

# Repetition Avoidance in Human Language

by

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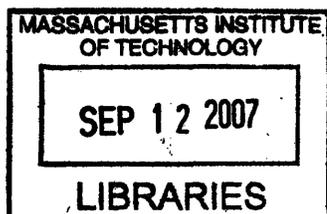
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by

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## **ABSTRACT**

Repetition is avoided in countless human languages and at a variety of grammatical levels. In this dissertation I ask what it is that makes repetition so bad. I propose that at least three distinct biases against repetition exist. First, repetition of articulatory gestures is relatively difficult. This difficulty results in phonetic variation that may lead to categorical phonological avoidance. I call this set of claims the Biomechanical Repetition Avoidance Hypothesis (BRAH), and support it with evidence from cross-linguistic patterns in repetition avoidance phenomena, articulatory data from music performance, and a series of phonetic experiments that document the proposed types of phonetic variation. Based on these data, I give an evolutionary account for antigemination in particular.

The second anti-repetition bias is a perceptual deficit causing speakers not to perceive one of a sequence of repeated items, of any conceptual category. This bias is already well-documented, as are the grammatical effects (primarily haplology). I provide here the evidence of gradient variation in production bridging the two, from avoidance of homophone sequences in English corpora.

The third factor is a principle disallowing the repetition of syntactic features in certain configurations within a phase domain. I document categorical effects of it in Semitic syntax of possession and relativization. These elicit repair strategies superficially similar to those of phonology (specifically, deletion and epenthesis/insertion).

Repetition effects, then, are traceable to a variety of independent, functional biases. This argues against a unitary, innate constraint against repetition. Rather, multiple anti-repetition biases result in particular avoidance patterns, with their intersection producing additional asymmetries. Possible categorical repairs are further constrained by the nature of the formal grammatical system.

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## **Chapter One: Introduction and outline of the dissertation**

Repetition plays an unusual role in human grammar in that it is sometimes mandated and sometimes forbidden. Despite identity-enforcing grammatical mechanisms such as reduplication, harmony processes, syntactic coordination, and so on, identity, or too high a degree of similarity, is also dispreferred and often outlawed for linguistic forms at every grammatical level. Some sort of anti-repetition generalization has been formulated for phonology (the Obligatory Contour Principle, or OCP), discourse (*horror aequi*), syntax (the Distinctness Principle), and human psychology generally (repetition deficit). It seems, then, that repetition avoidance is universal in the sense that it seems to occur in virtually every human language, in every grammatical subdomain, and in other cognitive domains as well.

In this dissertation I ask what makes repetition so bad. I claim that there are at least three distinct reasons for its difficulty, which stem from both production and perception. The first is physiological – repetition of gestures, some more than others, is articulatorily difficult. I call this claim the Biomechanical Repetition Avoidance Hypothesis (BRAH). The second is perceptual, and is based on the substantial psychological literature on repetition deficit. The third reason is based on the representational indistinguishability of syntactic feature bundles at the grammatical interface point of Spell-Out. I now briefly discuss each of these, and then the implications of the functional approach to repetition avoidance that I implement in appealing to these factors. The chapter closes with an outline of the dissertation.

### **1. 1 A physiological motivation for repetition avoidance**

Contrary to earlier analyses of repetition avoidance phenomena, even those which appeal to explicit anti-repetition principles, I argue that gestural repetition requires relatively great articulatory effort. This results in phonetic variation that makes repetition less effortful when it does occur (the variation may be purely mechanical side-effect of difficulty and fatigue, or the result of purposeful strategies). These phonetic patterns may lead to phonologized repetition repair. Thus the physiological difficulty of gestural repetition motivates cross-linguistic patterns of repetition avoidance at the featural and segmental levels. I call this set of claims the Biomechanical Repetition Avoidance Hypothesis, or BRAH.

The specific implementation of the BRAH that I propose makes a number of additional predictions about patterns of repetition avoidance, referring to both the triggers of repetition avoidance and the specific repairs employed. First, the crucial reference to articulatory effort implies that gestures which are inherently more effortful are preferentially subject to repetition avoidance. I argue that this prediction is fulfilled by the preponderance of consonantal place as repetition avoidance target. Place articulators have the greatest mass and therefore require more effort to use. The relatively high degree of tolerance observed for coronal place repetition is also predicted, as the tongue tip is the least massive of place articulators (and in some models is treated as altogether massless).

Second, the physiological difficulty is sharply delimited to a highly local temporal environment. This prediction is fulfilled by a strong effect of segmental proximity in consonant co-occurrence restrictions, and by the close proximity (in ms) that I find is required in order to elicit repetition-related phonetic variation.

Regarding the output of repetition repair processes, the BRAH predicts articulatory slowdown in repetitive contexts. This occurs most strongly at the transition between offset of the first gesture and onset of the second – that is to say, during the intervening vowel, if any. I document more retention of optionally devoiced/deleted vowels between identical versus non-identical consonants, and increased duration of vowels between identical consonants. These two patterns provide the phonetic precursor to the phonological process of antigemination. (A more general phonetic slowdown effect, which does not become phonologized, may persist beyond the immediate locus of repetition).

The difficulty of and therefore dispreference for repeated consonant sequences also provides a rationale for the complementary strategy of deleting vowels only between identical consonants. This phenomenon has previously been argued to preclude any repetition-based analysis of antigemination. I argue that it is merely another solution to the problem of gestural repetition, and its relative rarity is explained by the lack of a clear phonetic pathway such as antigemination has.

Finally, articulatory undershoot may also occur in contexts of difficulty, including that posed by gestural repetition. I document this phonetically and argue that it may lead to the phonological repair of dissimilatory spirantizing lenition in sequences of stop consonants. However, the antagonistic effect of increasing duration renders this repair a relatively rare one.

## **1.2 A perceptual motivation for repetition avoidance**

A large psychological literature shows that repetition of any conceptual category presents difficulty to the human perceptual system. This is true for multiple modalities (visual, auditory, etc.) as well as conceptual domains. When presented with repetition, humans fail to perceive one of the repeated items.

I conclude from this that repetition avoidance remains highly motivated even for linguistic forms outside the physiological domain captured by the BRAH. This is true for higher-level categories than the featural and segmental, and for all categories at greater temporal distances. The effect of this repetition deficit may be expected to arise at transition points within the speech production system (e.g. in the different stages of utterance planning) as well as in the perception of external signals.

While this phenomenon has been extensively explored in perception, a related prediction is that category repetition should be avoided when possible in production as well. Such avoidance may be attributed to lack of repetition perception in utterance planning and/or the desire to ease processing difficulty for oneself and one's interlocutor. I document such avoidance with respect to lexical word form repetition in a series of corpus studies, and argue that it bears out the production prediction. In addition, the nature of the behavioral variation – failure to perceive/produce a repeated token – complements the common grammatical repair strategy of haplology.

## **1.3 Spell-Out and repetition avoidance**

The third reason to avoid repetition stems from the nature of syntactic computations. Common assumptions of late lexical insertion and the need to linearize syntactic trees at Spell-Out result in syntactic feature bundles that cannot be ordered at that point with respect to other, identical ones in an asymmetrical c-command relationship. This results in the unacceptability of such structures, so that cooccurrence of syntactic features is avoided in such configurations within a phase domain. Repair strategies are then employed that are superficially similar to those seen in phonological repetition avoidance (epenthesis/insertion of an intervening element, deletion of one of the repeated items, etc.). I give a detailed analysis of Semitic construct state and relative clause formation along these lines.

#### **1.4 Implications of the functional approach to repetition avoidance**

The existence of these three distinct functional anti-repetition factors implies a trifecta for each – the factor itself, gradient patterning motivated by it, and corresponding grammaticalized repairs. The repetition repairs mentioned in 1.1 (cooccurrence restrictions, antigemination, dissimilation) are well-known. However, both the proposal regarding the physiological factor motivating them and the data on associated phonetic variation are entirely novel, as is the relationship among them and the phonological repairs. For the perceptual factor of 1.2 neither the functional difficulty nor the corresponding grammatical repair of haplology is new, but I present the first corpus-based evidence for gradient patterning motivated by it. The study of syntactic repetition avoidance is in early stages. I do not pursue evidence for gradience in it, but give a detailed grammatical analysis depending on this factor.

A common approach to grammatical repetition avoidance has been to posit a general ban on sequences of identical elements (such as the OCP). The extension of such a principle to account for phenomena at the featural, morphological, syntactic and other levels has generally been accommodated through indexation for domain and linguistic category. Thus authors introduce something like a “syntactic OCP” or (for phonetic data similar to what I present regarding antigemination) a “gestural OCP.” I maintain that this approach is fundamentally misguided. The gestural facts make it clear that at least at this level, ranking OCP constraints in a classic OT grammar does not satisfactorily account for the observed behavior, since multiple articulatory repair strategies are implemented simultaneously. Aside from this, the distinct natures and predictions of the three functional factors identified above argue against subsuming their effects into a single formal, universal grammatical principle. On the contrary, their number and disparate natures explains both the multiplicity of such effects and the difficulty researchers have had in agreeing on the proper statement or even existence of such a formal anti-repetition principle in grammar.

I argue that the robust functional biases against repetition mean that such a principle is not necessarily part of the grammar at all. Language users are already biased to avoid, alleviate or mis-produce repetition in their own production when possible, due to its difficulty. This results in underattestation of repetitive sequences in the speech signal. Such underattestation is compounded by the tendency not to perceive repetition in the speech of others, even when

present. These interacting tendencies result in linguistic input that is increasingly deprived of repetition over time, thereby setting up a cycle that can result in languages with gradient and even categorical repetition avoidance.

However, the grammaticalization of such avoidance may be instantiated in different ways cross-linguistically, rather than necessarily involving a generic UG ban on repetition. Nor does an emergent OCP-type constraint, based solely on patterns observed in the ambient linguistic data, suffice to explain the relationship between the phonetic patterns observed and grammatical repetition avoidance typologies. It is clear that the relationship between gradient patterns elicited by the presence of repetition and grammatical repetition repairs is constrained in some way, and that possible anti-repetition behaviors must be modulated by the possibilities allowed by the formal grammatical system. I discuss specific ways in which this plays out in the relationship between phonetic and phonological repairs. Thus rather than either innate or emergent constraints targeting repetition specifically, grammaticalization of its avoidance should make use of independently motivated grammatical mechanisms. I argue in favor of the constraint conjunction approach for most cases.

Finally, the intersection of these multiple factors at points of the grammatical spectrum accurately predicts asymmetries in the particular repetitive items or strings most likely to elicit repair. I argue that the apparent restriction of antigemination to identical rather than all homorganic segments is due to the fact that complete segmental identity also elicits the perceptual effect, thereby making such segments doubly vulnerable to repair of some kind. Similarly, the well-documented effect of similarity in consonant cooccurrence restriction patterns may be attributed to the cumulative effect of featural identity along multiple dimensions. Patterns in haplology also show an expected asymmetry, wherein potential  $C_1VC_1$  targets are especially likely to be targeted. These violate the BRAH and the repetition deficit. Finally, repetition of a syntactic category is more likely to be avoided if it also involves phonological form identity.

### **1.5 Outline of the dissertation**

The remainder of the dissertation is laid out as follows. In Chapter Two, I review some classic examples of the phonological OCP in action, which have been first and primarily discussed in categorical grammatical terms. These include consonant cooccurrence restrictions, dissimilation/deletion repairs, and antigemination. A more recent and burgeoning literature finds

gradient counterparts to many of these processes, which I make a particular effort to exemplify. I then lay out the details of the BRAH. I discuss articulatory, physiological reasons why segmental repetition is difficult. I argue that repetition of place gestures in particular presents a challenge to the articulatory system. The difficulty of such repetition results in phonetic variation that is a diachronic, phonetically natural source of the kind of repetition avoidance discussed at the beginning of the chapter.

Chapter Three provides experimental tests of this proposal. Given the arguments for difficulty of gesture repetition and the existence of gradient counterparts to many phonological OCP effects, it is natural to look for such gradient effects in the production of consonant sequences that are phonotactically licit, but nevertheless dispreferred by virtue of including repetition. I report a series of six phonetic experiments on American English which documents exactly such effects. Repetitive sequences are associated with variation in some properties of the consonants themselves, and also in the intervening vowel. Repetitive consonant sequences co-occur with increased duration of vowels intervening between them. Increased duration is also observed for the consonants themselves, particularly the one in prosodically weaker position, along with lower intensity and less complete closure constriction. Neighboring segments may also be lengthened in a more persistent effect of speech rate slowing. This chapter documents a novel, hitherto unexplored type of phonetic variation.

In Chapter Four I further explore the relationship of the observed phonetic patterns with phonological repetition repairs, and the implications for phonological analyses of repetition avoidance. I begin the chapter with a discussion of Articulatory Phonology treatments of similar phenomena, relying on a “gestural OCP” and concluding that they are insufficient to account for the range of phonetic effects found here. I then review other extant phonological analyses. These include proposals in favor of non-innate, emergent constraints against repetition; a universal, innate constraint family against repetition, and a constraint conjunction analysis that relies on neither. I argue in support of the third, on the grounds that the robust functional support for repetition avoidance makes specific constraints against repetition unnecessary. I also show that this analytical framework successfully predicts the ways in which the observed phonetic variation can be grammaticalized, and the ways it cannot be.

Chapters Three and Four show that some phonological repetition avoidance is traceable to articulatory difficulty. Gradient phonetic patterns reflecting that difficulty potentially lead to

grammaticalization of the phonological repairs. However, this is not true for all repetition avoidance cases. Chapter Five begins with a discussion of an additional source of difficulty associated with repetition. I review the evidence from the psychology literature for a more general perceptual repetition deficit across cognitive domains, applying to all sorts of psychological categories and concepts. This deficit motivates additional kinds of repetition avoidance processes and predicts additional gradient patterns of repetition avoidance in grammatical domains above the level of the segment. I summarize the literature on such cases and then present new data fulfilling this prediction at the lexical level. This data includes a series of studies on *that-that* sequences in American English,<sup>1</sup> and an exploratory study of underattestation of American English homophone sequences.

I then shift attention repetition avoidance effects at the morphosyntactic level. I focus here on cases that do not involve phonological identity of any kind, but nonetheless trigger repairs that are superficially similar to those seen in previous chapters. I give a detailed analysis for Semitic construct state and relative clause formation, and conclude that such cases are motivated by yet a third factor – the indistinguishability of syntactic feature dependents at Spell-Out. Late lexical insertion means that feature heads in the relevant hierarchical relationship cannot be adequately distinguished, and also guarantees the irrelevance of phonological form. Chapter Six concludes the dissertation.

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<sup>1</sup> This work was done in collaboration with T. Florian Jaeger.

## **Chapter Two: Phonological repetition avoidance and the biomechanical repetition avoidance hypothesis (BRAH)**

I begin this chapter with selected canonical examples of the phonological OCP in action. These include morpheme structure constraints on consonant cooccurrence possibilities; epenthesis/dissimilation/deletion processes that repair potential violations; and antigemination, which avoids the creation of adjacent repetitive sequences. I identify patterns in the cross-linguistic typology of such phenomena and argue that these patterns constitute evidence for a physiological repetition avoidance problem, encapsulated in the BRAH. In subsequent sections I outline the BRAH itself in more detail. I then present additional evidence for it, and for predictions derived from it, from articulatory modeling and music performance.

### **2.1 Phonological OCP effects**

The linguistic literature on repetition avoidance in human language focuses primarily on the phonological domain, attributing it to the Obligatory Contour Principle, or OCP. The advent of autosegmental phonology (specifically as applied to phonological tone; Leben 1973, Goldsmith 1976), led to the identification of this seemingly general principle in phonology that disprefers, and in many cases disallows, the proximity of identical elements. This principle has since been applied widely, and is typically formulated as:

- 1) The Obligatory Contour Principle:  
Adjacent identical elements are prohibited.

A substantial literature explores what constitutes adjacency and identity with respect to repetition avoidance, as well as which representational elements may trigger it. The OCP may manifest itself in several different ways:

- 2) OCP effect types
  - a. prohibition of violations in underlying representations (URs)
  - b. motivation of repairs of violations
  - c. blocking creation of violations

All these effects are well-documented and widely seen in languages of the world (Leben 1973, Goldsmith 1979, McCarthy 1986, Yip 1988, Odden 1988). Consonant cooccurrence restrictions, in Arabic, English and many other languages, exemplify type 2a. Type 2b can surface as epenthesis (English inflectional morphology), dissimilation, and deletion. Antigemination is a well-known effect of type 2c. OCP violations may also be tolerated in a grammar, as expected in a system of violable constraints. We shall see that even in such cases, however, dispreference for them may surface as gradient variation.

In what follows, I discuss canonical examples of the OCP, acting in each of these ways. I argue for an evolutionary approach to phenomena from each class, and claim that their cross-linguistic typology shows the effect of something like the BRAH.

### *2.1.1 Consonant cooccurrence restrictions*

One of the earliest discussions of the OCP focuses on the distribution of Arabic consonants, which have complicated restrictions on possible combinations within the root. Similar restrictions have since been documented for many other unrelated languages. The existence of such gradient patterns in consonant distribution, then, may be plausibly assumed to be universal. Pozdniakov and Segerer (to appear) argue explicitly for the stance, taking the position that avoidance of successive homorganic consonants within words is universal even with separation by a vowel. Their claim is based on the finding that homorganicity in such sequences is underattested by at least 15% for all or most place categories, and rarely for any others, in a survey of eight languages (Fula, Malagasy, Basque, Port Moresby Pidgin English, Quechua, Classical Mongolian, reconstructed Proto-Bantu, and Swahili).

In this section I summarize the consonant cooccurrence literature on the approximately forty languages for which it exists, from a wide variety of language families (~14; a list is provided in Appendix Four. Additional details on the cooccurrence patterns may be found in Appendix Three, with particular reference to evidence for the psycholinguistic relevance of these restrictions and for place-based asymmetries). Place repetition is particularly avoided, especially of non-coronal place. Beyond that, strong effects of similarity and proximity are observed, such that sequences of more similar segments that are closer together are the most avoided. Finally, the relevant kind of identity appears to be based on surface feature specifications rather than

underlying ones. Matching features matter for the computation of similarity whether or not they are contrastive, and when a surface allophone differs from an underlying phoneme, it is the surface specification that determines the degree of underattestation in cooccurrence.

I argue that these three generalizations – the particular relevance of place, especially non-coronal place, the proximity effect, and the surface-based computation of similarity – point to the restrictions being driven by the articulatory difficulty of repeating gross motor gestures in quick succession, rather than a more abstract kind of identity or distance.

Like other Semitic languages, Arabic contains families of morphologically related lexical items that share a subset of consonants with an associated semantic load:

- 3) An Arabic root: k-t-b
- a. kataba      he wrote
  - b. kaatib      writer
  - c. maktab      office
  - d. kitaaba      writing

In the example given above, all three consonants differ in place of articulation. McCarthy (1986, 1994) extends Greenberg's (1950) observation that this seems consistently to be the case, and proposes an explanation in which the OCP holds at the level of the consonantal tier to forbid the adjacency of identical place specifications. Thus there are no such Arabic roots as b-b-t or b-t-b.

McCarthy also observes that the OCP tends to apply to segments that share major class features (1994), rather than other feature types. The precise extent of this tendency and others has since been quantified, revealing strong effects of **similarity**, **position**, and **proximity** of the consonants involved in Arabic (Frisch, Pierrehumbert and Broe 2004, henceforth FPB, building on the work of Pierrehumbert 1993 and Frisch 1996). Place of articulation forms the core of the co-occurrence restrictions of Arabic (no underattestation is observed for any pair of consonants that do not share place of articulation), but the situation is considerably more complicated than any simple statement invoking homorganicity suggests. First, it is gradient rather than categorical. Second, a number of subpatterns affect the degree of underattestation, depending on featural specifications, position and proximity of the segments involved. The factors leading to more limited cooccurrence in Arabic are summarized below:

- 4) Factors *against* homorganic consonant cooccurrence:
- a. Consonant-tier adjacency in the root (C1-C2 & C2-C3 more restricted than C1-C3)
  - b. Leftward position in the root.
  - c. Non-coronal place.
  - d. Within coronals:
    - i. Matching voicing.
    - ii. Both liquid.
    - iii. Both emphatic.
  - e. Within labials: Both oral.
  - f. Within pharyngeals: Dorsal/pharyngeal manner.
  - g. Matching continuancy (fricative first)

The voicing effect holds true for the sonorants, for which the [+voice] specification is non-contrastive, as well as the other coronals. Thus the computation of similarity appears to be relatively surface-based.

I will now focus on the importance of place and coronality in such restrictions. The asymmetry between place and other features seen in Arabic also appears in Suzuki's (1998) cross-linguistic survey of dissimilation patterns. In a sample of dissimilatory patterns found in 57 languages, Suzuki finds that 10 refer to place (labial, coronal, or pharyngeal; 10 more refer to liquid, lateral or rhoticity/retroflexion), and only 5 to laryngeal features (voicing, spread glottis or restricted glottis). Two more patterns refer to continuancy, and one to nasality. It is clear that consonant dissimilation can certainly refer to feature types other than place, such as laryngeal ones, and there are famous cases of this kind like Grassmann's Law in Sanskrit, Lyman's Law in Japanese, and further cases in languages of the Americas discussed by MacEachern (1999). However, place-driven repetition avoidance appears to predominate over other sorts of manner features in both morpheme structure conditions and active phonological alternations.

Within the place category, coronal repetition seems to be more tolerated than that of other places (though see Appendix Three for complications). An analysis of English with the same level of detail as the Arabic studies has also been carried out (Berkley 2000), with supporting data from Latin and French. As in Arabic, more similar homorganic segments are less likely to

cooccur in English.<sup>2</sup> The restriction remains weaker for coronal cooccurrence. Thai also patterns with Arabic and English in allowing more cooccurrence among coronals than other places of articulation. Muna (Coetzee and Pater 2006) is also more permissive with coronal cooccurrence than with other places, like previously-discussed languages. It differs from them in that this asymmetry is not associated with a larger, more featurally-differentiated set of coronal consonants in the inventory.

After place, **proximity** is the most important factor in determining degree of underattestation among consonant combinations. The English data also shows cooccurrence as more restricted with segments in closer proximity. Vowel quality/quantity may play a role – and not just number of timing units – as Berkley claims that the strongest effect holds across specifically *short* vowels. However, no further detail on the nature of the vowel intervenor is provided. The English restriction is also stronger for tautosyllabic segments, a generalization that makes sense if absolute duration of the intervening segment(s) plays a role – for segments within a syllable, that syllable is necessarily closed and the nuclear vowel presumably shorter than one in an open syllable.

An important role for absolute duration also predicts stronger restrictions across unstressed (therefore relatively short) vowels compared to stressed ones. In fact, Berkley takes the opposite stance and claims it is stressed syllables that are subject to stronger cooccurrence restrictions. However, her generalization is not wholly substantiated by the hierarchy she identifies. In her observed hierarchy, the strongest restriction holds of initial *unstressed* syllables, followed by initial stressed, then stressed medial and unstressed medial respectively. Initial and medial syllables behave oppositely with respect to the role of stress, with initial ones fulfilling the prediction hazarded above and medial ones conforming to Berkley's claim. She speculates that the asymmetry in initial syllables is a spurious one, attributable to the relatively small number of initial unstressed syllables. In any case, this inconsistency makes the role of stress inconclusive.

The Latin case is particularly interesting in this respect, as the effects across a short vowel intervenor are classed separately from those across a long vowel or diphthong, which class with intervention by both a vowel and a consonant. Berkley construes long vowels and

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<sup>2</sup> Unlike Arabic, underattestation seems to exist for a few non-homorganic consonant pairs: p-k, b-g, f-θ, f-h, θ-h, v-ð. All match in voicing and are either both non-coronal oral stops, or both non-strident continuants.

diphthongs as two separate segments in making her proximity-based arguments. Whether or not this is the right approach, their necessarily longer duration compared to short vowels predicts a stronger restriction across the latter on the basis of absolute duration alone.

Thai presents a similar phenomenon (Haas 1955). Cooccurrence of similar homorganic consonants in monosyllables is generally underattested, and this is true to a greater extent across short vowels than long vowels (e.g. in p<sup>h</sup>óp vs p<sup>h</sup>âap). As in Latin, Thai vowel length is contrastive, so the roles of timing units versus absolute duration cannot be disentangled. Finally, behavioral data detailed in Appendix Three indicates that proximity by timing unit is also relevant for French, Korean, and Turkish.

The apparent importance of **position** in Arabic is not borne out cross-linguistically. Also as in Arabic, English cooccurrence is more restricted toward the left edge. Frisch (2004) proposes on this basis that that OCP effects on lexical repetition of identical/similar segments are due to the processing difficulty of linearization, and should therefore generally decrease toward the end of the word.<sup>3</sup> In this account repetition at the left edge leads to greater problems in accessing lexical item due to listeners' uncertainty whether the repetition is intended/lexical, or simply a stutter. Later in the word, when the cohort of lexically activated items is smaller, this presents less difficulty. An alternative argument can be made on the basis of absolute duration. Segments at the right edge are more likely to undergo final lengthening. This results in a gap of longer absolute duration between putatively co-occurring segments – by hypothesis, thereby reducing the difficulty in repeating the relevant gestures.

However, a quartet of languages constitutes a counterexample to this left-edge asymmetry. The positional restriction in Javanese (Mester 1986) is stronger at the right edge of the word than at the left edge, contrary to all the languages discussed so far. That is, the consonant skeleton [s-s-m] is possible and preferable to [s-m-m], unlike in Semitic. Yip (1989) states that this may be because the left edge is, at least historically, reduplicated. This explanation does not suffice for Muna (Coetzee and Pater 2006) and Japanese (Kawahara *et al.* 2005), for both of which the right edge is also the more restricted one. Finally, the Bantu language Tiene, which also has tri-consonantal roots, is permissive with respect to the place of C1 (Hyman to appear). However, C2 and C3 may not be homorganic.

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<sup>3</sup> Sevald and Dell (1994) make a similar claim based on asymmetry in speech errors elicited by repetition at left versus right word edges.

The directional effect does not appear to depend in any way on stress assignment. Japanese has pitch accent instead of stress, which does tend to occur at the right edge of the word but which is not associated with any variation in duration and is therefore unlikely to be driving this directional effect. Javanese stress is based on weight rather than position, and final position is not necessarily associated with stress (Gordon 2002b). Muna stress is wholly positional and assigned to even-numbered syllables from the right (Gordon 2002a). This dependency on number of syllables means that stress is not necessarily final, and therefore cannot be a deterministic source of the cooccurrence directional asymmetry.

For these languages, lexical access considerations cannot come into play here. Duration may do so if boundary-initial fortition results in increased duration of vowels intervening between co-occurring consonants. However, the persistence of such fortition beyond the word-initial segment is not expected, and in any case the extension of the durational account to both word edges robs it of predictive power. The expectation would then be that medial syllables should show the strongest co-occurrence restrictions – an assertion that is difficult to test, and in any case not observed in the languages of the sample, even English and Japanese which both include forms of the relevant kind. Arguments based on stress, outlined above, also seem insufficient to account for the observed asymmetries.

Finally, Kawahara and colleagues present additional arguments that the computation of **similarity** is **surface-based** rather than based on contrastive phonemic specifications (bolstering the data from the relevance of voicing for Arabic sonorants). The two Japanese surface allophones of [t] – [t] and [ts] – differ slightly in their cooccurrence patterning. Similarly, surface [ç] is underrepresented in combination with palatal [çʝ], even though it is underlyingly the phoneme [h] (surfacing as [ç] before [i]). Finally, the labial [ɸ] is underrepresented with other labials despite also being a conditioned surface allophone of [h].

The cumulative body of research on (primarily place-related) consonant cooccurrence restrictions is now sufficiently substantial to make it not at all novel or surprising when more such restrictions are documented for yet another language or language family. Rather, it seems increasingly unlikely that any language *lacks* such effects. In addition, for a number of unrelated languages these lexical effects are supported by phenomena in active synchronic phonology, and experimentally verified to be known by native speakers and active in speech perception and

production (see Appendix Three for data from Arabic, Hebrew, English, Korean, Turkish, Swedish). The default assumption at this point should be that this is the case for all such languages.

The size of the sample also makes it possible to begin to identify typological generalizations about properties and subpatterns of the cooccurrence restriction(s). The survey in this section makes it clear that place of articulation is the driving force of these restrictions, just as it is the most common target of dissimilation. Identity for other features may increase the degree of underattestation, but is rarely sufficient to elicit it independently.

Degree of underattestation also appears to depend on relatively surface-based representations. Incomplete contrastiveness of phonemes/feature contrasts has been convincingly argued to affect perceived similarity (Hume and Johnson 2003), but does not seem to matter here. The Japanese patterns make it quite clear that it is the phonetic articulation of a segment, rather than its underlying form, that is relevant in determining degree of underattestation.

Finally, I suggest that at least some of the positional/proximity effects are due to smaller absolute durations separating segments, rather than a more abstract phonological notion of distance (though morphological boundaries are abstract and also clearly relevant). These three points taken together point to consonant cooccurrence restrictions being driven by the articulatory difficulty of repeating gross motor gestures in quick succession, rather than a more abstract phonological kind of identity and distance.

### *2.1.2 Blocking and repairing OCP violations*

In addition to constraining underlying forms, the OCP has also been claimed to generate exceptions to otherwise regular processes when repetition would result. In this section I discuss selected examples, focusing in detail on the phenomenon of **antigemination**.

The tonal phenomena for which the OCP was first proposed fall into this category. One such example is the autosegmental analysis of Meeussen's Rule in Bantu (Leben 1973, Goldsmith 1976). This rule outlaws a sequence of two adjacent high tones by the lowering of the second one in some contexts. While this case was treated as an application of the OCP to underlying forms like the consonantal phenomena discussed above, OCP analyses soon extended to "undoing" active phonological processes such as English [t]-fricativization. Final [t] in English becomes [s] when followed by an affixal [i], as in (5a).

5) English [t]-fricativization

- a. vacant      vacancy
- b. honest      honesty

However, when the underlying final [t] is preceded by [s], fricativization does not occur (Xb; Borowsky 1986). This prevents the occurrence of an otherwise expected double-[s] sequence – even though geminate [s] across a morpheme boundary does occur in English when both are underlying, as in “dissimilar.” Nor does some other repair occur, like degemination to a single [s]. The preferred solution is to block the application of fricativization.

In addition to preventing the application of regular phonological processes, potential repetition may trigger the application of exceptional ones. Dissimilation is one such possible repair (see Suzuki’s 1998 typological survey of dissimilation processes). Ancient Greek (and Old Germanic) dissimilates sequences of coronal stops, for the feature [continuant] rather than place (Cser 2003, personal communication). Root-final underlying [t<sup>h</sup>], [t] and [d] surface as [s] when combined with a coronal-initial suffix.

6)	<u>Root</u>	<u>Gloss</u>	<u>1<sup>st</sup> aorist passive</u>
	peit <sup>h</sup>	persuade	e-peís-t <sup>h</sup> -ee-n
	komid	care for	e-komís-t <sup>h</sup> -ee-n
	pat	sprinkle	e-pás-t <sup>h</sup> -ee-n

Note that just as in the Arabic MSC, the fricative-first preference is observed. This is also true of one of the two cases of continuancy dissimilation in Suzuki’s cross-linguistic survey. In a sequence of two continuants of any place in Modern Greek, the second is dissimilated to a stop while frication is preserved for the first one (the other case is Northern Greek deletion of the first of two [s] segments).

Deletion rather than dissimilation of one of the violating segments is a third alternative. This happens in Suzuki’s other continuancy dissimilation case, which is Northern Greek deletion of the first of two [s] segments. The following examples from English are another example (for a full analysis involving further complexities, see Yip 1988):

- 7) English coronal deletion
- a. prescribe    prescription
  - b. resume        resumption
  - c. complete     completion
  - d. promote      promotion

On the assumption that the underlying form of the suffix is *-tion*, the last two forms present an unacceptable sequence of coronal consonants, the first of which is then deleted.

Deletion also applies gradiently in English in the case of final [t] and [d]. Guy and Boberg (1997) observe that final coronal stops are deleted more often when preceded by segments of greater similarity (e.g., in *mist* more often than *gift*). This effect is modulated by the presence of a morpheme boundary, so that final coronal deletion is less likely when one is present (e.g. for *missed* than *mist*). However, Stemberger and MacWhinney (1990) show that when past tense marking is appropriate, speakers more commonly err by omitting it when the preceding segment is phonologically similar to the tense marker. Thus we see the same effect in action even across morphemes, and as a gradient counterpart to a categorical process occurring elsewhere in the same language.

Antigemination is another case of repetition blocking (rather than repairing via dissimilation or deletion). McCarthy (1986) cites a number of languages in which a vowel syncope rule fails to apply when the vowel in question is flanked by identical consonants. Below is an example from Afar, in which unstressed vowels typically delete before stressed syllables (examples a-c; Bliese 1981). Exceptions occur when the flanking consonants are identical (examples d-f).

- 8) Afar vowel syncope
- a. gutúca        gutcé            push (pl.) / he pushed
  - b. barísay      barsé            let him teach / he taught
  - c. digíbté      digbé            she / I married
  - d. xararté      xararé           she / he burned
  - e. dananté      danané           she / he hurt

f. walaltá      walalá      she / he hurt

This and other cases of this type are attributed to OCP-motivated avoidance of a sequence of adjacent identical consonants.

Blevins (2005) puts forward an alternative analysis of antigemination couched in the framework of Evolutionary Phonology. The keystone of EP is that recurrent sound patterns result from phonetically-based sound change. As a corollary, universal markedness constraints are allotted no role in synchronic phonology (Blevins 2004). A synchronic account of antigemination, then, should not rely on a markedness constraint such as the OCP. Accepting this necessitates finding either a phonetically natural explanation for antigemination, or some other analysis that does not involve markedness. Blevins pursues the second option, with an account that does not crucially involve segment repetition at all. Rather than relying on the OCP as a motivating force, she considers antigemination to be a case of homophony avoidance. By characterizing it as a tool for the maintenance of paradigm-internal contrast, Blevins removes antigemination completely from the category of functional/evolutionary linguistic phenomena. In further support of this position, Blevins cites its tendency to be subject to morphological conditioning (unlike other phonetically-motivated alternations like final devoicing), and its non-attestation in diachronic syncope processes.

Blevins' anti-homophony analysis of antigemination goes beyond disallowing identical phonological forms for the same root within a single paradigm. While this traditional approach suffices for some of the cases McCarthy describes, it does not do so for all of them, and in particular not for Afar. To account for Afar, Blevins is forced to extend the prohibition against homophony to encompass not just items of the same phonological form, but also those that might be analyzed as a member of a different inflectional class. Michaels (2005) discusses the undesirable consequences of this move, as well as other potential problems for the anti-homophony approach. Specifically, it does not account for all the data of Afar, and makes problematic predictions both for Afar and typologically.

In an earlier EP-compatible account of antigemination, Blevins (2004) motivates exceptions to syncope through consonant release properties. Blevins points out that antigemination is only attested for languages which have underlying geminates. She claims that in such languages, and only those, release between identical consonants can *not* be interpreted as

transitional, consonant releases. This interpretation is unavailable, she claims, because no physical transition is necessary between consonants at the same place of articulation. Thus release between non-identical consonants is more likely to be interpreted as a redundant consonant-to-consonant coarticulatory effect than a release between identical consonants is. Thus perceptual factors explain the reluctance of speakers to categorize precursors to antigeminating forms as vowel-less.

While acknowledging the existence of an OCP constraint against repetition, Rose (2000) offers another analysis of antigemination that does not depend on it. She recalls Odden's (1986, 1988) observation that while vowels are sometimes preserved only between identical consonants, they are also sometimes deleted only between identical consonants (for a more recent review of this phenomenon, called anti-antigemination, see Blust's (2007) survey of it in Austronesian, where it is best attested). This dichotomy is difficult to explain from a standard view of phonological antigemination (Odden himself employs it as an argument against a universal OCP constraint). Rose's solution is to employ the OCP only for the second case, and attribute the first to avoidance of geminates as marked. In her analysis, a geminate is a marked entity, but does not violate the OCP. A CVC sequence involving identical consonants *does* violate the OCP, given her assumption of consonant adjacency across vowels. Thus for some constraint rankings gemination is avoided at the cost of an OCP violation, and for others an OCP violation is preferable to a marked surface geminate. Avoidance of this kind of OCP violation also motivates geminate integrity effects in her analysis. Finally, dissimilating one of the consonants avoids both kinds of violation at the cost of faithfulness, and she employs this strategy in her analysis of reduplication patterns.

Bakovic (2005) points out that antigemination does not apply between only identical segments – some differences seem to be irrelevant for the process. Moreover, the irrelevant contrasts uniformly are those which are also subject to contrast neutralization in the antigeminating language. One such case is Lithuanian prefixation of [at(i)]/[ap(i)]. The final [i] vowel is preserved when the stem for prefixation begins with a consonant that is identical except with respect to voicing and/or palatalization. Not coincidentally (according to Bakovic), voicing and palatalization are subject to assimilation in consonant clusters. Were the vowel not to intervene, then, the resulting cluster would be one of identical consonants, a surface geminate,

regardless of the underlying difference in voicing or palatality. Antigemination bleeds this potential assimilation.

English past tense and plural suffixation is a parallel case. Vowel epenthesis occurs in inflectional morphology to avoid coronal-coronal sequences, as the following examples illustrate:

9) English vowel epenthesis

- a. laugh      laughed
- b. load        loaded
- b. grieve     grieved
- d. greet       greeted

An intervening schwa vowel appears between stem-final consonant and suffixal consonant only when those consonants are identical (9b and 9d). However, voicing is ignored in the alternation, and (not coincidentally) tautosyllabic consonant clusters in English must agree in voicing.

While vowel epenthesis is the synchronic analysis of this alternation, it is clear that its historical source is antigemination. Bakovic cites convincing arguments that the synchronic suffix is only [d], but diachronically it was uniformly vowel+[d], as the orthography reflects and as earlier metrics make clear. The unstressed vowel was then lost except in restricted (corresponding to today's epenthetic) contexts. This belies Blevins' (2005) claim that diachronic antigemination cases do not exist, which she puts forward as a reason for not considering it a process with functional/phonetic motivation.

In dismissing this possibility Blevins is following the lead of McCarthy, based on three claims made in his original paper on the phenomenon. First, he describes four phonetic (versus phonological) syncope rules which do *not* make exceptions for tautomorphic identical consonants (of which English is one). These syncope rules share the properties of being optional, register-dependent, non-structure-preserving, and gradient. The fact that all four of the phonetic rules of this type that he identifies are unexceptional with respect to identical consonant sequences, unlike phonologized rules, leads McCarthy to the position that gradient syncope in phonetic implementation cannot be the source for phonologized syncope with grammaticalized, anti-geminating exceptions.

However, while each of the four phonetic rules allows a geminate output, McCarthy presents no data on the relative frequency of these outputs compared to heterorganic cluster outputs. The latter greatly outnumbering the former could still lead to phonologization of syncope in heterorganic versus homorganic consonant sequences.

McCarthy's second argument is also one from negative evidence. A phonetic source of antigemination predicts antigemination-like effects for homorganic but non-identical consonants as well – just as the morpheme structure constraints target homorganic consonants as well as identical ones, albeit to a lesser extent. However, no such cases are known (though its application to not-strictly-identical consonants is explored by Bakovic). On the other hand, the repair strategy of blocking vowel syncope is clearly preferred to other possible ones which would avoid identity while preserving homorganicity. One could imagine a repair that avoids strictly adjacent identical consonants by changing the voicing or palatality of one of the segments, for example. The lack of such repairs constitutes indirect evidence that homorganic consonant sequences are also dispreferred, as the evidence from the MSCs suggests.

McCarthy's third claim is that a phonetic explanation for antigemination based on the articulatory difficulty of repetition is unlikely because repetition is not actually difficult. He bases this claim on his own intuition that the “articulatory load is minimal from repeating exactly the same gesture.” The statement is not on its face implausible – one could conjecture that since the articulators are already maximally close to the target position due to the release of the previous, identical gesture, it would be easier to reach that target for a second time than when moving from a different and further away configuration. McCarthy bolsters this argument with his intuition that alliterative tongue-twisters (*Peter Piper...*) are less difficult than ones involving similar but non-identical segments (*she sells sea shells*). Subsequent researchers have not questioned his stance on this. However, I take the opposite position in this dissertation. The next section lays out the reasoning behind this position.

## **2. 2 Problems with gestural repetition**

I argue that gestural repetition is more difficult and/or takes longer to complete than a heterorganic sequence for three reasons. First, it involves sustained activity without a rest period for the relevant articulator. Second, the impossibility of overlapping coarticulation between

identical gestures lengthens the necessary transition time. Third, it requires rapid reversal of an articulator's trajectory. I will now justify these claims in turn.

The first claim makes the simple point that sustaining physical gestures of any kind requires more effort than not. Let us make the simplifying assumption that producing any particular place gesture requires the same amount of effort. This is almost certainly not true, but there are far too many unknowns to be in any way specific about how. As Kirchner (1998) points out, producing a coronal with the tongue tip may plausibly involve less effort than moving the more massive tongue body for a velar, but this difference may be offset by the larger jaw displacement required for the former, and so on. Given this assumption, rearticulation of the same gesture is more difficult than gestural alternation due to the sustained nature of the effort required. Just as maintaining the long closure of a geminate is more difficult than a singleton, continued use of the same articulator requires more effort than relaxing it.

The second claim is more to do with timing than with effort per se. Use of independent articulators in succession allows considerable overlap between articulation onset and offset movements. This possibility is extensively exploited in speech articulation. The following figure shows articulator movements in the English word *tickbite* (EMA data from Pouplier website, <http://www.ling.ed.ac.uk/~mpouplier>; data collected at Haskins Laboratories).

