Speech Error Elicitation and Co-occurrence Restrictions in Two Ethiopian Semitic Languages

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Running Head: Ethiopian Semitic Speech Error Elicitation

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Abstract

This article reports the results of speech error elicitation experiments investigating the role of two consonant co-occurrence restrictions in the productive grammar of speakers of two Ethiopian Semitic languages, Amharic and Chaha. Higher error rates were found with consonant combinations that violated co-occurrence constraints than with those that had only a high degree of shared phonological similarity or low frequency of co-occurrence. Sequences that violated two constraints had the highest error rates. The results indicate that violations of consonant co-occurrence restrictions significantly increase error rates in the productions of native speakers, thereby supporting the psychological reality of the constraints.

INTRODUCTION

Speech error research is predicated on the assumption that slips of the tongue are constrained by the phonological system of the language, therefore providing an important source of external evidence for phonological structure and specification. Numerous studies have demonstrated that increased similarity between consonants correlates with increased susceptibility to speech errors, whether natural or induced (Nooteboom 1967, MacKay 1970, Fromkin 1971, Shattuck-Hufnagel and Klatt 1979, van den Broecke and Goldstein 1980, Levitt and Healy 1985, Wilshire 1999, Walker 2004). Similarity is typically calculated by the number of distinctive phonological features shared by the consonants in question. Furthermore, slips of the tongue frequently result in 'distance interaction', a process in which two consonants either switch positions or assimilate features across intervening segments, either within or across words. Similarity and distance interaction are also hallmarks of co-occurrence constraints and consonant harmony in natural language, a parallel observed in recent research (Hansson 2001a,b, Rose & Walker 2004, Walker 2004). These authors hypothesize that avoidance of sound combinations which present production or processing difficulties, such as those attested in speech errors may become entrenched as grammatical constraints on consonant co-occurrence at a distance. Psycholinguistic evidence indeed suggests that speakers are sensitive to such co-occurrence constraints in wordlikeness judgment tasks (Frisch & Zawaydeh 2001), and speech perception experiments (Moreton 2004). The consensus from these studies is that co-occurrence constraints are encoded in speakers' phonological grammar. This leads to interesting research questions: i) do such long distance phonological co-occurrence constraints on similar consonants result in more speech errors than similar sequences that are not subject to co-occurrence constraints?[1] ii) will similarity between consonant combinations which do not violate a co-occurrence constraint still exhibit an increase of errors in speakers' productions? and iii) will a low frequency of consonant co-occurrence lead to an increase in errors? In other words, which of the following factors impose an inhibitory effect on the speakers' production planning, raising the probability of a speech error: the presence of a constraint, mere similarity between consonants, or low frequency of co-occurrence? This study addresses these questions through an investigation of co-occurrence constraints on consonants in two related South Ethiopian Semitic languages, Amharic and Chaha, which are not mutually intelligible.

Semitic languages are known for consonant co-occurrence constraints on their lexical roots, typically composed of three consonants (e.g. Cantineau 1946, Greenberg 1950, Koskinen 1964, Kurylowicz 1972, Bender 1978, Bender & Fulass 1978, Pierrehumbert 1993, McCarthy 1994, Elmedlaoui 1995, Buckley 1997, Bachra 2001, Frisch, Broe & Pierrehumbert 2004). The main restriction on Semitic consonantal roots concerns place of articulation. A second constraint identified for Ethiopian Semitic focuses on the laryngeal properties of stop consonants. Two experiments, one for each language, were designed to induce speech errors in order to determine the influence of three factors on speakers' productions: grammatical co-occurrence constraints, similarity of consonants and frequency of consonant co-occurrence. Each of these factors correspond to three main hypotheses.

The constraint hypothesis, the main hypothesis of the experiments in the paper, states that speakers' productions will be influenced by two co-occurrence constraints, identified through analysis of dictionary corpuses. Although it is hypothesized that similarity plays a role in the entrenchment or grammaticalization of constraints across the lexicon, it has not been determined how the presence of such constraints in a language impacts the speech error rates of its speakers. Evidence supporting the constraint hypothesis will come from a statistical comparison of the error rates of constraint combinations and combinations which have similar frequency and similarity but no known co-occurrence restrictions.

An interesting secondary component to this hypothesis is the presence of two constraints in the languages under investigation, and their potential for interaction. Given the assumption that each co-occurrence constraint reflects a processing difficulty, it is hypothesized that consonant combinations which violate two constraints will cause more production difficulty those combinations that violate only a single constraint.

The consonant combinations that are associated with co-occurrence constraints have two other features which may contribute to production difficulty, independent of the constraint itself: a high degree of similarity in terms of shared phonological features and low frequency of co-occurrence. The experiments were designed to test these factors independently. The similarity hypothesis states that consonant combinations with greater shared similarity will be associated with more production difficulty than consonant combinations that are more dissimilar. None of the consonant combinations in the similar or dissimilar groups violate a co-occurrence constraint and all have similar frequency of co-occurrence; thus only similarity is tested. If this hypothesis were supported by the data, it would be further evidence that speech errors arise from universal considerations of sound similarity and not from a motor system or practice effect. If this hypothesis is not supported by the data, it would be further evidence that increased error rates under the constraint hypothesis, if obtained, were due to the presence of a constraint and not simply due to the shared similarity.

Finally, if co-occurrence constraints exist in a language, these sequences will occur relatively infrequently. Therefore, one might expect speakers to experience production difficulty with such combinations due to their unfamiliarity with the sequence, perhaps as a motor/practice effect. The frequency hypothesis thus states that low frequency of sound combinations within the verb root will result in higher speech errors. Experimental evidence in favor of this hypothesis would be that among consonant combinations which are not subject to co-occurrence constraints and which have the same degree of similarity, more speech errors result in combinations that are less frequent within the verb root than those that are more frequent. If this hypothesis is supported by the data, and taking into account that the less frequent combinations do occur across word boundaries, this would indicate that frequency of occurrence at the verb root level plays a role in speech production, independent of similarity (if they are matched) and grammatical constraints. If this hypothesis is not supported by the data, it would be further evidence that increased error rates under the constraint hypothesis, if obtained, were due to the presence of a constraint and not simply due to low frequency.

BACKGROUND

As outlined in the preceding section, psycholinguistic research on phonological speech errors has revealed several important factors influencing the rate of errors. These include similarity of sounds, frequency effects (of sounds or words), and position in the word or syllable. These results are drawn from naturally occurring slips of the tongue as well as experimentally-induced speech errors.

Research has shown that the more similar segments are, the more likely they are to be associated with an increase in speech errors. This result has been reported for both naturally occurring speech errors (van den Broecke & Goldstein 1980, Abd-El-Jawad & Abu-Salim 1987, García-Albea, del Viso, & Igoa 1989, Berg 1991) and experimentally-induced errors (Stemberger, 1991, Wilshire 1999, Walker 2004). For example, Wilshire (1999) used a tongue twister paradigm with real words to elicit speech errors. A tongue twister paradigm involves a reading or repetition task in which subjects are asked to produce words or syllables which alternate in a variety of ways, similar to a tongue twister (MacKay 1970, Kupin 1982, Shattuck-Huffnagel 1992; Schwartz, Saffran, Bloch & Dell 1994, Frisch 2000, among others). Wilshire's results showed that more errors were evident for highly similar phoneme pairs than for less similar pairs.

