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The Acquisition of Voicing Contrasts in Word-Initial Obstruent Stops

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This paper presents two different perspectives on the acquisition of voicing in word-initial stops, in order to determine the patterns that children follow when acquiring the voicing contrasts of a language. The first contains a discussion based on voice onset time (VOT), the most commonly used method of testing voicing contrasts in speech. According to Macken and Barton (1980), "VOT refers to the time interval between the release of stop closure and the onset of vocal fold vibration." This section also includes a brief discussion on the influence of certain contexts during voicing acquisition. The last perspective is based on the underspecification theory presented from a nonlinear point of view, a more recent approach to phonology that relies heavily on distinctive features, in this case the features [voice] and [spread] under the laryngeal node.

The majority of data in this paper comes from English. However, other studies on voicing acquisition from various languages will be included in order to compare and contrast the voicing process cross-linguistically, to see whether there is a similar pattern among children, regardless of their input language. These other languages include Spanish, Thai, Cantonese, Mandarin, Hindi and Polish.

This paper will also argue that cross-linguistically the voiceless member of a stop pair is more common than the voiced member, and it is also acquired earlier by children. The evidence from languages like English, where the voiced member is predominant in both children's and adult output speech, challenges this statement. Therefore I think that it is important to address this statement with respect to the English language.

Terminology which will be used throughout this paper includes the three universal categories of stops: voiced stops, unaspirated voiceless stops and voiceless stops. The classification of each of these three stops is based on the length of time between the release of oral closure and the onset of glottal pulsing, or VOT. All languages show roughly the same distributions along the VOT continuum for all three categories of stops. According to adult data, voiced stops result in glottal pulsing occurring simultaneously or shortly after the release and show negative values along the voicing continuum, 'voicing lead'; voiceless unaspirated stops occur between 0-25ms after the release, 'short lag voicing'; voiceless stops occur between 40-100ms after the release, 'long voicing lag'. Any child, regardless of the language that they are first exposed to, will establish these three categories with a similar VOT value for each of them. These generalizations made by the child will eventually take on the categories of their input language.

What is known about the voicing of stops in the adult language is that different languages vary in the amount of contrasts that they allow word-initially. For example, English and Spanish differentiate between two different voicing contrasts of stops word-initially, whereas Thai distinguishes between all three of the universal voicing categories. Hindi is one of the rare languages that actually makes four voice contrast distinctions in word-initial position because it includes voiced aspirated stops, which are not included as one of the universal voice contrast categories.

Each child portrays three stages in the process of voicing contrast acquisition:

(1) No voicing distinction in terms of VOT most sounds produced between 0-30ms, 'short lag stops'.

(2) Distributions of voicing overlap, which means that a distinction is made by the child, but is not perceivable by the listener. This occurs because the contrast falls within the adult's perceptual boundaries of only one phoneme (generally voiced). This is considered the exploration stage because the VOT means for both the voiced and voiceless stops fluctuate in the child's speech because the child has not achieved total control over the laryngeal and supraglottal functions.

(3) Contrast is established. The voiced member of the pair is firmly established but the voiceless member still shows some variation. The child first overshoots the adult values of the voiceless stops by producing them with major long lag voicing before shortening the values back towards the adult target. This stage is also characterized by an increase in the long lag voicing values (as already stated) and a decrease in the voicing lead values.

VOICE ONSET TIME ANALYSIS

For clinical purposes, it is important to be able to establish a set of norms categorizing the ages when a child of a specific language should acquire a voicing contrast. To specify the exact age when a child accurately achieves the adult target voicing values is almost impossible considering the variability within each individual child. All children cross-linguistically show overlap when acquiring the voicing contrast.

