PRINCIPLES FOR A CONTRASTIVE PHONOTACTICS: THE HEBREW TRICONSONANTAL (CCC) ROOT SYSTEM A CASE IN POINT*

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I. INTRODUCTION: THEORETICAL AND METHODOLOGICAL BACKGROUND

In this paper we will present a quantitative analysis of the phonetic distribution of the Hebrew triconsonantal (CCC) root system based on the Columbia School approach of "Phonology as Human Behavior" which was originally presented for English in Diver (1979), further expanded and refined for Italian in Davis (1987), and compared and contrasted with other phonological theories in Tobin (1988a,b). One of the goals of this paper therefore will be to present a set of fundamental phonological or phonotactic principles which could be used in establishing a basic methodology for a contrastive phonotactics. According to this general approach, language is defined as a system of systems composed of various sub–systems (revolving around the notion of the linguistic sign) which are organized internally, and systematically related to each other to be used by human beings to communicate. Therefore "phonology as human behavior" is based on the following theoretical and methodological tenets:

(1) Phonetics and phonology are interrelated, mutually dependent and, thus, are not to be studied autonomously and independently of each other.

(2) Phonetics = Description of what sounds occur and which features (articulatory and auditory) they are composed of – i.e., how individual sounds are articulated and perceived – the "what" and "how" of the realized sound system of (a) language. ("What", "Where" and "How" = Description)

(3) Phonology = A postulation of the abstract units of the sound system of (a) language (e.g., the notions of the phoneme composed of distinctive articulatory and auditory features) as well as an explanation of the favored and disfavored combinatory distributions of different sounds – i.e. why different sounds occur or do not

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occur with different statistical skewings in: (i) specific phonetic environments as well as (ii) in collocation with other sounds. i.e., not just "where", "what", and "how", but "why". ("Why" = Explanation)

(4) The fundamental problem of phonology, therefore, is to explain the observable phonotactic skewings of the distinctive sound units of language which can be verified both synchronically and diachronically as they have developed over centuries by speakers of the language.

(5) We may assume that these long–range, non–random recurrent phonotactic skewings represent favorings and disfavorings of certain collocations of distinctive sound units in different phonetic environments.

(6) We may further assume that these different phonotactic skewings, i.e. the skewed favorings and disfavorings, are reflections of specific aspects of human behavior, perception and cognition which are exhibited in other areas of human behavior in general, and communicative behavior in particular, which, like language, are also learned.

(7) We also may infer that a disfavoring may represent a difficulty in the learning process, or in perception, and by examining what constitutes a difficulty in a particular learning process, we can infer what is being learned or perceived.

(8) What is being learned or perceived may then be identified as a characteristic of the distinctive units.

(9) Thus, an explanation of the long–range, non–random recurrent phonotactic skewings representing favorings and disfavorings of certain collocations of distinctive sound units in different phonetic environments may provide us with distinctive features of sounds in a way which will be comparable to other areas of human behavior; therefore allowing us to view phonology as an instance of human perception and cognitive behavior.

In short, we may view this approach of "phonology as human behavior" as axiomatically combining two synergetically interrelated orientations: the communication factor (the teleological function of language) with the human factor (the users of language). This approach, therefore, may be selectively viewed as part of an historical chain in the development of twentieth century phonological theory beginning with Saussure and continued by the Prague School and André Martinet. Since this study attempts to deal quantitatively with the combinatory phonology of the Hebrew (CCC) root system to specify the semiotic implications of the synergetic relationship between the communication and human factors, it may also be related to other quantitative approaches to sign–oriented language and phonology in general (Herdan 1966, Shannon and Weaver 1949), phonometrics (Zwirner 1970) and phonometric based phonotactics (Bluhme 1964), and language synergetics (Altmann 1978, Altmann and Lehfeldt 1980), approaches which have been discussed, compared and contrasted in Tobin (1988c,d).

II. THE DATA

We will present here only a partial analysis of a limited number of selected variables of the combinatory phonotactics of the (CCC) root system of a generalized (panchronic) view of Hebrew, leaving a more complete analysis for different periods and dialects of Hebrew for future research. Our analysis entails the application of general phonological principles that were previously postulated and examined for all the monosyllables found in English and Italian dictionaries to the more abstract pre–lexical notion of the (CCC) root system of Hebrew. In other words, our data represent abstract linguistic signs prior to the lexicalization process of word formation.

