Consonant inventory of infants aged 0-6 months

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Abstract

This paper examines the phonetic (consonant) inventory of four Australian infants during a six-month longitudinal study before the onset of babbling. By studying the developmental trends associated with the use of laryngeal consonants it shows that these articulations decrease in proportion across the course of the study as the infants gradually learn the sound patterns of Australian English and demonstrate the ability (cognitive and muscular co-ordination) to experiment with more oral articulations. In addition, other areas of laryngeal function such as voicing show developmental patterns that when combined with the consonant repertoire provide a broader picture of laryngeal use in infant vocalisations.

Index Terms: phonetic inventory, infant, laryngeal

1. Introduction

Numerous researchers across the last 70 years have conducted work on the sounds that infants produce. These have taken various forms, from cross linguistic longitudinal phonetic inventories [1] to work on parental perception of infant production capacities [2]. Of most import to this current work have been the previous findings that laryngeal articulations (either glottal or pharyngeal) are extremely prevalent in infant vocalisations [1, 3, 4, 5]. However few have studied these articulations in a systematic manner. Of these, none have linked changes in proportions of consonant articulations with other changes in laryngeal function, although research has tried to describe universal stages of speech development by documenting commonalities in early vocalisations related in part to changing anatomy, respiration and neuro-motor control [6, 7, 8]. This present study shows that, even before the onset of babbling, infants are modifying their linguistic behaviour. When articulations are grouped according to the percentage of production at each place of articulation and manner of articulation a number of longitudinal trends are noticeable. Of particular interest are the number of different laryngeal segments in evidence and their decline in proportion of total segments over the course of the study. Developmental trends related to the voicing of stops and fricatives are also evident. These trends show the impact of the infants' continual development and changing anatomy as well as raising the possibility of ambient language effects.

2. Method

A Sony DCR-TRV16E digital video recorder with integrated microphone was used to film four infants interacting with their caregivers or engaged in solitary play over the first six months of life. The infants were recorded at a sampling rate of 48kHz and 16 bit encoding. A total of 6,714 vocalisations comprise the corpus that was used for this analysis. Due to the young nature of the subjects (up to 26 weeks) no elicitation of segments was attempted; instead all vocalisations produced by the infants during the recording sessions were coded. Each vocalisation was broadly transcribed using a simplified IPA script in the phonetic database software EMU. The transcription was aided by visual inspection of broadband spectrograms and time waveforms. Randomly selected vocalisations from each week from two participants (a total of 1140 vocalisations) were labelled by an independent rater. Inter-rater reliability for this labelling was calculated at a Cohen's Kappa of 0.76. The consonant vocalisations[1] were then grouped according to four broad place categories: labials, coronals, dorsals and laryngeals, and also six manner categories: stops, fricatives, nasals, approximants, vegetative and trills. Sounds involving any contact with the lips (bilabial or labiodental) were considered labial. Coronals included all sounds produced with the tip or blade of the tongue and produced with either constriction or occlusion at the dental, alveolar or palatal places of articulation. Dorsals involved the back of the tongue or velum in their production. Any sounds produced in the pharynx or larynx were classified as laryngeals. These categories were utilised due to the difficulty in determining the precise place of articulations for young infants. By collapsing the segments into these categories broader trends are able to be seen clearly and the results compared with other studies using a similar methodology e.g. [4].

3. Results

The infants' results are shown in Figures 1-4 and include: place of articulation, manner of articulation and voicing of stops and fricatives.[2]

3.1. Places of Articulation

The combined proportional results for the four children are presented in Figure 1. Here, it it can be seen that laryngeal articulations are quite prevalent in the early months but decline over time. Labial articulations increase, whilst coronal and dorsal articulations are fairly consistent in their distribution. These results differ from those reported by [4] where laryngeal con-

[1] The term consonant is used throughout the paper to refer to all consonant-like sound productions. Although other terms such as closant [9] could have been used, it was decided to use consonant for ease of reference and comparability with other studies. The use of this terminology is not to suggest that the infants are producing canonical examples of this category.

