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Dissimilarity in the Arabic Verbal Roots [1]

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1 Introduction

The verbal roots of Arabic consist of a sequence of two to four consonants, with the canonical root having three. The vowels which surface interleaved with these consonants are provided by other morphemes, in a well-known example of a nonconcatenative morphological system. A paper by Greenberg (1950) lays out the cooccurrence restrictions on the consonants in the root. The basic observation is that combinations of homorganic consonants are disfavored. There is an absolute prohibition against beginning a root with consonants which are totally identical (as opposed to merely homorganic). However, what appear to be triconsonantal roots ending with two identical consonants are well-formed. A landmark paper by McCarthy (McCarthy, 1986) accounted for these anomalous roots by applying the Obligatory Contour Principle (the OCP), a principle first proposed in work on tone by Leben (1973) and Goldsmith (1976) which prohibits adjacent like elements. The roots are shown to have only two consonants in underlying representation, being subsequently expanded to triliteral form. As a result, in underlying representation all Arabic roots obey an absolute prohibition against adjacent identical consonants.

Subsequent research (Mester, 1986; McCarthy, 1988 and in press; Yip, 1988 and 1989) has extended this result to the case of homorganic but nonidentical consonants. In the extension, an OCP effect on place governs even nonadjacent consonants, because the place features are taken to be privative and located on separate tiers. For example in [1], the medial /q/ is invisible on the [labial] tier. As a result, the combination of /b/ and /f/ is ruled out by the OCP on the basis of the adjacent identical specifications for [labial].

[1] I am very grateful to Dedre Gentner, John J. McCarthy, and Donca Steriade for their critical advice.

[1]

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* b         q         f
  |         |         |
[labial]    |      [labial]
         [dorsal]
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This is the core idea in the standard model of how the OCP applies to nonadjacent phonemes. (Section 5 will discuss more complicated variants of this model proposed in Yip (1989), Padgett (in press) and Lamontagne (1992)).

This paper presents a detailed study of the canonical, or triconsonantal, verbal roots of Arabic. The aim of the study was to evaluate the extended model of OCP operation, in particular its success in handling effects on nonadjacent consonants. It was done by analyzing statistically all 2676 native and assimilated triconsonantal verbal roots in the 1979 edition of Wehr's dictionary of modern Arabic (Cowan, 1979). The statistical studies in McCarthy (1988, in press) used an earlier edition of the same dictionary. Biconsonantal roots were excluded because they do not permit an examination of nonadjacent consonants. Roots with more than three consonants were excluded because almost all are either reduplicative or conspicuously nonnative.

The index of the strength of the OCP for any pair of consonants used here is the ratio of the number of occurrences of that pair observed in the dictionary (O) to the number of occurrences which would be expected in the absence of any OCP effect (E). O/E ranges from 0 for an absolute effect (an effect so strong that none of the expected occurrences are found) up to 1.0 or more when there is no OCP effect (the combination occurs as often, or more, than expected). Since phoneme frequencies vary widely by position in the root, positionally correct frequencies were used in estimating E. Furthermore, the strength of the OCP depends on the positions within the root of the phonemes, and so O/E is computed for phoneme pairs by position. Chi square tests were used to assess the reliability of the effects, though details will not be reported here.

The study shows that the standard model is incorrect; it is impossible to describe the observed cooccurrence restrictions if the OCP refers only to features which are immediately adjacent on a tier. That is, the cooccurrence restrictions do cross intervening specifications for the same feature. In doing so, they operate in accordance with general principles in the perception and representation of similarity. A model based on these principles is developed. In the model, a linguistic constraint against homorganicity (which may grammaticalize constraints on motor programming) is enforced on pairs of consonants in proportion to their perceived similarity. The perceived similarity of the consonants being compared is a function both of their objective similarity in terms of all properties, and of their proximity. This model unifies the OCP effect on place with the OCP effect on total identity in a way which is not possible in the standard treatment. It also explains a number of major regularities in the cooccurrence restrictions, including the ability of coronal sonorants to combine with coronal obstruents.

2 Major Regularities and Current Theory

Twenty six consonants will be under discussion here. These are:

[2]	Labials	{b,f,m}
	Coronal Sonorants	{l,r,n}
	Coronal Obstruents	{t,d,s,z, T, D, S, Z, θ, ǯ, š}
	Dorsal Obstruents	{k,g,q}
	Guttural approximants	{χ, ʁ, ħ, ʕ, h, ʔ}

The dorsal sonorants {w,y} will be disregarded due to phonological pecularities described in McCarthy (1988) and (in press).

The capital letters /T,D,S,Z/ represent coronal obstruents with a secondary guttural articulation. /q/ is a uvular stop. The six guttural approximants are argued in McCarthy (in press) to form a natural class together with /q/, characterized by a feature [pharyngeal]. /χ/, /ʁ/ are uvular approximants (sometimes produced as fricatives), /ħ/, /ʕ/ are produced with retraction of the tongue root, and /h/,/ʔ/ are laryngeals. The first member in each pair is voiceless or breathy, and will accordingly be characterized as being [+spread glottis] in view of the fact that they are not obstruents (cf. Lombardi, 1991).

