The acquisition of manner in pre-vocalic sequences:
A cue is a cue[*]

Teresa Vanderweide

Abstract

This paper examines the acquisition of manner in pre-vocalic sequences using a Licensing-by-Cue (Steriade (1999), Gerfen (2001), and Kirchner & Varelas (2002)) approach to consonantal phonotactics. I argue that the robustness of acoustic cues as defined using articulatory overlap and resistance to environmental masking provides an explanation for (1), the possible paths available to learners, and (2) for the specific paths that learners follow when acquiring word initial CV and CCV sequences. Using Fikkert's (1994) Dutch acquisition data, I demonstrate that a cue-based learning theory can explain why children first acquire CV sequences that maximally contrast in continuancy. I also show that cue-based learning can account for the order in which children acquire plosive initial and fricative initial clusters.

1. Introduction

Levelt & van de Vijver (2004) investigate how children come to acquire different syllable types (e.g. CV, CCV, VC, and VCC). Two important insights result from their analysis. First, as children move from an unmarked to a more marked grammar each intermediate stage corresponds to an actual language. This is a desirable consequence, since the final state could, theoretically, be anywhere along the learning path. Each stage must therefore correspond to a possible language. Second, the children in the Levelt & van de Vijver study do not all follow the same learning path: some children first acquire complex onsets (CCV) while other children first acquire complex codas (VCC). Levelt & van de Vijver attribute both

---

[*] In Marina Tzakosta, Claartje Levelt & Jeroen van de Weijer (eds.), *Developmental Paths in Phonological Acquisition*. Special issue of *Leiden Papers in Linguistics* 2.1 (2005), 137-161
http://www.ulcl.leideniniv.nl ISSN 1574-4728

the learning path *and* the variation observed along this path to the frequency of different types of syllables in the input data. Levelt & van de Vijver, however, do not examine the order in which children acquire specific onset clusters (e.g. /pr/, /pl/, /sm/, /st/, /str/, etc). Studies that examine the acquisition order of onset clusters (Smith (1973), Gnanadesikan (1995), Pater & Barlow (2003), Jongstra (2003a,b), and Goad & Rose (2004) among others) tend to concentrate on describing, and accounting for, stages of acquisition in which children reduce word initial consonant clusters.

In this paper, I focus on accounting for the order in which children acquire word initial, simple and complex, onsets using data from Fikkert's (1994) study of the acquisition of prosodic structure in Dutch. Following Levelt & van de Vijver, I argue that children first acquire word-initial clusters that are less marked. I propose, however, that the markedness of onset clusters is linked to their perceptibility, rather than to their frequency of occurrence in the input data. I adopt a Licensing-by-Cue approach (Steriade, 1999). According to Licensing-by-Cue, co-occurrence restrictions are not phonologically motivated in that such constraints are independent of syllabic positions. Instead, the likelihood that a given segment occurs in a particular context is a function of the perceptibility of that segment in that context. Since Licensing-by-Cue takes the stance that consonantal phonotactics are string-based rather than structural conditions on the organization of segments, I refer to simple and complex onsets as pre-vocalic sequences. I argue that the distinction between a single pre-vocalic segment (CV) and a pre-vocalic cluster (CCV) as well as the division of pre-vocalic clusters into sonorant clusters (e.g. /pl/, /fl/, /sl/, /tw/, /sm/ etc.) and obstruent clusters (e.g. /sp/, /st/, /sχ/ etc), a division also typically linked to phonological factors, in particular sonority, is in fact linked to the recoverability of manner features under segmental release.

Segmental release is the burst that follows consonantal constriction, and has been shown to provide important acoustic cues to laryngeal, manner, and place features (Ohala (1990), Steriade (1997, 1999), Wright (1999), and Padgett (1997) among others). Segments under release, then, are more perceptually salient and their features more likely to be recovered and, ultimately, identified by the listener. I argue that the order in which children acquire pre-vocalic sequences as well as the variation that occurs as children acquire these sequences both follow from the perceptual salience of acoustic cues to articulation. As in the Levelt & van de Vijver study, I, therefore, take into consideration the influence of the ambient language on the acquisition process, while simultaneously accounting for the variation observed in the acquisition data.

The paper is organized as follows. Section 2 presents the theoretical framework upon which the analysis is built. Section 3 discusses the acquisition of a single segment pre-vocalically (CV sequences), while Section 4 examines the acquisition of pre-vocalic clusters (CCV sequences). Finally, Section 5 gives the overall conclusions.

2. Theoretical framework

2.1 Licensing-by-cue

According to Licensing-by-Cue (i.e. Steriade (1999), Gerfen (2001), Kirchner & Varelas (2002)), a contrast for a feature, (F), is licensed, if it is allowed to occur in a particular position, and whether or not a contrast occurs in a particular position depends on the perceptual cues to the contrast in that position. Contrasts, therefore, are permitted, or licensed, in contexts where acoustic cues are sufficient to allow for the recoverability, and, ultimately, the identification of place, manner, and laryngeal information, and neutralized in contexts where cues are insufficient. Perceptibility, however, is *relative*, rather than *absolute*. That is, some contexts allow for greater perceptibility, and hence recoverability, of a contrast than do others. Furthermore, the likelihood that a contrast will occur in a particular position, and therefore be licensed in that position, is a function of the strength of the cues available in that context.

I propose that contrast, rather than sonority, is central to achieving an explanation for the sequencing of segments within pre-vocalic clusters. Morelli (1999) argues that obstruent clusters, unlike sonorant clusters, are not constrained by sonority requirements. Instead, she proposes that obstruent clusters are subject to co-occurrence restrictions along the manner dimension. Morelli argues that obstruent clusters containing segments which contrast for the feature [continuant] are typologically less marked than those containing segments which do not contrast for the feature [continuant]. That is, /sp/, for example, is less marked than is /pt/. I extend Morelli's proposal and argue that constraints on *all* pre-vocalic clusters derive from the need to maintain contrast. However, unlike Morelli, I define contrast phonetically rather than phonologically. I propose that acoustically contrast for manner is based on the presence or absence of a continuous airflow.

A continuous airflow can be defined orally. For example, oral plosives and fricatives contrast with regards to a continuous oral airflow: oral plosives lack a continuous oral airflow, while fricatives are articulated with a continuous oral airflow. A second way to define a continuous airflow is nasally. For example, nasal and oral plosives contrast with regards to a continuous nasal airflow: nasal plosives are articulated with a continuous airflow through the nasal cavity, while oral plosives lack a nasal airflow. Nasal and oral plosives, of course, do not contrast in terms of oral airflow, since both types of plosives lack a continuous airflow through the oral cavity.

I propose that a segment which contrasts in terms of a continuous airflow with a following segment is more perceptible than a segment which does not contrast with regards to a continuous airflow. It is also possible to define *degrees* of contrast. Oral plosives exhibit more contrast with a following vowel than does a nasal plosive: oral plosives lack both an oral and a nasal airflow, while nasal plosives lack only an oral airflow. Oral plosives, then, are more perceptible pre-vocalically than are nasal plosives.

