Locality in Phonology and Production Planning[*]

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SUMMARY

This paper explores the idea that certain locality effects on phonologically conditioned allomorphy and external sandhi processes can be explained by the locality of production planning. The first part of this paper presents evidence for this hypothesis based on locality effects in phonological conditions on the choice of allomorph of the affix /ing/ between [in] and [iŋ]. A second and more speculative part explores how this view sheds new light on a number of puzzles that earlier accounts of locality in phonology failed to address: Why is it that sandhi processes tend to be variable, and what can this variability tell us about the nature of phrasal phonology? Why is it the case that different kinds of sandhi processes come with different kinds of locality conditions that seem to depend on their phonological substance? Why is it that lexical frequency and collocational cooccurrence seem to be able to affect sandhi processes in addition to syntactic and phonological factors?

1 LOCALITY IN PHONOLOGY

Phonological processes tend to apply locally. It is useful to distinguish two types of locality effects in phonology: One concerns locality constraints on phonological interactions that can be characterized in purely phonological terms. For example, place and voicing assimilation typically affect adjacent segments, tone interactions tend to affect nuclei of adjacent syllables, as does vowel harmony. Phonological action at a distance is possible within very tightly circumscribed limits. In vowel harmony, some segments can count as transparent such that vowels of non-adjacent syllables can interact (cf. Nevins, 2010, and references therein).

A second type of locality effect requires reference to extra-phonological morpho-syntactic information. Many sandhi processes are constrained in this way, they appear to be constrained by syntax and cannot apply across certain morpho-syntactic junctures.

There are three main ways of thinking about this type of morpho-syntactic locality effect in the current literature. The first is to allow for a direct influence of syntax or morphology on phonological processes (Selkirk, 1972; Odden, 1990); the second is to postulate that particular morphological or syntactic junctures receive particular phonological boundaries as phonological correspondents, and to state locality conditions in reference to these phonological objects, as in the theory of the prosodic hierarchy (Selkirk, 1984, 1986; Nespor and Vogel, 1986); the third approach, which I will henceforth call the *cyclic approach* since it originated with the transformational cycle in Chomsky and Halle (1968), is to devise a derivational theory of phonology such that only part of the ultimate phonological representation is available at any particular moment of phonological rule or constraint evaluation, and hence information outside of this locality domain is not available at a certain derivational point in the computation of phonology (Chomsky and Halle, 1968; Kaye and Piggott, 1973; Kiparsky, 1982, 2000; Bobaljik, 2000; Embick, 2010). These different approaches have been motivated based on a variety of different phenomena, and it is conceivable that these different phenomena require different explanations, so they are not necessarily mutually exclusive.

This paper explores a new way of thinking about locality effects, distinct from the three existing approaches in crucial and empirically testable ways. Rather than attributing the observed morpho-syntactic locality effects to a direct interaction between syntax and phonology or postulating some mediating phonological objects that effectively mimic syntactic structure, the proposal is that the locality of production planning can explain these interactions. The proposal is closely akin to the cyclic approach in that locality is explained as a lack of information at a certain point in time, but the relationship between syntactic locality and phonological locality is much more indirect than in the cyclic approach. The idea behind this perspective is that phonology in principle applies blindly across word boundaries, but that the phonological environment in the next word might not be available at the time of phonological evaluation simply because production planning has not yet progressed that far. The scope of production planning depends on a multitude of factors such as the time pressure under which an utterance is produced, and the semantic, syntactic and phonological complexity of the upcoming material, the rate of speech—all of would then be predicted to affect the application of phonological processes if these are indeed constrained by production planning constraints.

This view of locality in terms of production planning is highly modular: It can account for syntactic effects on phonology without any direct communication between syntax and phonology or any mediating prosodic structure. At least in some cases, syntax exerts its influence on phonology simply by affecting the likelihood of a requisite phonological environment in the next word being already planned out at the point where a phonological process might apply. It can thus effectively reduce a morpho-syntactic locality effect to a purely phonological locality effect.

The processing-based view also makes new predictions about variability. Variability of phonological processes has traditionally been considered a performance phenomenon that is marginal to the investigation of how phonology works. Considering the locality production planning might actually lead to new insights about what variability can tell us about the nature of phonological

processes. Higher level information such as the number of words in an upcoming constituent is available earlier in the production planning process than lower level information such as the number of syllables of a word or the precise segmental content, which is encoded very locally (Sternberg et al., 1978). Encoding fine phonological detail across word and phrase boundaries might in fact not be possible reliably. This would lead us to expect that across-word processes which apply in an environment that requires knowledge about upcoming segmental information are more variable that processes that apply in an environment that makes reference only to higher-level information. We can thus relate the degree of locality and the degree of a variability of phonological processes directly to the phonological substance of the environment that triggers them.

It is important to note that considering the locality of production planning will not be able to explain all interactions between syntax and phonology. But even in those cases where reference to syntax will still be necessary, it can inform our analysis and serve to make novel types of predictions. This first part of this paper reports experimental evidence for this idea based on a particular case of phonologically conditioned allomorphy in English; the second and more speculative part explores further implications and predictions for the locality of sandhi processes based on observations from the literature.

2   PHONOLOGICALLY CONDITIONED ALLOMORPHY

The realization of the English suffix /ing/ varies between (at least) two phonologically distinct pronunciations: [in] vs. [iŋ]. Across different varieties of English this variation has been shown to be influenced by gender, speaking style, and socio-economic factors (Fischer, 1958; Labov, 1972; **?**). The segmental phonological context has also been shown to matter (Houston, 1985, and references therein). Crucial for the present paper, the allomorph [in] is more likely when there is a coronal segment immediately following (as in (1-a)) than when there isn't (as in (1-b)).