As already noted, Arabic absolutely prohits adjacent identical consonants in the root. The Wehr dictionary contains only one possible counterexample to this claim, a nursery word. If consonants combined at random, one would expect to find 234 roots in the dictionary containing adjacent identical consonants. Statistical studies described by McCarthy (1988, in press), and replicated with the somewhat different statistical measure used here, lay out the main pattern of OCP effects on place for nonidentical consonants. These studies establish that the most important effects occur within the sets specified in [2]. That is, all major places of articulation (labial, coronal, dorsal, and guttural) are targets of an OCP effect. However, coronal sonorants cooccur freely with coronal obstruents. Furthermore, the pharyngealized coronals T,D,S,Z cooccur freely with consonants having a primary pharyngeal articulation. Yip (1989) and McCarthy (in press) also make note of two further effects which are not brought out in [2]. First, the coronal obstruents display a subdivision into stops and fricatives, with these subclasses displaying stronger OCP effects than the class of coronal obstruents as a whole. Second, the dorsal obstruents tend not to combine with the uvular approximants /χ/ , /ʁ/, which have the same place of articulation as /q/. Accordingly, both uvular approximants and dorsal obstruents are included in all subsequent tables under "Dorsals", with the uvular approximants also included as "Guttural Approximants".

It is extremely important to any theory of these effects that other features, apart from those specifying place, are not subject to OCP effects on their own. The point may be illustrated by considering the cooccurrence of various classes of consonants which differ in place of articulation but share other features. In Table [3], O and E have been computed for all combinations of a consonant in the second column with one in the third, in any order and pooled across all positions in the root.

[3]	Feature	Class1	Class2	O (Observed)	E(Expected)
	[nasal]	m	n	49	53.3
	[-cont]	coronal stops	noncoronal stops	167	154
	[+son]	coronal son.	noncoronal son.	906	756

In all three cases, O is essentially at or above E. That is, the two classes combine freely and there is no OCP effect for the indicated feature. Note that it is hardly surprising for O to be greater than E, for combinations not subject to any OCP effect. If some combinations are proportionately underrepresented, others must necessarily be overrepresented.

In order to account for these regularities McCarthy (in press) builds on McCarthy (1988), Mester (1986), Yip (1988), and more generally on underspecification theory (reviewed in Archangeli, 1988). A universal prohibition on adjacent identical elements is held responsible for the absence of roots with identical adjacent consonants. In addition, Arabic is claimed to have a separate and language particular constraint against homorganic consonants within the same root. By making this "place" OCP separate from the "total" OCP, it is possible to describe the fact that it is weaker than the "total" OCP.

The place OCP is formalized, as mentioned in connection with [2] above, by treating the major place features [labial], [coronal], [dorsal] and [pharyngeal] as privative and on separate tiers. Adjacent like specifications on each of these four individual tiers are prohibited. Since the features are privative, consonants which do not have a given place are not represented on that place tier and are thus invisible to the OCP operating on that tier. As a result, pairs of nonadjacent consonants are fully comparable to pairs of adjacent ones.

Two further assumptions are needed to effectively describe the major patterns reported. First, it is necessary to distinguish primary from secondary place features. The place OCP pertains to primary place only. Without this assumption, the model would erroneously predict that the pharyngealized coronals would fail to combine with the primary pharyngeals. In fact, they combine freely. Second, provision must be made for the free combination of coronal sonorants with coronal obstruents. McCarthy proposes to handle this phenomenon by treating the coronal sonorants (but not obstruents) as placeless in underlying representation. Thus, they are invisible during the evaluation by the OCP of the [coronal] tier. The failure of the coronal sonorants to combine with each other is attributed to a condition on the rule which assigns the place to these phonemes. The place node in the feature geometry tree is not permitted to branch (that is, it cannot be shared by two root nodes); branching place nodes are permitted to arise only through place assimilation.

3 Shortcomings of Current Theory

The current theory has three major shortcomings. First, it does not account for the great range in strength of the observed effects. The fact that the place OCP is weaker than the total OCP is described by treating it as a separate language particular principle, but is not really explained; after all, many language particular regularities are every bit as absolute as the total OCP, while universal tendencies which are not absolute are also reported. Similarly, no attempt is made to account for the weakening of the OCP effect for nonadjacent consonants, noted as an important outstanding problem in McCarthy (in press). Table [4] demonstrates the effect of nonadjacency, for each of the major classes of [2]. The first column is the pooled O/E for all combinations of consonants in each set, in either order, in first and second, or second and third positions in the root. The second column is the comparable figure for nonadjacent position, that is for first and third positions in the root.

