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Analysis of variation in Mayan child phonologies

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Abstract

This paper uses the methods of consonant inventories and discriminant analysis to examine the variation in word-initial consonants produced by 24 children acquiring six Mayan languages. The range of variation in the consonants that children produce has significant implications for theories that predict children follow universal processes of consonant development as well as theories that predict individual children exhibit unique developments. The results show variation exists between children acquiring the same language as well as between children acquiring different languages. Both the qualitative and quantitative results demonstrate the structure of the adult phonologies restricts the range of the children's variation within each language even though the children omit a variety of word-initial prefixes. The investigation of language acquisition in related languages reveals how children's attention to the adult language limits the operation of both universal and individual processes.

Keywords: Child phonology; Initial-consonant acquisition; Mayan languages; Crosslinguistic comparison

1. Introduction

Jakobson (1941/1968) viewed phonological development as a competition between the ‘‘unifying force’’ and the ‘‘particularist spirit.’’ On the physical level unifying forces derive from common features of motor development (Macneilage et al., 1997) as well as on a more abstract phonological level from feature markedness (Gnanadesikan, 2004). Jakobson, himself, claimed that ‘‘Whether it is a question of French or Scandinavian children, of English or Slavic, of Indian or German, or of Estonian, Dutch or Japanese children, every description based on careful observation repeatedly confirms the striking fact that the relative chronological order of phonological acquisition remains everywhere and at all times the same’’ (1941/1968:46).

The particularist spirit derives from individual children's cognitive propensities (Menn, 1983; Menn and Vihman, 2011; Macken and Ferguson, 1983). Vihman (2006) asserts that ‘‘the wide range of individual differences in this period [first words, CP] continues to resist coherent formulation in terms of universal phonetic or phonological principles, even across children acquiring a single language.’’ Straight proposed that ‘‘Phonology acquisition proceeds in a relatively piecemeal and idiosyncratic manner, despite presumably highly limited and homogeneous sources of input data from adult speakers’’ (1978:216).

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The competition between unifying forces and particularist spirits feeds into the debate between generative and constructionist theories of language acquisition. Generative theories propose universal processes of language development based on feature or constraint hierarchies (Bernhardt and Stemberger, 1998; Rose, 2009), whereas constructionist theories place greater emphasis on what individual children absorb from the input language (Lieven, 2010; Menn and Vihman, 2011).

Research into the effects of unifying forces and particularist spirits must address the range of variation in children's phonological productions. If language-independent unifying forces are major determinants of children's phonological inventories we expect to find little variation between children and across languages. On the other hand, if the particularist spirit predominates, we expect to find a great deal of variation between children acquiring the same or different languages. The issue of variation has interesting crosslinguistic implications. We might find that children follow the same process of phonological development in all languages or just in some languages. Children might also exhibit the same degree of variation across all languages or just in some languages. A crosslinguistic exploration of variation in child phonologies is an essential step to understanding how particularist spirits interact with unifying forces.

However insufficient attention has been devoted to the problem of crosslinguistic comparison (Pye, 2017). Corresponding phonetic segments in different languages may have similar voicing, place and manner of articulation features, but differ in strength, duration and attack features. Stress is realized by different combinations of duration, pitch and amplitude across languages. The ''same'' phonetic segments may be allophones of different phonemes and differ in their frequency of use and phonotactic constraints. The use of the same phonetic characters in studies of children acquiring different languages gives the false impression that the children have acquired the same phonological categories.

Finding similarities between children acquiring a few languages is not a sufficient basis for establishing universals of phonological development because the languages do not constitute a representative sample. Finding differences between children acquiring one or more languages is not evidence for the dominance of the particularist spirit because the sample of languages may exaggerate differences that are limited to those languages. Great care is needed to craft a method of comparing phonological development across languages in order to determine the balance between unifying forces and particularist spirits.

We present two studies of variation in the production of initial consonants by children acquiring six Mayan languages. The use of historically related languages minimizes the phonetic, phonotactic and phonological differences between the adult languages as well as cultural differences in child rearing and child-directed speech. These controls are instrumental to understanding individual variations in the children's developing phonologies. Study One uses a qualitative method to assess the similarities and differences in the children's initial consonant inventories. This study shows that Mayan children share a common core of early consonants, but nevertheless exhibit language-specific departures from the core. Study Two presents a statistical analysis of the variation in the children's consonant production. We find that although individual children vary in the consonants they produce, their range of variation differs from that of children acquiring the other languages. The two studies demonstrate the effect of the adult phonologies on the children's phonological development and argue against purely individualist and universalist accounts.

In the following section of the paper we describe the Mayan consonant inventories and their phonetic realizations. The third section of the paper describes the children and the method we used to record and analyze their consonant productions. We present Study One in the fourth section of the paper and Study Two in the fifth section. We conclude with a discussion of the findings.

2. The Mayan language family

The Mayan language family contains 30 languages which are currently spoken in Mexico, Guatemala, Belize and Honduras (England, 1994) with a historical divergence of approximately four thousand years (Kaufman, 1990). We analyzed acquisition data from children acquiring six Mayan languages: Teenek (Wastekan), Yucatec (Yukatekan), Ch'ol (Ch'olan), Q'anjob'al (Q'anjob'alan), Mam (Mamean) and K'iche' (K'iche'an). Fig. 1 shows the geographic distribution of these six Mayan languages.

Teenek is the autonym for the Wastek language. It is spoken in the states of San Luis Potosí and Veracruz in northeastern Mexico. Teenek was heavily influenced by the nearby Nahuatl languages, and is the only Mayan language that has the phonemes /kw, k'w and θ/. Varieties of Yucatec are spoken today across the Yucatan peninsula in Mexico. Yucatec has a long history of contact with the Ch'olan languages. Yucatec and Ch'ol share the innovated voiceless bilabial ejective /p'/ as well as the loss of the uvular stops /q and q'/. Ch'ol is spoken along the northern border of the state of Chiapas in southern Mexico. Q'anjob'al is spoken in the northwestern region of Guatemala in the department of Huehuetenango. Mam is spoken to the south of the Q'anjob'al region in the western border region of Guatemala. K'iche' is spoken to the east of Mam in the western highland region of Guatemala. While Mam and K'iche' are closely related historically, Mam has had intensive contact with the Q'anjob'alan languages. Q'anjob'al and Mam innovated the retroflex

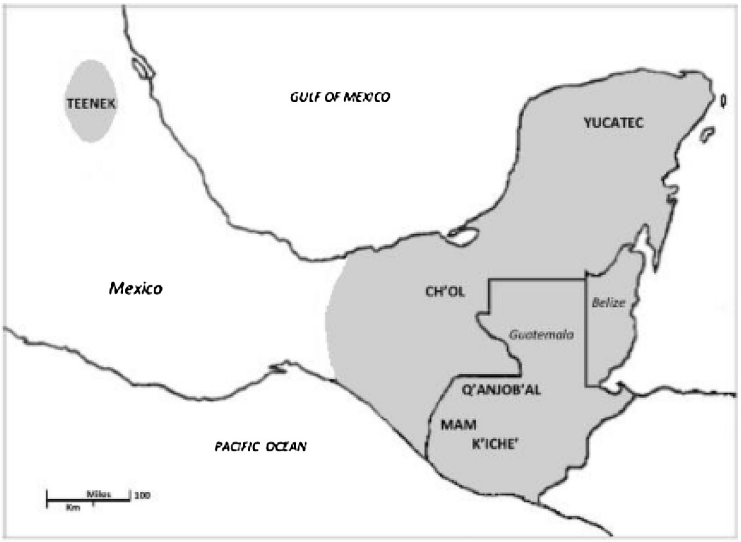

Fig. 1. Geographic distribution of the six Mayan languages.

