OCCLUSIVE SILENCE DURATION OF VELAR STOP AND VOICING PERCEPTION FOR NORMAL AND HEARING-IMPAIRED SUBJECTS

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ABSTRACT

Reduction of silence duration in an intervocalic voiceless stop consonant induces misperception of voicing. Psychoacoustic results suggest that temporal resolution could be at the origin of this phenomenon. In this study a high correlation was found between boundary of silence duration and of voiced murmur duration which supports this hypothesis. In addition this study shows that for some hearing-impaired subjects the time boundary for voicing misperception can be considerably greater than for normal hearing. Most of these subjects present a simple temporal shift with a normally steep change of perception. So for them adjustment of silent occlusion duration could be a beneficial acoustical processing.

1 - INTRODUCTION

The shortening of the duration of silence in an intervocalic voiceless stop consonant has been shown to induce a misperception of voicing in normally-hearing listeners (Lisker 1957). The time boundary for this effect is about 60 milliseconds for French as well as for English (Lisker 1957, Serniclaes 1973, Lisker 1981). At the fastest speaking rates closure duration is about 60 milliseconds and on average occlusion time is shorter for voiceless than for voiced stop consonants (Lisker 1981, Port 1981). The misperception of voicing induced by shortening silence duration of an intervocalic voiceless plosive can be thought to be governed by classification of the shortest occlusive duration of silence as belonging to the voiced category. It can also be thought to originate from an insufficient delay for auditory excitation of the preceding vowel to decay. Results from psychoacoustical experiments on temporal resolution indicate that at low frequencies around 100 Hz which correspond to the voicing frequencies of adult males detection of a silent gap requires a gap duration of about 60 milliseconds (Shailer and Moore 1983, 1985, Green and Forrest 1989, Grose et al. 1989). Several studies indicate that hearing-impaired persons show deteriration of temporal resolution (Fitzgibbons and Wightman 1982, Fitzgibbons and Gordon-Salant 1987, Glasberg et al. 1987, Nelson and Freyman 1987, Moore and Glasberg 1988, Grose et al. 1989). It was reasoned that if decay of auditory excitation is indeed the basis for voicing misperception induced by shortening occlusive silence duration, some hearing-impaired individuals should show abnormal time boundaries for this effect.

Some previous studies dealt with temporal processing and the perception of stop consonants voicing for hearing-impaired persons. Voicing in initial plosives was found slightly altered only (Parady et al. 1981, Ginzel et al. 1982, Tyler et al. 1982, Johnson et al. 1984); more errors were found for final plosives (Revoile et al. 1982). And, two studies indicate that elderly persons require occlusive durations longer by about 10 milliseconds (Price and Simon 1984, Dorman et al. 1985).

This study investigated for the same hearing-impaired subjects voicing perception of an intervocalic voiceless plosive as a function of occlusive silence duration and also the degree of forward masking of the preceding vowel.

2 - MATERIALS AND METHODS

Twenty subjects participated in this study, eight normally-hearing and twelve hearing-impaired with a sensori-neural deafness.

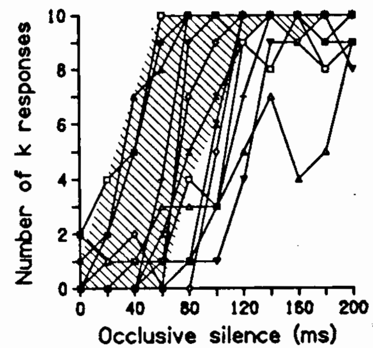
Samples of natural speech tokens "aka" and "aga" were recorded from an adult male speaker. Speech waveforms were edited in a computer. From the "aka" sound eleven tokens were formed by varying occlusive silence duration from 0 to 200 milliseconds in 20 milliseconds steps. From the "aga" sound one cycle of waveform during the voiced murmur was selected as having the same fundamental frequency as the "aka" sound. Bursts of murmur were then constituted by concatenations of this cycle and multiplication by a trapezoidal envelope with a rise time of 20 milliseconds and a plateau adjusted from 0 to 180 milliseconds in 20 milliseconds steps. Ten final stimuli were made by adding these various bursts at the end of the first "a" of the "aka" sound thus constituting "a+voiced murmur" stimuli. These stimuli are meaningless to french listeners.