[4]

Class	O/E, adjacent consonants	O/E, nonadjacent consonants
Labials	0.00	0.29
Coronal Sonorants	0.06	0.67
Coronal Obstruents	0.29	0.67
Dorsals	0.04	0.34
Guttural approximants	0.06	0.36

All classes show weakening of the effect for nonadjacent consonants, though for all O/E is still significantly lower than 1.0. However, treating O/E values as high as 0.67 as equivalent to zero is clearly an extreme idealization.

Second, the split between the coronal sonorants and the coronal obstruents is only the most important of an extensive set of subregularities concerning the relative strength of the effect amongst different subgroups of homorganic consonants. For example, various subgroups of the coronal obstruents (the coronal stops, the coronal fricatives, and the coronal emphatics) are all subject to a stronger OCP effect than the effect on coronal obstruents in general. Furthermore, sixteen out of seventeen roots containing two labials involve /m/ in combination with a labial obstruent, and in only one are two obstruents found. Also, /n/ combines more freely with /l/ and /r/ than they do with each other. However, the mechanism proposed to account for the split between coronal sonorants and coronal obstruents cannot generalize to cover these additional regularities.

Third, the formal character of the total OCP is not developed in the standard model, and close scrutiny reveals it to be extremely problematic for the case of nonadjacent consonants. Because the various place features are segregated onto separate tiers for the purposes of the place OCP, it follows that they must also be so separated for the purposes of the total OCP. That is, the total OCP does not refer to a single tier, but rather to all relevant tiers; it is violated if all tiers have adjacent identical specifications. It is not violated if any tier has an acceptable configuration. For example, the sequence /m n/ does not violate the total OCP, since the [labial] tier (where /m/ appears, but /n/ does not) is well-formed. Similarly, the sequence /t d/ does not violate the total OCP due to a difference on the [voice] tier (though it does violate the place OCP). Turning now to the case of nonadjacent consonants, it should be possible to block the total OCP by an intervening specification on any tier. For example, applying McCarthy's (1988) claim that all sounds are specified for sonority, the combination in [5] should not violate the "total" OCP.

[5]

b	n	b
|	|	|
[-son]	[+son]	[-son]
|	|	|
other features	other features	other features

That is, regardless of the other featural specifications, the [+son] specification for /n/ intervenes between the [-son] features of the two /b/'s. So the sonorant tier for the combination is well-formed. As a result, the acceptability of the combination is compromised only by the weaker "place" OCP; it should be no worse than a root with nonidentical labial consonants in first and third position. But as we will show, it is actually much worse.

In the simplest and most consistent interpretation of the total OCP, both privative and equipollent features should have the same status, both as targets of the constraint and as intervening material. Consider, for example, the sequence /t k/, which does not violate the total OCP by virtue of a difference in place, with /t/ represented on the [coronal] tier and /k/ on the [dorsal] tier. In evaluating this sequence, the total OCP refers to both the [coronal] and the [dorsal] tiers, although neither segment is represented on both tiers. As shown in [6], these tiers have acceptable configurations, each with a single token of a feature rather than a sequence of identical features. These good tiers suffice to render the entire sequence acceptable, even if other tiers (such as [cont] and [sonorant]) do have adjacent identical features.

[6]

```
      t            k
      |            |
  [coronal]        |
               [dorsal]
```

One might now inquire whether the [dorsal] tier is likewise relevant to evaluation of the first and third consonants in the combination:

[7]

```
      t            k            t
      |            |            |
  [coronal]        |        [coronal]
               [dorsal]
```

That is, does the presence of [dorsal] for the intervening consonant block the total OCP, by supplying one well-formed tier in the entire phonological representation for the triconsonantal sequence? Or is [dorsal] now invisible because it does not characterize a target consonant, but only an intervening consonant? The first alternative is surely simpler. In view of its evident descriptive inadequacy, however, we will also consider and reject a second alternative, whereby only opposite specifications for equipollent features, as in [5], block the total OCP.

Under either interpretation, the theory predicts that the total OCP should be vulnerable to intervening material. The place OCP, on the other hand, should be invulnerable, because it refers only to the tier for a single privative feature. However, neither prediction is supported. The total OCP in Arabic is far stronger than the theory would predict, for nonadjacent consonants. There are only sixteen roots in the dictionary with identical first and third consonants. 112 would be expected if consonants combined at random, and we would expect to find 48 (three times the observed count) on the basis of blocking of the total OCP on the sonorant tier alone.[1] The expected number of course increases the more equipollent features we allow for, making the rarity of such roots all the more significant. In general, the persistence of the total OCP is shown by table [8], which compares the strength of the OCP effect on identical versus nonidentical consonant pairs in each class, in nonadjacent position.

[8]

Class	O/E, identical	O/E, nonidentical
Labials	0.05	0.41
Coronal Sonorants	0.08	0.95
Coronal Obstruents	0.46	0.70
Dorsals	0.24	0.36
Guttural Approximants	0.05	0.69

Furthermore, the place OCP is more weakened by intervening material than the theory would predict. This is shown by Table [9], which corresponds to Table [4] except that combinations of identical consonants have removed been from the counts for O and E, leaving only combinations of nonidentical consonants.