Table 1
Lexical forms in six Mayan languages.

English	Teenek	Yucatec	Ch'ol	Q'anjob'al	Mam	K'iche'
Tree	te'	ʧe'	ce'	te'ex	tse'	ʧee'
Cold	tsamay	ké'el	tsäwaɲ	sik	ʧe'w	tew
Shoe	paahab	ʃanab	ʃaɲaɓ	ʂanaɓ	ʂjaɓ	ʃaxaɓ

Table 2
Word-initial consonant inventories in the six Mayan languages.

	Nasals	Stops	Affricates	Glottalized	Fricatives	Liquids	Glides
Tee	m n	p t k k^w ʔ	ts ʧ	b t' ts' ʧ' k' $k^{w'}$	s ʃ θ h	l r	w j
Yuc	m n	p t k ʔ	ts ʧ	p' b t' ts' ʧ' k'	s ʃ h	l r	w j
Cho	m ɲ	p c k ʔ	ts ʧ	p' b c' ts' ʧ' k'	s ʃ h	l r	w j
Qan	m n	p t k q ʔ	ts ʧ ʈʂ	ɓ t' ts' ʧ' ʈʂ' k' q'	s ʃ ʂ x h	l r	w j
Mam	m n	p t k k^j q ʔ	ts ʧ ʈʂ	ɓ t' ts' ʧ' ʈʂ' k' $k^{j'}$ q'	s ʃ ʂ x	l r	w j
Kic	m n	p t k q ʔ	ts ʧ	ɓ t' ts' ʧ' k' q'	s ʃ x	l r	w j

consonants / ʈʂ, ʈʂ' and ʂ/. Vocabulary lists for these languages, such as the one shown in Table 1, provide a glimpse of the effect of historical changes on the Mayan lexicon.

Table 2 displays the consonant inventories for the six Mayan languages based on Campbell (1984). All of the languages except Ch'ol have lost the Proto-Mayan contrast between alveolar and palatal nasals /n, ɲ/ and stops /t, c/; the other languages have an alveolar realization of these phonemes. Mam has innovated palatalized velar stops /k^j/ and /k^{j}'/, but these stops occur in very few words in Mam.[1]

Although the overall consonant inventories are similar across the Mayan languages, there are small differences in the number of phonemes and their phonetic realizations. The glottalized stops constitute the most heterogeneous phonetic category in that they are realized as implosives, ejectives or preglottalized stops depending on the language, the place of

[1] The Mayan languages have borrowed many words with the voiced stops /b, d, g/ from Spanish. Mayan languages integrate Spanish words with voiced stops into their phonologies by devoicing or omitting the voiced stops, e.g. Sp. *alcalde* 'mayor' > K'iche' *alcalte*. We excluded the borrowed words with voiced stops because they have not been fully assimilated to the Mayan phonologies. Straight (1976:32) states that ''Such nonhispanicized speech of course also tends to be deficient in the occurrence of loans; examples are therefore few and far between.''

articulation, or syllable position (Bennett, 2016; England and Baird, 2017).[2] We grouped together these sounds in the ''glottalized'' category because they share some kind of laryngeal articulation and are cognate with glottalized cognates in other Mayan languages. Edmonson (1988:36) writes that /b/ in Teenek is an unglottalized voiced bilabial stop initially. Straight (1976:31) describes the /b/ in Yucatec as a prevoiced stop, but adds that the prevoiced stops ''have a definitely [CP] laryngealized type of pre-release voicedness''. Vázquez Alvarez (2011:35) notes that this may also apply to the /b/ in Ch'ol. The Ch'ol /b/ has an implosive realization in word-final position (Vázquez Alvarez, 2011:19). Q'anjob'al and Mam speakers produce /ɓ/ with a stronger implosive articulation than speakers of K'iche'. Bennett (2016:485) concludes that ''The overall picture that emerges from the literature is that the phonetic realization of glottalized stops in Mayan varies quite widely across languages, dialects, and perhaps even individual speakers.''

The fricative consonants also vary in their phonetic realizations across the Mayan languages. Proto-Mayan had a contrast between /x/ and /h/, but many present day Mayan languages have merged /h/ with either /x/ or /ʔ/ (Kaufman, 1990:66). Edmonson (1988:36) states that the /h/ in Teenek is strong, audible and never lost. It has an [x] allophone before /i/. Straight (1976:33) says that the /h/ in Yucatec ''is always voiceless and much less frictional'' in phrase-initial position. Aulie and de Aulie (1998:xix) comment that the velar fricative in Ch'ol is pronounced without the friction that can be heard in the Spanish fricative /x/. We transcribe it as /h/ because its friction is barely audible. The velar fricatives are produced with greater friction in K'iche' and Mam than in the other languages.

The word-initial glottal stop is problematic in the Mayan languages. The variable realization of the word-initial glottal stops made it impossible for us to include them in our analysis of the children's productions. Mayanists, e.g. Kaufman (1990:66), claim that vowel-initial words in Mayan languages actually begin with a glottal stop even though it is not contrastive. In some languages, the word-initial glottal stops become salient when inflectional prefixes are added to the words (England, 1983:35; Vázquez Alvarez, 2011:38). Since the children regularly omitted inflectional prefixes we decided not to include the glottal stop in our analysis.

Edmonson (1988) provides a phonetic description of Teenek phonemes, Straight (1976) describes the phonetic features of Yucatec, Vázquez Alvarez (2002, 2011) provides a phonetic description for Ch'ol, England (1983) provides a description of the Mam phonemes, and Larsen (1988) provides a phonetic description of the K'iche' phonemes. Bennett (2016) and England and Baird (2017) survey the major phonetic features of Mayan phonemes.