[2] Voicing in this context refers to the auditory-perceptual distinction made in Australian English between [p] and [b].

sonants were the principal place of articulation during the first six months of life. Labials in contrast are the foremost place of articulation in this study. In both studies, coronals and dorsals were produced infrequently. These differences may be a result of the small sample sizes in both studies (two children in [4] and four children in the present study). It may also be a result of differing labelling methodology. Because this study was part of a larger project primarily interested in voice quality, certain segments that may have been labelled as glottal stops in other studies, were included as the beginning of creaky voice quality and not a separate consonant. This would have reduced the reported proportion of laryngeal segments. The present results are much closer to those found in a study of slightly older children by [10] where labials dominated English infant productions; they found that labial productions declined consistently once first words were produced. However over the course of this study labial articulations increased as a proportion of consonant productions. As this current study only has data for the first six months of life, it is possible these labial productions would then have declined as babbling and first words started to occur.

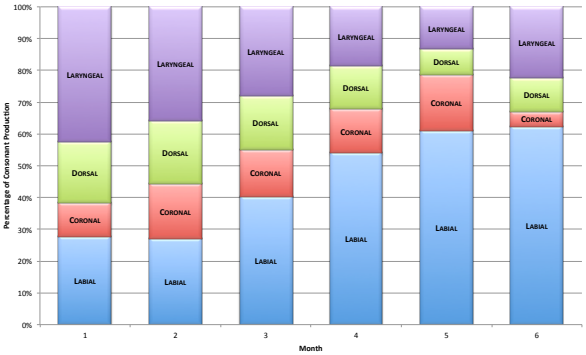

Figure 1: Place of articulation developmental trends for all children combined - Labial, Coronal, Dorsal and Laryngeal

3.2. Manner of Articulation

When grouped by manner of articulation, the results illustrated in Figure 2 show changes related to development. Nasal becomes the most common manner of articulation. When assessed by individual phone the bilabial [m] occurs most frequently. It is likely that the ease with which a bilabial nasal is produced is responsible for its common production. First, the anatomy of an infant vocal tract necessitates nasal breathing. Second, [m] is produced with the mouth closed meaning no constriction with the tongue is needed. Because of this it is an extremely 'easy' phone for the infants to produce. Other nasals [n] and [ŋ] were also common in production. The large tongue body gestures needed to produce nasals make it relatively easy for infants to control and produce these articulations. There is also a suggestion that due to infants' early sucking behaviour the myelination of the motor nerves in the lips occurs much sooner than other parts of the oral anatomy. The more rapid development of this part of the oral anatomy may also contribute to more sounds being produced in this manner [6]. By the conclusion of the study, nasalised consonants accounted for close to 50% of all productions.

Those sounds deemed vegetative or involuntary in other studies and thus discarded are frequent in this corpus, especially in the first three months. Over the course of the study they decline in occurrence of consonant segments. This initial frequency was the main reason that they were included for analysis in this study. When broken down, clicks are the most prevalent segment type from this 'manner' of articulation. Actual involuntary vocalisations (sneeze, hiccups and coughs) represent a very small proportion of consonant segments.

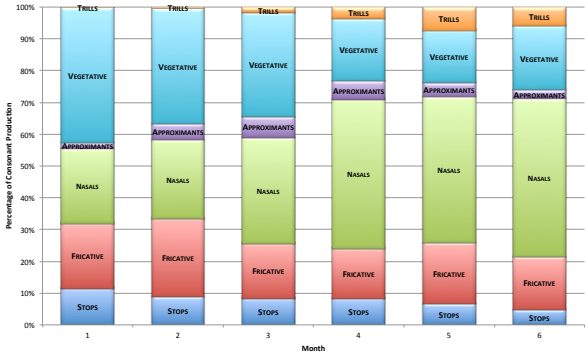

Figure 2: Manner of articulation developmental trends for combined children - Stops, Fricatives, Nasals, Approximants, Vegetative, Trills

Fricatives comprised a higher proportion of segments than stops across the entirety of the study. In every place of articulation, fricatives were more abundant than stops. Again, infant anatomy and the articulatory reality of producing these segments can be used to understand these differences. Infants' tongues almost fill their oral cavity. As such, precise articulation is difficult. In addition, the fine motor control needed for the precise articulatory gestures that stops require is still developing throughout childhood. As a result the muscle control required to produce a complete oral closure with no leakage of air is difficult for infants to muster. Non-sibilant fricatives (as weakened stops) are therefore easier to produce and thus more common than stops. The primary places of articulation that fricatives were being produced were velar/uvular and laryngeal. Approximants are rarely produced by the children. Trills are slightly more common due to the inclusion of the childhood staple 'raspberry' or bilabial trill.