(1)   a.   While the man was read[in] the book, the glass fell off the table.
          b.   While the man was read[iŋ] a book, the glass fell off the table.

The effect of phonology is arguably not simply a case of co-articulation or assimilation, since it interacts with morphology. For example, /ing/ is much less likely to be pronounced as [in] when it is part of an arguably mono-morphemic word like *ceiling* than when it is an affix (Houston, 1985). So the alternation between [in] and [iŋ] is sensitive to the identity of the morpheme the segmental string is part of. Whether the alternation involves the choice between two listed allomorphs [in] and [iŋ] or whether it is derived by morpho-phonological rule is a question that we can remain agnostic about since allomorph choice and morpho-phonological processes obey the same locality constraints (at least according to Kiparsky, 1996). We can thus investigate /ing/ to test claims about locality in morpho-phonology.

Cyclic theories of morphology assume that complex words are built from inside out, and predict that the phonology of material that is compositionally added later cannot influence earlier morphological choices. This claim has been argued for in various cyclic theories, including lexical theories of morphology (Carstairs-McCarthy, 1987), Lexical Phonology (Kiparsky, 1982, 1996) and some versions of Distributed Morphology (Bobaljik, 2000; Embick, 2010). It should then be impossible

for the choice between *the* and *a* to influence /ing/ across a syntactic boundary as in (2-a) but not in (2-b)—at least if the affix combines with the verb after the complement (as is assumed in Distributed Morphology):

(2)　　a.　　While the man was reading, || the/a book fell off the table.
　　　　b.　　While the man was reading the/a book, || the glass fell off the table.

In global theories of phonology/morphology like standard Optimality Theory (cf. the discussion in Embick, 2010), there is no reason why such locality generalizations should hold. While one can add locally restricted constraints to such theories that would force locality, a ranking without such locality effects in which a general phonological markedness constraint drives the choice of a particular affix without regard to syntactic or phonological boundaries should always be possible. In other words, this kind of theory cannot explain why locality should *necessarily* hold.

2.1　METHODOLOGY

A production experiment was conducted using 42 quadruplets (henceforth referred to as 'items') similar to those in (2). The experiment was run in a 2x2 latin square design, such that each participant saw only one condition from each item in pseudo-random order, and saw an equal number of trails from each condition across the experiment. There were 42 participants, all native speakers of North American English having grown up in Canada or the US. The recorded data was forced aligned by segment and by word using the prosodylab forced-aligner (Gorman et al., 2011). Participants were instructed to say the sentences as naturally as possible, as if in a conversation with a friend. We used a Praat script to extract acoustic measures of pitch, duration and intensity for each word. Furthermore, the data were annotated perceptually by 2 RAs for whether [in] or [iŋ] was used. The annotation was done using a Praat script that made the annotation blind to condition, and the annotators were only able to listen to the affix itself to make the choice.

2.2　RESULTS

Figure 1 illustrates the proportion of [in] choice by syntax (non-local vs. local) and phonology (vowel (*a*) vs. dental fricative (*the*)). A mixed model logistic regression was conducted with syntax and phonology as factors and item and participant as random effects, using the lme4 package in R (Bates and Maechler, 2010). The model showed significant main effects and a significant interaction. In other words, using [in] is more likely when *the* follows than when *a* follows, and when a direct object follows than when no direct object follows. The significant interaction shows that the phonological influence of the following word is stronger in the local environment. The interaction is predicted by cyclic theories but not by the global theory. However, unexpectedly for the cyclic approach, the effect of phonology was also significant in the subset of data only consisting of the non-local cases.

　　The full data pattern is unexpected both for the global and the cyclic view. It is as expected under the view that the phonological influence on the choice of allomorphs of /ing/ is subject to the locality of production planning, since the clause boundary separating the verb from the following
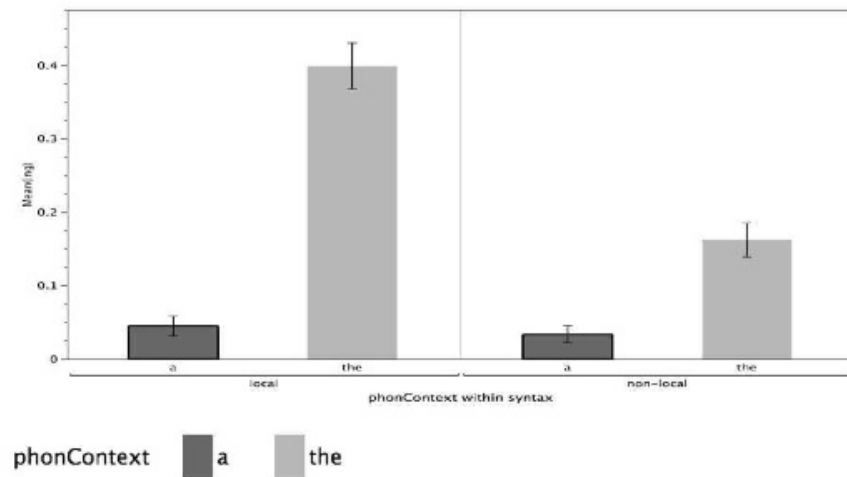
Figure 1: Proportion of [in] by syntactic and phonological context. Error bars show one standard error from the mean.

argument will plausibly have the effect that it is less likely that the upcoming word is planned at the point when the allomorphic choice is made.

To test this hypothesis, we quantified the strength of the boundary separating the affix and the following article by extracting a number of acoustic measures. The strength of the prosodic boundary between two words can arguably be taken as a proxy measure for the degree to which the second word was planned out at the time when the first word was encoded. While this is clearly not the only factor that will affect prosodic boundary strength, it seems plausible that it is one relevant factor. Recent studies have shown that disfluencies, which correlate with stronger prosodic boundaries, are more likely when the upcoming word is harder to retrieve and hence a strategy to 'buy time' in the process of planning the upcoming material.