English data:

The most appropriate indicator of the age of voicing contrast acquisition in English is based on the acoustic differences between phonologically contrastive pairs, such as /p/ and /b/. The earliest age shown for a child to establish the voice contrast is 1;5, but consistent progress is not noted until the age 2;0. Prior to this stage of contrast realization the children will produce most of their stops within the short lag voicing range (voiceless unaspirated). In general, based on the results of many studies, most children will acquire a stable voicing contrast by age 2;6, with the voicing contrast first appearing at the alveolar place of articulation. By the age of 3;0, the voiced member of a contrastive pair has a similar short voicing lag pattern to that of adults, but the voiceless counterpart still has a more widely dispersed VOT range.

Spanish Data:

Spanish only uses a two way voicing contrast in word initial stops, which include voicing lead (voiced) and short voicing lag (voiceless unaspirated). The voiced sounds consist of two allophones: a stop and a voiced spirant. The spirants occur more frequently than the stops in Spanish, however most descriptions of the language derive the spirants from the stops with the rule of spirantization. This rule is questionable because children acquire the spirant phones before the stop phones; thus it would be more plausible to have an allophonic rule of stopping rather than spirantization. As well, children seem to establish the voicing contrast earlier in spirants than in stops. Based on the above assumptions, it is obviously more useful in Spanish to use the feature [continuant] when determining the acquisition process of voicing as compared to using VOT. Thus, VOT isn't as critical to the child's underlying voicing specifications as frication. Children learning Spanish do not show any evidence of acquiring a voicing contrast until after the age 4;0. This seems problematic when compared to the English data because English children have generally established adult like voicing qualities by this age. An explanation for the late age of voicing acquisition in Spanish may result from the production of voicing lead stops being more difficult to learn. However, as seen from data on Hindi, this may not be the case, because voicing lead is the second contrast acquired by Hindi children. The conclusion from this as stated earlier, is that VOT is not the most prevalent factor when determining the age of voicing acquisition in Spanish children. One similarity though between English and Spanish children is that both acquire the short lag voicing first.

Based on cross-linguistic data it is apparent that children can discriminate between short lag voicing and long lag voicing regardless of whether this distinction is made in their input language, whereas, in order for a child to distinguish between lead voicing and short lag voicing the child must have experience with a language that shows this specific contrast. This supports the Spanish data that voicing lead stops are the most difficult to produce. The data on lead voicing vs. short lag voicing is criticized because the difference in voicing is difficult to portray, and there has not been sufficient data found to adequately support this claim.

Thai Data:

Thai represents all three voiced stops in word-initial position. According to Gandour and Petty (1986) Thai children acquire most of the voicing contrast in their language by age 3;0, except for the pairs [b vs. p] and [d vs. t], but by age 5;0 all of the voicing contrasts have been acquired. Once again as compared to both Spanish and English the short lag stops are acquired first by children learning Thai. The distinction between the voiced (lead voicing) and voiceless unaspirated stops (short lag voicing) is acquired late, which supports the notion summarized by the Spanish data, that lead voicing is more difficult to acquire than long lag voicing. This statement has proved to be problematic due to the fact that it is supported by the Spanish and Thai data, yet contradicted by the Hindi data. Obviously more studies need to be done on this topic in order to determine which side of the argument is stronger. An explanation for the late acquisition of lead stops in Thai may be due to the underlying specifications of the features that pertain to the voice contrast, which would appear in a nonlinear analysis.

Cantonese Data:

Cantonese differentiates between short lag voicing (voiceless unaspirated) and long lag voicing (voiceless aspirated) in word initial stops. Like English children, Cantonese-speaking children show contrast recognition of these two stops by an early age. By age 2;2 children show a significant VOT contrast for alveolar stops. Soon after, between the ages of 2;6 - 4;0, the children produce consistent voicing contrasts at all places of articulation, but the contrasts are not totally adult-like. Prior to a child achieving the voice contrast realization, they show high amounts of overlap between the ranges of VOT values of the two stops. This is similar to the pattern demonstrated by English children. As well, the Cantonese children generally produce a widespread pattern of VOT values for all the three possible stops, before restricting their productions to generally those in the short lag range. This is an interesting fact, because there is no evidence of voicing lead in the adult language, yet the child uses this in variation when acquiring their language. Once again this coincides with the above data from the other languages, that short lag voicing is acquired first. Aspiration was the last component of voicing to be acquired by the Cantonese subjects studied. One note regarding children acquiring Mandarin Chinese, is that they learn to produce aspiration rather early in their speech, between age 1;11 - 2;2.