3.3. Voicing

Voicing is the final aspect of the consonant inventory that was examined. It was found that over the course of the longitudinal study the children increased the proportion of voiced to unvoiced stops and fricatives. However there was a large amount of variation between the children as seen in Figure 3 and 4.

AB, AP and HL all increased their use of voiced stops over the course of the longitudinal study. In the initial months when stops occur, they are generally voiceless. The co-ordination required for a voiced stop is quite complicated requiring both the laryngeal and supra-laryngeal gestural timing. Those stops that are voiced in this corpus are primarily produced intervocalically. CM did not increase her use of voiced stops in the same remarkable fashion as the other children and her use of voiced stops remained under 20% for the whole of the study.

The pattern for fricatives is more varied. CM uses voiced fricatives 24% of the time in the first month. The use of these then declined until the fourth month before increasing again during the fifth and sixth month. HL increases his use of voiced fricatives until the fourth month and then reverts toward using increased proportions of voiceless fricatives during the fifth and

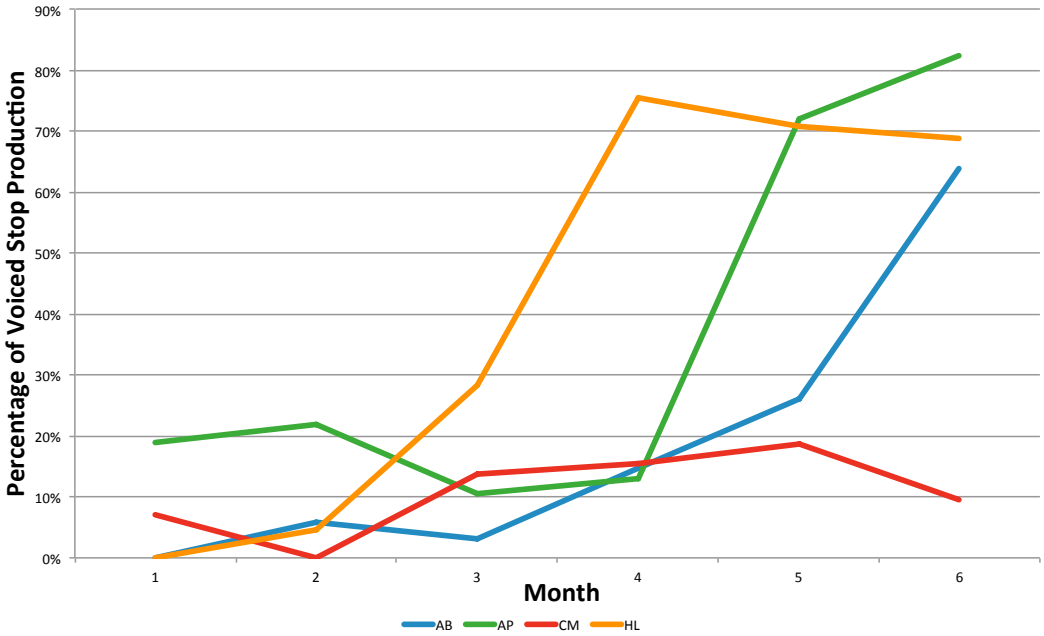

Figure 3: Percentage of stops realised as voiced for AB, AP, CM and HL

sixth month. AP patterns similarly to the voiced stops, with large increases after month three. By month six, voiced fricatives account for 60% of her fricative production. AB also increasingly uses voiced fricatives over the course of the study, though not in such an extreme tendency as AP. Overall, the four children can be seen to be experimenting with voicing and increasing in the proportion of consonants they are making with both laryngeal and supra-laryngeal co-ordinated gestures. However this experimentation shows clear variability between children.