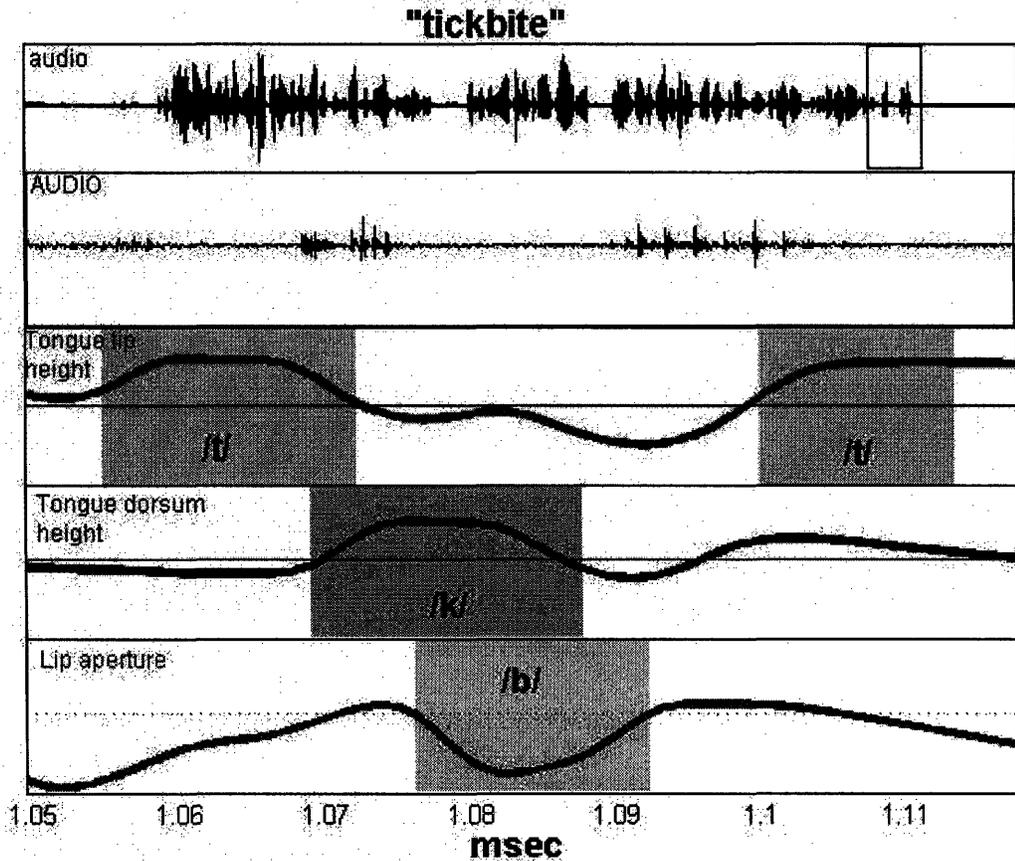


Figure 1. Electromagnetic articulography (EMA) data collected by Marianne Pouplier at Haskins Laboratories.

Note that the maximal constriction for the labial segment [b] has already occurred at the release offset of the velar [k] constriction. In the first syllable, overlap occurs even across a full vowel. The raising of the tongue dorsum for the velar [k] coincides with the release of the tongue tip for the word-initial [t].

However, such overlap is not possible when the same articulator is used twice in succession. In that case, the onset of the second gesture necessarily entails that the offset of the first is entirely completed (or as completed as it is going to be). This means that a given span of milliseconds cannot “count double” as the offset and onset of two independent gestures. The prediction is that longer transition times are needed between identical place gestures.

The third reason that gesture repetition requires both more effort and more time than gestural alternation has to do with overcoming the momentum of C1 release, and requires the most discussion. I will first put it in intuitive terms, then support the claim with a mathematical heuristic for changes in momentum and the force they require.

Figure 2 below is a schematic of tongue movement in a sequence of two articulatory gestures. Xa on the left represents the same gesture twice in succession, while Xb on the right represents a sequence of two different gestures.



Figure 2. Tongue movement schematics for repeated and non-repeated gestures.

We wish to determine the relative difficulty of the transition between the second and third vector arrows in 2a versus in 2b – that is, whether the sequence with a repeated gesture is more difficult than the one which does not repeat. To do so, we need to know the **force** needed in each case for the change in momentum from  $p_0$  in the offset from the first gesture, to  $p_1$  in the onset of the second gesture.<sup>4</sup> The hypothesis is that the rapid articulator reversal of Xa, which requires movement in the exact opposite direction (180 degrees) from the initial movement in the second vector arrow, is more difficult than a movement in some other direction as in 2b.

Formulae for initial and resulting momentum are given below (10a-c), as well as for the change between them (10d):

- 10) a.  $p_0 = mv_0$                       Momentum<sub>0</sub> = mass times velocity<sub>0</sub>.
- b.  $p_1 = mv_1$                       Momentum<sub>1</sub> = mass times velocity<sub>1</sub>.
- c.  $p_1 = m(v_0 + \Delta v)$           Momentum<sub>1</sub> = mass times (velocity<sub>0</sub> plus change in velocity).

<sup>4</sup> I assume that the distances for  $p_0$  and  $p_1$  are roughly equivalent ( $\|p_0\| \approx \|p_1\|$ ). Absolute equivalence is not required, since we ultimately use a proportion.

d.  $\Delta p = m\Delta v$       Change in momentum = mass times change in velocity.

Force is equal to the product of mass (here, of the articulator, and therefore constant) and acceleration (11a), and acceleration itself is the change in velocity over time (11b):

- 11)    a.  $F = ma$               Force = mass times acceleration  
        b.  $a = \Delta v / \Delta t$         Acceleration = change in velocity over change in time.  
        c.  $F = m \Delta v / \Delta t$       Force = mass times change in velocity over change in time.

Substituting for acceleration as in 11b into the equation for force generates 11c, with force put in terms of change in velocity. Change in velocity, along with the velocity vectors  $v_0$  and  $v_1$ , forms a triangle with angle  $\theta$  as in Figure 3.

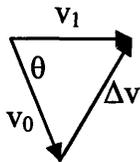


Figure 3: Velocity vectors.

By the law of cosines, we can recast the change in velocity  $\Delta v$  in terms of the cosine of the angle  $\theta$  and plug it back into our force equation as follows:

12)     $F \propto (\sqrt{|1 - \cos \theta|} / t)$       Force is proportional to the square root of one minus cosine theta over time.

The graph of the square root of the shifted cosine curve is depicted below (F independent of the proportional relationship with time). The y-axis is force in arbitrary units, and the x-axis is in degrees.

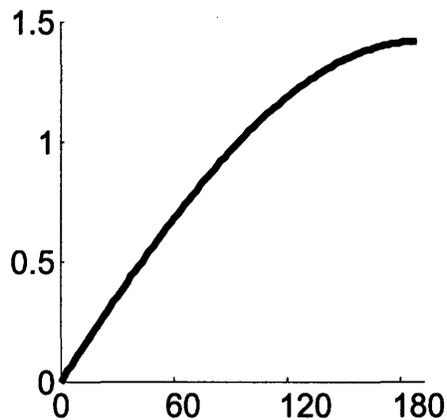


Figure 4: The graph of  $\sqrt{|1 - \cos \theta|}$ .

This graph shows that a change in momentum to the pre-existing momentum (that is, no change at all), requires the minimum amount of force (also none; bottom left-hand corner of the graph). As the number of degrees by which the second velocity differs from the first increases, the amount of force necessary also increases. Force reaches its maximum in the top right-hand corner of graph, which represents the 180 degree difference in direction of momentum in the schematic 2a above. As our hypothesis predicts, a momentum change in the opposite direction from the initial vector requires the most force to execute. The rapid reversal required by gestural repetition is more difficult than gestural alternation.

The graph assumes that exactly one (arbitrary) unit of time passes in the gestural reversal. Different changes in time would scale the graph (compress it upwards or downwards) without changing its shape – the minimum and maximum would stay the same. The inversely proportional relationship between force and time that is specified in the equation 12 (not depicted in the graph) shows that when the change in momentum of gestural repetition is accomplished over a longer period of time, less force (~articulatory effort) is required. Therefore, slower speech rate and the production of segments with longer durations should alleviate the difficulty associated with repetition.

This discussion disregards the intervening vowel, if any, and any effect an intervening vowel target may have. The simplification is legitimate when discussing only transitional and targetless schwa/reduced vowel separations between consonants. However, those separated by fully specified vowels have more complicated trajectories. The Articulatory Phonology approach

isolating vowel and consonant tiers in terms of gestural coordination may mean that the quality of an intervening vowel is not crucial. However, intermediate points such as vowel targets do affect the predictions of the mathematical model outlined above. Future imaging experimentation is necessary to address the role of vowel place.

I have stated my arguments for the problematic nature of gestural repetition in general terms, so that they apply to any articulator. However, it is clear that they exert the most force for place gestures, which necessarily involve the grossest motor movements and manipulation of the largest masses (albeit to a lesser extent for coronal than the others). Further complications arise when the place articulators are considered individually. The independence of the lips from the tongue tip and body articulators means that the third argument for articulatory repetition difficulty is not so relevant for labials. For velars, the picture is complicated by the loop-like articulation that they usually involve (Mooshammer *et al.* 1995, Hoole *et al.* 1998, Perrier *et al.* 2003). The persistence of this loop in repeated velar sequences has not been specifically investigated, and what little information is available in the studies cited suggests idiosyncratic subject-specific behavior. If the loop is preserved, then even longer transition times may be expected as the tongue body cycles around to re-articulate it. If it is suppressed after another velar, then the rapid reversal problem obtains. Either way, longer duration associated with repetition is expected.

In the next section, I give behavioral evidence supporting the hypothesis that rapid re-articulation with the same articulator is difficult, more so than alternating place of articulation. This evidence comes from music performance practices.

### **2.3 Double-tonguing**

By virtue of their training and profession, musical performers are aware of and adept at manipulating acoustic and articulatory properties of speech that have not been recognized until much later by academic and experimental literatures. For example, the psychoperceptual phenomenon of higher-pitched tones being perceived as louder has been known to musicians for centuries. This knowledge is reflected in musical arrangements and is compensated for by musicians individually in performance. Likewise, singers are trained in techniques to differentiate vowel backness quality when produced at fundamental frequency pitches above the usual F1 range for such vowels. It is clear that musical performance techniques are a rich but

somewhat neglected territory for phoneticians and phonologists investigating speech production and perception. They can reveal not only what is difficult in perception and production, but what possible articulatory responses may be made to alleviate the difficulty in either.

In this section I discuss one such technique – one employed by wind musicians, called double-tonguing. Players of wind instruments are trained to use an “attack” or onset articulation of coronal place with each articulated note. The choice of coronal place is logical since the tongue tip is capable of the quickest articulatory gestures. This status for coronals is recognized in task dynamic models of speech production such as Articulatory Phonology literature. Within it, Barry (1992) has argued that the tongue tip should be treated as a *massless* articulatory subsystem, unlike the tongue body, because of this relatively small mass. It means that coronal gestures are quicker and more likely to be masked by overlap from other gestures.

Thus a typical sequence of articulated notes corresponds to an articulatory sequence of syllables as in 13a below.

- 13) a. Single tonguing: ta ta ta ta ta ta  
b. Double tonguing: (ta ka) (ta ka) (ta ka)  
c. Triple tonguing: (ta ka ta) (ta ka ta)  
d. Triple tonguing: (ta ta ka) (ta ta ka)

Even though coronal onsets allow the fastest articulated sequences, the maximum speed of sequences such as in 13a may not be sufficient for pieces with shorter notes and at higher tempos. So as proficiency increases, training in double and triple tonguing begins. Typically it is introduced at the level of reasonably advanced high school musicians, and mastery of it is assumed on the part of any professional performer.

The double- and triple-tonguing techniques rely on the introduction of a velar articulation into the coronal stream, either in strict alternation (13b) or in second or third position in a triplet (13c, 13d). The goal of alternating the point of constriction in this fashion is to allow for much faster articulatory sequences than purely repetitive articulation. It also allows productions with more relaxed muscles, so that playing is less tiring and may be extended for longer periods. Arban’s (1982) standard conservatory method for trumpet and other treble-clef brass instruments advises that “by using this type of articulation, no passage will be too difficult...[and] sufficient

speed may be obtained....Once this movement is mastered, the most difficult passages may be played with all the speed, energy and strength desired.” Online instructional materials published by the Peabody Institute at Johns Hopkins University add that “because the stroke is so relaxed, the double tongue does not tire and can articulate...for long stretches.”

Let us introduce some specifics about the speeds under consideration here. Peabody Institute materials state that a fast single tongue rate (coronal articulation only) for saxophone can articulate sixteenth notes at quarter note=152 beats per minute. This means that the duration of each articulated syllable – coronal stop plus vowel – is only 99 ms. Some players may attain quarter note=168 for brief periods (syllable=89 ms). Professional bassoonist George Adams (1999) writes that his single-tonguing rate tops out at sixteenth notes when quarter note=116, a somewhat slower rate.

Double tonguing, on the other hand, allows articulation speeds of up to quarter note=232 beats per minute. This rate results in syllables of only 65 ms duration. (The speed is not double that of single tonguing, since tongue tip gestures are faster than those of the tongue dorsum so that the velar syllable cannot match the coronal’s maximum speed). These measurements do not separate the vowel duration from the consonant duration within the syllable. However, we may estimate that an inter-closure interval somewhat below 100 ms – perhaps 80 ms – is the threshold below which place gesture repetition is too difficult, and ameliorating phonetic variation occurs. To aid in approximating this threshold, the author made approximately five-second recordings of amateur trumpet fast-rate single tonguing and double tonguing, with short breaks between articulated quadruplets. This yielded 32 tokens for each syllable. Mean duration of the *vowel only* in these syllables is 69 ms for single tonguing (versus 48 ms for the double-tongued recording).

This is extremely short compared to syllables in fast speech. Peterson and Lehiste’s (1960) study of segmental duration in English finds mean durations of 180 milliseconds for the [ɪ] vowel (granted, in laboratory speech), which is the shortest among unreduced ones. These extremely short syllable durations are also occurring in a rather unnatural situation, and probably a more difficult one than normal speech production – the lips are under pressure, jaw movement is limited, and the air stream must be sufficiently fast to push through the instrument and its internal valves.

The established practice of double and triple tonguing shows that repeated consonant gestures are more difficult than non-repeated ones. They cannot be maintained at fast articulation rates, and are more tiring. Moreover, quantitative data based on it establishes a lower limit beyond which place gestural repetition cannot be pushed.

#### **2.4 A gestural difficulty account of repetition avoidance effects**

We have now seen a range of OCP-attributed repetition avoidance effects, and arguments that gestural repetition in articulation is difficult. I propose that the latter motivates the former. Gestural repetition difficulty leads to lexicalization and grammaticalization of repetition avoidance, and explains asymmetries in these avoidance patterns.

Consonant cooccurrence restrictions discussed in the section on MSCs overwhelmingly target place of articulation. The comparatively gross movements made by the lips and tongue in place articulations make sense of this restrictions – these larger-scale and more effortful gestures are the ones most subject to cooccurrence restrictions.

We have also seen that cooccurrence of coronals is consistently tolerated better than cooccurrence of other places of articulation, with an appeal made to the size of the coronal subclass as an explanation. The purely gestural fact that the tongue-tip coronal articulator is comparatively massless and can move more quickly and more easily predicts this coronal exceptionality.

Putative asymmetries in position based on word edge and stress location turn out to be inconsistent in our cross-linguistic survey. However, the proximity factor is highly relevant and also compatible with a gestural difficulty motivation for repetition avoidance. Closer proximity predicts more difficulty with place gesture repetition, particularly when only one vowel intervenes, and particularly when that vowel is short.

Finally, the crucial nature of surface representations versus underlying, abstract feature specifications only makes sense in a gestural difficulty account. It is logical to think that a constraint on underlying representations like the OCP-type MSCs should refer to the underlying feature specifications in that representation, but we have seen that this is not the case. The driving force of these cooccurrence restrictions is not abstract identity, but physiological identity with respect to the primary articulator.

Let us now consider repetition avoidance repairs. Given gestural difficulty in producing two identical articulations in quick succession, we can expect a variety of repairs.

- 14) Repetition avoidance repairs
  - a. Weakening of one of the gestures.
  - b. Deletion of one of the gestures.
  - c. Increased time between the gestures.

Each of these repair types is attested and discussed in Section 2.1. Gesture weakening in the form of fricativization occurs in Ancient Greek and Old Germanic. Difficulty in repeating the place gestures means that complete closure is not attained for both, and incomplete constriction of one of them occurs (the first, in another case of the fricative-first generalization). The force-time relationship explored in Section 2.2 makes clear why this repair is nonetheless relatively rare. Gestural difficulty may be alleviated by longer duration as well as incomplete closure. These two factors work against each other in production and perception – shorter durations are associated with lenited segments, and longer ones enable better target attainment (Lavoie 2001, Soler and Romero 1999).

Deletion, which could be considered the endpoint of the weakening repair, occurs in English coronal deletion. It applies both categorically, in the *prescription/promotion* contrast, and gradually, with word-final coronal affixes.

Antigemination and English vowel epenthesis fall into the third category. Articulatory difficulty associated with gestural repetition predicts slower articulator movements in repetitive sequences. This slowing should result in longer durations not only for the segments themselves, but for an intervening vowel produced during the offset of the first consonant of the sequence (C1) and onset of the second one (C2). Increased duration of the intervening vowel may arise as a wholly mechanical consequence of this difficulty, and may also be purposefully employed in order to ameliorate the difficulty.

Vowel syncope generally applies to non-salient, reduced, unstressed vowels. The natural, evolutionary phonology view of its genesis is that these vowels are more likely to be misinterpreted as consonant release or go unperceived entirely. This is eventually phonologized as syncope/deletion. I have hypothesized that vowel reduction, in terms of duration, applies *less*

to vowels between identical consonants than elsewhere. Longer duration allows more time for target attainment and makes articulatory undershoot less likely. Thus consonant lenition rates are highly dependent on speech rate (Soler and Romero 1999). For the intervening vowels under consideration here, this means that the ones between identical consonants are more likely to attain their quality targets. They will be perceived more as full vowels than as transitional vowels for which quality may vary highly and depends mostly on coarticulatory factors. Their longer duration also means that they are more likely to be perceived as vowels rather than as consonant transitions or zero.

Afar dialectal data provides some support for this phonetically natural account of the genesis of antigemination. The antigemination facts of Afar are found in Bliese's (1981) reference grammar of the language, which focuses primarily on the southern dialect(s). However, Bliese notes that in some Northern Afar dialects, vowels which occur in syncope position in the south do not delete, but rather are reduced.<sup>5</sup> This suggests that at an earlier stage in the history of the Southern Afar dialects, such vowels were also reduced rather than deleted. These reduced vowels might then have followed the course I outline in the previous paragraph. Those between non-identical consonants eventually were misperceived as consonant transitions or zero sufficiently often for phonologized syncope to occur. The vowels between identical consonants, however, which were longer and better preserved vowel quality, continued to be perceived faithfully and were retained. The result is synchronic antigemination.

The English vowel epenthesis before past tense suffixation is another example of exactly the same diachronic phenomenon. Hall (2007) documents a final example from English, noting that pronunciation dictionaries advise speakers to produce full vowels between two [r] tokens in words such as *error*, *juror*, and *mirror*. Her account of [r]-dissimilation relies on perceptual difficulty in distinguishing one from multiple tokens of [r] in particular. This stance is similar to Boersma's (1998) characterization of epenthesis/antigemination an OCP repair for recoverability considerations, since the presence of an intervening vowel makes it easier to identify a perceptual boundary between segments. I propose instead that this kind of variation in vowel quality and duration is precisely what we expect to see given the gestural difficulty account proposed here. The contribution of perceptual considerations is discussed in Chapter Five.

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<sup>5</sup> I thank Jennifer Michaels for bringing this to my attention.

Recall from the discussion of Rose's (2000) account of antigemination that an opposing phenomenon, in which vowels are deleted *only* between identical segments, is also attested. This point is raised as a problem for OCP accounts of antigemination by Odden (1986, 1988). Rose solves it by construing the OCP as applying only across vowels, with an additional and independently-rankable constraint against geminates to generate the observed typology.

The dichotomy of selective vowel presence versus absence between identical consonants is readily explicable if the chief difficulty for such sequences is gestural repetition/reversal, as I hypothesize. In that case, surface geminates also eliminate any need for such reversal, and the coexistence of this repair strategy with classical antigemination is not so surprising. Jun (2004) shares the insight that assimilation can be a means of avoiding repetition as well as dissimilation, through reducing a sequence of gestures to a single one. Thus difficulty of quick gestural reversal can be ameliorated by either longer intervening vowels (leading to vowel retention in this environment), *or* reduction to a single long closure in a geminate. The latter repair is a synchronic solution to the same problem. It is attested in the three languages Classical Arabic, Koya, and Telugu (McCarthy 1986), and is also common in Austronesian, where a strong preference for disyllabic forms provides an additional motivation for it (Blust 2007).

These attestations are considerably less than exist for antigemination. There are three reasons for this dispreference as a repair. First, Rose is undoubtedly correct that geminates are marked segments and thereby subject to a markedness-based dispreference that a CVC sequence is not. Second, electromyographical data indicates that it is language specific whether geminates are in fact produced with only one constriction peak of long duration, or if there are two (Lehiste *et al.* 1973; see also Lofqvist 2005 for review of geminate production studies). For languages with double-peak geminates, removing the intervening vowel does not result in reduction of two gestures to a single one. Finally, reduction to a geminate does not have a diachronic, phonetically natural path like the one I have proposed for antigemination.

## 2.5 Conclusions

We have now seen the examples of classic OCP effects in phonology, focusing on morpheme structure constraints and antigemination with some attention to dissimilation and deletion processes. We have also seen that often categorical effects have gradient counterparts. This is a commonplace in phonology, but it is a possibility that has not been fully explored – has in fact

been denied – for these kinds of repetition effects. I have proposed that gestural repetition presents difficulty to the articulatory system – again counter to previous claims – and that this difficulty motivates repetition repair processes and asymmetries among possible repairs. More specifically, I claim that gradient phonetic variation in response to repetition should exist; that it is due to articulatory difficulty with place gesture repetition; and that it is a potential diachronic source for categorical repetition avoidance processes in phonology, such as antigemination and dissimilation in constriction degree. The studies in the following chapter test this hypothesis experimentally.

## Chapter Three: Experimental studies of place gesture repetition

In this chapter I report the results of six studies testing the claim that place gesture repetition is difficult and systematically associated with phonetic variation that may underlie phonological repetition avoidance processes. I call the claims put forward in the preceding chapter, and in particular that this difficulty exists, the **Biomechanical Repetition Avoidance Hypothesis**, or BRAH. I find that the predictions of the BRAH from Chapter One are well supported. Vowels intervening between identical place gestures are longer than those between non-identical gestures. This is also true of allophonic aspiration bursts, when present. Both effects allow more time between place closures. Increased duration in some cases persists beyond the repeated gestures and vowel intervenor. Effects are also seen on the repeated gestures, with one of them showing incomplete closure, as well as increased duration coupled with lower intensity.

Experimental results bear out predictions not just about the expected phonetic variation in response to repetition, but also about which repetitive contexts are more likely to trigger this phonetic variation. We will see that place gesture repetition is crucial in this respect. Differences in orality/nasality do not result in any greater effect than simple homorganicity. Nor does difference along these non-place dimensions elicit such variation on its own. In addition, this kind of variation does not occur above a threshold of absolute duration corresponding roughly to the one established by the double-tonguing performance data. I conclude by pointing out the commonality with and the possible evolutionary pathway from these phonetic patterns and the phonological phenomena of antigemination (and less frequently, dissimilation).

Following the chapter is an appendix listing all experimental stimuli, another investigating possible vowel repetition effects, another including a more in-depth investigation of place-related asymmetries, and one listing languages for which place-based consonant cooccurrence restrictions have been documented, and finally an appendix devoted to the effect of repetition on speech error rates in the six experiments.

### 3.1 Experiment 1 – badageet

This experiment considers the duration of the schwa intervening between identical and non-identical word-medial voiced stops. Additional variables include the duration of the stops themselves and of the vowels flanking them, the intensity of the medial stop consonants, and a

qualitative measure of incomplete consonant closure based on visual inspection of spectrograms. The BRAH predicts longer durations for the vowel intervening between repeated segments, for one of the repeated gestures, and possibly for other neighboring segments as well. Incomplete consonant closure on the qualitative measure is predicted to occur more for repeated gestures, but the corresponding intensity measure may go either way depending on the effect of increased duration on the place gesture.

### 3.1.1 Procedure

Informed consent was obtained from 9 native speakers of American English. The subject pool includes 4 females and 5 males with vision normal or corrected to normal, none of whom reported hearing, language or neurological disorders. Subjects were presented with visual orthographic stimuli in random order using Psycscope software. The experiment was self-paced, with each new stimulus token appearing after a button press by the subject. They were instructed to repeat the item if they made a mistake. They then read aloud each stimulus first in isolation and then in the frame sentence “Do you know what a \_\_\_ is?” Utterances were digitally recorded in a sound-proof booth. This routine was repeated twice in succession for each subject.

Stimuli consisted of trisyllabic stress-initial non-words with medial schwas, with surrounding vocalic and consonantal segments permuted according to place and quality among the segments shown below. Complete stimulus lists are in Appendix One.

#### 15) Stimuli (orthographic)

b	{ a }	{ b }	a	{ b }	{ o }	t
	{ ee }	{ d }		{ d }	{ ee }	
	{ oo }	{ g }		{ g }	{ oo }	

#### 16) Stimuli (IPA)

b	{ æ }	{ b }	ə	{ b }	{ a }	t
	{ i }	{ d }	ə	{ d }	{ i }	
	{ u }	{ g }	ə	{ g }	{ u }	t

V1 C1 schwa C2 V2

The number of stimulus types totals 81. Each of these is produced 4 times per speaker. This results in a sample of 324 items per subject. Tokens for which C1 and C2 share the same place specification (as well as voice and manner, which are always shared), will be henceforth described as REP environments.

### 3.1.2 Schwa duration

Schwa duration was measured from consonant closure to consonant closure. The measure begins immediately at the offset of C1, including the release burst, if any. It ends at the closure point of C2. This measure was obtained by hand by the author based on spectrographic waveforms generated by the PRAAT acoustic analysis software program.

Schwa duration is significantly longer when produced between two identical consonants (*bagagot*) than when between non-identical consonants (*bagadot*; RM ANOVA,  $F(1,8)=40.157$ ,  $p<.001$ ). This asymmetry holds for each individual subject, as shown by the means (in ms) shown below.

Subject	C-REP	sd	non-C-REP	sd
1	61	9	50	12
2	61	14	50	11
3	52	19	47	10
4	47	34	44	9
5	78	12	63	10
6	83	9	76	13
7	68	17	49	17
8	67	10	53	13
9	66	13	55	10
<b>Overall</b>	<b>66</b>	<b>29</b>	<b>55</b>	<b>15</b>

Table 1: Mean schwa duration in consonantal REP and non-REP environments.

This supports the hypothesis that antigemination-like phonetic variation in vowel duration exists between identical consonants. If any repairs of the opposite kind exist – shorter or deleted vowels between identical consonants only – they are not of sufficient number to cancel out the more general pattern of longer vowel duration in these contexts. The following figures show that no bimodality in vowel duration exists of the kind predicted if these two repairs coexist at the phonetic level. Points are mapped by REP status along the y-axis, with schwa durations in an REP context marked along a horizontal line above the non-REP tokens. Duration increases along the x-axis. Note that the higher line is consistently shifted rightward relative to the lower one, as longer schwas are associated with the REP context. However, the points in that higher line do not cluster in two separate areas as predicted by the bimodality hypothesis.

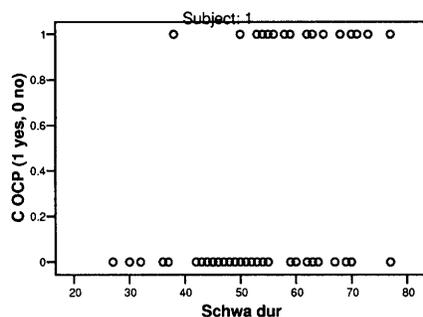


Figure 5.

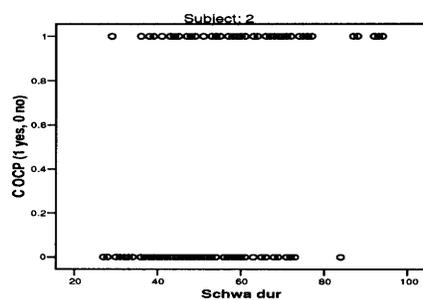


Figure 6.

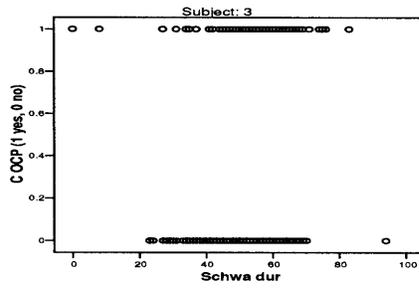


Figure 7.

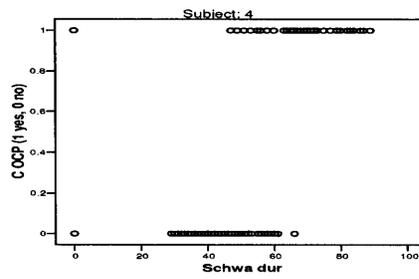


Figure 8.

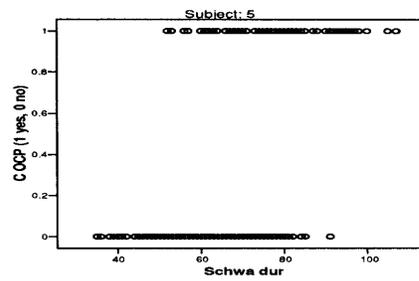


Figure 9.

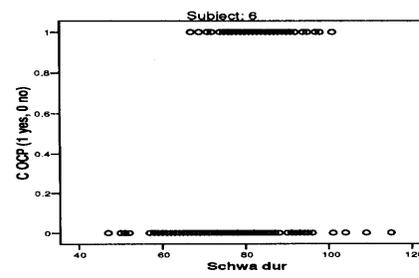


Figure 10.

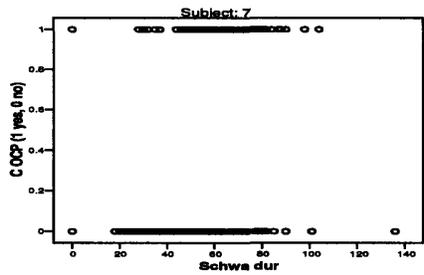


Figure 11.

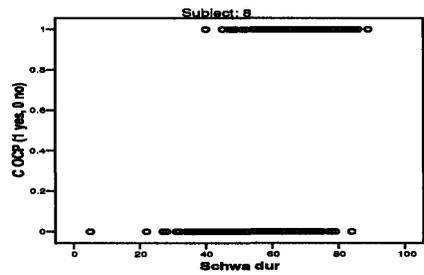


Figure 12.

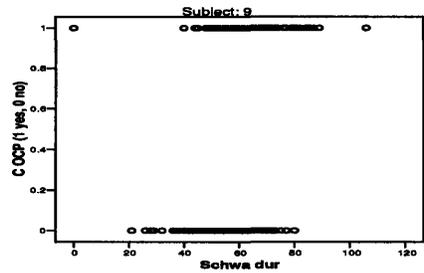


Figure 13.

### 3.1.3 Lenition

If consonantal repetition in close proximity presents a problem for speakers, another possible response is lack of complete target attainment for one or both of the repeated consonants. That is to say, we might expect more consonant lenition in such environments. I now briefly outline typical patterns and properties of lenited consonants in English, and how these were measured for the data in this experiment.

Lenition has been used to refer to a wide range of processes involving phonological voicing, continuancy, and deletion. Velars are often considered particularly weak in this sense, and therefore the most likely to undergo such processes (c.f. the diachronic loss of the velar

fricatives in English). In a cross-linguistic survey of phonological lenition processes, Lavoie (2000) finds that velars are more likely to undergo fricativization (when voiceless), debuccalization, and deletion, relative to consonants with other places of articulation.

As for English, Lavoie shows that *phonetic* lenition occurs significantly less often immediately before a stressed vowel (primary stress vs secondary/no stress), and also in word-initial position. This parallels Umeda's (1977) findings that English consonants vary predictably in length according to prosodic position. Similarly, Turk (1992) finds that prestress consonants tend to be longer (~not lenited; except for [g]), and that [b] tokens have shorter duration in the same environments where coronals undergo flapping. Finally, Nolan and Kerswill (1990) document fricativization of English velar stops (but not other consonants). Shorter duration is the most reliable cue to lenition, although approximantization (rather than true spirantization) also occurs.

The table below breaks down the rate of lenition diagnostics for voiced stops according to place of articulation in Lavoie's English data. Manner gives the percentage of stop tokens produced as approximants rather than stops, Seal gives the percentage not attaining complete closure, and Burst the percentage without a release burst. Thus a higher number indicates more lenition.<sup>6</sup>

	labial	alveolar	velar
<b>Manner</b>	5	28	24
<b>Seal</b>	22	37	41
<b>Burst</b>	21	33	45

Table 2: Lenition properties by place of articulation.

Note that velars are relatively susceptible to lenition, even compared to the alveolars, which undergo flapping. Lavoie hypothesizes that this is due to the lack of a velar fricative. Absence of this contrast means that the stop is free to encroach further on the acoustic space that is left unoccupied.

<sup>6</sup> This differs from Lavoie's presentation of the same data by a subtraction from 100, since her percentages show rates of *non*-lenition.

For the data of Experiment 1, lenition was measured in three different ways. First, a qualitative classification of each C1 and C2 segment as lenited or non-lenited was performed by the author based on visual inspection of spectrograms generated by the PRAAT acoustic analysis software program. Criteria for lenited classification were quite restrictive. Segments were not classified as lenited unless continuous voicing was observed (indicating vocal fold leakage throughout the segment), as well as the presence of formant structure. Coronal C1s were not considered for lenition classification, as they occur in a flapping environment.

Second, the duration of each C1 and C2 segment was measured. Lavoie identifies duration as the most reliable cue for lenition, and other experimenters have found consistent variation in it associated with lenition and weak prosodic positions. Duration was measured by hand by the author based on visual inspection of spectrograms generated by the PRAAT acoustic analysis software program. Measurement commenced from the onset of (possibly incomplete) closure constriction and ended at the release of the constriction. Release burst, if any, was allotted to the neighboring vowel and not included in the duration of the consonant itself.

Third, the intensity nadir of each C1 and C2 segment was measured. An intensity contour was produced and overlaid on a spectrogram using the PRAAT acoustic analysis software program. PRAAT computation of an intensity curve smoothes it by ignoring variation within a pitch period and averages it over short consecutive time slices, then squaring and convolving these values. The lowest point in this contour occurring during C1 and C2 was identified visually by the author and recorded. Means of these dB values were compared directly in the analysis below, without further computations such as subtraction of RMS amplitude from that of another segment in the utterance. Such modifications are potentially confounded in this experiment by independent variation in intensity of those other segments according to consonant place and vowel quality. No other potentially confounding independent sources of intensity variation are expected that would invalidate using the dB mean values. The only result is a data set with more extraneous variation, making it more difficult to reach statistical significance.

### *3.1.1.3 Qualitative lenition*

Let us first consider overall lenition rates based on the qualitative classification. Because the coronal segments occur in a flapping (~leniting) environment for C1, they are removed from the analysis for that position.

	velar	labial	total
<b>C1</b>	45	35	40
<b>C2</b>	9	4	6

Table 3: Lenition rates (% lenited) by consonant position and place of articulation.

Lenition occurs nearly half of the time overall for C1, but relatively rarely for C2. This is consistent with the lenition results described above and their correlation of lenition rate with position relative to stressed vowels. Lavoie contrasted primary stress vs secondary/no stress, while here we contrast secondary stress with no stress. Nevertheless, the same positional asymmetry holds.

In addition, velars consistently undergo lenition more often than labials, as expected based on the discussion above. Finally, frication noise was virtually never observed in lenited tokens. This is consistent with Lavoie’s claim that lenition is typically approximantization rather than true fricativization.

Binary logistic regression analysis was performed with C2 lenition for the factor REP/non-REP environment, which has a statistically significant effect (Wald=21.152,  $p < .001$ ). C2 lenition occurs for 10% of tokens in an REP environment, and only for 5% in a non-REP environment.

Let us now consider the distribution of lenited C1 tokens according to C-REP environment type. Greater rates of lenition are predicted for C-REP stimuli than otherwise. Just such an effect obtains overall. Again, binary logistic regression shows that the factor environment is significant (Wald=4.191,  $p = .041$ ). The table below gives C1 lenition percentages for individual subjects and overall, broken down by place and environment.

Subject	REP	non-REP	REP	non-REP	Overall
	velar	velar	labial	labial	
<b>1</b>	78	73	83	12	62
<b>2</b>	22	35	37	11	26
<b>3</b>	53	38	38	52	45
<b>4</b>	89	61	44	11	51
<b>5</b>	80	86	55	47	67
<b>6</b>	26	18	15	30	22
<b>7</b>	17	34	49	36	34
<b>8</b>	26	17	26	4	18
<b>9</b>	62	38	63	33	49
<b>Overall</b>	<b>48</b>	<b>43</b>	<b>44</b>	<b>30</b>	<b>41</b>

Table 4: C1 lenition rates (% lenited) by subject, place, and environment type.

While lenition rates show considerable variation among speakers, there are patterns in the relative likelihood of lenition in each context. For each place of articulation, REP contexts result in an overall higher lenition rate. This relationship holds overall and for the majority of subjects for each place (all but two for velar, and all but three for labial). Also, velars are more likely to be lenited than labials. This asymmetry holds overall and for all but three individual subjects.

### 3.1.3.2 Schwa-lenition interaction

Two different variables have now been shown to display REP-motivated variation. REP contexts with repeated consonants are associated with longer intervening schwa vowels, and with higher consonant lenition rates. The natural next question is how the relationship between these two variables works. That is, do speakers select one from among the possible ‘repair’ strategies for C-REP violations, e.g. by *either* lengthening schwa *or* leniting C1? Or do they use whatever means are at their disposal, in conjunction?

To address this question, the sample was limited to tokens in which C1 lenition is judged to have occurred. These were then tested to see whether a schwa duration effect for C-REP

context still obtains. Even within lenited cases, there is still a significant effect of REP context on schwa duration. Means are given in the following table.

Subject	C-REP	sd	non-C-REP	sd
1	61	10	54	11
2	67	15	50	10
3	54	20	52	10
4	45	35	45	10
5	79	12	62	11
6	82	9	80	14
7	63	19	47	17
8	71	8	59	12
9	68	15	57	9
<b>Overall</b>	67	21	57	14

Table 5: Mean schwa durations (ms) after lenited C1, according to C-REP context.

Not only does the effect remain, it is still consistent for each subject (with schwa length longer in C-REP contexts for all but one speaker, for whom it is equal), and the mean difference in length still reaches 11 milliseconds. The difference is highly significant (RM ANOVA  $F(1,8)=16.86$ ,  $p=.003$ ). It appears that speakers use all means at their disposal to ameliorate the articulatory difficulty associated with REP contexts. In addition, note that the schwa duration difference is of the same magnitude as with all tokens regardless of lenition – means of 67 and 57 ms, depending on context, versus 66 and 55 ms. No apparent trade-off between lenition and degree of duration increase occurs.

### 3.1.3.3 Lenition and intensity

The intensity results present an initially puzzling combination with the qualitative ones reported above. Intensity of C2 barely differs according to REP context, as shown by Table 6 below.

<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
55	5	56	5

Table 6: Mean intensity nadir in dB of C2 by REP context.

This 1 dB difference is not statistically significant ( $F(1,8)=2.703$ ,  $p=.139$ ). For C1, on the other hand, mean intensity does differ marginally but significantly by REP context ( $F(1,8)=5.765$ ,  $p=.043$ ). However, the difference goes in the opposite direction than expected.

	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
<b>1</b>	60	4	59	4
<b>2</b>	58	5	59	4
<b>3</b>	59	6	61	6
<b>4</b>	56	5	56	5
<b>5</b>	65	5	66	5
<b>6</b>	61	4	62	4
<b>7</b>	60	8	62	8
<b>8</b>	59	7	60	7
<b>9</b>	64	4	64	3
<b>Overall</b>	<b>61</b>	<b>6</b>	<b>62</b>	<b>6</b>

Table 7: Mean intensity (in dB) of C1 by REP context.

As Table 7 shows, intensity is very slightly but consistently and significantly *lower* for C1 in an REP context compared to a non-REP context. This finding seems to indicate less lenition in REP contexts than otherwise, contradicting the results of the qualitative lenition classification.

The following table shows the intensity means broken down by the variables of both lenition status and REP environment status.

<b>C-REP non-len</b>	<b>sd</b>	<b>non-C-REP non-len</b>	<b>sd</b>	<b>C-REP len</b>	<b>sd</b>	<b>non-C-REP len</b>	<b>sd</b>
58	6	58	5	64	5	65	5

Table 8: C1 mean intensity in dB by environment and qualitative lenition status.

The subclass of C1 that was classified qualitatively as lenited does have overall higher intensity than the non-lenited subclass, as expected (mean of 65 dB for lenited versus 58 dB for non-lenited). This suggests that the contradiction is not due to classification errors. We also see that lenited non-C-REP stimuli have higher mean intensity lenited C-REP ones. The difference is small (1 dB), but recall that dB are measured on a logarithmic scale which makes it larger than a single-unit difference may seem. In addition, we have seen in the C1 intensity results of Table 7 just above that a 1 dB difference can be statistically significant. I return to this issue after the discussion of consonant duration effects.

### 3.1.3.4 Lenition and duration

Duration of C2 is slightly shorter in REP contexts than non-REP contexts, as the following table shows (coronals included).

	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
<b>1</b>	64	10	64	12
<b>2</b>	73	16	73	16
<b>3</b>	60	24	53	19
<b>4</b>	40	25	55	14
<b>5</b>	51	16	53	16
<b>6</b>	86	20	85	18
<b>7</b>	66	19	71	22
<b>8</b>	71	11	76	10
<b>9</b>	57	14	63	16
<b>Overall</b>	<b>62</b>	<b>21</b>	<b>65</b>	<b>20</b>

Table 9: Mean C2 duration (ms) by subject and REP context.

This shorter duration is expected as a correlate of more consonant lenition. However, this difference is not significant (RM ANOVA  $F(1,8)=1.88$ ,  $p=.208$ ).

