Why Not "Spop"? OCP and Prominent Position Effects on the English Lexicon

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1. Introduction: "A hole in our dictionary"

In 1969, E. C. Fudge discovered that the English lexicon is conspicuously void of words like "spop," having the syllable structure *s*CVC, where the two consonants are specified for the same place of articulation (Fudge, 1969). Davis (Paradis & Prunet, 1991) conducted a computerized search of nearly 20,000 words in *Webster's Pocket Dictionary* and found that "no monomorphemic sCVC sequences were found in which the two C's were identical noncoronal consonants."[1] Words like *spop*, *spep* and *skik* are underrepresented in our vocabulary. In contrast, morphemes having the sequence *s*CVC when the two C's are different noncoronals, or where one C is coronal and the other is noncoronal, are common: we have words like *speak, skip, scaffold, scuba, stake, stop, stable*, and *stagger* (Table 1; Interestingly, both exceptions have only recently been added to the English lexicon).

Table 1: Occurrence of identical place of articulation in English morphemes

	C=labial	C=palatal	C=velar
spVC	**1** (spam)	216 (spit)	56 (speak)
skVC	58 (skip)	151 (skate)	**1** (skag)[2]

What's more, Davis observes that sequences of the form *s*NVN (where N = any nasal) and CLVL (where L = any liquid) are rare (Paradis & Prunet, 1991). We don't have words like *smom*, *smen*, or *snun*; and only a few identical liquids like *slalom* and *flail* make it into the English lexicon. We can generalize these trends into a composite statement.

(1) There is a resistance to $C_1C_2VC_3$ clusters where C_1 and C_2 are any allowable consonant cluster, and where C_2 and C_3 are specified for the same place of articulation.

[1] Davis observes that this underrepresentation does not apply when both C's are coronal. There are over 300 words having the structure "*st*VC" when C is a coronal. Typical examples he offers include *stud*, *study*, *astound*, *stadium*, *stash*, *stitch*, and *stone*. He argues that coronals are underspecified for the Place Node, in a model of feature geometry like the one proposed by (Sagey, 1986), and are therefore exempt. This has been challenged by Frisch (S. Frisch, 1997), who argues that the plentitude of coronals is due rather to frequency effects. This issue is tangential to the issue I am raising. Whether coronals appear frequently due to combinatorial likelihood or underspecification, the absence of labials and velars alone is conspicuous enough to demand explanation.

[2] Three velar nasals (ŋ) also occur, *skink*, *skank* and *skunk*, an exception that invites further inquiry. right! but shouldn't all constraints take place at surface level, like OT suggests?

2. Literature Review and Rationale

The Obligatory Contour Principle

What's wrong with these kinds of words? Why are there so few of them? The Obligatory Contour Principle (OCP) can account for the hole in the lexicon. The OCP identifies a general tendency in human languages: they "prefer adjacent sounds to be different if possible" (Weinberger, 2002).[3] This tendency affects segmental place of articulation in the form of the constraint "OCP-Place," a regulation against similarity of place of articulation in nearby segments. Evidence for OCP-Place can be found in languages such as English, Cantonese, Arabic, Modern Hebrew and Kikuyu (Weinberger, 2011), to name a few. Much work has been done analyzing Arabic trilateral root morphemes, which resist adjacency of homorganic segments (S. A. Frisch, Pierrehumbert, & Broe, 2004). OCP-Place has been shown to affect non-adjacent but nearby segments, separated by vowels (Davis, 1989). Many consider the strength of OCP-Place constraint to be a gradient that decreases with the number of intervening segments, rather than an absolute "on/off" (Frisch, 1997); (Guy & Boberg, 1997). The import of the OCP on words like *spop* can be clearly stated by (2).

(2) The OCP blocks the co-occurrence of the feature [place] inside a morpheme.

The two stops in *spop* are too similar, even when they are separated by a vowel. Problem solved—the missing words are accounted for by way of a parsimonious constraint.

But what about "pop"?