One measure of boundary strength is the 'strength' of the following word due to the effect of 'initial strengthening' (Keating, 2006). We measured the length of the article as a proxy for how big the boundary was between verb and following NP. Within the subset of data that included only the article *the*, the length of the article was a significant predictor of [in] pronunciation, and once that was added to the mixed model, syntax became irrelevant (the two factors are highly correlated).

Furthermore, the length of the article was a significant predictor even *within* the non-local and *within* the local syntactic environment. This means that the effect of phonology on allomorph choice depends gradiently on the prosodic strength of the boundary separating the affix from the phonological trigger (which in turn is affected by syntax). Another test with similar results was conducted using the normalized duration of the verb plus affix (raw length minus the expected length based on phonemes), a measure which reflects pre-boundary lengthening.

2.3 DISCUSSION

The results can be straightforwardly accounted for if we assume that the phonological environment for allomorph selection is stated in purely segmental terms such that [in] is chosen with a greater likelihood if a coronal segment follows. This, combined with the the assumption that phonology is constrained by the locality of production planning, can account for the observed data—at least if we make the plausible assumption that the prosodic strength of the boundary between two words correlates with the likelihood that the beginning of the second word will already by phonologically encoded at the time when the first word is planned (cf. Levelt, 1992; Wheeldon and Lahiri, 1997; Miozzo and Caramazza, 1999; Wheeldon and Lahiri, 2002, for discussions of the locality of production planning).

/ing/ is encoded as [in] with higher probability when a coronal sound follows—but whether the identity of the following segment is known at the time of encoding determines whether this phonological can take hold. Syntax and prosody influence how likely it is that segmental conditioning environment is present at the time of allomorph choice (or at the time of morpho-phonological alternation processes). The phonological environment can thus be stated in purely segmental terms.

A pronunciation of /ing/ as [iŋ] is more likely the stronger the boundary is, even in those cases where no coronal is following. This fact might have something to do with the fact that [iŋ] is longer than [in]. **?** show that the choice between *uhm* and *uh* in disfluencies in English depends on the size of the disfluencies. The phonologically bigger and phonetically longer *uhm* tends to preferred in the case of major disfluencies. across different languages, there are often 'pausal' allomorphs that are phonologically more contentful and longer, and the choice between [iŋ] and [in] might in part be due to the same kind of effect (Dresher, 1994, cf.)

This account of the locality effect makes a number of new predictions that have yet have to be tested. It predicts that there should be a left-to-right asymmetry in phonologically conditioned allomorphy, a prediction that that does not line up with the inside-out view of the cyclic account. For example, the phonological shape of a prefix should be able to influence allomorph choices of following prefixes or the stem. It also makes predictions about variability: regressive effects on allomorph choice should be more likely to be variable than progressive ones, since the phonological environment is less likely to be planned out already. Furthermore, phonological conditioning across phrase boundaries should be more variable than within phrases. For example, the choice between *a* and *an* in English depends on a phonological content that is only separated from the article by the very weak prosodic break that separates a function word from its complement—hence the choice should be much less variable than that between the pronunciations of /ing/, since here the prosodic break separating /ing/ from the following phonological context can be much stronger, it can be even an intonational phrase break. Any phonologically conditioned allomorph choice across word and phrase boundaries is in fact predicted to be variable by necessity given the tight constraints on phonological encoding found in the literature on production planning.

3 LOCALITY IN SANDHI PROCESSES

Phonological processes that apply across word boundaries are often referred to as an external sandhi processes. The idea that production planning constraints are at the heart of certain cases of locality

in phonology might shed some new light on some old questions in the grammar of such sandhi phe-
nomena. As we will see, this new perspective doesn't necessarily replace alternative accounts, but
it can rationalize otherwise arbitrary seeming properties of sandhi processes and make predictions
that link the locality and variability of processes directly to the kind phonological information nec-
essary for their application. In this section I will discuss three exemplary cases based on data from
the literature where a look at production planning might rationalize otherwise puzzling phenomena,
and outline how these ideas can be tested empirically in future research.

3.1 FLAPPING

A case where a locality condition in terms of production planning seems desirable is flapping in
English. Flapping has been observed to occur between constituents of essentially any syntactic size.
The following examples are taken from Nespor and Vogel (1986, 225):

(3)   a.   the whi[ɾ]e owl
      b.   invi[ɾ]e Olivia
      c.   A very dangerous wild ca[ɾ] escaped from the zoo.
      d.   Although that was not the first camel he ro[ɾ]e, it was most certainly the last one.

The fact that flapping is possible even across sentence boundaries led Nespor and Vogel (1986) to
posit that this is a phonological process that operates within the domain of the phonological utter-
ance. However, this characterization by itself is hardly helpful in picking out the conditions under
which flapping applies, because flapping often does not apply where it could under this character-
ization. And yet there is a systematic pattern to the distribution of flapping. Essentially, flapping
is more likely to apply across boundaries of weaker prosodic strength (Wagner, 2005). Nespor and
Vogel (1986) propose to account for cases in which flapping fails to apply although its segmental
environment is met by the additional assumption that pauses can be inserted in an utterance that
interrupt the application of flapping. But they do not explore how these pauses might distributed
relative to the prosodic structure of an utterance. But shouldn't the distribution of pauses itself not
be part of what a theory of prosodic phonology should account for? The difficulty that the theory
in Nespor and Vogel (1986) faces is that a process appears to be constrained by boundary strengths,
but the strength of the boundary does not correlate in any obvious way with syntactic boundaries
of a certain type. And yet the theory of prosodic phonology developed in Nespor and Vogel (1986)
rests on the assumption that certain types of syntactic constituents map to certain types of prosodic
constituents (see Wagner, 2005, 2010, for a more extensive discussion of this point).