As for C1, a significant difference in duration goes in the opposite direction (coronals included). C1 duration is *longer* in an REP context (RM ANOVA  $F(1,8)=13.953$ ,  $p=.006$ ).

	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
<b>1</b>	46	12	44	12
<b>2</b>	58	16	47	14
<b>3</b>	49	31	38	15
<b>4</b>	61	48	43	15
<b>5</b>	37	15	33	15
<b>6</b>	50	15	47	17
<b>7</b>	49	20	41	18
<b>8</b>	38	17	35	18
<b>9</b>	43	21	41	14
<b>Overall</b>	<b>46</b>	<b>25</b>	<b>39</b>	<b>16</b>

Table 10: Mean C1 duration (ms) by subject and REP context.

Like the lower intensity just observed, longer duration is an apparent contradiction of the qualitative lenition measure. The following table gives overall means of C1 duration for both contexts and lenition status (coronals not included; their inclusion does not alter the observed pattern).

<b>C-REP</b>	<b>sd</b>	<b>non-C-REP</b>	<b>sd</b>	<b>C-REP</b>	<b>sd</b>	<b>non-C-REP</b>	<b>sd</b>
<b>non-len</b>		<b>non-len</b>		<b>len</b>		<b>len</b>	
59	17	51	12	51	29	41	11

Table 11: C1 duration (ms, noncoronals) by environment and lenition status.

It shows that consonants classified as lenited do have shorter durations overall than those classified as non-lenited, as expected. But REP context works against this asymmetry. For non-lenited C1 tokens, duration is significantly longer in C-REP contexts than non-C-REP ones. The duration of lenited C1s is also significantly longer in C-REP contexts than non-C-REP.

### *3.1.3.5 Lenition summary*

The set of lenition results based on the three variables of qualitative classification (based on closure degree), intensity, and duration are initially puzzling and seemingly contradictory. The qualitative classifications bear out the expectation of more lenition in REP contexts. Intensity and duration means based on these qualitative classifications support their accuracy – the class of lenited tokens has overall higher intensity and shorter duration means, as expected.

However, more lenition in REP contexts predicts higher intensity and shorter durations in these sequences – cues associated with segment weakening. This prediction is contradicted. The expected correlations of intensity and duration with lenition in REP contexts are actually reversed. C1 in these contexts has mean lower intensity and longer durations, despite also being classified more often as lenited.

I propose that this apparent discrepancy is due to the opposition between the two ways in which effort is minimized in these contexts. One way is not to complete the constriction for one of the stops. The other way is to slow down the articulator reversal, as shown by the inverse relationship between force and time in Chapter One. However, such slower movements and longer durations also facilitate target attainment (Soler and Romero 1999, Lavoie 2001). Thus using the second strategy undermines the use of the first. Just as speakers recruit both longer schwa duration and consonant lenition in order to ameliorate the difficulty of repetitive sequences, they vary the repeated consonants themselves in multiple ways to minimize articulatory effort. The coexistence of and antagonism between these two strategies result in the seemingly contradictory results we observe. C1 in a repeated sequence is less likely to achieve complete closure (as shown by the qualitative measure). However, its longer duration means that its incomplete closures are closer than those of lenited segments in non-repeated sequence. Tables 8 and 11 above show that the prediction of shorter duration and higher intensity for non-REP lenited segments compared to REP lenited ones is borne out. Even in the absence of

repetition, lenition still occurs 36% of the time among non-coronals. This percentage is sufficiently high to skew the results in the observed fashion.

The antagonistic relationship between these two effort minimization strategies can also account for the relative rarity of spirantization lenition as a phonologized repair to identical consonant sequences. We have seen in Chapter One that this repair does occur, in Ancient Greek and Old Germanic. This fulfills our initial hypothesis, based on the difficulty of constriction target attainment in repeated place gesture sequences. However, it is rather infrequent compared to other repairs such as antigemination. This makes sense if the lenition cue of incomplete constriction is counterbalanced by the effect of longer duration, which biases listeners against interpreting a segment as lenited or spirantized.

Finally, it is interesting to note that it is primarily the first segment of the sequence which shows phonetic variation. While both C1 and C2 are more likely to be classified as lenited, this happens at a much lower rate for C2. This is as expected, given its position as initiator of a stressed syllable. Variation in intensity and duration occurs solely for C1. This asymmetry means that it cannot be the case that such variation occurs as the articulators become tired toward the end of a repetitive sequence. Its anticipatory nature shows that utterance planning must intend and incorporate this variation. In this case and in most of the experiments described below, phonetic variation in repeated consonants focuses on the one in prosodically weaker position, which is presumably more vulnerable to variation and lenition. This is true for all of the stimulus sets, and is reminiscent of grammatical positional faithfulness phenomena (Beckman 2004). However, prosodically weaker position also coincides with being the first segment in the repeated sequence for all but one set, so an ordering effect should not be completely ruled out. Such an effect may also contribute to the fricative-first generalization noted in Chapter Two (though the fricative-first rule applies regardless of identity/homorganicity, so cannot be completely traced to the effect seen here).

#### *3.1.4 Additional duration measures*

So far we have seen phonetic variation in repeated consonants themselves and in the schwa vowel intervening between them. The only remaining significant variation is a very slight change in duration of V2 (RM ANOVA  $F(1,8)=15.429$ ,  $p=.004$ ).

Subject	C-REP	sd	non-C-REP	sd
1	121	17	119	18
2	120	29	116	26
3	124	19	123	19
4	136	25	129	24
5	136	27	134	24
6	141	27	139	21
7	188	38	185	40
8	132	16	132	15
9	161	24	155	22
<b>Overall</b>	<b>144</b>	<b>32</b>	<b>141</b>	<b>34</b>

Table 12: Mean V2 duration (ms) by subject and environment.

As Table 12 shows, V2 duration is slightly but consistently longer when preceded by a repetitive consonant sequence. Repetition evidently elicits lengthening/slowing downstream from what causes the production difficulty, as well as in its immediate environment. Recall that no significant variation in duration was seen for C2, so for this stimulus set the duration increase effect skips a segment.

We will now review additional variables from the beginning to the end of the stimulus nonce words, none of which show significant variation.

No significant difference in V1 duration is associated with C-REP contexts in word-medial position (RM ANOVA  $F(1,8)=.16, p=.7$ ).

	C-REP	sd	non-C-REP	sd
<b>V1 duration (ms)</b>	109	37	108	28

Table 13: V1 duration (ms) according to C-REP context.

Since all nonce-words in the stimulus set begin with the phoneme [b], and [b] is also one of the segments permuting word-medially, the initial syllable offers a chance to test for repetition-

related variation at the left word edge as well as medially. As documented in Appendix 4's discussion of place asymmetries, vowels followed by [b] tend to be shorter than those followed by [d] or [g]. The percentage increase from –[b] to –[d] is approximately 10% for the overall group (49 to 55 ms), and slightly less than the increase going from –[d] to –[g]. The direction of the asymmetries makes this an appropriately conservative test case for a full-vowel REP effect. In order for increased length to be seen in [b]-V1-[b] sequences, the REP effect would have to counteract the effect of place.

The following table shows that this does not seem to be the case. Rather, V1 in a [bVb] sequence is shorter than those in [bVd] or [bVg] sequences, as predicted by the place rankings independent of repetition (a coronal/velar difference is not observed).

<b>Labial</b>	<b>sd</b>	<b>Coronal</b>	<b>sd</b>	<b>Velar</b>	<b>sd</b>
104	26	111	45	110	28

Table 14: Mean duration and standard deviation of V1 by C1 place.

The REP effect may still be active in making this gap smaller than it would otherwise be, since the percentage durational increase from –[b] to –[d] is only roughly 6%, compared to the 10% observed for schwa. However, no firm conclusions can be drawn.

Let us now consider the possibility of an REP-related effect for coronal place versus the other places at the right edge of the word, for V2. We have already seen that coronal and labial consonants tend to be followed by longer vowels than velar consonants (56 ms means for the former two, versus 52 ms for velars), though the percentage difference (8%) is smaller than the effect of the following consonant. An REP effect on V2 predicts further differentiation among the set, such that a coronal onset pulls ahead of labials as well as velars in terms of duration.

<b>Coronal</b>	<b>sd</b>	<b>Labial</b>	<b>sd</b>	<b>Velar</b>	<b>sd</b>
144	32	140	33	142	34

Table 15: Mean duration and standard deviation of V2 by C2 place.

A small difference does appear favoring coronal-onset sequences with respect to length. This difference is significant (RM ANOVA  $F(1,8)=4.205$ ,  $p=.034$ ; Mauchly's test of sphericity is met). Within-subject contrasts show that vowel duration between coronals is significantly longer than after a labial ( $p=.018$ ), but not a velar ( $p=.149$ ). This inconsistency suggests that the small difference observed is due to the previously noted coronal length effect, rather than repetition-related.

### *3.1.5 Experiment 1 summary*

The results presented here provide a novel kind of evidence for gradient effects of repetition avoidance in English speech production. Even when repetition is tolerated in the grammar, amelioration in production may occur – in the absence of grammaticalized repair strategies, speakers manipulate lower-level phonetic variables. This amelioration in turn is a potential source of the grammaticalized alternations in REP environments. The strategies seen here include longer duration for schwa intervening between identical consonants, higher lenition rates of both those consonants, and both longer duration and lower intensity for one of them. I argue that the schwa effect is a potential source of phonological antigemination, and lenition for spirantization, though this is undermined by the effects of longer duration. Increased duration also appears on the segment following the repetitive sequence.

## **3.2 Experiment 2 – tarradiddle**

Experiment 2 attempts to replicate the findings of the first one with respect to intervening vowel duration and the intensity and duration of repeated consonants in English. The tested consonants are still the voiced stop series. The intervening vowel may be either of the full vowels [ɪ] and [ʊ], so that this experiment tests the relevance of a vowel quality target in eliciting variation in intervening vowel duration. In this respect it is an extension of Experiment 1, as well as a replication. The goal is to distinguish between longer duration and existence of a place target as factors that may obviate vowel lengthening between identical consonants. While these full vowels are normally of longer duration than reduced schwa, a fast speaking rate was forced with the use of a metronome here, in an attempt to push the vowel durations downward toward the threshold below which an increase in duration is predicted. An additional goal is to test whether this variation may still occur across another intervening consonant – here, [r]. This could

distinguish between effects of consonant-consonant adjacency (even across a vowel, following Rose 2000) and onset-to-onset correspondence.

I find that at a forced fast speech rate, variation in vowel duration and consonant duration and intensity occurs in CVC sequences with repeated consonants, as predicted. The consonant effects appear on C2 in this experiment rather than on C1 as in Experiment 1. This reversal is expected if variation is more likely for the segment in weaker prosodic position, as hypothesized earlier. The same types of variation are not observed when another consonant intervenes, except for an unexpected intensity effect.

### *3.1.1 Procedure*

Informed consent was obtained from 9 native speakers of American English. The subject pool contains 5 females and 4 males with vision normal or corrected to normal, none of whom reported hearing, language or neurological disorders. Subjects were presented with visual orthographic stimuli in random order using Psyscope software. A metronome placed inside the sound-proof booth was started prior to initiation of the script, set to beep at the rate of 120 beats per minute. Subjects were instructed to time their productions to the metronome with one word per beat, to produce as many repetitions of each item as they could, and to pause and begin again if they made an error or became confused. An interval of 5 seconds was allowed between automatic stimulus presentations. This allows for a considerable reaction period, and time for up to 8 repetitions per stimulus, as well as recovery time if errors were made. Utterances were digitally recorded in the sound-proof booth.

Stimuli consisted of four-syllable stress-initial non-words with the full vowels [ɪ] and [ɛ] in third syllable. These lax, front, non-low vowels, receiving only secondary stress, are chosen in order to be maximally short for full vowels, while still being ineligible for reduction to schwa. The surrounding consonants permute as shown below (complete stimulus lists are found in Appendix One):

17) Stimuli (orthographic)

t a rr a  $\left\{ \begin{matrix} b \\ g \end{matrix} \right\}$   $\left\{ \begin{matrix} r \\ \emptyset \end{matrix} \right\}$   $\left\{ \begin{matrix} e \\ i \end{matrix} \right\}$   $\left\{ \begin{matrix} bb \\ gg \end{matrix} \right\}$  le

18) Stimuli (IPA)

t<sup>h</sup> ε ɹ ə  $\left\{ \begin{matrix} b \\ g \end{matrix} \right\}$   $\left\{ \begin{matrix} ɹ \\ \emptyset \end{matrix} \right\}$   $\left\{ \begin{matrix} e \\ i \end{matrix} \right\}$   $\left\{ \begin{matrix} b \\ g \end{matrix} \right\}$  ɿ  
C1 V C2

The resulting total is 16 stimuli, with each repeated several times per subject. Given the mean durations summarized in the preceding section, the goal is to elicit vowels with duration 80 ms or less, in order to approximate the duration threshold estimated from fast single-tongue rates in music performance. Estimates of mean segment duration based on those of the first experiment suggest that the metronome must enforce a speaking rate allowing less than approximately 600 ms per stimulus item in order to elicit vowels of the desired shortness. A tempo of 120 beats per minute allows 500 ms per stimulus item and is deemed just performable by the experimenter.

Contexts with repeated consonants and no intervening [r] will be referred to as local REP contexts, and those with consonant repetition and an intervening [r] as well as a vowel as non-local REP contexts. Measures of variation are made according to the procedure outlined in Experiment one, and include vowel duration between [b, g] consonants in the third syllable and duration and intensity of C1 and C2, and the duration of the liquid+vowel interval in those which include a liquid in the third-syllable onset. I will discuss testing repetition versus no-repetition *local* contexts before moving on to the non-local ones.

### 3.2.2 Local repetition results

As in the initial experiment, vowels intervening between and immediately adjacent to both C1 and C2 are significantly longer when C1 and C2 are identical (RM ANOVA  $F(1,8)=12.671$ ,  $p=.007$ ).

<b>Subject</b>	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
1	91	18	81	16
2	89	19	80	22
3	102	22	96	18
4	121	17	116	18
5	87	14	93	14
6	94	18	88	17
7	123	26	105	23
8	95	18	86	23
9	109	20	97	17
<b>Overall</b>	<b>101</b>	<b>23</b>	<b>93</b>	<b>22</b>

Table 16: Vowel duration (ms) by subject and local REP context.

Also as in Experiment 1, one of the consonants has significantly longer duration and lower intensity in a repetitive sequence compared to a non-repetitive one. Below are the durational means (RM ANOVA  $F(1,8)=12.41$ ,  $p=.008$ ).

<b>Subject</b>	<b>REP</b>	<b>non-REP</b>
1	59	58
2	71	69
3	46	43
4	74	63
5	63	58
6	42	41
7	65	60
8	45	43
9	43	40
<b>Overall</b>	<b>56</b>	<b>52</b>

Table 17: C2 duration (ms) by subject and local REP context.

As before, a one dB lower mean intensity in repeated versus non-repeated contexts is statistically significant (RM ANOVA  $F(1,8)=9$ ,  $p=.017$ ).

<b>Subject</b>	<b>REP</b>	<b>non-REP</b>
1	45	48
2	42	42
3	48	48
4	37	39
5	43	43
6	47	48
7	42	43
8	47	48
9	53	54
<b>Overall</b>	<b>45</b>	<b>46</b>

Table 18: C2 intensity (dB) by subject and local REP context.

No significant variation occurs in either duration or intensity of C1 (RM ANOVAs; for duration  $F(1,8)=.385$ ,  $p=.552$ ; for intensity  $F(1,8)=2$ ,  $p=.195$ ).

<b>Variable</b>	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
C1 duration	57	16	58	16
C1 intensity	46	6	46	6

Table 19: C1 duration (ms) and intensity (dB) in local contexts by REP context.

The consonant showing variation is the second of the sequence, reversed from the ordering in Experiment 1. However, it remains constant that the varying one is in the weaker prosodic position, initiating an entirely stressless syllable.

### 3.2.3 Non-local repetition results

Let us now consider these variables when an additional segment – the consonant [r] – intervenes between the two voiced stops as well as the vowel. Due to the difficulty of segmenting between this liquid and the intervening vowel, the duration of the [r]+V sequence is taken as a unit.

<b>Subject</b>	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
1	95	14	91	14
2	105	24	93	25
3	115	26	105	17
4	137	17	136	16
5	103	15	108	15
6	100	18	105	15
7	144	26	130	21
8	96	20	97	19
9	113	19	118	15
<b>Overall</b>	<b>111</b>	<b>26</b>	<b>109</b>	<b>23</b>

Table 20: Duration of [r]+V (ms) by subject and REP context.

Interestingly, the duration of the two-segment liquid+vowel sequences exceed those of the single vowel tokens in Table 20 by barely 10-16 milliseconds. But despite this minimal gap in overall duration, and even though overall mean duration is slightly longer in an REP versus a non-REP context, this asymmetry is inconsistent and not statistically significant (RM ANOVA  $F(1,8)=1.198, p=.305$ ).

It may be that the lack of an effect is due entirely to the durational increase that the [r] introduces. Though small, it could be sufficient to alleviate the production difficulty of stop consonant repetition. If that is the case, then the vowel lengthening effect may reappear with the when the stimulus subset including only the shorter [ɪ] vowels is considered (mean duration of [ɪ] tokens in the local stimulus set is 96 ms, compared to 112 ms for [ɛ]). However, the durational

difference between [ɪ] vowels in [r]-ful REP and non-REP contexts shrinks to a 1-millisecond gap (103 ms and 102 ms respectively). This does indeed put them in the durational range for which we see effects in the local conditions, but the difference is not significant (RM ANOVA  $F(1,8)=.704$ ,  $p=.426$ ).

Duration of both C1 and C2 also fails to vary significantly based on the presence of non-local consonant repetition (RM ANOVAs; for C1,  $F(1,8)=.929$ ,  $p=.366$ ; for C2,  $F(1,8)=2.202$ ,  $p=.171$ ).

	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
C1	57	16	58	16
C2	56	20	52	19

Table 21: Mean duration by consonant and REP non-local context.

However, intensity does vary for C2 just as it does in the local contexts and as it does for C1 in the first experiment – it is significantly lower in a repetitive environment than a non-repetitive one (RM ANOVA  $F(1,8)=10.563$ ,  $p=.012$ ).

<b>Subject</b>	<b>REP</b>	<b>non-REP</b>
1	46	46
2	41	42
3	48	51
4	38	38
5	43	46
6	48	48
7	42	43
8	42	45
9	52	54
<b>Overall</b>	<b>44</b>	<b>46</b>

Table 22: C2 intensity by subject and REP non-local context.

This C2 intensity difference is the only one present for the non-local REP context that corresponds to the variation seen in Experiment 1, and in this experiment locally. The intensity variation persists where the intervening duration variation does not. It is also not associated with duration variation in the consonant itself as we saw previously, though there is a trend toward longer duration.

An additional difference appears, however, which has no counterpart in Experiment 1 or the local effects of this experiment. This is a difference in intensity for C1, going in the opposite direction than we have seen before. As Table 23 demonstrates, C1 intensity is higher rather than lower in non-local repetitive contexts.

<b>Subject</b>	<b>REP</b>	<b>non-REP</b>
1	47	47
2	46	44
3	47	46
4	34	35
5	43	43
6	46	45
7	44	42
8	39	38
9	52	50
<b>Overall</b>	<b>44</b>	<b>43</b>

Table 23: C1 intensity by subject and REP non-local context.

#### 3.2.4 Experiment 2 summary

This experiment shows that the intervening duration effect *can* occur across full vowels. But it does not do so when a consonant intervenes, even when the intervening duration is as short as an intervening vowel that does elicit the effect. The interposition of a consonant appears to be crucial, even though the presence of a vowel quality target does not preclude duration variation.

Experiment 2 also replicates the variation in consonant duration and intensity for local repetition. As with the vowel duration variation, none is seen for consonants in [r]-ful, non-local repetitive stimulus sequences. Variation in C2 intensity is the only asymmetry that is replicated in the non-local stimulus set.

### **3.3 Experiment 3 – dadeed**

The first two experiments consider only identical consonant repetition. I have hypothesized that the crucial difficulty prompting repetition avoidance of the kind we have seen so far does not require complete identity, however, but only homorganicity. Experiment 3 tests this hypothesis across both schwa and full vowels by including nasals as well as voiced oral stops in the set of permuting consonants. I find that a homorganic sequence elicits significant duration variation in an intervening schwa vowel, and that this effect is of comparable strength to the variation elicited by complete identity. However, a full vowel shows no such variation.

The inclusion of nasals also makes it possible to test for an effect triggered by repetition of a non-place feature. I find that there is no significant effect of nasality repetition, as hypothesized in Chapter One.

#### *3.3.1 Procedure*

Experimental procedure follows the model of Experiments 1 and 2. Informed consent was obtained from 9 native speakers of American English. The subject pool includes 5 females and 4 males with vision normal or corrected to normal, none of whom reported hearing, language or neurological disorders. Subjects were presented with visual orthographic stimuli in random order using Psyscope software. They were instructed to read quickly in a casual style. Stimuli were read aloud in the following frame sentence:

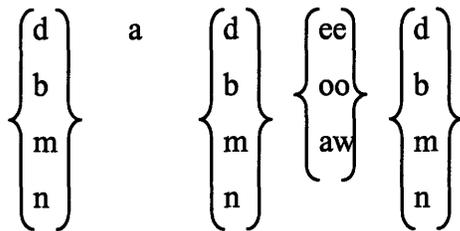
- 19) Stimulus sentence:  
Say dadeed quickly.

Utterances were digitally recorded in a sound-proof booth.

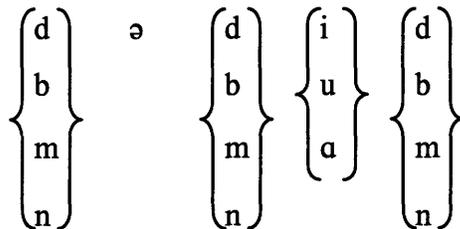
Stimuli consisted of disyllabic stress-final non-words with schwas in the initial syllable and full vowels in the second. The surrounding vocalic and consonantal segments permuted

according to place and quality among the segments shown below (complete stimulus lists are found in Appendix One):

20) Stimuli (orthographic)



21) Stimuli (IPA)



C1 schwa C2 V C3

The stimulus set included all permutations except *baboon*, which is a real word orthographically in English; those for which all three consonants are identical; and ten more items omitted in error from the stimulus list (for which see Appendix One).

Tokens for which two consecutive consonants are identical are called REP1 (left word-edge, with schwa) and REP2 (right word-edge, with full vowels). The measures of variation in this experiment are the durations of schwa and full vowels, and were obtained using the same procedures as the preceding two experiments.

### 3.3.2 Results

In consonant permutations at the left edge of the word (REP1), where only a schwa intervenes, the duration of that schwa is significantly longer between identical and homorganic consonants than non-identical ones. The following table gives mean schwa durations and standard deviations by subject for all three experimental contexts.

<b>Subject</b>	<b>Identical</b>	<b>sd</b>	<b>Homorganic</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
1	47	10	50	8	40	10
2	62	15	60	13	48	8
3	52	12	49	12	37	9
4	79	10	75	8	69	10
5	56	12	56	11	48	11
6	65	15	62	11	51	16
7	68	11	64	9	61	11
8	73	13	69	8	58	11
9	87	17	90	16	86	14
<b>Overall</b>	<b>66</b>	<b>18</b>	<b>64</b>	<b>16</b>	<b>55</b>	<b>18</b>

Table 24: Mean schwa durations and standard deviations by subject and condition.

A repeated-measures ANOVA with the three-level factor identity/homorganicity/non-identity shows that this difference is significant ( $F(2,8)=24.113$ ,  $p=.001$ ; Mauchly's test of sphericity is met,  $w=.621$ ,  $p=.189$ ). Planned comparisons indicate that schwa duration for level 3, non-identical flanking consonants, is significantly different from schwa duration of both identical and homorganic consonant series. Schwa duration between homorganic consonants does *not* differ significantly from schwa duration between identical ones. It appears that homorganicity is the crucial factor, and there is no additional effect of complete identity.

Nasality is subject to dissimilation cross-linguistically, whereas orality is not. This occurs in Chukchi and in clusters associated with nasality in several Australian languages (Suzuki 1998). The disparity has been cited as an argument for privativity of the nasal feature, as well as nasal markedness. Despite this asymmetry, however, the BRAH predicts that a sequence of multiple nasal articulations should not elicit phonetic variation in the same way that place repetition does. We will now investigate whether repetition of nasality, divorced from primary place of articulation, evokes any variation in schwa duration. A small difference does appear in the direction of longer schwas between two nasals, regardless of their place.

<b>Subject</b>	<b>Nasal</b>	<b>sd</b>	<b>Non-nasal</b>	<b>sd</b>
1	47	11	44	10
2	55	16	53	12
3	49	12	41	12
4	72	11	73	10
5	56	13	50	11
6	62	15	56	16
7	66	12	63	10
8	63	16	64	11
9	83	15	89	15
<b>Overall</b>	<b>62</b>	<b>17</b>	<b>59</b>	<b>19</b>

Table 25: Mean durations and standard deviations of schwa by subject and nasality of context.

However, this difference is not significant (RM ANOVA  $F(1,8)=2.346$ ,  $p=.164$ ). Just as the gestural repetition avoidance predicts, place gestures present difficulty that repetition of other feature types does not.

A persistent slowing effect is also seen for the full vowel in the following syllable. This vowel is significantly longer following repetition at the left word edge, as shown by the following table (RM ANOVA; Mauchly's test of sphericity is met, so with sphericity assumed  $F(2,8)=10.141$ ,  $p=.001$ ).

<b>Subject</b>	<b>Non-REP</b>	<b>Homorganic</b>	<b>Identical</b>
1	266	269	282
2	114	119	118
3	154	154	152
4	173	175	183
5	156	155	159
6	159	163	165
7	197	195	202
8	178	179	186
9	174	177	179
<b>Overall</b>	<b>175</b>	<b>176</b>	<b>181</b>

Table 26: Mean V2 durations (ms) by REP1 context.

Note that here the homorganic series patterns with the non-REP sequences, rather than with the identicals above.

While the full vowels at the right edge of the word show variation associated with repetition in the previous syllable, they do *not* have significantly longer duration when between identical or homorganic consonants themselves. This is not surprising, since the mean durations reported in the table below far exceed the threshold suggested by the double-tonguing data. (Because the categories identical and homorganic do not differ significantly at the left word edge, they are collapsed in the category REP below).

<b>Subject</b>	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
1	163	38	171	36
2	118	33	116	29
3	150	24	154	23
4	171	23	177	21
5	155	25	157	27
6	148	22	163	27
7	195	26	198	30
8	180	33	180	28
9	164	30	178	29
<b>Overall</b>	<b>172</b>	<b>48</b>	<b>177</b>	<b>48</b>

Table 27: Mean durations and standard deviations of V by subject and condition.

However, they do show a directional asymmetry going in the opposite direction than expected – full vowels are shorter between identical/homorganic consonants. This variation in duration is significant, though its p-value does not approach the level seen for other the effects (RM ANOVA  $F(1,8)=2.346$ ,  $p=.022$ ). I speculate that this asymmetry is due to the experimental error reported earlier. Of the ten items erroneously omitted from the stimulus set, nine of them have onset and coda [d] in the second syllable. Recall that coronals are associated with slightly longer neighboring vowels in both this experiment and the first one. Their omission results in an imbalance in the stimulus set with respect to the second syllable, so that the REP subclass includes fewer coronal consonants than the non-REP subclass. This could result in the small overall duration advantage that we see for the latter.

### 3.3.3 Summary

This experiment replicates once more the appearance of longer schwas between identical compared to non-identical consonants. It also shows that a similar effect obtains for homorganic ones. The problem with consonant repetition appears to lie in reproducing the primary place gesture, rather than in the representation or planning of a sequence involving total phonemic

identity. Moreover, the effect of repetition is not cumulative, modulated by degree of similarity. Identical consonants evoke no greater variation than homorganic ones. Finally, place of articulation appears to be the only feature type that requires repair via phonetic variation. Repetition of nasality elicits no effect. Nor was a duration increase observed in the vowel of the second syllable. This lack is expected according to the BRAH, given the long observed duration of these vowels. I attribute the small effect going in the other direction to experimental error.

In sum, complete phoneme identity is not necessary to elicit phonetic variation in repetitive contexts, nor is it sufficient when a full vowel intervenes.

### **3.4 Experiment 4 – kawdid**

The previous experiment provides evidence that place gestures are the main drivers of phonetic variation associated with repetition difficulty. As predicted, differences in other features did not eliminate or affect the magnitude of phonetic effects alleviating this difficulty. Another possible approach to make the same point is to show that underlying featural identity does not elicit such variation when the gestural implementation of a segment is the same. This is the goal of Experiment 4. This experiment constructs a context in which some dissimilation of the place gesture is permitted via an optional allophonic alternation (English flapping), to see if its optional application rate is modulated by the presence of a neighboring homorganic oral stop consonant. The BRAH predicts that flapping should apply at a lower rate when it would otherwise result in a sequence of identical gestures.

When flapping does apply, an underlying voicing contrast is also neutralized. The BRAH predicts that the complete segmental identity that results should not elicit any longer intervening vowel duration than homorganic flanking consonants that have the same underlying voicing – despite the underlying non-identity – since it is the gestural implementation of a segment that is crucial and not its underlying identity. In addition, it is place and not voicing identity that presents the main articulatory difficulty.

This experiment yields limited data, because subjects were found to be highly averse to producing flap sequences of any kind. The expected variation in the application of the flapping rule was not observed. For the few subjects who produced complete stimulus sets available, the prediction of no variation in intervening vowel length depending on identity versus non-identity of the flanking consonants was borne out.

### 3.4.1 Procedure

Informed consent was obtained from 8 native speakers of American English. The subject pool includes 4 females and 4 males with vision normal or corrected to normal, none of whom reported hearing, language or neurological disorders. Subjects were presented with visual orthographic stimuli in random order using Psyscope software. Those from experiments 5 and 6, reported below, were also included in the stimulus set as distractors. All three sets of stimuli were read aloud in the inflecting frame sentence given below:

22) Stimulus sentence:

She kawdids a lot. She's a kawdider now.

Utterances were digitally recorded in a sound-proof booth.

Stimuli consisted of disyllabic stress-initial non-words with full vowels in the initial syllable and the short lax [ɪ] vowel (possibly reduced schwa) in the second. The surrounding vocalic and consonantal segments permuted according to place and quality among the segments shown below (the complete stimulus list is in Appendix One):

23) Stimuli (orthographic)

$$\left\{ \begin{array}{c} k \\ p \\ s \end{array} \right\} \left\{ \begin{array}{c} aw \\ ee \\ oo \end{array} \right\} \left\{ \begin{array}{c} d \\ t \end{array} \right\} \quad i \quad \left\{ \begin{array}{c} d \\ t \end{array} \right\}$$

24) Stimuli (IPA)

$$\left\{ \begin{array}{c} k^h \\ p^h \\ s \end{array} \right\} \left\{ \begin{array}{c} a \\ i \\ u \end{array} \right\} \left\{ \begin{array}{c} d \\ t \end{array} \right\} \quad i \quad \left\{ \begin{array}{c} d \\ t \end{array} \right\}$$

C1    V    C2

An REP context occurs when C1 and C2 share underlying phonemic identity (both [d] or both [t]). The number of stimulus types totals 36, each of which is produced twice per speaker (in different inflectional/derivational forms), resulting in a sample of 72 test items for each subject.

The C1 coronal occurs in an obligatory flapping environment in both forms (in a stressed-unstressed syllable sequence). Thus the orthographic representation supplies the only indication as to the C1 flap's underlying status as [t] or [d]. The C2 position, however, allows for variation in production both across and within forms. For the verbal form (*kawdids*), C2 must be pronounced faithfully as [t] or [d]. For the nominal [-er] suffixed form, however, C2 occurs in an environment for which flapping may occur. Flapping is optional in this context (between unstressed syllables). It is further inhibited by the presence of a morpheme boundary such as occurs here ([-er]), and by its occurrence in a novel nonce word. Low lexical frequency is known to correlate with a lower flapping rate, and I assume that non-words are treated as maximally infrequent (Patterson and Connine 2001). These factors, in addition to the formal setting of a laboratory environment, should be conducive to lack of a ceiling effect for flapping so that observable variation results in this environment.

The nominalized form, then, provides the crucial environment of interest to us: a series of two consecutive flappable segments. This set of 36 items is evaluated for two different measures of variation. The first is the duration of the vowel intervening between the two flappable segments. The underlying representation of flaps is known to affect the phonetic environment, specifically including duration of the preceding vowel (Patterson and Connine 2001). A role for underlying phonemic identity in repetition-related repairs predicts longer schwas between UR-identical flaps than between UR-non-identical ones. The BRAH predicts no such asymmetry.

The second is the flapping rate of C2 in the [-er]-suffixed stimulus set. Each C2 token was classified by the author as flapped or unflapped through auditory inspection. Listener judgments have been shown to be highly consistent and reliable in making flapping judgments (Fukaya and Byrd 2005, Patterson and Connine 2001). A dissimilation-type repair between identical consonants could manifest as lower flapping rates where such variation is possible. Finally, duration of the flappable segments was measured following the procedure of the duration measures in the previous experiments. Variation in duration is a potential correlate of the extent of flapping when it is unclear perceptually, especially for flapped [d].

### 3.4.2 Results

Subjects show extreme sensitivity to repetition in that they experience great difficulty in producing sequences of flaps at all, regardless of their underlying phonemic identity. This difficulty exists to such an extent that only two speakers, from the subject pool of 8, completed the task as instructed.

	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
<b>Subject 1</b>	75	8	74	8
<b>Subject 2</b>	71	9	70	7
<b>Overall</b>	74	8	72	8

Table 28: Mean vowel durations and standard deviations (ms) by context.

These two subjects, when their results are evaluated individually, do not show significant variation in vowel duration according to the underlying identity of the flanking consonants (within-subjects independent samples t-tests, with equal variance assumed since Levene's test is met for both subjects; subject 1  $t=.757$ ,  $p=.452$ ; subject 2  $t=.279$ ,  $p=.782$ ).

Both subjects also consistently flap C2, so that no significant variation in flapping rate according to consonant identity is observed. Durational measures of both consonants similarly fail to vary.

	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
<b>C1</b>	32	9	32	9
<b>C2</b>	49	12	51	15

Table 29: Mean C1 and C2 durations and standard deviations (ms) by context.

It is interesting to note that duration is much longer in a context for which flapping is optional (C2), despite the consistent percept of flapping in both environments. However, no durational change is associated with underlying identity of flaps.

The remaining six subjects avoid potential double-flap sequences primarily by shifting stress so as to preclude flapping in one of the contexts (further details are provided in the discussion of speech errors in Appendix Five). Such a repair strategy is not a well-attested one cross-linguistically, and falls into the category of unattested repairs discussed by Wilson (2003), in which higher-level prosody would change to avoid a local sound change. I conjecture that its use here is paralinguistic as well, and traceable to deficiencies of stimulus construction. The fact that for many stimuli the second syllable is a possible independent word of English may have contributed to the difficulty and biased subjects toward stressing it or toward treating the stimuli as compounds with stress on each syllable.

### *3.4.3 Summary*

Speakers are highly reluctant to produce sequences of flaps. The behavioral effect observed here is mirrored in word derivation. Berkley (1994b) finds that words with final [t] do not take the [-ity] suffix even when it might be expected, with only 3 cases appearing in a set of 1246 [-ity]-suffixed forms she identifies. Suffixation which could give rise to multiple flap sequences is so strongly avoided as to be essentially categorical. This aversion for flap sequences is strong enough to swamp any residual effect of the underlying voicing status of the consonants involved. The data obtained from subjects who did complete the task as requested is insufficient in terms of statistical power to establish any variation according to underlying consonant identity, nor does it even trend in that direction. In so far as a lack of effect is precisely what the BRAH predicts, however, these results provide a small measure of support for the hypothesis.

## **3.5 Experiment 5 – papeen**

This experiment investigates repetition-associated phonetic variation for a different set of flanking consonants. The relevant consonants here come from the voiceless oral stop series of English rather than the voiced stop series, and enable investigation of release burst duration as an additional variable (in place of intensity). I find that VOT duration of an aspirated voiceless stop increases for the first consonant of a repeated sequence. This increase provides more time between consonant closures, which the BRAH predicts should make articulator reversal less effortful. The increase in high-frequency noise associated with a longer aspiration period may

also facilitate the phonologization of spirantization as an effort-minimizing repair for stop consonant repetition.

The increase in duration seen in previous experiments with voiced stops does not occur. I argue that it is precluded by a trading relationship between VOT and closure duration – an increase in the former prevents the otherwise expected increase in the latter. This experiment also provides further support for a persistent speech rate slowing effect beyond the immediate environment of gesture repetition. The duration effect on intervening schwa remains robust. The voicelessness of the flanking consonants also results in some intervening schwa deletion. The deletion rate is lower when flanking consonants are identical, which I argue provides further support for a functional origin of antigemination.

### 3.5.1 Procedure

Informed consent was obtained from 8 native speakers of American English. The subject pool includes 4 females and 4 males with vision normal or corrected to normal, none of whom reported hearing, language or neurological disorders. Subjects were presented with visual orthographic stimuli in random order using Psyscope software. The stimulus set contained those of Experiments 4 and 6 as distractors. Subjects were instructed to read quickly in a casual style. Stimuli were read aloud in two inflecting frame sentences.

#### 25) Stimulus sentences:

She papeens a lot. She's a papeener now.

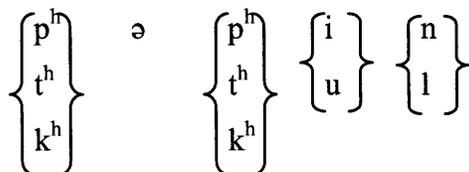
Utterances were digitally recorded in a sound-proof booth.

Stimuli consisted of disyllabic stress-final non-words with schwas in the initial syllable, with surrounding vocalic and consonantal segments permuted according to place and quality among the segments shown below (complete stimulus lists are found in Appendix One):

#### 26) Stimuli (orthographic)

$$\left\{ \begin{array}{c} p \\ t \\ k \end{array} \right\} \quad a \quad \left\{ \begin{array}{c} p \\ t \\ k \end{array} \right\} \quad \left\{ \begin{array}{c} ee \\ oo \end{array} \right\} \quad \left\{ \begin{array}{c} n \\ l \end{array} \right\}$$

27) Stimuli (IPA)



C1    schwa   C2    V    C3

The number of stimulus types totals 36, each of which is produced twice per speaker (in different inflectional/derivational forms), resulting in a sample of 72 test items for each subject. Both C1 and C2 are always allophonically aspirated – the former by virtue of its word-initial position, the latter due to its introducing a (primary) stressed syllable. Tokens for which C1 and C2 share the same place specification (as well as voice and manner, which are always shared), will henceforth be described as REP environments.

Phonetic variables in this experiment include the durations of C1 and C2 closures and VOT, schwa, V, and C3. Unlike the experiments with voiced stop consonants, the duration of the release burst was not included in that of the following vowel. Duration was measured from the onset of closure to the offset of closure for C1 and C2. The release burst, including aspiration noise, was measured independently as a separate variable. In addition, each schwa is classified as present or deleted. This classification was performed by the author based on visual inspection of spectrograms. A schwa was classified as deleted if no voicing was present between C1 and C2 consonant closures.

### 3.5.2 Schwa duration and deletion

Schwa durations are overall much shorter in these stimuli, between voiceless aspirated consonants, than between the voiced ones of previous experiments. Nevertheless, the same increase in schwa duration between identical consonants applies.

<b>Subject</b>	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
1	36	11	27	10
2	36	11	23	9
3	48	12	33	11
4	40	13	30	9
5	53	9	41	9
6	66	22	61	13
7	40	13	26	9
8	39	8	32	10
<b>Overall</b>	<b>45</b>	<b>16</b>	<b>34</b>	<b>15</b>

Table 30: Mean schwa durations and standard deviations (ms) by REP context, excluding devoiced/deleted tokens.

The means in Table 30 exclude those schwas were which classified deleted and therefore are of zero millisecond duration (including the deleted tokens does not affect the asymmetry). This difference in duration is highly significant (RM ANOVA  $F(1,7)=73.677$ ,  $p<.001$ ).

Although the issue did not arise with the schwa tokens flanked by voiced consonants in Experiment 1, schwa *deletion* is by no means uncommon in casual spoken English. It has been described as an optional phonological rule (Zwicky 1972), as an existing but purely phonetic process (as opposed to phonological; Kager 1997, Hewlett 1981), and been the subject of quantitative studies of deletion rates (Patterson, LoCasto and Connine 2003; Dalby 1986). The following table gives rates of schwa deletion word-initial or medial position in slow-read, fast-read, and broadcast speech, drawn from Dalby's experimental study.

	<b>Word-initial</b>	<b>Word-medial</b>
<b>fast speech</b>	44	62
<b>broadcast speech</b>	9	23
<b>slow speech</b>	2	13

Table 31: Percentage schwa deletion by speech rate and context (Dalby 1986).

Observe that schwas are deleted up to half the time in fast speech, and that deletion rates remain healthy even in the relatively formal speech of television broadcasts, and in speech explicitly elicited as “slow.” Patterson, LoCasto and Connine (2003) use impressionistic syllable counts to arrive at schwa deletion rates in data from the Switchboard corpus of spoken speech (Godfrey *et al.* 1992), and observe rates ranging from 6% to 65%, depending on syllable count, morphological complexity, existence of a schwa-less lexical competitor, and word frequency.

These factors are irrelevant for the non-word data of this experiment. It controls morphological complexity (each stimulus is bimorphemic), the nonce words have no schwa-less lexical competitors, and are all of frequency zero. While the morphological inflection does create a syllable count difference, it is balanced across conditions in the stimulus set.

The overall schwa deletion rate in this experiment is quite high, even in the laboratory environment in which the recordings were made, though individual subject data reveals extreme differences in deletion rates for different speakers. The following table lists these percentages.

<b>Subject</b>	<b>REP</b>	<b>non-REP</b>
1	65	73
2	29	48
3	9	9
4	0	9
5	0	0
6	0	0
7	0	28
8	17	6
<b>Overall</b>	<b>24</b>	<b>31</b>

Table 32: Schwa deletion rates (percentage deleted-schwa tokens of total) by subject and REP context.