Walker, Hacopian & Taki (2002) and Walker (2004) used the SLIPS technique (Baars, Motley & MacKay 1975, Motley & Baars 1975, Stemberger 1990, Levitt & Healey 1985, Dell 1991, among many others) to elicit speech errors. The SLIPS technique uses priming by presenting subjects with several pairs of real or novel words with similar initial sounds followed by a critical cue pair of words with the same initial sounds switched. Subjects are asked to read the cue pair, which, due to the influence of the first few pairs, often results in speech errors. The aim of Walker's experiment was to discover whether similar pairs of consonants (nasal-voiced stop) would induce more errors than non-similar (nasal-voiceless stop). The results confirmed more errors with similar pairs than non-similar pairs. Spreading-activation models of speech errors suggest that speakers form connections between speech sounds that are similar, and this activation can result in production problems (Dell 1984, Dell & Reich 1980, MacKay 1970, 1987, McClelland & Rumelhart 1981, Stemberger 1982, 1985a,b).

The role of frequency in influencing speech errors is less straightforward. Shattuck-Hufnagel & Klatt (1979) and Stemberger (1991b), in studies of naturally-occurring errors, found that high frequency sounds such as /s/ are more likely to be replaced (act as targets) by low frequency sounds such as /ʃ/ (act as intrusions). Yet, using a tongue twister paradigm, Levitt & Healey (1985) elicited speech errors in two tongue twister nonsense syllable experiments in English using coronal sounds: /s ʃ tʃ t θ/. They found an anti-frequency bias: infrequent segments tend to serve as targets whereas frequent segments tend to serve as intrusions. Stemberger (1991a) attributes the anti-frequency effect to coronal underspecification. If coronals are underspecified for place of articulation, other segments' place specifications will intrude more easily.

In the aforementioned studies, frequency is calculated individually for each consonant. Studies which focus on frequency of cooccurrence typically refer to permissible syllable constituents (i.e. onset sequences in Moreton 2004) or positions in the word (word-initial position in Shattuck-Hufnagel 1988, Frisch 2000). In the Semitic languages under investigation, syllable position is not pertinent, since the constraints pertain to the lexical root, whose consonants appear in different syllabic positions in different paradigmatic surface forms. The only relevant effect of position is in relation to the tri-consonantal sequence, i.e. root-initial or root-final.

With respect to co-ocurrence constraints themselves, most studies report that speech errors rarely result in the production of sequences that violate phonotactic constraints (MacKay 1972, Abd-El-Jawad & Abu-Salim 1987, Vousden, Brown, & Harley 2000, Goldrick 2004), and some studies are designed explicitly to address this question (Dell, Reed, Adams & Meyer 2000). Yet, none of these studies focuses on whether illicit sequences will engender more errors than licit sequences, which is the goal of the current study.

Co-occurrence constraints on consonants

Numerous languages show evidence of co-occurrence constraints on combinations of vowels or consonants. Although many such constraints may be expressed in terms of syllables (i.e. permissible onsets), constraints are also imposed on non-contiguous speech segments, disallowing two consonants of a particular class within a word or morpheme. These constraints may take the form of inducing 'harmonic' patterns, as the following example illustrates from Aari, an Omotic language of Ethiopia (Hayward 1990). In Aari, there is a co-occurrence constraint prohibiting a combination of alveolar and palatoalveolar fricatives within the word. However, roots with two alveolar fricatives or two palatoalveolar fricatives are attested. This constraint not only restricts root structure, but also produces alternations when suffixes with an alveolar fricative are attached to roots containing a palatoalveolar fricative – the alveolars are converted to palatoalveolar.

(1)	Aari	duuk-sis	‘cause to bury’
		ʃaan-ʃiʃ	‘cause to urinate’

Two recent typological studies of long-distance harmonic or agreement constraints (Hansson 2001, Rose & Walker 2004) establish two striking generalizations. The first is the high degree of similarity between interacting segments, computed in terms of shared features, and the second is the parallel between consonant harmony and speech processing (Hansson 2001a,b). Hansson observes that the 'palatal bias' effect found mainly in anticipatory speech errors (Shattuck-Hufnagel & Klatt 1979, Stemberger 1991a), in which high frequency sounds such as /s/ are more likely to be replaced by low frequency /ʃ/ sounds, is found in coronal harmony systems, which also tend to be anticipatory and involve similar alveolar/palatal restrictions.

In other languages, constraints on consonants may be dissimilatory in nature. For example, in Imdlawn Tashlhiyt Berber (Elmedlaoui 1995), roots may not contain two labial consonants. When the reciprocal labial prefix /m-/ associates to a root with a labial consonant, it dissimilates to [n], as in (c,d) (Elmedlaoui 1995: 74-77):

(2)	*Verb base*	*reciprocal*	
a.	krrd	m-karrad	‘maîtriser dans un corps-à-corps’
b.	ħsad	m-ħasad	‘jalouser’
c.	bddl	n-baddal	‘changer’
d.	χalf	n-χalaf	'contrarier’

See also McCarthy 1986, 1988, Yip 1988, 1989, MacEachern 1997[1999], Suzuki 1998 on typological dissimilation. While on the face of it, dissimilatory and harmonic constraints appear to be contradictory, they are united under a basic principle: similar but non-identical consonants are either rendered more similar or identical (harmony) or less similar (disharmony). For example, the sequence /m…b/ may be converted to [m….m] through nasal harmony, a process which occurs in Bantu languages such as Ndonga (Viljoen 1973) or Bemba (Hyman 1995), or to [n….b] via place dissimilation, as the Berber example above illustrates.

