 1	/pɔj23-wɛw55-ŋɛm33/	2	/ŋɛw55-jɔj23-ŋɛn33-mɔm33/	2
Step 2	/tɛw21-ŋɔm55-mɛn33/	2.33	/kʰɛn33-ŋɛw22-ŋœ:55-wɛw35/	2.5
Step 3	/pɛw23-ŋœ:33-mɔp3/	3	/wœm55-pʰœ:23-ŋɛw33-ŋap5/	3
Step 4	/ŋɛw23-kʰɔm22-ŋut5/	3.33	/jap5-ŋɔn23-tɛn21-pʰɛw22/	3.5
Step 5	/ŋɔm22-kɛw21-sɔm23/	4	/pɔm21-tsʰɛw22-tœ:23-ŋɛw21/	4
Step 6	/fik3-ŋɛm22-fɔj23/	4.33	/tʰɛm22-kʷʰut5-mɛm33-ɛn35/	4.5
Step 7	/wɛm33-fɛp3-tsɔm21/	5	/mœk5-wɛw23-tsʰɛp2-ŋɐt3/	5
Step 8	/tœm23-tsʰɔp2-wɛw21/	5.33	/fɛw23-wœm33-ɛp2-hœm23/	5.5

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