Segments that are less perceptible in a specific context are predicted to occur, typologically, only if segments that are more perceptible in that context are also found. With regards to acquisition, the prediction is that children will acquire segments that are more perceptible in a particular context before they acquire those that are less perceptible in that context. The next section outlines the acoustic cues that license segments pre-vocalically.

2.2 Acoustic cues

Two types of acoustic cues are relevant to this analysis: internal and contextual. Wright (to appear) identifies three internal cues to manner: silence, fricative noise, and formant structure. I link these internal cues to the degree of stricture that occurs during the medial, or closure phase, of a segment's articulation. I follow Steriade (1992) in using oral aperture to represent differences in stricture. Steriade (1992) defines three degrees of oral aperture: A_0: minimal aperture, A_f: intermediate aperture, and A_{max}: maximal aperture. These are shown below in (1).

(1) Oral Aperture

Aperture:	**Manner:**	**Acoustic Cue:**
A_0	Plosives	Silence
A_f	Fricatives	Fricative noise
A_{max}	Approximants	Formant structure

A complete occlusion of the oral cavity results in a minimal aperture. Since air is prevented from escaping, a minimal aperture corresponds to silence, and as such, is found in the articulation of a plosive. A narrowing of the vocal tract sufficient to create a turbulent airflow results in an intermediate aperture. Fricative noise, therefore, is a cue to sounds (fricatives) articulated with an intermediate aperture. A maximal aperture is present when the oral cavity is more open. This type of aperture results in an airflow that is free from turbulence and allows the vocal tract to resonant. Formant structure, therefore, is a cue to sounds (approximants) articulated with a maximal oral aperture.

Nasal airflow can also be correlated with internal cues. I propose two degrees of nasal aperture. A minimal aperture results when the velum is raised so that no air is permitted in the nasal passages. In contrast, a maximal aperture is found when the velum is lowered to that air can flow through the nasal passages. I use N_0 (minimal velopharyngeal opening) to represent an oral airflow, and N_{max}

(maximal velopharyngeal opening) to represent a nasal airflow, as shown below in (2).

(2) Nasal Aperture

Aperture:	**Manner:**	**Acoustic Cue:**
N_0	Oral Plosives	Silence
N_{max}	Nasal Plosives	nasal pole-zero

A maximal nasal aperture, like a maximal oral aperture, results in formant structure. I follow Wright (1999, to appear), and refer to the cues found in the formant structure of nasals as "nasal pole and zero". Note that "pole" refers to the low frequency of the first formant and "zero" to the weakening of the upper formants in comparison to that found in the formant structure of approximants.

While internal cues are generated during the medial phase of a segment's articulation, contextual cues to articulation exist in the offset, or release, phase of a segment's articulation. Unlike internal cues to manner, contextual cues to manner are found only in oral airflow. For plosives, contextual cues to manner are found in the noise burst that follows the sudden movement away from the oral constriction. According to Steriade (1992), a maximal oral aperture (A_{max}) occurs as the oral constriction is released. The presence of this oral aperture is correlated with the presence of a noise burst. However, for a noise burst to be present in the acoustic signal, a plosive must be audibly released. A plosive is audibly released, if it is followed by a sound that is *not* articulated with a complete oral occlusion, and silently released, if it occurs before a sound lacking a continuous oral airflow (Henderson and Repp, 1982). Thus, contextual cues to a plosive vary according to the environment in which the plosive is found. As will be discussed in Section 4, differences in the strength of contextual cues to plosives has implications for the order in which children acquire plosive initial and fricative initial CCV sequences.

Finally, it should be noted that fricative noise can also be considered a contextual cue; fricative noise continues through the offset phase, since fricatives are always released. I follow Wright (1999), however, in classifying fricative noise solely as an internal cue. As will become apparent from the discussion in the next section, the reason for this classification is linked to the relationship between the amount of continuous oral airflow and the robustness of internal and contextual cues to manner of articulation.

2.3 Cue robustness

Wright (1999, to appear) defines cue robustness as meaning (1) the presence of strong acoustic cues, and (2) the presence of redundant acoustic cues.[1] The former refers to the ability of an acoustic cue to resist environmental masking, while the latter refers to the redundancy of cues in the speech signal as the result of articulatory (gestural) overlap.

I link resistance to environmental masking with periodicity. Aperiodic sounds (plosives and fricatives) lack a regular pattern making them susceptible to environmental masking. In contrast, the presence of a regular pattern, which generates formant structure, renders periodic sounds (approximants) less vulnerable than aperiodic sounds, to the effects of masking.

Cue redundancy is encoded in the speech signal through articulatory overlap. In continuous speech, the offset phase of one segment coincides with the onset phase of a following segment. This results in overlapping articulation so that in the acoustic signal, information about one articulation temporally overlaps with information about another articulation (Laver, 1994). I propose that differences in the degree of oral aperture between two adjacent segments can be correlated with the presence of redundant cues to articulation resulting from articulatory overlap. Adjacent segments exhibiting a greater difference in oral aperture have the potential for encoding more redundant cues to their articulation into the speech signal than do adjacent segments having more similar degrees of oral constriction. Since it is the *offset* phase of a segment's articulation that overlaps with a following segment, my hypothesis is that cue redundancies can be correlated with stronger contextual cues.

The overall perceptibility of a segment, then, is a function of the strength of contextual and internal cues available to the listener in a specific context. The next section examines the relationship between acoustic cues and the positive evidence children use in acquiring pre-vocalic sequences.

2.4 Cue-based learning

I assume that when acquiring the grammatical knowledge that determines the permissibility of a particular pre-vocalic cluster, children use positive and not negative evidence. That is, children are not required to notice that a particular pre-vocalic cluster does not occur in the input in order to arrive at the target grammar. Second, I take this positive evidence to be information found in the internal and contextual cues that exist to the articulation of a particular segment in a particular

---

[1] Cue robustness also involves the auditory impact of cues. Studies (i.e. Sinex & Geisler (1983), Miller & Sachs (1983), and Delgutte & Kiang (1984)) have shown that since the auditory system tends to boost certain aspects of the signal (i.e. formant transitions out of a consonant closure), not all acoustic cues in the speech signal will necessarily have the same impact on the listener.

context. These cues indicate to the learner that a pre-vocalic sequence occurs in words of the target language. However, since all acoustic cues are available to the learner in the speech signal, it is necessary to establish why learners do not immediately process all of the auditory information contained within these cues.

I follow Carroll (1999, 2001, 2002) in distinguishing between input and intake. For Carroll, all linguistic data to which the learner is exposed constitutes the input, while intake refers to information encoded in the input that is accessible to learners. Intake, therefore, is a subset of the input. When acquisition begins, children have access to only a limited amount of input data, since analysis of this data depends on their grammatical systems which are only just beginning to develop. As acquisition proceeds differences between the learner's input and intake disappear, since children's emerging grammatical knowledge allows them greater access to the input data.