Despite the degree of individual variation, the rate of schwa deletion in contexts without segment repetition is greater than or equal to the rate in repetitive contexts for all but one subject. Schwa is more likely to be deleted between non-identical consonants than identical ones. This asymmetry shows only a trend toward statistical significance (binary logistic regression for the factor REP context; Wald=2.333, p=.127). The durational tendency to separate identical consonants by longer-than-expected schwas has a parallel in a tendency to preserve schwa between identical consonants, instead of deleting it at the expected rate.

### 3.5.3 C1 and C2 results

Intervening between C1 and C2 in this experiment is not only the schwa vowel when present, but also the release/aspiration burst/VOT of the first consonant of the series. C1 VOT duration means by subject and REP context are given in Table 33 below.

<b>Subject</b>	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
1	57	22	42	15
2	40	19	39	14
3	48	12	40	11
4	46	12	39	13
5	28	16	22	12
6	50	15	43	12
7	41	14	41	17
8	39	21	26	11
<b>Overall</b>	<b>46</b>	<b>20</b>	<b>37</b>	<b>15</b>

Table 33: Mean C1 burst durations and standard deviations (ms) by subject and condition.

VOT duration is significantly longer when C1 and C2 are identical than when they are not (RM ANOVA  $F(1,7)=15.213$ ,  $p=.006$ ). This increase has the effect of separating the two consonant place gestures by an interval of longer duration, thereby easing the articulatory burden as the BRAH predicts.

No significant variation exists in the VOT duration of C2 (RM ANOVA  $F(1,7)=.114$ ,  $p=.746$ ).

	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
<b>VOT</b>	73	20	73	20

Table 34: C2 VOT (ms) duration by REP context.

This is as expected, since such an increase would not affect the interval between C1 and C2 place gestures. Note that since VOT is generally longer for C2 than for C1 (overall means are 73 and 40 ms), this increased duration effect for C1 results in a greater degree of similarity between them, rather than dissimilation, in a kind of anti-Grassmann effect.

### 3.5.4 Additional duration measures

The duration of C1 closure does not increase in REP contexts, as might be expected based on earlier experiments and the BRAH.

Subject	REP	sd	non-REP	sd
1	51	11	55	13
2	47	11	50	17
3	50	19	52	18
4	62	13	67	16
5	49	15	52	12
6	53	15	58	13
7	60	14	61	13
8	61	16	67	14
<b>Overall</b>	<b>54</b>	<b>15</b>	<b>57</b>	<b>15</b>

Table 35: C1 closure duration (ms) by subject and context.

Instead C1 closure duration is slightly but consistently *shorter* in REP contexts than in non-REP contexts. This difference is significant (RM ANOVA  $F(1,7)=37.025$ ,  $p<.001$ ). I propose the expected slowdown of the consonant articulation as an effort minimization strategy is precluded by a trading relationship between the duration of VOT and the consonant closure. Lack of aspiration on English stops in s-stop clusters, as well as partial devoicing of liquids in voiceless-stop-liquid clusters, suggests that the timing of the voicelessness period is rather inflexible. If this is true, then allotting more time to VOT necessitates shortening the voiceless closure period. Indeed, in this data set the two durations are strongly negatively correlated (Pearson's correlation coefficient=  $-.392$ , two-tailed  $p<.001$ ).

We have seen in the previous experiments that subjects employ multiple strategies to minimize articulatory effort in repetitive sequences. They may undershoot a target closure as well as manipulating the duration of multiple segments, for example. However, increasing duration of consonant closure as well as of its VOT does not seem to be possible, based on the

trading relationship documented here. Increasing the interval between closures prevents increasing duration of the first closure.

C2 closure duration is also unaffected by repetition, like its VOT duration and C1 closure duration (RM ANOVA  $F(1,7)=.1$ ,  $p=.761$ ).

	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
<b>Closure</b>	66	18	68	15

Table 36: C2 closure duration by REP context.

As in other experiments, the prosodically stronger consonant in a repetitive sequence appears to be immune to phonetic variation. Here, initiating a syllable with primary stress appears to outweigh word-initial position in terms of prosodic prominence.

However, subsequent segments do show increased duration following repetitive sequences. The stressed vowel is significantly longer after consonant repetition (RM ANOVA  $F(1,7)=10.661$ ,  $p=.014$ ).

<b>Subject</b>	<b>REP</b>	<b>non-REP</b>
1	91	87
2	61	59
3	86	80
4	95	98
5	115	112
6	102	96
7	97	89
8	129	124
<b>Overall</b>	<b>96</b>	<b>92</b>

Table 37: V duration by subject and REP context.

The same is true of the final consonant (RM ANOVA  $F(1,7)=7.955$ ,  $p=.026$ ).

<b>Subject</b>	<b>REP</b>	<b>non-REP</b>
1	90	87
2	49	46
3	59	54
4	66	65
5	66	62
6	71	74
7	60	56
8	74	71
<b>Overall</b>	<b>71</b>	<b>68</b>

Table 38: C3 duration by subject and REP context.

As before, the articulatory slowdown triggered by consonant repetition appears to persist after the sequence itself is completed.

#### 3.5.4 Summary

Earlier experiments show that speakers produce vowels of longer duration between consonants with the same place of articulation. I hypothesize that this duration increase alleviates the production difficulty associated with place repetition. Experiment 5 exemplifies an additional intervention effect. Aspiration/VOT of the first consonant in a repetitive sequence, when present, also has longer duration in the same contexts. As before, speakers recruit multiple ways of ‘repairing’ REP violations.

Recall that the aspiration increase on C1 makes it more acoustically similar to C2 rather than less, in the face of my conjecture that this variation is the potential source of a dissimilation process. The same is true for the closure durations of C1 and C2 in both Experiment 1 and the local contexts of Experiment 2. In Experiment 1, where closure duration of C1 was significantly longer in REP contexts, the resulting mean duration was only 16 ms shorter than that of C2, which initiates the next syllable (bearing secondary stress). The C1-C2 duration gap for non-REP contexts, on the other hand, was 26 milliseconds. For the local contexts in Experiment 2, mean

duration of prosodically weak C2 is only 1 ms shorter than that of C1 when both are in REP contexts, versus a 6 ms gap in non-REP contexts.

In each case, the phonetic variation associated with repetition has resulted in consonants that are more similar to a neighboring identical one rather than less. But I have also argued that this variation is the seed of spirantization as a phonological *dissimilation* process, rather than *assimilation* as the phonetic properties seem to suggest. I now offer a rationale for how acoustically assimilating behavior is encoded phonologically as dissimilation.

The apparent contradiction is resolved by the contribution of other associated cues and of prosodic position. Recall that C1 in stimuli like *badageet* from Experiment 1 is much more likely not to attain complete closure than the relatively prosodically prominent C2, in spite of the former's increased duration in REP contexts. This makes it a more likely candidate for phonological lenition. In Experiment 5, the additional high-frequency noise introduced by its increased VOT duration makes it more likely to be misperceived as a fricative, particularly in combination with the shorter duration that I will now document. Segments in weaker positions are also more likely to be misperceived in general, making them more vulnerable to phonological change. This applies to the word-initial segment of stimuli in this experiment as well, which appears to be prosodically weak compared to the one initiating the syllable with primary stress. Finally, the phonetic effects of being in an REP context may make a segment more like another token of the same phoneme in a different, stronger prosodic position. However, this also makes it more *unlike* its prototypical realization in its own prosodic position. This dissimilarity from its typical realization in a particular environment seems to be sufficient for phonetic variation to lead to phonologization of dissimilation rather than assimilation. Frequency-based expectations about the probability of phoneme sequences are likely to feed this bias. Finally, we have already seen in Chapter One that perceptual biases exist against repetition as well as the articulatory one that I argue for here (possibly supported by knowledge of the articulatory one).

One previous effect that is not replicated in this experiment is the lengthening effect on consonant closure duration. I attribute this to the trading relationship between closure duration and a measure that does vary in the expected way (aspiration/VOT duration). Finally, duration increases downstream from the locus of repetition support a persistent effect of slower articulator movements.

### 3.6 Experiment 6 – papareet

The sixth and final experiment in this chapter also tests for phonetic variation in and between English voiceless stop consonants. It differs from the previous one in that here the intervening vowel is full and bears primary stress. Only one of the phonetic variables (C1 closure duration) exhibits significant variation according to the presence of repetition. Variation in this measure is somewhat surprising given that it occurs in the prosodically stronger consonant, but phonologization of it would fit in with the fricative-first generalization in phonology. Also, the lack of a VOT effect is consistent with the hypothesis outlined above that the predicted variation in C1 closure duration should preclude it, and vice versa.

I attribute the overall lack of variation to the relatively long duration of the primary-stressed vowel intervening between consonant repetitions in combination with long VOT/aspiration, which sufficiently alleviates articulatory difficulty without additional phonetic repair.

#### 3.6.1 Procedure

Informed consent was obtained from 8 native speakers of American English. The subject pool includes 4 females and 4 males with vision normal or corrected to normal, none of whom reported hearing, language or neurological disorders. Subjects were presented with visual orthographic stimuli in random order using Psyscope software. The stimulus set included the items from Experiments 4 and 5 as distractors. Subjects were instructed to read quickly in a casual style. Stimuli were read aloud in the same two inflecting frame sentences as in the previous two experiments.

#### 28) Stimulus sentences:

She papareets a lot. She's a papareeter now.

Utterances were digitally recorded in a sound-proof booth.

Stimuli consisted of trisyllabic stress-initial non-words with full vowels in the initial syllable. The surrounding vocalic and consonantal segments permuted according to place and quality among the segments shown below (complete stimulus lists are in Appendix One):

29) Stimuli (orthographic)

$$\left\{ \begin{array}{c} p \\ k \end{array} \right\} \left\{ \begin{array}{c} a \\ o \end{array} \right\} \left\{ \begin{array}{c} p \\ k \end{array} \right\} \quad a \quad \left\{ \begin{array}{c} l \\ r \end{array} \right\} \left\{ \begin{array}{c} ee \\ oo \end{array} \right\} \quad t$$

30) Stimuli (IPA)

$$\left\{ \begin{array}{c} p^h \\ k^h \end{array} \right\} \left\{ \begin{array}{c} \text{æ} \\ o \end{array} \right\} \left\{ \begin{array}{c} p \\ k \end{array} \right\} \quad \text{é} \quad \left\{ \begin{array}{c} l \\ r \end{array} \right\} \left\{ \begin{array}{c} i \\ u \end{array} \right\} \quad t$$

C1    V1    C2    schwa+liq    V2    C3

The number of stimulus types totals 32, each of which is produced twice per speaker (in different inflectional/derivational forms), resulting in a sample of 64 test items for each subject. In this set C1 is obligatorily aspirated, by virtue of being word-initial and the onset of a (primary) stressed syllable, but C2 is not. Tokens for which C1 and C2 share the same place specification (as well as voice and manner, which are always shared), will be henceforth described as REP environments.

The measures of variation in this experiment are the durations of C1 and C2 closures and VOT, V1, schwa+liquid, V2 and C3. Durations were obtained using the procedure outlined for the previous experiments. V2 and C3 duration was measured as a unit, due to the difficulty of segmenting between the schwa vowel and liquid.

### 3.6.2 Results

In discussing the results we will move from the left edge of the word to the right edge. The first measure, C1 closure duration, is also the only one to vary in a statistically significant fashion.

<b>Subject</b>	<b>REP</b>	<b>non-REP</b>
1	52	53
2	57	46
3	66	61
4	73	55
5	64	56
6	62	59
7	68	49
8	63	62
<b>Overall</b>	<b>62</b>	<b>60</b>

Table 39: Mean C1 closure duration by subject and condition.

C1 consonant closure is significantly longer between identical consonants than non-identical ones (RM ANOVA  $F(1,7)=9.096$ ,  $p=.019$ ). In reporting the previous experiment, I suggest that repetition-related variation in C1 VOT duration should prevent such variation in its closure duration, and vice versa. In that light, it is not surprising that no significant difference in C1 VOT duration exists (RM ANOVA  $F(1,7)=1.044$ ,  $p=.341$ ). The C1 closure variation reported first precludes it.

	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
<b>VOT</b>	53	14	55	14

Table 40: Mean C1 VOT duration by condition.

What is surprising is variation in the much more prosodically prominent C1 instead of in C2.

The vowel intervening between the two consonants shows only a trend toward longer duration (RM ANOVA  $F(1,7)=3.706$ ,  $p=.096$ ).

<b>Subject</b>	<b>REP</b>	<b>sd</b>	<b>non-REP</b>	<b>sd</b>
1	68	11	65	11
2	65	13	63	8
3	71	10	70	9
4	73	12	75	11
5	94	18	90	13
6	65	9	61	10
7	77	14	78	12
8	75	13	74	11
<b>Overall</b>	<b>73</b>	<b>15</b>	<b>71</b>	<b>14</b>

Table 41: Mean vowel durations and standard deviations (ms) by subject and condition.

Although the vowel itself falls under our hypothesized duration threshold for articulatory difficulty with repetition, recall that substantial aspiration/VOT also intervenes. When both are considered together, the mean intervening duration reaches approximately 130 ms. This duration does exceed the posited boundary.

The C2 does not vary significantly in either closure or VOT duration. Nor do the remaining segment durations of the schwa+liquid, V2, or final [t] (C3). The following table provides means for all these measures, as well as the results of repeated-measures ANOVAs.

<b>Measure</b>	<b>REP</b>	<b>non-REP</b>	<b>RM ANOVA</b>
C2 closure	62	65	F(1,7)=3.898, p=.089
C2 VOT	29	29	F(1,7)=.061, p=.812
schwa+liq	104	102	F(1,7)=.606, p=.462
V	84	84	F(1,7)=.232, p=.644
C3	51	51	F(1,7)=.208, p=.662

Table 42: Mean durations by condition and RM ANOVA results.

### 3.6.3 Summary

This experiment generally shows a lack of variation associated with repetition. This lack is predicted given the length of the interval between consonant place gestures. The only significant effect (in C1 closure duration) is surprising in its location (and in its occurrence at all), but otherwise compatible with our hypothesis given the trading relationship mentioned previously.

## 3.7 Conclusions

The experimental results of this chapter show repetition-driven phonetic variation in several positions of the word: initially/left edge (dadeed, papeen), medially (badageet), and toward the right edge (tarradiddle). Variation occurs both within syllable boundaries (tarradiddle) and across them (badageet, dadeed, papeen). We see these effects for place gestures regardless of other features in the segment (dadeed), and a lack of them for other features without homorganicity (nasality/orality in dadeed) and for underlying difference in the face of surface identity (kawdid). Finally, we see them regardless of the intervening vowel quality, or lack of a specification thereof.

Recall that the discussion of double-tonguing puts a temporal boundary on place gesture repetition at 89 ms per CV coronal syllable. This represents the absolute fastest articulation rate possible – a rate of 99 ms per coronal syllable is still considered fast for professional musicians, and one such writes that his top rate is somewhat slower than that (Peabody Institute 2005, Adams 1999). Keep in mind that coronal articulations are quickest, and actual speech production must include other places of articulation. Short samples of amateur trumpet fast-rate single tonguing yielded a mean duration of 69 ms for the vowel in these syllables. Let us check this threshold minimum against the observed intervening durations in the experimental data. The following table gives the mean durations of intervals between consonant closures in ascending order.

	<b>Experiment</b>	<b>Duration</b>
<b>Variation</b>	1 (badageet)	58 (schwa)
	3 (dadeed)	60 (schwa)
	5 (papeen)	71 (40 C1 VOT+31 schwa)
	2 (tarradiddle)	97 (V)
<b>No Variation</b>	4 (kawdid)	73 (schwa V)
	1 (badageet)	98 (V1=[i])
	2 (tarradiddle)	110 (r+V)
	1 (badageet)	129 (V2=[i])
	6 (papareet)	126 (54 C1 VOT+72 V)
	3 (dadeed)	163 (V2=[i,u])

Table 43: Mean durations and standard deviations of intervenors between consonant gestures.

The results split neatly according to intervening duration, with the boundary occurring at 97 ms. Those experiments with intervening durations below this boundary elicit phonetic variation, and those above the threshold of roughly 100 ms do not. The only exception is Experiment 4 (kawdid; schwa duration = 73 ms), for which limited data is available and which does not involve a surface contrast of the relevant type. The repetition difficulty threshold established by the behavioral data of this chapter compares closely with the one predicted by the musical performance data.

These patterns among stimulus types eliciting variation support the BRAH predictions outlined in Chapter Two. Position is not relevant, so long as a durational threshold between consonant closures is breached. Moreover, this threshold corresponds closely to the one predicted by the double-tonguing data presented in conjunction with the BRAH. Similarly, the featural properties eliciting variation also fall into broad classes as predicted by the BRAH. Place elicits variation, even in a lack of total segmental identity, whereas other features such as nasality do not. Some evidence also points to the primacy of surface identity versus underlying identity.

When evoked, the observed phonetic variation falls into three types. First, elements intervening between the two consonant closures may increase in duration. These elements

include the vowel as well as the aspiration interval of a voiceless aspirated consonant. When vowel deletion is possible, it applies less often in between repeated consonants. I argue that these processes represent the evolutionary seeds of phonological antigemination processes, along the lines discussed in Chapter Two. Less frequent deletion, and longer average duration, for these vowels makes them less likely to go unperceived as such when occurring between identical consonants.

Second, closure degree, duration and intensity may vary for the consonant in the weaker prosodic position in a repetitive sequence. Complete closure is less likely to be achieved. This effect is modulated by increased duration of these consonants as an effort minimization measure, which tends to have the opposite effect. This effect of increased duration also leads to the observed variation in intensity, which is lower for the consonants in question rather than higher as more lenition predicts.

I argue that this variation may lead to dissimilatory lenition, despite the greater similarity of repeated segments it elicits. This account goes against Ohala's (1993) generalization that there are no principles of speech production predicting dissimilative changes. He argues that dissimilation is uniformly due to "the listener's misapplication of corrective processes [in speech perception]," which "undo or reverse the predictable perturbations found in speech." Listeners are spurred to dissimilate by hypercorrecting in their normalization of the acoustic signal, so that intended acoustic/articulatory properties are interpreted as unintended byproducts of coarticulation. This stance has been widely taken up in the literature, and Kiparsky's (1995) review article on phonological change reiterates the view that because dissimilation is not articulatorily natural, it is necessarily due to perceptual reanalysis (via hypercorrective normalization).

Here I propose an alternative source of dissimilation and a potential example of its application. In at least this case, dissimilation is due to the interpretation of this variation as intentional – not because of variation being interpreted as *unintentional* coarticulation. An independent bias toward contour perception (see Chapter Five) may bolster this behavior. However, due to the contradictory nature of the phonetic variation induced in repeated consonants, phonological dissimilation prompted by it occurs less often than antigemination.

Finally, a third effect is a persistent increase in duration that extends rightward beyond the locus of repetition itself (skipping the prosodically strong consonant if second in the sequence). This non-local effect does not appear to have phonological counterparts in grammar.

## Appendix 1: Stimulus lists

### Experiment 1 stimulus list (n=81)

bababeet	badadeet	bagageet	beedabeet	beegadeet	boobageet	boogabeet
bababoot	badadoot	bagagoot	beedaboot	beegadoot	boobagoot	boogaboot
bababot	badadot	bagagot	beedabot	beegadot	boobagot	boogabot
babadeet	badageet	beebabeet	beedadeet	beegageet	boodabeet	boogadeet
babadoot	badagoot	beebaboot	beedadoot	beegagoot	boodaboot	boogadoot
babadot	badagot	beebabot	beedadot	beegagot	boodabot	boogadot
babageet	bagabeet	beebadeet	beedageet	boobabeet	boodadeet	boogageet
babagoot	bagaboot	beebadoot	beedagoot	boobaboot	boodadoot	boogagoot
babagot	bagabot	beebadot	beedagot	boobabot	boodadot	boogagot
badabeet	bagadeet	beebageet	beegabeet	boobadeet	boodageet	
badaboot	bagadoot	beebagoot	beegaboot	boobadoot	boodagoot	
badabot	bagadot	beebagot	beegabot	boobadot	boodagot	

### Experiment 2 stimulus list (n=16)

tarrabebble	tarrabrebble	tarragebble	tarragrebble
tarrabibble	tarrabribble	tarragibble	tarragribble
tarrabeggle	tarrabreggle	tarrageggle	tarrareggle
tarrabiggle	tarrabriggle	tarragiggle	tarragriggle

### Experiment 3 stimulus list (n=169)

babawd	bamood	daboon	daneeb	madoob	nabawm	namoob
babawm	bamoom	dadawb	daneed	madoom	nabawn	namood
babawn	bamoon	dadawm	daneem	madoon	nabeeb	namoom
babeed	banawb	dadawn	daneen	mamawb	nabeed	namoon
babeem	banawd	dadeeb	danoob	mamawd	nabeem	nanawb
babeen	banawm	dadeem	danood	mamawn	nabeen	nanawd
babood	banawn	dadeen	danoom	mameeb	nabob	nanawm

baboom	baneeb	dadoob	danoon	mameed	nabood	naneeb
badawb	baneed	dadoom	mabawb	mameen	naboom	naneed
badawm	baneem	dadoon	mabawd	mamoob	naboon	naneem
badawn	baneen	damawb	mabawm	mamood	nadawb	nanoob
badeeb	banooob	damawd	mabawn	mamoon	nadawm	nanood
badeem	banood	damawm	mabeeb	manawb	nadawn	nanoom
badeen	banoom	damawn	mabeed	manawd	nadeeb	
badoob	banoon	dameeb	mabeem	manawm	nadeem	
badoom	dabawb	dameed	mabeen	manawn	nadeen	
badoon	dabawd	dameem	maboob	maneeb	nadoob	
bamawb	dabawm	dameen	mabood	maneed	nadoom	
bamawd	dabawn	damoob	maboom	maneem	nadoon	
bamawm	dabeeb	damood	maboon	maneen	namawb	
bamawn	dabeed	damoom	madawb	manoob	namawd	
bameeb	dabeem	damoon	madawm	manood	namawm	
bameed	dabeen	danawb	madawn	manoom	namawn	
bameem	daboob	danawd	madeeb	manoon	nameeb	
bameen	dabood	danawm	madeem	nabawb	nameed	
bamoob	daboom	danawn	madeen	nabawd	nameen	

Items erroneously excluded: badawd badeed badood madawd madeed madood nadawd nadeed nadood nameem.

Experiment 4 stimulus list (n=36)

kawdid	keetid	pawdid	peetid	sawdid	seetid
kawdit	keetit	pawdit	peetit	sawdit	seetit
kawtid	koodid	pawtid	poodid	sawtid	soodid
kawtit	koodit	pawtit	poodit	sawtit	soodit
keedid	kootid	peedid	pootid	seedid	sootid
keedit	kootit	peedit	pootit	seedit	sootit

Experiment 5 stimulus list (n=36)

kakeel	kapool	pakeel	papool	takeel	tapool
kakeen	kapoon	pakeen	papoon	takeen	tapoon
kakool	kateel	pakool	pateel	takool	tateel
kakoon	katool	pakoon	pateen	takoon	tateen
kapeel	kateen	papeel	patool	tapeel	tatool
kapeen	katoon	papeen	patoon	tapeen	tatoon

Experiment 6 stimulus list (n=32)

kakaleet	kokaleet	pakaleet	pokaleet
kakaloot	kokaloot	pakaloot	pokaloot
kakareet	kokareet	pakareet	pokareet
kakaroot	kokaroot	pakaroot	pokeroot
kapaleet	kopaleet	papaleet	popaleet
kapaloot	kopaloot	papaloot	popaloot
kapareet	kopareet	papareet	popareet
kaparoot	koparoot	paparoot	poparoot

## **Appendix 2: Vowel repetition effects?**

In addition to the consonant effects investigated in the preceding chapter, potential effects of vowel repetition were also investigated. Vowel repetition has been shown to result in slower, more erroneous responses in a nonword reading task (Tamaoka and Murata 2001), just as slower speech production rates in contexts involving consonantal repetition have been documented previously by Sevald and Dell (1994). However, Odden (1988) points out that while vowel deletion is often sensitive to identity/similarity of the flanking consonants, consonant deletion never appears to be likewise sensitive to the identity/similarity of flanking vowels. This asymmetry suggests that vowel repetition is not generally subject to dispreference in the same way as consonant repetition is. In addition, Suzuki (1998) points out in his cross-linguistic study of dissimilation that vowel dissimilation is not only less frequent than dissimilation between consonants, but happens in more restricted environments (only between adjacent vowels, whereas consonant dissimilation can apply over considerable distances). The typological prevalence of vowel harmony systems bolsters this point, especially as compared with the relative rarity of consonant harmony, which is never known to occur with respect to place of articulation (Hansson 2001).

Lexical MSCs on vowel cooccurrence have not been investigated to nearly the same extent as consonant cooccurrence restrictions, but what little evidence is available suggests that vowel cooccurrence is favored rather than disfavored. Carre and colleagues have documented a statistical tendency toward vowel harmony in the French lexicon (Carre *et al.* 1995), and Tamaoka and Murata (2004) show that cooccurrence of identical vowels in Japanese forms happens at a greater than expected rate.

To the extent that evidence is available, then, it suggests that vowels and consonants follow opposite tendencies with respect to repetition. Articulatory Phonology encodes this distinction by stipulating contiguity of vowels even across intervening consonants, but not of consonants across vowels (Gafos 1999). This reflects the smooth transitions between vowel articulations in such contexts, observed since the 1960s (Öhman 1966).

If repetition of vowel gestures behaves similarly to consonant gesture repetition, we should expect to see the same kinds of effects on V1, V2 and intervening segments when vowel quality is repeated as we do for consonant repetition. If vowels are subject to the opposite

restriction, no duration variation is predicted and assimilation of vowel quality is expected. The remainder of this appendix preliminarily investigates these opposing predictions.

*Duration*

In fact, a small effect of vowel repetition on schwa seems to appear just as it does for consonants (e.g. *beedageet* vs *beedagoot*; RM ANOVA,  $F(1,8)=14.696$ ,  $p=.005$ ). That is, schwas flanked by two [i] vowels or two [u] vowels are slightly but significantly longer than those for which the neighboring vowels differ.

Subject	V-REP	sd	non-V-REP	sd
1	52	14	54	11
2	57	14	53	13
3	51	14	48	13
4	47	21	44	21
5	70	12	66	13
6	79	11	78	13
7	58	19	54	17
8	61	12	58	14
9	63	11	57	12
<b>Overall</b>	<b>61</b>	<b>17</b>	<b>57</b>	<b>22</b>

Table 44: Mean schwa duration in vocalic REP and non-REP environments.

Post-hoc tests (Tukey HSD) reveal that schwa duration in both [i]-REP contexts and [u]-REP contexts differs significantly from in non-REP contexts ( $p=.037$  and  $.047$  respectively), but not from each other ( $p=.999$ ). Means provided above show that the durational asymmetry holds within subjects for all but one individual (Subject 1). This effect appears even though the set of non-REP tokens are subject to coarticulation with low vowels, which should lower the quality of the schwa via coarticulation and therefore be associated with longer duration. Also, it occurs even though the durational threshold established between the repeating vowels by the medial CVC sequence is considerably longer than the one derived from the double-tonguing data (mean

medial CVC duration of approximately 160 ms, versus a boundary beneath 100 ms for single-tongue sequences).

The presence of both C-REP and V-REP contexts suggests a cumulative effect for repetition on schwa duration, with C-REP taking precedence. As this table shows, duration increases with the presence of each REP context.

<b>non-C-REP</b>	<b>sd</b>	<b>non-C-REP</b>	<b>sd</b>	<b>C-REP</b>	<b>sd</b>	<b>C-REP</b>	<b>sd</b>
<b>non-V-REP</b>		<b>V-REP</b>		<b>non-V-REP</b>		<b>V-REP</b>	
54	14	57	15	64	19	68	19

Table 45: Mean schwa duration in ms for both REP environment types.

The durational effect on schwa appears to be the only one prompted by vowel repetition, however. No durational difference is observed for V1 and V2 themselves when classed by V-REP context:

	<b>V-REP</b>	<b>non-V-REP</b>	<b>RM ANOVA</b>
<b>V1=[i]</b>	93	92	F(1,8)=1.175, p=.31
<b>V1=[u]</b>	95	92	F(1,8)=.976, p=.352
<b>V2=[i]</b>	124	126	F(1,8)=4.209, p=.074
<b>V2=[u]</b>	130	129	F(1,8)=3.408, p=.102

Table 46: V1 and V2 durations (ms) according to V-REP context and RM ANOVA results.

Nor is there any significant effect on C1 duration according to V-REP context (RM ANOVA F(1,8)=1.664, p=.22).

### *F2 Frequency*

Let us now investigate vowel quality as a variable. Reduction to a less extreme articulatory position might be expected for one or both vowel tokens, either due to inherent articulatory difficulty presented by repetition or as a sort of dissimilation from a non-reduced token in the

repeated sequence. Alternatively, formant values might be closer together for repeated tokens, in a phonetic harmony effect prompted by coarticulation.

F2 of V1 and V2 [u] tokens is tested as such a variable. The F2 value at the midpoint of each [u] vowel token was obtained using the PRAAT acoustic analysis software program. American English is characterized by variation in the front/backness of [u] (Labov *et al.* 2005). Thus like schwa length and voiced stop lenition, it is a dimension which might be expected to vary and therefore be exploitable for the purposes of ameliorating articulatory repetition.

However, the difference between F2 values of the vowels in either position (V1 or V2) according to V-REP context is minimal. Mean F2 in Hz over the entire duration of the vowel is given in the table below.

	<b>V-REP</b>	<b>sd</b>	<b>non-V-REP</b>	<b>sd</b>
<b>F2-V1</b>	1437	390	1414	399
<b>F2-V2</b>	1744	400	1763	402

Table 47: Mean F2 values in Hz of V1 and V2 [u] tokens according to V-REP context.

In addition to the raw F2 frequencies of these vowel tokens, the gap between the F2 values of V1 and V2 tokens in individual stimulus tokens containing [u]-repetition was computed. The size of this gap was then compared to the expected one calculated from non-V-REP occurrences of [u] in each position. The table below gives the mean difference in F2 (Hz) between left-edge [u] tokens and right-edge [u] tokens for each REP environment. The third column contains the difference between the two differences – that is, whether and how much larger the V-REP gap is compared to the expected, non-V-REP gap.

Subject	V-REP	non-V-REP	Difference
1	265	267	-2
2	276	395	-19
3	333	339	-6
4	334	374	-30
5	309	349	-40
6	360	337	23
7	208	253	-45
8	292	258	34
9	375	464	-89
<b>Overall</b>	<b>307</b>	<b>349</b>	<b>-42</b>

Table 48: Difference in Hz between F2 values in V1 and V2 positions.

The overall gap is in fact *smaller* in V-REP tokens than non-V-REP tokens, but individual subject data reveals that this tendency is inconsistent in both size and direction. The F2 gap is not significantly either smaller or larger in contexts involving vowel repetition (RM ANOVA  $F(1,8)=3.572, p=.095$ ).

### *Summary*

Cross-linguistic tendencies suggest that vowels may be subject to repetition enforcement in preference to repetition avoidance. The results of these preliminary investigations are generally compatible with this view. While vowel repetition seems to elicit a durational increase on an intervening segment (schwa) similar to the consonant repetition increase, the difference is much smaller. It is also associated with an otherwise much longer interval between the relevant repeated segments, contrary to what is observed and expected for consonants. This suggests that the effect, if it is a real one, may be due to some other cause than gesture repetition.

In addition, none of the other segments local to the repetition environment show a duration increase such as the one that consonant repetition elicits. Finally, no consistent effect on vowel quality appears.

### **Appendix 3: Place asymmetries**

Chapter Two points out that place of articulation is preferentially targeted in consonant cooccurrence restrictions. Within the category of place, there are various reasons to expect asymmetries according to primary articulatory. For example, I have argued that the relatively high tolerance of coronal cooccurrence is due to its masslessness and the correspondingly lesser articulatory effort required to employ it.

Alternatively, underspecification of coronals also could predict more cooccurrence within this class, since they would then be identical on one less dimension than other consonant categories. Newman, Sawusch and Luce (1999) have argued that the high token frequency of coronals in English makes them less perceptually similar to each other, which might also correspond to more tolerance of their cooccurrence. FPB account for the exceptional behavior of coronals by reference to the generally larger number of them in phonemic inventories. Finally, the relatively wide-ranging target areas of both velars and coronals could render their cooccurrence more tolerated compared to labials.

In this appendix I first review place of articulation-related asymmetries in the consonant cooccurrence restrictions discussed in Chapter Two. I then review behavioral evidence for the continuing relevance of these restrictions synchronically and psycholinguistically, which suggests that they also have an effect in the experimental data of Chapter Three. The next section explores possible place asymmetries in that experimental data.

Although coronal cooccurrence does seem more likely to be tolerated in the lexical data, the typology is inconsistent. Neither are the experimental results clear-cut, and even the coronal effect seems to be reversed in them. I close with a brief look at featural asymmetries other than place.

#### *Lexical place asymmetries*

The behavior of labials is puzzling. Van de Weijer (2005a) finds that in the quartet of Germanic languages he examines (Dutch, German, English, Swedish), labials are *overattested* in combination with each other, rather than *underattested* as their homorganicity predicts. His lexical statistics are supported by Alfonso's (1981) experimental finding for English that while homorganicity with the onset in general leads to misperception of a coda consonant as heterorganic, this generalization can be reversed for labials. Contradicting these apparent effects

of labial exceptionality to repetition restrictions is Coetzee's observation that repetition of [p] in sCV(C)C English forms, both attested words and non-words, is less frequent and perceived as worse than repetition of [k] in such contexts. Amharic and Chaha also allow less cooccurrence of labials than of velars, while for Muna labials fall in the middle of the place hierarchy. In the Mayan language Chol underattestation of homorganic consonants within a root is significant for coronals and velars, but near-categorical for labials. Finally, Suzuki's cooccurrence data shows much less cooccurrence permitted for labials than any other place – in his sample, labial is the preferred target of consonant place dissimilation by far.

The labial consonant class, then, can fall on both the more restricted and less restricted ends of the cooccurrence continuum – even within a single language, depending on task and context. I have no insight to offer for why this is so. While labials are set apart from other places by virtue of their robust visual cues and their use of muscles not employed by other consonants, these factors cannot address their seemingly contradictory behavior as a class.

Velars also behave somewhat contradictorily. While they are singled out less as a class than either labials or coronals, they also appear at both ends of the cooccurrence spectrum. Velars can cooccur less than other places in Muna and Korean, but more so than labials in Amharic and Chaha. (However, the latter may be an artifact of the strange behavior of labials rather than a true generalization about velars). Even the Muna/Korean asymmetry is belied by Suzuki's dissimilation corpus, however, as velars prompt no dissimilation at all in his sample (versus two dissimilation processes for coronals and seven for labials). This implies that their cooccurrence should be more tolerated, rather than less as in Muna and Korean.

Cooccurrence of coronals tends to be tolerated best (in Arabic, English, Thai, and Muna). In their survey of eight languages, Pozdniakov and Segerer classify labials and velars together as a single superclass, and find that they show greater cooccurrence avoidance than coronals. FPB attribute this asymmetry to a larger class inventory leading to less perceived similarity, though Muna has been claimed not to be amenable to this explanation. In English at least, frequency may also be relevant.

The following table summarizes these place-related asymmetries:

Language	Less-to-More cooccurrence
Arabic	non-coronals < coronals
Eng-lexical	non-coronals < coronals
Eng-percep	velars/coronals < labials
Eng-sCvC	labials < velars < coronals
Dutch	non-labials < labials
German	non-labials < labials
Swedish	non-labials < labials
Thai	non-coronals < coronals
Amharic	labials < velars
Chaha	labials < velars
Muna	velars < labials < coronals
Korean	velars < non-velars
Chol	labials < coronals, velars
Latin	no place asymmetries

Table 49: Languages with consonant cooccurrence place asymmetries.

Place-related asymmetries abound, but are not wholly cross-linguistically consistent. This lack of consistency is expected in the FPB model, which predicts differences based on the structure of the phonemic inventory, though it does not seem to account for all the asymmetries observed.

*Behavioral data*

Frisch and Zawaydeh (2001) present evidence that at least in its most general form, the restriction against identical/homorganic consonant cooccurrence is known and actively employed by Arabic speakers. They show that when presented with nonce forms violating the homorganicity restriction, speakers rate them as significantly less wordlike than forms containing accidental gaps of similarly low frequency. A second study shows that wordlikeness ratings correlate with similarity and proximity of the relevant consonant pair in the predicted fashion. FPB also present evidence from Romance loanwords into Maltese, a historically Semitic

language, that forms which do not violate the homorganicity restriction are preferentially borrowed over those that do. Their conclusion is that the OCP-like restriction(s) on consonant cooccurrence are therefore an active part of the grammar rather than a static, residual effect on the lexicon.

Hebrew has also been the object of psycholinguistic experimentation, showing that speakers disprefer OCP-violating non-roots on a gradient scale in ratings tasks and are quicker to reject non-words that include OCP violations (Berent, Everett and Shimron 2001; Berent and Shimron 1997).

Also as in Arabic, the apparent lexical OCP effect in English is well supported by a variety of experimental evidence coming from behavior, perception, and corpus analysis. Alfonso (1981) finds that in CVC monosyllables, misidentification of C1 place is significantly more frequent when it is identical to C2 place, such that homorganic sequences are misperceived as heterorganic. Coetzee (2005a,b) bolsters these observations with experimental results showing that English speakers shift phonemic categorization boundaries along the labiovelar continuum in nonwords of the form sCVC, so that the place of C2 differs from that of C1. Again, speakers tend to misperceive OCP-violating forms as non-violations. In a lexical decision task, the former, OCP-violating forms are also more quickly rejected than the non-consonant-repeating ones.

The OCP also seems to motivate certain gradient effects in the derivational morphology of English. Berkley (1994b) documents variation in –[ity] affixation in which the ability to do so correlates with the similarity of the final consonant to the suffixal consonant [t]. In Chapter Two we will see synchronic evidence that speakers are highly resistant to producing sequences of flaps which could result when that final consonant is one of the two most-similar consonants, [t] or [d]. A similar pattern of underattestation is seen in for –[ate] suffixation and, after velar-final forms, –[ic] suffixation. These effects are lexical in a similar sense to the root-internal effects discussed above, with synchronic variation also existing. While comparative –[er] suffixation has been argued to contravene the pattern established so far and be more rather than less likely after [r]-final forms (Quirk *et al.* 1985), Mondorf (2003) finds a strong effect going the other direction. This is expected given the otherwise inevitable (and OCP-violating) sequence of multiple [r] tokens. In such cases, the periphrastic *more* construction is preferred to suffixation. Finally, Mondorf identifies a similar bias is found against superlative –[est] suffixation for sibilant-final forms, as previously posited by Jespersen (1956) and Sweet (1968). Similar

patterns in suffixation are seen for unproductive ones in Chichewa, which avoid homorganic bases (Hyman to appear).

In addition to English, Berkley discusses French and Latin in this respect. French effects specific to suffixation are summarized by Roche and Plenat (2003) – briefly, suffixation which would result in the sequence [isis] is haplologized, and for those which tautosyllabic [d] and/or [t] would result, additional segments intervene that result in more distance between the two coronal stops. A lexical decision study on Swedish also supports active knowledge of these consonant cooccurrence restrictions. Van de Weijer (2005b) finds that Swedish speakers are slower to accept real words containing identical consonants separated by two or more segments, and quicker to reject nonce words of such form.

An (2007) provides synchronic and experimental evidence for the persistence of cooccurrence constraints in Korean grammar in her discussion reduplication process applying to vowel-initial stems, usually with a VCVC skeleton. In the reduplicant, the stem onset is filled with some consonant the choice of which involves considerable optionality, but with the restriction that it may not match the stem consonant(s) in place or, preferably, manner. In a corpus of such reduplicated forms, An finds that the inserted consonants categorically avoid matching the leftmost base consonant in both place and manner, and in the majority of cases match it in neither. The reduplicant C (RC) and leftmost base C (LC) match in place of articulation only 15% of the time. Interestingly, the independent effect of manner is nearly as strong, with manner-matching occurring only 24% of the time. This may be because the most frequent non-stop inserted consonant is [tʃ], which appears to be construed by An as differing from coronal only in the manner feature. Insofar as its palatality constitutes a place difference as well, the strength of this kind of place effect would artificially boost the rate of manner non-matching.

Similar generalizations hold of the RC and rightmost base consonant, though to a weaker extent. The prohibition against matching in both place and manner is no longer categorical, and happens in 10% of cases, while 40% rather than a majority of pairs differ in both place and manner. When considered separately, the place and manner features are of roughly equivalent dispreferred status when it comes to cooccurrence, each doing so 33-35% of the time. Interestingly, the RC-rightmost C pair is actually closer together in terms of timing slots than the RC-LC pair considered in the previous paragraph, since the reduplicated outputs are of the form

(base)VCVC-CVCVC(reduplicant). A distance effect like that of other languages applies, but apparently only within the base form – the presence of a morphological boundary appears to significantly relax the cooccurrence restriction strength, as in other languages, despite greater surface proximity to the RC. Finally, in a word creation experiment in which subjects were asked to reduplicate nonce form base words, An finds that all the same tendencies exist to an even stronger degree than in the corpus of attested reduplicative forms.

Turkish is not known to restrict consonant cooccurrence in the lexicon in the same way as these preceding languages, though Wedel (2000) does find that voiceless consonants in it are rarely followed by their homorganic voiced obstruent counterparts. Setting this aside, it also has an emphatic reduplication process highly reminiscent of the one documented by An (Dobrovolsky 1987, which documents similar processes in Uzbek and Yakut; Demircan 1987, Kelepir 1999, Yu 1999). The first CV of base forms is employed as a prefixal reduplicant, and the coda of the resulting initial syllable filled with one of the consonants from the set [p, s, m, r]. Again there is a degree of optionality in the choice of the inserted consonant, and again it is typically restricted to those which are neither identical nor “too similar” to any consonants of the base form, with some effect also of proximity to the insertion site (though for alternative analyses of consonant choice see Yavas 1980, Vaux 1998). Wedel (1999) provides experimental evidence in a forced reduplication task of the continuing productivity of this process and the role of OCP-like restrictions on it.