3. Study One – consonant inventories

We use data from children acquiring six Mayan languages to explore the variation found in children's early consonant inventories. Barbara Pfeiler recorded children acquiring Teenek in the communities of Tampaxal, Tamaletón and Tancanhuits in the state of San Luis Potosí in Mexico between 2010 and 2013. Between 1994 and 1998 Pfeiler (2003) recorded children acquiring Yucatec in Yalcobá in the eastern part of the state of Yucatán, Mexico. Pye recorded children acquiring Ch'ol living in Tila, Chiapas, Mexico between 2007 and 2009 as well as children acquiring Mam living in San Ildefonso Ixtahuacán, Guatemala. Mateo Pedro (2015) recorded children acquiring Q'anjob'al living in Santa Eulalia, Guatemala between 2007 and 2009. Pye (1983) recorded children acquiring K'iche' who lived in Zunil, Guatemala between 1977 and 1980. All of the children were recorded in and around their own homes and the recording periods were approximately 1 h for each child. The recordings were made in a variety of contexts, which included play with siblings and neighbors, eating and looking at picture books. Straight describes a field experience that each of us encountered in one form or another in writing that two-year-old Yucatec children ''never would let me or my recorder or microphone within five yards of them without raising a great howl'' (1976:4–5). Table 3 provides general measures for the language samples. Transcripts for Ch'ol, Q'anjob'al, Mam and K'iche' are accessible at <almaya.org>.

We focus exclusively on the children's production of initial consonants in this study due to space limitations. We defined a 'word' in terms of the adult target. We excluded exclamations (*nn*, *ah*, *oh*) and onomatopoetic forms from the analyses. We counted stems with different inflections as separate words, e.g. /nu-q'aaɓ/ 'my hand' and /a-q'aaɓ/ 'your hand' (K'iche'). Where the children contracted two or more words together, we divided the pieces into separate words. For example, one of the Mam children produced the form /ataw/, which corresponds to the adult phrase /at ta'w/ 'it hurts'. In this case, we counted the initial /a/ in the child's form as the realization of the adult word /at/ and /taw/ as the realization of the word /ta'w/.

We defined 'initial consonant' as the initial consonant in the children's production. For example, the Q'anjob'al child XHIM produced the adult word /xuntsan/ 'plural' as /tʃan/. We treated the omission of the initial syllable as a process of syllable omission occurring at a level distinct from the process of phonological realization. We then analyzed the child's /tʃ/ as an initial consonant corresponding to the /ts/ of the adult target. We treated the absence of inflectional morphemes in

[2] There is other phonetic variation between the sounds in the adult Mayan languages, which we have not analyzed for this article, cf. the discussion of Mayan syllable nuclei in Brown and Wichmann (2004).

Table 3
General measures for the Mayan children.

Language	Child	Age	Transcript	Number of words	Number of consonants
Teenek	SAN	2;0	TS180710	87	22
	ELV	2;4	TE090411	178	
	VLA	2;3	TV030610	306	
	UKL	2;7	TU210410	37	
Yucatec	DAV	2;1	D050800	42	21
	ARM	2;0	A041196	43	
	SAN	2;0	S072495	60	
Ch'ol	ALI	2;5	CE081207	54	20
	MAR	1;9	CC281205	61	
	EMA	1;8	CE250206	79	
	MAN	3;11	CM130805	29	
Q'anjob'al	XHUW	1;11	QA050407	187	25
	MEK	1;11	QM181105	58	
	XHIM	2;3	QG260805	119	
	TUM	2;8	QD140905	180	
Mam	WEN	2;0	MW080107	201	26
		2;1	MW010207		
		2;1	MW130207		
	CRU	2;4	MC021005	212	
			MC161005		
			MC301005		
	JOS	2;7	MJ021005	296	
			MJ161005		
			MJ301005		
	ART	3;9	MA120805	222	
K'iche'	TUN	1;7		22	22
	TIY	2;1	KT260577	62	
	LIN	2;0		128	
	CHA	2;9	KC140477	145	
	CAR	3;1	KR220477	113	

the same fashion. For example, the Q'anjob'al child TUM produced the adult verb /ha-miʈʂ'a'/ 'you-grab it' as /mitʃ'a'/, omitting the initial agreement morpheme. We analyzed the child's /m/ as an initial consonant which corresponds to the /m/ of the adult verb stem.

We extracted the child phonologies for each language using Ingram's method of phonological inventories (1989). Ingram divides children's sounds into three categories – Marginal, Used and Frequent, on the basis of a Criterion Frequency (CF). The CF compares the children's productions to a baseline frequency based on the number of consonants in each language. The CF equals the number of words the children produced divided by the number of consonants in the language (20–26). The number of consonants that occur in each language is given above in Table 3. The Marginal sounds that the children produced do not meet the CF or were not produced accurately in more than 50% of the adult targets. Used sounds meet the CF and were produced accurately in more than 50% of contexts. Frequent sounds were produced at least twice the CF.

4. Results from study one

Table 4 displays the child phonological inventories and includes a composite inventory that represents the average phonological structure for children acquiring each language. The Marginal sounds are shown in parentheses, and Frequent sounds are marked with a plus. The Used sounds are not marked. The composite phonologies only include sounds used by a majority of children in each language.

Looking across this data set, we find evidence of the particularist spirit for children acquiring the same language. The children's production of the affricate /ts/ is particularly telling in this regard. This affricate was produced by two Teenek children, two Ch'ol children, two Q'anjob'al children and one K'iche' child. The affricate /ts/ is present in all six of the languages and has similar articulatory features. The seven children who produced it have different ages so we can

Table 4
Mayan child phonologies.