The difference in the unit of analysis has certain theoretical and methodological implications. Much of the research on English and Italian focussed on word–inital and word–final consonants. Therefore, these consonants were being examined at the beginnings and ends of clearly defined and relatively well–segmented independent units. This is not the case with the Hebrew (CCC) root system. Hebrew roots do not appear *as* words, but rather *in* words. Unlike words, however, these roots are not clearly defined, well–segmented independent units. The first and third consonants of a (CCC) root do not necessarily appear in word initial and word final positions. Not all (CCC) roots are transparent, nor are they always easily segmented within words. Thus, the successful application of phonological principles previously applied to the more concrete unit of monosyllabic words to this more abstract pre–lexicalized level of (CCC) roots should provide a strong confirmation of their theoretical and methodological validity.

Our data base consists of all the (2773) (CCC) roots appearing in the latest edition of the *Even–Shoshan Condensed Hebrew Dictionary*, a standard dictionary used in Israel today. This particular dictionary was chosen because it lists the roots and indicates the historical period (Biblical, Talmudic, Mishnaic, Medieval, Modern and Contemporary) of entries, and also includes the entire range of spoken and written registers. The use of a dictionary as a data source forces us to rely on a standard Hebrew orthography, which, like most alphabets (or syllabaries), represents a fairly accurate phonemic analysis of the sound (or consonants) of the language spoken when the writing system was developed. Such a standardized orthography may best represent a general or panchronic view of language's sound system. The choice of all the (CCC) roots found in the lexicon is motivated by the principle of "the least possible evil" with regard to finding a reasonable representation of the various diachronic and synchronic stages of both spoken and written Hebrew which would provide as broad a data base as possible to yield significant statistical generalizations about Hebrew.[1]

[1] We are presenting an (oversimplified) panchronic view of Hebrew whereby certain unavoidable diachronic, orthographic and dialectal inconsistensies are present. These include the Biblical occlusive–spirant allophonic (today basically phonemic) alternations (p–f, b–v, k–x) (which have also been partially maintained in General Israeli), as well as the similar (g–ɣ, d–ð, t–θ) alternations which have been lost. Orthographically, each pair is represented by a single letter only. We also will maintain the pharyngeal "*xet*", "*ayin*" and the glottal stop "*aleph*" as well as the so–called "apical (r)" which do not necessarilly appear in General Israeli, and (lip +) post–dorsal /w, q/, even though /w/ has been replaced by /v/ and /k/ and /q/ have merged. We list "*tet*" and "*taf*" as +Ṭ–t" but view them as a single sound, while +"S" representing two distinct sounds today, (ʃš + s) will be treated as a single unit. We will not specifically deal with the ejective consonants well–known in Semitic either. We would like to add, however, that the patterns we have uncovered for this panchronic view of Hebrew are even strengthened in General Israeli speech where there are fewer communicative distinctions involving fewer (particularly back) active articulators.

III. ACTIVE ARTICULATORS, CONSTRICTION AND AIR FLOW

We first found the traditional consonantal categories (e.g., place of articulation, manner of articulation, voicing) previously used in studies of the Semitic and Hebrew root system (e.g., Greenberg (1950), Herdan (1962), Morgenbrod and Serifi (1981)), to be wanting for the following reasons:

(1) Place of articulation often merely labels a passive or receptive articulator only, (dental, alveolar, palatal or post–alveolar, velar, etc.).

(2) Manner of articulation often includes specific place information together with labels indicating different degrees of constriction and air flow (e.g., oral vs. nasal stops, central vs. lateral (alveolar) fricatives and/or approximants) and also includes place oriented and/or articulator oriented phonation processes (e.g. labialization, dentalization, palatalization, velarization, nasalization, glottalization, etc.).

(3) These and other manner categories (e.g., consonants versus vowels, semi–vowels, liquids, glides, approximants, and/or obstruents versus resonants, etc.) often depend on the concept of voicing and are all directly or indirectly related to different degrees of constriction and air flow.

(4) Voicing also spans the opposition of place and manner and is related to both specific articulators (the larynx, glottis, vocal folds) and different degrees of the control of air flow (fortis vs. lenis).

Therefore, we replaced these imprecise traditional categories by alternative concepts such as "active articulators" and "scales of relative degrees of stricture and airflow" which have been applied more directly to the communication and human factors inherent to our approach.[2]

IV. THE HEBREW CONSONANT SYSTEM: THE ACTIVE ARTICULATORS

We first examined the Hebrew consonant system according to the concept active articulators. The six active articulators which can be postulated for Hebrew are the lips, the tongue divided into three parts (apex, ante–, post– dorsum), the pharynx, and the glottis.