#### *Experimental place asymmetries*

In addition to the possible reasons for place-based asymmetries mentioned above, Experiment One (*badageet*) introduces two experiment-specific ones. Velars are the only place in the stimulus set for which there is never a triple sequence within the word, and might therefore elicit a different effect. C1 coronals are subject to flapping and C2 coronals are not. The resulting allophonic difference makes them less similar, which is another reason they might show a lesser effect.

However, none of the above hypotheses about place of articulation effects on schwa variation are borne out. Schwas have overall *longer* durations when between two coronals than between two velars or two labials, as shown by the table below.

Subject	Cor-V-Cor	sd	Lab-V-Lab	sd	Vel-V-Vel	sd
1	63	11	54	9	64	7
2	68	9	56	17	60	14
3	55	10	48	22	52	22
4	75	7	35	29	18	31
5	86	9	75	11	74	11
6	77	7	86	9	84	9
7	62	18	74	100	67	13
8	74	8	59	8	68	8
9	66	9	60	13	71	13
<b>Overall</b>	<b>70</b>	<b>14</b>	<b>63</b>	<b>42</b>	<b>64</b>	<b>21</b>

Table 50: Mean schwa duration according to place of flanking identical Cs.

However, a repeated-measures ANOVA shows no statistically significant overall effect of place on schwa duration ( $F(1,8)=1.763$ ,  $p=.203$ ). In planned comparisons, coronal place is not significantly different from either labial ( $F(1,8)=3.103$ ,  $p=.116$ ) or velar ( $F(1,8)=1.331$ ,  $p=.282$ ). The same result obtains if statistical analysis is carried out over the percent change in schwa duration from the mean in non-REP contexts, rather than values in absolute milliseconds – no significant differences by place emerge (RM ANOVA  $F(1,8)=.906$ ,  $p=.424$ ).

It is possible that these measures are confounded by independent effects of consonant place on neighboring vowel length, regardless of repetition. I attempt to address this issue by establishing an expected value for schwa duration according to the place of the preceding and following consonant. The mean schwa duration per subject in each environment is averaged together to obtain this value (e.g. mean schwa durations before and after coronals, divided by two). This expected value is given in the following table.

Subject	Cor-X	X-Cor	C-C	Lab-X	X-Lab	L-L	Vel-X	X-Vel	V-V
1	57	47	<b>52</b>	48	52	<b>50</b>	57	61	<b>59</b>
2	56	58	<b>57</b>	51	49	<b>50</b>	53	54	<b>54</b>
3	52	49	<b>51</b>	47	46	<b>47</b>	48	51	<b>50</b>
4	58	55	<b>57</b>	40	39	<b>40</b>	36	38	<b>37</b>
5	69	72	<b>71</b>	68	62	<b>65</b>	64	68	<b>66</b>
6	79	75	<b>77</b>	77	79	<b>78</b>	78	80	<b>79</b>
7	60	58	<b>59</b>	51	43	<b>47</b>	49	59	<b>54</b>
8	66	57	<b>62</b>	55	52	<b>54</b>	53	66	<b>60</b>
9	59	59	<b>59</b>	56	55	<b>56</b>	61	63	<b>62</b>
Overall	56	55	<b>56</b>	56	49	<b>53</b>	52	59	<b>56</b>

Table 51: Mean schwa duration by subject and preceding/following consonant, plus expected value of schwa in REP environment between identical ones.

This calculation does not take into account the already-observed lengthening effect on schwa when in an REP environment, but a further comparison of the observed schwa duration relative to the expected schwa duration will reveal *how much* of a lengthening effect occurs for each place. The durational difference is reported below for each place both in absolute terms (milliseconds) and as a percentage of the expected value.

Subject	Observed	Expected	Difference (ms)	Difference (%)
1	63	52	11	21
2	68	57	11	19
3	55	51	4	8
4	75	57	18	32
5	86	71	15	21
6	77	77	0	0
7	62	59	3	5
8	74	62	12	19
9	66	59	7	12
<b>Overall</b>	<b>70</b>	<b>56</b>	<b>14</b>	<b>25</b>

Table 52: Schwa duration between coronal consonants

Subject	Observed	Expected	Difference (ms)	Difference (%)
1	54	50	4	8
2	56	50	6	12
3	48	47	1	2
4	35	40	-5	-12
5	75	65	10	15
6	86	78	8	10
7	74	47	27	57
8	59	54	5	9
9	60	56	4	7
<b>Overall</b>	<b>63</b>	<b>53</b>	<b>10</b>	<b>19</b>

Table 53: Schwa duration between labial consonants.

Subject	Observed	Expected	Difference (ms)	Difference (%)
1	64	59	5	8
2	60	54	6	11
3	52	50	2	4
4	18	37	-19	-51
5	74	66	8	12
6	84	79	5	6
7	67	54	13	24
8	68	60	8	13
9	71	62	9	15
<b>Overall</b>	<b>64</b>	<b>56</b>	<b>8</b>	<b>14</b>

Table 54: Schwa duration between velar consonants.

Subject	Coronal	Labial	Velar
1	21	8	8
2	19	12	11
3	8	2	4
4	32	-12	-51
5	21	15	12
6	0	10	6
7	5	57	24
8	19	9	13
9	12	7	15
<b>Overall</b>	<b>25</b>	<b>19</b>	<b>14</b>

Table 55: Percentage increase in duration by subject and place.

Note first of all that the difference is almost invariably positive, as we expect due to the REP schwa lengthening effect already observed. More importantly, the percentage increase for

coronals is greater than for the other two places for six of the nine subjects. This matches our expectations based on the previous finding of overall greater length for coronals as well, though the asymmetry seen here is not totally consistent. Comparisons of observed and expected durations in repeated-measures ANOVAs show a highly significant difference for coronals and a significant one for labials, but not for velars (respectively, coronals  $F(1,8)=20.829$ ,  $p=.002$ ; labials  $F(1,8)=5.229$ ,  $p=.052$ ; velars  $F(1,8)=1.798$ ,  $p=.217$ ).

It seems that place of articulation is not strongly associated with differences in degree of schwa lengthening. If the coronal effect is a real one, it is not explicable by means of any of the place-related hypotheses listed above.

Experiment Three (*dadeed*) also finds the longest schwa vowels between coronals, but only within the nasal subclass. Data from this experiment show no strong independent effect for place or nasality on duration of a neighboring schwa independent of the presence of repetition, as the following table demonstrates.

	<b>b</b>	<b>sd</b>	<b>d</b>	<b>sd</b>	<b>m</b>	<b>sd</b>	<b>n</b>	<b>sd</b>
<b>Duration of following schwa</b>	59	19	58	21	60	15	63	17
<b>Duration of preceding schwa</b>	58	16	61	20	59	18	61	19

Table 56: Mean durations and standard deviations of schwa by neighboring consonants.

The range of mean duration is tightly compressed within 5 ms at most. One can estimate an expected duration of each schwa, regardless of neighboring consonants, as approximately 60 ms. This suggests that systematic variation in schwa duration among REP contexts, if it exists, is wholly attributable to differing degrees of difficulty among the repetitive sequences.

The following table gives mean schwa durations by subject for each REP context.

<b>Subject</b>	<b>b-b</b>	<b>sd</b>	<b>d-d</b>	<b>sd</b>	<b>m-m</b>	<b>sd</b>	<b>n-n</b>	<b>sd</b>
<b>1</b>	38	9	45	9	51	9	56	7
<b>2</b>	55	11	55	16	62	11	75	13
<b>3</b>	53	7	37	8	60	8	58	5
<b>4</b>	72	9	87	9	74	7	82	7
<b>5</b>	49	7	52	10	53	10	71	8
<b>6</b>	68	13	57	17	64	19	71	8
<b>7</b>	62	7	67	14	66	6	76	12
<b>8</b>	72	16	71	11	72	18	75	9
<b>9</b>	83	18	97	15	71	10	98	8
<b>Overall</b>	<b>61</b>	<b>17</b>	<b>63</b>	<b>22</b>	<b>64</b>	<b>14</b>	<b>74</b>	<b>14</b>

Table 57: Mean durations and standard deviations of schwa by neighboring consonants in identity-repetitive contexts.

A repeated-measures ANOVA shows a significant effect for environment among these ( $F(1,8)=33.673$ ,  $p<.001$ ). Planned comparisons reveal that the only significant contrast is one of the coronal nasal [n-n] sequence compared to the other three. Just as in the first experiment, coronals are associated with longer intervening schwas than other places of articulation. Here, however, the effect is limited to nasal coronals, despite the inertness of these features independently.

Unlike in Experiments One and Three, coronal place does not stand out as eliciting longer intervening schwas than other places of articulation in Experiment Five (*papeen*). On the contrary, labial REP sequences are associated with the longest schwas, followed by velars, and coronal place has the smallest mean.

<b>Subject</b>	<b>Cor-V-Cor</b>	<b>sd</b>	<b>Lab-V-Lab</b>	<b>sd</b>	<b>Vel-V-Vel</b>	<b>sd</b>
1	4	7	35	14	22	21
2	30	14	26	15	34	22
3	25	18	56	11	49	9
4	36	18	41	11	44	10
5	55	7	57	6	47	11
6	78	27	59	11	57	17
7	43	20	37	8	41	9
8	24	16	37	3	37	23
<b>Overall</b>	<b>33</b>	<b>28</b>	<b>42</b>	<b>15</b>	<b>37</b>	<b>20</b>

Table 58: Schwa durations in REP environments by subject and place.

However, there is no statistically significant effect of place on the REP effect (RM ANOVA  $F(2,7)=.949$ ,  $p=.411$ ; planned comparisons indicate no significant contrasts).

Experiment Two (which in any case uses only the places labial and velar) was not tested in this regard, and Experiment Four (*kawdid*) provides no relevant place-related data, as all the crucial consonants are coronals. Experiment Six is also uninformative due to the lack of a baseline duration increase effect. The available evidence from the other three only adds another layer of inconsistency to an already inconsistent typology.

*Non-place asymmetries*

Many of the above languages subclassify their consonant inventories so that certain pairs are less likely to cooccur, on top of the place-based asymmetries discussed above. This occurs primarily with the coronal class, which is typically both larger than the other place series and more tolerant of cooccurrence in general. The following table lists subclassifications of the coronal place class:

<b>Language</b>	<b>Cooccurrence subclassification</b>
Thai	obstruents/sonorants
Amharic	obstruents/sonorants/fricatives
Chaha	obstruents/sonorants/fricatives
Javanese	obstruents/sonorants
Japanese	obstruents/sonorants
Arabic	voiced/unvoiced
Chol	obstruents/stridents

Table 59: Cooccurrence subclassifications of the coronal series.

For all the above languages, segments in these subclasses are less likely to cooccur if they fall in the same subclass. For some other subclassifications, greater restrictions hold only of one half of the subclass, as if the relevant feature is privative. This is true for the feature liquid for the five languages Arabic, English, Dutch, German, and Swedish. Arabic also has a stronger restriction against cooccurring pharyngealized (“emphatic”) coronal consonants. This restriction is categorical, and doubtless related to the widespread process of “emphasis spread” or pharyngealization harmony in Arabic. The relevance of potential contrast neutralization in OCP

processes has been noted with respect to antigemination by Bakovic (2005). We will return to this question in the discussion of antigemination below.

Moving beyond the coronal class, Arabic more generally restricts the cooccurrence of segments matching in continuancy (so that fricatives are favored as the first of a series). Pharyngeals are subclassified by dorsal/pharyngeal manner. Finally, oral labials may cooccur less than labials of other manners. Russian, Rotuman and Japanese subclassify by sonorancy in general, not just for the coronal subclass, and Muna does so by voicing. Note that the Muna case, in combination with the Arabic coronal voicing subclassification, belies Padgett's (1995) claim that voicing is invariably irrelevant in this respect. However, obstruent/sonorant appears as the cross-linguistically most common subclassifying characteristic, and coronal the class most likely to be subdivided. In Arabic, the sonorancy effect extends to continuancy as well. Stop-stop and fricative-fricative consonant pairs tend not to co-occur within the coronal class of consonants, and Elmedlaoui (1995) shows that this generalization also extends to the other places of articulation. For consonant pairs which do differ in continuancy, the preferred order is for the fricative to occur first in the word. Elmedlaoui speculates that OCP-Place violating sequences prefer decreasing sonority profiles, an observation more descriptive than explanatory. The role of continuancy in homorganic sequences is revisited in Chapter Three.

#### Appendix 4: Languages and language families with consonant cooccurrence restrictions

	Language	Language Family	Reference
1	Arabic	Semitic	Greenberg 1950, Frisch & Zawaydeh 2001, McCarthy 1986, Pierrehumbert 1993
2	Hebrew	Semitic	Koskinen 1964
3	Amharic	Semitic	Bender & Fulass 1978, Rose and King 2003
4	Chaha	Semitic	Rose and King 2003
5	Akkadian	Semitic	Reiner 1966
6	Maltese	Semitic	FPB
7	Tigrinya	Semitic	Buckley 1997
8	English	Indo-European- Germanic	Berkley 2000, Coetzee 2005, van de Weijer 2005a
9	Pidgin English (Port Moresby)	Indo-European- Germanic	Pozdniakov & Segerer to appear
10	German	Indo-European- Germanic	van de Weijer 2005a
11	Swedish	Indo-European- Germanic	van de Weijer 2005a, van de Weijer 2005b
12	Dutch	Indo-European- Germanic	van de Weijer 2005a
13	French	Indo-European- Romance	Berkley 2000
14	Latin	Indo-European- Romance	Berkley 2000
15	Russian	Indo-European- Slavic	Padgett 1995

16	Turkish	Altaic	Demircan 1987, Yavas 1980, Yu 1999, Kelepir 1999, Wedel 2000
17	Uzbek/Yakut	Altaic	Dobrovolsky 1987
18	Classical Mongolian	Altaic	Pozdniakov & Segerer to appear
19	Japanese	Japanese	Kawahara <i>et al.</i> 2005
20	Korean	Korean	An 2007, Ito 2007
21	Malagasy	Austronesian	Pozdniakov & Segerer to appear
22	Muna	Austronesian	Coetzee & Pater 2006
23	Rotuman	Austronesian	McCarthy 2003
24	Javanese	Austronesian	Mester 1986
25	Ponapean	Austronesian	Yip 1989
26	Tsou	Austronesian	Wright 1996
27	Cambodian	Austro-Asiatic	Yip 1989
28	Thai	Tai-Kadai	Haas 1955
29	Ngbaka	Niger-Congo	Broe 1995
30	Pomo	Niger-Congo	Yip 1989
31	Fula	Niger-Congo	Pozdniakov & Segerer to appear
32	Swahili	Niger-Congo	Pozdniakov & Segerer to appear
33	Tiene	Niger-Congo	Hyman to appear
34	Chichewa	Niger-Congo	Hyman to appear
35	Bantu reconstructed proto-lg	Niger-Congo	Pozdniakov & Segerer to appear
36	Luo/Alur	Nilo-Saharan	Yip 1989
37	Finnish	Uralic	Anttila 2002
38	Yucatec Maya	Mayan	McCarthy 1989
39	Chol	Mayan	Coon & Gallagher 2007
40	Basque	Basque	Pozdniakov & Segerer to appear
41	Quechua	Quechua	Pozdniakov & Segerer to appear

## Appendix 5: Speech errors

The presence of speech errors indicates difficulty in speech processing. It follows that if repetition is difficult, its presence should be associated with a higher rate of speech errors. Indeed, repetitive sequences have been found to evoke more errors in naturalistic corpora as well as in laboratory speech (Stemberger 1983). This appendix investigates the twin hypotheses that stimuli including repetition should be more subject to speech errors, and that these errors should tend to repair that repetition. Surveys of speech error research indicate that the most errors at the segmental level involve misorderings (Dell 1986, Levelt et al. 1999), so we might expect segment switches which resolve repetitive into non-repetitive consonant sequences.

The discussion below includes only error trials which were self-corrected by experimental subjects. (All errors, self-reported or not, are excluded from the analysis in the rest of the chapter). However, no effect of either kind is seen. The discussion below presents results in the same order as the experiments are discussed previously in this chapter.

### *Speech errors – badageet*

The table below gives the distribution of experimental stimuli according to place/quality and presence of repetition. Of the complete stimulus set, 28% of the stimulus items include a C-REP context, and 22% include a V-REP context. These repetitive subgroups are evenly divided among place of articulation (C-REP) and vowel quality (V-REP).

C1	C2	V
34% lab	33% lab	11% i
33% cor	34% cor	11% u
33% vel	33% vel	
33%		22%
CREP		VREP

Table 60: Experiment 1 stimulus distribution.

The following table gives these percentages for the smaller set of targets for which an erroneous response was produced.

C1	C2	V
42% lab	33% lab	16% i
38% cor	32% cor	14% u
20% vel	33% vel	
28%		30%
CREP		VREP

Table 61: Experiment 1 error-inducing stimulus distribution.

The likelihood of a C-REP target inducing an error goes slightly in the opposite direction than predicted – only 28% of the error-inducing stimulus targets involve repetition, compared to 33% in the stimulus set as a whole. As this difference is small, it is unlikely to be significant. However, the predominance of C1 labial stimuli in the error-eliciting subgroup may be due to constant presence of initial [b] for all stimuli. This [b] segment means that more repetition of labials occurs in the stimulus set. For example, the stimulus *babagot* is not classified as a C-REP stimulus in the analyses above, but nonetheless involves a repetitive sequence of [b] segments.

However, this fails to explain the even larger gap between coronals and velars, and seems incongruous with the overall apparent lack of effect. Also, data presented earlier showed no effect on the intervening vowel in this repetitive context.

In contrast to the consonants, V-REP contexts do appear to induce more errors. Thirty percent of the error-inducing set fall in the V-REP class, compared to only 22% of the entire set – a difference of 8%, compared to 5% (in the opposite direction) for consonants. The errors are split relatively evenly between the V-REP sequences of [i] versus [u] vowels.

### *Error types*

The set of *input* forms eliciting speech errors does not appear to fulfill our prediction, except possibly for repeated vowels. We will now consider possible effects of repetition on error *outputs*. The following table demonstrates the wide range in number of errors made per subject, with nearly half the error corpus due to a single speaker.

<b>Subject</b>	<b># of errors</b>
1	13
2	9
3	3
4	10
5	56
6	9
7	5
8	2
9	13
<b>Total</b>	<b>120</b>

Table 62: Number of errors by subject.

In spite of this variation, the error types detailed below are distributed quite evenly between subjects, and robust generalizations about error types can be made. Let us now consider the nature of the errors themselves. The following table lists the types of errors that occur and the number of each.

Error Type	Number	Example: Target>Production
Stress	7	BAbadoot>babaDOOT
V1 error	4	beebadoot>boobadoot
C1 error	31	babadot>bada
V2 error	17	bababoot>bababot
C2 error	19	beedagoot>beegadoot
Repetition	12	babadoot>babadoot
Medial syllable deletion	2	bababot>babot
Medial pause	1	bagadeet>baga-deet
Truncation	27	beegadot>beega
<b>Total</b>	<b>120</b>	

Table 63: Subtypes of speech error outputs.

Errors in stress assignment always shift it from the first syllable to the last, otherwise secondarily stressed syllable. Two of the V1 errors are of orthographic [oo] for orthographic [ee], a confusion that is plausible on visual grounds. Similarly, 15 of the 17 V2 errors involve confusion of orthographic single [o] for double [o] or vice versa (the remaining two are of [e] with [o]). These errors owe nothing to the linguistic properties of the stimuli, but instead seem to be motivated by the visual phenomenon of repetition blindness discussed in Chapter Five.

Repetition errors are those for which the subject self-corrected and repeated, despite there being no auditorily identifiable error in the first production. This leaves the majority of the errors as those of the two consonants C1 and C2, and/or of truncation. Regarding the latter, the following table identifies the point in the stimulus at which it was truncated. Forms for which truncation is the only error (*beegadot>beega*) are enumerated separately on the second row, above those for which another segmental error is present in addition to truncation (*beedabot>beedad*).

<b>Endpoint</b>		<b>b</b>	<b>ee</b>	<b>d</b>	<b>a</b>	<b>g</b>	<b>ee</b>	<b>t</b>	<b>Total</b>
<b>Trunc only</b>	2	0	8	0	14	3	0	--	27
<b>Trunc+error</b>	--	0	1	0	21	4	2	65	93
<b>Total</b>	2	0	9	0	35	7	2	65	120

Table 64: Endpoints of truncated erroneous forms.

Slightly over half (65/120) of the erroneous forms are complete forms, ending with the invariant final segment [t]. By far the next largest category (35/120, or slightly over one quarter) consists of truncated disyllables, comprising only the first foot of the target form. The rest are scattered thinly among the remaining options, with no other category approaching 10% of the total.

Let us now consider the 19 errors in C2, which are enumerated in the table below.

Error	Subject	Target	Production	Sub	Notes
1	8	bababeet	babageet	g/b	C-REP
2	7	beedageet	beedad	d/g	rt-copy
3	3	beedagoot	beegadoot	d/g	metathesis
4	5	boodageet	boogadeet	d/g	metathesis
5	5	boodageet	boogadeet	d/g	metathesis
6	9	boogagoot	boogadoot	d/g	C-REP
7	1	badabeet	badadeet	d/b	rt-copy
8	6	beebaboot	beebadoot	d/b	C-REP
9	5	beedabeet	beedadeet	d/b	rt-copy
10	2	beedabeet	beedadeet	d/b	rt-copy
11	1	beedabot	beedad	d/b	rt-copy
12	1	boodaboot	boobadoot	d/b	metathesis
13	8	babadeet	badab	b/d	metathesis
14	4	babadeet	bababeet	b/d	rt-copy
15	2	babadeet	bababeet	b/d	rt-copy
16	6	beebadeet	beedabeet	b/d	metathesis
17	4	beebadeet	beedabeet	b/d	metathesis
18	2	beebadeet	beebabeet	b/d	rt-copy
19	4	beebadot	beebabot	b/d	rt-copy

Table 65: Errors in C2 production.

Errors for C2 invariably involve substitution of one of the other possible C2 consonants in place of the target – that is, either of the two other voiced stops. The target forms are relatively evenly split between C2 place of articulation (7 [b], 7 [d], 5 [g]), whereas in the erroneous outputs velar place is dispreferred in favor of coronal (7 [b], 11 [d], 1 [g]). I have no hypothesis to offer that addresses this asymmetry, other than the generally more marked status of velars cross-linguistically.

While the output place data suggests a notion of (coronal) default substitution for C2, a relationship of substituted C2 to the other segments in the form also exists in most cases. The substituted C2 is the same as the C1 to its left in nine cases (approximately half), in a sort of rightward-copying of consonantal place. C1 and C2 appear to have metathesized in seven more of the forms. These within-word relationships may be epiphenomenal, given the lack of substitutions outside of the set of three possible C2 consonants. If one of the three consonants [bdg] must be used, and the previous consonant must also be chosen from the same set of three, then the appearance of rightward-copying is to be expected in roughly one third of the cases. Metathesis is also expected given the tendency toward segment reordering in speech errors (Levelt *et al.* 1999). This also makes the paucity of other substitutions surprising. Such substitutions occur only for the three remaining items, for which the erroneous C2 is either [g] (1) or [d] (2). These three items are also the only ones which fall into the C-REP category. Of course, either rightward copying of C1 or metathesis with C1 would be undetectable for C-REP forms, even if it did occur.

Rightward copying is obviously incapable of repairing an REP-violating sequence of identical consonants – on the contrary, it introduces one. As for the other errors, all three of the C-REP forms involve a substitution which avoids the C-REP sequence of the target. Six more errors (13-18) from the metathesis and rightward-copying classes also avoid a sequence of homorganic consonants – not word-medially, but at either the left or right edges of the word, and sometimes both. Thus as far as homorganic consonant sequences go, properties of the stimulus set mean that the error output forms are not significantly better or worse than the target/inputs.

This brings us to the predominant error form – a truncated disyllable with an erroneous C1 – accounting for slightly over one quarter (31/120) of all errors. These forms are given in the table below. Some are repeated from the C2 error table, since metathesis errors are double-counted in this respect.

Error	Subject	Target	Production	Sub	Notes
1	5	badageet	baga	g/d	?
2	5	beedageet	beega	g/d	?
3	5	beedageet	beega	g/d	?
4	5	beedageet	beega	g/d	?
5	4	beedageet	beega	g/d	?
6	3	beedagoot	beegadoot	g/d	metathesis
7	5	beedagot	beega	g/d	?
8	5	beedagot	beega	g/d	?
9	5	beedagot	beega	g/d	?
10	5	boodageet	boogadeet	g/d	metathesis
11	5	boodageet	boogadeet	g/d	metathesis
12	5	boodageet	booga	g/d	?
13	5	boodagoot	booga	g/d	?
14	2	beebagoot	beega	g/b	?
15	5	beebagot	beega	g/b	?
16	9	boobadot	booga	g/b	
17	5	boobagot	booga	g/b	?
18	2	bababoot	badab	d/b	C-REP
19	8	babadeet	badab	d/b	metathesis
20	4	babadeet	badadeet	d/b	l-copy
21	7	babadot	bada	d/b	?
22	5	babadot	bada	d/b	?
23	6	beebadeet	beedabeet	d/b	metathesis
24	4	beebadeet	beedabeet	d/b	metathesis
25	5	beebadeet	beeda	d/b	?
26	7	beegagot	beeba	b/g	r-copy; C-REP
27	5	boogabeet	booba	b/g	?
28	5	beedabeet	beebabeet	b/d	l-r-copy

29	9	beedaboot	beebea	b/d	?
30	5	beedadoot	beebadoot	b/d	r-copy; C-REP
31	1	boodaboot	boobadoot	b/d	metathesis

Table 66: Errors in C1 production.

Like C2, the substitution made in place of C1 is always one of the other two members of the set [bdg]. Unlike C2, the target forms are not evenly distributed in terms of place: rather, velar is underrepresented as an error target (12 [b], 17 [d], 2 [g]). As for the C1 error outputs, here velars are favored rather than dispreferred – counter to both the C1 target pattern and the C2 error output pattern, in which velars are avoided (6 [b], 8 [d], 17 [g]). Taken together, these two tendencies imply that velar is favored in C1 position – C1 place is not changed *from* it, and errors often involve a change *to* it. Again, I leave aside this complication.

Other generalizations about the source of the substituted segment in C1 position are more difficult to come by, given the truncated nature of most errors falling into this category (22/31, over two-thirds). For nearly all output forms, (27/31), the substituted C1 is the same as the target C2. Seven of these forms are definitely metathesized, and one a leftward copy of C2. Three more are [b]-substitutions potentially rightward-copied from the word-initial segment (or in one case, from either there or C2). Three more are substitutions with no within-word origin. But the remaining 18 items, over half the total, are indeterminate between metathesis and leftward-copying errors. The observed 7-to-1 ratio between metathesis and leftward copying among complete forms in this set suggests that most fall into the former category, and that the majority of forms, if completed, would result in C-REP repairing sequences rather than C-REP violating ones. However, this tendency is unverifiable (and does not hold for the C2 data set, a point against it). Thus each of these errors could potentially introduce a C-REP violation in addition to potentially repairing one.

Unlike the other error types, this one is dominated by errors from a single subject (Subject 5), who accounts for over half of the errors in this category (18/31). Therefore, a quick check against the set limited to the other eight subjects is in order. The tendency against targeting velars remains (8 [b], 4 [d], 1 [g] target), although it no longer predominates as an output (3 [b], 6 [d], 4 [g] outputs). Five of the forms are metathesized, one leftward-copied, and three

indeterminate between the two (one more is potentially rightward-copied, and another indeterminate between left and right copying). For both sets, then, it is impossible to say whether the observed errors are motivated by avoidance of homorganic consonant sequences, or a by preference for them as a kind of harmonizing operation.

### *Summary*

The REP status of a stimulus does not appear to influence its likelihood of being produced erroneously when it comes to consonants. Only a slight such tendency, if any, appears for vowels. Error outputs themselves divide relatively evenly with respect to REP status when C1 is considered, while C2 errors are unrevealing for unrelated reasons.

### *Speech errors – tarradiddle*

For this experiment we do not look at errors as such, but at the number of correct productions subjects produce for each condition (recall that a very fast speaking rate was enforced as part of experimental procedure). The expectation is that fewer tokens are produced of stimuli which include segmental repetition (~REP stimuli), particularly when the repetition is local (that is, without the segment [r] intervening as well as the vowel). This expectation is not borne out, as shown by the data in Table 67 below.

Subject	REP	non-REP	REP	non-REP
	local	local	r-ful	r-ful
1	41	37	50	45
2	45	55	44	49
3	56	58	50	56
4	41	37	41	43
5	51	45	48	42
6	38	40	44	44
7	49	41	41	46
8	46	48	52	53
9	56	49	52	52
<b>Overall</b>	<b>423</b>	<b>410</b>	<b>422</b>	<b>430</b>

Table 67: Number of stimulus tokens elicited by condition.

In the [r]-less conditions, more rather than fewer stimulus tokens are produced when segmental repetition is involved (n=423 versus 410). This tendency is not consistent, occurring for only 5 of the 9 subjects, and a repeated-measures ANOVA reveals that the asymmetry is not significant ( $F(1,8)=.548$ ,  $p=.48$ ). As for the [r]-ful conditions, the tendency is in the expected direction of fewer productions for stimuli with repetition, but again for only 5 of the 9 subjects, and again statistical significance is not reached ( $F(1,8)=.393$ ,  $p=.548$ ). Thus no reliable generalization can be made about the direction and nature of production numbers.

#### *Speech errors – dadeed*

Like Experiment 1, this experiment elicited a sizable number of speech errors, relatively evenly distributed among subjects (though with 2 noticeably more error-prone than the rest).

<b>Subject</b>	<b># of errors</b>
<b>1</b>	13
<b>2</b>	15
<b>3</b>	11
<b>4</b>	10
<b>5</b>	40
<b>6</b>	26
<b>7</b>	8
<b>8</b>	8
<b>9</b>	6
<b>Overall</b>	<b>137</b>

Table 68: Number of errors by subject.

The following table shows the percentage of REP contexts at each word edge for both the stimulus set as a whole, and for the subset of stimuli which are targets for erroneous productions.

	<b>All Stimuli</b>	<b>Error Targets</b>
<b>REP1</b>	25	17
<b>REP2</b>	25	20

Table 69: Percentage REP contexts by word position and stimulus set.

For both word positions, the percentage involving repetition is somewhat *lower* for the set eliciting speech errors than in the stimulus set as a whole. This is true for the left edge context already shown to prompt strong and consistent repetition-related variation, as well as for the right edge of the word which appears to be immune to such variation.

Let us now review types of errors generated from the stimulus targets.

<b>Error type</b>	<b>#</b>
C change only	66
C-change + trunc	28
Trunc only	13
Pause	13
C insertion	9
Vowel anomaly	8
Elsewhere	5
Undetectable	5

Table 70: Number of errors by type.

In addition to the types listed in the above table, one item inserts a word-final schwa vowel, two are produced anomalously slowly, and one includes an anomalously elongated nasal consonant. The resulting error count is higher than the total of 137 given above, since some forms contain multiple error types (e.g. partially truncated forms including a consonant substitution).

Most of the error types comprise only a handful of tokens – in particular, those for which subjects self-corrected despite no error being present that is audible to the experimenter, and those involving errors in the frame sentence outside the stimulus itself. Disfluent pauses before or during the stimulus occur to some extent, as do anomalously articulated vowels. Such vowel errors most often involve the pronunciation of the orthographic sequence [aw] in accordance with IPA norms rather than English orthography norms, and are doubtless due to the subject pool having some exposure to phonetic transcription.

Errors of consonant insertion are unevenly distributed among positions and phonemic types, as the table below shows.

	1	2	3
<b>B</b>	<b>mba</b> (mawm)	babdoob	badeebd
		mabdeem	namawbd
		nabdeeb	
<b>D</b>			
<b>M</b>	( <b>mba</b> )	nambeeb	
<b>N</b>	ndameeb	manmeen	

Table 71: Consonant insertion errors by position and inserted consonant.

Inserted segments are in bold. Most of the insertions are of [b], and occur word-medially or finally. In addition, the target position of insertion always immediately precedes a [d] segment. I have no speculation as to why that is the case. In only one example does the inserted [b] interrupt a identical-repetitive consonant sequence (though another does interrupt a non-identical but homorganic one). In an equal number of cases (one of identity, one of homorganicity), the insertion introduces rather than avoids a repetitive sequence. Finally, the errors cannot all or even most be the result of coproductions among the target constituent consonants – the kind that has been observed experimentally for errors which perceptually resemble consonant substitution (Pouplier and Hardcastle 2006) – since in many cases the inserted consonant is not otherwise present in the target form.

Truncation errors are distributed among possible endpoints as illustrated in the table below.

	d	a	d	ee	Total
<b>Trunc only</b>	1	10	1	1	3
<b>Trunc+C-change</b>	1	4	1	9	15
<b>Total</b>	2	14	2	10	28

Table 72: Truncation errors by endpoint.

As in Experiment 1, truncation seems to be bound by the syllable or primary-stressed vowel. Many of truncation errors include at least the first two consonant positions. In combination with the much greater number of consonant substitution errors which do not involve truncation at all, this yields the largest data set of all the experiments for investigating repetition outcomes.

With that in mind, let us move to the consonant substitution errors that constitute the bulk of the corpus. The following table gives the number of errors occurring by substitution and position. For each consonant substitution abbreviation **xy**, target **x** is produced instead as segment **y**.

	<b>bd</b>	<b>bm</b>	<b>bn</b>	<b>db</b>	<b>dm</b>	<b>dn</b>	<b>mb</b>	<b>md</b>	<b>mn</b>	<b>nb</b>	<b>nd</b>	<b>nm</b>	<b>Total</b>
<b>C1</b>	0	6	0	3	1	4	6	0	2	0	2	4	<b>28</b>
<b>C2</b>	8	8	1	0	0	1	8	0	5	0	2	3	<b>36</b>
<b>C3</b>	4	2	0	8	1	4	1	0	9	0	1	7	<b>37</b>
<b>Total</b>	<b>12</b>	<b>16</b>	<b>1</b>	<b>11</b>	<b>2</b>	<b>9</b>	<b>15</b>	<b>0</b>	<b>16</b>	<b>0</b>	<b>5</b>	<b>14</b>	<b>101</b>

Table 73: Errors by consonant substitution and position.

The likelihood of erroneous substitution is greater outside word-initial position, and the likelihood of the various substitutions correlates noticeably with similarity/perceptual confusability (Miller and Nicely 1955). Substitutions are most likely between segments sharing either place of articulation (labial pairs more so than coronals), or nasality/orality (nasal pairs being more substitutable than oral pairs).

Recall that the speech error literature finds most phoneme substitutions arising from the local context. Out of the substitutions elicited here, 12 are possible cases of metathesis with a neighboring consonant, 15 of leftward copy, and 13 of rightward copy. The total does not even approach the number of substitutions observed, even granted that additional ones could come from the preceding or following stimulus, not considered here. Rather, subjects appear to simply substitute one of the 4 possible consonants that are easily identifiable by the subjects as the set from which all are drawn.

Of the errors, the great majority (84/101) involve a substitution in only one position. Of the remaining 17, 2 involve a substitution at all three positions. Both these forms invert the

ordering of the consonants within the word (*dabeed badeeb, daneed nadeen*). Repetition is neither repaired nor introduced. Two more forms have errors in both C1 and C3 positions – one introducing a repetition at the right edge of the word (*namawd damawm*), and one a possible long-distance metathesis (*namawm mamawm*; repetition not introduced, but shifted to left edge). Multiple errors in contiguous positions are slightly more common. Five occur for C2 and C3, all of which are metathesis errors. One introduces repetition and one repairs it; homorganic pairs show the same symmetry, with one produced erroneously with total identity and one repaired to non-identity. Finally, 8 errors occur for both C1 and C2 positions. Half of these are metathesis errors, one of which repairs a repetitive sequence. One more could be considered either metathesis or leftward copying of a consonant. Two items involve leftward shift of C2 and C3 to the preceding positions, with either truncation or coproduction in C3 position. For the last such item, oral consonants are both produced as their nasal counterparts.

Among the set of single-consonant errors, some neither introduce nor repair repetition, but rather simply shift its location within the word. One might expect a bias in the direction of this shift, given the well-known Semitic pattern of repetition at the right edge of the word, and the corresponding gradient pattern in English stems (Berkley 2000). No such bias is observed here, however. The 11 relevant cases in the error corpus divide evenly between word edges, with 6 shifting the locus of repetition to the left edge and 5 to the right. However, a preference does seem to show up for repetition of orals relative to nasals (4 items, only 1 in opposite direction) and of coronals relative to labials (5 items, none in opposite direction). In both cases, the perceptually less similar pairs are more amenable to repetition.

Identity repetition is introduced in 18 forms (again divided evenly with respect to word edge, with 8 at the left edge, 7 at the right, and 3 resulting in repetition at both). For 10 of these the relevant sequences were already both nasal; for 4 already homorganic; for 3 both oral; for 2, differing along both dimensions. The preference for substitution of already-similar segments shows here. Of the resulting violations, 13 are of nasals versus only 6 orals, and 11 are labials versus 8 coronals. This differs along both dimensions from the asymmetries seen in the previous paragraph. Eight more forms introduce repetition with respect to place, if not total identity (e.g. *b...d b...m*). Again introduction of labial repetition predominates (6/8).

Repair of identity repetition occurs in 12 forms (6 at right edge, 6 at left edge). Of the 12, 6 repair so that a sequence of nasals remains, and 3 so that homorganicity remains. Again, the

maximally different substitution is rarely made. Like the preceding paragraph but not the one before, nasal repetitive outputs seem to be favored over oral ones. A minority of 3 forms substitute a consonant differing along both dimensions. Homorganicity itself elicits 8 more repairs (with only 4 labial target sequences, so no labial dominance as seen in the preceding paragraph).

An additional set of errors does not change with respect to identity or place, but rather in nasality/orality. A sequence of non-homorganic nasals elicits a repair only once, but nasal sequences are introduced in 8 items, appearing to be preferable to orals once more. Sequences of target orals do not show such a marked asymmetry, with one being changed in the output 6 times but such a sequence being introduced 4 times.

### *Summary*

As in previous experiments, the gap between repetitive and non-repetitive stimuli in the error-inducing set is not large, but goes in the opposite direction that repetition difficulty predicts. Asymmetries according to place and manner of targets and elicited errors are inconsistent.

Because the set of consonants possible in each position is so small, identity repetition is expected to result more than one-third of the time simply by chance if the consonants are chosen randomly from the permuting set, as suggested above (one-in-three chance of matching the neighbor for edge consonants, plus increased likelihood for medials with two flanking Cs for potential matching; likewise for resulting homorganicity and manner-matching, and leaving aside for now the influence of similarity to the original target<sup>7</sup>). That it occurs for only 18% of the items in the consonant substitution corpus may then be taken as evidence of a sort for repetition avoidance. This is despite the paucity of repetition repair, which itself is expected to occur much more often than it does (over one-third of the time versus 12%).

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<sup>7</sup> If it's already maximally different, then it has to get more similar; if it's intermediate, could go either way; and if it's already identical, it can't be counted as this type, and must be subject to repetition repair instead. Therefore, there is a bias in the direction of greater similarity.

### *Speech errors – kawdid*

As reported previously, this experiment yields little of the hoped-for data due to subjects' extreme reluctance to produce flap sequences. Let us now examine what precisely speakers do in order to avoid these.

All subjects accurately produced two pre-test items in the desired fashion. Subjects 1 and 2 continued to do so for the full course of the experiment. However, Subject 3 immediately changed production type upon beginning experimental trials. Medial C1 [t] (kootid) is consistently produced without flapping, even though the environment should make flapping obligatory. Subject 4 also produces stimuli in a 'compound'-type fashion from the very beginning. In addition, main stress is shifted to the second syllable for this speaker. Subjects 5 and 6 also produce unflapped C1 throughout the experiment. Subject 7 is not so consistent. The status of C1 as flapped or unflapped is unpredictable, but this variation still precludes experimental analysis of this subject's data. In addition, the vowel quality of the second syllable was anomalous for this subject, often being produced as a full tense [i] vowel. Finally, Subject 8 shifts stress rightward to the second syllable as Subject 4 does, with concomitant loss of the possibility of flapping C1. Subject 8 also joins Subject 7 in changing the quality of the vowel. The lax [ɪ] persists in some cases, but more often it is rendered as tense [i]. Occasionally [u] surfaces instead, for stimuli in which this is also the vowel of the initial syllable.

Thus the most frequent response is for subjects to produce the disyllabic stimuli as compounds rather than as single stems. This results in equal stress assignment to the two syllables, and loss of the flapping environment for C1. Two subjects instead reassign primary stress to the second syllable, with the same result as far as flapping is concerned. This strategy may have been inadvertently facilitated by the form of the stimuli, as the syllables sometimes are separable into independent English words (e.g. left-edge paw, saw, see; right-edge did, tit; non-orthographically, left-edge koo and soo).

### *Speech errors – papeen*

Despite the same laboratory conditions for subjects in this experiment as in Experiment 1 (*badageet*), this experiment yields substantially fewer speech errors, totaling only 18. Of the 18, five items include an REP consonant sequence (28%). This is comparable to the percentage in the stimulus set as a whole (one third, or 33%). No striking place asymmetries appear: for C1,

stimuli include 8 tokens of [p], 5 of [t] and 5 of [k]. For C2, there are 7 tokens of [p], 6 of [t], and 5 of [k].

In this experiment the relevant CVC sequence occurs at the left edge of the word, so that the dilemma of distinguishing metathesis from copying in error outputs should be resolved. Despite this experimental modification, no generalization or subclassification among speech errors seems possible. In fact, neither metathesis nor consonant copying occurred as a major error type – only one example (of the former) occurred. The most common error was a self-correcting repetition of the stimulus item, without any perceptible error in the first rendition. This occurred for four items. Misassigned stress to the first syllable of the word occurred twice, disfluent pauses twice, and truncations three times. One of the truncations also involved consonant substitution. The remaining six errors contain infelicitous intonation, vowel quality, or consonant insertion.