However, if we hold to our explanation in (2) for $C_1C_2VC_3$, we encounter a challenging obstacle: when C_1 is absent, there appears to be no resistance to place similarity between C_2 and C_3. Take away the cluster, and the OCP effects vanish. We have plenty of words exemplifying homorganic CVC, like *pop* (stops), *none* (nasals), and *lull* (liquids, although possibly fewer). Davis is aware of this:

> *It is interesting to note that while English has a MSC on sCVC sequences, there appear to be no systematic constraints on CVC sequences. Such monosyllables as pip, kick, tight, pub, cog and toad, with homorganic consonants flanking both sides of the vowel, occur in CVC sequences. I repress the temptation to speculate on why the MSC only holds for sCVC sequences….* (1991, 59) !!!

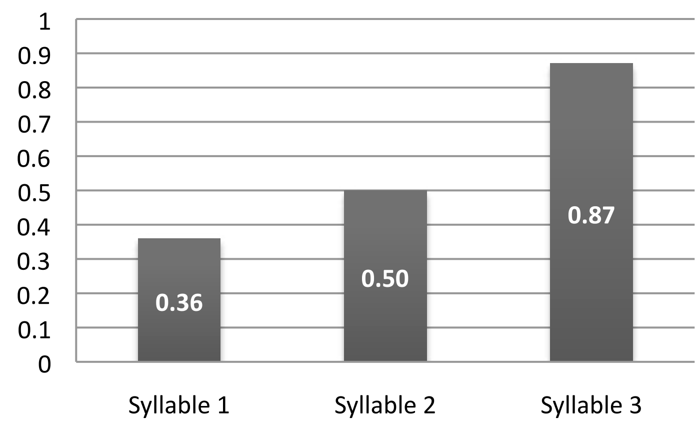
Stefan Frisch's dissertation (S. Frisch, 1997) succumbs to Davis' temptation and probes the lexical data further. Frisch conducted a study of the CELEX dictionary, a large online dictionary of British English that contains phonological, morphological, syntactic, and semantic information. He observed that there actually is a co-occurrence restriction against homorganic onsets and codas—even when they are not part of a cluster—when they occurred in unstressed syllables. The observed/expected (O/E) ratio for homorganic onset and coda segments in unstressed syllables is .28 (S. Frisch, 1997), that is, words like "papoon" (with emphasis on the

[3] Theoretically, this stems from language's overall purpose of communication—signals are best understood when they provide contrast. Consider computer programming's binary "on-off."

second syllable) occur only 28% as often as we would expect based on the number of possible combinations.

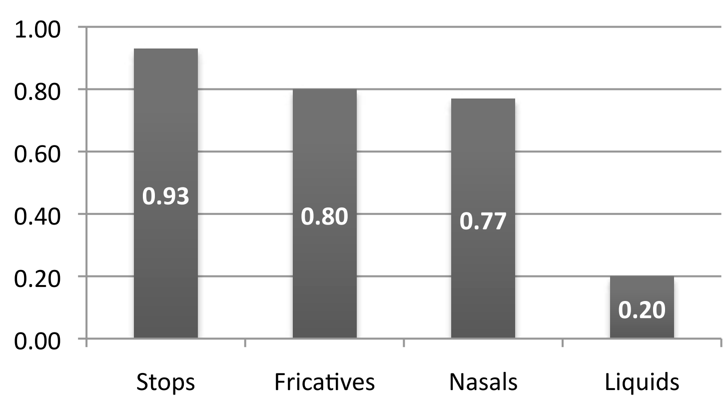
Berkeley (Berkeley, 1994b) found that co-occurrence is also restricted in stressed syllables, among homorganic segments that are *maximally similar*. Maximal similarity is defined as differing in only one feature, such as *bop*, where [voice] differs between onset and coda (See Fig. 1; see Appendix for complete data).