The Hebrew consonants distribute in the following manner with regard to the active articulators:

(1) lips:	/p, b, m/;
(2) apex:	/t–T, d, n, ts, r, s, z, l/;
(3) ante dorsum:	/ʃ, j/;
(4)a post–dorsum:	/k, g/;
(4)b (lips/velum +) post–dorsum:	/ħ, ʕ/;
(5) pharynx:	/ħ, ʕ/;
(6) the glottis:	/ʔ, h/.

[2] Diver (1979) originally proposed two alternative distinctive manner features (stabile + mobile) to explain all the various favorings and disfavorings of of initial consonant clusters composed of "stop + r" versus "fricative + l" in English monosyllables. In Davis (1987) this approach is expanded and includes these and other consonant and vowel features as part of a single continuum.

The first basic tenet of phonology as human behavior is that speakers of a language are learning how to control the musculature of different articulators to systematically produce distinctive sounds composed of relative degrees and patterns of constriction and air flow to communicate.

V. THE DISFAVORING OF ADDITIONAL ARTICULATORS

The second basic tenet of phonology as human behavior is that there should also be a direct connection between the relative difficulty involved in learning how to control the musculature of the various articulators needed to produce distinctive sounds and the non–random distribution of those sounds within the language. If, for example, we examine what are traditionally called the voiceless–voiced–nasal triads of the Hebrew labials /p–b–m/ and apicals /t–d–n/ according to the number of active articulators speakers must learn to control, we find that they form the following tri–dimensional hierarchy:

(1) Voiceless (0)	= active (oral) articulators only;
(2) Laryngeal (+1) (L)	= active (oral) articulator(s) + vocal folds;
(3) Nasal or Velar (+2) (V)	= active (oral) articulator(s) + vocal folds + uvular).

An examination of the twenty–two consonants of Hebrew with the number of sets of active articulators speakers must learn to control reveals:

0	–	/p, t–T, ts, s, S, k, q, h, ʔ, ħ/	= 11
+1 (L)	–	/b, d, r, l, z, j, g, w, ʕ/	= 9
+2 (V)	–	/m,n /	= 2

The largest number of consonants in Hebrew (11) entail the fewest active articulators needed to be controlled (Ø); closely followed (9) by those consonants where only one additional set of active articulators needs to be controlled (+1); followed by a sharp drop (2) for those consonants where a second additional set of active articulators needs to be controlled (+2). There is a direct connection between the Hebrew consonant system and this tri–dimensional hierarchy clearly indicating a consistent disfavoring of those consonants for which speakers have to learn to control additional sets of active articulators. Therefore the Hebrew (CCC) root system reflects the well–known synergetic principle of linguistic economy: the need for communicative efficiency (a maximum number of distinctive communicative oppositions) maintained with a minimum of effort.[3]

[3] This principle may also be applied, in part, to the loss or merger of certain oral consonants as well. (There may be additional sociolinguistic reasons for the well–known loss of pharyngeal or glottal consonants in Hebrew.) Indeed, many of those consonants which have been replaced by or have merged with other consonants, (e.g. /w–v/, /q–k/, /T–t/, are precisely those consonants requiring the control of more than than one articulator, (lips/velum + P–Dorsum, ejective versus non–ejective).

VI. THE DISFAVORING OF ADDITIONAL ARTICULATORS IN ADJACENT PHONETIC ENVIRONMENTS

This disfavoring of additional articulators may not only be observed within the phonemic system, but also may have wider implications for the combinatory phonology or phonotactics of a language. It has been shown, for example, that there is a general and significant disfavoring of the use of additional articulators in adjacent phonetic environments. The specific adjacent phonetic environments examined include consonants composing word initial consonant clusters in English monosyllables; word initial consonant clusters and word final consonants and consonant clusters in English monosyllables; word initial and word final consonants in English and Italian monosyllables.

An examination of the first and third consonants of the Hebrew (CCC) root system according to the tri–dimensional hierarchy of the number of active articulators reveals the following distribution:

	Ø		L (+1)		V (+2)	
I	1537	55.4%	917	33.1%	319	11.5%
III	1284	46.3%	1084	39.1%	405	14.6%

(1) Approximately half of all the initial and final consonants involve only one set of active articulators (Ø).