4. Discussion

The consonants produced in these four children's vocalisations differ from the ambient language environment. English only has the one laryngeal phoneme [h], which occurs relatively infrequently, yet infants produce large proportions of their vocalisations utilising their laryngeal articulators. Previous studies have found up to 87% of consonants in the first two months of life as being either [h] or [ʔ] [11]. Whilst this present study did not find the occurrence of laryngeal segments quite as high as either [11] or [4], the use of laryngeal segments does follow the trends of decreasing in frequency across the course of the study. The longitudinal decrease can be explained by the corresponding perception and production capabilities of the infants. They are gradually becoming attuned to the phonetic contrasts that are relevant in the language to which they are exposed and are starting to replicate those sounds. At this early stage of development, this can be seen as proportional decreases in non-native sounds and vegetative noises rather than any explicit cessation. This is because the productions in evidence are the result of a mixture of factors including ambient language environment, anatomy and muscular control as well as the infants' own individual personalities. As a result, there are large variations between infants in the proportion of consonant phones produced each month [3]. However the consistent trends of decreasing laryngeal articulations and increasing labial articulations do point to a common developmental pattern. Infants begin life with a high larynx which predisposes them to produce laryngeally constricted sounds [12]. This includes the production of laryngeal consonants. However as the larynx descends over the first year of life, the infants have the ability to experiment across a broader range of places of articulation. Increase in proportions of non-laryngeal articulations point to the possibly of greater supra-laryngeal control.

There is also evidence of increasing experimentation in other areas of the vocal tract with labial articulations becoming more common. Of particular note was the bilabial nasal [m] which was the principal contributor to segments of this category. The ease of articulation may be one reason for its prominence. It may also be evidence of the beginning of infant motor frame of mandibular oscillation as proposed by [13]. Very little movement of the speech articulators such as the tongue, lips and soft palate are actually required for producing the perception of speech-like rhythmic vocalisation [13]. The combination of phonation, a consonant percept resulting from the close phase of the jaw cycle (e.g. [m]) and a vowel percept from resonance properties enabled by the open phase (e.g. [a]) are the product of rhythmic close and open jaw cycles. Although not yet babbling, the infants are beginning to utilise some of the mechanisms that will eventually make it possible.

The final area in which there is growth and development is the combined use of oral and laryngeal articulators. This is seen most plainly in the increased proportion of voiced stops. The majority of these voiced stops occurred in the labial place of articulation, whilst voiced fricatives were predominantly found at both labial and laryngeal places of articulation. Tyler and Saxman [14] have found previously in older children that voicing contrast acquisition can be described as phonetically gradual. That is, accurate production was restricted to 'old' words that were present in the children's lexicon prior to data collection in contrast to 'new' words that were added afterwards. Whilst the infants at this stage are not producing words and the viability of an infant lexicon is beyond the scope of this study, the places of articulation they produce voicing at (labial and laryngeal) could