Fig. 1: O/E of maximally similar consonants in stressed syllables



Additionally, Frisch (S. Frisch, 1997) noted that, in word-initial stressed syllables, identical (not maximally similar) singleton onset/coda pairs with *high sonority* do not co-occur as often as they are predicted to (Fig. 2.; see Appendix for complete data). Liquids only occur 20% as often as they are predicted to; nasals and fricatives are more frequent but still not as copious as we would expect. The class of segments that throw off the consistency of the OCP the most are the stops. We can generalize that lexical frequency is inversely proportional to sonority. Segments of a higher sonority class are less likely to surmount the OCP-Place constraint and "make it into the lexicon."

Fig. 2: O/E of identical singleton onsets and coda in morpheme-initial stressed syllables



Considering these trends, several factors must converge into our account of why English allows words with CVC syllables that violate the OCP. We know that two tautomorphemic segments will probably obey the OCP according to the following general tendencies.

(3) a. Unstressed syllables do not violate the OCP
b. Syllables with onset clusters do not violate the OCP
c. High-sonority segment pairs are less likely to violate the OCP
d. Maximally similar pairs do not violate the OCP

Therefore, two tautomorphemic segments will most likely bypass the OCP only if they are low-sonority, are identical, not maximally similar, are located in a stressed syllable with a simplex onset. Almost all of our token words like *pop* and *kick* are of such form.

Why do these factors produce violations of the OCP? Frisch (1997) references evidence that stress catalyzes natural articulatory differences between stops in onset and coda positions (such as aspiration). He proposes that "the perceived similarity of onset and coda consonants, particularly those of low sonority, is reduced by the positionally dependent allophonic variation in stressed syllables".

However, Frisch does not attempt to prove this proposal; he mentions it only in passing, acknowledging that "an articulatory and acoustic analysis of the differences between consonants of different degrees of sonority in onset and coda position of stressed and unstressed syllables is needed to verify or disprove the hypothesis." He calls for further research into the nature of this dissimilarity.

Objectives

I believe Frisch is onto something, and I believe the universality of the OCP ought to be defended against this large corpus of threatening anomalies. I will attempt to unite his ideas to the theory of Augmentation in Prominent Positions championed by Smith (2005). I will begin with an "articulatory and acoustic analysis" examining the perceptual differences of consonants in onset and coda positions of stressed and unstressed syllables. I will then motivate the lexical behavior in terms of a phonological constraint acting to augment those differences. We will find that there are indeed phonetic distinctions, for stops at least, and that these are acted upon by a high-ranked faithfulness constraint for prominent positions, such that prominent positions license violations of the OCP. The constraint accounts for the underoccurrrence data. Ultimately we will see an example of the effects of phonological forces on which words the English lexicon contains and does not contain.

3. The Positional Phonetic Variation of Stops

Obstruents take different phonetic forms depending on where they are located in a syllable. The phenomena that vary include release bursts, aspiration and devoicing.

Unreleased codas

One of the clearest phonetic differences between obstruents that occur in syllable- or morpheme-initial positions has to do with the release burst, which will be our primary focus. The release burst is the air that escapes the vocal cavity immediately following the release of the closed position of the articulators when making a plosive. It is very brief (around 20 ms), and helps to give acoustic shape to the plosive. The actual instant of stop closure cannot provide perceptual information because no air is projecting out of the mouth (Silverman, 1997). The perturbed airflow of the release burst helps clarify voicing and place of articulation contrasts (Hudson, 1995). In short, since the total closure of a stop gives no sound, stops are identified by the small intervals of sound before and after closure, on the approach from a preceding vowel (in VC positions) or the ascent to a subsequent vowel (in CV positions). Release bursts are key to perceiving the identity of the stop.

In word-final, postvocalic positions (VC), stops do not always have a release burst. The presence of release burst is very unpredictable in English. Kent and Read (1992) note that “The burst is not a reliable acoustic cue for word final stops” (Kent, 1992); that is, a speaker will sometimes choose to produce a release burst in formal speech, or when attempting to increase intelligibility, but not always. For example, a frequent realization of /pop/ is [pʰop̚]. This follows the trend that syllable-final obstruents are generally “weak,” that is, less acoustically salient and subject to neutralization (Hudson, 1995). Obstruents in codas have weak release bursts.

