The ’transposer’ and a model of speech perception

Risberg, A.

journal: STL-QPSR
volume: 6
number: 4
year: 1965
pages: 026-030

http://www.speech.kth.se/qpsr
III. SPEECH COMMUNICATION WITH HARD OF HEARING SUBJECTS

A. THE "TRANSPOSER"* AND A MODEL OF SPEECH PERCEPTION

A. Risberg

Many subjects with impaired hearing have residual hearing in the low-frequency range. The possibility to improve speech perception for this category by a frequency-transposition was discussed already in the middle of the twenties (9) and some attempts to construct hearing aids and to perform experiments according to this principle have been reported now and then. As a rule experiments did not pass the stage of a preliminary exploration of possible technical solutions. Very few experiments with hard of hearing subjects were undertaken and it is, as a rule, very difficult to draw any definite conclusions from these earlier experiments.

The experimental approach can be divided into two categories. In the first category there are attempts where the whole speech spectrum is transposed to a lower frequency range, usually by dividing all frequencies by a constant factor (8)(10). In the second category there are attempts where only elements in the speech signal, which are impossible or very difficult to perceive with the type of hearing loss in question, are translated to low-frequency signals (3)(4)(6).

The most interesting and promising of the latter type of devices is the so-called "transposer" invented by B. Johansson at the Institute of Technical Audiology, Karolinska Institutet, Stockholm. B. Johansson started his experiment in 1954 and technical descriptions and results of training have been published in the Proceedings of the IIIrd and Vth ICA (5)(11). A block diagram showing the principle of the transposer is seen in Fig. III-A-1. In actual class-room equipment amplitude-compression is also included in the direct and the transposed channel. In 1957 the IBM applied for a patent on a device of the same type intended for use on telephone lines with inferior high-frequency transmission (2).

The experiment described in this article is an attempt to relate the effect of frequency-transposition of the type used in the transposer to a model of speech perception. A frequency-transposition using a device with a mode of operation that is shown in

* The name "transposer" is registered by B. Johansson.
Fig. III-A-1. Block diagram of hearing aid for transposing high-frequency sounds to lower frequencies. After B. Johansson, see ref. (3).
Fig. III-A-1 will transpose all high-frequency energy above the cutoff frequency of the high-pass filter down to a low-frequency region. This means that an [s] will be heard as a low-frequency noise with long duration and a [t] as a short noise burst, and so on. To a certain extent different fricatives can be discriminated by the particular pitch of the low-frequency noise providing the necessary training is given and a relatively wide frequency range of useful residual hearing (5) is retained.

Model

In a distinctive feature model of speech perception the information in the acoustic speech signal is conceived of as transmitted in several parallel channels and a listener makes an independent decision on each of these (7). Consonant features may be divided in two main categories, namely information about manner of articulation and about place of articulation. Statistical analysis of the English language shows that the information about manner of articulation is much more important than information of place of articulation (1). It has been shown that this is also the case for Swedish (12) and it is probably a general rule for any language.

In fricatives and stops the information about manner of articulation is transmitted by the duration and timing of noise (the frequency spectrum being unimportant) whereas the place of articulation is related to the frequency spectrum of the noise and formant transitions. If this is true a normal hearing subject listening to speech processed by the device of Fig. III-A-1 followed by a low-pass filter with a cutoff frequency below 1000 c/s will receive sufficient information about manner of articulation just by hearing the transposed noise of the high-frequency consonants. This will increase his means of message reception even if he has no training whatsoever on the device in question. A further increase can of course be expected after training.

Experiment

To test this hypothesis an experiment was designed, mainly to get preliminary information. As experiment equipment a device of the type shown in Fig. III-A-1 was used but to decrease
the influence of the transposition on high-frequency formant in
front vowels a voiced-unvoiced detector was included that switched
off the transposing channel for low-frequency sounds. The action
time for this device was around 20 msec. It is doubtful if this
voiced-unvoiced detector can be included in a hearing aid as it
tends to be very sensitive to low-frequency noise in the room.