[1] In making this estimate, the requirement that the medial consonant be nonhomorganic to the flanking consonants has been treated as absolute. In fact this requirement is not absolute, so the true expected count would be higher.

[9]

Class	O/E, adjacent	O/E, nonadjacent
Labials	0.00	0.41
Coronal Sonorants	0.09	0.95
Coronal Obstruents	0.32	0.70
Dorsals	0.04	0.36
Guttural Approximants	0.07	0.69

For all classes, the place OCP per se is weakened by distance.

4 The Similarity Model

In the standard model, the gradience of the dissimilarity requirements in the Arabic verbal roots is disregarded, and the cooperation of several grammatical mechanisms is invoked to cover those regularities which are described. In the alternative approach to be developed here, the gradience is exploited both to improve the descriptive coverage and to unify the most categorical effect (the total OCP on adjacent consonants) with less categorical effects. The alternative model builds on the observation in Lightner (1973) that homorganic consonants which differ in many features combine more freely in Arabic than ones which differ in only a few features.[2] That is, the strength of the effect is related to the overall similarity of the target segments.

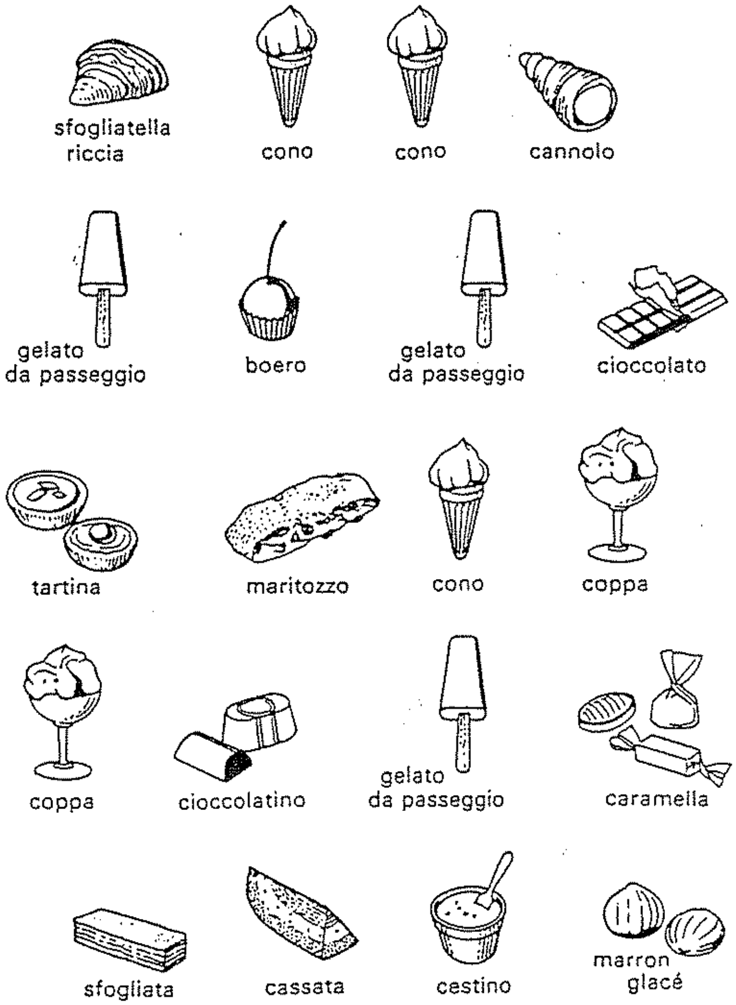
We propose that Arabic has an OCP effect on place alone. It applies only to consonants which are perceived to be similar, and the strength of the effect increases with perceived similarity. Identical consonants are viewed as maximally similar, and so the total OCP arises as the limiting case of maximally strong enforcement of the place OCP. Arabic differs from other languages in targeting place (rather than e.g. the laryngeal features) for an OCP effect, and also in its relatively low similarity threshold for the effect to be active. That is, even rather dissimilar combinations of homorganic consonants, such as /f/ and /m/, are found less often than one might expect. Languages exhibiting only a total OCP may be viewed as having an OCP effect subject to the highest possible similarity threshold. The fact that the total OCP is both stronger and typologically more widespread than the place OCP follows directly from the similarity gradient used to describe it.