Aspirated onsets

Obstruents in onsets, on the other hand, are always released. Syllable-initial position requires increased perceptual salience; in fact, the formant transient by which the consonant shifts into the vowel (C→V) contains some of the most perceptually distinct characteristics of a syllable. Ohala and Kawasaki(1984) concluded that “it is generally the case that the most salient acoustic modulations in a syllable occur near the CV interface”. Articulation is generally more prominent in onsets. For example, the length of stop articulation is longer (Keating, Wright, & Zhang, 1999). Byrd, et al. affirmed that consonants occurring syllable initially had longer total durations, constriction durations, and time-to-peak velocities than those that occurred syllable finally, concluding, “The notion that consonants are more prominent in word- or syllable-initial positions holds on a temporal level,” i.e. they are longer (Byrd et al. 2005, 3872).

A key feature that aids the perceptibility of the initial consonant is aspiration. Aspiration, a period of voiceless breath in the formant transitions of a stop, cues both place and voicing features to the hearer. In fact, in tests when aspiration was replaced by silence, the hearer's accuracy at identifying the place of articulation dropped by 24% (Just, Michaels, Shockey, & Suskick, 1978). This perception is most helpful for consonants in onsets, because aspiration causes a momentary devoicing influence on the following vowel (Steriade, n.d.). Aspiration also appears to have an augmenting effect on the release burst. Irrespective of other variations, bursts tend to show more strength when they are accompanied by aspiration, according to the hierarchy *voiceless aspirated* > *voiceless unaspirated* > *voiced* (Coleman, n.d.). Aspiration also lengthens the Voice Onset Time (VOT), the crucial period before the vibration of the vocal chords that helps characterize stops as voiced or voiceless. Unaspirated stops have a VOT of around 30 ms, whereas aspirated stops can have VOTs of 50-120 ms (Kent, 1992).

Thus aspiration helps stops become more perceptible by reinforcing the strength of the release burst and lengthening the VOT, and creating a clearer distinction with their "sister" voiced stops. Thus aspiration amplifies the natural phonetic differences in stop release that occur in onset and coda positions. Therefore, whereas obstruents in codas are often weakened (e.g. unreleased), obstruents in onsets are augmented (e.g. aspirated).

Aspiration occurs in English only in the formant transitions of voiceless stops when they are in the onsets of stressed syllables, except when those stops are preceded by /s/ (Kent & Read, 1992). In English, voiceless stops are *not aspirated in the non-initial positions of onset clusters* (e.g. *[sp^{h}ike]). This will prove crucial to our analysis.

Partial devoicing of voiced onsets

Voiced stops are not aspirated, yet they too are allowed, in the face of the OCP. How can we account for words like "bob" and "gag"? There are differences between onset and coda positions for voiced stops too. The general characteristic that distinguishes voiced stops is glottal vibration (voicing) during the period of stop closure (Liberman, Delattre, & Cooper, 1958). However, in the initial position of a word, voiced as well as voiceless stops are often produced with silent closure intervals (Lisker & Abramson, 1964). Smith notes that voiced stops at the head of a phrase experience voicing at the moment of release, not during closure, making them "actually voiceless unaspirated stops, like those in French" (J. Smith, n.d.).[4] Lisker and Abramson admit that /b, d, g/ are somewhat "voiceless" syllable-initially and commonly appeal to the aspiration in /p, t, k/ to differentiate them. Thus, voiced as well as voiceless stops experience a difference in initial positions too—they are partially devoiced.

[4] Smith specifically mentions the "phrase initial" position but I suggest that this generalizes for word-initial stressed positions. For example,

Problem solved: dissimilarity

Therefore there are at least three phenomena that affect the allophonic variation of stops based on their location in the syllable.

(4) a. *Release bursts* are not equally characteristic of codas.
b. *Aspiration* occurs in onsets, when in a stressed syllable, and not a part of a cluster.
c. *Partial devoicing* occurs in voiced stops in initial position.