One of the co-occurrence constraints found in the two Ethiopian Semitic languages, Chaha and Amharic, is the place of articulation constraint (POAC). This constraint states that a verb root may not contain two consonants from the same place of articulation. This is a dissimilatory-type constraint, and a pan-Semitic pattern documented for Arabic (Bachra 2001, Cantineau 1946, Elmedlaoui 1995, Frisch, Broe & Pierrehumbert 2004, Frisch & Zawaydeh 2000, Greenberg 1950, Kurylowicz 1972, McCarthy 1988, 1994, Pierrehumbert 1993, Yip 1988), Akkadian (Reiner 1966), Hebrew (Bachra 2001, Koskinen 1964, Kurylowicz 1972, Tobin 1990, Weitzman 1987), Amharic (Bender & Fulass 1978) and Tigrinya (Buckley 1997). It is also found in other Afro-Asiatic languages such as Afar (Hayward & Hayward 1989) and Berber (Elmedlaoui 1995), as well as in Javanese (Mester 1986), Russian (Padgett 1995), Muna (Pater & Coetzee 2005), Japanese (Kawahara, Ono & Sudo 2005) and English (Berkley 1994, 2000). This constraint is often referred to by the name 'Obligatory Contour Principle' (OCP), a general phonological principle originally proposed by Leben (1973) for tone, but since extended to include any identical phonological features or segments. In Semitic, it takes the form of banning roots with two or more consonants drawn from the same place of articulation (labial, coronal, dorsal, guttural). The coronal class is usually subdivided into a class of coronal sonorants and coronal obstruents. The other co-occurrence constraint found in Chaha and Amharic is a 'Laryngeal constraint' (LC), and was described for Chaha in Leslau (1979), Banksira (2000), O'Bryan & Rose (2001) and Rose & Walker (2004). It takes the form of a harmony constraint, and applies only between coronal and velar stops, as labials show no contrast for laryngeal features[2]. It states that a verb root may not contain two contrasting oral stops with different laryngeal features. Chaha and Amharic have a three way contrast in coronal and velar stops between voiceless plain stops, voiceless ejectives and voiced stops: /t t' d k k' g/. Laryngeal harmony constraints are also attested in other languages, such as Kera, Ngizim, Hausa, Ijo, Aymara, Zulu (MacEachern 1997 [1999], Hansson 2001b, Rose & Walker 2004), and as dissimilatory constraints in Sanskrit, Cuzco Quechua (MacEachern 1997[1999] and Muna (Pater & Coetzee 2005). Chaha and Amharic differ in the scope of the LC. In Amharic, the constraint is more restricted, such that a verb root may not contain two contrasting *voiceless* oral stops with different laryngeal properties (i.e. /t/ /k'/).

Both the POAC and the LC have specific properties typical of co-occurrence constraints on words. First, the constraints are not exceptionless, and show gradient effects. Some places of articulation have more exceptions than others. This has been amply demonstrated for the POAC by Greenberg (1950) McCarthy (1994), Pierrehumbert (1993), Frisch, Broe & Pierrehumbert (2004) and Bachra (2001) for Arabic. Second, the constraints have a stronger effect in adjacent positions than in non-adjacent ones. Again, this has been shown for the Arabic place of articulation constraints. Finally, the constraints are root-bound. They show no evidence of operating across word-boundaries. The following examples illustrate that two labials, two coronal sonorants, and two alveolar stops with differing laryngeal features are attested in the languages:

(3)	Chaha	place:	b-əməddər	'in the place'
		laryngeal:	t-ɨt'u	'let her suck'
	Amharic	place:	l-ɨn-rot' nəw	'we are going to run'
		laryngeal:	sət'-to nəbbər	'his having given'

The fact that the POAC and LC consonant combinations may arise across morpheme boundaries suggests that frequency of combination may not constitute a large factor in potential speech error rates and further minimizes an analysis of error rates as due to a motor or practice effect. Speakers of the language do use sequences in other positions that are dispreferred by the constraints within roots. In fact the affix /t(ə)/ is an exceptionally frequent prefix/suffix in both languages, with multiple uses (2sg.fem. subject, reciprocal, reflexive-passive, converb, preposition, etc..). Other frequent prefixes and suffixes are kə-, lə-, bə-, sɨ-, al-, -n in Amharic and bə-, nə-, -nə -m, in Chaha.

Overview of Amharic and Chaha sound structure

The phonemic inventory of Amharic is /t, tʃ, k, k^w, b, d, dʒ, g, g^w, t', tʃ', k', k'^w, f, s, ʃ, h, z, ʒ, s’, m, n, ɲ, l, r, w, j/. The sound [dʒ] and [ʒ] alternate as quasi-free variants. The sound /h/ and /s’/ are rare, particularly in verb roots. The Chaha inventory is similar: /t, tʃ, k, k^j, k^w, b, b^w, d, dʒ, g, g^j, g^w, t’, tʃ’, k’, $k’^j$, $k’^w$, f, f^w, s, ʃ, z, ʒ, s’, m, m^w, r, w, j, (x, x^j, x^w, n)/. The sound [n] is derived from /r/ (Petros 1996), but does contrast in a few words (Banksira 2000). The sounds [x] and [k] alternate. Banksira (2000) analyzes /x/ as the phoneme and [k] as an allophone. The sounds [b] and [β] also alternate – Banksira analyzes /β/ as the phoneme and [b] as its allophone, appearing word-initially or post-nasally. In addition, there are a series of palatal/palatalized or labialized consonants in both languages, which are probably derived via processes of palatalization or labialization. Their distribution in verb roots is heavily skewed towards initial position. Finally, the glides /j w/ have irregular phonology, particularly within the verb roots.

This study examined only the fourteen evenly distributed, most frequent consonants (calculated from databases – see below). For the two languages, the frequency scales are given below:

(4) *high* *low*

Amharic: r l m b n s t’ d k’ g f t z k

Chaha: r (n) s t’ f b d k’ m g t k z (x)

(underlined sounds = same frequency)

The list contains only stops, fricatives, nasals and liquids, with no palatalized or labialized sounds.

Databases

Evidence for the constraints is based on an assessment of two databases. The Amharic corpus consisted of 4244 verbs taken from Kane's (1990) Amharic-English dictionary. The analysis was performed over 1874 non-reduplicative triliteral verb roots. In Semitic languages, the root consists of three consonants (or two or four), which combine with vowels in different positions to produce aspectual/tense distinctions in the verb, as well as other nominal/adjectival forms. For example, a root /dgm/ in Amharic produces the verb forms dəggəmə 'he repeated', jɨ-dəgm-al 'he repeats', jɨ-dgəm 'let him repeat', dəgaggəmə 'he reviewed' and the nouns dəgəma 'recitation', dəgim 'repetition', dɨggami 'something done more than once', adjective dɨggɨm 'repeated', and so on. This combinatorial characteristic of the language is useful in that it underplays the role of syllable or word position in assessment of the co-occurrence constraints. The remainder of the roots in the dictionary were either reduplicative (repetition of root consonants) or were quadriliteral, with four consonants. The Chaha corpus consisted of 855 verbs taken from Leslau's (1979), Banksira (2000) and the authors' fieldnotes. The analysis was performed over 303 non-reduplicative triliteral verb roots. The Chaha database is significantly smaller, as it is a less well-studied and less widely spoken language than Amharic, and does not have a significant written tradition. Although the constraints may also be operative in nouns, we focused on verbs for two reasons. First, this is the traditional locus of place of articulation constraints in Semitic. Second, Chaha has many non-native nouns borrowed from neighboring Cushitic languages (Leslau 1952), which may or may not conform to the constraint.

The analysis of the presence of a constraint was calculated using the Observed/Expected ratio (Pierrehumbert 1993, Frisch 1996, Frisch, Broe & Pierrehumbert 2004). This ratio compares the number of attested verbs that contain a pair of consonants to the number of verbs that would be expected by chance to contain that pair, taking into account the frequency of each individual consonant in the database. Cooccurrence of a pair of consonants is unrestricted if the value of O/E is equal to or greater than one. The presence of a constraint is indicated if the value of O/E is near zero. The classes of consonants used for the place of articulation are as follows:

(5) *Place of Articulation Constraint classes*

Labial – b m f

Coronal stops– t t' d

Coronal fricatives – s z

Coronal sonorants – r n l

Velar – k k' g

Coronal stops and fricatives are often grouped as a single class of obstruents in discussions of Arabic (Greenberg 1950, Frisch, Broe & Pierrehumbert 2004). Following Yip (1989), Padgett (1995), we divide coronal obstruents into two groups.