It is well known that the ability to make comparisons is affected by spacing and the presence of intervening material. Effects of temporal spacing on the relevant time scale for speech (a couple of seconds or less) are well-documented in perception, both for vision and for audition. Temporal separation per se weakens the ability to compare items when the percept of the first has decayed by the time the second is reached (Pisoni, 1973; Eriksen and Schultze, 1978). Data in Pisoni (1973) specifically show such an effect for comparisons of consonants by phonological category, although this effect is weaker than for phonological comparisons of vowels or for comparisons of phonemes as speech sounds. In addition, the ability to compare the first and third of three items in a sequence is impaired when the second masks or degrades the percept of the first, with differential effects depending on the exact character of the medial item. (Massaro, 1970). These studies emphasize the perception of differences; however, they indicate that spacing and intervening material lead to inaccuracy in the perception or recall of the first item in a comparison, leading to the prediction that the perceptibility of above average similarity should also be degraded. That is, both extreme similarity and extreme dissimilarity should be made less perceptible by greater spacing and by intervening material.

[2]Lightner also suggests that the separation of the consonants is relevant. However, his remarks concentrate on separation by a vowel in the surface form, and he does not relate the effects of distance to the effects of similarity.

The general approach may perhaps be clarified by an analogy to a different domain. Figure [10] shows rows of Italian desserts.

[10] Which rows have two ice creams?



The presence of two ice creams is immediately obvious when the ice creams are identical and adjacent (first row). If the ice creams are either nonadjacent but identical (second row) or adjacent but not identical (third row), the presence of two ice creams is somewhat less obvious. It is still less obvious when the two are neither adjacent nor identical (fourth row). If the ice creams are extremely dissimilar, it may not be obvious even when they are adjacent (fifth row; cassata and cestino).

All models following this general approach share a number of properties. First, comparisons between consonants will cross intervening featural specifications on the same tier, although the availability of such comparisons decreases with distance. Second, nonhomorganic consonants, no matter how similar, can cooccur. Third, subregularities in the strength of the effect reflect the cross-classification of the consonants. Fourth, impossible combinations are described as having probabilities less than 0.5 in 2676 (the total number of verbal roots in the dictionary). Since the set of forms is finite (and speakers are presumably implicitly aware that it is finite), it is not necessary to assign probabilities of zero to

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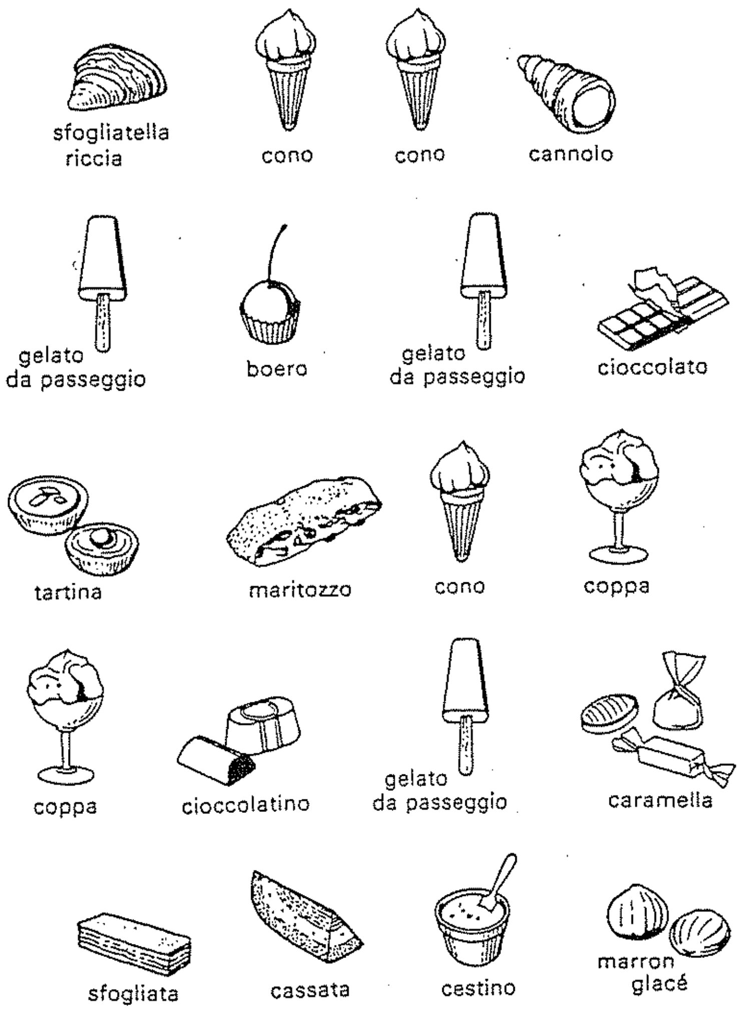

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In fleshing out the general approach, then, the major challenge is to achieve a generalizable explanation of the split between the coronal obstruents and the coronal sonorants. That is, how does it happen that /f/ and /m/ are sufficiently similar to be subject to an OCP effect, whereas /s/ and /n/ are not? How does the answer to this question bear on the treatment of less extreme regularities in the data?