(2) Approximately one–third to forty per cent of articulators involve one additional set of active articulators (+1);

(3) Approximately ten to fifteen per cent of consonants involve the use of a further additional set of active articulators (+2).

This disfavoring of additional articulators in the Hebrew C–I and C–III positions both reflects the distribution of the Hebrew consonants within the phonemic system and supports the previous research done for English and Italian.

VII. THE HEBREW CONSONANT SYSTEM: STRICTURE AND AIR FLOW

Before we could further examine the skewed phonotactic distribution of the Hebrew consonants within the (CCC) root system, we had to look at the other important features of consonants: "scales of relative degrees of stricture and airflow". Three degrees of air flow and five degrees of stricture have been postulated for both the consonants "phonemes of constriction" and vowels ("phonemes of aperture") of Italian (Davis 1987). However, since we are dealing exclusively with consonants, or "phonemes of constriction", we will only need to present here two degrees of each.

The Hebrew consonants can be classified in the following way based on this hierarchical scale (Ø–2) of stricture and air flow:

(1) Complete constriction (Ø) and complete obstruction of the air flow (Ø): /p, t–T, k, ʔ, q, b, d, g/.

(2) Complete constriction (0) and partial (non–turbulent) obstruction of air flow (2): /m, n/.

(3) The next degree of (incomplete) stricture (1) and (turbulent) air flow (1): /(f–v), s, S, (x) h, ħ, z, ʕ/.

(4) Transitory (complete–incomplete) constriction (Ø–1) and (obstruction–turbulent) air flow (0–1): /ts/

(5) The next degree of incomplete stricture (2) and (non–turbulent) air flow (2): /l, j, w/.

(6) Lastly, an intermediate degree of constriction (1/2) and (turbulent) air flow (1/2): /r/.

There is an integral connection between the active articulators and the relative scale of stricture and air flow. Both sets of features must be taken into account when studying the combinatory phonology of the Hebrew root system.

VIII. THE DISFAVORING OF ADDITIONAL ARTICULATORS IN ADJACENT PHONETIC ENVIRONMENTS FOR DIFFERENT ARTICULATORS

We first observed the general disfavoring of additional sets of active articulators for what traditionally has been referred to as voiceless–voiced–nasal oppositions. We then examined whether a similar disfavoring can also be found for what is usually referred to as voiced versus voiceless obstruents. A comparison of those consonants sharing the same active articulators and the same degrees of constriction and air flow, but differing (Ø, +1) within the tri–dimensional hierarchy reveals the following distribution:

	Lip			Apex			P-Dorsum		Pharynx	
				First Position: C-I						
			T	77			q	139		
(Ø)	p	166	t	144	s	144	k	110	ħ	175
				—				—		
				221				249		
(+1)	b	127	d	103	z	77	g	121	ʕ	159
		—		—		—		—		—
Difference:		(39)		(- 118)		(- 67)		(- 128)		(- 16)

	Lip			Apex			P-Dorsum		Pharynx	
				Third Position: C-III						
			T	99			q	148		
(Ø)	p	141	t	73	s	105	k	81	ħ	126
				—				—		
				172				229		

(+1)	b	137	d	144	z	61	g	67	ʕ	119
		—		—		—		—		—
Difference:		(-4)		(-103)		(-44)		(-162)		(-7)

These data indicate a further "across the board" disfavoring of additional articulators (Ø, +1) (voicing) in the phonetic environment of C–I and C–III positions for consonants sharing the same active articulators and the same degree of stricture (Ø– Ø stops) (1–1 fricatives), for the following active articulators:

(a) lips:	/p–b/	(I – 39),	(III – 4)
(b) apex:	/t+T–d/	(I – 118),	(III – 103)
	/s–z/	(I – 67),	(III – 44)
(c) p–dorsum:	/k+q–g/	(I – 128),	(III – 162)
(d) pharynx:	/ħ–ʔ/	(I – 16),	(III – 7)

This further disfavoring of additional articulators within adjacent phonetic adjacent environments supports the previous research done for English and Italian. It must be mentioned, however, that these data, are particularly vulnerable to the methodological problems we have previously discussed.[4]

IX. THE PREFERENCE FOR PHONEMES WITH COMPLETE STRICTURE IN ROOT INITIAL AND FINAL POSITIONS

An examination of the distribution of root initial and root final consonants with regard to degree of stricture (Ø–2) reveals a clear favoring of consonants with complete stricture (Ø) both in C–I and C–III positions:

First Position C–I

Stricture		Number of Roots	%
Ø	/p,t–T,k,q,b,d,g,ʔ,m,n/	1477	53.3%
Ø–1	/ts/	95	3.4%
1–2	/r/	146	5.3%
1	/s,z,S,ħ,ʕ,h/	871	31.4%
2	/l,j,w/	184	6.6%
		2773	100%

[4] These data present additional problem for various diachronic as well as other reasons related to the distribution of (CCC) roots within words. In particular, the historical occlusive–spirant allophonic alternations in opening (occlusive) and closing (spirant) syllables must be considered. This problem is not purely diachronic either: Schwarzwald (1981) has demonstrated that a confusion exists among many speakers of Hebrew today regarding this particular (and other) alternations. There are other methodological problems regarding the combining of historically distinct consonant phonemes (t–T, k–q) which have merged and have the same active articulators and degrees of stricture and air flow today.

Third Position C–III

Stricture		Number of Roots	%
Ø	/p,t–T,k,q,b,d,g,ʔ,m,n/	1358	49%
Ø–1	/ts/	91	3.3%
1/2	/r/	320	11.5%
1	/s,z,S,ħ,ʕ,h/	768	27.7%
2	/l,j,w/	236	8.5%
		2773	100%

(1) Approximately half of all the initial and final consonants are those with complete stricture (Ø).

(2) Approximately thirty per cent of all the initial and final consonants are those with incomplete stricture of the first degree (1);

(3) Approximately fifteen to twenty per cent of all the initial and final consonants are those with varying degrees of stricture (0–1, 1/2, 2).

It must be noted, however, that these data, are open to the methodological problems we have previously mentioned.

X. THE FAVORING OF STRICTURE OVER ACTIVE ARTICULATORS IN ROOT INITIAL AND FINAL POSITIONS

This favoring of complete constriction may be shown to be even stronger than that of the number of active articulators, particularly if we take the following theoretical and methodological issues into account:

(1) the problem of the historical occlusive–spirant allophonic alternations (/p–f, b–v, k–x/, etc.) (cf. fns. 1,4);

(2) the fact that we are dealing here with roots and not words.

The crux of the problem is, of course, that we cannot always predict which degree of stricture these C–I and C–III phonemes will occur in words. There is, however, one class of Hebrew consonants with consistent complete constriction regardless of phonetic environment: the nasal consonants. The nasal consonants also involve the control of two sets of additional articulators and are therefore generally disfavored. Indeed, we have already demonstrated this general disfavoring in the phonemic system and in the phonotactic distribution of all consonants in C–I and C–III positions.

To test the relative strengths of the number of active articulators and complete stricture, we examined the distribution of the voiceless–voiced–nasal labial and apical triads (/p–b–m/, /t–d–n/) in C–I and C–III positions and found:

	C–I		C–III	
	Lip	Apex	Lip	Apex
Ø	p – 166	t+T–221	p –141	t+T–172
(L) +1	b – 127	d – 103	b –137	d – 144
(V) +2	m – 152	n – 167	m–177	n – 228

(1) The nasal consonants (+2) with consistent complete stricture are favored over the voiced consonants (+1) with variable stricture in both root initial and root final positions;

(2) The nasal consonants (+2) are the most favored in the voiceless (Ø), voiced (+1), nasal (+2) triad in root final position (where there may be a general tendency for root final consonants to appear in their spirantized form with incomplete stricture).

	C–I	C–III
most favored Ø	– 387 (p,t+T)	V (+2) – 405 (m,n)
less favored V (+2)	– 319 (m,n)	Ø – 313 (p,t+T)
least favored L (+1)	– 230 (b,d)	L (+1) – 281 (b.d)

This preference for complete stricture is also found in the consistent favoring of apical stops (t+T–d) over apical fricatives (s–z) in C–I and C–III positions:

	C–I	C–III
Ø Stricture	t–T – 221	t–T – 172
	d – 103	d – 144
	324	316
1 Stricture	s – 144	s – 105
	z – 77	z – 61
	221	166

This stronger preference for complete stricture in C–I and C–III positions is worthy of further study in relation to the diachronic development of the synergetic connection between the human and communication factors.