The following table provides the Observed/Expected Ratios for place of articulation for Amharic. C1C2 refers to the first two consonants of the triconsonantal root, C2C3 to the second and third and C1C3 to the non-adjacent pairs in first and third position.

TABLE 1

Observed/Expected Ratios for POAC constraint in Amharic

	C1C2	*C2C3*	*C1C3*	*Total*
Labials	0.029	0.028	0.345	0.134
Coronal Fricatives	0.027	0.036	0.309	0.124
Coronal Sonorants	0.024	0.126	0.875	0.342
Coronal Stops	0.360	0.032	0.637	0.343
Velar Stops	0	0	0	0
Grand total	0.088	0.044	0.433	0.188

Chi-squares were performed for each place of articulation, collapsing across position, and were statistically significant ($p<.00019$), indicating that attested combinations occurred less often than expected given the frequency of occurrence of the individual phonemes in the database. Each of the three positions were also attested less often than expected, including the non-adjacent C1C3 position ($\chi2(1) = 19.019$, $p < .00001$).

The Observed/Expected Ratio Table for Chaha is given below. It is clear that the constraint is absolute in adjacent positions, and for particular classes – coronal fricatives and velar stops. Unlike Amharic, Chaha has no contrast among coronal sonorants, so this group is left out. No chi-squares were necessary due to the 0 results.

TABLE 2

Observed/Expected Ratio for POAC constraint in Chaha

	C1C2	*C2C3*	*C1C3*	*Total*
Labials	0	0	0.356	0.119
Coronal Fricatives	0	0	0	0
Coronal Stops	0	0	0.587	0.196
Velar Stops	0	0	0	0
Grand total	0	0	0.236	0.079

From these results, it is clear that both languages show evidence of a place of articulation (POAC) constraint. In addition, both languages have zero combinations of velars. Finally, both languages show lower O/E ratios in adjacent positions, consistent with analyses of Arabic (McCarthy 1994, Pierrehumbert 1993, Frisch, Broe & Pierrehumbert 2004) and Tigrinya (Buckley 1997).

The laryngeal constraint has not previously been reported for Amharic, but has been reported for Chaha (Rose & Walker 2004). An analysis of non-homorganic pairs of consonants in Amharic verb roots was conducted to see if there was any evidence of a laryngeal constraint. Homorganic pairs would also violate the place of articulation constraint, so these would be disfavored independently. The results are shown below, with significant squares shaded.

TABLE 3

Observed/Expected ratios for laryngeal constraint in Amharic

	C1C2	*C2C3*	*C1C3*	*Total*
different [cg] [voice] k' d t' g	1.09	0.94	1.15	1.06
different [voice] k d t g	1.57	0.82	1.11	1.17
different [cg] k t' t k'	0.33	0.25	0.98	0.52
Total	1.00	0.67	1.08	0.92

Chi squares show significant results for adjacent voiceless stop combinations ($\chi2$ (1) = 9.674, $p < 0.002$), but not for voiceless stops in C1-C3 non-adjacent position ($\chi2$ (2) = 5.524, $p < 0.07$). Therefore, Amharic shows a laryngeal constraint for a subset of consonant combinations – the voiceless stops in adjacent positions.

The results from Chaha heteroganic pairs are shown below with significant squares shaded:

TABLE 4

Observed/Expected Ratios for Laryngeal constraint in Chaha

	C1C2	*C2C3*	*C1C3*	*Total*
different [cg] [voice] k' d t' g	0	0.27	0.70	0.32
different [voice] k d t g	0.96	0	2.27	1.08
different [cg] k t' t' k	0	0	0	0
Total	0.32	0.09	0.99	0.47

A significant result for all positions overall was found ($\chi2(3) = 28.322$, $p < 0.0001$). As in Amharic, the non-glottalized pairs had the highest overall O/E ratio and the voiceless pairs the lowest. Unlike Amharic, however, the *adjacent* positions are significant overall.

Different voicing was only significantly underrepresented in C2C3 position. In conclusion, Chaha shows evidence of a laryngeal constraint, but primarily when the glottalic feature differs between the two consonants.

EXPERIMENT 1: AMHARIC

Two experiments were conducted in order to determine the psychological status of the cooccurrence constraints in Amharic and Chaha, as well as to investigate the roles of similarity and frequency in speech errors. These experiments were conducted using the speech elicitation method of syllable ‘tongue twisters’ employed in Levitt & Healy (1985) and Wilshire (1999).

Experiment 1 investigates the speech error rate of Amharic consonant combinations. Specifically, the experiment is designed to determine whether native speakers will apply the POAC and the Laryngeal constraint on voiceless stops to the stimuli, as evidenced by a higher error rate for consonant combinations which violate these constraints than for consonant combinations which do not. Additionally, it will be determined whether such constraints are additive in nature, such that combinations which violate both constraints will be associated with more errors than combinations which violate only one constraint. And finally, it will be determined what role, if any, similarity and frequency play in speech errors separate from co-occurrence constraints.

Method

Subjects. The subjects were twenty native speakers of Amharic (10 male/10 female) born and raised in Addis Ababa, aged between 18 and 34, with no reported eyesight or hearing problems. Their education level ranged from completion of grade 8 through completion of grade 12. Subjects were reimbursed for their efforts. Subjects spoke minimal English and no other Ethiopian language. Their ability to read was checked by asking them to read aloud a short paragraph. The experiment was conducted in Amharic with the help of an Amharic-speaking research assistant. The first author was present for the experiment.

Materials. The stimuli consisted of 90 consonant pairs arranged into CV syllable quadruples, which did not correspond to real words. Four twisters were obtained from each pair for a total of 360. The CV syllables used the fourteen most frequent, evenly distributed consonants /b m f t t’d s z n l r k g k’/. The vowels were [ə] and [a], the most frequent vowels in Amharic verbs. Consonants were arranged in either an ABBA/BAAB or an ABAB/BABA pattern. Corresponding vowels were arranged in the opposite pattern in one of two orders (either ABBA or ABAB). An example of the four possible quadruples are given below:

(6)	ra lə rə la	rə la lə ra	la rə lə ra	lə ra rə la
C	A B A B	A B B A	B A B A	B A A B
V	A B B A	A B A B	A B B A	A B A B

The consonant pairs were divided into six sets, listed in Table 5.

