# A SUPPLEMENTARY TACTILE SPEECH AID TRANSMITTING F0-INFORMATION

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## ABSTRACT

First experiments are reported on a method for electrotactile F0-coding enabling hearing-impaired persons to detect intonation tactually while using a hearing aid. It is suggested that speech perception can be enhanced by simultaneously delivering segmental information by ear and suprasegmental features by skin.

## INTRODUCTION

Within the framework of a TIDE research project on the development of a signal conditioning communication aid for the hearing-impaired [1] it is argued that the selection of the tactile senses as a channel for transmitting suprasegmental features would facilitate the use of residual hearing for the auditory perception of segmental cues.

Early investigations [2] have already shown that frequency differences in a.c.-stimulation can be perceived for frequencies below 200 Hz with just noticeable differences of 1-2 %. Thus, prima facie, electrocutaneous transmission seems to provide one appropriate method for heteromodal presentation of F0-information. But in addition it must be taken into account that identifiability, discriminability and discomfort of electrotactile stimuli are strongly dependent on stimulation methods and electrodes used. Advantages of vibrotactile stimulation have also been discussed [3]. Nevertheless, frequency discrimability is similar for both tactile stimulation modes for low frequencies, and the hardware needs for electrocutaneous stimulators are easier to meet.

## APPARATUS AND SUBJECTS

The electrocutaneous stimulation device SEHR-3 [4] used to carry out the experiments produces bipolar rectangular impulses of variable amplitudes and durations which can freely be arranged in sequences. Impulse sequences are delivered to the skin by pairs of circular gold-layered electrodes (9 mm in diameter each with a center-to-center distance of 10 mm between the electrodes of each pair).

Based on pre-test results single impulses had a duration of 208 µs and amplitude was adjusted by subjects before each test session to a subjectively optimal value in the range of 0.33 to 5 mA. Three subjects participated in Exp. 1, seven in Exp. 2.

## EXPERIMENT 1

### Procedure

To code F0 the method developed by Sparks [5] to construct the apparent movement phenomenon has been adopted. Sparks built patterns of repetitive tactile pulses evoking oscillating movements along a lineal multistimulator array and varied pulse repetition frequency. His results showed that subjects could clearly distinguish successive stimulation (i.e. no apparent movement) at low frequencies, good apparent movement, and partial movement (i.e. a movement perceived along a part of the overall distance between the edge stimulators arranged in line, but of greater subjective strength) at high frequencies. Such a design should be suitable for a tactile transformation of F0 and - if transposed into an appropriate frequency range it also allows marking of out-of-range F0 values by crossing the boundaries of the categories found by Sparks when varying frequencies.

To evaluate the usability of apparent movement for this purpose using the impulse forms and electrode sizes of SEHR-3 two series of electrical pulse sequences were designed. Both series activate adjacent electrode pairs of lineal stimulator matrices successively at constant rate. Series I consists of six pulse sequences with pulse repetition rates of 100, 91, 83, 77, 71, and 67 Hz to cover the transition from partial to good movement. For Series II 43, 37, 32, 29, 26, and 23 Hz were chosen as repetition rates (good to successive movement). Three arrangements of two electrode pairs were used. For each test run, one of these electrode matrices was applied to the dorsal side of the left forearm. The distal electrode pair was placed 2 cm from the wrist, the proximal one 2, 4 or 6 cm apart. Ten repetitions of each pulse sequence were presented in random order. Subjects had to identify whether they sensed successive movement or good apparent movement in one subtest, good or partial in another.

### Results and Discussion

Fig. 1 shows that the three categories given could be identified, but that

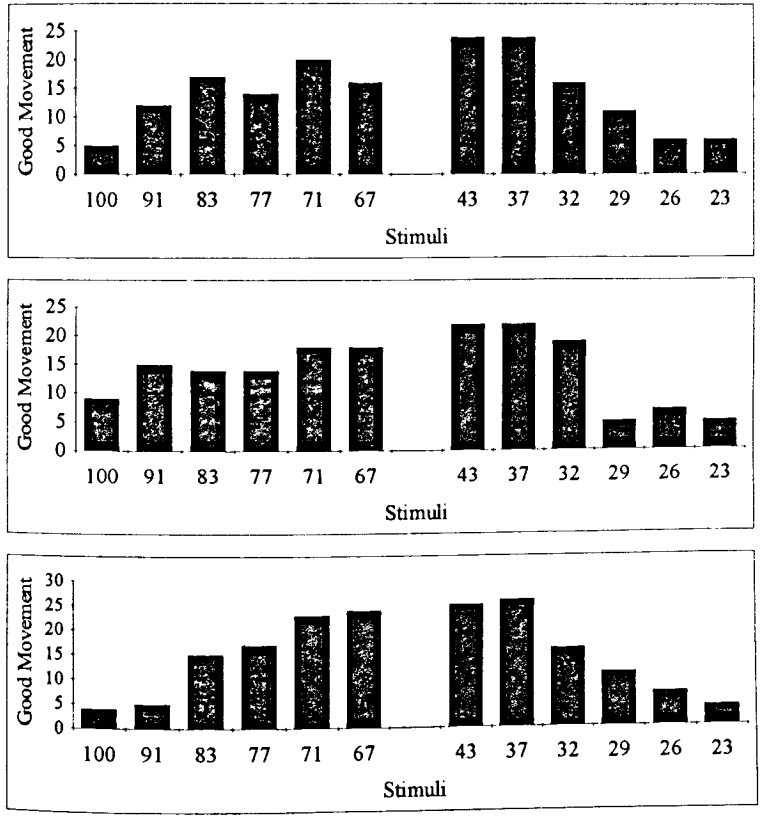


*Figure 1. Results of Experiment 1 (Good apparent movement identification). Distance between electrodes: 2 cm (top), 4 cm (mid), and 6 cm (bottom). Scalings in Hz and absolute answers.*

recognizability was clearest for the largest distance between electrode pairs. As a conclusion from Exp. 1, this electrode arrangement was chosen for tactile F0 presentation, and it was suggested as a working hypothesis that presenting tactile F0 with a fundamental pulse repetition rate equivalent to the half of an average male speech F0 should be expected to yield optimal results.