From the above data it is obvious and well documented that the early acquisition of short lag voicing by children shows a universal pattern. One basis for supporting the early acquisition of voiceless unaspirated (short lag) stops cross-linguistically is that they are less complex to articulate, as compared to the voiceless aspirated (long lag) and voiced (lead) stops. Two independent articulatory gestures are needed in order to accurately produce a stop consonant; articulations allowing stop closure and release, and initiation of the vibration of the vocal cords. Production of the stops in the long lag range and lead range on the VOT continuum require more fine controlled timing between the laryngeal and stop closures. As well, adduction of the vocal cords from open to closed (oscillating) position requires more complex muscle activity during production. Timing constraints are the most important factor associated with the emergence of adult productions because a child must gradually refine these constraints in order to stabilize their productions, when acquiring all aspects of phonology. The data from Spanish and Thai point out the fact that the acquisition of voicing does not come early in all languages, which leads to the conclusion that the age of acquisition is not only variable across each individual child but it is also variable across languages.

Many studies on the contextual effects on voicing acquisition have been published. For example, segments produced in isolation show longer VOT values than segments produced spontaneously in conversation. As well, across languages, voiced segments are less common in word-final position. This may be due to glottal control differences which result in voiced segments occurring more frequently in word-initial position. The lexicon has also proved to influence a child's phonological acquisition. Tyler and Edwards (1993) proved that before contrast realization of voicing occurs, English children restrict their correct productions of voiceless stops to old words (ones already present in their system) as opposed to new words (those just entering their system). They assumed that because the old words were produced more frequently, they had a better chance of containing tokens portraying the correct emergence of voiceless stop production. After contrast realization of voicing occurs, children produce most of the voiceless tokens correctly regardless of whether the words are old or new.

## NONLINEAR ANALYSIS: UNDERSPECIFICATION THEORY

The underspecification theory allows direct reference to the features specifically involved with voicing in one's speech. The features that are important in acquiring a voicing contrast are situated under the laryngeal node of the feature tree. It is important to note that the phonological information is underspecified whereas the phonetic output is specified. The underspecification theory data that is used for English comes from the well-known study of Amahl (age 2;2). This view accounts for the acquisition of correct voice features, in order to establish a voicing contrast in the language. At the earliest stage of a child's acquisition, [voice] is shown as non-contrastive in the child's underlying representation. The basis for this assumption is that voiced and voiceless obstruent stops in English occur in complementary distribution in the child's repertoire, therefore there is no voice contrast throughout the different word positions. That is, the voiced obstruents are found in prevocalic position ( both word-initially and word-medially) and the voiceless obstruents are found in word final position. To account for this distinction both of the [voice] values are underspecified in the child's underlying representation of all word positions. The following underlying rule is proposed by Dinnsen (1996) in order to fill in the corresponding values of the voice feature. "Given a prevocalic obstruent stop that is underspecified for [voice], the default value to be filled in is [+voice]; elsewhere, the default value is [-voice]." Due to the fact that all obstruent stops are underspecified for [voice], the voicing value of the stop is realized in the child's underlying representation with the above rule. Rice (1996) states that, "In the absence of distinctive laryngeal contrasts, stops are relatively free in their laryngeal realization." This indicates that a distinction under the laryngeal node is not introduced until the child's voicing contrast becomes adult-like. Once the contrast is established, the amount of variation in the child's speech decreases because only one of the stops is marked for voicing. All children will first show variability when acquiring a language because they have to deal with the allophones of segments.