TABLE 5

Classification of consonant pair stimuli

Set	*Label*	*Description*	*Status*
1	LC-VLESS	Heterorganic laryngeal-plain voiceless stops (k' t, t' k)	Violates LC
2	POAC	Homorganic pairs (labials, coronal sonorants, coronal fricatives, coronal stops, velars)	Violates POAC
3	DUAL	Homorganic pairs of voiceless coronal or velar stops (k' k, t t')	Violates LC and POAC
4	LC-OTHER	Heterorganic laryngeal – voiceless-voiced stops	Violates LC in Chaha, but not Amharic
5	SIM	High similarity pairs with same POA or same manner	Comparison set for constraint sets
6	DISSIM	Low similarity pairs	Comparison set for similarity set

The DUAL set consists of those combinations that violate both constraints. In the determination of the presence of the POAC constraint in the Amharic database (Table 1), the velar and coronal stop consonant categories included members of the dual category (k k' and t t'), but these are separated here to better test the hypotheses. Set 4 (LC-OTHER) was isolated as a separate group to maintain a design correspondence with the Chaha experiment. However, due to the fact that this group does not violate the LC constraint in

Amharic, it was not included in any of the statistical comparisons. Set 5 SIM was used to test the hypothesis that similarity plays a role in speech errors in Amharic even when no co-occurrence constraint is present. Set 5 was constructed from consonant pairs that share place of articulation (only coronals) or manner of articulation. They were all obstruent pairs except for the nasal pair /m n/.

In addition, each consonant combination is classified according to frequency. Relative frequency for each pair was calculated based on the frequency of adjacent pairs in the database. Frequency rates were divided into two groups: Low (0-.5) and High (>.51). Some pairs fell into a Low/High group - a combination in which one direction is low and the other is high. For example the sequence /k' f/ has a frequency of 0.19 (low), whereas the reverse /f k'/ has a frequency of 0.58 (high).

TABLE 6

Amharic consonant sets

	Frequency	*# of pairs*	*Sample Examples*
Set 1 – LC-VLESS	Low	2	k’ t, t’ k
Set 2 – POAC	Low	11	s z; r l ; t d; b f
Set 3 – DUAL	Low	2	k’ k, t’ t
Set 4 – LAR-OTHER	Low	1	k d
	Low/High	3	k’ d; t g
Set 5 – SIM	Low	6	f z; z d; t s
(match on place or manner)	Low/High	6	t’ s, t k; bg; k b
	High	5	k’ t’; d g; t’ b
Set 6 – DISSIM	Low	4	z k
(no match on place or manner)	Low/High	15	f g; z g; t’ f; s k’; z b
	High	35	s b; l g; n f; t’m
Total		90	

Procedure. The stimuli were presented to subjects on a DELL Inspiron 4000 laptop computer using the DMDX program. The items were written in black Ethiopic script (EthioSoft™ font, 36 point) on a white background with spaces between syllables. Each syllable was conveyed by a single unique symbol (the Ethiopic script is essentially a syllabary), as in the following example: ታ ከ ተ ካ *(= ta kə tə ka)*. It is important to note that similar consonants such as /k/ and /k’/ have very different symbols, i.e. ከ (kə)and ቀ (k’ə). The chance of orthographically- induced reading errors is thus reduced. The frame duration of each quadruple was 130 ticks (2.158 sec) with a delay between frames of 40 ticks (0.664 sec). Stimuli were presented to each subject in a different random order, automatically generated by the DMDX program. The subjects received the following instructions (in Amharic)

(7) *Instructions to subjects:*

1. These are arbitrary sequences of Amharic syllables.

2. Read each presented item as they appear on the screen, maintaining the same rate of speech. Try to ignore errors and avoid self-correction.

The experiment was divided into three sessions of 120 tokens, each with a rest period between sessions. The experiment took less than 30 minutes.

Error transcription. Recordings were broadly transcribed by the first author, who speaks some Amharic. Although more detailed transcription or acoustic analysis might reveal higher error rates or different kinds of errors (e.g. Mowrey & MacKay 1990, Frisch & Wright 2002, Pouplier 2003, Goldstein, Pouplier, Chen, Saltzman & Byrd, submitted), the large number of tokens did not allow for this kind of detailed measurement. The transcriptions for two subjects chosen at random were double-checked by a native Amharic speaker, and the agreement with the original transcription was 98%.

In reading the stimuli, all subjects divided the quadruple into two prosodic units of two syllables, with stress on the first syllable. Pilot tests in which subjects were instructed to read each syllable individually to avoid rhythmic patterns resulted in fatigue on the part of the speaker, and comments from the subjects that it was highly unnatural. Therefore, subjects were only given instructions to read the stimuli, and natural rhythm ensued. In addition to the prosody, speakers fairly consistently geminated either the second or fourth consonant in the twister if the preceding vowel was [ə]. The Ethiopic script does not normally indicate gemination; readers must recognize which words should be pronounced with gemination through context. The fact that subjects in the experiment did not geminate the third consonant is further confirmation that the twister was produced as two prosodic units, as the third consonant would be in initial position and ineligible for gemination. Amharic only has word-internal or word-final gemination. Nevertheless, gemination following [ə] in bisyllabic words is not required, ex.: <u>səga</u> 'meat', and gemination is also possible following [a]: ex. <u>sassa</u> 'he became thin'. Therefore, the consistent gemination does not appear to be correlated with existing lexical items, unless speakers were interpreting all bisyllabic sequences as 3rd person masculine singular perfective verbal forms (the citation form in the dictionary), in which case gemination following [ə] would be required, ex. <u>səbba</u> 'to be fat (animal), and gemination following [a] would be excluded, ex. <u>sabə</u> 'to draw, pull', except in reduplicative verb forms. The [a] in these verbs is the historical residue of a former 3rd root consonant, a guttural. However, as there was no indication that subjects processed the sequences as verbs, a more likely explanation is a prosodic one. The rhythmic repetitive character of the experiment may have induced a prosodic balance between the two bisyllabic sequences. Since /ə/ is a short vowel and /a/ a long one, gemination could have occurred following /ə/ to lengthen the stressed syllable on a par with the syllable containing /a/. A search of

Kane's dictionary, taking into account possible conjugation patterns, failed to find any bisyllabic CaCCə forms, whereas CəCCa forms are common.

Error coding. Each token was counted as 'correct' or 'incorrect'. Some tokens contained more than one error. The analysis reported here did not distinguish between tokens with one error and tokens with more than one error. Errors were coded for general error type: vowel, consonant, syllable or other. Stuttering errors were not counted. 'Syllable' involved complete exchange of two syllables: ex. ka nə na kə → ka nə kə na. 'Other' were cases in which the subject failed to finish the twister, or added an extra syllable. Vowel and consonant errors were coded for specific type of error – substitution, exchange or featural transmission (anticipation or perseverance), and for location of the error. Substitution errors resulted when a feature or consonant/vowel not present in the stimuli was produced. Exchange errors involved metathesis of consonants or of vowels, ex. sa mə ma sə → sa mə sa mə. Featural transmission errors were assimilatory-type errors where a consonant took on the feature of another consonant. The error ga kə ka gə → ga kə ga gə involves anticipation of the voicing of the fourth consonant.

Results

Although all subjects completed the task, there were some excessively high error rates, which may have been due to nervousness with the task. All subjects with error rates over 30% were excluded from analysis, leaving 14 subjects (6 were excluded). Individual error rates of remaining subjects ranged from 1% to 22.5%. The overall rate of consonant errors was 5.01% and that of vowel errors was 9.71%. These error rates are consistent with other speech error studies (Dell 1984, Wilshire 1999) [3]. There was no indication of fatigue or practice effects ($t(13)=1.6199$, $p > 0.1292$). The results for each set of consonants are shown below. Sequences that had Low/High frequency rates (see Table 6) were removed from the analysis (24 in all), leaving a total of 66 pairs. Error rates greater than 10% are shaded. LC-OTHER is maintained as a separate category, since this combination is a constraint violation in Chaha.