Let's put it together: in a typical C_1VC_2 syllable, C_2 is likely to be marked [-release], whereas C_1 will be marked [+aspirated] if it is voiceless, or, if voiced, will have a shifted VOT/be partially devoiced compared to C_2. Thus C_1 and C_2 aren't phonetically identical as they appear on the surface. If they aren't entirely identical, then they are less opposed by the OCP, which disfavors *similarity*. Perhaps the OCP accepts same place of articulation, *if* there are other features to distinguish the two segments. We know that the OCP behaves as a gradient that grows increasingly strong as similarity between the segments increases (Frisch et al., 2004), so this concept is not hard to accept. We can take the assumption (5).

(5) OCP-place violation between two segments in CVC is permissible if they contain perceptible allophonic variation.

This generalization can account for words like gag and pop.

4. Positional Faithfulness

We would like to account for our observations in terms of some constraint in the phonological grammar—without a constraint acting on the phonology, allophonic variation would have no affect on the English lexicon. If our idea about similarity is true, we must be able to observe some constraint that refers to similarity and interacts with the OCP-Place constraint. To discover this constraint we must look at the concept of the prominent position.

Prominent positions

In (3a), we note that a place of articulation co-occurrence will be allowed in a stressed syllable, but the same form is unacceptable in an unstressed syllable. This requires us to acknowledge that languages have "prominent positions" which receive special attention (Beckman, 1998). Beckman lists onsets, stressed syllables, root-initial syllables, and word initial syllables as prominent positions—in other words, these are the very positions where we find our exceptions. Smith notes that prominent positions are subject to unique markedness and faithfulness constraints, for example, ONSET/σ_1 which requires the presence of a syllable onset in the initial syllable, and the [*ONSET/X]/σ_1 subhierarchy, which favors low-sonority onsets in this positions. Positional constraints have the ability to "resist neutralization of processes that affect other positions" (J. L. Smith, 2005). If the OCP eliminates "fatally similar" consonantal features from the English lexicon, constraints that designate prominent positions might have the license to resist, preserving sub-optimal forms.

A new positional constraint

We know that stressed syllables are phonetically prominent positions; let us suppose that stressed syllables also have psycholinguistic strength in English. Smith argues that positional faithfulness constraints that apply to stressed syllables do so for phonetic reasons, such as enhancing the accuracy of the output (2005). For example, a heavy syllable is a phonetically strong position because its weight needs more attention to be accurately realized. The problem is that, as Smith argues, such constraints cannot address consonantal features (which sensitivity we need for the two C's in our CVC).

On the other hand, faithfulness constraints that apply to psycholinguistically strong positions (i.e. those that are important for recognizing the word) can license the preservation of consonantal features (Smith, 2005). Morpheme-initial and word-initial positions are included in this set. I would like to suggest that stressed syllables are also treated as psycholinguistically strong in English, i.e. that they are more important for processing and word recognition in English; for example, prosodic meter depends only on stressed syllables, not on the total number of syllables; and significant V→ə reduction occurs in unstressed syllables. However, a detailed analysis is outside the scope of our discussion. If stressed syllables are of psycholinguistic salience in English, we can modify our assumption in (5) into a prominent position constraint that especially licenses OCP violations.

(6) **FAITH(Δ)/σ´ -** Preserve two segments C_1 and C_2 in $(C_1VC_2)_\sigma$ if σ is a stressed syllable, and they vary perceptibly.

This constraint looks for a stressed syllable and the presence of perceptible allophonic variation, and licenses the word only in the case of both. The precedent comes from a combination of two factors: the existence of faithfulness constraints, especially of those that apply to prominent positions, and the proposed significance of perceptual variance. With the ranking (7), this positional faithfulness constraint accounts for the stressed/unstressed differences, and will also be able to account for our exceptional data.

(7) FAITH(Δ)/σ´ » OCP-Place » FAITH

The following tableau demonstrates the acceptability of the four CVC contexts according to FAITH/$\sigma_{1!}$, if we consider Ø to be the option whereby no forms are optimal enough to receive a lexical entry.