The small corpus of errors in this experiment, and their diverse nature, precludes any generalization correlating errors with inclusion of consonant repetition.

#### *Speech errors -- papareet*

As in Experiment 5 (*papeen*), this stimulus set elicited comparatively few speech errors. Of a total of 17 errors, 8 have a target including a repetitive sequence. This is comparable to the 50% of the stimulus set with REP environments, rather than exceeding it as repetition difficulty predicts. C1 place of articulation is unevenly split, with 6 [p] tokens and 11 [k]s, while the C2 place ratio is exactly the opposite (11 [p], 6 [k]).

Erroneous production of V1 is the most common error, accounting for 13 of the 17 errors. The substituted segment is most often either the other V1 target possibility (5 items, all [a] [o]), or schwa (also 5 items) with primary stress shifted to the final syllable. Of these 13 items, 6 also undergo truncation. The endpoint may occur after C2 (3 items), after V1 (2 items), or once, after the liquid consonant.

Of the remaining four errors, one involves a mistake in the frame sentence rather than in the stimulus itself. Two include disfluent pauses, one with additional truncation. Finally, one is a substitution for the final vowel of the other possible vowel for that position in the stimulus set.

Again, the different placement of repetition within the word fails to elicit sufficient errors to illustrate an REP effect. For those errors that do occur, the presence of repetition does not seem to be relevant.

#### *Errors summary*

Repetitive stimuli are generally slightly less likely to be error targets. Experiment 1 (*badageet*) elicits 28% error targets including an REP context, versus 33% REP forms in the stimulus set as constructed. Experiment 3 (*dadeed*) is 17% or 20% REP stimuli among error targets (1<sup>st</sup> vs 2<sup>nd</sup> syllable) versus 25% REP stimuli in the stimulus set as a whole. Experiment 5 (*papeen*) has the same percentages (28% vs 33% respectively). Experiment 6 (*papareet*) elicits error targets according to REP context of 47% versus 50%, based on an extremely small number of errors (n=17). Experiment 2 finds that repetition-including stimuli are produced more often than those not including repetition for the local contexts that show phonetic variation (though the non-local contexts go the opposite direction).

These differences are all small, but consistently show the opposite effect than expected. The frequent coproduction of speech error consonants documented in recent imaging work, as opposed to true substitution, may explain this tendency. An additional potential contributing factor is the undetectability of substitution or metathesis errors between identical consonants. Such undetectable errors would boost the numbers of REP target stimuli if counted, so that they would not be really fewer than expected.

As for the potentially repetition-repairing error outputs, the stimulus set of Experiment 1 turns out to be crucially flawed for addressing this point given the error types observed – repetition repair cannot be distinguished from repetition introduction. Experiments 3, 5 and 6 remedy this deficiency by shifting the locus of repetition to the left word edge. Experiment 3 provides tentative support for the prevalence of repetition repairs in error outputs, since repetition of identical consonants occurs in only 18% of such outputs versus the expected 33%. However, the absolute number of outputs repairing repetition is still less than of those that introduce it (12 versus 18, or 20 versus 26 for homorganicity only). Percentage-wise, repetition-repairing outputs also occur less often than expected (12% versus 33% of error outputs). Thus the results of this experiment do not provide good evidence for a repetition-motivated asymmetry

in error outputs. Experiments 5 and 6 elicit only small numbers of errors, none of which either introduce or avoid repetition.

The initial hypotheses that speech errors target and repair repetition are not borne out.

## Chapter Four: Formalizing repetition avoidance in phonology

Chapter Two proposes that gesture repetition is difficult, and that this difficulty leads to phonetic variation which may then be phonologized. Chapter Three provides experimental evidence in support of this hypothesis. In this chapter I investigate formalisms of phonologized repetition avoidance. That is, what is the formal mechanism by which phonological repetition avoidance is accomplished in grammars? I compare a number of proposals both on their own merits and on how well they succeed in accommodating and predicting the ways in which the observed phonetic variation results and does not result in phonological patterns. I conclude that constraint conjunction provides the best fit in the most parsimonious fashion.

I begin with a discussion of the Gestural OCP proposed by Gafos and colleagues (Gafos 1999, 2002, Benus *et al.* 2004), who attribute to it speech behavior similar to what I observe in Chapter Two. Their formulation differs in that it is based on the formal representations of Articulatory Phonology. Also, its proponents consider the effects they use it to account for to be grammatical rather than functional biases toward grammaticalization. Despite its superficial applicability to the variation documented in Chapter Two, I argue that Gafos' Gestural OCP is in fact unable to account for this variation satisfactorily, and also undesirable on independent theoretical grounds.

I then consider three possible instantiations of phonological repetition avoidance in grammar. First, it is possible that OCP-like constraints are active in grammars, but not innate themselves or decomposable into innate constraint schemas. Instead, they emerge from a combination of functional pressures and observations of statistical properties of the lexicon. This is the stance taken by Frisch, Pierrehumbert and Broe (2004). I argue against this position on the grounds that not all phonetically motivated alternations and repairs involving repetition are present in grammars. Phonologization of the observed phonetic variation must be further constrained by the nature of the innate constraint set.

Second, I discuss OT treatments of repetition avoidance phenomena that import the OCP into the set of constraints (CON) as a constraint or constraint family, with particular attention to Suzuki's (1998) Generalized OCP. In this view, a constraint (schema) against repetition is an innate phonological primitive. I argue that such innateness is unnecessary given the functional pressure(s) against repetition, and that it is preferable to make use of independently motivated

formal constraints to account for repetition avoidance phenomena if and when this is possible. I then discuss a third proposal in this vein, which employs local constraint conjunction (Alderete 1997, Ito and Mester 2003). I conclude that this formalism provides the best fit for the observed repetition avoidance phenomena.

#### 4.1 Gestural OCP

In this section I outline an alternative gesture-based approach to repetition avoidance that relies on phonologically represented gestural scores, grammaticalized timing relations applying to them, and a gestural OCP constraint embedded in an OT framework. I begin with background information on Browman and Goldstein's (1986, 1992, 2001) theory of gestural representations, followed by examples of gestural OCP-driven variation in Moroccan Arabic (Gafos 2002) and English (Benus *et al.* 2004). I then argue for the inadequacy of this approach in general and specifically as an account of the variation observed in Experiments 1-6.

##### 4.1.1 Gestures in Articulatory Phonology

The representational primitives in Browman and Goldstein's theory are dynamically defined gestures and the timing relations among them. A gesture is defined as the formation of a constriction by some articulator at some place in the vocal tract. A fully specified gesture includes a value for the three categories of articulator, constriction degree, and constriction location. Possible specifications for each are listed below.

- 31) Articulator: lips, tongue tip, tongue blade, tongue body, tongue root...  
Constriction degree: closed (stop), critical (fricative), narrow, mid, wide (approximants and vowel height)  
Constriction location: labial, dental, alveolar, postalveolar, palatal, velar, uvular, pharyngeal

The speech stream, of course, consists of series of overlapping gestures, even within a given segment. Browman and Goldstein explicitly represent the timing relations between them in *gestural scores*. A score for the syllable [p<sup>h</sup>a] is depicted below (from Gafos 2002).

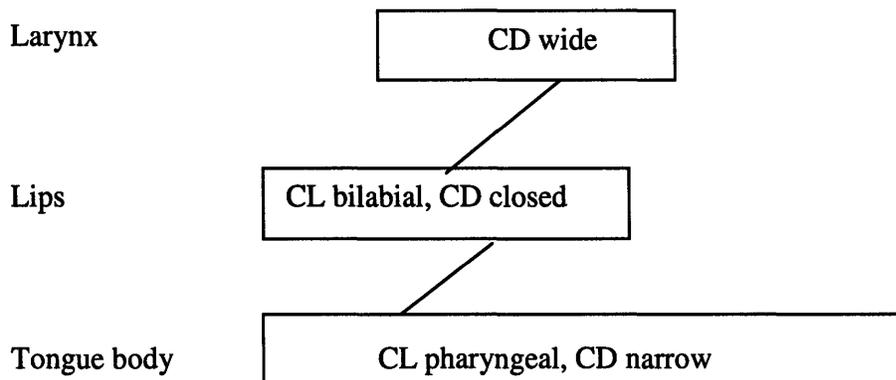


Figure 14: Gestural score of [p<sup>h</sup>a]

The length of a box indicates its temporal duration from onset to release offset, with intergestural temporal relations expressed by the connecting lines.

Gafos provides a more elaborate representation of these timing relations, as follows. The following diagram depicts the temporal landmarks of a single gesture (from Benus *et al.* 2004).

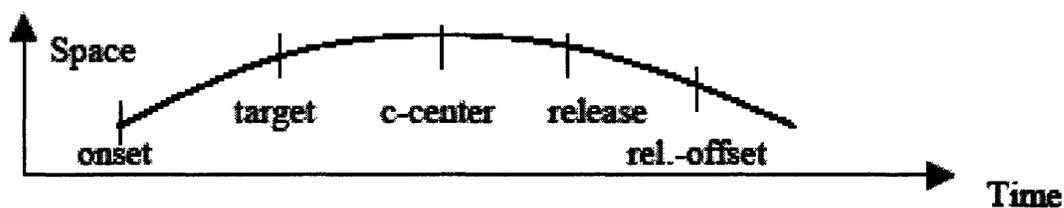


Figure 15: Gestural temporal landmarks.

Gestures may overlap with each other at different points in their time-courses, with different degrees of overlap described with reference to the above landmarks. Gafos (2002) describes a number of following possibilities for temporal relations between gestures. The one in the following figure corresponds to *open transition* in the descriptive literature.

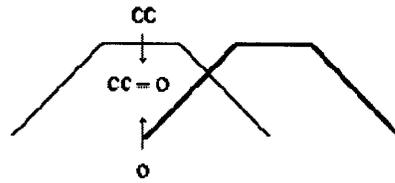


Figure 16: Open transition.

Open transition aligns the *c-center* of one gesture (the mid-point of the closure period) with the *onset* of another (beginning of movement toward the articulatory target). Some overlap between the movements involved in the two gestures occurs, but a release phase intervenes between the two closures. This release may be perceived as a short burst following a consonant, or a schwa-like vocoid.

This type of transition differs from *close transition*, depicted below.

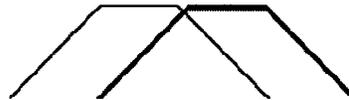


Figure 17: Close transition.

Here the release of the first gesture aligns with the target of the second gesture. Closure in the vocal tract is maintained throughout, whether of the first or second gesture, so that there is no chance for any release to occur between them. This relation holds among consonants in clusters in English. Finally, it is also possible for no gestural overlap to occur, with the release offset of one gesture co-occurring with the onset of another.

Gafos formulates these coordination relations as OT alignment constraints, using the following schema.

32) Gestural coordination constraint schema

ALIGN(Gesture 1, Landmark 1, Gesture 2, Landmark 2):

Align Landmark 1 of Gesture 1 to Landmark 2 of Gesture 2.

Landmarks may be any of the set of five labeled in Figure 15 above. An alignment constraint exists for at least four kinds of coordination relation: CV, VC, VV, and CC. The CV relation holds between onset consonants and their nucleus vowels. Since this is true for each onset consonant, the relation may hold across an intervening consonant for complex onsets. The VC relation holds between a vowel and the first post-vocalic consonant. No coordination across it to a subsequent coda consonant in a cluster is permitted. The relation between adjacent vowels, regardless of intervening consonants, is expressed by the VV relation.

Finally, the CC relation holds between consonants in a cluster. Unlike the VV relation applying across consonants, it does not hold across intervening vowels. The figure below, repeated from Chapter One, shows that overlap can occur across full vowels – it does so in the first syllable, *tick*. The release of the first consonant [t] coincides with the onset of the second consonant [k], resulting in an open transition such as the one mandated between consonants in MCA clusters.

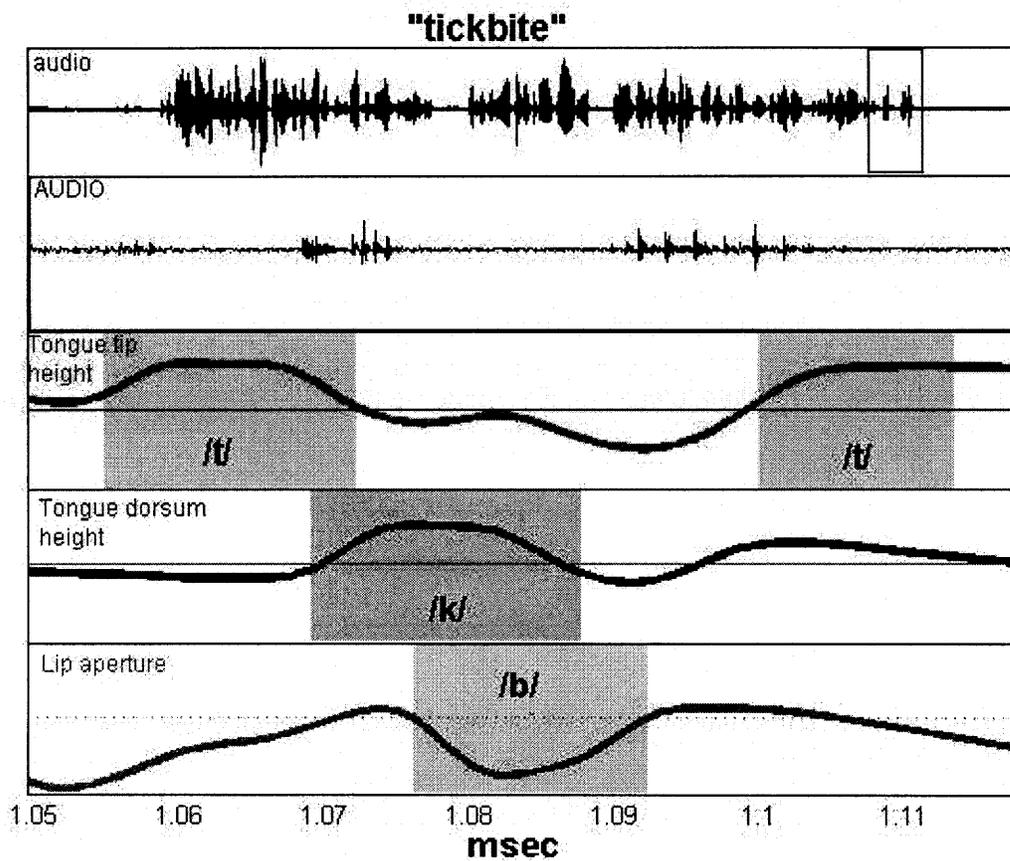


Figure 18. EMMA data collected by Marianne Pouplier at Haskins Laboratories.

However, there is no such overlap in the second syllable (*bite*), in which the intervening vowel is low and of considerably longer duration. Nor do the endpoints of the onset and coda consonants align (C1 release offset and C2 onset). This lack of consistency in the extent of overlap in otherwise similar contexts indicates that no particular alignment is being enforced by a coordination relation between the consonants flanking the nucleus vowels. Overlap between such consonants is permitted, but not mandated or controlled.

Each of the existing coordination relations is expressed in Gafos' theory by an alignment constraint of the type in 32, the form of which may differ cross-linguistically. Two possibilities are given in 33 below.

- 33) CC-COORD Constraints
  - a. ALIGN(C1, RELEASE, C2, TARGET)
  - b. ALIGN(C1, C-CENTER, C2, ONSET)

The close transitions in English consonant clusters are expressed by the constraint in 33a, while open transitions in languages that have release bursts within clusters have the constraint in 33b.

#### 4.1.1 *The gestural OCP*

Gafos (2002) presents a case study of consonant cluster coordination in Moroccan Colloquial Arabic (MCA) employing the formalism outlined above. Word-final two-consonant clusters in MCA are produced with a schwa-like vocoid intervening between them. Gafos argues that this vocoid is not a true vowel, but rather simply a by-product of open transition (see his paper for detailed argumentation on this point). This means that an open transition consonant coordination constraint like 33b must be in force.

The vocoid occurs even between identical consonants, however, for which the same coordination relation cannot hold. If it did, then the relevant articulator would already be at its target position when the gesture of the second segment was initiated. Closure would persist across both segments, precluding any release burst or vocoid separating the two. Given the actual

presence of the vocoid, something must be preventing use of the usual coordination relation. Gafos proposes that it is outranked by a gestural OCP constraint, which he formulates as follows:

34) Gestural OCP:

Overlapping segments of equal sonority with identical oral gestures are prohibited.

This high-ranking constraint forces the gestures to move apart temporally in order to avoid overlap, thereby surfacing in a different temporal relation than the default mandated by MCA's CC-COORD constraint. Gafos goes on to derive additional higher-order phonological properties of templates from this characterization of MCA grammar.

Gafos also provides the more formal definition in X:

- 35) Let S1, S2 be two segments and G1, G2 be two oral gestures of S1, S2 respectively. The sequence S1-S2 (in which the default gestural coordination relation holds) is prohibited if and only if G1=G2.

This version refers within it to a coordination relation holding between the two segments in question.

Benus and colleagues give a similar account of past tense and plural schwa epenthesis in English (final cluster in *type-typed* versus schwa insertion in *need-needed*; see discussion in Chapter Two). The default close transition relation holding between consonants in English clusters is outlawed by the same gestural OCP constraint proposed by Gafos if and only if the consonants are homorganic. This leads to violation of the overlapping coordination relation, and interpolation of a targetless schwa between the stem-final and affixal consonant (this vocoid is explicitly distinguished from English lexical schwa).

#### 4.1.3 A gestural OCP analysis and its problems

An analysis along the lines of the Articulatory Phonology/Gestural OCP framework laid out above is an initially attractive possibility for the experimental findings of Chapter Three. I now sketch out an approach to such an analysis, before identifying problems that rule it out.

Enforcing a lack of overlap between segments with equal sonority and identical oral gestures should result in longer transition intervals between consonant closures for such sequences of such segments compared to others. This is precisely what we see for the vowels intervening between identical or homorganic stop consonants. Thus an important prediction of Gafos' gestural OCP model is borne out by the data in Chapter Three. The disappearance of the vowel length effect when the vowel is already of sufficiently long duration is also expected in such an account. Once the interval is long enough that no gestural overlap occurs, it is not necessary to extend its duration further. The effect on the intervening aspiration burst fits in less neatly, since in the Articulatory Phonology framework the timing of this laryngeal gesture should depend only on its alignment with the head (oral) gesture of the initial consonant. However, it may plausibly be assumed to contribute toward satisfying the Gestural OCP's lack of overlap requirement via the longer intervention duration it results in.

The increased presence of incomplete consonant closure in repetitive contexts also fits in as a repair motivated by Gafos' Gestural OCP. His formulation applies to segments with equal sonority and identical oral gestures. Recall that an oral gesture is specified for articulator, constriction degree, and constriction location. Changing the constriction degree of a segment from closed (stop) to critical (fricative) or narrow (approximant) is another way to satisfy the Gestural OCP, since the repeated place gestures would no longer be identical. In an imaging study of MCA consonant production (Gafos to appear), Gafos reports that one speaker of the Oujda dialect does spirantize the first segment in a series of identical consonants (personal communication). This joins the English data and phonological cases of spirantization dissimilation from Chapter Two as evidence for the possibility of this repair in both phonetics and phonology.

More problematic is the cooccurrence of repair types in both the English and Moroccan data. If both the schwa lengthening and lenition repairs are attributable to the operation of fully grammatical constraints, it is surprising to see both employed, in both languages, rather than a single repair. One possible solution is to allow continuous optimization of the kind proposed by Flemming (2001) for acoustic representations, or Gafos (2006) for gestural ones. In a classical OT framework such as the one Gafos implements in his Gestural OCP analyses, however, this coexistence should not occur.

Another problem is the full participation of the nasal stop consonants in Experiment 3 (*dadeed*) in eliciting variation. Gafos' formulation of the Gestural OCP is specifically limited to apply only to segments of equal sonority. This is crucial in his later work on English with Benus and Smorodinsky (2004), in which word-final nasal-oral stop sequences such as [nd] are allowed because of their sloping sonority contour (*pinned*), but coronal oral sequences trigger epenthesis in suffixal morphology (*pitted*). The sonority proviso means that Gafos' gestural OCP cannot account for the way that homorganic nasal-oral stop sequences in Experiment 3 elicit the same variation, of the same magnitude, as oral-oral stop sequences. The divergent patterning of nasals in the experimental data versus suffixal alternation means that at least two versions of the Gestural OCP must be active in English phonology, one specifying equal sonority and one not. Alternatively, but also unsatisfyingly, the variation associated with identical consonants could be phonological and the nasal-oral homorganic stop variation only phonetic. Both leave the parity of the experimental effects between phonemic and place-only repetition unexplained, and are undesirable complications compared to a unified biomechanical explanation for the vowel length effect.

The repetition of nasality itself elicits no effect, as expected according to Gafos' formulation of the English Gestural OCP constraint (he also specifically rules out laryngeal features as OCP triggers). This is partly a matter of language-specific constraint implementation for him, as his English OCP constraint is situated in a family that can be featurally articulated. However, he also makes the more general claim that this asymmetry between feature types should be at least somewhat systematic, based on the idea that "inter-segmental coordination constraints coordinate the head or oral gestures of two segments. Within a segment, non-head gestures are in turn coordinated with the head gesture in the characteristic way particular to that segment." Thus only head gestures are subject to the *gestural* OCP – though the restrictions on secondary articulations that are actually observed can be due to other constraints of the OCP family referring to feature cooccurrence at higher prosodic levels. No justification for the choice of place gestures as segmental heads is given. I, on the other hand, provide the principled reasoning in Chapter Two that they are preferentially the targets of OCP-like restrictions due to the larger mass of their articulators and the correspondingly greater effort that moving them and transitioning between them entails.

The Gestural OCP also has nothing to say about the final main type of variation from Chapter Three – the persistent duration increase that is sometimes observed beyond the repetitive sequence. This is not necessarily a problem, since the phonological Gestural OCP does not rule out the existence of biomechanical difficulty and associated, non-phonologized variation. However, the inability of the former to account for all the observed variation makes it a less satisfying approach.

Perhaps the most serious problem facing the Gestural OCP with respect to this data is the extent of the intervening vowel effect. In the Moroccan and English showcase examples, the “vowel” in question is taken to be a transitional, epenthetic schwa. No vowel is underlyingly present. This is fundamental for the analysis, because the statement of the Gestural OCP constraint requires that a coordination relation hold between the two gestures in question.

However, it is not possible for this to be the case for consonants across an intervening vowel in the framework as currently formulated. Any underlying vowel prevents such a relation, and means that the Gestural OCP as currently formulated cannot apply to the flanking consonants. Therefore, any variation observed in such contexts cannot be attributed to it. This is true even if the vowel is a lexical schwa, as opposed to the epenthetic, transitional schwas of Moroccan and, putatively, the English suffixes.

The fact that the variation in Chapter Three occurs with intervening lexical schwas, then, is highly problematic. Even more so is the variation in Experiment Two (*tarradiddle*) in sequences that include fully-specified underlying full vowels. The Gestural OCP as formulated by Gafos and colleagues cannot after all account for the repetition-related variation in any of these experiments. Experiment Two precludes any attempt to salvage the approach by distinguishing lexical but targetless schwas from full vowels, which in any case is explicitly ruled out as a possibility in their work (Benus *et al.* 2004).

Thus the initial attractiveness of the Gestural OCP proposed by Gafos and colleagues as an analysis of the variation seen in Experiments 1-6 is belied by a number of implementation problems, summarized below.

- 36) Implementation problems with Gafos’ Gestural OCP
  - a. variation in aspiration burst duration
  - b. simultaneous coexistence of multiple repair strategies

- c. equal participation of phonemes that are not of the same sonority
- d. persistent duration increases beyond the locus of repetition
- e. variation across lexical schwas and full vowels

These problems, some more intractable than others, all concern the implementation of the Gestural OCP to account for the experimental data of Chapter Three. They are joined by the more theory-internal difficulties listed below.

37) Theoretical problems with Gafos' Gestural OCP

- a. defining the nature of overlap between identical gestures
- b. lack of generalizability to other repetition phenomena

The first problem relates to an issue briefly raised in Chapter Two in the discussion of why gesturally repetitive sequences should take longer, independently of being more articulatorily effortful. I list there three contributors to articulatory difficulty with gestural repetition: sustained activity of the same articulator requires more effort, no overlapping coarticulation between different articulators means that transitions are necessarily longer, and rapid reversal of momentum requires more force. The second reason makes it clear that the lack of overlap enforced between identical gestures by Gafos' Gestural OCP is essentially tautological – it is impossible for the articulators to violate it.

This fact highlights a rather deceptive property of the gestural coordination diagrams shown above. In one like 16, repeated below as 19, the offset and onset articulations below the intersection point of the two depicted gestures still occur for heterorganic consonants.

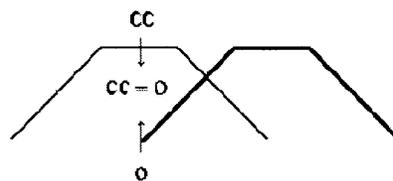


Figure 19: Open transition overlap between gestures.

The under-intersection, overlapped part of the articulations may be acoustically obscured, but still exists.

This is not the case for homorganic sequences. It is not possible for the lips, for example, to move simultaneously away from each other (in the first segment's offset) and toward each other (in the second segment's onset). The under-intersection is not merely masked, as it is for heterorganic sequences, but non-existent. Any articulation underneath the intersection does not occur. The logic of introducing an abstract constraint in order to rule out an impossible articulatory configuration is dubious.

The second theoretical objection to Gafos' formulation of the Gestural OCP is its lack of generalizability to other repetition avoidance phenomena. The original conception of the gestural OCP places it in a continuum of anti-repetition constraints at different prosodic levels. However, as currently formulated it is unable to take a place in any OCP constraint schema yet devised, because the notion of overlap cannot apply to repetition of any element above the featural/phoneme level. But once it is granted that a constraint against repetition exists in the grammar, theoretical parsimony demands that processes obviously related to repetition avoidance should be traceable to the activity of a single constraint or constraint family against it. The Gestural OCP constraint as currently formulated by Gafos and colleagues is not amenable to such extension. It not only fails to account after all for the phonetic variation observed, but is not compatible with repetition avoidance phenomena in phonology generally. As such, it fails to meet the standard set by the BRAH, for which I argue. The latter accounts for all the experimentally observed variation, is independently well supported by the arguments presented in Chapter Two, and does not require the introduction of multiple incompatible constraints in the grammar to generate the observed phonological patterns.

I propose that the English data discussed by Gafos and colleagues presents a diachronic example of normal antigemination. I do not provide a full reanalysis of the Moroccan data here, but it is worth noting that rampant loss of short vowels has occurred in the development of Moroccan Arabic from Classical Arabic. Thus many of the same considerations apply regarding the duration and non-deletion of the original intervening vowels, which could lead to the preferential retention of an intervening schwa when the flanking consonants are identical.

## 4.2 Emergent OCP

In the previous section I argue that although the phonetic variation observed in Chapter Three can lead to phonologized repetition avoidance, it is not itself phonologically encoded by a Gestural OCP constraint *a la* Gafos and colleagues. I now explore different phonological approaches to repetition avoidance and evaluate how well they capture the ways in which phonetic variation becomes part of phonology.

One such approach states that while OCP-like constraints exist in synchronic grammars, there is no universal, innate constraint against repetition. Instead, non-phonologized anti-repetition functional pressures result in underattestation of OCP-violating forms in the lexicon. This is the stance taken by Frisch, Pierrehumbert and Broe (2004) with respect to consonant cooccurrence MSCs, though they focus on the perceptual difficulty presented by repetition, rather than the articulatory, production-based one with which I am concerned here. In their view, underattestation comes about due to the favoring of non-violating forms in acquisition, borrowing, and day-to-day usage. Violations are less likely to be acquired, less likely to be introduced as loanwords or novel coinages, and less likely to be used in general when they do exist, leading to lower frequency and therefore higher probability of dropping out of the lexicon. Once a pattern is established, speakers become aware of it in their construction of abstract generalizations over the lexicon. These generalizations then further constrain the items introduced into the lexicon, and bias against retention of violating forms. A feedback loop emerges that reinforces the initial, functionally-motivated underattestation, and may lead to categorical phonological phenomena.

This kind of diachronic progression toward synchronic phonology is very similar to the kind of phonologization pathway I envision for antigemination and other repetition repairs. However, I differ as to the eventual form of the phonologization. While FPB acknowledge that the resulting generalizations “are not made over visceral perceptual patterns,” and depend on segmental and prosodic structure, the potential eventual form of the putative OCP constraint remains far too unconstrained.

We have seen that place gesture repetition is associated with incomplete closure, longer duration, and lower intensity for one of the consonants; that intervening vowels are longer; and that duration increases persist past the locus of repetition. Yet not all these phonetic effects have corresponding phonological repairs. The attestation but infrequency of dissimilation via

fricativization in repeated homorganic stop sequences has already been discussed in this respect, and may be attributed at least partly to conflicting phonetic cues. The lack of phonological repairs to nasal-oral stop sequences even though phonetic effects are seen for such sequences may also be due to acoustic factors. Even though the vowel in a [NVS] sequence may be longer, it may also be more likely to be interpreted as part of the nasal rather than an independent vowel, due to lack of a clear voicing boundary or interruption of the air stream between them such as occurs with even lenited stops, and some persistent nasalization into the vowel.

However, other expected cross-linguistic alternations predicted by the phonetic variation in repetitive contexts are also unattested, and are less clearly attributable to acoustic properties of the speech signal. For example, we might expect the duration effects on intervening vowels to be associated with changes in quality or contrastive length. The longer durations associated with [+low] vowels might lead to all vowels intervening between identical place gestures being [+low], or at least [-high]. Alternatively, only contrastively long vowels might surface between identical consonants.

This does not seem to happen. Even the place-based variation seen in the consonant cooccurrence patterns, if not the phonetic data, appears to be flattened out in phonologized antigemination patterns – they apply to all places, across the board. Yet with constraints emerging based only on functional difficulty, even with emergence constrained by dependence on segmental and prosodic structure, there is nothing identified so far that could prevent a constraint like \*[bib], or one against CVC sequences in which the consonants are identical and the vowel is high. That such constraints do not appear to arise suggests that the nature of the constraint set must be exerting more influence on the phonologization process than this kind of emergence allows.

### **4.3 The OCP as innate OT constraint family**

Perhaps the most common recent approach to the OCP has been to import a version of its original autosegmental formulation into the OT constraint set. This addresses many of Odden's (1986, 1988) well-known objections to the formulation of the OCP as a unified and universal principle. Its violability is then expected, as is the language-specificity of its effects. The characterization of the OCP constraint or constraint family in OT has been the subject of a number of proposals. In this section I review these proposals, before moving on to competing

accounts of repetition avoidance that reject the status of the OCP as either a constraint or a phonological primitive.

The importation of the OCP as an OT constraint was pioneered by Myers' (1997) analysis of tone in Shona. Myers proposes an OCP constraint defined as in 38a below.

38) OT-OCP (Myers 1997)

- a. \*F F, where F is a parsed feature specification.
- b. Two identical specifications must not occur in the same domain.

The stronger constraint in 38b is also proposed in order to account for non-adjacency effects such as the voicing co-occurrence constraint of Yamato Japanese, which disallows more than one non-redundant voicing specification.

This general approach has been widely adopted and the OT OCP was quickly extended, as the autosegmental one was, to other phenomena than tone. For example, Golston (1995) employs an OT OCP constraint to prevent repetition of lexical items when a syntactically acceptable alternative exists, in making his argument that a body of syntactic OCP constraints universally outranks the phonological constraint class (and likewise the phonology class outranks morphology). Thus in English, the existence of the grammatical phrase type in 39a below means that the bracketed phrase in 39b cannot be preceded by a determiner identical to its first word, as in 39d; only the post-posing alternative which does not involve lexical repetition (39c) may be used.

- 39) a. The video of *Macbeth*  
b. The *Macbeth* video  
c. The video of *The Dead*  
d. \*The *The Dead* video

The famously acceptable homophone sequences of German, on the other hand (*dass das das Problem ist* 'that this is the problem'), are tolerated because no grammatically acceptable reordered alternative exists. Golston concludes that such repetitive sequences are phonologically dispreferred, but that higher-ranking syntactic constraints must be satisfied. Only when a

synonymous, non-OCP-violating sequence is syntactically acceptable can an OCP-type constraint come into play. Supporting data comes from Ancient Greek, in which center-embedded noun phrases are allowed *except* when adjacent homophonous articles would result.

Myers' constraint 38b, and the different level of operation of the OCP in Golston's data than the tonal domain, open the possibility of an OCP constraint *family* in OT. Yip (1998) makes a proposal regarding the nature of this putative constraint family. Her formulation of the OCP (which she states may be better conceived of as \*REPEAT) may refer to at least the four categories feature, segment, stem, and affix, leaving the possibility open of additional indexation possibilities.

The segmental constraint accounts for restrictions on the surfacing of multiple English [s] affixes (plural and possessive). Repetition of [s] is repaired by epenthesis when one of the tokens is a stem segment (40a) but by haplology when both are affixal (40b).

- 40) Plural                      Plural+Possessive  
a. cats                      cats' (\*cats's)  
b. Katzes                      Katzes' (\*Katzes's)

Yip's OT account formalizes Stemberger's (1981) intuition that affixation is vacuously satisfied by any pronunciation of the mandated phonological string, even if the result is multiple correspondence of morphological features to segments. This explains the phenomenon he calls Stem-End Haplology, or absence of an affix or clitic when the adjacent part of the stem is homophonous with it.

Stemberger cites evidence from acquisition for this phenomenon, such as haplological production of [s] and [d]-final words by English-learning children as though they are already marked for plural or past tense (Berko 1958). He also describes an experiment on adult English speakers presented with sentences with *-ing* and the copula *is* variably deleted. Subjects fail to notice deletion significantly more often for haplological contexts than others. This happens even with the verbal form, which is never optional in standard English. Stemberger hypothesizes that "two similar events are not distinguished properly in memory buffers used for production, so that only one is 'remembered.'" In this he anticipates the tokenizing difficulty proposed for repeated

stimuli in other cognitive domains, discussed in the next chapter. These behaviors in acquisition and perception may give rise to grammatical haplology of the kind discussed here.

Returning to Yip's account of the English [s] case, while stem segments themselves are not subject to haplology, a single [s] affix may satisfy both of the constraints in 41 below.

41) Affixation constraints (Yip 1998)

- a. PLURAL: Plurals must consist of a stem and an [s] affix.
- b. POSSESSIVE: Possessives must consist of a stem and an [s] affix.

Ranking these constraints above one mandating distinct tokenwise output contents for distinct morphemes obtains the desired result of no more than one surface [s] affix.

Yip's stem repetition constraint, in turn, motivates partial (rather than fully faithful) reduplication, while the affix version allows for constraints against repetition specific to particular affixes. A form of this constraint is invoked to explain phenomena like the *double-ing* effect in English (Ross 1972). The utterances of 42a and 43b lead one to expect grammaticality for 43c.

43) Double-ing avoidance

- a. John wants to start reading the book.
- b. John was starting to read the book.
- c. \*John was starting reading the book.
- d. She likes to sing ringingly.

The unexpected ungrammaticality of 43c is attributed to a restriction on *-ing* cooccurrence which cannot be purely phonologically motivated, given 43d, and which holds across intervening stems. Szmrecsanyi (2005) provides quantitative support for the generalization stated categorically above – when a head verb ends in *-ing*, the likelihood of a complement *-ing* form is reduced by 98%. Rudanko (2000, 2002, 2003) makes the same argument based on historical corpus data for selected head verbs. This kind of phenomenon, referred to in the discourse literature as *horror aequi*, holds despite a countervailing tendency toward *syntactic priming*

(Bock 1986, Bock and Griffin 2000), which favors using a particular construction when it is preceded by another such instance in the utterance or discourse.

Similar cases, both categorical and gradient, abound. Szmrecsanyi presents the same sort of evidence for sequences of the infinitival alternative to gerundial forms. That is, despite the clear grammaticality of double infinitive sequences, speakers are relatively unlikely to use them (??*they want to start to test that idea*). Rather, an infinitive head very increases the probability of a gerundial rather than infinitival complement to it by 350% (*they want to start testing that idea*). Rohdenburg's (2003) work on such sequences, in which he introduces the term *horror aequi* and defines it as "a widespread tendency to avoid the repetition of identical and adjacent grammatical elements and structures," identifies additional avoidance strategies. These include *and*-substitution, as in the now-idiomatic (*to*) *wait and see*, (vs ?? *to wait to see*), and interpolation (*to wait a bit to see*). He concludes that structures potentially involving undesirable identity effects, like double infinitives, may constitute functional niches in which obsolescent but contextually well adapted constructions can survive a bit longer. Alternatively, adaptive novel constructions (like *and*-substitution) may become established earlier there than elsewhere.

In the categorical domain, Yip presents several additional examples, such as the ban on adjacent items bearing the Hindi case affix *-ko* (in such cases reordering is forced; see also Mohanan 1994). These phenomena force an extension of the OCP beyond strict adjacency of the repeated strings themselves (to which Golston adheres).<sup>8</sup> But the stems to which affixation occurs are implicitly assumed to be always adjacent, and as in Myers' work, there is no explicit discussion of what may constitute a domain for repetition avoidance. Yip closes by claiming that "identity avoidance is fundamentally phonological in nature." Phonological identity may not be sufficient to prompt repair, but is always necessary, in her view. We shall see in Chapter Five that this is not strictly accurate.

In another survey of morphological repetition avoidance contemporaneous with Yip's, Plag (1998) also draws heavily on the cases discussed by Stemberger (1981) as well as by Menn and MacWhinney (1984). Like Stemberger, and subsequently Yip, Menn and MacWhinney refer crucially to morphological structure in their repetition strictures. They formulate the Repeated Morph Constraint, stated as follows.

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<sup>8</sup> The lack of an obvious syntactic synonymous alternative to 43c calls into question Golston's claim that the OCP can only act when such an alternative is available. I leave aside the larger issue of ineffability in OT frameworks.

44) Repeated Morph Constraint (Menn and MacWhinney 1984)

Avoidance of adjacent identical morphemes.

“\*XY, where X and Y are adjacent surface strings such that both could be interpreted as manifesting the same underlying morpheme through regular phonological rules, and where either (a) X and Y are both affixes, or (b) either X or Y is an affix, and the other is a (proper subpart of a) stem.”

This constraint proceeds from the assumption that repetition is difficult for language processing, and that the difficulty is ultimately traceable to the perceptual system. On the assumption that repetition is difficult perceptually, its difficulty in production is attributable to the use of the perceptual system in at least of some of the self-monitoring of production, and to the coevolution of the production system in such a way as to be compatible with perception, and therefore designed to produce strings that are not confusing to it.

Menn and MacWhinney further assume that the set of responses to this difficulty can be ordered with respect to the amount of information that each requires the production mechanism to consider, and that response choice is part of the grammar. The constraint itself is not, however – it is purely psycholinguistic, and applies when allomorphy comes into existence but does not persist as a synchronic entity in grammars.

Plag modifies these generalizations by importing them to an OT framework (as Yip does), but also by eliminating reference to morphological structure (unlike Yip). The full elaboration of his OT-OCP constraint family is given below, along with Yip’s for comparison.

45) OCP Constraint Family (Yip 1998)

Indexed for: Feature, segment, affix, stem

46) OCP Constraint Family (Plag 1998)

Indexed for: Feature, segment, onset (\*ta.ti), nucleus (\*pa.ta), and (onset, coda) (\*.pap.)

The (onset, coda) constraint refers to segmental identity and is inherently domain-specified, while the nucleus and onset ones hold for segmental identity in the relevant position in only adjacent syllables. This constraint family is employed to account for exceptions in derivational

morphology (the limitation of his study to such effects implies some parameterization of faithfulness constraints according to stem versus affix status, despite the putative irrelevance of such boundaries to the OCP itself).

Plag uses this formulation, with its elaboration with respect to syllable structure and removal of morphological boundary information, to reanalyze Raffelsiefen's (1996) account of stem variation in English *-ize* suffixation. Based on data like the following, Raffelsiefen (1996) proposes an output constraint on identical onsets in adjacent syllables in the derived word.

47) Suffixation of *-ize*, standard

- a. standard + ize          standardize
- b. conceptual + ize        conceptualize

48) Suffixation of *-ize*, with deletion

- a. feminine + ize          feminize (\*feminize)
- b. minimum + ize          minimize (\*minimumize)
- c. metathesis + ize        metathesize (\*metathesize)

Plag's OCP(ONSET) constraint successfully rules out these forms (though with an exception for bisyllabic stems, in order to avoid stress lapse), without reference to morphological constituents. His constraint referring to both onset and coda within the syllable accounts for exceptions to *-en* suffixation like the following.

49) *-en* suffixation

- a. redden
- b. blacken

50) Exceptions to *-en* suffixation

- a. \*greenen
- b. \*bluen

Here the prohibition extends to sonorancy, not only complete phonemic identity. Plag does not address repetition avoidance of non-strictly adjacent affixes.

In a comprehensive study of dissimilation, Suzuki (1998) proposes an OCP constraint schema which he calls the Generalized OCP, modeled upon the generalized alignment approach in OT (McCarthy and Prince 1993). We have already seen an example of the use of such a schema in the formulation of the gestural coordination constraints discussed above. Suzuki's application of it to repetition is given below.

51) Generalized OCP

\*X...X: A sequence of two X's is prohibited in some domain D.

Where  $X \in \{\text{PCat}, \text{GCat}\}$

"..." is intervening material.

Here X may be drawn from the sets of phonological categories (PCats: features, root node, syllable, foot, *etc*) and grammatical categories (GCats: stem, affix, *etc*). It thereby straightforwardly encapsulates the morphological effects discussed so far, as well as the classical featural and segmental applications of the OCP. A high ranking of this constraint when X is a root node straightforwardly rules out geminates and long vowels in a language, an elegant way of accounting for their cross-linguistic markedness. Syllable profiles as X can also account cases of length dissimilation and clash avoidance, in which prosodic identity is outlawed.