At the age of 2;4 the feature [voice] became contrastive in Amahl's underlying representation but this did not result in the correct productions of all his stops. Dinnsen (1996) states that the phonetic realization of a voicing contrast does not occur until 2;7 when the voice contrast reaches the adult target system and becomes stable.

Three different accounts for the underspecification of [voice] are given in order to explain what happens within Amahl's representations of the [voice] feature underlyingly, and it will become evident as to which account Dinnsen supports.

The Contrastive Specification account argues that when the [voice] contrast is introduced into a child's system, both of the contrastive [voice] values must be specified. This causes all the obstruent stops to change from being underspecified for [voice] to becoming specified for either [+voice] or [-voice]. If this were the case then Dinnsen's rule would no longer apply to the child's system. This account would cause the prevocalic stops, which are indeed realized as voiceless in the target speech to become specified for [-voice], but the other prevocalic stops which remain voiced in Amahl's inventory would need to be specified as [+voice]. Thus, this result would cause a contradiction which contrastive specification cannot account for.

The context free Radical Underspecification account refers to only one of the voice contrast values becoming specified underlyingly and allows you to eliminate the predictable information. With reference to markedness in nonlinear phonology, those sounds first acquired by a child are unmarked and portray the '-' value whereas the sounds acquired later by a child are more marked and portray the '+' value. These assumptions cause the prediction that the [+voice] value would be specified due to the unmarked status of [-voice] obstruents. Thus, [-voice] would end up being the default feature used to illustrate all of the underspecified obstruents. This hypothesis does not cause problems for the change in voicing of stops in word final position but it does create a problem prevocalically. Many of the stops which remain voiced prevocalically in the child's speech would have to change underlying from unspecified to specified for [+voice]. The feature change would occur underlyingly without a phonetic change. With regard to the prevocalic stops that did change phonetically to voiceless, a phonetic change would occur without an underlying change. Since the underlying and phonetic changes are not in accordance with each other, they both violate the compatibility assumption.

The Compatibility Assumption states that segments are only allowed to take on the underlying specifications if the specification agrees with the target value.

The context-sensitive Radical Underspecification account can solve the problems of the other two accounts, and is thus supported by Dinnsen as a plausible explanation of a child's underlying feature system when acquiring the feature [voice]. This account gives a better justification because it conforms to the contextual constraint and compatibility assumption by allowing both of the contrastive values to be specified underlying but in different contexts. When the voicing contrast is introduced to the child only the words that change phonetically would also change underlyingly. For example, if the prevocalic stop becomes voiceless it will change from being underspecified underlyingly to becoming specified for [-voice]. The other prevocalic stops which don't change to voiceless will stay underspecified with the default [+voice], as stated by Dinnsen's rule above. The difference is that [-voice] would be the underlyingly specified value for prevocalic stops and [+voice] would be the underlyingly specified value for final stops.

Use of underspecification theory when acquiring a voicing contrast leads to the conclusion that all the stop obstruents in the child's underlying representation will remain underspecified for [voice] even after the contrast is fully acquired. The earlier stated rule will then supply the child with the default values.

Some problems arise in the nonlinear theory with regard to the features under the laryngeal node in a child's underlying representation. Specifically, a problem with markedness occurs regarding the feature [+voice]. When referring to markedness, the frequent phonemes are the ones less marked, containing the '-' value. These unmarked phonemes are acquired first when acquiring a language, because the unmarked values are a part of Universal Grammar, and do not need to be learned. Because [+voice] is the more marked feature we would assume that it is acquired last by the child and the [-voice] feature is acquired first, but of course this appears contradictory to what happens during voice contrast acquisition in English. Thus, a problem is created. Based on this assumption that voiceless obstruents appear more frequently than voiced obstruents in many of the worlds languages, how does one explain the predominance of voiced stops in English? There are two logical answers to this question. The first is based on the introduction of the feature [spread] under the laryngeal node and the second is based on my own idea as to the misconception of the feature [voice].