An alternative account offered in Wagner (2005) and Wagner (2010) is based on the idea that
the mapping between syntax and phonology fixes is not the particular phonological category of a
prosodic constituent but rather the strengths of boundaries relative to each other. So in contrast to
the theories of syntax-phonology mapping in Nespor and Vogel (1986) and Selkirk (1986), there are
no designated syntactic categories in this theory that map to designated phonological categories (cf.
the discussion of this issue in Dresher, 1994). In this alternative view flapping is one of many cues
that speakers use to encode *relative boundary strength*.

The perspective of production planning adds a new twist to this relational view of flapping: Maybe flapping is a process that is purely defined in reference to segmental structure, and the relevance of an intervening boundary is entirely indirect. Depending on how much of the segmental and prosodic representation of the current word has already been planned at the time when the following phonological material becomes available, the following material can either be integrated into the foot structure and flapping can apply or not. Even without any reference to boundaries this account can explain the influence of syntax: The syntactic structure of the utterance can make it more or less likely that the upcoming word has been sufficiently planned at the time when flapping might apply.

This view has advantages over alternative accounts. To see this more clearly, we have to bring to light the numerous questions the account in terms of prosodic phonology fails to answer. A central question is: Why is it that flapping across word boundaries is variable? Could there be a language like English in which it isn't? The view from production planning can offer an answer: It is hard if not impossible to reliably plan out the segmental content of upcoming prosodic words without fail. In other words, even when stated in purely segmental terms a process like flapping *has* to be variable under this view since the environment for its application is not reliably present at the time when a word with a final coronal stop is phonologically encoded. It can also account for the phonetic locality of flapping: flaps in English are only allowed intervocalically, so it is not actually sufficient to know that a vowel follows to apply flapping, its phonetic realization requires a gestural timing that it closely tied in to both preceding and following vowel. Production planning can potentially also explain why it is that factors such as frequency can have an effect on flapping (Patterson and Connine, 2001): Fequent words are easier to retrieve and hence it is more likely that all the information relevant for the application of flapping is available at the time when the flappable stop is phonologically encoded. The perspective of production planning can thus link the properties of flapping—variability, prosodic locality, frequency and collocational effects—directly to the phonological substance of the change and the environment under which it occurs.

So far this is just a hypothesis, but one that can be tested empirically: Factors known to influence the amount of look ahead in production planning are predicted to influence the likelihood of flapping, and any cases in which flapping occurred should show a greater degree of look ahead than those in which flapping could have occurred but didn't. These predictions can be tested in experimental studies similar to the one presented here.

3.2 THE LOCALITY OF TONE SANDHI

As a simple illustration of the kinds puzzles that a better understanding of production planning might shed light on, let's look briefly at patterns of tone sandhi in Chinese languages. Tone sandhi in Xiamen (Chen, 1987) has played a pivotal role in the development of our understanding of the relationship between syntax and phonology. Xiamen, described by Chen as a southern Min dialect of Chinese that is also referred to as Amoy, Hagu, Hokkien, and Hoklo, along with certain related dialects of Taiwanese shows a tone sandhi process in which all but the last lexical words within a certain domain undergo a tone chain shift. On syllables that do not have a stop coda ('free syllables'), Xiamen distinguishes five different lexical tones, which are often transcribed as 44, 24, 22, 21, and 53; syllables that have a stop coda ('checked syllables') have a more limited inventory of

two tones, but they also undergo tone sandhi under the same circumstances. Words that do not occur at the end of a so-called *tone group*, a sandhi tone surfaces rather the underlying tone (Chen, 1987).

(4)   a.   tsin p'ang
             very fragrant
             'very fragrant'
             Underlying tone: 44 44
             Surface tone: 22 44

       b.   p'ang   tsui
             fragrant water
             'fragrant water'
             Underlying tone: 44 53
             Surface tone: 22 53

What counts as a tone group in Xiamen? According to Chen, the generalization can be stated as follows: Mark the right edge of every XP with #, except where XP is an adjunct. The symbol # is used as a boundary of a tone group, and any material between two # s or a boundary and an utterance edge counts as a tone group. Chen shows that this simple idea is able to derive correct tone groupings for a wide range of intricate examples, even in cases where the tone group does not seem to line up with syntactic constituency:

(5)   lao tsim-a-po # m   siong-sin ying-ko # e   kong-we
       old lady   not believe   parrot   can talk
       'The old lady doesn't believe that the parrot can talk.'

This idea of marking syntactic edges has been hugely influential in the literature on the syntax-phonology interface, and has lead to the development of edge-based alignment theories between syntax and phonology (e.g. Selkirk, 1986; Truckenbrodt, 1999; Selkirk, 2011). A central assumption of these theories is that syntactic structure is mapped to a hierarchical prosodic representation, the prosodic hierarchy, which obeys certain well-formedness conditions, one of which is the so-called strict-layer-hypothesis (Selkirk, 1984). Tone sandhi in Xiamen, however, doesn't fit very well with this assumption. An insightful observation from Chen's paper that is less often considered is that the domain of tone groups is actually *orthogonal to the surface prosodic phrasing*. Chen notes that there can be bracketing mismatches between intonational phrases and tone groups:

(6)   Mismatch between Tone Group and Intonational Phrase
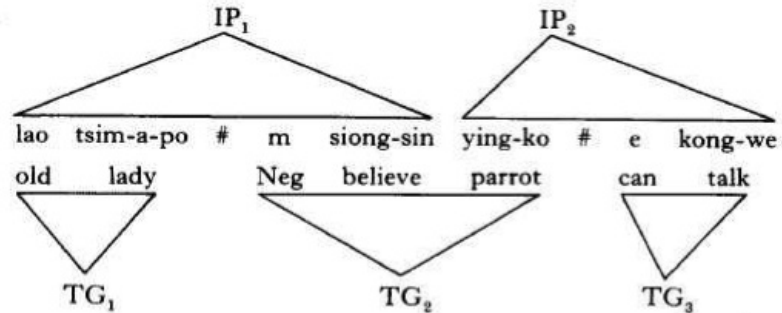
Note that the intonational phrasing actually fits well with the syntactic constituent structure, while the tone groupings disobey the syntactic grouping. Crucially, they do not align with the intonational phrasing as would be expected based on the strict layer hypothesis. The embarrassment raised by this mismatch between tone group and intonation phrase for current theories of the syntax-phonology interface is twofold: The first problem is that the mismatch constitutes a direct refutation of at least the strongest version of the theory of the prosodic hierarchy which holds i) that syntactic locality effects in phonology are mediated by the prosodic hierarchy, and ii), this hierarchy obeys a strict layering of phonological constituents. Either the tone group is part of the prosodic hierarchy, just as the intonational phrase, and strict layering is not obeyed, or else the tone group has to be defined outside the prosodic hierarchy, which would constitute an undesirable proliferation of types of prosodic representations.

The second problem runs deeper: Current theories of the relation between syntax and phonology provide no expectation for when to expect a clean relationship between prosodic phrasing and the application of a phonological process and when to expect a Xiamen-style mismatch. Also, given that there is a mismatch, why is it that intonational phrasing aligns better with syntax and tone groups don't, and not the other way around?

This second problem can be brought to light further by a comparative look at tone sandhi in Mandarin. Mandarin Chinese has four tones: 55 (level), 35 (rising), 214 (low-rise), and 51 (falling). When a T3 (214) is followed by another T3, it changes into T2 (35). The domain in which this sandhi process happens is partly determined by syntax, partly phonologically. Surprisingly, the definition of 'tone group' relevant for this sandhi process differs from the tone group in Xiamen in being entirely congruent with surface prosodic phrasing.

Apart from the fact that it remains mysterious why the definition of tone group is different in the two Chinese languages, current theories have no insight to offer why it is the sandhi process in Mandarin that is true to surface prosody and the one in Xiamen that allows mismatches and not the other way around.

Taking production planning as a factor into account might be able to shed new light on this issue: The literature on production planning reports clear evidence that the locality window within which certain kinds of information about upcoming words and constituents are available depends on the granularity of the information. Sternberg et al. (1978), for example, find that utterance initiation

time is influenced by the number of words within an entire utterance. More concretely, Sternberg et al. (1978) found that utterance initiation time for the production of lists showed a linear increase for lists of up to 6 words, and then reached a ceiling, suggested that the planning window is about 6 content words long. It is plausible that the actual syntactic and semantic relation between the upcoming words will affect the size of the planning window, but this was not manipulated in their experiments. Interestingly, the number of syllables within the first word of an utterance also had an effect, but the number of syllables in later words had no influence. In other words, lower level and finer grained information about the phonological content of a word is available within a much more local window that higher level information such as the number of words within a certain domain.

Sternberg et al. (1978) proposed to account for the observed effects by positing a model in which different levels of representation of an utterance are planned out at different points in time. The idea is that a motor program can contain sub-programs which eventually fill in the more detailed information such as the segmental content, but at the time of utterance initiation only the number of sub-programs and the internal properties of the first subprogram have an effect. The concrete hypothesis advanced in Sternberg et al. (1978) is that the unit of of the sub-programs is the stress-group, later work suggested that it coincides with the *prosodic word* (Wheeldon and Lahiri, 1997). Keating and Shattuck-Hufnagel (2002) proposed that not just higher level syntactic information, but also higher level prosodic information is planned earlier than lower level syllabic and segmental information.

These findings from research on production planning could provide precisely the rationalization of the differences between tone groups in Mandarin and Taiwanese that we've been looking for: The application of tone sandhi in Taiwanese only requires knowledge of whether or not a word is the last one within a certain syntactic domain, while in Mandarin knowledge about the precise lexical tone of the upcoming tone is needed. Under the plausible and testable hypothesis that the former but not the latter kind of information is available across intonational boundary breaks, this difference in the phonological definition of the environment can account for the difference in the locality condition on the process.

3.3 A PHONETIC LOCALITY EFFECT ON LIAISON CONSONANTS

French liaison consists of the pronunciation of an otherwise unpronounced word-final consonant when a word beginning with a vowel or a glide follows Selkirk (1972, 206):

(7)   a.   Lorenzo est petit en comparaison de Jean.
        b.   Lorenzo es[t] un peti[t] enfant.

In (7-a), both the [t] at the end of *est* and that at the of *petit* are lost, but for different reasons. The word *est* is followed by a consonant-initial word, *petit*, and hence there is no liaison. *Petit*, in turn, although followed by a vowel-initial word, remains unpronounced as well. The problem here is that it does not form a liaison context together with the following word, due to the syntactic relation between the two words. In (7-b), on the other hand, both [t]s are preserved since both words are followed by vowel-initial words and in addition, they bear the right syntactic relation to the following words, hence liaison applies. Correctly capturing the domain of liaison in French has

been a recurring issue in work on the phonology-syntax interface at least since Selkirk (1972).

Selkirk (1986) and Nespor and Vogel (1986) propose that liaison applies within a certain phonological domain, the phonological phrase, and whether words are phrased together into such a unit depends on the syntactic relation to each other. More generally, work within prosodic phonology assumes that phonological processes that seem to be sensitive to syntax are in fact sensitive to certain phonological domains, and it is in the formation of these domains that syntax indirectly exerts its influence on phonological processes.