## EXPERIMENT 2

### Procedure

Exp. 2 was designed to test the identification of frequency rises and falls in tactile impulse sequences. For Exp. 2a two series of stimuli were constructed as in Exp. 1, but impulse repetition rate remained constant only for the first 350 ms of the sequence (50 Hz for Series I and 70 Hz for Series II) and continuously changed during the final 250 ms (target rates for Series I: 30, 40, 60 and 70 Hz, for Series II: 50, 60, 80 and 90 Hz). Both series were tested separately (10 repetitions in randomized order) and subjects were asked to identify positive or negative acceleration in the sequences. For Exp. 2b the overall duration of the stimuli was 500 ms, and instead of the final change, frequency peaks with flat or steep slopes were inserted as visualized in Fig. 2. Again, Series I and II were tested separately, but different slopes were mixed (10 repetitions of 4 peak forms with 50% level stimuli added). Subjects had to answer whether they perceived a frequency rise or not.

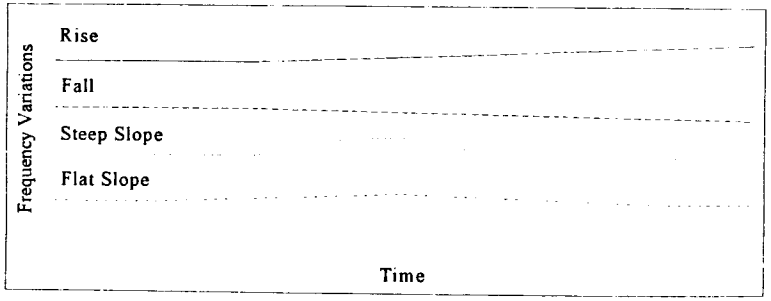


*Figure 2. Stimulus examples for Experiment 2.*

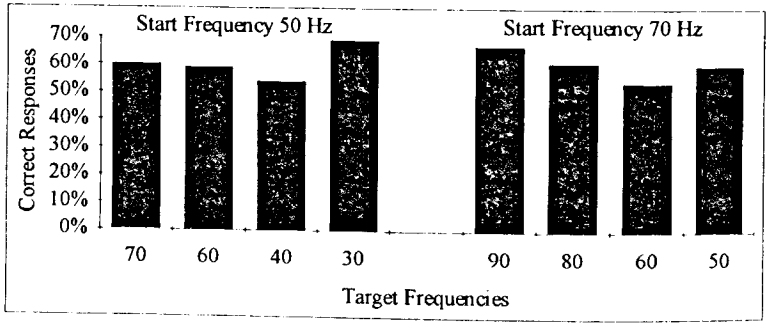


*Figure 3a. Results of Experiment 2a (Identification of Rises and Falls).*

### Results and Discussion

Fig. 3a shows correctly identified rises and falls in Exp. 2a. Greater frequency changes yield better results in either direction. The highest rates are found for the 70-90 Hz rise and the 50-30 Hz fall



which both reach the boundary of the good apparent movement category, but overall recognizability of rises and falls is less than expected.

Fig. 3b, presenting the results of Exp. 2b, reveals one hint to the explanation of these low rates: identification of F0 peaks is similar to the results of Exp. 3a, but also in about 60% of the stimuli with constant F0, frequency changes were perceived.

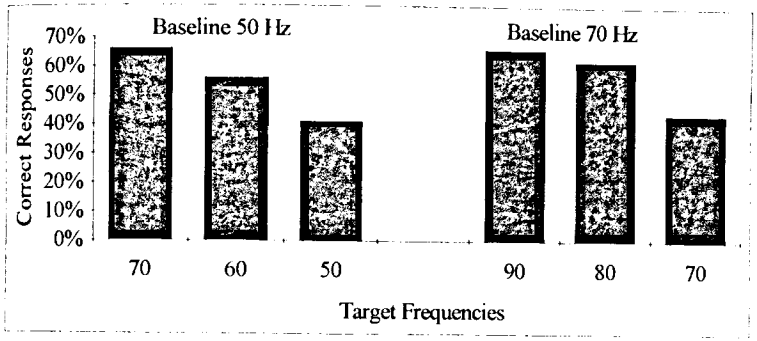


*Figure 3b. Results of Experiment 2b (Identification of Peaks and Levels).*

## GENERAL DISCUSSION

The experiments show that the categorical aspects of the apparent movement phenomenon were clearly recognized, but that a transposition of speech F0 into the good apparent movement range alone is not sufficient to code electrotactile F0. Since subjects often perceive F0 peaks in stimuli with constant frequency, it can be suggested that frequency must decrease over the pattern to ensure the perception of a clearly constant frequency. This would mean that speech F0 declination must be preserved in the transposition method for tactile stimulation and, since the identification of tactile frequency shifts was poorer than expected, F0 variations have to be increased.

## ACKNOWLEDGEMENT

Research was supported by the Commission of the European Communities (TIDE project No. 1090: SICONA).

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