The ellipsis between X tokens indicates that the two of them may or may not be strictly adjacent. Suzuki posits a universal, fixed-rank proximity hierarchy along the lines of the sonority hierarchy, in which the pair X-X may be separated by nothing, by a single segment, by a mora, by two moras, by a syllable, by a foot, and so on. Note that this list includes only prosodic categories. This restriction succeeds in ruling out unattested repetition-related variation affecting vowel quality, as posited in the preceding section. The continuum of the proximity hierarchy may be interrupted by interleaved constraints, and their interaction generates the prevalence of repetition avoidance for closer items. The set of possible domains is also quite inclusive, and includes the morphological categories root and (potentially affixed) stem as well as prosodic units such as syllables and metrical feet.

One additional elaboration of this constraint schema has since been proposed by Rose (2000), who adds the dimension of consonant adjacency, defined as follows:

52) Consonant adjacency

Two consonants in sequence are adjacent irrespective of intervening vowels.

The sole exception is for strictly adjacent identical consonants, which are held to be geminates (and in her framework, do not violate the OCP). This move potentially eliminates the role of the syllable as a dissimilatory domain, though Rose does not press this claim. It also contrasts with Gafos' approach to (non)locality of consonants across vowels. Rose points out that his arguments focus on the need to prevent assimilation between such consonants, and that dissimilation processes may refer to different domains. In her later work, however, consonant adjacency is in any case subsumed in the interaction of the constraint PROXIMITY and consonant correspondence (Rose and Walker 2004).

53) PROXIMITY: Correspondent segments must be within the domain of adjacent syllables.

This reintroduces syllable structure in the place of formalized consonant adjacency.

An additional innovation is Suzuki's invocation of local constraint conjunction in order to account for the observation that some version of the OCP is more likely to hold for things that are more similar. Any conjunction of two separate OCP constraints from the generalized schema will lead to preferential repetition avoidance of items which are identical along more than one dimension.

The sets of primitives employed by Suzuki are richly articulated, extending beyond the minimal list proposed by Yip and including the morphological information which Plag disregards. It easily accommodates many of the formulations of the OCP found elsewhere in the OT literature for particular languages (though not Gafos' Gestural OCP). Finally, it has the advantage of being straightforwardly upwardly-generalizable to other grammatical subdomains than phonology. We will see in the next chapter that such effects in discourse and syntax are prevalent, so that this is a desirable property.

Suzuki's framework captures a number of properties of repetition avoidance phenomena that other approaches do not. In addition to being easily generalizable, it accounts for the preferential application of restrictions to more similar, closer-together, and more marked elements, and dissimilation between non-identical items (e.g. non-low vowels from high

vowels). However, the biomechanical repetition avoidance hypothesis that I have advanced provides an independent functional explanation for all but the last of these properties. The more closely a segment mirrors the articulation trajectory of a neighboring one, with respect to both articulator and constriction target, the more difficult repetition will be. This corresponds to the similarity restriction. Closer proximity, in terms of absolute milliseconds, and therefore as reflected by adjacency, is also highly relevant. Finally, markedness generally corresponds to articulatory complexity. This means that marked segments have higher baseline difficulty in articulation, so that the added difficulty introduced by repetition is more likely to put it beyond the tolerable threshold, and therefore trigger a repair.

The functional underpinnings of these factors mean that it is not necessary for them to be directly reflected in the grammar, and therefore undermines them as justifications for Suzuki's framework. Finally, Suzuki introduces the use of local constraint conjunction in order to model the similarity bias of repetition avoidance effects. Others have proposed accounts relying solely on this mechanism. If tenable, the greater simplicity of this approach would make it more desirable. I discuss it further in the following section.

#### **4.4 Repetition avoidance through constraint conjunction**

Ito and Mester (2003), Fukazawa (1999) and Alderete (1997) propose an alternative model of repetition avoidance that depends on the local self-conjunction of markedness constraints. Such constraints are assumed to exist for all features and segments, and often higher-order elements as well. Constraint conjunction offers a way to combine them within a given domain, which may be either morphological or phonological/prosodic.

Ito and Mester (2003) formally define local conjunction as follows:

##### 54) Local constraint conjunction

Let C1, C2 be constraints and  $\acute{\epsilon}$  be a (phonological or morphological) domain (segment, syllable, foot, prosodic word, ...; root, stem, morphological word,...). Local conjunction is an operation “&” mapping the triplet (C1, C2,  $\acute{\epsilon}$ ) into the locally conjoined constraint denoted by C1&C2..., the  $\acute{\epsilon}$ -local conjunction of C1 and C2.

Self-conjunction, of course, is the special case in which  $C1=C2$ . The conjoined constraint then outlaws multiple tokens, e.g. repetition, of the object of a markedness constraint within the domain  $\acute{e}$ . A violation of the conjoined constraint is assessed for each pair of violation marks accrued for the two individual constraint components in that domain.

This formalism results in a set of possible repetition-related statements that is as highly articulated as any OCP constraint family. It has the additional advantages of being simpler, especially given Suzuki's invocation of constraint conjunction within his model, and independently motivated. Constraint conjunction is not limited to treatments of repetition, and has been employed in analyses of numerous other phenomena (see Ito and Mester for discussion and citations).

Ito and Mester (2003) and Fukazawa (1999) also argue that specific conjunctions exist only when language-specifically motivated. This assumption limits the constraint set in a desirable way, and makes the emergence of repetition-related constraints more highly constrained than a purely emergent OCP constraint does. Again, this is a desirable outcome, as argued in section two of this chapter. For example, a conjoined constraint can make no reference to the specification of a segment intervening between two consonants (except to rule out featural repetition that may occur there as well as on either of the consonants). This successfully rules out hypothetical alternations based on the quality of the intervening vowel, which a purely emergent constraint cannot do.

This also constitutes a drawback of the approach, however, since the options for expressing different degrees of locality are far more limited than Suzuki's proximity hierarchy allows. Ito and Mester acknowledge that even strict adjacency, for example, must still play a role in some way that is currently not part of their model. Expanding the list of domains to include possibilities like  $\acute{e}=CC$ , or  $CVC$ , weakens its advantage relative to purely emergent constraints.

#### **4.5 The BRAH and phonological repetition avoidance**

Ito and Mester point out that "it is left to some other part of the theory to explain why (certain) self-conjunctions are preferentially activated...." To take the concrete example they introduce, "there is more to the repeated violation of NOLAB within a root than the violation of two markedness constraints that happen to be identical."

This is where the BRAH comes in. We have seen that the choice of phonological repetition avoidance mechanism constrains which phonetic amelioration strategies may be grammaticalized. It is also true that the phonetic, biomechanically motivated variation biases speakers toward the use of some formally possible grammatical processes more than others. As Reiss (2003) observes, “all attested patterns must be generatable by the UG-given phonological capacity, but not all generatable patterns will arise, due to the nature of sound change and language acquisition.” Moreton (2006) refers to this duality as *channel bias* and *analytical bias*, defined below.

55) Channel bias: phonetically-systematic errors in transmission between speaker and hearer, caused largely by subtle phonetic interactions which serve as precursors for phonologisation; systematic errors [and, presumably, non-erroneous variation –MW] which cause the phonological representation received by the learner to differ from the one intended by the speaker.

Analytical bias: cognitive biases which facilitate the learning of some phonological patterns and inhibit that of others....[usually] under the name of Universal Grammar....Systematic predispositions in what a learner infers from the received representations.

Moreton argues that both must be taken into account in any adequate theory of typology. Again, the interaction of the BRAH and choice of phonological repetition avoidance formalism illustrates precisely this point. It is shown that some kinds of repetition are biomechanically less difficult than others – these are the ones that are not associated with either ameliorating phonetic variation or phonological repairs. A number of such ameliorating phonetic patterns do exist, but only a subset of the possible phonological alternations reflecting these enter phonologies.

Hayes (1999) also emphasizes the relationship of substantive (~phonetic) information in the induction of OT constraints. In his model the constraint set is limited by representational and formal properties, but a phonetic map also specifies the relative difficulty of perceptibility and articulation of output forms. Constraints are admitted to the set entertained by the learner only if they assign violations to more rather than less difficult forms with higher probability than other constraints. Hayes and Wilson (2006) present arguments that though the set of possible

constraints is predetermined, only those emerge which are supported through linguistic experience and the statistics of the lexicon.

I have presented evidence of phonetic variation associated with repetition difficulty, and argue that some, but not all, of this variation may subsequently be encoded in phonological grammars. Which actually is can depend on properties of the formalism employed, and offers another way to evaluate different proposals for this formalism. Proponents of the one for which I argue, local constraint self-conjunction, point out that the phonological processes it makes possible are not uniformly attested, and that the disparities among them must be traceable to some other source. The interaction of phonetic and phonological repetition avoidance, then, makes an exemplary case study of the reciprocal relationship between phonetics and formal phonology.

In this chapter I have discussed phonological repetition avoidance formalisms and how they constrain the grammaticalization of the phonetic repetition-related variation documented in Chapter Two. It is clear that these mechanisms can and do accommodate a far wider range of phenomena than the gesture-based ones predicted by the BRAH – in particular ones preventing cooccurrence for larger prosodic subunits and across much longer temporal distances. The question of what motivates these additional phenomena, if not the BRAH, remains. I take it up in the next chapter.

## **Chapter Five: Perceptual and syntactic biases against repetition and their effects**

Chapters Two and Three propose and present evidence for a functional bias against repetition that is highly local in its effects. As the phonological phenomena described in Chapters Two and Four make clear, however, this bias is not sufficient to motivate the wide range of repetition avoidance phenomena that are attested in grammars. In particular, repetition avoidance above the level of the gesture or segment, and at longer distances that roughly 100 milliseconds or at most two segments, cannot be attributed to the BRAH. Such avoidance can easily be captured by the formal mechanism(s) discussed in the previous chapter, and is well attested cross-linguistically. Its functional motivation, however – if any – must lie elsewhere.

In this chapter I begin with a discussion of another bias against repetition. This is the perceptual repetition deficit, well documented in the psychology literature, which I review below. It is to some degree anticipated in the discussion of Menn and MacWhinney's (1984) and Stemberger's (1981) work in the previous chapter, and applies both in perception and at self-monitoring of production interfaces. The existence of this deficit predicts underattestation of sequences of identical representational chunks, just as we see underattestation of segment sequences in consonant cooccurrence MSCs.

A series of studies of adjacent homophone avoidance constitutes the next section of the chapter, and bears out this prediction. A cognitive, perceptual repetition deficit applying to all conceptual/representational entities exists, has gradient effects on word form cooccurrence, and provides functional motivation for the avoidance of repeated elements larger than individual segments/place gestures and at longer distances.

The second half of the chapter focuses on syntactic repetition avoidance which may make no reference to the phonological form of the repeated element. Repetition may be avoided even when the syntactic feature specification is not the same, if it falls into the same head category (for example, multiple but non-identical case specifications). I give an extended case study of Semitic construct state and relativization as an example of this type. I follow Richards (2006) in arguing that in the categorical grammatical cases such as the Semitic example, it is due to the impossibility of linearization at Spell-Out for syntactic categories that do not have the distinguishing information that lexical insertion later provides.

### 5.1 A repetition deficit in perception

Coetzee's (2005, to appear) psycholinguistic work shows that in addition to rating OCP-violating stems as worse than others, speakers tend to misperceive OCP-violating consonant sequences as OCP-obeying ones. This perceptual bias toward contour is supported in recent work by Kingston (2006), who investigates sequential contrast and perception of coarticulated segments. Kingston documents "perceptual exaggeration of differences between successive intervals." That is, contour is imposed perceptually on the acoustic stream.

Another mode of misperception that results in percepts more internally differentiated than the actual input, is failure to perceive a repeated item at all. Such failure is a common tendency not only in language, but in other cognitive domains. This tendency is documented in a substantial body of work on repetition avoidance in human perception that has developed concurrently with, though in isolation from, the literature on linguistic repetition avoidance. In her seminal paper on repetition difficulty for vision, Kanwisher (1987) cites a number of previously documented problems involving perception of repetition. One such problem is *apparent motion*, in which a stimulus flashed in one location followed by an identical one presented in another location is perceived as a single, moving object. The *Ranschburg effect* occurs in reporting of item lists, of numbers for example, for which reporting is better when no repetition occurs within the list (see also Frick 1987). The *repeated letter inferiority effect* shows similar behavior for letters (Bjork and Murray 1977, Egeth and Santee 1981, Mozer 1989). Finally, typing errors tend to involve misallocations of tokens between types in words that include repetition: erroneous *liitle* or *scrren* in place of *little* and *screen*, for example. This implies difficulty in perceiving/allocating tokens among multiple occurrences. At the lexical level, Microsoft Word grammar-checker includes a specific rule for detection of repeated-the errors. This shows both how common a tokenization error in production can be, and how difficult it is to detect when present.<sup>9</sup>

Kanwisher adds to this list a phenomenon she calls *repetition blindness*. In rapid serial visual presentation of words (e.g. five words per second, above normal reading rate but well within limits of accurate reading potential) subjects have great difficulty in detecting repeated words. This is true even when the two tokens are non-consecutive and differ in case. When asked which word in a list is repeated, responses are inaccurate and confidence ratings low. Many

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<sup>9</sup> I thank Adam Albright for bring this to my attention.

subjects claim not to have seen a repetition, even when their response identifying it is accurate. When asked to repeat sentences involving lexical repetitions, second tokens are often omitted. Surprisingly, this occurs even when the result is an ungrammatical utterance.

Kanwisher's findings have since been extended to other stimulus types beyond orthographic words. Repetition blindness has been found for letters (Park and Kanwisher 1994); numbers (Bavelier and Potter 1992), color patches (Kanwisher et al 1995); locations (for different letters in same location just as for identical letters in different ones; Epstein and Kanwisher 1999); pictures (Bavelier 1994), including images of the same item from different angles, and different types within a category (e.g. airplanes; Kanwisher, Yin and Wojciulik 1997); mixed-language translational equivalents (though this finding is disputed by Altarriba and Soltano 1996); and non-words as well as words (Soto-Faraco and Spence 2002, though see Coltheart and Langdon 2003 for a contrary finding even after familiarization). It is also evoked for phonologically identical but orthographically non-identical forms such as homonyms (ate-eight) and alliterating or rhyming pairs (certify-sir, freight-great; Bavelier 1994), in addition to phonologically similar pictures and words, both semantically identical and not: cat-cat and sun-son, for example. Some task-sensitivity appears, such that phonological effects are greater when a task, such as reading aloud, requires phonological encoding. Bavelier concludes that a repetition deficit exists for any repeated stimulus, not only orthographically presented words. The deficit is elicited as long as the task requires them to be encoded along dimensions on which they are similar, a task dependency reflecting the level on which attention is focused (see also Kanwisher, Driver and Machado 1993 on color and letter identity; Baylis, Driver and Rafal 1993). Any sort of mental representation is claimed to be a possibility, whether semantic, visual or phonological.

Experiments on overlapping segment strings within words reveal behavior similar to morphological haplology, though still only for orthographic presentation. Thus repetition of single letters across words elicits worse responses, and repetitive sequences may be discarded altogether (Harris and Morris 2001):

56)	<u>Stimulus</u>	<u>Perception</u>
	grow throw ank	grow thank
	band sand	band s...
	group grand	group [st]and (guess made for substituted letters, possibly based on frequency)

As for the auditory modality, the same deficit occurs for repeated pitch tones (Palmer and Drake 1997). The work of MacKay and colleagues takes up this line of research for linguistic stimuli in the auditory modality, and finds repetition deafness effects that parallel the visual deficit. This occurs for spoken word lists and (to a lesser extent) prosodically-inflected sentences. Just as repetition blindness can occur between conceptual tokens regardless of presentation style (e.g. *nine* vs *NINE* vs 9), repetition deafness occurs for items pronounced by different talkers and differing in other phonetic detail properties (Miller and MacKay 1994, Soto-Faraco and Sebastian-Galles 2001). Thus representational identity seems to be important, not identity in visual/auditory detail. The behavior of representationally similar versus identical stimuli has also been the topic of debate, with claims that deficits for similarity repetition are qualitatively different than identical repetition (Chialant and Caramazza 1997), with different causes for each. However, the most recent research finds that similar stimuli behave like identical ones with respect to the deficit (Harris and Morris 2001), though eliciting a smaller difference (Soto-Faraco and Sebastian-Galles 2002) and are therefore presumably of comparable origin (Harris and Morris 2001).

What is the source of this repetition deficit? One possibility is that the deficit is not a perceptual phenomenon, but rather a bias against repetition in the output – that is, the bias occurs in subjects’ self-monitoring of their own responses rather than in stimulus perception (Fagot and Pashler 1995). This view is not widely held.

Other researchers attribute the deficit to a refractory period, like the one which precludes a second activation of muscle cells and neurons (Luo and Caramazza 1995, 1996; Chialant and Caramazza 1997). After stimulation, a short period follows in which reactivation cannot occur (the *absolute refractory period*). This is followed by another interval in which activation is inhibited – it can occur, but necessitates a stronger stimulus than is usually required (the *relative refractory period*). Such inhibition is already incorporated into models of psycholinguistic

activation in lexical access, and plausibly could apply to visual presentation of orthographic word forms as well as other stimulus types.

Kanwisher and colleagues cite evidence from priming to rebut the refractory period hypothesis. Due to more accurate performance in identifying the final item of a list of unpredictable length in a repeated condition than in an unrepeated one (though this effect has not been robustly replicable), they argue that the deficit stems from a problem with individuating tokens within types. They also point out that the repetition deficit may be reduced or eliminated when episodic distinctiveness of tokens is enhanced (e.g. by different coloring or motion; see Soto-Faraco and Spence 2002 for further arguments on this point that they claim favor the refractory period hypothesis). In this approach each token is perceived, but subjects are unable to tokenize them, because of a general bias in the perceptual/nervous system to be more sensitive to novel sensory information than repeated, and to minimize the number of tokens formed to account for the sensory data” (Treisman and Kanwisher 1998, Epstein and Kanwisher 1999; this approach was anticipated for speech by Stemberger, see above). This has a functional explanation, since the input stream may frequently be disrupted (by blinks and saccades in vision, for example, or stuttering in speech) in ways that would otherwise lead to erroneous perception of multiple tokens. Additional evidence against the refractory period account comes from cases in which it is clear that it is the first item which goes unperceived. Suzuki’s survey of dissimilation shows that at least in the linguistic domain, and to the extent that erroneous lack of perception results in dissimilation or deletion, the undergoer is not determined by left to right ordering as the refractory period hypothesis predicts. Rather, it is the morphological status which is crucial (e.g. in the stem versus in the affix). A refractory period cannot account for this behavior.

Regardless of the effect’s origin, it is clear that repetition poses a problem to the perceptual system that could easily affect learning linguistic processes. The tendency for subjects not to perceive one of the repeated tokens also implies the form of what is perhaps the most common grammaticalized repair – lack of one of the tokens, or haplogy. An analogue in production is also expected. Repetition at this level should be avoided in order to reduce processing difficulty and the chance of misinterpretation, for the speaker in utterance planning and production as well as for the listener. However, very little research bears on this prediction (Stemberger (1981) briefly reports the results of a pilot study). The following sections document

just such a production counterpart to the perceptual problem, at the level of phonological word forms. Section 5.2 focuses specifically on highly controlled corpus studies of that-that sequences in English, whereas Section 5.3 reports the results of an exploratory study on homophone sequences in English generally.

## 5.2 Repetition avoidance in optional *that* usage

When used in its function as complementizer or relativizer, the English word that can often be omitted. Examples 57a and 57b illustrate that omission in complement clauses (henceforth CCs) and in non-subject-extracted relative clauses (henceforth NSRCs), respectively.

- 57) a. I realize [(that) John wanted to see you].  
b. I bought Peter [<sub>NP</sub> the book [(that) you recommended \_]].

In addition to its use as complementizer or relativizer (henceforth optional that), that can also occur as a demonstrative determiner (henceforth determiner that) or pronoun (henceforth pronoun that). So, if the embedded subject of a complement or relative clause begins with determiner that, (58a), or if the subject is a pronoun that, (58b), speakers have the option to avoid uttering two adjacent thats by omitting the optional that.

- 58) a. I believe (that) that drug makes you sleepy.  
b. I believe (that) that makes you sleepy.

This phenomenon is employed here to investigate the effect of repetition avoidance on lexical/constructional choice.

Double that sequences, as in 058, constitute a rare kind of environment in which two identical word forms can appear in immediate proximity (i.e. without intervening phonological material). In double that sequences, the adjacent items are identical only in terms of the abstract phonological representation of their word forms. The two adjacent thats come from different lemmas and belong to different syntactic classes – relativizer/complementizer and determiner/pronoun. Furthermore, the phonetic realization of optional that often differs from the phonetic realization of pronoun and determiner that (Jurafsky, Bell, and Girand 2002) in a way

that cannot be reduced to contextual factors (they occur in different prosodic, syntactic, and phonological environments). Jurafsky et al. found that optional that is frequently subject to vowel reduction (while pronoun/determiner that almost never is)<sup>10</sup>, and optional that is never accented (but determiner/pronoun that frequently is). They also found differences in the mean length between different uses of that (see also Berkenfield 2000). Thus double that sequences are also qualitatively different from purely phonetic repetition effects.

Finally, optional that omission provides an environment in which identical adjacent words can be avoided without resulting in ungrammaticality (and as argued below, at least in some cases without resulting in a change of meaning). Given the optionality of relativizer/complementizer that, a repair to a repetitive double that sequence is readily available. For this reason, optional that is an optimal testing ground for repetition effects. If repetition affects optional that, then that omission should be significantly more frequent before embedded subjects that begin with (or are) that, compared to other embedded subjects.

The next section reviews factors known to influence the distribution of optional that. Two studies are then presented arguing that repetition avoidance holds for pronoun that. The subsequent three studies argue that the effect also applies before determiner that. Both sets of studies present data from syntactically parsed corpora (Penn Treebank III) and from the World Wide Web (WWW). While the WWW data is noisier, it allows us to investigate a variety of genres and registers. Also, for some questions, there was not enough data available in the parsed corpora. I conclude with a brief summary before going on to consider other cases of homophone strings.

### *5.2.1 Optional complementizers and relativizers*

The choice of optional that over the competing zero form has been attributed to at least three different sources: (a) a difference in linguistic meaning (e.g. Dor 2005; Thompson and Mulac 1991); (b) differences in style/register (Adamson 1992; Huddleston and Pullum 2002); and (c) differences in processing efficiency (e.g. Hakes, Evans, and Brannon 1976; Hawkins 2004, 2001; Ferreira and Dell 2000; Race and MacDonald 2003; Rohdenburg 1998; Jaeger and Wasow

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<sup>10</sup> In at least one American English dialect, the two forms of that have vowels of different quality altogether, independent of reduction (Elliot Moreton, personal communication). For those dialects I might expect a lesser degree of repetition avoidance, unless it is boosted by interaction with other speakers for whom the forms are phonologically non-distinct.

2005). There is no reason for these different approaches to be mutually exclusive. Indeed, there is evidence that all of the above sources influence that omission. Optional that correlates with measures of processing complexity, such as the presence of speech disfluency in the embedded clause (Jaeger 2005), the grammatical weight of the embedded clause (Race and MacDonald 2003; Roland, Elman, and Ferreira in press; Jaeger, Orr, and Wasow 2005), and the predictability of the embedded clause (Wasow and Jaeger 2005; Jaeger, Orr, and Wasow 2005). This suggests that at least some of the variation in that omission is not due to difference in meaning (whether social or linguistic) associated with optional that. At the same time, register (Ferreira and Dell 2000) and the gender of speakers (Jaeger and Staum 2005) influence optional that frequency beyond the known processing factors. Hence a meaningful test of repetition avoidance can only be conducted while other factors are controlled.

Repetition avoidance makes predictions about the frequency of optional that before embedded subjects that begin with that compared to other types of subjects. Crucially, that omission has also been shown to correlate with the complexity of the embedded subject: the more complex the subject of a CC or NSRC, the more likely is optional that (Roland, Elman, and Ferreira in press for complementizer omission; Jaeger and Wasow 2005 for relativizer omission). So in order to have an adequate baseline for the comparison of that omission before embedded subjects with initial that, it is especially important to find another type of subject that differs minimally from that-initial subjects.

In the studies presented below, demonstrative this (either in its function as pronoun or in its function as determiner) serves as baseline. Demonstrative this is suitable for the comparison with demonstrative that since both forms are similar in meaning (deictic determiners), and have similar phonological forms (the same syllable structure, phoneme count, and onset; approximately equal duration).<sup>11</sup> Furthermore, pronoun this and that have been shown to correlate with the same degree of discourse accessibility (Gundel, Hedberg, and Zacharski 1993). This is relevant since higher accessibility of CC and NSRC subjects has been linked to the likelihood of optional that (Jaeger and Wasow 2005). Unlike the demonstrative pronouns, *determiner* this and that have been argued to differ in discourse accessibility (Gundel, Hedberg,

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<sup>11</sup> Both syllable/stress structure and the complexity of the onset of words influence the phonetic reduction of preceding words (Bell et al. 2003), in the present case optional that. So even if word omission is partly driven by phonetic reduction – or, more generally, even if that omission is partly driven by the phonetic/phonological environment – demonstrative this is a suitable baseline.

and Zacharski 1993). Crucially, however, the difference biases the results *against* a repetition avoidance effect.<sup>12</sup> Some of the studies presented below include additional controls, which are discussed as part of those studies.

### 5.2.2 Optional that before pronoun that

As an initial test, the distribution of optional that before pronoun that and pronoun this is compared in two studies on different corpora. The first study is based on the WWW. The second study confirms the results on the parsed Penn Treebank III corpora (Marcus et al. 1999). Even though the first study is arguably less controlled, it is included to show the pervasiveness of the effect across different corpora.

Repetition avoidance predicts that optional that is omitted significantly more frequently if the adjacent embedded subject is the demonstrative pronoun that. As tests on the Treebank III corpora do not indicate that that omission is affected differently by the presence of an adjacent pronoun that in CCs versus NSRCs, the pooled results for that omission in the two clause types are presented.

In Study 1, The WWW was searched using the search engines Google and AltaVista, using two different search engines since it is known that the results of web searches sometimes differ depending on the search engine. All searches were performed on 07/18/2005 and include only English pages located on servers in the USA.<sup>13</sup> Below we are not interested in the absolute number of matches for any search, but rather the relative ratios of the number of matches. So we use the number of *pages* containing matches to a search (which is what Google returns) as an estimate of the number of matches.

To get an estimate of the rate of optional that before pronoun that, searches were conducted for the strings that is and that that is. The rate of optional that was calculated by

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<sup>12</sup> The more accessible the subject of NSRC, the less likely is a relativizer (Jaeger and Wasow 2005). For example, NSRCs with a pronominal subject lack a relativizer more frequently than NSRCs with a lexical subject. This calls for caution when comparing clauses with embedded subjects of different degrees of accessibility, as arguably we do by comparing this N and that N. But as this N has been argued to refer to *more* accessible referents than that N (Gundel, Hedberg, and Zacharski 1993), there should be *more* relativizers before that N is than before this N is. Repetition avoidance predicts the opposite. Thus the baseline we chose should result in a conservative test of the hypothesis.

<sup>13</sup> While the reliability of web searches has been questioned (see Veronis 2005 and references therein), most of the known problems pertain only to one-word searches. All searches presented here matched strings of words. Keller and Lapata (2003) show that online data can be used for reliable frequency estimates that resemble the distribution of carefully balanced corpora.

dividing this number by the number of hits for that is (the estimate for the number of *all* CCs and NSRCs with a pronoun that subject). The rate of optional that before pronoun that was then compared to the rate of optional that before pronoun this subjects (which was calculated parallel to the pronoun that cases).<sup>14</sup>

The inclusion of the copula is into the search strings serves three purposes. First, including the verb into the search string excludes cases of determiner that/this. Second, keeping the embedded verb constant reduces variation in that omission due to other factors (see previous section). The verb is was chosen because it is highly frequent (and therefore guarantees a high number of matches for the searches). Third, the singular form was chosen because it is necessary to exclude instances of that followed by a verb with plural agreement. While that and this share most of the environments in which they can be followed by a plural verb (e.g. All people doing this/that are cowards), there are environments in which only that can be followed by a plural verb: at the beginning of a CC or NSRC that can be followed by a plural verb (namely when that is optional that). Using a singular-marked verb form (here the copula is) excludes those case.

Comparing over 260,000,000 instances of that is to over 370,000,000 instances of this is, we found that optional that was much less likely before pronoun that than before pronoun this (about 15.8 times according to Google, and about 8.9 times according to AltaVista; Fisher's Exact  $P < 0.001$ ).<sup>15</sup>

This result provides initial support for repetition avoidance, which predicts avoidance of optional that before pronoun that (to avoid double that sequences). But could it be that, despite

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<sup>14</sup> Note that this procedure rests on three crucial untested assumptions. There is no reason to believe that these assumptions are problematic, but they are mentioned here for the sake of completeness. First, the search strings that is and this is do not only match cases we are interested in but rather *any* demonstrative subject NP (embedded in a CC/NSRC or not). Thus, if for some reason there are proportionally more false positives of this kind for this is than for that is, this could cause a false alarm (i.e. an unjustified rejection of the null hypothesis in favor of repetition avoidance). Second, the search strings that that is and that this is do not distinguish between CCs and NSRCs. However, CCs have a higher base rate of that omission. So, if for some reason pronoun that subjects are proportionally more frequent in CCs (than in NSRCs) compared to pronoun this subjects, this, too, could result in a false alarm. Finally, search engines do not filter out punctuation. For example, the search string that that is also matches "... I cannot believe I missed *that*. *That is* so stupid. ...". So, if for some reason this occurs more frequently immediately preceding punctuation than that, this could result in a false alarm. All of these potential problems with the search patterns do not matter here as long as they affect the that- and this-search strings in the same way. Furthermore, Study 2 avoids the above-mentioned problems and confirms the results of Study 1.

<sup>15</sup> Additional searches were performed including strings in which the copula forms a contraction with the pronominal subject (e.g. that is that's). The results were qualitatively the same, though contraction was observed to be more frequent following zero (90%) than optional that (80%). This complies with the generalization that syntactic deletion is often accompanied by phonological reduction (e.g. Dressler 1972).

efforts to find an adequate baseline, this difference is driven by some property of pronoun that or pronoun this that has nothing to do with repetition? The most striking difference between the two pronouns is the [+/- proximate] feature. To control for an effect of this difference, rates of that omission were calculated before the strings these are and those are (these and those also differ in terms of the [+/- proximate] feature). The rate of that omission was then normalized before the singular demonstrative pronouns by the rate of that omission before the plural demonstrative pronouns. Even after controlling for the [+/- proximate] difference, optional that is still much less likely before pronoun that than before pronoun this (about 9.9 times according to Google, and about 5.8 times according to AltaVista). The distribution of optional that before pronoun that on the WWW thus provides support for repetition avoidance.

Study 2 provides corroborating evidence from a more reliable source than web searches. It was conducted on the Penn Treebank III corpora (Marcus et al. 1999), which consist of about 800,000 parsed and part-of-speech tagged sentences from spoken language and 1.3 million sentences from written language. The syntactic annotation of the Penn Treebank III corpora is quite reliable (all parses have been hand-checked by syntactically trained annotators). In this dataset, we estimate the rate of false inclusion to be less than 1%. Tgrep 2 (Rohde 2001) was used to extract CCs and NSRCs out of the Wall Street Journal corpus (written English; henceforth WSJ), Brown Corpus (written English from a variety of genres, see Francis and Kucera 1979, henceforth BC), and Switchboard Corpus (informal spoken English from transcribed telephone conversations between two strangers on selected topics, see Godfrey, Holliman, and McDaniel 1992, henceforth SWBD). We found 17,813 CCs and 6,576 NSRCs in the Penn Treebank (to reduce noise in the dataset only CCs immediately adjacent to their embedding verb and NSRCs with either no relativizer or optional that were included).

Since only 21 NSRCs with pronoun that subjects were found, only the results for CCs are reported below. Averaged across all three corpora, CCs were introduced by optional that in about 28% of all cases.

A total of 830 CCs were found beginning with a pronoun this or that subject in the Penn Treebank corpora. The distribution of optional that (% OPT) is reported in Table 74. The last row gives the significance level of Fisher's Exact tests (two-sided) for each of the three corpora and across the three corpora (Total). All three corpora display the same trend that was observed in Study 1: optional that is less frequent before pronoun that than before pronoun this, on average

3.1 times less frequent. The repetition avoidance effect is highly significant for the pooled results (see the last column of Table 74). The difference also reaches significance for the WSJ and SWBD (BC lacks enough data to reach significance).

Subject	WSJ		BC		SWBD		Total	
	% OPT	Total	% OPT	Total	% OPT	Total	% OPT	Total
Pronoun <u>this</u>	26%	39	58%	19	18%	50	28%	108
Pronoun <u>that</u>	2%	41	33%	6	9%	675	9%	722
Fisher's Exact	<b>p&lt;0.01</b>		<b>n.s.</b>		<b>p&lt;0.05</b>		<b>p&lt;0.001</b>	

Table 74: Rate of optional that (% OPT) before pronoun that and this in CCs

As an additional control, data were extracted on that omission before pronoun these and those subjects, but not find enough cases were found for statistical testing (N=21).

As predicted by repetition avoidance, the results from Study 1 and Study 2 show significantly less optional that immediately preceding pronoun that than one would expect a priori. Shortcomings of the web searches presented in Study 1 are addressed in the second study. Taken together, the two studies show that double that sequences are avoided across a wide range of genres and styles/registers (which at least the WWW data averages over). Furthermore, the effect does not seem to be limited to written language (cf. the SWBD results). We will return to this point in the general discussion.

### 5.2.3 Optional that before determiner that

Repetition avoidance also predicts an effect for CC and NSRC subjects with determiner that, as in (3a), repeated below. This prediction is tested in the next three studies.

59) a. I believe (that) that drug makes you sleepy.

Study 3 is based on web searches. Study 4 uses the Linguist's Search Engine (Elkiss and Resnik 2004) to conduct syntactic searches on corpora gathered on the WWW. Study 5 uses the Penn Treebank III corpora.

Study 3 is based on web searches. Study 4 uses the Linguist's Search Engine (Elkiss and Resnik 2004) to conduct syntactic searches on corpora gathered on the WWW. Study 5 uses the Penn Treebank III corpora.

Parallel to Study 1, Google was used in Study 3 to compare the rate of optional that before determiner that and determiner this (AltaVista searches were also conducted but are not reported here since they do not differ from the Google results in any relevant way). All searches were performed on 07/17/2005 (only English pages located on servers in the USA). This time we were interested in matches to the searches (that) that/this ... is, where ... is the rest of a subject NP introduced by the demonstrative determiner. To reduce false inclusions (as well as unwanted variation due to different types of subject NPs), a list of singular nouns was used (see Table 75 below) and we searched for the strings that N is (this N is) and that that N is (that this N is). For each N, we calculated and compared the rate of optional that before this N is and that N is (just as was done, *mutatis mutandis*, in Study 1).

The inclusion of the copula is into the search string has been discussed in Study 1. Here including the copula has an additional purpose. It excludes hits in which N is not the complete subject, e.g. phrasal compounds, as in (60a,b).

- 60) a. I think that *peer to peer* file sharing is wrong.  
b. I think that *boy meets girl plots* are the best kind.

Only Ns that do not lend themselves to use as bare nouns were used. This was done since the polysemy of that combined with singular noun subjects that can be used with and without a determiner (the latter would be a bare noun) can result in ambiguity that lasts for several words after the embedded verb or even does not get resolved at all. Consider the following case, where that can either be optional that followed by a bare noun (generic) NP beer or the beginning of the NP that beer referring to a specific, deictically identified brand of beer:

- 61) I told you that beer from my hometown is bad.

Since speakers may avoid such ambiguities, they are excluded from the current study. We return to the issue of ambiguity avoidance in the general discussion.

To see whether repetition avoidance holds across different types of embedded subjects, three nouns were tested of each of the following seven types: monosyllabic animate nouns (e.g. girl), monosyllabic inanimate nouns (e.g. bed), disyllabic animate nouns with initial stress (e.g. husband), disyllabic inanimate nouns with initial stress (e.g. picture), nouns with three to four syllables and initial stress (e.g. capitol), nouns with three to four syllables and stress on the second syllable (e.g. infection), nouns with the primary stress on a later syllable (e.g. explanation).

Table 75 summarizes the mean ratio of optional that before that vs. this for each of the seven types of nouns. Repetition avoidance predicts values larger than 1, which indicate that optional that was less frequent before that N is than before this N is for that noun.

Type of noun			Total number of hits		(% OPT before <u>this N</u> ) / (% OPT before <u>that N</u> )
Syll.	Stressed	Animate	<u>this N is</u>	<u>that N is</u>	
1	1 <sup>st</sup>	Y	881,142	913,805	7.8
1	1 <sup>st</sup>	N	14,846,405	147,494	3.9
2	1 <sup>st</sup>	Y	208,670	90,261	8.7
2	1 <sup>st</sup>	N	1,964,900	191,060	1.5
3+	1 <sup>st</sup>	-	44,250	44,435	67.6
3+	2 <sup>nd</sup>	-	2,984,294	80,323	10.8
3+	Later	-	236,902	61,420	14.7
<b>OVERALL</b>			<b>21,166,563</b>	<b>1,528,798</b>	<b>3.4</b>

Table 75: Optional that rates before this N is vs. that N is

An analysis of variance (ANOVA) with the nouns (not the types of nouns) as random factor and determiner type (that vs. this) as only fixed effect confirmed that optional that is significantly less frequent before determiner that ( $F(1,20)=23.7$ ,  $p<0.001$ ). The control comparison of optional that before these N vs. those N did not reach significance ( $F(1,19)=1.1$ ,  $p>0.3$ ; one noun search did not yield enough hits): optional that seems to be equally frequent before determiner these and determiner those.

To conclude, the web data supports repetition avoidance (the lack of an effect for the control comparison means that the effect cannot be due to the [+/-proximate] feature). Optional that is less frequent before determiner that than before determiner this, despite the fact that omitting that before determiner that introduces (temporary) ambiguity. Although quite a bit of variation appears in the strength of the effect (cf. last column of Table 75), this seems to be due to differences between the nouns, not between the types of nouns (we found that the optional that rates differ as much or more *within* each group of nouns as they differ *between* the different types). We thus tentatively conclude that the effect for determiner that is independent of properties of the subject noun.

The high number of matches returned by web searches makes it possible to hold several factors known to influence the distribution of optional that stable (the embedded verb and the complexity of the embedded subject). But web searches contain considerable noise. So the results were replicated on more controlled corpora, the LSE Web Collection and the Penn Treebank III corpora. These studies are discussed next.

The LSE Web Collection consists of 3.5 million parsed and part-of-speech tagged sentences from 175,000 documents gathered on the web. We used the Linguist's Search Engine (Elkiss and Resnik 2004) to extract 546 CCs and 31 NSRCs that start with a determiner that or this.

For CCs, optional that before determiner that (total N=72) is about 2.9 times less frequent than before determiner this (total N=474). This difference is significant (Fisher's Exact  $p < 0.001$ ). The 31 NSRCs are not enough for a meaningful statistical test, but numerically the same tendency holds as for CCs. Optional that in NSRCs beginning with determiner that is about 2.7 times less frequent than in NSRCs beginning with determiner this. Only 11 CCs and 2 NSRCs starting with determiner these or those were found, which made a comparison to this vs. that impossible. Nevertheless, data from the LSE Web Collection confirm the trend observed in Study 3 and provide further support for repetition avoidance.

The purpose of Study 5 was to confirm the results observed on the WWW by a more controlled study on the Penn Treebank III corpora. The same databases were used as in Study 2. Only 11 instances of NSRC subjects beginning with that or this were found (of which only one was preceded by optional that), too few for any meaningful investigation. In the 17,813 CCs of

the Penn Treebank corpora, a total of 93 CCs were found with a subject beginning with determiner that or this.

Table 76 summarizes the results. Overall optional that is about 2.7 times less frequent before CC subjects that begin with determiner that compared to subjects that begin with determiner this (two-sided Fisher's Exact  $p < 0.02$ ). The result also reaches significance for the WSJ, but not for the SWBD and BC.

Subject	WSJ		BC		SWBD		Total	
	% OPT	Total	% OPT	Total	% OPT	Total	% OPT	Total
Det <u>this</u>	22%	18	50%	6	35%	17	32%	41
Det <u>that</u>	3%	32	50%	2	22%	18	12%	52
Fisher's Exact	<b>p=0.05</b>		<b>n.s.</b>		<b>n.s.</b>		<b>p&lt;0.02</b>	

Table 76: Rate of optional that (% OPT) before determiner that and this in CCs

The results are consistent with repetition avoidance. Only two of the corpora contain enough examples for a meaningful test (WSJ, SWBD). While both of these corpora display the same trend, only one of the tests reaches significance. Furthermore, the overall difference of optional that before determiner that [-proximate] vs. this [+proximate] is only slightly stronger than the difference before determiner those [-proximate] vs. these [+proximate]: optional that is about 2.2 times less frequent before determiner those (25%) than before determiner these (50%) and this difference approaches significance (Fisher's Exact  $p < 0.06$ ,  $N=54$ ). While the results for that vs. this resemble the results for those vs. these *averaged across corpora*, the effect is observed in different corpora. The only somewhat significant ( $p=0.1$ ) effect for those vs. these comes from the Switchboard corpus. Given the small number of occurrences, it is not possible to test whether optional that is disfavored before determiner that even after the effect of the [+/-proximate] feature is controlled for.

All three studies (using five different corpora consisting of different genres, registers, and modes) show significantly less optional that before determiner that than before determiner this. Study 3 suggests that this is not due to the [+/-proximate] difference between this and that. Study 4 did not yield enough data to confirm this. Study 5 shows a slightly larger asymmetry between

determiner that vs. this than between determiner those vs. these, but the difference is too subtle to draw a strong conclusion. At least some evidence suggests that the avoidance of optional that before determiner that is not due to the [+/- proximate] feature.