There are a number of challenges for the analysis in terms of phonological phrases, however: The word lending the initial vowel with the liaison consonant can be separated by a prosodic phrase break from the liaison word, and the liaison consonant can be pronounced either word finally before the pause or word-initially after the pause (Ågren, 1973). See also Post (2000) and Pak (2008) for evidence that liaison is not closely tied to surface prosody. Another issue is that the taxonomy of syntactic liaison environments is complex, there are environments where liaison has been argued to be obligatory, optional and impossible respectively, but variability has been found in all environments to some degree (Mallet, 2008). Finally, it seems clear that morphological and syntactic factors play a role that cannot be reduced to phonological factors, e.g., certain lexical words are much more likely to show liaison than others, and certain glide-initial words trigger liaison on the preceding word and others don't. Many of these objections were already voiced in Morin and Kaye (1982) and earlier works they cite, issues that later prosodic analyses never addressed. For a particularly clear demonstration that an analysis of liaison of prosodic domains is untenable, in contrast to some other true prosodic processes such as clash resolution, see Post (2000). It seems clear from the results in the experimental literature that the application of liaison is sensitive to syntactic factors (in certain syntactic environments liaison applies even with novel words) and morphologically/lexically factors (the likelihood of liaison depends on lexical factors such as frequency, likelihood of co-occurrence) that cannot be reduced to phonology (Post, 2000, for experimental evidence and a recent review).

The aspect of liaison that I want to focus on here is a different one, however. The traditional analysis of liaison has been that certain words in French have an underlying final consonant that is only pronounced if a vowel- or certain glide-initial word follows. There are different variations on this theme, from analyses in terms of suppletion of alternate stems forms to autosegmental analyses. Alternative accounts analyze the liaison consonant as epenthetic, as a separate morpheme, or as part of the of *following* word (Côté, 2012).

One argument against this traditional analysis of the source of the liaison consonant is phonetic in nature: A number of studies has found that liaison consonants are phonetically distinct from their cousins, invariable final consonants, and also from invariable onset consonants at the beginning of words. In other words, the following minimal triplet is not homophonous (Spinelli and Meunier, 2005; Côté, 2012, and references therein):

(8)   a.   Liaison

       peti[t]   ami
       small.masc friend.masc

       'boy friend'

b.   Invariable word-final consonant

peti[t]e   amie
small.fem friend.fem

'girl friend'

c.   Invariable onset consonant

pet[i]t   [t]amis
small.masc sieve

'small.masc sieve'

The final liaison consonant in (8-a) has been found to differ both from a word-final invariable con-
sonant as in (8-b) and an invariable onset consonant as in (8-c), which has been used as argument
that the traditional analysis of liaison consonants as originating as an underlying final consonant
and being syllabified into the onset of the following word has to be incorrect. It is this challenge
that I want to address here, as a response to the discussion of liaison at MOT in the context of the
presentations by Marie-Hélène Côté and Marc van Oostendorp.

    One thing is uncontroversial about liaison: whether or not the following word begins with a
vowel matters. This uncontroversial fact alone might already be sufficient to explain some phonetic
differences, once we consider the effect of production planning. Suppose we pick out 1,000 2-
word sequences from a corpus of spoken French with a liaison consonant in the onset of word 2 as
and match this set by a 1,000 of phonologically similar 2-word sequences with an initial invariable
consonant in the onset of word 2. If we then compare the acoustic properties of the final consonants,
we have arguably already confounded two issues: liaison vs. non-liaison and the locality of the
phonological encoding of the two words. This is so simply because we know of our first set of
1,000 liaison word sequences that when planning the first word the following word was already
planned out enough for the speaker to know that it begins with a vowel. This is not the case of the
other sample of word sequences with invariant consonants, or at least it would be highly surprising
if it were the case by accident. But if the second word isn't planned out yet, this plausibly results
in a stronger following prosodic break and longer segments, due to initial strengthening (Keating,
2006). On average, liaison and invariant consonants are therefore going to differ phonetically, but
arguably for reasons that relate to how they were sampled rather than to an underlying difference
in their representation. In other words, the argument against the traditional analysis from phonetic
differences between liaison consonants and invariable initial consonants does not go through unless
the confound from production planning is controlled for.

    There is independent support for the idea that production planning locality is a relevant factor
for liaison. The complexity of the upcoming constituent has an effect whether its first word can
trigger liaison. Morin and Kaye (1982, 296) report a contrast between the following two utterances:

(9)   a.   D'habitude, ils   mangen[t] après avoir fini   leur partie d'échecs.
             usually   they eat   after have finished their game of.chess
             'Usually, they eat after they have finished their chess game.'

       b.   Ils   travaillent d'abord et   mangen[t] aprés.
             they work   first   and eat   later
             'They work first and eat later.'

Liaison is more likely when the upcoming constituent is less complex as in (9-b) than when it is syntactically complex as in (9-a). This can be related to production planning as follows: Watson (2002) reports that a more complex upcoming constituent requires more planning, and hence increases the likelihood of a prosodic break before that constituent. Suppose if a complex constituent lies ahead, this delays the planning of the segmental detail of its first word longer than when a less complex constituent is coming up—this is a testable hypothesis. Then we would expect that liaison should be less likely to occur if the following constituent is complex.

Both liaison and flapping require information about the onset of the upcoming word, and yet their locality conditions seem different: First, liaison is syntactically restricted in ways that flapping isn't; second, liaison seems less local in some ways since it is possible for an intonational phrase break to occur either before or after the liaison consonant, while flaps in English seems to require both preceding and following phonological context to be phonetically very close. The fact that one process has become syntactically and morphologically conditioned might just be a result of the fact that liaison has been part of the grammar of French for longer and is less productive now that it used to be. It has become grammaticalized in ways that haven't happened yet to flapping, and might on its way to become a fossilized remnant of a formerly regular postlexical phonological process. Some of the differences might simply be the a result of the phonotactic constraints on flaps in English—words that end in flaps or begin in flaps without a preceding sonorant in the previous word are ill-formed. The consonants that are involved in liaison, on the other hand, are acceptable both as codas and as onsets of words in the absence of a following vowel.