Firstly, one solution to this problem is to introduce the feature [spread], which represents post-lexical aspiration. If the spread feature plays a role in the child's acquisition process, it can be used to explain the confusion that arises regarding the feature [voice] under the laryngeal node. In fact, [spread] is only necessary in aspirated languages such as English and Cantonese for the sole purpose of defining the post-lexical aspiration of word-initial voiceless stops.

Davis (1995) states that the pertinent surface representation of the contrast lies within the feature [spread], rather than [voice]. She states that a child first produces the contrasts of the [spread] feature before [voice]. This could be used to explain the early occurrence of unaspirated voiceless stops, because they are less specified than the aspirated stops which need the extra [spread] feature under the laryngeal node in order to be realized. Thus, the less specified segment would be acquired earlier, as it has proven to be. The major difference between the [spread] and [voice] features is that [spread] has larger lag time differences than [voice] and it is easier for children to distinguish between pairs of sounds that involve a longer lag time. Davis uses three hypotheses as a basis for determining which will provide the most accurate account for describing the child's stages of development when acquiring a voice contrast.

The Voiced Distinction Hypothesis states that [voice] is more salient to a child learning a language than the feature [spread]. As well, phoneme pairs which consist of different specifications of [voice] are acquired earlier than those pairs with the same voicing distinction, with no regard to the feature [spread].

The Spread Distinction Hypothesis is the opposite to the above. The surface feature [spread] is considered the most salient as opposed to [voice] in the child's representations. This hypothesis does in fact account for an English child's early acquisition of contrastive VOT productions.

The last hypothesis is the Acoustic Difference Hypothesis. It states that the order in which a child acquires a voicing contrast is determined solely by the acoustic properties of the contrasts, with no regards to features. Precisely, the lag time VOT values that show a large difference between two members of a contrastive pair are acquired first by the child, before the contrasts that show only small differences between VOT values. Thus, if a child has acquired the VOT values showing just a small difference, they will have already established the VOT values with a large difference in their inventories. English children acquire the large difference in lag time VOT values by approximately age 2;0.

The Acoustic Difference Hypothesis is supported by the data in Davis' study, which shows that a child acquires a productive voice contrast based on the acoustic differences in the adult target speech. This hypothesis may be more useful to explain cross-linguistic differences than the notion previously assumed, that the differences were based on the phonological complexities of each language.

Spanish and English children have identical underlying representations of the [voice] and [spread] features (neither language has [spread] underlyingly), but the difference lies in their surface representations. English has a surface contrast of the spread feature, and the '+' value for voice is optional, thus the Spread Distinction Hypothesis would apply here. Spanish has the feature [-spread] for both stops therefore it is the voice feature that is relevant to the surface contrast. Thus the Voice Distinction Hypothesis would more accurately describe the contrasts which occur in Spanish. According to Davis, the Acoustic Difference Hypothesis could account for the voicing in both of these languages. Data from Hindi backs up the Acoustic Hypothesis because

Hindi shows both contrasts of [spread] and [voice] on the surface, so it doesn't conform to either the Voice or Spread hypotheses. It is here where Davis obtained the data which proves that contrasts with large lag differences are acquired early across languages.

Based on the above information it may be plausible to assume that the spread contrasts are acquired earlier than the voice contrasts, because English children acquire the voicing contrast earlier than Spanish children. This is another possible explanation for the late acquisition of a voicing contrast in Spanish, but there are also a few other logical reasons. Late production in Spanish could be caused by the stop and fricative allophone alternations, something that is not present in the English language. Also as summarized earlier, two constituents of a contrastive pair are acquired early if they show a large difference in lag time. This large difference is due to the contrastive spread features for voiced and voiceless stops. Spanish doesn't show a contrast of the spread feature whereas English does, so this therefore supports the earlier acquisition of voicing in English.