TABLE 7

Amharic consonant error corpus

	Frequency	*Total twisters with errors*	*Total twisters produced*	*Error rate*
1 – LC-VLESS	Low	12	112	0.1071
2 – POAC	Low	88	616	0.1429
3 – DUAL	Low	34	112	0.3036
4 – LC-OTHER	Low	0	56	0.0000
5 - SIM	Low	5	336	0.0149
	High	9	280	0.0321
6 – DISSIM	Low	1	224	0.0045
	High	36	1960	0.0184
Summary		185	3696	0.0501

A vowel error corpus was also created, but there were no significant error rates based on consonant combination type. Although all errors were coded for type (i.e. metathesis, assimilation, etc..), type results will not be addressed in this paper.

Analysis

The experiments were designed to test the roles that similarity, frequency, and the presence of one or more constraints on speakers' productions of tongue twisters. In order to test each of the three factors in turn, the groups being compared must be matched on the other two factors. To achieve this goal, the mean and the 95% confidence intervals around the mean were calculated for the properties of similarity and frequency for each set. If the confidence intervals for the sets under comparison overlapped, it will be assumed that the sets share comparable values for that property. It will be disclosed in the discussion of each comparison if any of these conditions were not met. For the constraint hypothesis and the dual hypothesis, it was necessary to isolate the presence or absence of a constraint violation from the factors of similarity and frequency. The constraint hypothesis maintains that the presence of a phonological constraint on consonant co-occurrence will result in a higher error rate than combinations not subject to a constraint (all else being equal) and the dual hypothesis maintains that combinations that violate two constraints will result in a higher error rate than those that violate just one. 2 x 2 Chi-squares were performed to test the inequality of error probabilities. For example, a Chi-square will determine if the proportion of errors in the POAC set is greater than the proportion of errors in the SIM set (no violation)? All comparisons were tested for significance at Bonferroni-adjusted α levels to maintain a family α-level of 0.05. A total of 18 comparisons were made; 9 for the entire error corpus and 9 for the consonant error corpus subset, although we report only on the consonant error corpus here. Anything reported as significant for the constraint hypothesis had a p-value less than 0.0083 (.05/6). Anything reported as significant for the dual hypothesis had a p-value less than 0.0167 (.05/3)

For the constraint hypothesis, the constraint sets LC-VLESS and POAC were compared against the low frequency members of Set 5 - SIM, the set of consonant combinations which also had high similarity. Similar consonants were those that shared the same place of articulation but different manner (i.e. /s t/) or same manner but different place of articulation (i.e. /b k/).

Results of the chi-squares were significant: Set 1-LC-VLESS vs. Set 5-SIM was ($\chi 2(1) = 19.586$; $p < 0.0001$) and Set 2-POAC vs. Set 5-SIM was ($\chi 2(1) = 28.768$; $p < 0.0001$). Both constraint groups (even though they did not contain combinations that violated both constraints) had significantly more errors than the control group.

Another method of computing similarity is the feature classes (SFC) method (Frisch 1996, 2000, Frisch, Broe & Pierrehumbert 2004), based on the following calculation:

(8)

$$\frac{\text{shared feature classes}}{[\text{shared feature classes} + \text{non-shared feature classes}]}$$

This method returns similarity rates for individual consonant combinations. To see whether computing similarity in this fashion altered the results, the similarity ratings of low-frequency consonant combinations in sets 5 and sets 6 were computed in a post-hoc analysis. Combinations with a high similarity rating and low frequency were used as the control group. A similarity rating of .30 or above resulted in four of the six pairs of Set 5-SIM (t s; d z; d s; s f). A similarity rating of .25 or above resulted in all six pairs of Set 5-SIM (t s; d z; d s; s f; f z; t z) plus one more (n t). The error rate for the small grouping is 4/224 = .0179, and that for the larger group is 5/392 = .0128, comparable to the .0149 rate with the experiment design method of calculating similarity. There was no difference in the results - both methods of calculating similarity resulted in significantly higher error rates for the constraint sets. Chi-squares for the smaller group are calculated here: (Set 1-LC-VLESS vs. Set 5-SIM-SFC was ($\chi2(1) = 11.183$; $p < 0.0004$ and Set 2-POAC vs. Set 5-SIM-SFC was ($\chi2(1) = 24.240$;$p < 0.0001$).

Turning to the dual hypothesis, Set 3- DUAL had double the error rate of Set 2-POAC ($\chi2(1) = 17.547$; $p < 0.0001$) and almost triple the error rate of Set 1-LC-VLESS ($\chi2(1) = 13.241$; $p < 0.0003$). It had significantly higher error rates than Set 5-SIM (Set 3-DUAL vs. Set 5-SIM ($\chi2(1) = 88.087$; $p < 0.0001$).

To summarize, the consonant combinations violating constraints had significantly higher error rates than those combinations that were only highly similar. In addition, the Set 3-DUAL category with two constraint violations had significantly higher error rates than the categories with single constraint violations, Set 2-POAC and Set1-LC-VLESS.

For the similarity and frequency hypotheses, it was necessary to isolate similarity from the factors of constraint violation and frequency, and for the frequency hypothesis, to isolate frequency from the factors of constraint violation and similarity. Based on previous research, it was expected that combinations of similar consonants would result in a higher error rate than more dissimilar consonants, and that less frequent consonant combinations would result in a higher error rate than frequent. 2 x 2 Chi-square were performed to test the inequality of error probabilities. All comparisons were tested for significance at Bonferroni-adjusted α levels to maintain a family α-level of 0.05. A total of 18 comparisons were made; 9 for the entire error corpus and 9 for the consonant error corpus subset. Anything reported as significant for the similarity and frequency hypotheses had a p-value less than 0.0083 (.05/6).

Consonant combinations with high similarity rates were assessed against combinations with low similarity (using the place/manner method) where the frequency matched. For frequency, consonant combinations with low frequency were assessed against combinations with high frequency. The results were not significant. Chi squares for high vs. low similarity with low frequency: ($\chi 2(1) = 1.376$; $p = .2408$) and for high vs. low similarity with high frequency: ($\chi 2(1) = 2.362$; $p = .1243$). Chi squares for high vs. low frequency with low similarity: ($\chi 2(1) = 2.049$; $p = .1523$) and for high vs. low frequency with high similarity: ($\chi 2(1) = 2.333$; $p = .1266$). Therefore, no significant effect of similarity or frequency on speech error rate was found when co-occurrence constraints were excluded.