I propose that while all acoustic cues present in the environment constitute the input, the strength or robustness of these cues affects when in the acquisition process, they become part of the learner's intake.[2] (3) depicts how children's intake of the acoustic input develops over time.

(3) The Development of Intake

Time	T_I → T_F
Cue	More Robust → Less Robust

where:
T_I = Initial Time
T_F = Final Time

My hypothesis is that children first process information contained in acoustic cues that are more robust. This translates into children first acquiring segments occurring in contexts of greater perceptibility. This is because information pertaining to manner of articulation is more recoverable in such contexts due to the greater robustness of cues to a particular segment in that context. As acquisition proceeds, learners process information found in cues that are less robust. A segment found in a less perceptible context, therefore, will be acquired only after that segment has been acquired in a context of greater perceptibility. Variation is predicted when cues are of relatively the same robustness in a particular context.

---

[2] This is not to say that children are unable to perceive all acoustic cues in the input data, but rather that the robustness of cues determines when these cues become available as part of the learning process for establishing their productive grammars. While not considered further in this paper, I assume that children's intake develops in a similar fashion for both their perceptual grammars and their productive grammars (see Pater (2004) for an analysis along these lines).

Of relevance to this paper are the environments in which an obstruent, either a plosive or a fricative, can be found. An obstruent can occur before a vowel, before a sonorant as well as before another obstruent. Vowels, due to the greater amplitude found in their formant structure, have the strongest periodicity cues of the sonorants. Consequently, contextual cues resulting from articulatory overlap with a vowel are the most robust. Furthermore, contextual cues are stronger before sonorants than before obstruents: cues to sonorants, in contrast to cues to obstruents, are periodic. Contextual cues that result from articulatory overlap, therefore, are more robust in a pre-sonorant position than in a pre-obstruent position. The scale in (4) captures the robustness of contextual cues in these three contexts.

(4) __V > __S > __O

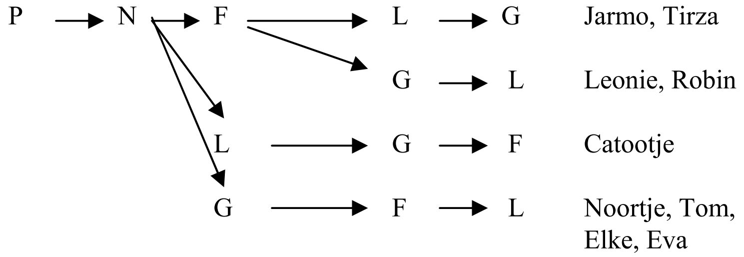
Acquisition tends to follow the perceptibility scale shown above in (4). Children begin by acquiring segments in a pre-vocalic position followed by segments in a pre-sonorant position, and finally segments in a pre-obstruent position. In each of these environments, children must determine which segments are permitted to occur. Contrast comes into effect here. Adjacent segments that exhibit a greater acoustic contrast in terms of a continuous airflow have stronger contextual cues than those which do not contrast in terms of a continuous airflow.

My overall hypothesis, then, is that children will acquire segments that contrast for manner of articulation in a particular environment before they acquire segments that do not contrast in that environment. Section 3 examines this hypothesis with respect to the acquisition of segments in pre-vocalic positions. Section 4 does the same for the acquisition of segments in pre-sonorant and pre-obstruent positions.

3. *Learning CV sequences*

The learning path Dutch children follow as they acquire manner of articulation pre-vocalically is shown in (5).

(5) The Learning Path (Fikkert, pg. 64)



I argue that the acquisition order in (5) follows from the degree of contrast that exists between a pre-vocalic consonant and a following vowel. In Section 3.1, I motivate a hierarchy of internal cues to manner of articulation. This hierarchy will then be linked, in Section 3.2, to the robustness of contextual cues to manner which in turn will be used, in Section 3.3, to motivate three developmental stages in the acquisition of CV sequences.

3.1 A hierarchy of internal cues

I begin by examining the strength of internal cues to manner with regards to both the presence, and the type of continuous airflow responsible for generating these cues. I propose that segments having a continuous airflow have stronger internal cues than do segments lacking a continuous airflow. First consider the relationship between oral aperture and a continuous airflow. Segments articulated with either an intermediate or a maximal oral aperture have stronger internal cues than do segments articulated with a minimal aperture. Formant structure and fricative noise, therefore, are both stronger internal cues to manner than is silence. Similarly, segments articulated with a maximal nasal aperture have stronger internal cues (nasal pole-zero) than do segments articulated with a minimal nasal aperture (silence). Again, this follows from the presence of a continuous airflow.

While segments articulated with a maximal aperture, either oral or nasal, have periodic cues to their articulation, the strength of periodic cues resulting from these maximal apertures is not the same. The presence of an oral constriction in the articulation of a nasal creates anti-resonances which weaken the intensity of the nasal formants in comparison to those found in the articulation of an approximant (Wright (2004), Ladefoged (2001), Borden et al., (2003)). The higher intensity of the formant structure found in approximants, therefore, is a stronger internal cue than is the lower intensity of the formant structure found in nasals. For this reason, formant structure can be ranked above nasal pole-zero.

To summarize, internal cues to manner can be ranked as shown below in (6).

(6) Aperture Cues:
fricative noise > nasal pole-zero > silence
formant structure

(6) captures the relationship between aperture and the strength of internal cues to manner: cues resulting from a continuous oral airflow (fricative noise and formant structure) are stronger than cues resulting from a continuous nasal airflow (nasal pole-zero). Silence, of course, is the weakest internal cue, since it is correlated with the complete absence of a continuous airflow. The next section examines the relationship between the strength of internal cues and the strength of contextual cues.

3.2 Contextual cues and contrast

The strength of contextual cues is linked to articulatory overlap during the offset phase of a segment's articulation. I propose that the strength of contextual cues is correlated with similarities and differences in the degree of aperture between adjacent segments. First, consider plosives. Plosives are articulated with a noise burst in the offset phase of their articulation. For articulatory overlap to robustly encode contextual cues to a plosive, a plosive must occur in a position of release. Plosives are released pre-vocalically, and therefore have strong contextual cues in this position. Plosives also exhibit a greater difference in degree of oral aperture with a following vowel than do fricatives and approximants. Fricatives and approximants, in exhibiting less contrast in degree of oral aperture with a following vowel, have less articulatory overlap with this vowel than do plosives. Fricatives and approximants, therefore, have weaker contextual cues pre-vocalically than do plosives. Thus, an inverse relationship exists between internal and contextual cues pre-vocalically: segments having relatively strong internal cues (fricatives and approximants) have relatively weak contextual cues, while segments having weak internal cues (plosives) have strong contextual cues.

This inverse relationship can be linked to the amount of contrast that exists between a segment and a following vowel. Three degrees of contrast, summarized in (7), can be defined for pre-vocalic segments.