The idea that production planning differences are at the heart of the reported differences rests on premises that can be directly tested: When we compare cases in which liaison occurred and in which liaison has not occurred, all other things being equal the prosodic boundary between the two words should be weaker. Also, factors influencing production planning should affect the likelihood of liaison: Having more time to plan an utterance should correlate with a higher rate of liaison, and producing utterances under time pressure with less time before utterance initiation should result in a lower rate of liaison. The effect that a higher speaking rate is predicted to have is less clear: On the one hand, there will be weaker prosodic boundaries; on the other hand, a higher speaking rate should make it harder to plan ahead. Pak and Friesner (2006) found a decreased rate of liaison with a higher speech rate.

The processing perspective might provide a reason why a higher rate of liaison is associated with a more formal register. Today this tendency may have been conventionalized, but the question arises why it is that *more* liaison counts as formal and not *less*. To some extend the reason might be purely historical: the more conservative pronunciation (in terms of earlier stages in the history of French) might count as the more formal pronunciation. Suppose that people tend to plan ahead more

in formal registers—again, a testable hypothesis—then the prediction of the production planning account would be that in formal registers the rate of liaison should increase. A look across different sandhi processes in different languages would be necessary to explore the merit of this idea.

To sum up, the perspective of production planning might resolve some apparent puzzles in the analysis of liaison, and might serve to account for some of the challenges of the analysis that views liaison consonants as originating as underlying final consonants. Perhaps most importantly it has the potential to make the variability in the application of phonological processes bear directly on questions that relate the phonological representation involved in a process and the locality conditions that apply to it.

4   CONCLUSION

This paper explored the hypothesis that across-word-boundary phonological processes such as phonologically conditioned allomorphy and sandhi phenomena are constrained by the locality of production planning. Experimental evidence was presented in favor of this hypothesis. It was furthermore argued that it can potentially explain why phonological effects across word boundaries tend to be variable: Speakers don't consistently encode the next phonological word, so the conditioning environments may simply not be present at the point in time when the allomorph choice is made. Further predictions for what types of processes should obey what type of locality pattern were outlined.

The ideas presented here link phonological locality phenomena directly with the online processing in speech production, which is unconventional from the point of the generative tradition, even if it fits well with recent psycholinguistic models of phonological processing (cf. Goldrick, 2011). This move toward a theory informed by processing considerations has the desirable effect that it can connect the phonological substance of the structural change and the structural environment of a process to the particular type of morpho-syntactic locality it should obey, and can also make predictions about whether or not it will be variable. Both types of predictions lie outside of what current models of the syntax-phonology interface can explain.

A better understanding of production planning and its effect on phonology has the potential of doing to morpho-syntactic locality in phonology what autosegmental theory did to purely phonological locality: In autosegmental phonology, at least where it was most successful, the phonological locality conditions of a particular process became directly derivable from the postulated phonological representation. Likewise, production planning consideration can create a direct link between phonological representation and the the particular kind of morpho-syntactic locality condition a process obeys, and in fact, also to the type of variability that we might expect. It is important, however, to point out that a lot of work will be necessary to develop and test the ideas sketched here further, and it is obvious that this article remains speculative and tentative, but I hope that it succeeds in conveying why these are ideas worthwhile to explore further.

I am indebted to Glyne Piggott in many ways, one is that he keeps me thinking about morphology, and how syntax interacts with phonology. The road taken in this paper is charting a different territory than the one Glyne has been exploring, and for any linguist trained in a generative framework an obvious question is whether it is justified to bring in processing considerations to account for how

syntax influences phonology. Ultimately, this idea should be subjected to the same criteria that the introduction of the phonological cycle about 40 years ago was subjected to: Do we gain any new insight by going down this road? I want to conclude with a quote from a paper that made a particularly convincing case in favor of the cycle (Kaye and Piggott, 1973), in the hope that a future instance of this paper will make an equally compelling case for the usefulness of processing considerations in phonology: 'Although other analyses not involving ~~the cyclical treatment of T-Palatalization~~ *the locality of production planning* are, of course, in principle possible, those that we have considered seem to miss significant generalizations with respect to other aspects of ~~Ojibwa~~ *phrasal* phonology.'

REFERENCES

Ågren, J. (1973). *Enquête sur quelques liaisons facultatives dans le français de conversation radiophonique*. Acta Universitatis Upsaliensis, Uppsala.

Bates, D. M. and Maechler, M. (2010). lme4: Linear mixed-effects models using S4 classes. R package version 0.999375-33.

Bobaljik, J. D. (2000). The ins and outs of contextual allomorphy. *University of Maryland Working Papers in Linguistics*, 10:35–71.

Carstairs-McCarthy, A. (1987). *Allomorphy in Inflexion*. Croom Helm, London.

Chen, M. Y. (1987). The syntax of Xiamen tone sandhi. *Phonology Yearbook*, 4:109–49.

Chomsky, N. and Halle, M. (1968). *The sound pattern of English*. Harper & Row, New York.

Côté, M.-H. (2012). French liaison. In van Oostendorp, M., Ewen, C., Hume, E., and Rice, K., editors, *Companion to phonology*. Wiley-Blackwell.

Dresher, B. E. (1994). The prosodic basis of the Tiberian Hebrew system of accents. *Language*, 70(1):1–52.