	NASALS		STOPS			AFFRICATES			GLOTTALIZED					FRICATIVES				LIQUID GLIDES		
TEENEK																				
SAN 2;0	m	n+	p+	t+	k+		(ts)	(tʃ)	b	(t')	(k')			(θ)	(ʃ)		h+	l	(w)	(j)
VLA 2;3	m	n	p	t+	k			tʃ	b	(t')	k'	(ts')	(tʃ')	(θ)	(ʃ)		h+	(l)	(w)	(j)
ELV 2;4	m+	n	p+	t+	(k)		ts	(tʃ)	b	(t')	(k')			(θ)	(ʃ)		h+	(l)		
UKL 2;7	(m)	n		t+	k+			tʃ	b+					(θ)	(ʃ)		(h)	l+	(w)	
Composite	**m**	**n**	**p+**	**t+**	**k**			**tʃ**	**b**	**(t')**	**(k')**			**(θ)**	**(ʃ)**		**h+**	**l**	**(w)**	
YUCATEC																				
ARM 2;0	m	n	p	t+	k			(tʃ)	b						ʃ		h	l+	w+	(j)
SAN 2;0	m+	n	p+	t+	k+			tʃ+	b				tʃ'		(ʃ)		h+	l+	w	
DAV 2;1	m+	n	p+	t+	k			tʃ	b+	(t')		(ts')		(s)			h	l+	w	(j)
Composite	**m+**	**n**	**p+**	**t+**	**k**			**tʃ**	**b**						**(ʃ)**		**h**	**l+**	**w**	**(j)**
CH'OL																				
MAR 1;9	m+	ɲ	p														h+		w	j
EMA 1;8	m+	ɲ+	p	c	(k)		(ts)	tʃ+	b						(ʃ)		h	l	(w)	j+
ALI 2;4	m+	ɲ	p	c+			(ts)	tʃ+	(b)								h+	l+	w+	j
MAN 3;11	m+	ɲ	p	c	k+			tʃ+	b					(s)	ʃ		h+	l	w	j
Composite	**m+**	**ɲ**	**p**	**c**				**tʃ+**	**b**								**h+**	**l**	**w**	**j**
Q'ANJOB'AL																				
MEK 1;11	m+	n+	p	t+	(k)		(ts)	(tʃ)								x+	(h)	l+		
XHU 1;11	m+	n	p	t+				tʃ+							ʃ		h+	l	w	
XHIM 2;3	m+	n	p+	t+	k+			tʃ+							(ʃ)	x	(h)	l	w+	j
NIK 2;3	m	n+	(p)	t+	k+		ts	(tʃ)	b		(k')					x	h+		w	j
TUM 2;8	m+	n	p	t+	k+			tʃ+			k'		(tʃ')		(ʃ)	(x)	h+	l	w+	j
Composite	**m+**	**n**	**p**	**t+**	**k+**			**tʃ+**							**(ʃ)**	**x**	**h+**	**l**	**w**	**j**
MAM																				
WEN 2;0	m	n	p+	t+	k+												(h)		w+	j+
CRU 2;4	m+	n+	p	t+	k+			tʃ+					(tʃ')		(ʃ)			l+	w	(j)
JOS 2;7	m	n+	p	t+	k+			tʃ+								x		l	w	(j)
ART 3;9	m+	n+		t+	k+			tʃ+								x+		l	w	j
Composite	**m**	**n+**	**p**	**t+**	**k+**			**tʃ+**										**l**	**w**	**j**
K'ICHE'																				
TUN 1;7		n	(p)		(k)			tʃ										l+	w+	
TIY 2;1		n+	p	t+	k+			tʃ+	b							x		l+	w+	(j)
LIN 2;0	m	n+	p+	t+	k+	(q)		tʃ	b		(k')			(s)	ʃ+	x		l+	w+	(j)
CHA 2;9	m	n	p+	t+	k+			tʃ+							ʃ+	x		l+	w+	(j)
CAR 3;0	m	n	p	t+	k+	(q)	(ts)	tʃ+	b		(k')		(tʃ')	s+		x+		l (r)	w	
Composite	**m**	**n**	**p**	**t+**	**k+**			**tʃ+**	**b**							**x**		**l+**	**w+**	**(j)**

conclude that the production of /ts/ does not reflect their articulatory development. Four of these seven children did not produce the fricative /ʃ/ which indicates that their production abilities were not uniformly advanced in relation to the other children. These data confirm that individual children acquiring the same language will produce a variety of different consonants.

Ingram (1989) discusses the effect that analysis methods can have on determining the degree of variation in children's early phonologies. We used the method of consonant inventories because it minimizes the variation in children's phonological inventories due to accidental productions of non-target sounds. This method uses the criterion frequency and substitution analysis to distinguish between the children's intended phonological targets and their accidental productions. It is telling that even with the use of this method we find evidence of the particularist spirit at work.

Many of the children produce consonants that the other children do not produce. There are many differences between the children in whether the consonants are Marginal, Used or Frequent. Nevertheless, there is a stunning overall similarity in the initial consonants that the children within each language produce. We find many features that are common to the phonologies of the children acquiring each language. Children acquiring Teenek have marginal /t', k' and θ/. Children acquiring Yucatec and Q'anjob'al produce /h/. Children acquiring Ch'ol produce /ɲ/ and /c/. These sounds distinguish the children's phonologies in these languages from children's phonologies in the other languages. These differences are relatively minor in comparison to the many sounds that are common to children acquiring all six Mayan languages.

Table 5
Composite Mayan child phonologies.

	NASALS	STOPS	AFFRICATE	GLOTTALIZED	FRICATIVES	LIQUID	GLIDES
Teenek	m n	p+ t+ k	tʃ	b (t') (k')	(θ) (ʃ) h+	l	(w)
Yucatec	m+ n	p+ t+ k	tʃ	b	(ʃ) h	l+	w (j)
Ch'ol	m+ ɲ	p c	tʃ+	b	h+	l	w j
Q'anjob'al	m+ n	p t+ k+	tʃ+		(ʃ) x h	l	w j
Mam	m n+	p t+ k+	tʃ+			l	w j
K'iche'	m n	p t+ k+	tʃ+	b	x	l+	w+ (j)
Composite	**m+ n**	**p t+ k+**	**tʃ+**	b	**(ʃ) x h**	**l**	**w j**

We compare the composite child phonologies for each language in Table 5. Table 5 also includes a composite of the composite phonologies, which are produced by a majority of the children acquiring the six Mayan languages. We include the fricative /x/ in the general Mayan composite because it was produced by a majority of the children acquiring the languages with this fricative. This common Mayan phonological core underlies the variation that we find in each Mayan child's phonology. While Teenek children vary in their use of individual consonants, they produce a common Teenek variation on the common Mayan theme. The results expand findings from an earlier study of phonological acquisition in K'iche' (Pye et al., 1987).

We determined how much each child's initial consonants differ from the common Mayan composite by comparing the number of composite consonants they used and did not use with the number of non-composite consonants the children used and did not use. The total number of sounds for each child equals the number of consonants in the adult language. This analysis is shown in Table 6. These results show that only two of the youngest children, the Ch'ol child MAR (1;9) and the K'iche' child TUN (1;8), produced few of the composite consonants. The other children target the composite consonants and avoid producing the non-composite consonants.

Table 6
Number of used and unused initial consonant produced by Mayan children.

