THE DEVELOPMENT OF PHONOLOGICAL BIAS: PERCEPTION AND PRODUCTION OF SWEDISH VOWELS AND TONES BY ENGLISH SPEAKERS

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ABSTRACT

English-speaking adults and children were tested for perception and production of Swedish vowels and tones. Six-year-olds showed greater reliance on vowel than tone distinctions, and more perceptual flexibility with vowels than older subjects, showing the emergence of a perceptual bias between 6 and 10 years. However, bias in speech production appeared later, around 14 years.

INTRODUCTION

Infants can discriminate many consonant contrasts, even those phonologically irrelevant in the ambient language [1]. A major part of speech perception development thus involves the *loss* of perceptual ability for irrelevant speech sounds. There appears to be two developmental periods in which this loss occurs. In early infancy, Werker [2] established that 7-month-old English language environment (ELE) infants perceive various Hindi and Salish Indian consonant contrasts but this ability deteriorates between 7 and 11 months. The second period of loss seems related to the onset of reading: Burnham [1] found inferior performance on non-native consonant contrasts by 6-year-olds compared with younger and older children; and a positive relationship between reading and phonological bias - children who were good readers were also better at perceiving native than non-native contrasts.

More recently work has been conducted on developmental processes in vowel and tone perception. This is important in the context of second language learning because it seems that foreign accents are carried mostly on vowels and tones. Kuhl [3] found that by 6 months infants have established prototypes for native vowels and, in what is called the "magnet effect", that nearby non-native vowels are absorbed into these prototypes. Kuhl found a perceptual drift for American infants towards the English vowel /i/, and for Swedish infants towards the Swedish vowel /y/. With regard to tones, there is some evidence that tonal distinctions are more functionally salient for infants than consonantal distinctions [4]. However, in children from non-tonal language environments tone perception appears to be relatively depressed by 6 years: Burnham and Francis [5] found that ELE 6-year-olds were better at discriminating a Thai non-native consonantal contrast than Thai tonal contrasts, while for adults the opposite was true. They suggest that, due to phonological bias, non-tonal language 6-year-olds have difficulty perceiving tones, despite their high acoustic salience.

Here we investigate the development of Swedish vowel and tone perception and production by English-speaking children and adults. Swedish was chosen because it has a tonal distinction and many vowels not found in English.

SUBJECTS

A total of 72 subjects were tested, 18 at each of four ages, 6 years, 10 years, 14 years, and adults. All were English speakers and none had experience with a tonal or a Scandinavian language. All 14-year-olds had reached puberty but no 10-year-olds had. All participated in both a perceptual discrimination and then a perceptual identification task, and 12 randomly-selected subjects at each age participated in a production task.

DISCRIMINATION EXPERIMENT

Subjects were tested by laptop computer, which stored and presented sounds, on an AX discrimination task and had to respond "same" or "different" by pressing one of two keys mounted on a response box providing digital I/O to the computer. Each trial was initiated by pressing a "ready" key, after which the two sounds were presented separated by either 500 msec or 1500 msec. (Results were later pooled as analysis showed no difference between these intervals.)

All stimulus items were natural Swedish productions carried on the nonsense word [mɛb*n]. Three levels of vowel contrast difficulty were tested (near, medium, and far in terms of distinctive features). In each age group two sub-groups (n=9) were tested, one in which both members of the pairs of vowels were phonologically irrelevant to English speakers (Swedish-Swedish (SS) sub-groups), and one in which one member of each pair was irrelevant and one was the same as an English vowel (Swedish-English (SE) sub-groups). (Here slight phonetic differences between the two languages were ignored.) For the SS sub-groups, the contrasts were [y] vs [ɵ], [y] vs [ø], and [y] vs [o]; in the SE subgroups [y] vs [i], [y] vs [e], and [y] vs [ɑ]. In addition, the Swedish tone contrast, [mɛbýn] vs [mɛbỳn] was tested in both sub-groups. Two blocks of 16 trials (4 of each of the 4 contrast types) were presented. Three exemplars of each sound were available on disk and the program selected from these at random to minimise the effect of acoustic cues and maximise the salience of phonetic cues. The dependent variable was a discrimination index (DI) - the number of correct responses on different trials (hits) minus the number of incorrect responses on same trials (false positives) over the number of trials of each contrast type.

It was expected that 6-year-olds should discriminate vowels better than tones, while the reverse should be true for adults [6]; and that phonological bias should increase with age [1].

Mean DIs for SS vowels, SE vowels, and tones across ages are shown in Figure 1. An age x vowel group x (contrast type) analysis of variance (ANOVA) revealed that all subjects discriminated vowels better than tones and SS better than SE vowel contrasts. Inferior performance on SE vowels indicates that a magnet-type effect was occurring: the S vowel in SE pairs was assimilated into the nearby E vowel prototype, while for the SS vowel pairs, the unfamiliar vowels remained more distinct perceptually. Post-pubescent subjects discriminated all contrasts better than did pre-pubescent subjects as did 10-year-olds over 6-year-olds. Such general effects can be understood in terms of subjects' improving ability to attend and fulfil the requirements of the task. So it is *differential* changes over age which are most important to note. Of specific interest to the hypotheses, there were significant effects of vowels/tones x pre/post pubescence, $F(1,64) = 25.34$, vowels/tones x 6/10 years, $F(1,64) = 9.64$, and of vowels/tones x SS/SE x 6/10 years, $F(1,64) = 4.11$. These results show that there was greater improvement for tones than vowels between pre- and post-pubescence, and even earlier between 6 and 10 years. In addition, as there was greater improvement for SS than SE vowels between 6 and 10 years, it seems that 6-year-olds are showing less of a magnet effect and thus less phonological bias. This can be seen better in Figure 2, in which SS minus SE scores are shown

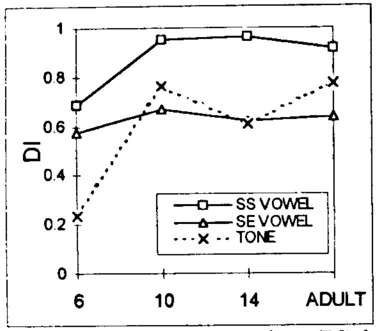

Figure 1. Discrimination indices (DI) for tones and vowels.