Here, the split between coronal sonorants and obstruents will be derived from the total size of the homorganic set as a consequence of the number of features needed to distinguish amongst members of the set. In Arabic, the set of coronals has fourteen members, being as in many other languages larger than the set for any other place of articulation. Keating (1991) attributes this typological fact to the large number of degrees of freedom in the tongue blade articulation. A minimum of four features would be needed to describe the contrasts amongst the coronals, and a more linguistically motivated analysis uses more. At the other extreme, there are only three labials, distinguishable from each other, both in principle and in practice, by only two features ([sonorant] and [continuant]). As a result, the analogy of /f/, /m/ to /s/, /n/ is only superficially appropriate. In fact, /f/ and /m/ share one feature ([labial]) and differ in two features ([sonorant] and [continuant]). /s/, /n/ again share one feature ([coronal]) while differing in the many features needed to distinguish them from their near relatives such as /š/, /t/, /l/. Thus, the claim is that /s/ and /n/ are more different from each other than /f/ and /m/ are, in fact so dissimilar that they are not subject to any OCP effect.

Carrying through this argument in the detail needed to display an example of the model requires additional assumptions. Specifically, the similarity of X to Y is assumed to be the same as the similarity of Y to X for any X and Y (symmetry). Sharing the broad assumptions both of feature geometry theory and of Stevens and Keyser (1989), more important features are assigned before less important ones. Sonority and major place of articulation are assigned first. Features such as [nasal] and [voice] are assigned only if distinctive after place and sonority are assigned. Minor place features such as [anterior] and [radical] are assigned only if distinctive within a major place. Feature assignments for the pharyngeals are based on the detailed phonetic and phonological analysis of McCarthy (in press). Most notably, except for /q/, all pharyngeal consonants are viewed as sonorant. Accordingly, so-called voiceless pharyngeal approximants are viewed as [+ spread glottis], and stricture is taken to be nondistinctive for these sounds. The exact set feature assignments used in the calculations presented here are attached as an appendix. It should be noted that these are intended only as an example, and that substantially similar results can be obtained with a variety of feature assignments.

The measure of similarity used is the number of features two consonants have in common divided by the sum of the features in common and the features different:

[11] Same/(Same + Different)

This measure ranges from 0.0 when there are no features in common to 1.0 for total identity (no features different). If a feature is equipollent, both a match on + and a match on − are counted as "same". However, a match on lack of a feature is not counted as "same"; /b/ and /m/ are not taken to agree in the irrelevance of the feature [lateral]. Hence, for privative features only a match on + counts as the "same". A difference is noted when segments have opposite values of an equipollent feature, or when a feature is defined for one segment but not for the other. That is {+, −}, {+, null} and {−, null} all count as differences. This way of evaluating matches and mismatches is consistent with the standard view of rule application. It is inconsistent with Yip's (1989) proposal that nondistinct segments match for purposes of the OCP.

The results of this computation are displayed in Tables [12]–[14]. Each entry shows the computed similarity of the pair of consonants indicated by the row and column labels. Entries below the diagonal are omitted because similarity is taken to be symmetric.

[12] Labials

	b	f	m
b	1.00	0.67	0.33
f		1.00	0.33
m			1.00

[13] Coronals

	t	d	s	z	T	D	S	Z	θ	ʒ	š	l	r	n
t	1.00	0.75	0.50	0.40	0.80	0.60	0.60	0.40	0.60	0.40	0.60	0.20	0.20	0.20
d		1.00	0.33	0.60	0.60	0.80	0.40	0.60	0.40	0.60	0.40	0.20	0.20	0.20
s			1.00	0.67	0.43	0.29	0.57	0.43	0.67	0.50	0.67	0.14	0.14	0.14
z				1.00	0.33	0.50	0.50	0.67	0.60	0.80	0.50	0.17	0.17	0.17
T					1.00	0.80	0.80	0.60	0.50	0.33	0.50	0.17	0.17	0.17
D						1.00	0.60	0.80	0.33	0.50	0.33	0.17	0.17	0.17
S							1.00	0.80	0.67	0.50	0.67	0.17	0.17	0.17
Z								1.00	0.50	0.67	0.50	0.17	0.17	0.17
θ									1.00	0.80	0.67	0.17	0.17	0.17
ʒ										1.00	0.50	0.17	0.17	0.17
š											1.00	0.17	0.17	0.17
l												1.00	0.50	0.50
r													1.00	0.50
n														1.00

[14] Dorsals and Pharyngeals

	k	g	q	χ	ʁ	ħ	ʕ	h	?
k	1.00	0.67	0.50	0.20	0.25				
g		1.00	0.50	0.20	0.25				
q			1.00	0.50	0.67	0.20	0.25	0.25	0.33
χ				1.00	0.75	0.60	0.40	0.75	0.50
					1.00	0.40	0.50	0.50	0.67
ħ						1.00	0.75	0.75	0.50
							1.00	0.50	0.67
h								1.00	0.67
?									1.00