Language	Child	Composite		Non-composite	
		Used	Not used	Not used	Used
TEENEK	SAN 2;0	12		5	4
	VLA 2;3	12		4	5
	ELV 2;4	10	2	5	4
	UKL 2;7	10	2	8	1
YUCATEC	ARM 2;0	12		7	
	SAN 2;0	11	1	6	1
	DAV 2;1	11	1	4	3
CH'OL	MAR 1;9	6	6	7	
	EMA 1;8	12		6	1
	ALI 2;4	10	2	6	1
	MAN 3;11	12		6	1
Q'ANJOB'AL	MEK 1;11	9	4	10	1
	XHU 1;11	9	4	11	
	XHIM 2;3	12	1	11	
	NIK 2;3	11	2	9	2
	TUM 2;8	12	1	9	2
MAM	WEN 2;0	8	4	13	
	CRU 2;4	10	2	12	1
	JOS 2;7	10	2	13	
	ART 3;9	9	3	13	
K'ICHE'	TUN 1;7	6	7	9	
	TIY 2;1	10	3	9	
	LIN 2;0	12	1	6	3
	CHA 2;9	11	2	9	
	CAR 3;0	10	3	6	3

In this study we investigated the degree of variation to be found in the initial consonant inventories of children acquiring six Mayan languages. The results show that some variation exists between children acquiring the same language, but the degree of variation is more limited than would be expected if each child followed their own particularist spirit. Children acquiring the same language produce a similar set of initial consonants which makes it is easy to extract a composite consonant inventory. Individual children acquiring Yucatec, Ch'ol, and Mam do not produce the non-composite consonant /k'/ even though a few children acquiring Q'anjob'al and K'iche' produce this sound and the sound is part of the composite inventory for Teenek. Table 6 shows how closely the individual children stick to the composite set of consonants within each language. A completely particularist pattern would produce many more instances of non-composite consonants in each language.

The children also do not produce a universal set of consonants. Children acquiring Teenek, Yucatec, Ch'ol, Q'anjob'al use /h/, children acquiring Q'anjob'al and K'iche' use /x/, and children acquiring Teenek have a marginal /θ/. Mayan children have an early production of /tʃ/, /ʃ/, and /l/ and do not produce the glottalized consonants with the exception of /b/. These results show that the children neither produce the same consonants nor do they display completely variable consonant sets. The consonant sets in the adult languages guide children's early consonant choices over and above the difficulties that individual children might have with articulating specific consonants.

The analysis of children's phonological inventories produces a qualitative assessment of the consonants that children produce which are correct and match a criterion frequency, but it does not make complete use of the information found in the variation in the children's consonant production. In Study Two, we compare the number of words in which the children produced each sound in order to statistically assess the range of variation in consonant production between children.

5. Study Two – analysis of variance

We expect to find language-independent variation if children's consonant production is solely a reflection of non-linguistic factors such as articulatory development or individual attention. We expect to find language-specific ranges of variation if linguistic factors such as the number of lexical stems beginning with specific consonants in the adult languages affects children's consonant production. In order to test for differences in the variation of consonant production, we devised a procedure that makes maximum use of the sparse data that was collected from individual children. We grouped the children's initial consonants together by their manner and place of articulation for this study. We present the manner analysis first.

6. Manner of articulation

We grouped the production of /m, n, ɲ/ as nasal consonants, /p, t, c, k, k^y, k^w, q/ as stop consonants, /ts, tʃ, ʈʂ/ as affricates, /b, ɓ, p', t', c', tʃ', ʈʂ', k', $k^{w'}$, $k^{y'}$, q'/ as glottalized, /θ, s, ʃ, ʂ, x, h/ as fricatives, /r, l/ as liquids, and /w, j/ as glides.[3] We then compared the variation in the children's production of the nasal, stop, affricate, glottalized, fricative, liquid and glide classes of consonants. Table 7 presents the children's lexical frequency and percentage of production for each manner of articulation. The percentages sum to 100 for each child with small differences due to rounding.

These results show that Teenek and Yucatec children produce more glottalized consonants, mainly /b/, than children acquiring the other Mayan languages. Children acquiring Ch'ol and Mam produce more affricates than children acquiring the other Mayan languages. The results suggest that significant quantitative differences exist between children acquiring different Mayan languages. The question we address now is whether this variation merely reflects random variation from different samples or actual differences between children speaking different Mayan languages.

We performed an analysis of variance (ANOVA) to test whether any of the language group differences in manner were significant. We ran seven ANOVAs, one for each manner of articulation. Table 8 shows the *p*-values for each manner classification as the dependent variable. The results are significant at the 0.05 level for two of the seven manner groups: the glottalized and liquids, and close to significant for the stops. These results show that even with small numbers of children from each language there are significant differences in the relative usage of the manner groups between the Mayan languages to be explored.

While the ANOVA results provide information about the differences in manner of articulation between the language groups, they do not provide information about the relations between the different manners of articulation within the language group. We used discriminant analysis to explore the relationships between the manners of articulation and

[3] We remind readers that we classified /b/ as a glottalized consonant because of its laryngeal features in the languages with /b/ in place /b/. In keeping with the requirement to make maximum use of sparse data we were forced to place the glottalized stops and affricates into a single category. This decision is supported by the finding that the children produce glottalized forms of both stops and affricates later than plain stops and affricates which indicates that the manner features of stop and affricate are secondary to the glottalization feature.

Table 7
Children's initial consonant production grouped by manner of articulation.

Language	Child	Nasals		Stops		Affricates		Glottalized		Fricatives		Liquids		Glides	
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Teenek	SAN 2;0	19	21.6	36	40.9	4	4.5	6	6.8	13	14.8	7	8.0	3	3.4
	ELV 2;4	22	21.0	24	22.9	10	9.5	23	22	21	20.0	2	1.9	3	2.9
	VLA 2;3	32	16.8	53	27.7	22	11.5	38	20	28	14.7	5	2.6	13	6.8
	UKL 2;7	3	8.6	16	45.7	5	14.3	4	11.4	3	8.6	3	8.6	1	2.9
Yucatec	ARM 2;0	5	14.7	10	29.4	1	2.9	3	8.8	4	11.8	5	14.7	6	17.6
	SAN 2;0	8	14.0	17	29.8	7	12.3	5	8.8	11	19.3	6	10.5	3	5.3
	DAV 2;0	6	15.4	12	30.8	2	5.1	6	15	3	7.7	7	17.9	3	7.7
Ch'ol	MAR 1;9	10	25.6	8	20.5	3	7.7	4	10	6	15.4	3	7.7	5	12.8
	EMA 1;8	10	21.3	13	27.7	8	17.0	3	6.4	4	8.5	3	6.4	6	12.8
	MAN 3;11	12	23.1	12	23.1	9	17.3	2	3.8	9	17.3	2	3.8	6	11.5
	ALI 2;5	8	20.0	10	25.0	6	15.0	1	2.5	4	10.0	4	10	7	17.5
Q'anjob'al	MEK 1;11	17	29.3	21	36.2	4	6.9	2	3.4	9	15.5	4	6.9	1	1.7
	XHU 1;11	26	17.6	48	32.4	15	10.1	4	2.7	34	23.0	11	7.4	10	6.8
	NIK 2;3	8	20.5	13	33.3	3	7.7	4	10	7	17.9	0	0	4	10.3
	XHIM 2;3	19	17.3	40	36.4	18	16.4	2	1.8	10	9.1	4	3.6	17	15.5
	TUM 2;8	24	15.1	41	25.8	25	15.7	13	8.2	24	15.1	10	6.3	22	13.8
Mam	WEN 2;0	23	13.9	80	48.2	4	2.4	1	0.6	7	4.2	5	3	46	27.7
	CRU 2;4	35	20.6	50	29.4	25	14.7	15	8.8	8	4.7	24	14.1	13	7.6
	JOS 2;7	46	15.3	138	46.0	34	11.3	6	2	26	8.7	19	6.3	31	10.3
	ART 3;9	30	18.4	57	35.0	29	17.8	1	0.6	20	12.3	11	6.7	15	9.2
K'iche'	TIY 2;1	7	12.5	19	33.9	10	17.9	2	3.6	5	8.9	6	10.7	7	12.5
	LIN 2;0	24	20.3	37	31.4	7	5.9	10	8.5	17	14.4	14	11.9	9	7.6
	CHA 2;7	14	13.1	35	32.7	14	13.1	3	2.8	17	15.9	11	10.3	13	12.1
	CAR 3;0	11	11.8	29	31.2	11	11.8	8	8.6	19	20.4	8	8.6	7	7.5

Table 8
Analysis of variance *p*-values for manners of articulation.