(7)

Most Contrast	More Contrast	Less Contrast
Oral Plosives	Nasal Plosives	Fricatives Approximants

Oral plosives have the weakest internal cues (silence), the strongest contextual cues (noise burst), and exhibit the most contrast with a following vowel. The articulation of a nasal plosive, like that of an oral plosive, results in weak internal cues (silence), but strong contextual cues (noise burst). Nasal plosives, however, exhibit less contrast with a following vowel than do oral plosives due to the presence of a continuous nasal airflow which results in stronger internal cues to their articulation. Nasal plosives, of course, exhibit more contrast with a following vowel than do fricatives and approximants, in that nasal plosives lack a continuous oral airflow. Finally, fricatives and approximants both have stronger internal cues (formant structure and frication respectively) than do plosives, both oral and nasal, but weaker contextual cues. As such, approximants and fricatives exhibit the least amount of contrast with a following vowel in terms of a continuous oral airflow.[3] The three degrees of contrast in (7) translate into three developmental stages for the acquisition of CV sequences. These are presented next.

3.3 The developmental stages

Three developmental stages are proposed to account for the learning path in (5). In Stage One, children only permit oral plosives pre-vocalically. Oral plosives, in having the strongest contextual cues pre-vocalically, exhibit the most contrast with following vowel. Children, therefore, first acquire segments in a pre-vocalic position that lack a continuous oral airflow. In Stage One, then, children only permit CV sequences that *maximally* contrast in terms of oral aperture.

In Stage Two, children permit both oral and nasal plosives pre-vocalically. While children still only permit pre-vocalic segments that lack a continuous oral airflow, children now permit pre-vocalic segments that have a continuous nasal airflow. Nasal plosives exhibit less contrast with a following vowel than does an oral plosive due to presence of a nasal airflow. Essentially, children now allow pre-vocalic segments that *maximally* contrast with a vowel either in oral *or* in nasal aperture.

In Stage Three, children begin to license fricatives, liquids, and glides pre-vocalically. Children now permit segments that have a continuous oral airflow; segments are no longer required to *maximally* contrast with a following vowel in terms of oral aperture. Fricatives, liquids, and glides exhibit the least amount of contrast with a following vowel, in terms of a continuous oral airflow. Since

---

[3] Note that fricatives actually exhibit more contrast with a following vowel than do approximants. Approximants are articulated with a maximal aperture, while fricatives are articulated with an intermediate aperture. Thus more oral airflow occurs during the articulation of an approximant. Stronger internal cues, therefore, are found to an approximant articulation in comparison to a fricative articulation. Consequently, approximants exhibit less contrast with a vowel than do fricatives. However, since both fricatives and approximants fail to maximally contrast in degree of oral aperture with a following vowel, making this further distinction is unnecessary.

fricatives, liquids, and glides all fail to exhibit a maximal contrast in terms of a continuous oral airflow with a following vowel, variation in the order in which these manners are licensed is expected. Fikkert's acquisition data supports this prediction as shown by the learning path in (5). Finally, although no children in Fikkert's study acquire (1) liquids followed by fricatives and then glides, or (2) glides followed by liquids and then fricatives, these gaps are predicted to be accidental, since fricatives, liquids, and glides, like a following vowel, are all articulated with a continuous oral airflow.

To summarize, using cue robustness to describe the developmental paths Fikkert observed for the acquisition of CV sequences provides an explanation, not only for why children begin the acquisition process requiring a maximal contrast pre-vocalically, but also for why pre-vocalic inventories expand along the continuancy dimension. The next section examines the relationship between cues, their robustness, and the order in which children acquire CCV sequences.

4. Learning CCV sequences

The acquisition of CCV sequences corresponds to children acquiring segments in pre-sonorant and pre-obstruent positions. The children in Fikkert's study acquire plosives and fricatives in these positions as shown below in (8).

(8) The Acquisition Order of CCV Sequences (Fikkert, 1994)

Child:	**Cluster:**				
Robin, Noortje	FP				
Leonie	PL				
Elke	PL	FP			
Jarmo	PL	FL			
Tirza	PL	FL	FF	FP	
Catootje	PL	FL	FP	FN	FG
Tom	PL	FL	PG	FP	FF
Leon	PL	FL	PG	FF, FP	FG, FN
Enzo	PL	FL	PG	PN	FN

I propose that the learning path children follow when acquiring plosive initial and fricative initial clusters is related to (1) the strength of contextual cues as defined using differences in oral aperture, and (2) the robustness of periodicity cues to the following sonorant or obstruent.

Sections 4.1 and 4.2, examines the robustness of contextual cues to initial plosives and fricatives along these two dimensions. Section 4.3 discusses the robustness of cues to various approximants. Sections 4.4 and 4.5 outline the developmental stages in the acquisition of plosive initial and fricative initial pre-vocalic sequences. Finally, Section 4.6 demonstrates that children interleave acquiring plosive initial and fricative initial clusters.

4.1 Cue robustness in pre-sonorant positions

I begin by examining the robustness of contextual cues in pre-sonorant positions. First consider the relationship between cue robustness and contrast as pertaining to release. For contextual cues (noise burst) to a plosive to be manifested in the acoustic signal, a plosive must be audibly released. A plosive is audibly released only if it is followed by a segment that is *not* articulated with a complete oral occlusion (Henderson and Repp, 1982). This is necessary to ensure that there will always be an outgoing flow of air to carry the cues found in the release burst (Henderson and Repp, 1982). Plosives are audibly released before an approximant, since approximants are articulated with continuous oral airflow, but silently released before a nasal, since nasals are articulated without a continuous oral airflow. Plosives, therefore, have stronger contextual cues to their articulation in a pre-approximant position than in a pre-nasal position.

This difference in the robustness of contextual cues can be captured using oral aperture: plosives exhibit a greater difference in degree of oral aperture with a following approximant than with a following nasal. Similarly, since fricatives are always released, contrast can also be correlated with differences in the robustness of contextual cues to fricatives in pre-sonorant positions. However, unlike with plosives, fricatives exhibit a greater difference in oral aperture with a following nasal than with a following approximant. Fricatives, therefore, have weaker contextual cues before an approximant than before a nasal.

Next, consider the robustness of contextual cues to plosives and fricatives as defined using periodicity. The periodicity cues to a following sonorant affects how robustly contextual cues are encoded in the speech signal as the result of articulatory overlap. Both approximants and nasals are articulated with maximal apertures, oral and nasal respectively, and as such generate formant structure. However as was discussed in Section 3.1, the oral constriction found in the articulation of a nasal weakens this periodicity cue to nasals, in relation to those resulting from an approximant articulation (Ladefoged, 2001). As such, nasals have weaker internal cues than do approximants, as shown in (9).

(9) <u>Periodicity Cues:</u>
formant structure > nasal pole-zero

Contextual cues resulting from articulatory overlap with an approximant, therefore, are more robust than are contextual cues resulting from articulatory overlap with a nasal. Furthermore, this is valid for both a preceding plosive and a preceding fricative.