For tests all sounds were delivered monaurally through a Bayer DT 330 MKII headphone. Stimuli were presented at an intensity of 85 dB peak SPL at the maximum peak of the first a vowel. The contralateral ear received a broadband noise at about 85 dB above threshold. In a first test the various "aka" tokens were presented randomly ten times each and the subject was asked to respond each time by pressing a button marked "k" or "g" according to his perception. In the second test two stimuli were presented succesively. The first was always the first "a" of the "aka" item and the second was one of the various "a+voiced murmur" token. Each "a+voiced murmur" was presented ten times randomly and the subject was asked to indicate whether the stimuli were different or not in anyway by pressing one of two response buttons. Before starting each test the subjects were familiarized with twenty to thirty presentations of the stimuli.

3 - RESULTS

Results from the first experiment are presented in figure 1. The score curves of identification of voicing as a function of occlusive silence duration for normally-hearing individuals were similar to those previously reported in the literature. The range of results obtained from normals are presented in figure as a shaded area. On the same figure all individual curves obtained from pathological ears are plotted. It can be seen that about one half of these curves lie within boundaries for normal ears, the other half exhibiting abnormal results. The curves outside the normal range all show, but in one case, a simple shft along the time axis keeping a steepness similar to normal curves.

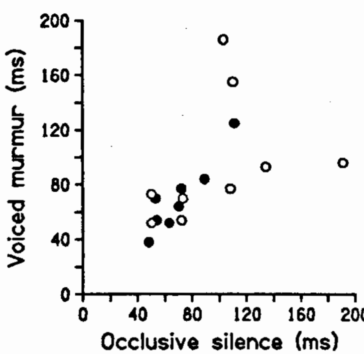
Figure 1



Results from the second experiment gave a series of curves having a similar shape as those of figure 1. Five hearing-impaired subjects indicated they could not perform this test in spite of some supplementary training.

From the score curves of experiments 1 and 2 the duration corresponding to a score of 75% was computed and served for analysis. A plot of the results of both tests is given in figure 2. It can be seen that for the normal ears the results seem to lie closely along a line, a correlation coefficient calculated on these data indicate the high value of 0.925 significant at the 0.001 level. The results from hearing-impaired ears show a considerable scatter, associated with a correlation coefficient of 0.354 not statistically significant. Hearing-impaired ears with normal results at experiment 1 also showed normal results at experiment 2, only results outside normality show a considerable scatter. If all normal results are considered whether coming from normal or pathological ears ; a correlation of 0.836 significant at the 0.01 level. In the group of pathological ears correlations were further considered with the following audiological data : etiology of deafness, age of the patient, duration of deafness, and auditory thresholds at octave frequencies from 250 to 8000 Hz. Only two correlations were found significant at the level of 0.05. They linked auditory thresholds at 250 and 500 Hz with results of experiment 1. It must be noted however that the two worst scores at experiments 1 and 2 were observed for patients diagnosed as probable Ménière.

Figure 2



Duration of occlusive silence versus duration of voiced murmur, both giving a score of 75% success for all subjects of these experiments. Black dots : normal ears, circles : pathological ears.

4 - DISCUSSION

Results of this study show an abnormally long silence duration needed by hearing-impaired individuals to perceive correctly the voicelessness of an intervocalic velar plosive. Data from the second experiment support the idea that this originate from a deteriorated temporal resolution at voicing frequency.

The observed temporal shift in the hearing-impaired indicate that it may contribute to make their identification more vulnerable to fast speaking rates and to noisy background. This study revealed that the time shifts for hearing-impaired subjects are significantly longer than those reported for elderly persons in earlier studies (Price and Simon 1984, Dorman et al. 1985). The normal steepness of variations in perception may be a basis for improvements observed when speaking clearly for the hard of hearing (Picheny 1986, 1989). It also indicate that such a signal processing could be useful to several hearing-impaired persons. The high correlation observed in this study between the first and the second experiment support the hypothesis of an abnormally long ringing at low frequencies after the cessation of a sound in some pathological ears. Other masking effects may also occur on the burst or formant transitions of the following vowel but they are quite unlikely since they would occur at higher frequencies where detection of temporal gaps requires much shorter durations (Shailer and Moore 1983, 1985, Green and Forrest 1989, Grose et al. 1989); the correlations with audiogram impairement at low frequencies also support this notion. The worst results associated with probable Ménière agree with physiological findings on experimental hydrops of altered coding of brief low frequency sounds (Cazals and Horner 1988).

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