Perception of Coarticulated German Vowels by Prelingual Infants: Formant Transitions Specify Vowel Identity

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Abstract: German-learning infants were tested for discrimination of four German vowel contrasts in the Silent Center paradigm to examine which spectral properties of coarticulated vowels (target spectral, dynamic spectral) define vowel identity in prelingual infants. The original /dV/-syllables were electronically modified to obtain test syllables which contained target spectral information, only initial or only final formant transitions, or initial and final transitions in their appropriate temporal relationship (vowel nucleus attenuated to silence). Forty German infants aged 7-11 months, who successfully discriminated one of the unmodified contrasts /I/-el, /el/-hl, /d/-le, /lo/-lu), were tested in the conditioned head turn procedure for their discrimination of the test syllables. Results indicate that prelingual infants do not need target spectral information to discriminate these native vowel contrasts; rather, dynamic spectral information defined over syllable onsets and offsets is sufficient to specify vowel identity in infants.

INTRODUCTION

Previous studies of infant vowel perception have shown that the ability to discriminate both native and non-native vowel contrasts in naturally produced coarticulated syllables depends upon the specific vowel contrast tested, the age of the infant, and the direction of presentation of the contrast (1, 2). It is not known, however, which of the sources of acoustic information provided by coarticulated syllables infants use when they discriminate vowel contrasts successfully. Previous studies of native vowel perception by adult American English listeners and by adult German listeners have shown that three types of acoustic information contained in consonant-vowel-consonant (CVC) syllables contribute to vowel identity: target spectral information (reflecting the target configuration of the vocal tract), dynamic spectral information of the syllable onsets and offsets (reflecting the opening and closing gestures of the vocal tract), and temporal information. Strange and her collaborators established the relative importance of these three types of information. The most important finding was that adult native listeners identify and discriminate coarticulated native vowels highly accurately if target spectral information has been electronically removed from the CVC syllables (3, 4, 5). In addition, the presence or absence of target spectral information does not affect how accurately non-native listeners identify German vowels (6). For adult listeners, therefore, vowel identity does not depend on acoustic information on spectral targets. Instead, the perceptually relevant information for vowel identity seems to reside in the changing spectral structure of coarticulated syllables. - We conducted a series of experiments to examine the role of the three sources of acoustic information in prelingual infants' discrimination of native vowel contrasts. This paper reports on the relative importance of target spectral as opposed to dynamic spectral information in infant vowel perception.

METHOD

Four tokens each of the vowels /I/, /l/, /el/, /el/, /h/, /lo/, produced in /dV/-syllables by a male native speaker of North German, were selected for presentation in the contrasts /I/-el, /el/-hl, /d/-le, /lo/-lu/ because these contrasts were relatively confusable for adult native North German listeners (4). Analyses of formant movement in these tokens revealed no vowel inherent spectral change, rather, any formant movement in these truly monophthongal vowels was caused by coarticulation with the surrounding alveolar consonants. To test the role of target vs. dynamic spectral information, the original syllables were modified as follows. Silent Center (SC) stimuli were generated by attenuating to silence the center portion of each of the original syllables, leaving onset and offset portions in their original temporal relationships. The onset and offset portions included the major part of the transitions. Vowel Centers (VCs) were generated by silencing the onset and offset portions, Initials (INs), by silencing both center and offset portions, and Finals (FNs), by silencing both onset and center portions. - Forty infants, aged 7-11 months (mean age: 8.2 months), served as subjects. The infants were being raised in monolingual German-speaking families in Kiel, Germany. - Infants were tested using the headturn procedure (for details of our implementation, see 2). Discrimination of a vowel contrast in one of the conditions (e.g., /I/-el/ as
SC) was tested in a single session. Custom software controlled stimulus delivery, activation of the reinforcers, and trial selection (change vs. no-change trial), and also recorded the number of trials (≥ 25 per testing stage), hits, misses, correct rejections and false alarms. - 10 subjects each were assigned to one of 4 groups, which were defined by the 4 vowel contrasts. Each subject was first tested for discrimination of the unmodified contrast. Only infants who discriminated full syllables (criterion: 7 of 8 consecutive correct trials and >60% correct responses) were then tested on separate days on discrimination of the same contrast tested initially in the edited conditions.

RESULTS

The effects of experimental condition and vowel contrast were examined by conducting ANOVAs on the % correct scores and on the A’ values. The results of both ANOVAs were identical. For the four vowel contrasts tested, the discriminability of unmodified syllables (mean % correct: 72.4), SCs (mean % correct: 68.2), and VCs (mean % correct: 70.7) did not differ significantly (F (2,72) = 1.375, p = 0.2595). The interaction of vowel contrast and condition was not significant (F (6,72) = 1.857, p = 0.1001). For the two subgroups of infants who were additionally tested in either the IN or the FIN condition, additional ANOVAs revealed significant effects of condition. Post-hoc tests suggested that the effects were obtained because INs (49.4% correct) and FINs (55.2% correct) were discriminated at significantly lower levels than the unmodified, SC, and VC syllables.

CONCLUSIONS

The most important finding was that German-learning infants discriminated each of four German vowel contrasts equally well when these contrasts were presented as unmodified full syllables or as SCs, which preserve only the dynamic spectral information of the syllable onsets and offsets in their appropriate temporal relationships. This suggests that infants do not need target spectral information to discriminate spectrally similar vowel contrasts. Rather, trajectory information specified over syllable onsets and offsets is a good source of information for vowel identity in prelingual infants, as it is for adult native listeners of American English (3), of German (4, 5), and for non-native listeners of German vowels (6). The overall pattern of results for the German infants is quite similar to that for native and non-native adult listeners. Irrespective of language background and of native or foreign language experience, dynamic spectral information defined over syllable onsets and offsets defines vowel identity just as well as target spectral information. However, neither syllable onsets alone (INs) nor syllable offsets alone (FINs) provide sufficient information on vowel identity. It is of some significance that the German vowels presented in this and other experiments (4, 6) were truly monophthongal. Formant movement, if observed, was associated only with coarticulatory influences from the surrounding alveolar consonants. This means that the dynamic sources of information which infants and adults used so successfully in the SC condition were associated with the opening and closing gestures at the margins of CVC-syllables, as predicted by Strange's Dynamic Specification Theory (3, 4). Further research is underway to establish the generality of the results reported here by examining how accurately infants discriminate vowels produced in varying consonantal contexts and by multiple speakers when presented only with dynamic information specified over syllable onsets and offsets.

ACKNOWLEDGMENTS

Research supported by DFG grants Bo-1055/3-1, 3-2 to O. Bohn. We thank D. Saludes and S. Trent for assistance in generating stimuli, and K. Schriever, T. Soldat, A. Steinlen, and A. Yassine for assistance in testing subjects. Special thanks go to W. Strange for her essential support, advice, and encouragement.

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