Table 2: Stressed syllable (voiceless)

/pɔp/	FAITH(Δ)/σ´	OCP-Place	FAITH
pɔp	!*	*	
☞p^hɔp		*	*
Ø	!*		*

The final [p] may be unreleased, but unreleased is by nature "inaudible," which does not produce distinction; rather the lack thereof. Therefore the unaspirated form violates FAITH(Δ)/σ´ since the two [p]s do not differ perceptibly. Needless to say, the null entry violates faithfulness.

Table 3: Stressed syllable (voiced)			
/bɔb/	FAITH(Δ)/σ´	OCP-Place	FAITH
bɔb	!*	*	
☞b̥ɔb		*	
Ø	!*		*

The "voicing during closure" that makes voiced stops distinct is present in the final [b], and in the initial [b] of the first entry, making them fatally similar. The selected initial [b] lacks voicing during closure, which produces acceptable asymmetry. Needless to say, the null entry violates faithfulness.

Table 4: Unstressed syllable			
***/pɔp.ˈtun/**	FAITH(Δ)/σ´	OCP-Place	FAITH
pɔp.tun		!*	
☞Ø			*

In Table 4, since the homorganic CVC does not occur in a stressed syllable, FAITH(Δ)/σ′ does not apply. Therefore the OCP is the highest acting constraint, and no lexical entry is selected.

Table 5: Stressed syllable with an onset cluster			
***/spɔp/**	FAITH(Δ)/σ′	OCP-Place	FAITH
spɔp	*	!*	
☞Ø	*		*

In Table 5, aspiration is not an option (English never aspirates after [s]), and the two [p]s are therefore not perceptually distinct. Therefore, FAITH(Δ)/σ′ is inevitably violated, and the OCP becomes the next highest violation; no lexical entry is selected.

We have thus accounted for why homorganic CVC is allowed, only in stressed syllables, whereas sCVC clusters are never allowed regardless of stress. Let us now consider other CCVC clusters, the high-sonority clusters, like *sNVN.

5. Sonority

Recall that the OCP evidences gradient effects. It will gradually alleviate with decreasing similarity between segments (or distance between segments). Within the exceptions to the OCP in stressed syllables (Figure 2), it can be seen that more sonorant pairs violate the OCP less. From our "fatal similarity" approach, we must ask whether more sonorant pairs are more similar to each other. This is the case. Phonetic distinctions between onset and coda, such as aspiration and partial devoicing, cannot be seen in highly sonorant clusters—they are naturally distinctive of obstruents. Saussure attributed the sonority scale to the potential of the phone types for distinguishing "explosion" and "implosion," that is, the acoustic effects of closure versus release that characterize onsets/codas, since the two movements become less distinct as aperture increases (Hudson, 1995). High-sonority pairs like in "smum," being approximate in their articulator contact, are inherently incapable of producing a sharp distinction in their articulators. Therefore, only segments in low-sonority ("obstruent-like") onsets are capable of having the kind of sharp allophonic variation that causes perceptual dissimilarity between their initial and final versions.[5] Without those hints of dissimilarity, a constraint which appeals to them (in our case FAITH(Δ)/σ´) doesn't take effect. This accounts for why high-sonority segments violate OCP-Place less, as in Figure 2.

6. Maximal similarity

We have to explain why maximally similar data does not follow the other data (Figure 1)—this poses a bit of a problem, because maximally similar pairs seem to vary perceptibly. (Most English speakers know the difference between the final [p] in *pup* and that in *pub*.) Since fricatives cannot appear as the co-occurring C in CCVC (*[pfaf]), there are only two kinds of maximal similarity that deal with obstruents: we can have a voiced onset and voiceless coda, or a voiceless coda and voiced onset. For example, in the case of labials:

(8) bVp

(9) pVb

Example (8) suggests a phonetic explanation. Recall from section (3.3) that initial voiced consonants are partially devoiced so that they become "actually voiceless unaspirated stops" (Smith, n.d.), and that stops in coda position are often unreleased, decreasing their perceptual distinctiveness. (Similarly, voiced stops are also somewhat devoiced word-finally.) This renders the narrow transcription of the word bop as [b̥ɔp˺] Additionally, [p] is aspirated in stressed onset position, which augments its perceptual distinctiveness. Therefore I suggest that [b̥] and [p˺] are actually more perceptually similar than [ph] and [p˺]. This is a testable statement that requires further research; however, such a test is outside the scope of the current paper. The results of such tests have the capability to narrow and simplify the cause of this otherwise-difficult data.