The relative robustness of contextual cues to fricatives and plosives in pre-sonorant positions is presented below in (10).

(10) Robustness of Contextual Cues in Pre-Sonorant Positions

Manner:	**Pre:**	**Cue Robustness:** **Oral Aperture**	**Periodicity**
Plosives	Approximant	More	More
	Nasal	Less	Less
Fricatives	Approximant	Less	More
	Nasal	More	Less

Crucially, (10) illustrates that contextual cues to plosives are of the same robustness regardless of whether robustness is defined in terms of oral aperture or periodicity. Furthermore, this holds in both pre-approximant and pre-nasal positions. This is not the case for fricatives. For fricatives, the robustness of cues varies in both pre-approximant and pre-nasal position for both oral aperture and periodicity. Before the implications of this patterning with regards to acquisition can be discussed, I first show that this same pattern of robustness is found in a pre-obstruent position.

4.2 Cue robustness in pre-obstruent positions

First, consider differences in the strength of contextual cues to plosives and fricatives, as related to release. Plosives are silently released before another plosive, since this plosive, like the preceding plosive, is articulated with a complete oral occlusion. In contrast, plosives are audibly released before a fricative due to the presence of continuous airflow in the articulation of the fricative. Plosives therefore have stronger contextual cues before a fricative than before another plosive. Again, this can be captured using differences in the degree of oral aperture: plosives contrast in terms of a continuous oral airflow with a following fricative, but not a following plosive. Similarly, contrast also captures differences in the strength of contextual cues to fricatives in a pre-obstruent position: fricatives contrast with a following plosive, but not a following fricative. Plosives, therefore, have stronger contextual cues before a fricative than do fricatives, while fricatives have stronger contextual cues before a plosive than do plosives.

Next, consider the robustness of contextual cues to plosives and fricatives as related to the strength of periodicity cues to the following obstruent. Periodicity cues are stronger for fricatives (fricative noise) than they are for plosives (silence), as shown below in (11).[4]

(11) Periodicity Cues:
fricative noise > silence

Fricatives, in being articulated with an intermediate rather than minimal aperture have more robust periodicity cues (i.e. fricative noise) to their articulation than to plosives (i.e. silence). This is because the oral constriction that occurs during the closure phase of a plosive's articulation results in the absence of even aperiodic noise. Contextual cues resulting from articulatory overlap with fricative, therefore, are more robust than are contextual cues resulting from articulatory overlap with a plosive. Again, this applies to both an initial plosive, and an initial fricative.

The robustness of contextual cues to plosives and fricatives in pre-obstruent position as defined using degree of oral aperture and periodicity are presented in (12).

(12) Robustness of Contextual Cues in Pre-Obstruent Positions

		Cue Robustness:	
Manner:	**Pre:**	**Oral Aperture**	**Periodicity**
Plosives	Fricative	More	More
	Plosive	Less	Less
Fricatives	Fricative	Less	More
	Plosive	More	Less

Comparing (12) with (10) reveals that the robustness of contextual cues to both plosives and fricatives in a pre-obstruent position is identical to the robustness of contextual cues to plosives and fricatives in a pre-sonorant position. I argue in Section 4.4 and 4.5 that with regards to acquisition, similarities in the robustness of cues to plosives as defined using either oral aperture or periodicity explain the lack of variation in the acquisition of plosive initial clusters. Similarly, differences in the robustness of cues to fricatives along the two dimensions accounts for the greater variation observed in the acquisition of fricative initial clusters. However, before this hypothesis can be explored further, the robustness of cues to the different approximants must first be examined.

---

[4] Note that the periodicity cues in (11) are ranked below the periodicity cues in (9). This follows from the greater robustness of cues to periodic sounds in contrast to aperiodic sounds.

4.3 Cue robustness to approximants

With regards to articulation, degrees of oral aperture distinguish between plosives, fricatives, and approximants, while acoustically, periodicity cues distinguish between these manners. Neither of these two dimensions, however, can distinguish liquids from glides. I argue in this section that within the class of approximants, the articulation of a glide is more open than that of a liquid.

Halle (1964) classifies the narrowing of the vocal tract, present in the articulation of a glide as an obstruction rather than an occlusion. An obstruction describes a less extreme narrowing of the vocal tract than what is found when an occlusion is present. Halle further defines an occlusion as a narrowing that is *capable* of producing turbulence. I propose, therefore, that an oral occlusion is present in the articulation of both a fricative *and* a liquid. Given that the amount of oral constriction causes the degree of narrowing present in the vocal tract, liquids are therefore articulated with more oral constriction than are glides. Since the presence of less constriction implies that more air flows through the oral cavity, glides have a more open aperture (A_{open}) than do liquids.

Next, consider the relationship between openness and articulatory overlap. Cues are more redundantly encoded in the speech signal, when segments are released in decreasing apertures (Mattingly, 1981). Consider, for example, a plosive approximant vowel sequence (PLV). The articulation of the liquid overlaps with the articulation of the plosive. Overlap, however, does not obscure the cues to the plosive, since the liquid is articulated with a partial rather than a complete oral closure. Similarly, the vowel overlaps, but does not obscure cues to the liquid, as the vowel is articulated with less of an oral closure than is the liquid. The same is not true in a plosive glide vowel sequence (PGV). Glides, in having a more open aperture than liquids, have a more similar degree of aperture with a following vowel than do liquids.[5] Consequently, while the glide in a PGV sequence will not obscure the cues to the plosive, the vowel may obscure cues to the glide. Pre-vocalically, contextual cues to liquids, therefore, are more robust than are contextual cues to glides.

The next two sections examine the relationship between cue robustness and the order in which children acquire pre-vocalic clusters. Section 4.4 outlines the developmental path children follow in the acquisition of plosive initial clusters. Section 4.5 does the same for fricative initial clusters.

---

[5] Vowels, of course, have the most maximal oral aperture. The degree of aperture in vowels is linked to vowel height (Clements and Hume, 1995). Vowels with a lower tongue height have a more open articulation, while vowels with a higher tongue height have a less open articulation. Such differences may play a role in accounting for which glide vowel sequences are more preferred over others. However, since my goal is to account for the overall order in which children acquire clusters, including those containing liquids and glides, this possibility is left for future research.

4.4 Learning plosive initial clusters

The order in which children acquire plosive initial clusters follows from the greater robustness of contextual cues, both aperture and periodicity, before approximants, than before nasals, as shown above in (10). I posit three developmental stages to account for the order in which children acquire plosive initial clusters. In Stage One, learners acquire plosive+liquid clusters; in Stage Two, plosive+glide clusters; and finally in Stage Three, plosive+nasal clusters. It should be noted that, in Dutch, an initial plosive may only be followed by a sonorant.

Since the robustness of cues to an initial plosive is a function of release, I relate these developmental stages to aperture. Learners acquire clusters in which segments exhibit the most contrast in oral *and* open aperture before they acquire segments that exhibit less contrast along these dimensions. This is shown below in (13).