Since subjects divided the quadrisyllabic stimuli into two prosodic units, it is possible that some of the bisyllabic sequences corresponded to actual lexical items, and that familiarity with the lexical items led to fewer errors. A thorough search of Kane's dictionary was undertaken and all lexical items that corresponded to the stimuli ($C\text{ə}C_i(C_i)a$ or CaCə forms) were identified. Of all the possible combinations of test consonants, there were 14 combinations that were unattested in the dictionary (11 of these constraint violations) and 15 combinations with only one attestation (3 of these constraint violations). However, in order to test whether lexical item attestation played a role in error rate independently of constraints, non-constraint combinations were examined. As it was independently determined that similarity and frequency do not play a role in error rate, all non-constraint combinations were grouped together:

TABLE 8

Error rates corresponding to attested lexical items

Attested Lexical Items	*Number of combinations*	*Number of errors*	*Error rate*
0	3	1	1/168 = .006
1	12	10	10/672 = .015
2	21	27	27/1176 = .022
3	23	29	29/1288 = .023
4	13	14	14/728=.019
5	4	1	1/224 = .004

The results show that there is no worse error rate when combinations correspond to zero or one lexical item than when they correspond to many. The highest error rates occur when combinations correspond to two or three lexical items. Therefore, there is no evidence of a correspondence between attested lexical items and error rate when constraints are not present.[4]

In summary, the results revealed that there were significantly high error rates with those consonant combinations that violated the Laryngeal Constraint and the Place of Articulation Constraint, confirming the constraint hypothesis. Furthermore, those combinations that violated both constraints had the highest error rate of all, significantly higher than either single constraint alone, confirming the hypothesis that the constraints are cumulative. However, the hypotheses that similar consonant combinations and less frequent consonant combinations, independent of the constraints, would result in high error rates were not confirmed.

EXPERMENT 2: CHAHA

Methods

The Chaha experiment used the same methodology as the Amharic experiment. Differences will be pointed out where appropriate.

Subjects. The subjects were twenty native speakers of Chaha (14 male/6 female), born and raised in the Gurage Zone, aged between 18 and 35, with no reported eyesight or hearing problems. The Chaha subjects were bilingual in Amharic and spoke minimal English. Bilingual subjects were necessary due to the written nature of the experiment.

Chaha is not generally a written language (apart from a few novels and the New Testament) but when written, the same Ethiopic script is used with some slight modifications for sounds not found in Amharic; students learn to read and write using Amharic. Education level was completion of grade 8 up to completion of grade 12.

Subjects were reimbursed for their participation. The experiment was conducted in Chaha with a Chaha-speaking assistant. The first author was present for the experiment.

Materials. The stimuli consisted of 74 consonant pairs arranged into CV syllable quadruples, which did not correspond to real words. Four twisters were obtained from each pair for a total of 296. The CV syllables used the twelve most frequent, evenly distributed consonants, based on a frequency count of the Chaha database: /b m f t t' d s z r k g k'/. The consonants [n] and [x] were also included, despite their quasi-allophonic status (of /r/,/k/). Both occur in the surface form of verb roots, ex. k̲əfətəm 'he opened' or gən̲əzəm 'he became old'. The vowels were [ə] and [a]. Consonants were arranged in either an ABBA or an ABAB pattern Corresponding vowels were arranged in the opposite pattern (either [a ə ə a] or [ə a ə a]).

The consonant pairs were classified according to the same five sets as in Amharic. The total was only 70, since four pairs were pulled from the analysis (see below).

TABLE 9

Chaha consonant sets

	Frequency	*# of pairs*	*Examples*
Set 1 – LC-VLESS	Low	2	k' t; t' k
(voiceless-ejective)			
Set 2 – POAC	Low	4	s z; m f
Set 3 - DUAL	Low	6	t d,; k’ k; k g
Set 4 – LAR-OTHER	Low	4	t’ g ; k d
(voiced-voiceless or voiced-ejective)			
Set 5 – SIM	Low	8	z d ; z t’; g b; f z
(match on place or manner)	Low/High	2	s f ; s d
	High	7	k' t'; d b; k b
Set 6 – DISSIM	Low	3	z k’ ; z k
(no match on place or manner)	Low/High	7	b z ; k’ m
	High	27	r m; f r; d r; g n
Total		70	

Procedure, transcription, coding. The procedure, transcription and coding was the same as for Experiment 1. All subjects divided the quadruple into two prosodic units with stress on the first syllable. Unlike Amharic speakers, no gemination was noted for the

Chaha speakers. Chaha does not have geminates, and this alleviates concerns that the subjects might have been processing the syllable twisters as 'Amharic', due to the nature of the reading task. Furthermore, the fact that the experiment was conducted in Chaha, instructions were given in Chaha, and that the instructions specified the syllables as 'Chaha syllables' reinforces the Chaha nature of their productions.

There were some reading problems with the consonant [x]. Twenty-five consonant errors involved tokens with [x], 16 of which involved non-contextual substitution of [k] for [x]. Eight consonant errors occurred in which [x] substituted for [k]. Since [k] and [x] are allophonic, this may have been due to the allophonic status of the sounds. However, no such similar problem occurred with [n] and [r], which are also allophonic. [x] is not commonly used in Amharic and inexperience with this character may have led to more errors. In addition, the two symbols for [k] and [x] are similar. [x] is a modification of the symbol for [k]. Since non-contextual subsitutions were relatively uncommon in the data (17 in total), the conclusion is that the [x] errors were likely orthographic reading errors[5]. Therefore, all tokens with [x] were removed from the analysis (total of 136 for 17 speakers).

Results

As with Experiment 1, all subjects completed the task successfully, but there were three subjects with error rates above 30%. These subjects were excluded, leaving 17. Individual error rates of the remaining subjects ranged from 3.8% to 22.5%. There were 227 tokens with consonant errors (5.56%) and 195 tokens with vowel errors (4.78%). The results for each set of consonants are shown below.

TABLE 10

Chaha consonant error corpus

	Frequency	*Total twisters with errors*	*Total twisters produced*	*Error rate*
1 – LC-VLESS	Low	15	136	0.1103
2 – POAC	Low	31	272	0.1140
3 - DUAL	Low	90	408	0.2206
4 – LC-OTHER	Low	9	204	0.0441
(LC 1 + 4)	Low	22	540	0.0407
5 - SIM	Low	22	544	0.0404
	High	18	476	0.0378
6 – DISSIM	Low	3	204	0.0147
	High	39	1836	0.0212
Total		227	4080	0.0556

As with Amharic, the rates for Sets 1 and 2 have error rates above 10%. Set 4-LC-OTHER, which does constitute a constraint set in Chaha, has an error rate below 5%. In addition, the DUAL category in the Chaha chart includes those consonant combinations that violate LC-OTHER as well, namely [t’ d, k’ g, t d, k g]. Similarity to existing lexical items was not determined to be a factor in Chaha, due to the extreme paucity of forms that corresponded to actual word in Chaha. In particular, unlike Amharic, the 3rd person masculine singular verb conjugation in Chaha occurs with a prefix or a suffix.