XI. DISFAVORING OF THE SAME ARTICULATORS IN ADJACENT PHONETIC ENVIRONMENTS

Previous research has also shown that there is a significant avoidance of consonants made by the same active articulators in word initial and final positions for English and Italian monosyllables. An examination of the Hebrew (CCC) root system, reveals a similar avoidance of the use of the same active articulators in all root positions:

Distribution of Consonants According to Active Articulators in the (CCC) Root System

Articulator	Phoneme	C–I	C–II	C–III
	p	166	3	17
Lip	b	127	2	9
	m	152	5	7
	t	144	25	78
	T	77	43	35
	d	103	23	36
	n	167	52	72
Apex	r	146	41	55
	l	82	11	39
	ts	95	34	26
	s	144	57	54
	z	77	25	31
A–Dorsum	S	265	7	5
	j	92	7	6
P–Dorsum	k	110	1	2
	g	121	0	3
Lip + P–Dorsum	q	139	11	2
	w	10	0	1
Pharynx	ħ	175	0	1
	ʕ	159	1	4
Glottis	ʔ	171	5	14
	h	51	0	10
		2773	353	507
% of C = C–I		100%	12%	18%

(1) The use of the same active articulators is consistently disfavored in both C–1 + C–II and C–I + C–III positions, with a stronger disfavoring for the more adjacent C–I + C–II position. The number of consonants made by the same articulators in CCC I + II positions is 353 (12%) versus C–I + III 507 (18%) of C–1 2773 consonants).[5]

(2) We heve already shown a consistent disfavoring in the use of additional sets of articulators for consonants of the (CCC) root system according to the tri–dimensional hierarchy of voiceless (Ø), voicing (+1), nasals (+2) in general. This disfavoring also exists in those consonants made the same set of articulators within the (CCC) root system:

				C–I		C–II		C–III	
(a)	(Ø)	(voiceless)	=	1537	(55.4%)	186	(53%)	244	(48%),
(b)	(+1)	(voiced)	=	917	(33.1%)	110	(31%)	184	(36%)
(c)	(+2)	(nasal)	=	319	(11.5%)	57	(16%)	79	(16%)
				2773	100%	353	100%	507	100%

These consistent favorings and disfavorings throughout the (CCC) root system may be attributed to the great difficulty of learning to control the same set of ar-

[5] The use of the same active articulators is disfavored for all consonants in the C–I + C–II and C–I + C–III positions, but only for 16 out of 22 (73%) of consonants in the C–II + C–III positions. Most of these "exceptional" consonants are those which already have been discussed /T, ts, S, q/.

ticulators in close proximity. The more difficult it is to control the same set of musculature within limited and restricted space and time, the less frequent the use of the same set of active articulators, the more proximate the environment, the greater the disfavoring. These data support the previous research done for English and Italian.

XII. DISFAVORING OF THE SAME PHONEME IN ADJACENT PHONETIC ENVIRONMENTS

Previous research has shown that this disfavoring of the use of the same set of active articulators is even greater in its most extreme case: the specific avoidance of the same phoneme in adjacent phonetic environments. An examination of the Hebrew (CCC) root system reveals the following distribution:

Repetition of the Same Phoneme in the (CCC) Root System

Articulator	Phoneme	C–I = C–II	C–I = C–III	C–II = C–III
	p	1	3	9
Lip	b	1	1	14
	m	2	3	10
	t	0	8	10
	T	0	2	5
	d	1	0	12
	n	1	6	12
Apex	r	0	2	11
	l	1	1	14
	ts	0	2	5
	s	0	4	7
	z	0	2	6
A–Dorsum	S	2	5	7
	j	0	0	0
P–Dorsum	k	1	2	1
	g	0	1	4
Lip + P–Dorsum	q	0	1	5
	w	0	0	0
Pharynx	ħ	0	0	6
	ʕ	1	4	2
Glottis	ʔ	0	1	0
	h	0	9	7
		11	57	147

%OF C–I = C–II/C–III, C–II = C–III: C–I (2773), C–II (353), C–III (507)

0.4%	2%	5%
3%	1%	29%

(1) This general disfavoring of the same sets of active articulators is even greater in its most extreme case: the specific avoidance of the same phoneme in all CCC position.

The nine repeated phonemes in both CCC I + II positions appear 11 times (0.4%) of C–I 2773, (3%) of C–II 353. The 18 repeated phonemes in CCC I = III positions appear 57 times (2%) of C–I 2773, 11% of C–III 507. This disfavoring is not as strong in C–II + C–III positions where there are 147 examples of 19 repeated phonemes (5% of C–I 2773, and 29% of C–III 507).