(13) Developmental Stages

Stage:	**Contrast:**		**CCV Sequence:**
	Oral Aperture (*xy*)	**Open Aperture (*yz*)**	
One	YES	YES	PLV
Two	YES	NO	PGV
Three	NO	YES	PNV

In Stages One and Two, learners require the initial segment (*x*) in a pre-vocalic cluster to contrast in oral aperture with a following segment (*y*). An approximant, therefore, licenses a plosive as *x*. In Stage One, learners require *y* to contrast in terms of an open aperture with a following vowel, *z*. Of the approximants, liquids, and not glides, contrast in openness with a vowel. Learners, therefore first acquire plosive+liquid (PL) clusters. In Stage Two, learners still require *x* and *y* to contrast in oral aperture, but no longer require *y* to contrast with a following vowel in terms of an open aperture. Learners now acquire plosive+glide (PG) clusters. Finally, in Stage Three, learners no longer require *x* and *y* to contrast in oral aperture. This corresponds to the acquisition of plosive+nasal (PN) clusters. The next section examines the acquisition of fricative initial clusters.

4.5 Learning fricative initial clusters

In Dutch, an initial fricative may be followed by either a sonorant or an obstruent.[6] Again, I propose that the learning path is correlated with the robustness of contextual cues. However, unlike for an initial plosive, an inverse relationship exists between the aperture and periodicity cues that define the robustness of contextual cues to an initial fricative: if contextual cues resulting from differences in aperture are *more* robust, periodicity cues are *less* robust, and vice versus (see (10) and (12)). Consequently, I propose that children have a choice in each stage as to whether they extract aperture or periodicity, cues from the input data. Children will, therefore, first license fricatives in positions where either the strongest aperture, or the strongest periodicity, cues to their articulation are found. I also propose that asymmetries in the robustness of contextual cues to an initial fricative result in children interleaving the acquisition of fricatives in pre-sonorant positions, with the acquisition of fricatives in pre-obstruent positions.

These hypotheses translate into two developmental stages for the acquisition of fricative initial clusters. These are presented in (14).

(14) Developmental Stages

Stage One	**Stage Two**
Fricative+Approximant	Fricative+Nasal
Fricative+Plosive	Fricative+Fricative

First, consider Stage One. Since approximants have the most robust periodicity cues, children who extract periodicity cues first license a fricative in a pre-approximant position. For the same reasons outlined in the previous section, children license a fricative in a pre-liquid position before they license a fricative in a pre-glide position. Extracting periodicity cues, therefore, results in the acquisition of fricative+liquid (FL) clusters. In contrast, children who first extract aperture cues license a fricative in a pre-plosive position. Fricatives exhibit the most contrast in terms of a continuous airflow with an oral plosive. Similarly, plosives exhibit the most contrast in continuous airflow with a following vowel. Children who extract aperture cues, therefore, first acquire fricative+plosive (FP) clusters.

Most children first extract periodicity cues. This is because a fricative, in having strong internal cues, exhibits less articulatory overlap with a following segment than would a plosive. Periodicity, therefore, ensures that, the contextual cues that do result from articulatory overlap are robustly encoded. Thus, children

---

[6] Only an initial /s/, however, may be followed by an obstruent, either a plosive or a fricative. This restriction is not considered further.

are more likely to first acquire FL clusters rather than FP clusters in Stage One. Fikkert's data support this prediction: of the twelve children in her study, only two (Robin and Noortje) first acquired FP clusters.

As shown above in (14), in Stage Two children may acquire either fricative+nasal (FN) *or* fricative+fricative (FF) clusters. However, since in Stage One, children, in all likelihood, acquire FL clusters, the acquisition of FP and fricative+glide (FG) clusters is deferred to a later stage. In Stage Two, therefore, children, actually have a choice among four types of clusters as shown below in (15).

(15) Stage Two Choices

Aperture:	**Periodicity:**
Fricative+Nasal	Fricative+Glide
Fricative+Plosive	Fricative+Fricative

Again, children may extract either aperture or periodicity cues. Children who extract aperture cues acquire either FP or FN clusters. The greater robustness of aperture cues to an initial fricative in a pre-plosive position predicts that children will acquire FP clusters before they acquire FN clusters. Fikkert's data supports this prediction: of the five children (Tirza, Catootje, Tom, Leon, and Enzo) who progress beyond acquiring FL clusters, only Enzo (2;5.9) acquires FN clusters, without first acquiring FP clusters. Extracting aperture cues, therefore, results in children acquiring FP clusters after they acquire FL clusters.

In contrast, children who extract periodicity cues may acquire either FG or FF clusters. Periodicity cues are more robust to glides than they are to fricatives. Consequently, children should license a fricative in a pre-glide position before they license a fricative in a pre-fricative position. The acquisition data, however, does not support this prediction: of the four children (Catootje, Tirza, Tom, and Leon) who acquire either, or both, FG and FF clusters, only Catootje (2;1.3) first acquires FG clusters. I hypothesize that the weaker contextual cues between the glide and the vowel are responsible for continuing to delay the acquisition of FG clusters. Extracting periodicity cues rather than aperture cues, then, results in children acquiring FF clusters, after they acquire FL clusters.

Children, of course, must continue extracting aperture and periodicity cues until they acquire all fricative initial clusters. First, consider children (Catootje and Tom) who acquire FP clusters after they acquire FL clusters. These children now have a choice among FN, FG, and FF clusters. Catootje extracts aperture cues. This results in her acquiring FN clusters (2;0.20): both FG and FF clusters have more robust periodicity cues. She then extracts the more robust periodicity cues that result in the acquisition of FG clusters (2;1.3). In contrast to Catootje, Tom, after acquiring FP (2;0.17) clusters, next extracts periodicity cues. Like Tirza and

Leon, he first extracts the periodicity cues that result in the acquisition of FF clusters (2;1.14) and not FG clusters. Again, this follows from the weaker contextual cues to a glide, pre-vocalically.

Finally, consider the path that children (Tirza and Leon) who acquire FF clusters after they acquire FL clusters, follow. These children now have a choice between FP, FN, and FG clusters. Children who extract aperture cues will acquire either FP or FN clusters. Again, cue robustness predicts that children will first acquire FP clusters. Leon then extracts the periodicity cues that result in the acquisition of FG cluster, and finally the aperture cues that result in the acquisition of FN clusters.