2 x 2 chi-square analysis was performed for the Chaha results. The constraint set of voiceless consonants and the constraint set of POAC had significantly higher error rates than the similar control set: Set 1-LC-VLESS vs. Set 5-SIM was ($\chi 2(1) = 10.318$; $p < 0.0013$) and Set 2-POAC vs. 5-SIM was ($\chi 2(1) = 16.143$; $p < 0.0001$). However, Set 4-LC-OTHER (voiceless-voiced and voiced-ejective) combinations, which did show evidence of a constraint in the database analysis of Chaha, did not have significantly higher error rates (Set 4-LC-OTHER vs. Set 5-SIM was ($\chi 2(1) = 0.050$; $p = 0.8222$)), and neither did the LC category as a whole: LC (1-LC-VLESS + 4-LC-OTHER) vs. 5-SIM was ($\chi 2(1) = 3.855$; $p < 0.0496$).

As for the Dual hypothesis, comparisons of the Dual category with each of the single violation categories were significant: Set 2-POAC vs. Set 3-DUAL ($\chi 2(1) = 12.682$; $p < 0.0004$), LC (Sets 1 + 4) vs. Set 3-DUAL ($\chi 2(1) = 32.302$; $p < 0.0001$, Set 1-LC-VLESS vs. Set 3-DUAL ($\chi 2(1) = 7.966$; $p < 0.0048$. Finally, Set 3-DUAL vs. Set 5-SIM was ($\chi 2(1) = 72.888$; $p < 0.0001$).

To test the similarity hypothesis, consonant combinations with high similarity rates were assessed against combinations with low similarity (using the place/manner method) where the frequency matched. To test the frequency hypothesis, consonant combinations with low frequency were assessed against combinations with high frequency where similarity matched. The results were not signficiant. Chi squares for high vs. low similarity with low frequency: ($\chi 2(1) = 3.042$; $p = .0812$) and for high vs. low similarity with high frequency: ($\chi 2(1) = 4.318$; $p = .0377$). Chi squares for high vs.

low frequency with low similarity: ($\chi 2(1) = 0.046$; $p = .8293$) and for high vs. low frequency with high similarity: ($\chi 2(1) = 0.389$; $p = .5328$).

In summary, the results revealed that there were significantly high error rates with those consonant combinations that violated the Place of Articulation Constraint, confirming the main hypothesis. As a whole, the LC group did not show evidence of a significantly high error rate, but the sub-group LC-VLESS did. Those consonants that violated both constraints had the highest error rate of all, significantly higher than either single constraint alone, confirming the hypothesis that the constraints are cumulative. However, the hypotheses that similar consonants and less frequent consonant combinations, independent of the constraints, would result in high error rates were not confirmed.

GENERAL DISCUSSION

The results from both experiments demonstrate that those consonant combinations that violated the POAC and the Laryngeal constraint on voiceless stops were associated with significantly higher error rates than consonant combinations which did not violate a constraint and matched on similarity and frequency. The expanded Laryngeal constraint in Chaha (LAR-OTHER) which included the plain voiceless-voiced and voiced-ejective combinations, did not show significantly high error rates, despite low O/E ratios. There are several possible explanations for the lack of effect with Laryngeal-other. First, Chaha shows evidence for Laryngeal-other constraint with voiced-ejective pairs, but for voiced-voiceless only in C2C3 position; it is possible that the voiced-voiceless combinations are responsible for the non-significant result. Nevertheless, the error rate for heterorganic ejective-voiced pairs was still low at .05. Second, O/E ratios are based on underlying 'root' representations, not surface representations. Chaha verbs exhibit a devoicing process that devoices penultimate consonants under certain conditions (see Banksira 2000), leading to voicing mismatches in verbal paradigms. From the underlying root /gdr/, forms with [d] are found (jɨgədɨr 'he puts to bed' and those with devoiced [t]: gətərəm 'he put to bed'. This process could undermine the effect of the Lar-other constraint. It may also suggest that speakers reference surface forms rather than underlying representations. Finally, the similarity rating LC-OTHER according to the shared feature class method of computing similarity is very low compared to LC-VLESS (LC-OTHER ranges from .15 to .17 vs. .40 for LC-VLESS and a range of .24 to .42 for POAC). Thus, one wouldn't predict the presence of a constraint on LC-OTHER from the similarity rating.

Both languages confirmed that doubling up the constraints on a consonant combination led to double the error rate, and this occurred despite the inclusion of LC-OTHER in the dual category for Chaha. The dual category was also carrying the weight of the significant differences between POAC as a whole and the comparison sets. The Chaha results are also revealing as all the POAC combinations had 0 frequency of O/E ratios, and yet the greater error rate for the duals suggests that knowledge of the laryngeal constraint did influence the error rate. The results thus support the hypothesis that the effects of co-occurrence constraints are cumulative, and further support the hypothesis that co-occurrence constraints reflect processing difficulties which are additive in nature.

Neither language showed evidence of frequency impacting error rates. Only Chaha showed a trend towards impact of similarity on error rates, but only with high frequency consonants, and it was not significant. This is somewhat unexpected given previous research on similarity and error rates. However, it could be that the consonants examined were not similar enough to produce processing difficulties. Or, this could be an artifact of the method of measuring similarity –more detailed correspondence might reveal a correlation.

CONCLUSION

Although Semitic languages are known to have co-occurrence restrictions on non-identical consonant combinations, little psycholinguistic research has been performed on this aspect of their structure (although see Berent, Vaknin & Shimron 2004 on a contrast between identical and 'similar' consonants). The two experiments presented here shed light on the grammatical status of co-occurrence restrictions in two Semitic languages that have not been previously investigated using psycholinguistic methodology. The experiments reveal that speech errors occurred at a significantly higher rate for consonant combinations that violated co-occurrence constraints in the languages. Even though the consonants involved in co-occurrence constraints bore high similarity to each other, similarity was not shown to be a factor in impacting the speech error rates in the languages. Frequency of co-occurrence also did not play a role in the error rates, suggesting that error rates were not due to lack of familiarity with the consonant combinations. From this we can conclude that the two similarity-based co-occurrence constraints, but not similarity or frequency, influence the productions of speakers of Chaha and Amharic. Further, the result that doubling the constraint violations doubles the error rate suggests that the constraints are reflections in the grammar of the processing difficulty associated with these combinations.

ENDNOTES

[1] The term ‘phonotactic constraint’ or ‘co-occurrence constraint’ can be used to refer to constraints on the occurrence of particular sounds in specific positions, such as ‘no syllable-initial [ŋ]’ in English, or no syllable initial [tl] or [dl] sequences. The focus in this discussion is on co-occurrence constraints on consonants regardless of syllable or word position.

[2] In both languages, the labial stops [p] and [p’] occur in borrowed words. In addition, in Chaha, [p] is the reflex of a former geminate *bb. Banksira (2000) further argues that the bilabial phoneme is the sonorant /β/ for Chaha, which has [b] as an allophone.

[3] For example, Dell (1984) found 3% on non-critical pairs and 8% on critical pairs using the SLIPs technique, Wilshire (1999) had an error corpus of 4.5% of words uttered in the experiment.

[4] It was not possible to test for frequency of usage of the attested combinations.

[5] Some of the other substitution errors may be attributed to reading errors. For example, the symbols for /f/ and /r/ are relatively similar, as are those for /k/ and /b/ or /m/ and /t’/. Yet there was only one of each of these substitutions.

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