These tables are interpretable on the assumption that the lower bound for existence of an OCP effect is about 0.3. The effect is stronger as stronger as the similarity index increases above 0.3, and is maximal when the similarity reaches 1.00. On this assumption, many of the observed regularities are captured. The labials are all subject to an OCP effect, but the effect is strongest for the two obstruents. A major split divides the coronals into the sonorants and the obstruents; the similarity of all sonorants to all obstruents is 0.2 or less, predicting the absence of an OCP effect. Within the coronal obstruents, various more cohesive subgroups may be identified, most notably the stops, the fricatives, and the pharyngealized coronals. Within the dorsals and pharyngeals, /q/ patterns correctly both with the velar stops and with the uvular approximants. It is less similar to the other pharyngeals, which differ from it both by their sonority and by their lack of a dorsal articulation. The uvular approximants, however, do come out quite similar to the other sonorant pharyngeals.

The model does not capture all of the observed regularities. The dorsal stops /k/ and /g/ come out as insufficiently similar to the uvular approximants. In fact, sequences of dorsal stops and uvular approximants are found less than expected. On the other hand, /q/ is excessively similar to /?/; there is no OCP effect for this pair on the order of the effect for combinations of /m/ with a labial obstruent. The subdivision of the coronal sonorants into {/l/, /r/} as against /n/ also fails to be modelled. Not shown is the fact that the pharyngealized coronals are also excessively similar to /q/.

Some of these regularities might be captured by adjusting the featural characterizations of the phonemes. For example, the pharyngealized coronals can actually be separated from /q/ by treating as equipollent some features which are commonly viewed as privative, or making the common distinction between primary and secondary articulations. The regularities might also be captured by bringing to bear additional results from the psychological literature. Specifically, in calculations for Tables [12]–[14] no weighting of features was used, although differential weighting of comonalities and differences is explored in Tversky (1977). Experimental results by Markman and Gentner also indicate that not all differences are equivalently weighted in cognitive representations: specifically, "alignable differences" (appearing here as the difference between + and -) are less important than "non-alignable differences" (the contrast between a feature being present and its being undefined or irrelevant). Furthermore, it is clear that some features may be more important, across the board, than others. For example, weighting [nasal] more than [lateral] and [rhotic] would make /n/ stand out from the other coronal sonorants. Experiments on English by Greenberg and Jenkins (1964) indicate that some features are in fact more important to perceived similarity than others. Further work is needed to evaluate more complicated models than the one presented here. The quantitative interaction of distance with objective similarity also requires investigation.

5 Discussion and Conclusion

The behavior of the constraint against totally identical consonants in Arabic shows that such constraints are not confined to strictly adjacent featural specifications. That is, cooccurrence restrictions can be enforced across intervening featural specifications on the same tier. But these restrictions do obey general principles in the representation and perception of similarity. One implication is that the already cumbrously titled OCP is also misnamed. In Arabic, many triconsonantal combinations which do indeed display a contour are still impermissible due to the excessive similarity of their component consonants.

The problem posed by constraints against total identity in nonadjacent position is raised in Pierrehumbert (in press). This study shows that English systematically excludes medial triconsonantal clusters in which the first and third consonants are identical (such as /lfl/). In addition, a number of previous studies of the place OCP have reported that its operation can be affected by specifications for other features which are not necessarily adjacent on their own tiers. Yip's (1989) description of the OCP in Semitic entails reference to nonadjacent specifications for [continuant], [sonorant] and [consonantal]. Padgett (in press) provides a cross-linguistic survey of cases in which the place OCP is only enforced when the specifications for [continuant] and [sonorant] are also identical, noting that these features can play a role even when they are not adjacent on their own tier. Problematic reference to nonadjacent specifications for [sonorant] and [continuant] is also reported in Lamontagne (1992).

In order to handle such observations about the place OCP, Yip (1989) proposes that it refers both to articulator features if adjacent, and also to features which c–command Place in the feature geometry tree whether or not they are adjacent. That is, adjacency is determined within the Place categories, and the features [sonorant],[continuant] and [consonantal] matter only within, not across, these categories. Padgett (in press), making different assumptions about the form of the tree, suggests that the OCP can only invoke the features which dominate or are dominated by the place feature, in addition to the place feature itself. In Lamontagne (1992), the definition of adjacency governing the place OCP is modified so as to refer not only to the target feature itself, but also to the dominating node in a feature geometry tree. These proposals may all be viewed as a step in the general direction proposed here, since they have the effect of making the operation of the place OCP depend on whether two consonants which share the same place of articulation are also similar in some other respect or respects. None of the proposals deal with the findings about total identity presented here, because all undertake to limit the reference to features other than place features. As a result, they cannot deal with the findings about total identity presented here, which necessarily involve reference to all features. They do not support cross-classification of consonants in general, nor do they provide any basis for describing the relative strength of nonabsolute effects. As a result, they do not treat the total OCP as the limiting case of the place OCP, or relate the effects of nonadjacency to effects of featural differences.