#### 5.2.4 Summary

Repetition avoidance seems to have an effect on the distribution of optional that even after other factors known to correlate with optional that are controlled. Before pronoun that and before determiner that, optional that is significantly less frequent than expected. The effect is strong (double that sequences are on average between 2 to 4 times less frequent than expected given the baseline). Furthermore, the studies take into account only one avoidance mechanism (dropping optional that). The potential use of other ways of avoiding adjacent repetition (e.g. constituent reordering such as topicalization in the embedded clause; the choice of which instead of optional that for nonhuman head nouns in NSRCs; insertion of intervening material such as fillers or editing terms like you know or uh/um, or adverbials such as to the best of my knowledge; etc.) means that these tests provide a conservative estimate of the effect. In sum, the results support a role for repetition avoidance in lexical/constructional choice. This preference appears to be an active if gradient effect, with strong consequences for online linguistic production.

One prediction of this account has not yet been tested. Utterances that contain double that sequences must have some property that otherwise tends to be associated with higher likelihood of optional that. That is, CCs and NSRCs with double that should be more complex than otherwise comparable clauses (i.e. CCs and NSRCs with this-initial subjects). Further research is necessary to verify this point and determine what kind(s) of complexity can outweigh the dispreference for double that.

One could object to our conclusion that the results argue for *word form* repetition avoidance. Orthographic identity holds in the case of two thats as well as word form identity, and thus is an alternative source of the effect. But while most of the results we have presented are based on written language, we have included results from spoken language, for which the observed effect is smaller but still significant. Thus the observed effect appears to be at least in part driven by word form identity. The next section presents research on non-orthographically identical English homophone strings, in an additional attempt to tease apart the relative contributions of orthographic and word form dimensions of identity.

### 5.3 Additional homophony effects

The methodological disadvantages of using web search results as linguistic data have been mentioned above. However, in looking at homophone sequences, the advantage of corpus size is paramount. Given the relative (un)likelihood of particular multiple lexical item sequences in other corpora, the size of the WWW makes it the only feasible arena of investigation.

Searches were performed using the Google search engine on March 16, 2005. Sixteen homophone pairs were considered. They are matched with comparable pairs that are synonymous when possible (*passed past* versus *passed by*) but may also involve using the next item in a sequence (*for four* versus *for five*) or a word, possibly an antonym, of comparable frequency (*knew new* versus *knew old*) or with similar semantic properties (*wear where*<sup>16</sup> versus *wear when*). The second item in the pair, then, may be homophonous or non-homophonous.

A second series of pairs retains the second items from the preceding series, while keeping constant a non-homophonous first item. The resulting quadruplets are given in the following table, with the homophonous sequences leftmost. The use of these quadruplet strings should allow for a comparison of homophonous versus non-homophonous ones, while minimizing the influence of different frequencies for component items (residual variation due to different cloze probabilities for the different strings may still be expected). Establishing a ratio between the number of hits for each item in columns A and B controls for the frequency of the first word in these two-word sequences, which remains constant. The corresponding ratio between the number of hits for each item in columns C and D does the same for the second items in the string pairs of A and B, while the first item is again kept constant (though differs from the one used in A and B, so that no homophony occurs in these columns). What is of interest, then, is the difference between the ratio of B/A versus the ratio of D/C, since the first involves homophony and the second does not. Underuse of homophonous strings predicts a larger difference for B/A than for D/C.

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<sup>16</sup> Pairs involving wh-words are not wholly homophonous if the /wh/ sequence is not pronounced as [h], but are included on the assumption that for most speakers they are.

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>1</b>	won one	won a	has one	has a
<b>2</b>	to too	to also	them too	them also
<b>3</b>	to two	to a couple	in two	in a couple
<b>4</b>	two too	two also	a couple too	a couple also
<b>5</b>	for four	for five	in four	in five
<b>6</b>	it's its	it's his	that's its	that's his
<b>7</b>	ate eight	ate nine	have eight	have nine
<b>8</b>	passed past	passed by	walked past	walked by
<b>9</b>	knew new	knew old	saw new	saw old
<b>10</b>	they're there	they're here	he's there	he's here
<b>11</b>	there's theirs	there's hers	here's theirs	here's hers
<b>12</b>	whether weather	whether it	if weather	if it
<b>13</b>	whole hole	whole thing	entire hole	entire thing
<b>14</b>	you're your	you're my	I'm your	I'm my
<b>15</b>	plain plane	plain airplane	fast plane	fast airplane
<b>16</b>	wear where	wear when	hear where	hear when

Table 77: Homophonous and non-homophonous search strings.

The following table gives raw numbers of hits generated for each of the search strings. Cells correspond to those in the previous table (so that cell 12B contains the number of hits for the string “whether it,” for example). In addition, it provides the ratios mentioned above. The final column provides the subtraction of the two ratios,  $(B/A) - (D/C)$ . Recall that our prediction is for this difference to be positive. Avoidance of homophone strings predicts the number of hits in column A to be fewer than otherwise expected, relative to those of the other three columns which should remain constant, so that the  $B/A$  ratio should be greater than the  $D/C$  one.

	A	B	B/A	C	D	D/C	B/A - D/C
1	278,000	6,300,000	22.66	7,690,000	56,400,000	7.33	15.33
2	681,000	4,120,000	6	2,220,000	1,390,000	0.63	5.42
3	20,000,000	909,000	0.05	29,600,000	2,640,000	0.09	-0.04
4	53,100	173,000	3.26	7,980	3,800	0.48	2.78
5	10,300,000	8,500,000	0.83	14,300,000	11,000,000	0.77	0.06
6	25,000	663,000	26.52	45,700	280,000	6.13	20.39
7	828	813	0.98	350,000	228,000	0.65	0.33
8	776	6,460,000	8324.74	307,000	451,000	1.47	8323.27
9	8,050	5,660	0.70	71,200	31,700	0.45	0.26
10	365,000	310,000	0.85	179,000	212,000	1.18	-0.34
11	89	3,160	35.51	79	5,060	64.05	-28.55
12	839	12,500,000	14898.7	165,000	44,400,000	269.09	14629.6
13	790	4,850,000	6139.24	5,530	31,800	5.75	6133.49
14	63,500	848,000	13.35	726,000	88,600	0.12	13.23
15	3,740	92	0.02	5,140	1,920	0.37	-0.35
16	25,900	181,000	6.99	55,600	260,000	4.68	2.31
Mean	1,987,913	2,863,983	1842.53	3,483,014	7,338,993	22.7	1819.83

Table 78: Hits generated for homophonous and non-homophonous search strings.

This prediction is borne out. Subtractions show that the gap between hits generated is greater when homophonous strings are involved for 12 of the 16 search strings, as predicted by our hypothesis. Wilcoxon's signed rank test shows that this effect is statistically significant ( $p=.01$ ,  $z= -2$ ). Of the four exceptions, only one is at all sizable, with the other three differing by less than one digit. The values of the D/C ratio, for which no difference is predicted and which should therefore cluster around 1, do so as expected, with a mean of 22.7. Those of B/A, which involve homophonous strings, range far higher.

The results of this section suggest that avoidance of word form repetition extends beyond the case of *that-that*, discussed in detail and more statistical rigor at the beginning of this chapter,

to other sequences of homophones. In addition, the effect exists for these homophones even though they lack orthographic identity. This provides further evidence that the observed effect is lexical, rather than purely visual.

This chapter has so far focused on repetition avoidance in which phonological form is constant and syntactic/semantic properties differ. The remainder of the chapter considers effects for which syntactic/semantic features are shared, and phonological ones may or may not be.

#### **5.4 Syntactic repetition avoidance and the Distinctness Principle**

Many of the repetition avoidance phenomena discussed so far can be construed as phonological, morphological, discourse-related, syntactic, or as some subset of these. In this section I describe a few less ambiguously syntactic repetition avoidance effects, coming primarily from the expression of possession and relativization in Semitic. I account for these effects with an analysis appealing to the Distinctness Principle formulated by Richards (2006), and presented by him as a sort of “syntactic OCP.” While the Distinctness Principle does result in grammatical phenomena that are superficially similar to those documented earlier (epenthesis/insertion of spacing elements, deletion of one of the otherwise repeated elements), I argue that it should not be considered a member of any such constraint family (which in any case I argue against the existence of in Chapter Four). Rather, it is the third, independent factor against repetition that I mention in Chapter One.

##### *5.4.1 Syntactic repetition avoidance*

Many of the repetition avoidance triggers described in Chapter Four rely on identity along multiple dimensions – phonological as well as morphosyntactic. Thus while the effect on the Hindi suffix *–[ko]* results in the very syntactic operation of word order change and is driven by identity of the very syntactic idea of case, the trigger suffixes also are identical in terms of phonological form. While identity of phonological form is not always sufficient to trigger repetition avoidance (recall its irrelevance in the *double-ing* phenomenon), very few cases involving morphosyntactic repetition avoidance do not also involve it.

Many of these so-called syntactic effects involve clitic clusters (Menn and MacWhinney 1984). For example, in an expected sequence in Italian of impersonal subject clitic *si* and reflexive *si*, one of the tokens surfaces instead as *ci*, the first person plural clitic. The repetitive

sequence cannot be universally excluded, since it persists in at least one dialect and is tolerated when the first *si* is a complementizer rather than a clitic. But in this case, clitic substitution occurs according to which is the next best match with respect to syntactic features, and which features are valued more highly by the ranking of feature-specific faithfulness constraints. Ackema (2001) extends this analysis to Dutch complementizers. The homophonous form *of* means both ‘or’ and ‘whether.’ In utterances for which a sequence *of of* is expected (e.g. “do you know whether x...*or whether* y”), the second occurrence is instead realized as *dat* ‘that.’ Similarly, syntactic extraposition is employed in avoidance of expected *dat dat* sequences, a dispreferred outcome that is also avoided in English, as we have seen.

Nevertheless, a few cases that do not involve complete phonological form identity do exist. Spanish clitic substitution applies to the two non-identical forms *le/lo* (Grimshaw 1997; though such sequences would still result in consonant-adjacent identical segments, which as we have seen may be dispreferred for other than syntactic reasons). Kornfilt (1984) applies George’s (1980) Stuttering Prohibition in discussing one such case involving nominal agreement morphemes of different phonological form in Turkish. Ackema concludes that featural content is in some sense more basic to the OCP than phonological form, since even cases involving identical phonological forms “must still share some featural content in order for the OCP effect to be triggered” (such as belonging to the same functional category, as in the *si si* example from Italian). Some other types of repetition, such as English reduplication (Do you *like her* like her?) are tolerated since one of the copies lacks featural content (in Ackema’s analysis).

Neeleman and van de Koot (2003) consider additional cases of repetition avoidance with respect to functional heads. Although their work focuses on the behavior of polysemous Dutch *er*, which also depends on phonological form identity, they discuss additional cases which do not. One of these involves deletion of the Romanian possessive marker introducing a postnominal possessive, if it would otherwise surface adjacent to the (non-phonologically-identical) definite article. This deletion does not occur in an adjective or demonstrative form intervenes. In addition, both Old French and Arabic omit weak (non-focussed) pronouns when they would be adjacent to the inflectional ending they agree with. This effect is independent of phonological identity, which does not hold for these cases. Suppression of plural agreement for postverbal subjects in Arabic is also attributed to the presence of the subject adjacent to the verbal ending (VSO word order).

All these cases so far involve linear adjacency of the forms involved. Indeed, Neeleman and van de Koot argue that “for most cases of haplology involving free forms a purely syntactic analysis is unsatisfactory, primarily because....it cannot but treat the relevance of adjacency as epiphenomenal.” Grimshaw’s (1997) OT formulation of a syntactic OCP, formulated as an analysis of clitic cluster phenomena and stated below in 62, specifies no domain. This is on the assumption that it applies only in cases of strict adjacency.

62) Grimshaw’s (1997) syntactic OCP:

Sequences of identical functional heads are ill-formed.

However, even for the *double-ing* phenomenon already discussed, linear adjacency does not suffice to capture the observed pattern. While *-ing*-inflected forms are generally avoided, the prohibition against them does not apply for those in which a *wh*-trace, and therefore a phase boundary intervenes (*\*it’s continuing raining*, versus *the children that I was watching \_\_\_ playing*). We will see that in some cases not only must a domain be specified (the strong phase), the hierarchical relations within it are relevant too. The latter are impossible to incorporate into any OT OCP constraint schema discussed or proposed so far, which is one reason for abandoning the attempt to integrate these two types of repetition avoidance.

#### 5.4.2 Possession in Semitic

Let us now move to a detailed consideration of apparent repetition avoidance phenomena in Semitic syntax, focusing first on the expression of possession.<sup>17</sup> Hebrew expresses possession in the following two semantically equivalent ways (examples from Richards 2006):

- 63)   ha bayit šel ha mora  
      the house of the teacher  
      the teacher’s house

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<sup>17</sup> Irish displays a strikingly similar set of facts with some suggestive differences, for which I refer the reader to Richards (2006).

- 64) beyt ha mora  
 house the teacher  
 the teacher's house

It is not possible to simply concatenate the two DPs, as below:

- 65) \*ha beyt ha mora  
 the house the teacher  
 \*the teacher's house

It seems, then, that definiteness cannot be expressed on both the nouns when they are strictly adjacent. Either a spacing element must intervene, or definiteness must be stripped from the first noun.

A similar set of facts holds for a great number of the Semitic languages. Unlike Hebrew, Akkadian has no overt marking for definiteness/indefiniteness. However, also unlike Hebrew, Akkadian has overt case-marking. As the following examples show, the expression of possession is formally identical in Hebrew and Akkadian, except that where Hebrew shows definiteness marking, Akkadian shows case-marking. Likewise, Akkadian case-marking is lost in the same environment as Hebrew definiteness marking is lost (Huehnergard 1997).<sup>18</sup>

- 66) kasp-um ša šarr-im  
 silver-nom of king-gen  
 king's silver

- 67) kasap<sup>19</sup> šarr-im  
 silver king-gen  
 king's silver

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<sup>18</sup> For masculine plural nouns only, and dual ones in dialects for which the dual is retained, diptotic case marking is preserved (Huehnergard 1997:57).

<sup>19</sup> The second /a/ vowel in this example is the result of epenthesis and vowel copy, as a repair to the complex coda that would otherwise result from case deletion.

It is clear that in both languages, the concatenation of DPs to express possession must result in either the insertion of a spacer element (Hebrew *šel*, Akkadian *ša*), or the deletion of functional material from the first DP (Hebrew definiteness, Akkadian case). For both languages only one such kind of material is present overtly, and it is deleted.

Classical Ethiopic, or Ge'ez, exhibits behavior similar to Akkadian, though its operation is more difficult to discern. While lacking definiteness marking, nouns in Ge'ez show a distinction between accusative case (-/a/ suffix) and non-accusative case (null case-marking) (Lambdin 1978).

68) Hora<sup>20</sup> neguš  
went king (nom)  
the king went

69) Hora neguš-a  
went king-acc  
he went (to) the king

A suffix that is phonologically identical to the accusative one marks the first noun in construct state (Lambdin 1978).

70) neguš-a hagar  
king-constr city  
city's king

Based on Arabic, which will be discussed in detail below, the expected case specifications for construct phrases like that in 70 are for the second noun to be genitive, and the first one to be able to express the full range of case-marking available in the language. Thus in a sentence such

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<sup>20</sup> In Lambdin's (1978) transcription, the initial segment of this word is an h with a dot underneath. I use here a capital letter instead.

as 71, we expect to see both an accusative suffix /a/ on king, and also a construct suffix /a/. In fact we see a single short /a/ vowel.

- 71) Hora neguš-a hagar  
He went to the king's city

Note that Ge'ez has contrastive length for the vowel /a/ (Lambdin 1978). Thus both /a/ and /aa/ are distinct phonemes of the language. Moreover, it exhibits regular and productive coalescence of /a+/a/ vowel sequences into a single long vowel (Dillmann and Bezold 2003:77). Therefore, the fact that the suffix on the first noun of a possessive construct remains short provides evidence that one of the two /a/ vowels has been deleted – in this analysis, the accusative case vowel. The expected sentence in which the case and construct vowels have coalesced into /aa/ is not attested, suggesting that case deletion is obligatory in this context.

- 72) \*Hora neguš-aa hagar  
\*He went to the king's city

Ge'ez also has a spaced alternative to construct state, exemplified below (Lambdin 1978:107):

- 73) neguš za-hagar  
king of-city  
city's king

Thus despite its relatively impoverished system of case-marking and the homophony of accusative and construct morphology, Ge'ez can be seen to behave exactly as Akkadian does in terms of resolving DP sequences that violate distinctness.

Classical Arabic displays a richer system of morphological marking on the noun than Hebrew, Akkadian, or Ge'ez. As illustrated below, Arabic nouns show both definiteness and case marking.

- 74) al-kitaab-u-l-mumtaaz-u  
 the book nom the excellent nom  
 the excellent book

In construct state, the first noun loses definiteness marking, but retains the full range of overt case-marking. The following three examples show this with respect to nominative, accusative and genitive case, respectively:

- 75) kitaab-*u*-l-walad-i hunaa  
 book-nom-the-boy-gen here  
 The boy's book is here

- 76) qaray-tu kitaab-*a*-l-walad-i  
 read-1sgsubj book-acc-the-boy-gen  
 I read the boy's book

- 77) qaray-tu-hu fii kitaab-*i*-l-walad-i  
 read-1sgsubj-3sgobj in book-gen-the-boy-gen  
 I read it in the boy's book

Note that Arabic differs from the cases discussed previously, in at least two respects. All the languages discussed so far manifest only one layer of functional material overtly, and it is deleted. The Arabic data shows that when more than one kind of functional material is marked on nouns, it is sufficient for one layer of it to be deleted in order for linearization to take place, rather than all functional material of the DP.

Finally, Arabic also has the spacing option, as shown by 78.

- 78) al-kitaab-u <sup>°</sup>and al-walad-i  
 the-book-nom poss the-book-gen  
 the boy's book

The structure is rather marked in Classical Arabic but quite natural in the colloquial dialects, which differ as to the phonological realization of the intervenor. To conclude, Arabic is also compatible with the distinctness account of construct state, once independently-motivated modifications to DP structure are taken into account.

One last piece of information comes from Sabaic, a Semitic language formerly spoken in southern Arabia. The nature of Sabaic orthography presents a complication, since (like that of other Semitic languages) it represents only consonants (the status of long vowels is unclear). For this reason, the behavior of case cannot be observed. Definiteness, however, is observably marked with a consonantal suffix /n/ (Beeston 1984). Moreover, this suffix is not present on the first noun of a construct phrase.

- 79) ‘mt’lmqh sb’-y-t-n bt xdqm                      hqny-t...Slm-t-n                      ð-t-ðhb-n                      ð-šft-t
- A Saba-adj-f-def daughter X promise-3sf...statue-f-def of-f-bronze-def which-promised-3sf
- Amatilumquh, the Sabaean woman, daughter of Xadaqum, has dedicated...the female statue of bronze which she had promised...

There are several features to note in this short inscriptional passage (Jamme 1962; inscriptions without royal name #706). The suffixal definite article appears first on the second word of the passage. On the third, however, it is omitted. Here is an example of a construct phrase (*daughter of Xadaqum*), in which definiteness marking is lost from the head noun. In the next-appearing noun phrase (*statue of bronze*), the definiteness suffix does appear on the first noun, and the expected spacing particle also does, in order to adequately separate it from the second noun. Finally, observe the identity of the relativizer with the noun phrase spacer (*modulo* gender inflection).

It is not certain whether Sabaic patterns with Hebrew (definiteness and no case; definiteness lost) or Arabic (definiteness and case; definiteness lost). Nevertheless, it is clear that it fits into one of these classes. Cross-linguistically, then, the Semitic languages avoid having adjacent nouns that are both inflected for whatever surface morphology the language in question permits (case or definiteness). This is true even when the features to be expressed are not identical. That is, a sequence of indefinite+definite nouns in Arabic is avoided just as a sequence

for which the definiteness specification is identical (both definite or both indefinite). Similarly, case-inflected sequences are disallowed in Akkadian even though those specifications necessarily differ.

#### 5.4.3 *Relativization in Semitic*

Relative clause formation in Semitic has been noted to share striking formal similarities with the expression of possession (for dialectal Arabic see Haddad and Kenstowicz 1980, for a review of the language family see Gensler 2005). In this section I review its properties across the language family.

Recall the morphology associated with possession in Akkadian, repeated below:

80) kasp-um ša šarr-im  
silver-nom of king-gen  
king's silver

81) kasap šarr-im  
silver king-gen  
king's silver

Now observe the parallelism with the behavior of relative clauses, shown below:

82) kasp-um ša itbal-u(šu)  
silver-nom that he took-subordination marker-(it)  
the silver that he took

83) kasap itbal-u(šu)  
silver he took-sub.-(it)  
the silver that he took

As with construct state and its spaced counterpart, the two alternants are semantically equivalent. The head noun of a relative clause may either be case-marked and followed by the particle *ša*, or lose case and not be followed by such a particle, just as in construct phrases.

Also as with construct phrases, it is unacceptable for a fully inflected noun to be immediately followed by something other than the spacer *ša*.<sup>21</sup>

- 84) \*kasp-um itbal-u(šu)  
 silver-nom he took-sub.-(it)  
 \*the silver that he took

Unlike Akkadian and other Semitic languages (discussed further below), Arabic does not make use of a spacing element that is identical in form to the one in free genitive phrases. It does have an overt relative marker, the form and inflectional properties of which are shown below:

	masculine	feminine
singular	allađii	allatii
dual      nom	allađaani	allataani
acc/gen	allađaini	allataini
plural	allađiina	allawaatii/allaatii

Table 79: Forms of the Arabic relative marker.

The following examples show its use in the context of a masculine singular head noun:

- 85) al-kitaab-u allađi qaray-tu-hu  
 the-book-nom that read-I-it  
 the book that I read

- 86) \*al-kitaab-u qaray-tu-hu

<sup>21</sup> It is also unacceptable to use the construct form of the noun when the spacer is present (\*kasap sha itbal-u(shu). I assume that sha-insertion is avoided when not necessary as a spacer, as a violation of principles of economy.

the-book-nom read-I-it  
the book that I read

87) *kitaab-u-n qaray-tu-hu*  
book-nom-indef read-I-it  
a book I read

88) *\*kitaab-u-n allađi qaray-tu-hu*  
book-nom-indef that read-I-it  
a book that I read

Observe that the relative marker is obligatorily present for definite nouns, and obligatorily absent for indefinite ones.<sup>22</sup>

Most of the other Semitic languages also may introduce relative clauses by a noun in construct state, without an intervening relativizer, whatever the morphological properties of construct state in that language may be (Huehnergard 1999). In Gensler's (2005) survey of Semitic relativization types, he finds the alternative of construct noun+relative clause, without an intervening relative marker that is otherwise present, in the Ugaritic, Hebrew, Old South Arabian, and Ethiopic languages (for further documentation on Hebrew, Ge'ez, and (arguably) Amharic, see Dillmann and Bezold 2003).<sup>23</sup> Aramaic displays residual traces of such an alternation as well, though it is not productively present in the language as attested.

For those languages in which nouns may head a relative clause in the construct state without a relative marker or fully inflected with one, the intervening relative marker takes the

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<sup>22</sup> Indefinite head nouns of relative clauses are dissimilar from construct nouns in two respects. First, in the Arabic dialects, they do not undergo the same phonological process that results in pronunciation of a final /t/ for feminine nouns (except optionally in Lebanese; Haddad and Kenstowicz 1980). Secondly, they are marked with the indefinite suffix (as opposed to the construct nouns, which receive no definiteness marking at all). It may be the indefinite is the default for Arabic, in much the same way that Irish construct nouns are consistently inflected with default nominative. If that were the case, however, it remains mysterious why all construct nouns are not also marked as indefinites. In any case, the point remains that the expression of (in)definiteness is restricted in both contexts, such that the range of inflection otherwise possible in the language may not be realized.

<sup>23</sup> For the latter, this construction is particularly frequent with time nouns – c.f. the use of *yawm* 'day' and *Hiin* 'moment' in Qur'anic Arabic, the former of which has been relexicalized as the wh-word 'when' in Gulf dialects of Arabic.

same form as the “spacing” element found in free genitive phrases, as shown in Table 80 (adapted from Gensler 2005).<sup>24</sup>

Language	Akkadian	Ugaritic	Hebrew	Aramaic	S. Arabian	Ethiopic
Spacer/ rel. marker	ša	d	ašer, še, zu (rare)	ḏii	ḏ	za

Table 80: Spacer/relative markers across Semitic

Below is the paradigm for the Modern South Arabian languages, which are omitted from Gensler’s survey (Simeone-Senelle 1997:412,418).

MSA language	Singular	Plural
Jibbali	é	é
Mehri	w/d	ḏ/d
Others	ḏ/d	l

Table 81: Relativizer/possessive particle in MSA

While MSA currently has no construct state other than residually in fixed idiomatic phrases, this state of affairs suggests that an equivalence like that described for Akkadian, above, held at some point in its previous history. The same is true of the Amharic object marker *yä*, which appears on possessors and introduces relative clauses (Ouhalla 2004, den Dikken 2003). It is not subject to the kind of morphological alternation discussed here, but is further evidence for the formal unity of the two constructions (for further discussion of its behavior in distinctness-motivated processes, see Richards (2006)).

In sum, relativization in Semitic uniformly displays striking formal similarity with the expression of possession in the same languages. For both, a head noun must either lose a layer of functional material or be separated by a spacing element from the material that would otherwise

<sup>24</sup> This spacer/relative marker is typically traceable historically to a demonstrative form.

follow. In addition, the form of the spacing element when present is consistently the same for both possessive and relativized constructions. In the following section, I present a formal account of this set of facts.

#### 5.4.4 Linearization and the Distinctness Principle

The two alternatives of deletion of functional material and insertion of a spacing element correspond roughly to the repetition avoidance repairs of deletion and epenthesis in phonology. The existence of both implies some problem with the structure that would presumably otherwise result, which I have argued is related to the repetition of functional material in it.

This hypothesized but ungrammatical structure is given below for Hebrew and Akkadian possessive forms (disregarding for now the brackets).

Hebrew  
 \*ha beyt ha mora  
 the teacher's house

Akkadian  
 \*kaspum šarr-im  
 king's silver

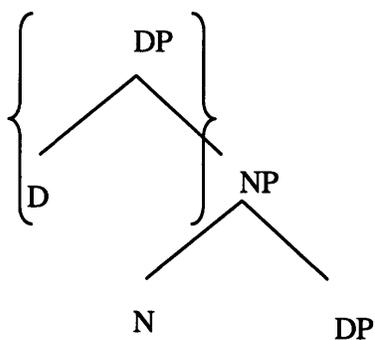


Figure 20

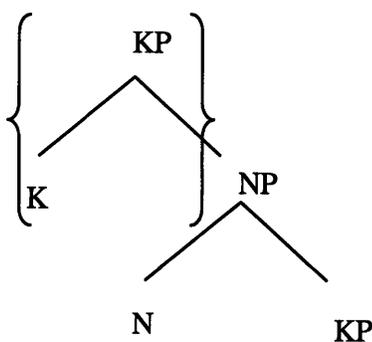


Figure 21

Kayne's Linear Correspondence Axiom (LCA; 1994) holds that linearization of the nodes of such trees (barring traces, which need not be linearized) must occur in the operation of Spell-Out. This occurs for each strong phase, via the computation of ordered pairs of nodes in which the first node label asymmetrically c-commands the second, and therefore linearly precedes it and everything it c-commands (its *image*).

The problem with the above trees, then, is that they result in pairs such as <D,D> and <K,K>, respectively. Had the two node labels in each been of different syntactic categories, such a pair would suffice to establish an unambiguous linearization of the lexical items that each one dominates. However, the features in this case are identical. On the assumption of late lexical insertion, no further details about the forms depending from these nodes are available at this point in the derivation process. This means that phonological dissimilarity does not help to distinguish the two nodes (and also guarantees its irrelevance for this kind of repetition avoidance). As it stands, these structures are not linearizable – they generate a linearization pairs that are at best ambiguous, and at worst contradictory.

The phenomenon illustrated by the above two structures necessitates what Richards terms the Distinctness Condition on linearization. This is a well-formedness statement that disallows sequences of identical syntactic categories that are adjacent in the sense described above, and is formally stated as follows:

89) Distinctness Principle (Richards 2006):

If a linearization statement <a, a> is generated, the derivation crashes.

(Identical feature bundles in an asymmetrical c-command relation may not co-occur within a strong phase).

Richards employs this condition to rule out multiple occurrences of identical feature bundles within strong phase boundaries, with no reference necessary to linear adjacency within those boundaries or the phonological form of these features' eventual realization.

Let us now consider possible repairs to the kinds of distinctness violations illustrated above. One can imagine at least two possible repairs to the structures of Figures 20 and 21. The first option is to delete the top layer of functional material, as shown in the brackets of those figures. In that case, the first noun will surface stripped of some inflectional material. I argue that this is precisely what happens in the construct state.

Another option is to insert an additional and typewise-distinct category between the two identical ones. This inserted layer must be assumed to introduce a phase boundary. In that case, the two nodes (here, Ds or Ks) will no longer be sent to Spell-Out to be linearized together, so no linearization statement involving the pair of them can be generated. This solution provides

another way of avoiding violations of the Distinctness Principle. I propose that the insertion of the Semitic spacing elements is an example of this solution. Their presence introduces a prepositional phrase (PP), which establishes the necessary intervening phase boundary.<sup>25</sup>

Let us now consider how relativization fits into this account. I make the common assumption that such clauses are introduced with a DP operator (in Akkadian, this may correspond instead to a KP with the usual top layer of nominal functional material). The hypothetical but ungrammatical structure that we might expect in Akkadian is depicted below in Figure 22.

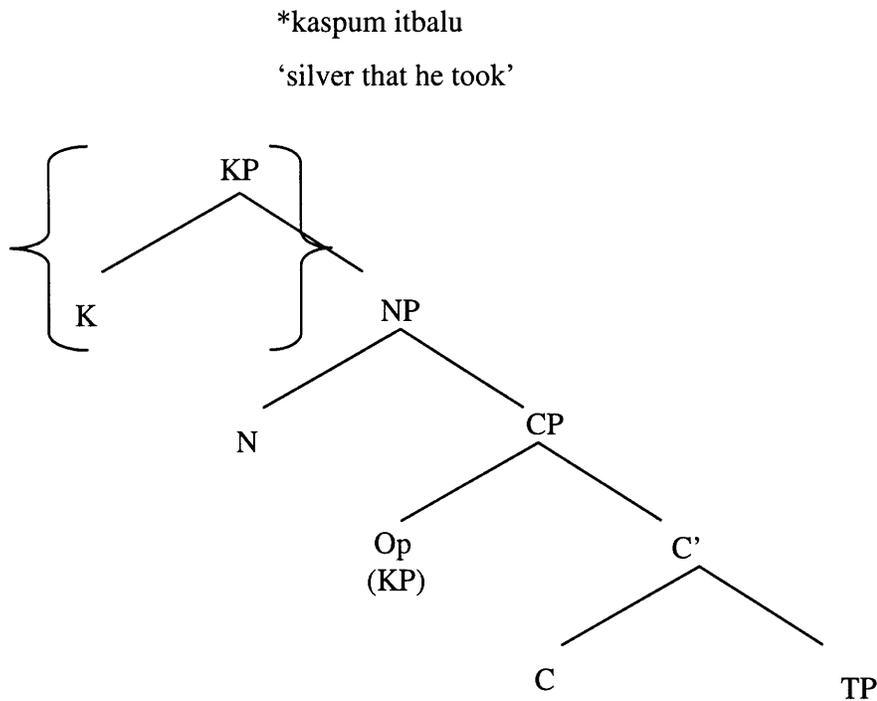


Figure 22

Precisely the same considerations apply as in the expression of possession. The K head of the first noun is unlinearizable with the K head of the operator. It is not surprising, then, that exactly

<sup>25</sup> A third option in Akkadian constitutes the exception that proves the rule. Neighboring nouns may both surface with case if and only if one of them is a deverbal form. I hypothesize that the deverbal forms contain a layer of verbal functional material which suffices as a boundary between the two nouns. Support for this idea comes from the fact that such forms also assign accusative case to other nouns, and that their order with respect to a neighboring possessed noun is reversed from the usual, mirroring instead the usual SOV order of Akkadian clauses.

the same repair strategies are possible. Either the top layer of functional material is not permitted on the head noun, or a spacing element is introduced – the same one as is used for possession, thereby introducing a phase boundary. Note that in Akkadian the construct alternative cannot be used for complement clauses of nouns, but is limited to relative clauses (Rebecca Hasselbach, personal communication). This is as predicted if the trigger for using a construct noun is a distinctness violation that results from the presence of relative operators.

The situation for Arabic is somewhat more complicated than for the other Semitic languages, as the two repairs are not in more or less free variation. Instead, the relative marker is obligatorily used for definite head nouns, and is impermissible for indefinite ones. However, the result remains that the expression of the top layer of functional material on the head noun (here, definiteness) is restricted in these contexts. In addition, it has been argued that the relative marker/spacing element itself is a D head (primarily due to the apparent isomorphy of the definite article and the initial segments of the relative marker; Ouhalla 2004, Aoun and Choueiri 2000). If this is the case, its use compounds rather than solves the linearization problem. I propose instead that the Classical Arabic relative marker introduces a KP, NumP or gender node. This seems plausible given the fact that it does not observably inflect for definiteness but does so, if marginally, for all three other features. This proposal is also compatible with the idea that certain CPs are dominated by shells with functional material typically associated with nouns (Han 2005 and references therein).

Finally, up to this point I have assumed an analysis of relative clauses in which the head noun originates outside of the clause. However, relative clause head nouns appear to originate inside the clause on at least some occasions (Brame 1968, Kayne 1994, and others), and has been suggested for Arabic based on evidence from idiom and binding effects (Ouhalla 2004, Aoun and Choueiri 2000). Analyses of this type are not obviously compatible with a distinctness one, since in the absence of a DP operator there is no violation of distinctness to be repaired by deletion or insertion of a functional layer. Fortunately, the *matching analysis* of relative clause head noun location both captures the reconstruction facts and involves structures for which a distinctness account remains plausible (Sauerland 1998 *et seq*, Hulsey and Sauerland 2004, Safir 1999). On this account, relative clause head nouns are argued to be generated both internal and external to the clause. The internal one is then elided or (as in the case of Arabic) pronounced as a resumptive pronoun. This account is also compatible with the analysis outlined above. Its use

makes possible a unified account of the formally similar behavior of nominal functional material across Semitic and with respect to both possessive phrases and relative clauses. Accounts of the Arabic relative clause that depend on clause-internal head raising and a D relative marker, like Ouhalla's, fail to do so.

### **5.5 The interaction of anti-repetition factors**

In this chapter I have reviewed evidence for the existence of two additional anti-repetition factors in human language. First, a perceptual bias leads to listeners not perceiving one token in a repeated sequence. I provide novel evidence for the relevance of this bias in speech production as well as perception – speakers avoid producing sequences of lexical items with identical phonological form.

Second, I have shown that alternations involving concatenations of DPs in a number of languages are consistent with an account that crucially relies upon the notion of distinctness as applied to syntactic categories. This account provides a unified explanation for the expression of possessive phrases across the Semitic language family, as well as for conditions on the use of overt relativizers in these languages, which displays striking formal similarities to that of DP sequences expressing possession. In syntax as in other domains of the grammar, the avoidance of sequences of identical elements plays an active role in determining linguistic productions. However, such avoidance is driven by yet another bias, not by either the physiological or perceptual ones posited earlier in this dissertation. Nor are the patterns it captures amenable to inclusion in any general OT OCP constraint schema. This provides a piece of evidence against the use of such a schema, which if it exists should be able to capture all processes which are obviously motivated by repetition avoidance.

In addition, the syntactic sections present evidence that repetition avoidance is motivated by identity at very abstract levels of representation. It may be elicited by syntactic features independent of any similarity in phonological form. In some cases, like Akkadian case and Arabic (in)definiteness, even the feature specification may differ – presence of a feature head suffices to elicit repair.

With all three of the proposed anti-repetition factors in hand, we may proceed to consideration of the interactions between them. Although each is conceptually independent, it has already been pointed out that for many instances of potential repetition, more than one of

them may apply. For example, while the repetition of a place gesture elicits variation primarily because of the biomechanical difficulty it presents, this difficulty is presumably compounded by the repetition of the gesture as a representational entity (i.e. a feature), because of which it also is subject to the general cognitive/perceptual bias against repetition of any conceptual category (the repetition deficit discussed at the beginning of this chapter). The influence of the repetition deficit alone is not, apparently, enough to elicit variation – this is demonstrated by the lack of such variation elicited by repetition of nasality. However, in other cases the cumulative effects of representational identity along multiple dimensions may constitute a boost to an independent repetition avoidance effect. I conjecture that the similarity effect in gradient consonant cooccurrence restrictions is partly attributable to such a cumulative effect.

Recall also that no counterexample has been found to one of McCarthy's original arguments against any phonetic/articulatory motivation for antigemination – that such a role predicts antigemination processes involving homorganic consonants as well as strictly identical ones. The interaction of the repetition deficit with the BRAH goes some way toward explaining this lack. Strictly identical segments are subject to the repetition deficit as conceptual categories independent of their component features. The intersection of these two factors, then, predicts much stronger such effects for identical segments than homorganic ones, if not a total lack of the latter.

Similar considerations apply to repetition deficit-motivated haplology and the BRAH. When the repetition deficit factor is considered on its own, no asymmetry is necessarily expected between haplology of different-sized chunks – say, single segments versus syllables. However, Stemberger's (1981) sizable corpus of haplological processes reveals that the distribution is actually strongly biased. Out of the 23 cases he considers, 14 of them would otherwise result in  $C_1VC_1$  sequences. I propose that it is not accidental for over half the corpus to consist of cases that would otherwise result in the same kind of sequence to which the BRAH applies. Of the remaining cases, 5 more are of processes that avoid  $C_1C_1$  sequences, which are also potentially subject to the BRAH. Only 3 examples involve repetition avoidance of any other type, and 2 of those are isolated, irregular examples (Latin *nutritrix* and *distortor*; the final case does not fall neatly into any of these categories).

Just as the second anti-repetition factor, the repetition deficit, favors antigemination of strictly identical segments over homorganic ones generally, the BRAH means that haplology

motivated primarily by the repetition deficit preferentially applies to repeated sequences that are also biomechanically difficult.

Finally, let us consider the interaction of the repetition deficit with the kind of syntactic repetition avoidance discussed in the preceding section. It was observed that while syntactic repetition avoidance referring purely to syntactic properties does occur, regardless of phonological form identity, such cases are relatively little attested. The more typical example is one like the *double-ing* phenomenon, in which syntactic properties are relevant – not every sequence of phonological *-ing* is disallowed – but phonological form identity also exists. I propose that this is the expected result of the independent activity of the repetition deficit at multiple levels in some cases – where both syntactic and phonological identity apply – and possibly of the deficit with the Distinctness Principle in others.

I have argued that the three anti-repetition biases identified in this dissertation are independent – conceptually distinct and motivating different kinds of repetition avoidance phenomena. This very independence is an argument against a unitary grammatical constraint against repetition (particularly an innate one, since the functional pressures apply in the absence of any innate bias). However, these biases can and do interact with each other at interface points. These interactions yield asymmetries in the distribution of repetition repairs, such that some sequences are preferentially targeted.

## Chapter Six: Conclusion

Repetition avoidance is wide-ranging both in terms of cross-linguistic attestation and the grammatical categories to which it can apply. This dissertation has illustrated the great extent of such effects in both senses, focusing on the gestural, lexical and syntactic domains in multiple languages. A common approach to these phenomena and their frequency is to attribute them to and model them with a universal, innate grammatical principle against repetition. The ascendancy of grammatical models involving violable constraints solves many of the problems previously identified with this approach.

Nevertheless, I have taken a different tack in this dissertation. I argue that grammatical repetition avoidance is driven by a set of independent and functional biases against repetition, with different causes and different effects. The first of these is the Biomechanical Repetition Avoidance Hypothesis (BRAH). It consists of the claims that gestural repetition (particularly of more massive articulators like the place ones) is articulatorily difficult, that this difficulty leads to predictable kinds of phonetic variation, and that the phonetic variation is the source of many phonological repairs. Specifically, I present an evolutionary account of antigemination and a particular type of dissimilation along these lines. I support these claims with evidence from cross-linguistic patterns in phonological repairs and tendencies among gradient ones; from music performance; and from a series of phonetic studies of English. All of these constitute novel types of evidence in favor of the hypothesis, which is itself a new proposal.

Providing this kind of functional motivation obviates the need to incorporate many asymmetries in repetition avoidance into complicated grammatical formalisms. For example, the proximity and similarity effects observed for both morpheme structure constraints on consonant cooccurrence and for phonological dissimilation are the direct result of the functional pressures encoded in the BRAH, and need not be accounted for in the grammatical system. On the other hand, the phonetic effects observed are not all mirrored as phonological patterns. This points to a role of formal properties of the system in constraining possible grammaticalizations. Thus grammars are constrained by both functional pressures and the possibilities allowed by the formal system. The phenomenon of repetition avoidance provides a rich arena in which these considerations play out.

The second anti-repetition bias discussed here is the perceptual deficit causing speakers not to perceive one of a sequence of repeated items, of any conceptual category. Chapters Two and Three take an established set of phonological phenomena and propose both a functional motivation for it and document gradient patterns of behavior that provide a bridge between the functional bias and the categorical effects. In the case of the repetition deficit the functional bias is already well-documented, as are the grammatical effects (primarily haplology). I provide here the bridge evidence of gradient variation in production. This evidence comes from avoidance of homophone sequences in English corpora.

Finally, the third factor is a principle disallowing the repetition of syntactic features in certain configurations within a phase domain, concentrating this time on categorical rather than gradient effects. Semitic syntax provides a rich set of cross-linguistic data exemplifying such an effect, which elicit repair strategies superficially similar to those of phonology (specifically, deletion and epenthesis/insertion).

The range of repetition avoidance effects identified here belies claims that it is primarily either phonological (Yip 1998) or syntactic (Ackema 2001), as claimed by researchers coming from the two subfields. To the extent that all the documented effects occur at Spell-Out or later – that is, at the interface point with Phonological Form (PF), it is true that repetition avoidance is ultimately phonological. However, avoidance may occur prior to lexical insertion, before the phonological content of lexical items is known. In that sense, it may not be very phonological at all. In this broader sense, then, either type of identity can be the crucial one. Identity along some other dimension is a kind of bonus that does increase vulnerability to a repetition avoidance repair, thereby explaining preponderances among forms triggering repetition repair.

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