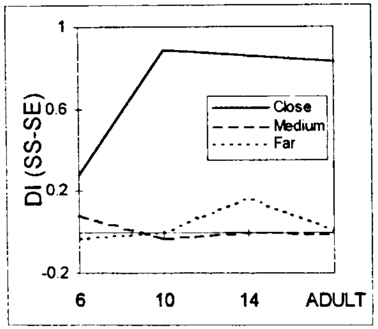

Figure 2. Magnet effect, DI (SS-SE) for close, medium, and far vowels.

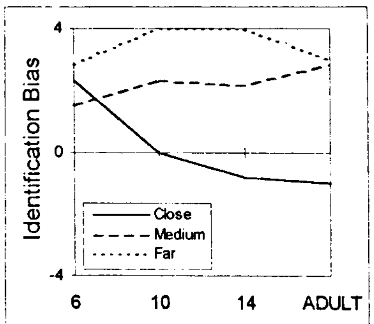

Figure 3. Identification bias (positive = vowel bias, negative = tone bias) for close, medium, and far vowels.

for the three vowel distances across ages. The ANOVA revealed interactions of SS/SE vowels and 6/10 years with the linear effect of vowel distance, F (1,64) = 8.91, and with the quadratic effect of vowel distance, F (1,64) = 12.52. When vowels are far or a medium distance apart, there is no superiority of SS over SE. However when vowels are close there is a large magnet effect for 10-year-olds and older subjects, but not for 6-year-olds. Thus, 6-year-olds show less phonological bias than older subjects for vowels (Figure 1), despite the fact that they appear to be biased against the use of tonal contrasts in a linguistic context (Figure 2).

IDENTIFICATION EXPERIMENT

If 6-year-olds are unable to use tone to distinguish lexical items, then this should show up in a task in which vowel and tone distinctions are functionally relevant. The same apparatus was used as in the discrimination experiment. However, here just a single sound was presented on each trial. In training trials subjects were presented with one of two sounds, eg., [mɛbýn] or [mɛbȉn], which differed both in vowel and tone, and were required to press one of two buttons. Once they reliably identified these to criterion, 8 test trials were presented, 2 of each of the following: [mɛbýn], [mɛbȉn] (the original training stimuli), and [mɛbỳn], and [mɛbín]. The latter two were designed to test whether the vowel cue or the tone cue was more salient for subjects. This training-test sequence was repeated twice so that subjects received a total of 8 novel test stimuli. As in discrimination, three versions of the task were employed for close, medium, and far vowels.

It was expected that subjects should base their identifications on vowels when the distance is great, but on tones when the vowel distance is reduced.

An age x SS/SE x vowel distance ANOVA revealed a significant linear trend over vowel distance, F (1,48) = 27.20, a significant linear x SS/SE effect, F (1,48) = 17.41, and a close to significant linear trend x 6- vs 10-year-olds, F (1,48) = 3.75. As can be seen in Figure 3, there is a definite vowel bias for far and medium vowels. For close vowels the 6-year-olds maintain their vowel bias, even though older subjects now rely more on tones. Thus despite a difficult vowel discrimination task, 6-year-olds are unable to use the presumably more salient tonal difference, due to their difficulty in attending to tonal distinctions in a linguistic context.

PRODUCTION

For production the subjects' task was to repeat various words modelled by a native Swedish speaker. The Swedish-only vowels [y], [ɵ], [ø], [o], and Swedish/English vowels [a], [e], [i] were presented in a [hVd] context. For tones, 'anden', 'biten', and 'tomten' were pronounced with either the single tone (falling on second syllable) (English = 'duck', 'the bit', and 'building site'), or with the double tone (rise on first and rise-fall on second syllable) (English = 'spirit', 'bitten', and 'santa claus'). The single tone was taken to be native in the sense that it uses a tone sequence familiar to English speakers and the double tone to be non-native. Two native Swedish speakers scored whether the vowels were correct and which of the tone words the subjects said. Subjects were better at native than non-native sounds and better at tones than vowels. Preliminary analyses show that the curves for native and non-native vowels are relatively parallel and flat across age, while for tones there is pre- to post-puberty improvement on the native tone and a reduction for non-native tones. The latter is consistent with the notion that in the perception tasks adults' superior performance with tones is due to the relatively high acoustic salience of tone differences compared with spectral qualities of vowels, rather than to any linguistic salience of tones. The results also provide some support for the notion that the ability to produce non-native speech sounds deteriorates after puberty.

CONCLUSIONS

For phonologically-irrelevant vowels perceptual flexibility decreases markedly between 6 and 10 years. However, 6-year-olds are much *less* flexible with tones than are their older counterparts. Paradoxically 6- and 10-year-olds show equivalent ability in producing native and non-native tones, while 14-year-olds' and adults' show superior ability with native tones. Thus there seems to be little correspondence between English speakers' perception and production of Swedish vowels and tones.

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