In example (9), no such explanation is forthcoming, since certainly the initial [p^h] is more distinct from the final [b] than from [p˺]. To the extent that words like *pub* occur, the OCP violation is inexplicable. I suggest a more detailed analysis of the English lexicon to determine whether this type of maximally similar words have higher representation in the English lexicon than the type in (8). I predict so, but such analysis is outside the scope of this argument.[6] We may alternatively point out that all of type (9) are also of the highly marked form of having a voiced final obstruent—which may be entering the constraint ranking, something like:

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[5] I consider the "dark l" to be an exception, since it often occurs post-vocalically; but the contextual predictability of dark l varies too much between dialects of English.

[6] I ran an unscientific test on the CELEX dictionary for English lemmas containing every possible pVb, bVp, kVg, and gVk combination (we've been excluding coronals). I generated 48 words that complied to the normal English spellings for producing these phonetic combinations (see Appendix for the list). The results returned only five entries *beep, bop, cog, keg*, and *pub*. Furthermore, all of these except pub had low frequency of use in the lexicon: beep, bop, cog and keg all had an occurrence of only 1-2 times per million. (Pub occurred 30 times per million.) Compare this with pop's rate of 55 per million—only pub is a common word. However, this preliminary analysis needs to be corroborated by better studies.

(10) *CODA$_{+VOI}$ » FAITH(Δ)/σ´ » OCP-Place » FAITH

This and our phonetic explanation of type (8) would satisfy the maximally similar data.

7. Conclusion

In Section (2) we observed that homorganic consonants are allowed to violate the OCP in stressed syllables, especially when they are obstruents. In Section (3) we followed Frisch and confirmed perceptual variance for obstruents in onset vs. coda positions, including release/nonrelease, aspiration, and partial devoicing. We also showed that this variation depended on the phonetic nature of low-sonority segments. Assuming the stance that stressed syllables are important to English psycholinguistic perception, I attempted to motivate the lexical gaps by a faithfulness constraint on stressed syllables, FAITH(Δ)/σ´. The data for maximally similar segments shown by (Berkeley, 1994a) can be accounted for by perceptual similarity between [b̥] and [p̚] and the possible involvement of the *CODA$_{+VOI}$ constraint. In the end, this accounts for our original question, "Why not *spop*?" The answer is: The OCP blocks *spop* and not *pop* because the two segments in *spop* are more perceptually similar, so perceptually similar that they cannot be protected by the faithfulness constraint that protects the allophonically varied *pop*.

The overall rationale is simple: like all languages, English values perceptual salience, and the grammar reflects this. Stressed syllables are the most important for perception, so they get special preference. This preference allows constraints that would reduce lexical variation to be broken. But since the OCP is a gradient, some forms may be able to trump it, whereas some similar, more severe violations may not be able to. That is exactly what we find in English, and that's why there's nothing in the dictionary for "spop."

Appendix

O/E of maximally similar consonants in stressed syllables			
	Syllable 1 O/E	**Syllable 2 O/E**	**Syllable 3 O/E**
Labial	.22	.26	.98
Coronal Obs.	.49	.73	.75
Coronal Son.	.46	.63	.67
Dorsal	.26	.36	1.08
Average	**.36**	**.50**	**.87**

Table 10.5: Identical singleton onset and coda in word initial stressed syllables.