Embick, D. (2010). *Localism versus globalism in morphology and phonology*. MIT Press.

Fischer, J. (1958). Social influences on the choices of a linguistic variant. *Word*, 14:47–56.

Goldrick, M. (2011). Utilizing psychological realism to advance phonological theory. In Goldsmith, J., Riggle, J., and Yu, A., editors, *Handbook of phonological theory*. Blackwell, Oxford, 2nd edition.

Gorman, K., Howell, J., and Wagner, M. (2011). Prosodylab-aligner: A tool for forced alignment of laboratory speech. *Proceedings of Acoustics Week in Canada. Canadian Acoustics*, 39(3):192–193.

Houston, A. C. (1985). *Continuity and Change in English Morphology: The Variable (ing)*. PhD thesis, University of Pennsylvania.

Kaye, J. and Piggott, G. (1973). On the cyclical nature of ojibwa t-palatalization. *Linguistic inquiry*, pages 345–362.

Keating, P. and Shattuck-Hufnagel, S. (2002). A prosodic view of words form encoding for speech production. *UCLA Working Papers in Phonetics*, 101:112–156.

Keating, P. A. (2006). Phonetic encoding of prosodic structure. In Harrington, J. and Tabain, M., editors, *Speech Production: Models, Phonetic Processes and Techniques*, Macquarie Monographs in Cognitive Science, chapter 11, pages 167–186. Psychology Press, New York.

Kiparsky, P. (1982). From cyclic phonology to lexical phonology. In Hulst, H. and Smith, N., editors, *Structure of Phonological Representation II*, pages 131–175. Foris.

Kiparsky, P. (1996). Allomorphy or morphophonology? In Singh, R., editor, *Trubetzkoy's orphan: Proceedings of the Montreal roundtable Morphonology: contemporary responses, Current Issues in Linguistic Theory*, volume 144 of *Current Issues in LInguistic Theory*, pages 12–31.

Kiparsky, P. (2000). Opacity and cyclicity. *The Linguistic Review*, 17(2-4):351–366.

Labov, W. (1972). *Sociolinguistic patterns*. University of Pennsylvania Press.

Levelt, W. (1992). Accessing words in speech production: Stages, processes and representations. *Cognition*, 42(1-3):1–22.

Mallet, G. (2008). *La liaison en français: descriptions et analyses dans le corpus PFC*. PhD thesis, Université Paris Ouest.

Miozzo, M. and Caramazza, A. (1999). The selection of determiners in noun phrase production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 25(4):907.

Morin, Y. and Kaye, J. (1982). The syntactic bases for french liaison. *Journal of linguistics*, 18(02):291–330.

Nespor, M. and Vogel, I. (1986). *Prosodic Phonology*. Foris, Dordrecht.

Nevins, A. I. (2010). *Locality in Vowel Harmony*. MIT Press, Cambridge, MA.

Odden, D. (1990). Syntax, lexical rules and postlexical rules in Kimatuumbi. In Inkelas, S. and Zec, D., editors, *The phonology-syntax Connection*, pages 259–278. CSLI and CUP.

Pak, M. (2008). *The postsyntactic derivation and its phonological reflexes*. PhD thesis, University of Pennsylvania.

Pak, M. and Friesner, M. (2006). French phrasal phonology in a derivational model of PF. In et al., C. D., editor, *Proceedings of NELS 36*, volume 2, pages 480–191.

Patterson, D. and Connine, C. M. (2001). Variant frequency in flap production: A corpus analysis of variant frequency in american english flap production. *Phonetica*, 58:254–275.

Post, B. (2000). Pitch accents, liaison and the phonological phrase in French. *Probus*, 12:127–164.

Selkirk, E. (1986). On derived domains in sentence phonology. *Phonology Yearbook*, 3:371–405.

Selkirk, E. (2011). The syntax-phonology interface. In Goldsmith, J., Riggle, J., and Yu, A., editors, *The Handbook of Phonological Theory*. Blackwell, Oxford, 2nd edition.

Selkirk, E. O. (1972). *The Phrase phonology of English and French*. PhD thesis, MIT.

Selkirk, E. O. (1984). *Phonology and Syntax. The relation between sound and structure*. MIT Press, Cambridge, MA.

Spinelli, E. and Meunier, F. (2005). Le traitement cognitif de la liaison dans la reconnaissance de la parole enchaînée. *Langages*, 158:79–89.

Sternberg, S., Monsell, S., Knoll, R., and Wright, C. (1978). The latency and duration of rapid movement sequences: Comparisons of speech and typewriting. *Information processing in motor control and learning*, pages 117–152.

Truckenbrodt, H. (1999). On the relation between syntactic phrases and phonological phrases. *Linguistic Inquiry*, 30(2):219–255.

Trudgill, P. (1972). Sex, covert prestige and linguistic change in the urban British English of Norwich. *Language in society*, 1(02):179–195.

Wagner, M. (2005). *Prosody and Recursion*. PhD thesis, MIT.

Wagner, M. (2010). Prosody and recursion in coordinate structures and beyond. *Natural Language & Linguistic Theory*, 28(1):183–237. In Press.

Wagner, M. (2011). Production-planning constraints on allomorpy. *Proceedings of the Acoustics Week in Canada. Canadian Acoustics*, 39(3):160–161.

Watson, D. G. (2002). *Intonational Phrasing in Language Production and Comprehension*. PhD thesis, Massachusetts Institute of Technology, Dept. of Brain and Cognitive Sciences.

Wheeldon, L. and Lahiri, A. (1997). Prosodic units in speech production. *Journal of Memory and Language*, 37:356–381.

Wheeldon, L. R. and Lahiri, A. (2002). The minimal unit of phonological encoding: prosodic or lexical word. *Cognition*, 85(2):31–41.