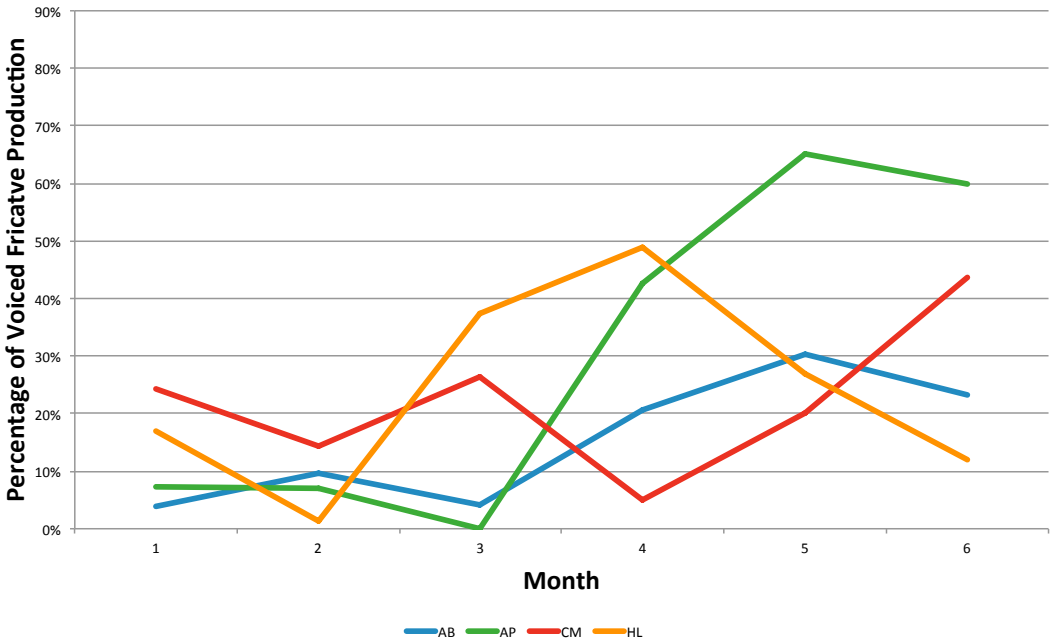

Figure 4: Percentage of fricatives realised as voiced for AB, AP, CM and HL

be considered 'old'. This is because they have control over production in these places of articulation as demonstrated by the proportion of consonants produced by them. In contrast, coronal and dorsal places of articulation are infrequently used by the infants for any stop or fricative production and can be considered 'new', meaning diffusion of accurate voicing of stops and fricatives is limited. The use of both voicing and co-ordinated oral gestures required to produce a full closure increases over the course of the study. The timing necessary for these gestures to be co-ordinated needs to be finely controlled. The increase in proportion of stops being produced in this fashion (even as the overall proportion of stops compared to other manners of articulation decreases) is a signal of growing abilities of the infants to co-ordinate complex articulatory gestures.

5. Conclusion

The consonantal phonetic inventory seen in these four infants shows the impact of their continual development and changing anatomy. Laryngeal consonants decrease in proportion across the course of the study as the infants gradually learn the sound patterns of English and experiment with oral articulations. The proportion of voicing increases in stops and fricatives showing greater control of laryngeal articulators in tandem with their capacity to use the oral cavity. All of these changes reflect the dynamic system of the infant oral and laryngeal tract.

6. References

[1] Locke, J. L. Phonological acquisition and change. Academic Press, Sydney, 1983.

[2] Ramsdell, H. L., Oller, D. K., Buder, E. H., Ethington, C. A., and Chorna, L. B. Identification of Prelinguistic Phonological Categories. Journal of Speech, Language and Hearing Research, 55(6):1626–1639, 2012.

[3] Robb, M. P. and Bleile, K. M. Consonant inventories of young children from 8 to 25 months. Clinical Linguistics & Phonetics, 8:295–320, 1994.

[4] Grenon, I., Benner, A., and Esling, J. H. Language-specific phonetic production patterns in the first year of life. In 16th International Congress of Phonetic Sciences, 1561–1564, Saarbrcken, 2007.

[5] Iyer, S. N. and Oller, D. K. Prelinguistic Vocal Development in Infants with Typical Hearing and Infants with Severe-to-Profound Hearing Loss. The Volta review, 108(2):115–138, 2008.

[6] Kent, R. D. Articulatory-Acoustic Perspectives on Speech Development. In Stark, R. E., editor, Language behavior in infancy and early childhood, 105–239. Elsevier Science Ltd, Holland, 1981.

[7] Kent, R. D. Psychobiology of speech development: coemergence of language and a movement system. American Journal of Physiology - Regulatory, Integrative and Comparative Physiology, 246(6):R888R894, 1984.

[8] Stark, R. E. Stages of Speech Development in the First Year of Life. In Yeni- Komshian, G. H., Kavanagh, J., and Ferguson, C., editors, Child Phonology: Production, 7392. Academic Press, Ann Arbor, 1980.

[9] Bauer, H. R. The ethologic model of phonetic development: I. Phonetic contrast estimators. Clinical Linguistics & Phonetics, 2(4):347–380, 1988.

[10] de Boysson-Bardies, B. and Vihman, M. M. Adaptation to language: Evidence from babbling and first words in four languages. Language, 67(2):297–319, 1991.

[11] Kent, R. D. and Miolo, G. Phonetic Abilities in the First Year of Life. In Fletcher, P. and MacWhinney, B., editors, The Handbook of Child Language, 303–334. Blackwell Publishing, Oxford, 1995.

[12] Esling, J. H., Benner, A., Bettany, L. D., and Zeroual, C. Le contrle articulatoire phontique dans le prbabillage. In Bel, B. and Marlien, I., editors, Le contrle articulatoire phontique dans le prbabillage, 205–208. AFCP, Fs, Maroc, 2004.

[13] Davis, B. L. and Macneilage, P. F. The frame/content theory of speech evolution: from lip smacks to syllables. Primatologie, 6:305–328, 2004.

[14] Tyler, A. A. and Saxman, J. H. Initial voicing contrast acquisition in normal and phonologically disordered children. Applied Psycholinguistics, 12(04):453–479, 1991.