Manner	Nasals	Stops	Affricates	Glottalized	Fricatives	Liquids	Glides
Probability	0.112	0.055	0.523	0.012*	0.175	0.010*	0.178

* Significant at the 0.05 level or better.

language groups. A discriminant analysis looks to find a set of linear combinations (or functions) of the observed variables such that the scores derived from evaluating each function for the subjects will have the highest possible variation between group means relative to the variation of scores within groups. If there are systematic differences in the use of manner articulations between language groups, we should expect to see variation within groups that is significantly less than the variation across all scores in the dataset and differences between group mean scores that are higher than the random variation one would expect if all group scores were random samples from the same population. On the other hand, if there are no differences in manner articulations between language groups, the means and variances for scores from each group should only differ as the result of random sample variation.

The data consisted of 24 cases of child subjects and variables corresponding to the seven manner groupings discussed above. Because the sum of the percents over all seven variables for any subject is always 100%, we had a redundancy in the data that is unworkable for the mathematics underlying discriminant analysis. We removed the affricate variable to avoid this redundancy and selected this variable because its values showed the least significant differences between language groups based on the individual ANOVA *p*-values reported in Table 7.

The discriminant analysis algorithm identifies the linear combinations, or functions, one at a time, starting with the combination that is most effective in maximizing differences in group means relative to within group variation, and successively creates additional discriminant functions to address the residuals unexplained by previously identified functions. This procedure could result in up to six linear discriminant functions (because there are six manner group variables), but the analysis of these data stopped at five discriminant functions because there were negligible unexplained residuals after defining five discriminant functions. Table 9 shows the structure of the five discriminant functions for the

Table 9
Standardized canonical discriminant function coefficients and percent contributions to language group discrimination.

	Discriminant functions				
	1	2	3	4	5
Nasals	−0.444	−0.137	−0.069	0.293	1.003
Stops	1.198	−0.289	0.577	−0.187	1.047
Glottalized	1.278	−0.169	−0.224	0.503	0.576
Fricatives	0.764	0.691	−0.336	−0.821	0.857
Liquids	0.677	1.144	0.120	0.060	0.502
Glides	0.020	0.815	0.076	0.158	0.944
Contribution	55.3%	31.3%	7.7%	4.8%	0.9%

manner variable data. The contribution entries on the last line of the table indicate how much of the total variation in the dataset is contributed by each function. These contributions decrease with each successive discriminant function.

The first discriminant function provides 55.3% of the explanatory power of all discriminant functions to distinguish language groups. A positive subject score for this function reflects a higher relative propensity for using plain and glottalized stops, and a lower propensity for the use of nasals. By itself, the first discriminant function successfully distinguishes between the languages Ch'ol, Q'anjob'al, Mam, K'iche' and Yucatec, with the mean discriminant scores for these language groups ranked (from most negative to most positive) in this order.

The second discriminant function adds another 31.3% of explanatory power to the first discriminant function in distinguishing the language groups. A positive score for this function reflects a higher propensity for using liquids, glides, and fricatives. This second discriminant function is effective in discriminating Teenek subjects from the children speaking Yucatec, with the Teenek subjects scoring more negatively. Together, the first and second discriminant functions are effective in capturing over 86% of the variance in the dataset that is explained by the five discriminant functions. Fig. 2 provides a plot of the subject scores for the first two discriminant functions with the first function plotted on the horizontal axis.

This result supports the hypothesis that there are significant differences in the distributions of consonant usage by manner of articulation between language groups that reflect language-specific factors in the emergence of consonants among young children. This study shows that even though the children share a common core of initial consonants, their frequency of producing the consonants reflects language specific differences in their initial lexicon. We emphasize the abstract nature of the children's lexicons in that the children frequently omit prefixes that are obligatory in the adult grammars. The omission of prefixes by the children changes the frequency of the initial consonants in their ‘‘words’’.

7. Place of articulation

Analysis of the data by place of articulation does not yield the same pattern of results as the manner analysis due to the reduced number of places the children produced. We grouped the children's consonant production by place of articulation, and excluded the uvular and glottal consonants because the children produced few consonants with these places of articulation with the exception of /h/ in some of the languages. We grouped /h/ with the other velar consonants in this analysis. The results for place of articulation are shown in Table 10.

We plotted the means of the children's place data by language as shown in Fig. 3. This figure shows interesting relationships between the children's production of consonants by place. The means data in Fig. 3 suggest that the four place variables can be reduced to two because the production of bilabial and velar consonants displays an inverse relationship, as do the alveolar and palatal consonants. The bilabial means display a linear relationship from Yucatec to Mam and K'iche' that resembles the relationship we found in the discriminant analysis for manner.

A discriminant analysis of the place data yielded an initial ANOVA on the individual variables that investigates whether there are significant differences between the language group means relative to the variation within language groups. The number of children for each language limits the power of these tests, but their results can still reveal interesting features of the place variables. On the individual place variables ANOVA tests, differences between groups for labials were very significant with a *p*-value of 0.008. Palatals and velars were significant at the 0.1 level, but not at the 0.05 level, with *p*-values of 0.066 and 0.88, respectively. Only alveolars, with a *p*-value of 0.343, gave no indication of possible group mean differences. The labial results confirm our assessment of the group means for the labial data.

For the discriminant analysis, we ordered the variables by *p*-value so alveolars would be the variable that is dropped to avoid the linear dependency (needed because all the data values for a subject sum to 100.0 and causes problems with matrix inversion). The discriminant analysis derived three discriminant functions (since there were three place variables).

Table 10
Children's initial consonant production grouped by place of articulation.