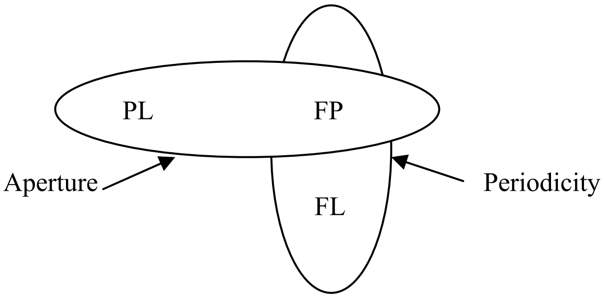
Overall, differences in the robustness of contextual cues to an initial fricative in both pre-sonorant and pre-obstruent positions makes available a number of paths for children to follow as they acquire fricative initial clusters. To account for the acquisition order shown in (8), I argue that children also interleave the acquisition of plosive initial and fricative initial clusters. The next section examines the paths available to children that results from this interleaving.

4.6 Interleaving plosive and fricative initial clusters

I propose that in each of the three developmental stages posited for the acquisition of plosive initial clusters (see (13)), children extract either, aperture, or periodicity cues. I further argue that in each of these stages, children have a choice between *one* plosive initial cluster and *two* fricative initial clusters. The former follows from similarities in the robustness of aperture and periodicity cues to initial plosives. The latter follows from differences in the robustness of aperture and periodicity cues to an initial fricative. Since contextual cues to an initial plosive are of the same robustness for both aperture and periodicity, but vary for each of these dimensions for an initial fricative, variation is predicted along (1) the aperture dimension, for the acquisition of both fricative initial and plosive initial clusters, and (2) along both the aperture and periodicity dimensions for the acquisition of fricative initial clusters.

I begin with Stage One. In this stage, the acquisition of PL clusters interleaves with the acquisition of FP and FL clusters. This is shown below in (16). Note that the circles indicate the clusters, whose acquisition order is predicted to vary.

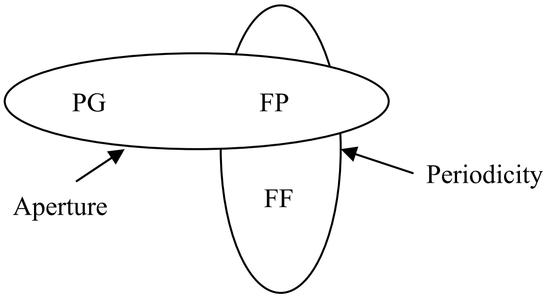
(16)



Again, acquisition begins with children extracting the most robust contextual cues. Plosives, in a pre-approximant position have the strongest contextual cues to their articulation: both the most robust aperture and the most robust periodicity, cues exist to a plosive in this position. Children, therefore, are predicted to first acquire PL clusters. It is also possible, though, for children to first acquire FP clusters. This is because robust aperture cues also exist to an initial fricative in a pre-plosive position. However, children are more likely to acquire PL clusters, since less robust periodicity cues exist to the initial fricative in FP clusters than in PL clusters. The acquisition data supports this prediction: of the twelve children in Fikkert's study, only Robin (2.0;20) and Noortje (2;9.12) first acquire FP clusters. As well, Elke, after extracting the aperture cues that license a plosive in a pre-approximant position (2;3.27), next extracts the aperture cues that license the initial fricative in a pre-plosive position (2;4.15). However, and as was discussed in the previous section, most children will next extract the more robust periodicity cue that licenses a fricative in a pre-approximant position..

Next, consider Stage Two. In this stage, the acquisition of PG clusters interleaves with the acquisition of FP and FF clusters, as shown below in (17).

(17)

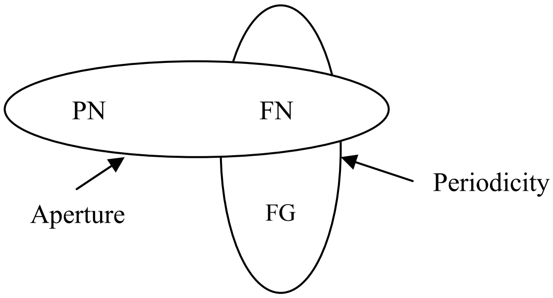


Notice that FP clusters are shown in both (16) and (17). This is because the contextual cues, that license a fricative in this position, are less robust than are the contextual cues that license, both plosives and fricatives, in pre-approximant positions. As such, this cluster is likely to be deferred until Stage Two.

For aperture cues, the choice in Stage Two is between the cues that license a plosive in a pre-glide position, and the cues that license a fricative in a pre-plosive position. Enzo (2;3.28), Tom (1;5.28), Leon (2;4.29) all first acquire PG clusters, while Catootje (2;0.6) first acquires FP clusters. Again, it is more likely that children will first acquire PG clusters given that plosives have the strongest aperture and periodicity cues in a pre-approximant position. Tom continues extracting aperture cues, and next acquires FP clusters. He then extracts periodicity cues to license a fricative in a pre-fricative position. Tirza and Leon, in contrast, both choose to extract periodicity cues rather than aperture cues. They acquire FF clusters followed by FP clusters. Again, more robust periodicity cues are found to an initial fricative in pre-fricative than in pre-plosive positions.

Finally, in Stage Three, the acquisition of PN clusters interleaves with the acquisition of FN and FG clusters as shown below in (18).

(18)



When extracting aperture cues, children can extract the contextual cues that license a plosive in a pre-nasal position or the contextual cues that license a fricative in a pre-nasal position. An oral plosive contrasts with a following nasal in terms of nasal aperture, while a fricative contrasts with a following nasal in terms of both continuous oral and continuous nasal airflow. Children, then, are predicted to acquire FN before PN clusters. Fikkert's acquisition data supports this prediction: of the four children, who acquire clusters containing a nasal, only Enzo (2;5.9) first acquires PN clusters. However, this exception is not all that unlikely, since both fricatives and nasals have continuous air: fricatives have a continuous oral airflow, while nasals have a continuous nasal airflow. Again, not all children first extract aperture cues. Leon first extracts periodicity cues. He begins by extracting the more robust periodicity cues that license a fricative in a pre-approximant position.

To summarize, distinguishing between aperture and periodicity cues accounts for (1) the greater variation in the acquisition of fricative initial clusters as compared to plosive initial fricatives, and (2) the overall learning path children follow as they acquire pre-vocalic clusters.

5. *Conclusion*

This paper has investigated the possibility that acoustic cues can function as the positive evidence children use when acquiring the grammatical knowledge that determines the permissibility of word initial pre-vocalic sequences in the target grammar. Acquisition begins with children acquiring those pre-vocalic sequences having the most robust cues to their articulation. This translates into children first acquiring segments in pre-vocalic positions. Variation along this learning path occurs when contextual cues are of the same robustness. Children then acquire segments in pre-sonorant and pre-obstruent positions. Variation along this path is linked to both differences in the type of contextual cues (aperture or periodicity) that children extract from the input data and the robustness of these cues

While the focus in this paper has been on the acquisition of manner in pre-vocalic sequences, I hypothesize that acoustic cues can also account for the acquisition of place in pre-vocalic sequences. This possibility is left for future research.

References

Booij, G. (1995). *The Phonology of Dutch.* Oxford: Clarendon Press.

Borden, G., K. Harris, & L. Raphael. (2003). *Speech Science Primer.* Baltimore: Lippincott Williams & Wilkins.