(2) The disfavoring of additional sets of active articulators in the tri–dimensional hierarchy holds for the same phonemes in C–I = C–III positions and for almost all the voiced–voiceless oppositions as well.[6]

(Of the 57 instances of repeated phonemes in C–I and C–III positions 37 (65%) are (Ø) voiceless, 11 (19%) are (+1) voiced and 9 (16%) are (+2) nasals.)

(3) The disfavoring of additional sets of active articulators does not hold for the same phonemes in C–II medial positions in general, but basically holds for the voiced–voiceless oppositions.

(Of the 11 instances of repeated phonemes in C–I + C–II positions, 4 (36.4%) are both (Ø) (voicesless and (+1) voiced and 3 (27.2%) are nasals; the voiced–voiceless opposition only holds for the k–g pair).

(Of the 147 repeated phonemes in C–II + C–III positions, there are 62 (42.2%) (0) voiceless, 63 (42.9%) (+1) voiced, and 22 (14.9%) nasals; the voice–voiceless opposition is almost complete).[7]

			C–I = C–III	C–I = C–II	C–I = C–III
(a)	(Ø)	=	37 (65%)	4 (36.4%)	62 (42.2%)
(b)	(+1)	=	11 (19%)	4 (36.4%)	63 (42.9%)
(c)	(+2)	=	9 (16%)	3 (27.2%)	22 (14.9%)
			57 100%	**11 100%**	**147 100%**

The same reason accounts for the observed disfavoring of the repetition of the same phoneme (most consistently in C–I and C–III positions). If it is difficult to control the same active articulators in adjacent environments, it is even more difficult to do so in the extreme case of repeating the very same phoneme. These data also support the previous research done for English and Italian.

XIII. THE FAVORING OF APICAL CONSONANTS

A skewing of the number of consonants produced by each of the different active articulators may also be observed. Indeed, both the previously cited research (as well as a cursory glance at the IPA and other phonetic charts) show a strong favoring

[6] The voice–voiceless distinction holds for all the pairs /p–3 vs b–1; t+T–10 vs. d–0; s–4 vs. z–2; S–5 vs j–0; k+q–3 vs. g–1/ , save for the pharyngeals /ħ–0; ʕ–4/. The pharyngeal consonants in general and determining the exact manner of articulation for "*ayin*" are well–known problems which will not be dealt with here.

[7] The data for the voiced–voiceless opposition are: /t+T–15 vs d–12; s–7 vs z–6; k+q–6 vs. g–4; ħ–6 vs. ʕ–2/, except for the labials /p–9 vs b–14/.

for those consonants produced by the apex. An examination of the consonant system of Hebrew reveals that the apex controls 40% or more than twice to four times as many consonants as any other active articulator:

Articulator	Number of Consonants	%
Lip	3	14%
Apex	9	41%
A–Dorsum	2	9%
P–Dorsum	4	18%
Pharynx	2	9%
Glottis	2	9%
	22	100%

An examination of the relationship between (a) the active articulators, (b) the number of phonemes per articulator, and (c) the number and percentage of (CCC) roots per articulator in C–I position reveals:

Articulator	Phonemes	Roots	%
Lip	3	445	16.1%
Apex	9	1035	37.3%
A–Dorsum	3	357	12.9%
P–Dorsum	2	231	8.3%
(L+ V) + P–Dorsum	2	149	5.4%
Pharynx	2	334	12.0%
Glottis	2	222	8.0%
	22 phonemes	2773 roots	100%

The data for C–I position indicate that consonants produced by the Apex are favored and account for over 37% of the roots followed by the Lip (16%), the P–Dorsum (14%), the A–Dorsum (13%), The Pharynx (12%) and Glottis (8%).

An examination of the relationship between (a) the active articulators, (b) the number of phonemes par articulator, and (c) the number and percentage of (CCC) roots made by the same articulator in C–II position reveals:

Articulator	Phonemes	Roots	%
Lip	3	10	3%
Apex	9	311	88%
A–Dorsum	3	14	4%
P–Dorsum	2	1	0.3%
(L+ V) + P–Dorsum	2	11	3%
Pharynx	2	1	0.3%
Glottis	2	5	1.4%
	22 phonemes	353 roots	100%

The data for C–II position indicate that consonants produced by the Apex are even more clearly favored and account for 88% of the roots followed by the A–Dorsum (4%), the Lip and P–Dorsum (3%), the Glottis (1.4%) and the Pharynx (0.3%).