An important consequence of these findings is that arguments for separation of tiers based on the OCP are shown to be questionable. In earlier work, the existence of an OCP effect between nonadjacent segments was viewed as prima facie evidence that all intervening segments lacked featural specifications on the target tier for the OCP effect. This conclusion no longer follows; if it is possible to refer to nonadjacent specifications of some features, why not all features? Similarly, the absence of an OCP effect between adjacent segments cannot be viewed as evidence for assigning their features to separate tiers, if the segments are otherwise dissimilar. In particular, OCP effects cannot be expected to bear on the ongoing discussion about whether vowels and consonants are characterized by the same nodes in the feature geometry tree (see Clements, 1985; Steriade, 1987b; Odden, 1991; Hume, 1992). Since consonants and vowels are generally dissimilar (just as coronal obstruents and coronal sonorants are) no OCP effect would be expected even if tongue body or lip features appeared on the same tier for both consonants and vowels. This is a welcome result in view of the great prevalence of processes assimilating vowels and consonants, which tend to suggest that they are represented on the same tiers.

The model presented here relies on contrastive underspecification, as defended in Steriade (1987a) and as actually practiced in e.g. Jakobson (1949) and Stevens and Keyser (1989). Contrastive underspecification is used in contrast both to full specification (according to which all phonologically present features are assigned values for all phonemes, whether or not these values are predictable) and to radical underspecification (according to which featural representations are absolutely minimized, even at the expense of ordered redundancy rules). Full specification was rejected because it forces all phonemes to have the same featural complexity, and hence fails to capture the fact that large homorganic sets (such as the coronals) display more diversity than small homorganic sets (such as the labials). Radical underspecification was rejected because in all models which applied it, the least marked phonemes failed to be grouped with their most similar relatives. It may be noted that truly radical underspecification is inconsistent with current ideas of feature geometry. In feature geometry, theory minor features such as [lateral] can be assigned only as dependents of the more major features, even if the major features are entirely predictable from the minor ones.

The model also relies specifically on the assumption that feature [coronal] is specified at the level the dissimilarity requirements are enforced, contra Paradis and Prunet (1991, 1992). As noted in McCarthy and Taub (in press), there is a fundamental tension between the need to refer to coronals as a class (as in this case), and the need to render them transparent in other cases. The need to refer to coronals as a class is taken as decisive here, since one general thrust of the findings is that transparency may come about otherwise than through underspecification.

The present study deals only with the mechanism by which dissimilarity requirements are enforced, and not with the level of representation at which this enforcement occurs. In McCarthy (1986), the OCP applies to morphemes in underlying representation, and it fails to apply across morpheme boundaries. However, both the existence of morpheme structure conditions and the level of application of the OCP have been controversial. Ehret (1987) argues that the triconsonantal roots of Arabic arose historically from biconsonantal roots through suffixation. If this is the case, then at the historical point when the suffixation occurred, the homorganicity constraint may well have been enforced across the morpheme boundary. However, the formal problem of describing the constraint is substantially the same with or without the morpheme boundary. As a result, Ehret's claim does not bear on the present issue. By showing that the constraint can refer to nonadjacent featural specifications, the present results do tend to undermine the evidence that the OCP *must* apply in underlying representation. There is no absolute impediment to evaluating the homorganicity of the consonants after vowels are inserted, and any treatment which did not erroneously extend the requirements to consonants supplied by nonroot morphemes may in principle be considered.

6 Appendix: Featural descriptions used in model

Labials

	b	f	m
Sonorant	–	–	+
Labial	+	+	+
Continuant	–	+	0

Coronals

	t	d	s	z	T	D	S	Z	θ	ð	š	l	r	n
Sonorant	–	–	–	–	–	–	–	–	–	–	–	+	+	+
Coronal	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pharyngeal	0	0	0	0	+	+	+	+	0	0	0	0	0	0
Continuant	–	–	+	+	–	–	+	+	+	+	+	0	0	0
Voiced	–	+	–	+	–	+	–	+	–	+	–	0	0	0
Lateral	0	0	0	0	0	0	0	0	0	0	0	+	0	0
Rhotic	0	0	0	0	0	0	0	0	0	0	0	0	+	0
Nasal	0	0	0	0	0	0	0	0	0	0	0	0	+	0
Anterior	0	0	+	0	0	0	0	0	0	0	–	0	0	0
Dental	0	0	–	–	0	0	0	0	+	+	0	0	0	0

Dorsals and Pharyngeals

	k	g	q	χ	ʁ	ħ	ʕ	h	?
Sonorant	–	–	–	+	+	+	+	+	+
Dorsal	+	+	+	+	+	0	0	0	0
Pharyngeal	0	0	+	+	+	+	+	+	+
Voice	–	+	0	0	0	0	0	0	0
Spread Glottis	0	0	0	+	0	+	0	+	0
Radical	0	0	0	0	0	+	+	0	0

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