The speech material consisted of syllables \([sa, qa, 
\text{\&}a, fa, ha, ta, pa, ka, spa, sta, sk\)] and phonetically balanced
monosyllabic words. The clusters sp- st- sk- were included to
provide unaspirated stops which should be difficult to identify
when the speech is low-pass filtered. They are also very common
in Swedish\(^3\).

The syllables were arranged in lists where each syllable was repeated five times in a random order. Five syllable lists and five PB word lists were read by a male talker in an anechoic room using a Erdel & Kjær condenser microphone and were re-
corded on an Ampex type-recorder. Each list of syllables was
started with fifteen syllables for training purpose.

From this recording two series of test lists were pre-
pared by playing the tape through the transposing equipment and
then through a low-pass filter. In one set of five lists the level
control in the transposing channel was set to zero and the low-pass
filter cutoff frequency was 500, 750, 1000, 1500, and 2000 c/s.
In the other set of five lists the level control was set to give
about the same level on the transposed fricative sounds as for the
vowels. The same cutoff frequencies were used. The filter had a
damping of about 120 dB/oct. White noise was added to give a
signal-to-noise ratio of 20 dB.

* A brief analysis of 2 pages of Swedish prose gave the following
number of occurrence:

| [s] surrounded by low-frequency speech sounds | 88 |
| [qa] | 4 |
| [\&a][\&]\(n\) | 9 |
| [f] | 53 |
| clusters sp- st- sk | 36 |
| other -clusters, 8 different types | 30 |
Two groups of normal hearing subjects then listened to these tapes. Each group consisted of five listeners and all had some experience of listening tests but no training on listening to speech transmitted through a transposing equipment. The listeners heard the signals through TDH 39 headphones in MX-41AR cushions. The syllable test was a forced choice between the syllables used in the test.

Result

The results were analyzed by means of confusion matrices, see Fig. III-A-2. In these confusion matrices the subjects' responses were divided into two parts, correct manner of articulation and correct place of articulation. The phonetically balanced word lists were analyzed with respect to the number of words correctly identified. The results of this analysis for the five cutoff frequencies are given in Fig. III-A-3.

As seen from Fig. III-A-3 the perceived information on place of articulation decreases rapidly as the low-pass cutoff frequency falls below 1.5 kc/s. Information about manner of articulation falls monotonically as the low-pass filter cutoff decreases. The introduction of transposition of high-frequency sounds does not add to the identification of the place of articulation but provides an almost 100% correct identification of the manner feature of the test syllables. The increase of transmitted manner information is associated with an increase in the percent correctly perceived phonetically balanced words as predicted from the model.

Discussion

This experiment is a pilot study for finding out whether a model of speech perception based on separating the information in the acoustic speech signal into two independent parts; place of articulation and manner of articulation, is useful for planning experiments with hearing aids employing transposition of high-frequency parts of the spectrum to lower frequencies. The results of the experiment indicate that the proposed model serves its purpose of explaining the essential gain in performance and can be used in planning further tests with normal hearing and hard
Fig. III-A.2. Confusion matrices for the test with low-pass filter cutoff 750 c/s. Responses within broad line terminated squares are correct in manner of articulation. Responses in cells marked with diagonal lines are correct in place of articulation.
Fig. III-A-3. Results of the test.

- - - - - - only low-pass filtering

transposed high-frequency sound and low-pass filtering
of hearing subjects for evaluating this type of hearing aids.

References:


(3) Johansson, B.: Application for Swedish patent No. 1353, 1955: "Förfarande och anordning för uppköning av överförda information inom begränsade frekvensband" (Method and apparatus for increasing the amount of transmitted information in a limited frequency band).


(12) Weiss, M.: "Undersökning av taluppfattningen vid nedsatt perceptionsförmåga" (Investigation on speech perception by hearing impairment), thesis for fíl.líc. degree at the University of Uppsala (Sweden), 1963.