Language	Child	Bilabial		Alveolar		Palatal		Velar	
		n	%	*n*	%	*n*	%	*n*	%
Teenek	SAN 2;0	20	22.7	43	48.9	8	9.1	17	19.3
	ELV 2;4	35	33.3	39	37.1	10	9.5	21	20.0
	VLA 2;3	56	29.3	63	33.0	22	11.5	50	26.2
	UKL 2;7	6	17.1	17	48.6	4	11.4	8	22.9
Yucatec	ARM 2;0	13	40.6	13	40.6	4	12.5	2	6.3
	SAN 2;0	16	34.0	16	34.0	8	17.0	7	14.9
	DAV 2;0	14	35.9	18	46.2	3	7.7	4	10.3
Ch'ol	MAR 1;9	15	38.5	11	28.2	8	20.5	5	12.8
	EMA 1;8	11	23.4	18	38.3	14	29.8	4	8.5
	MAN 3;11	17	32.7	9	17.3	13	25.0	13	25.0
	ALI 2;5	15	37.5	12	30.0	8	20.0	5	12.5
Q'anjob'al	MEK 1;11	15	27.3	28	50.9	3	5.5	9	16.4
	XHU 1;11	33	26.8	60	48.8	26	21.1	27	3.3
	NIK 2;3	9	27.3	11	33.3	3	9.1	14	30.3
	XHIM 2;3	36	33.6	30	28.0	26	24.3	15	14.0
	TUM 2;8	43	29.7	31	21.4	43	29.7	28	19.3
Mam	WEN 2;0	45	27.3	51	30.9	32	19.4	37	22.4
	CRU 2;4	38	22.8	63	37.7	33	19.8	33	19.8
	JOS 2;7	66	22.0	112	37.3	47	15.7	75	25.0
	ART 3;9	27	16.6	51	31.1	37	22.7	48	29.4
K'iche'	TIY 2;1	11	19.6	21	37.5	9	16.1	15	26.8
	LIN 2;0	28	24.6	45	39.5	23	20.2	18	15.8
	CHA 2;7	31	29.2	31	29.2	26	24.5	18	17.0
	CAR 3;0	19	20.7	39	42.4	11	12.0	23	25.0

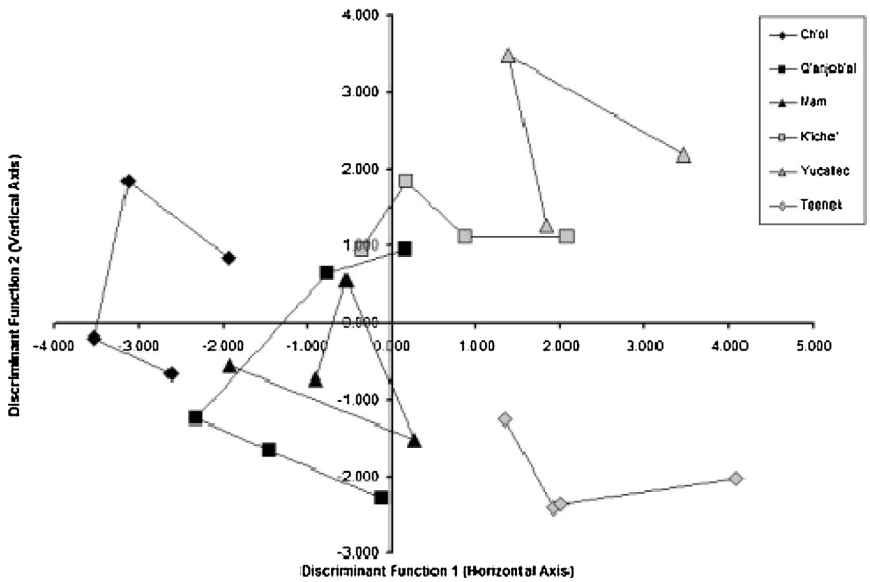

Fig. 2. Plot of children's scores on two discriminant functions for manner.

The first two explain nearly all of the variation in the three place variables, but probably only the first is statistically significant, based on the Wilks' lambda and being the only function with an eigenvalue larger than one (Table 11). The first linear discriminant function loads high on labials and low on velars, which reflects the relationship noted in Fig. 3. The second discriminant function correlates positively with palatals and negatively with alveolars.

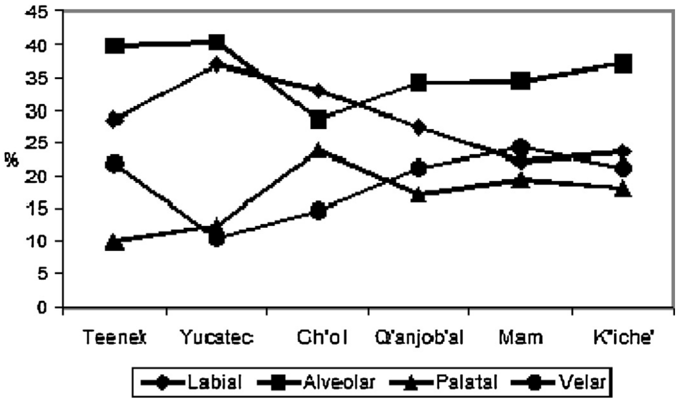

Fig. 3. Frequency analysis of Mayan children's initial consonant production by place.

Table 11
Standardized canonical discriminant function coefficients and percent contributions to language group discrimination.

	Discriminant functions		
	1	2	3
Labial	.768	.188	.637
Palatal	−.230	1.011	.040
Velar	−.535	.133	.897
Contribution	68.8%	30.2%	1.0%

The plot of scores for the first two discriminant functions based on place of articulation does not yield the same patterns and does not so nicely separate the six language groups (Fig. 4). The plots for the individual children display more intermingling on the plot for place than manner. The intermingling for the place results confirms the robustness of the manner discriminant analysis. However, the place analysis shows a clear separation of the Yucatec children from the Mam and K'iche' children on the first discriminant function, plotted horizontally. The place analysis groups the Mam and

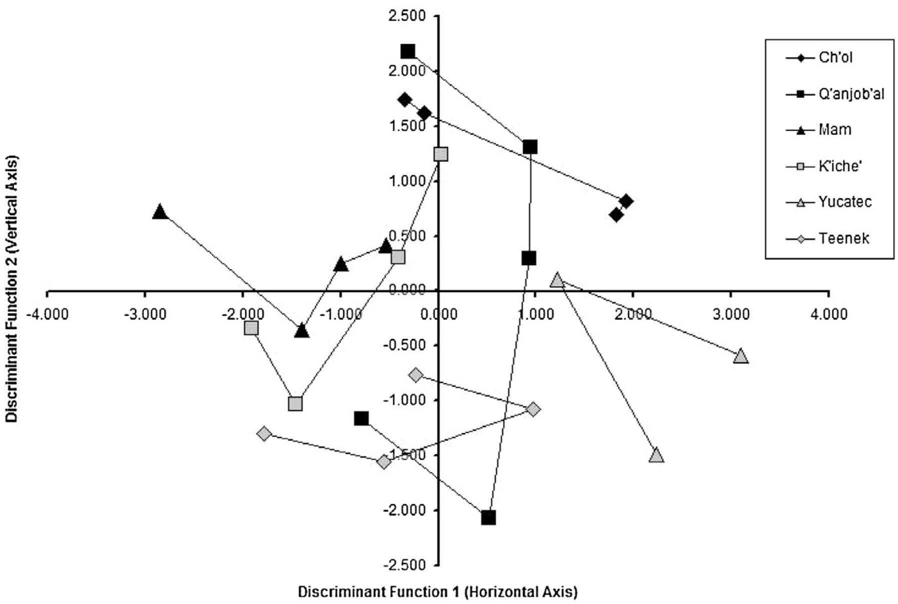

Fig. 4. Plot of children's scores on two discriminant functions for place.