Carroll, S. (1999). Putting ‘input’ in its proper place. *Second Language Research* **15**: 337-388.

Carroll, S. (2001). *Input and Evidence.* Amsterdam: John Benjamins Publishing Company.

Carroll, S. (2002). Induction in a modular learner. *Second Language Research* **18**: 224-249.

Clements, G.N. & E. Hume. (1995). The Internal Structure of Speech Sounds. In John. A. Goldsmith (ed.), *TheHandbook of Phonological Theory*, MASS: Blackwell. 245-306.

Delgutte, B. and N.Y.S. Kiang. (1984). Speech coding in the auditory nerve: IV. Sounds with consonant-like dynamic characteristics. *Journal of the Acoustical Society of America*. **75**(3): 897-907.

Dresher, B.E. (1999). Charting the Learning Path: Cues to Parameter Setting. *Linguistic Inquiry* **30**: 27-67.

Fant, G. (1970). *Acoustic Theory of Speech Production*. The Hague: Mouton.

Fikkert, P. (1994). *On the Acquisition of Prosodic Structure.* Dordrecht: HIL Dissertations.

Fry, D. (1979). *The Physics of Speech*. New York: Cambridge University Press.

Gerfen, C. (2001). A Critical View of Licensing by Cue: Codas and Obstruents in Eastern Andalusian Spanish. In L. Lombardi (ed), *Segmental Phonology in Optimality Theory.* Cambridge: Cambridge University Press.

Gnanadesikan, A. (1995). Markedness and faithfulness constraints in child phonology. Ms. University of Massachusetts, Amherst. (ROA-67). Published (2004". In R. Kager, J. Pater, and W. Zonneveld, eds. *Constraints in Phonological Acquisition.* Cambridge Mass.: Cambridge University Press. 73-108.

Goad, H. & Y. Rose (2004). Input elaboration, head faithfulness and evidence for representation in the acquisition of left-edge clusters in West Germanic. In R. Kager, J. Pater, and W. Zonneveld, eds. *Constraints in Phonological Acquisition.* Cambridge Mass.: Cambridge University Press. 109-157.

Halle, M. (1964). On the bases of phonology. In J. Fodor, & J.J. Katz, (eds). *The Structure of Language.* New Jersey: Prentice-Hall Inc. 324-333.

Henderson, J. & B. H. Repp. (1982). Is a stop released when followed by another stop? *Phonetica*. **39**: 71-82.

Ingram, D. (1989). *First language acquisition. Method, description, and explanation*. Cambridge, England: Cambridge University Press.

Jongstra, W. (2003a). Variation in reduction strategies of Dutch word-initial consonant clusters. Doctoral Dissertation, University of Toronto.

Jongstra, W. (2003b). Variable and stable clusters: variation in the realization of consonant clusters. *Journal of Canadian Linguistics*. **48(3/4)**: 265-288.

Kirchner R. & E. Varelas. (2002). A Cue-Based Approach to the Phonotactics of Upper Necaxa Totonoc. Ms. University of Alberta**.**

Ladefoged, P. (2001). *Vowels and Consonants.* Cambridge Mass: Blackwell Publishers

Laver, J. (1994). *Principle of Phonetics.* Great Britain: Cambridge University Press.

Levelt, C. & R. van de Vijver. (2004). Syllable types in cross-linguistic and developmental grammars*.* In R. Kager, J. Pater, & W. Zonneveld, eds. *Constraints in Phonological Acquisition.* Cambridge Mass.: Cambridge University Press. 204-218.

Mattingly, I. G. (1981). Phonetic representation and speech synthesis by rule. In T. Myers, J. Laver, & J. Anderson, eds., *The Cognitive Representation of Speech*. The Netherlands: North Holland Publishing Company. 415-420.

Miller, M.I. & M.B. Sacks. (1983). Representation of stop consonants in the discharge patterns of auditory nerve fibers. *Journal of the Acoustical Society of America*. **74**(2): 502-517.

Morelli, F. (1999). The phonotactics and phonology of obstruent clusters in optimality theory. Doctoral Dissertation. University of Maryland.

Ohala, J. (1990). The phonetics and phonology of aspects of assimilation. In J. Kingston & M.E. Beckman (eds.), *Papers in laboratory phonology I: between the grammar and physics of speech.* New York: Cambridge University Press. 258-75.

Padgett, J. (1997). Partial Class Behavior and Nasal Place Assimilation. In *Proceedings of the Arizona Phonology Conference: Workshop on Features in Optimality Theory*, Coyote Working Papers, University of Arizona, Tuscon.

Pater, J. (2004). Bridging the gap between receptive and productive development with minimally violable constraints. In R. Kager, J. Pater, and W. Zonneveld, eds. *Constraints in Phonological Acquisition.* Cambridge Mass.: Cambridge University Press. 245-291.

Pater, J. & J.A. Barlow (2003). Constraint conflict in cluster reduction. *Journal of Child Language*. **30**: 487-526.

Sinex, D.G. and C.D. Geisler. (1983). Responses of auditory nerve fibers to consonant-vowel syllables. *Journal of the Acoustical Society of America*. **73**(2): 602-615.

Smith, N. (1973). *The Acquisition of Phonology.* Great Britain: Cambridge University Press.

Steriade, D. (1992). Complex Onsets as Single Segments: The Mazateco Pattern. In J. Cole & C. Kisseberth, eds. *Perspectives in Phonology*. Stanford: CSLI.

Steriade, D. (1997). Phonetics in phonology: the case of layrngeal neutralization Ms. UCLA.

Steriade, D. (1999). Alternatives to syllable-based accounts of consonantal phonotactics. In O. Fujimara, B.D. Joseph, & B. Palek, eds., *Proceedings of LP '98: Item order in language and speech*. Prague: The Karolinum Press. Vol. **1**: 205-245.

Trommelen, Mieke. (1984). *The Syllable in Dutch.* Dordrecht: Foris.

Wright, R. (1999). Tsou consonant clusters and auditory cue preservation. In E. Zeitoun & P. Li (eds.), *Selected papers from the eighth international conference on Austronesian linguisitics Volume 1.*. Taipei: Academia Sinica, Institute of Linguistics. 227-312.

Wright, R. (2001). Perceptual cues in contrast maintenance. In E. Hume & K. Johnson, eds., *The role of speech perception in phonology*. San Diego: Academic Press. 251-277.

Wright, R. (to appear). A review of perceptual cues and cue robustness. In B. Hayes, R. Kirchner, & D. Steriade (eds.), *The phonetic bases of markedness.* Cambridge University Press.

Title:	The acquisition of manner in pre-vocalic sequences: A cue is a cue.
Author:	Teresa Vanderweide Mount Royal College / University of Calgary
Postal Address:	Mount Royal College Faculty of Arts, Language Department 4825 Mount Royal Gate S.W. Calgary AB CANADA T3E 6K6
E-mail:	tvanderweide@mtroyal.ca