An examination of the relationship between (a) the active articulators, (b) the number of phonemes per articulator, and (c) the number and percentage of (CCC) roots made by the same articulator in C–III position reveals:

Articulator	Phonemes	Roots	%
Lip	3	33	6.5%
Apex	9	426	84%
A–Dorsum	3	11	2.2%
P–Dorsum	2	5	1%
(L+ V) + P–Dorsum	2	3	0.6%
Pharynx	2	5	1%
Glottis	2	24	4.7%
	22 phonemes	507 roots	100%

The data for C–III position indicate that consonants produced by the Apex are also more clearly favored and account for 84% of the roots followed by the Lip (6.5%), the Glottis (4.7%), the A–Dorsum (2.2%), the P–Dorsum (1.6%), and the Pharynx (1%)

These data indicate that the apex – the most adroit and easily–controlled of the active articulators – is the most highly favored articulator. In other words, that articulator which is the easiest one to learn to control, is the one which is the most exploited by speakers of the language.

An examination of the distribution of the repeated phonemes in the (CCC) root system reveals, not unsurprisingly, a similar favoring of apical consonants. There was, however, a slight favoring for the labial consonants in initial C–I = C–II position:

	I=II	I = III	II = III
	Roots – %	Roots – %	Roots – %
Lip	4 – 36.4%	7 – 12.3%	33 – 22.4%
Apex	3 – 27.2%	27 – 47.4%	82 – 55.8%
A–Dorsum	2 – 18.2%	5 – 8.8%	7 – 4.8%
P–Dorsum	1 – 9.1%	4 – 7 %	10 – 6.8%
Pharynx	1 – 9.1%	4 – 7 %	8 – 5.4%
Glottis	0	10 – 17.5%	7 – 4.8%
	11 – 100%	57 – 100%	147 – 100%

This preference for labials in root initial position was also found for word initial position both for English and Italian monosyllables as well. Labials, like the saying goes about children, "should be seen and not (only) heard".

Therefore, a tendency for the favoring of visible phonemes in initial position – precisely where the largest number of clues are necessary for effective communication – should not be too surprising when we take the synergetic connection between the communication and human factors into account. Indeed, a comparison of the labial stops with their simple apical and P–Dorsal counterparts reveals a similar favoring for more clearly visible sounds in C–I position:

Lip	Apex	P–Dorsum
p 166	t 144	k 110
b 127	d 103	g 121

This "visibility factor" in root initial position is, of course, susceptible to various diachronic and methodological considerations as well.[8]

XIV. SUMMARY AND CONCLUSION

In this paper, we have extended previous research in the combinatory phonology of English and Italian to the Hebrew (CCC) root system, following a specific approach to phonology inspired by the definition of language as a system of systems used by human beings to communicate. In short, we have attempted to statistically examine the synergetic connection between the human and communication factors of language as they are reflected in the phonotactics of the Hebrew (CCC) root system.

Theoretically and methodologically this view of language and phonology has been influenced by:

(1) the Saussurian notion of system in general and the need to combine both articulatory and auditory features in the study of sound systems;

(2) further developed within the teleogical functional framework of the Prague School and distinctive feature theory;

(3) and continued by Martinet who recognized the role of the human factor in communication, thus making the notion of "economy" a crucial element for phonological explanation.

Throughout this paper we have observed a direct connection between the effort invested by speakers in learning to control the active articulators involved in the production of consonants and the observed favorings and disfavorings of these consonants. This has been true both for the distribution of consonants within the Hebrew phonemic system as well as their phonotactic distribution within the (CCC) root system.

In particular, we discovered certain general tendencies which showed:

(1) the disfavoring of additional articulators in the phonemic system of Hebrew in general, in C–I and C–III root positions in particular, as well as in the phonemic oppositions of individual active articulators;

(2) the favoring for phonemes with complete stricture in C–I and C–III root positions as well the relationship between stricture and number of active articulators;

[8] The nasals as "temporally extended stops" may even be more visible than their oral counterparts, as may historically ejective consonants which were not included here.

(3) the avoidance of the use of the same articulators and the repetition of the same phoneme in all (CCC) root positions;

(4) The general favoring of consonants made by the apex in all the above environments with an additional favoring of visible phonemes in C–I and CI = CII positions.

We have not claimed to solve all the problems related to the Hebrew (CCC) root system. We merely have presented a preliminary set of basic criteria which may serve as a first step to better understand some of the most fundamental phenomena related to the combinatory phonology of Hebrew which both supported analyses of the combinatory phonology of English and Italian and may also serve as a basis for a methodology for further work in contrastive phonotactics.

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