The average difference in lag time between a short lag and long lag pair in English is 60ms, whereas in Spanish the difference between a lead vs. long lag pair is only 29ms. Thus, Spanish voicing contrasts are acquired later due to the smaller difference in lag times as compared to English. The reason why the Spanish lag times are smaller than those of English comes back to the [spread] and [voice] features. Since the Spanish stops show the same [-spread] feature their articulatory gestures are also the same, thus the VOT difference in Spanish is caused by the different articulations for the [+voice] and [-voice] values, making the difference in lag time shorter.

English [k] and [g] have basically the same lag time differences as Hindi [$k^h$] and [k], therefore children should acquire these contrasts around the same age, and they do. This once again supports the Acoustic Hypothesis as defined by Davis.

The answer that I formulated provides a solution to the markedness problem in English and explains why it is in fact the voiceless member of a contrastive pair that appears more frequently across languages. After extensive study, it seemed evident to me that the problem does not exist within the markedness theory but it is derived out of the terminology used to explain the voicing contrast distinction. In general, adult speakers of English produce their voiced stops in the short lag region according to VOT measurements. Short lag voicing is the region on the voicing continuum for voiceless unaspirated stops, so the English voiced stops aren't in fact [+voice] as many would presume.

The symbols that are used in English to represent the voiced and voiceless segments are based on broad phonetic transcriptions and can be quite misleading. What occur most frequently in word-initial position are the voiceless stops [p t k], and not the voiced stops [b d g]. In order to determine how the voiceless stops [p t k] differ from [b d g], the former pair are classified as tense and the latter as lax. One could then presume that the contrast in English stops is caused by tenseness rather than voicing. This highlights another possible explanation for the stated problem, but there is insufficient data on this exact hypothesis to allow for further discussion. In non-aspiration languages, such as Polish, this problem does not arise, because they have only fully voiced members and voiceless members of a contrastive pair. This information is useful in order to explain why the feature [-voice] is termed the unmarked value according to the nonlinear theory.

Markedness is seen as a problem in the theory because most adults assume that the "voiced" stops being produced word-initially are in fact voiced. It is the terminology that leads to this sort of confusion, because in fact it is a voiceless unaspirated stop, termed voiced, that is being produced word-initially by adult speakers of English. The assumption that cross-linguistically children acquire the short lag voicing (voiceless unaspirated) stops first, does support the markedness theory that [+voice] is the marked value and [-voice] is the unmarked. The term aspiration also causes some confusion (only in languages where aspiration applies), and that is why the [spread] feature is necessary as well as the [voice] feature under the laryngeal node. Thus, the default node in a child's speech consists of [-voice] and [-spread] which surfaces as the voiceless unaspirated stop. The statement that voiceless stops are more frequent in the majority of languages can now be regarded as true, rather than questioned.

This paper has argued that children, regardless of the language they are acquiring, follow a similar pattern when acquiring a voicing contrast in word-initial stops. It is evident that cross-linguistically the short lag stops (voiceless unaspirated) are the earliest acquired member of a contrast, regardless of the actual age of acquisition by a child. The age of acquisition is shown to vary due to the specific factors that affect each individual language, as in Spanish and Thai. Both the voice onset time analysis and the Underspecification Theory have proved to accurately describe what occurs within a child's system as they acquire a voice contrast. VOT is obviously the most salient method of measuring the acquisition process of the child due to the well-documented studies that support it. The Underspecification Theory is also quite sufficient when explaining what occurs in the underlying representations of a child's speech, but this theory seems to have a few flaws which need further research in order to make the data more consistent. I think that one of the major problems in the nonlinear theory arises from the definitions of the features under the laryngeal node. This area of the theory must involve more explicit explanations in order to provide an understanding of what is actually happening within the child's underlying system. This way, people are not misled by the chosen terminology.

This paper has demonstrated that a single method or theory cannot describe the acquisition of voicing in every language. Rather, research in each language must rely on a specific method that is best suited to it to accurately measure voicing contrasts.

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