Stops				Fricatives			
	Observed	Expected	O/E		Observed	Expected	O/E
/p/	11	8.8	1.25	/f/	2	3.0	0.66
/b/	6	3.6	1.68	/v/	0	1.2	0
/t/	13	13.8	0.94	/s/	7	9.1	0.77
/d/	4	6.0	0.67	/z/	1	0.7	1.44
/k	11	17.0	0.65	/ʃ/	2	0.9	2.19
/g/	3	2.3	1.32	/ʒ/	0	0.0	0
Total	48	51.3	0.93	Total	12	15.0	0.80
Nasals				**Liquids**			
	Observed	Expected	O/E		Observed	Expected	O/E
/m/	15	15.2	0.99	/l/	4	16.3	0.25
/n/	9	16.0	0.56	/r/	4	24.6	0.16
Total	24	31.2	0.77	Total	8	40.9	0.20

References

Beckman, J. (1998). *Positional faithfulness*. University of Massachusetts, Amherst.

Berkeley. (1994a). The OCP and gradient data. *Proceedings of FLSM V. Studies in the Linguistic Sciences* (Vol. 24.1/2, pp. 59-72).

Berkeley, D. (1994b). Variability in obligatory contour principle effects. *Papers from the 30th regional meeting of the Chicago Linguistics Society* (pp. 1-12). Chicago: University of Chicago Press.

Coleman, J. (n.d.). Acoustic structure of consonants. Retrieved April 3, 2011, from http://www.phon.ox.ac.uk/jcoleman/consonant_acoustics.htm

Davis, S. (1989). Cross-vowel phonotactic constraints. *Computational Linguistics*, *15*, 109–110.

Frisch, S. (1997). *Similarity and frequency in phonology*. Northwestern University.

Frisch, S. A., Pierrehumbert, J. B., & Broe, M. B. (2004). Similarity avoidance and the OCP. *Natural Language & Linguistic Theory*, *22*(1), 179–228.

Fudge, E. C. (1969). Syllables. *Journal of Linguistics*, *5*(2), 253-286.

Guy, G. R., & Boberg, C. (1997). Inherent variability and the obligatory contour principle. *Language Variation and Change*, *9*(02), 149–164.

Hudson, G. (1995). Consonant release and the syllable. *Linguistics*, *33*(4), 655-672.

Just, M., Michaels, S., Shockey, L., & Suskick, R. (1978). Acoustic cues and psychological processes in perception of natural stop consonants. *Department of Psychology*. Retrieved from http://repository.cmu.edu/psychology/320

Keating, P., Wright, R., & Zhang, J. (1999). Word-level asymmetries in consonant articulation. *UCLA Working Papers in Phonetics*, 157–173.

Kent, R. D. (1992). *The Acoustic Analysis of Speech*. San Diego, Calif: Singular Pub. Group.

Kent, R. D., & Read, C. (1992). *The Acoustic Analysis of Speech*. San Diego, Calif: Singular Pub. Group.

Liberman, A. M., Delattre, P. C., & Cooper, F. S. (1958). Some cues for the distinction between voiced and voiceless stops in initial position. *Language & Speech*, *1*(3), 153-167.

Lisker, L., & Abramson, A. (1964). A cross-language study of voicing in initial stops: acoustical measurements. *Word*, *20*(3), 384-423.

Ohala. J., & Kawasaki, H. (1984). Prosodic phonology and phonetics. Phonology Yearbook, 1, 113-127.

Paradis, C., & Prunet, J.-F. (Eds.). (1991). *The Special Status of Coronals: Internal and External Evidence*. San Diego: Academic Press.

Sagey, E. (1986). *Representation of Features and Relations in Non-linear Phonology* (Doctoral Dissertation). MIT, Cambridge, Massachusetts.

Silverman, D. D. (1997). *Phasing and Recoverability*. Outstanding dissertations in linguistics. New York: Garland Pub.

Smith, J. (n.d.). Voice Onset Time. University of North Carolina. Retrieved from http://www.unc.edu/~jlsmith/ling520/handouts/vot.pdf

Smith, J. L. (2005). *Phonological Augmentation in Prominent Positions*. Outstanding dissertations in linguistics. New York: Routledge.

Steriade, D. (n.d.). Alternatives To Syllable-Based Accounts Of Consonantal Phonotactics. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.16.9358

Weinberger, S. (2002). Alien Phonology, 37.

Weinberger, S. (2011). *Obligatory Contour Principle*. Linguistics 692 Class Document, George Mason University.