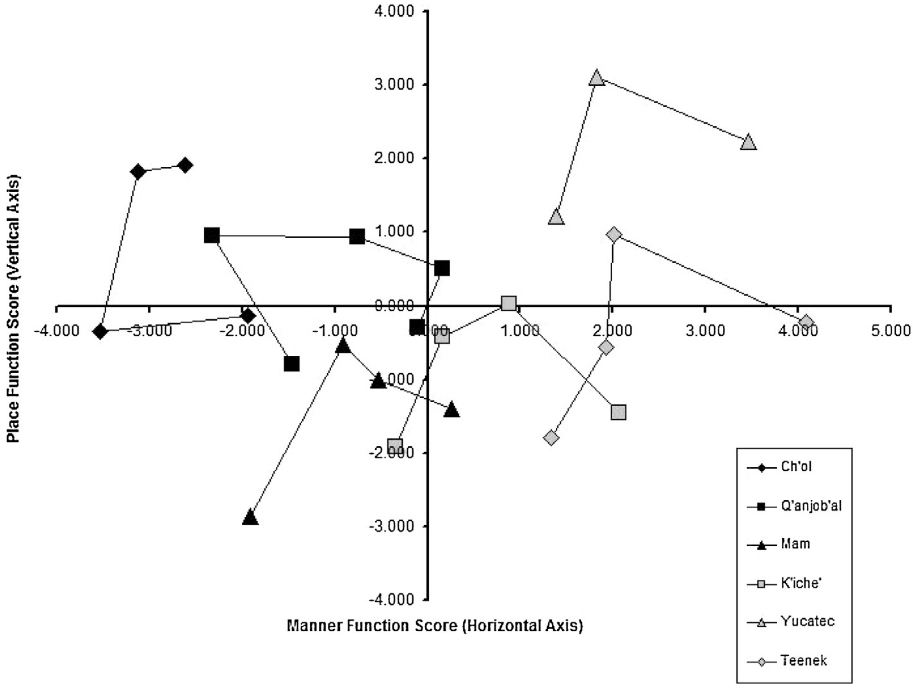

Fig. 5. Plot of children's scores on the first discriminant scores for manner and place.

K'iche' children together on the second discriminant function. The place results again put Ch'ol, Teenek and Yucatec at three extremes with two Ch'ol children overlapping one Yucatec child on the first discriminant function.

The data that we submitted to these analyses are far from ideal. Nevertheless, these data support the hypothesis that the children's consonant production, although variable, is restricted by the phonological structure of the adult language. Separate analyses for manner and place do not capture the relationship between manner and place in the children's productions. In order to provide an idea of this relationship, we plotted the children's first discriminant function scores for manner against their first discriminant function scores for place. This plot is shown in Fig. 5. The manner scores are plotted on the horizontal axis and the place features are plotted on the vertical axis.

The first discriminant function for the manner data provides the most effective linear combination of manner category percents for the purpose of separating mean scores between language groups. The first discriminant function from the place data discriminant analysis represents the most effective linear combination of place percent usages for the purpose of separating mean scores between language groups. The power of these first discriminant functions in capturing the variation in the data is substantial based on the large eigenvalues (4.249 vs. a maximum possible value of 6 for manners and 1.656 vs. a maximum possible value of 3 for places) reported in the SPSS output. Plotting the two functions together confirms the separate interpretations for manner and place, but makes the relationships between the scores for Q'anjob'al, Mam and K'iche' more clear. While the Q'anjob'al and Mam scores occupy a similar space on the first discriminant function for manner, the discriminant function for place separates them nicely.

To summarize Study Two, we analyzed the variance in the children's consonant production by manner and place. Both analyses reveal a limited degree of variability in consonant production among children acquiring the same language. However, the first and second discriminant function scores indicate there is more variability between language groups than would be expected from the variability within language groups, and the results suggest that there are differences in the average frequencies of consonant usages between Mayan language groups.

8. Conclusion

In this paper we used qualitative and quantitative methods to assess the within-language and between-language variation found in the initial consonants produced by children acquiring six Mayan languages. The method of phonological inventories showed how language-specific sounds (Teenek /θ/; Ch'ol /ɲ/; Q'anjob'al and K'iche' /x/) quickly enter children's phonological repertoires and lead to the distinctiveness of their initial consonant production. The method of phonological inventories also showed that Mayan children produce a common core of consonants despite some individual variation between children acquiring the individual languages. These findings demonstrate the effect of the adult phonologies on the children's initial consonant inventories beyond particularist and universalist factors.

Study Two used two statistical techniques to assess the variation in consonant production in the children. The ANOVA analyses showed significant between-language differences in both manner and place features of the children's initial consonants. The analysis of variation makes an important contribution to the study of child phonology in that it determines the limits of variation between individual children acquiring specific languages. Plots of the discriminant functions for manner and place show how quantitative techniques provide insight into the relative variation of children within the same language and between different languages.

The two studies combine to demonstrate that much can be learned from small-scale studies of children's phonological development. Study Two supports the findings of Study One in finding language specific limits to children's initial consonant production. Individual children may differ but only within the limits imposed by the structure of the adult phonological grammar. The children's developing articulatory abilities impose limits to what the children produce but only to the degree imposed by the adult phonology. The studies clearly show that children construct a language-specific phonology that is continuous with the adult grammar.

We did not explore the details of how the adult phonology acts on the children's consonant productions due to the limits of space. Recent investigations by Van Severen et al. (2013) and Stokes and Surendran (2005) suggest the discriminatory function of word-initial consonants in the minimal pairs of words that adult caretakers address to children is the main linguistic factor that is responsible for children's consonant production. This may not be the case for the Mayan languages in which many of the adult words have inflectional prefixes that the children omit. Our study advances this research in one respect by demonstrating a linguistic factor even exists in polysynthetic languages in which the children generally omit the initial prefixes in words. Thus, the initial consonants that children process may differ from the initial consonants in the adult words that they hear, but still reflect phonological features that are distributed throughout the adult lexicon. Understanding the details of how children extract these features remains a project for future investigations.

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