

THE ELECTRO CUTANEOUS STIMULATION SYSTEM "SEHR" AND THE PERCEIVABILITY  
OF TACTILE SYLLABLES

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ABSTRACT

Over the last few years several electrocutaneous stimulation systems have been developed in our institute for conducting experiments intended to lead to the construction of technical aids for the deaf ("speech to skin"). All versions of these systems deliver current-controlled bipolar impulses to the skin. In the first part of our paper a short summary of the software and hardware components of the systems SEHR-1/ SEHR-2 and SEHR-3 will be given. In the second part an overview of general results of identification and discrimination tests will be presented. The third part describes a learning experiment that was conducted to compare experienced and inexperienced subjects.

INTRODUCTION

According to our theory (ref 1) speech perception is based on the recognition of articulatory events. Therefore, as opposed to earlier devices our "System for Electrocutaneous Stimulation SEHR" is planned to have two subcomponents, one dealing with the articulatory information transmitted by the acoustic speech signal, whereas the second has to transfer the reconstructed articulatory event to the skin.

THE SEHR-SYSTEMS

SEHR-2 is an advanced version of the prototype SEHR-1. Both, the SEHR-1 and SEHR-2 stimulation devices, which are controlled by a PDP-11 computer, are 16-channel pulse train generators connected to pairs of circular gilded brass electrodes, the smallest distance between each pair being about 1 mm. At each electroded pair series of current-controlled rectangular pulses variable in their duration (0-500  $\mu$ s) and amplitude (0-5 mA) are produced. The memory and logical control unit (fig. 1) gets its information from the computer interface via optocouplers and generates the duration and amplitude of the impulses. The 16 channels are successively activated in a period which determines the pulse repetition rate. The frequency of this cyclic repetition is manually set to a value between 100 and 500 pulses per second (pps). After every such cycle the memory and logical control unit can accept new data from the computer interface. By editing a stimulus description file we select one or more channels, define the duration of pulse trains, insert the intervals between the pulse trains and determine the number of pulse train repetitions. Since impulse amplitude and impulse duration are responsible for subjective sensation magnitude, they are controlled individually in a calibration procedure preceding each test session.

SEHR-3 is based on a new technical conception (fig. 2). The stimulation device is connected to a PDP-11 by a 4x16-bit parallel interface (DRV11-J). Bipolar rectangular impulses can have durations of the positive and negative rectangles from 32  $\mu$ s to 256  $\mu$ s (in steps of 32  $\mu$ s) and amplitudes from 0.33 mA to about 5 mA. The galvanic separation

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of the channels is guaranteed. Each channel is controlled by its own microprocessor which allows the preprogramming of a great variety of stimulus patterns. As opposed to SEHR-1/2 amplitudes and durations can be specified individually for each single impulse. In the prototype version the microprocessors of the channels are exactly synchronized by a 4- $\mu$ s clock.

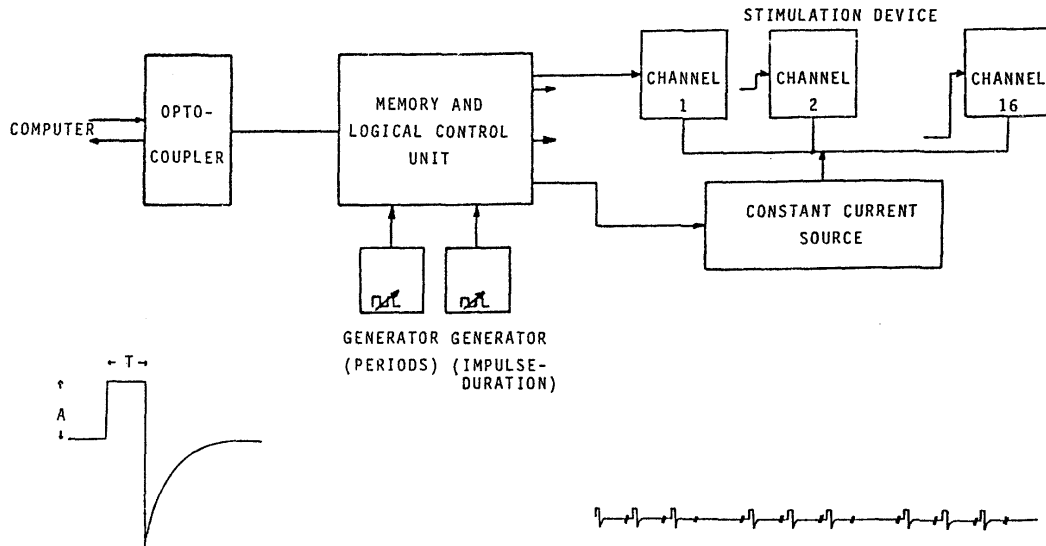


Fig. 1: Block Diagram of SEHR-2 (lower left: Single Impulse,  $A$  Amplitude,  $T$  Duration, lower right: Pulse Train Sequence Consisting of 3 Taps)

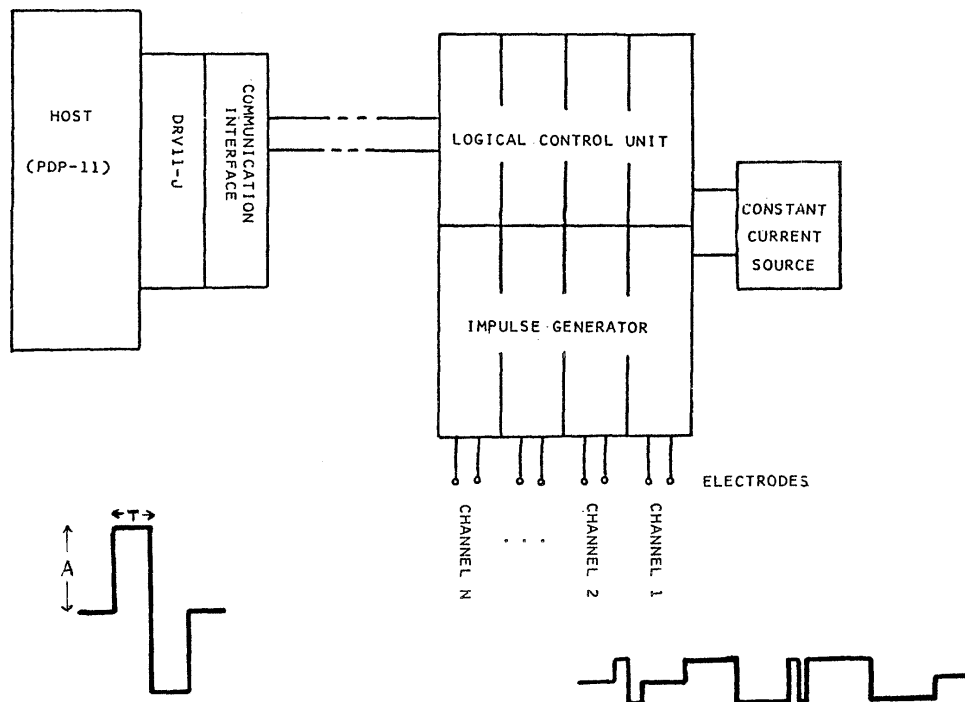


Fig. 2: Block Diagram of SEHR-3 (lower left: Single Impulse,  $A$  Amplitude,  $T$  Duration, lower right: Pulse Train Sequence with Variable Impulse Durations)

## SUMMARY OF EARLIER RESULTS

Our first experiments were devoted to determination of pulse train forms for appropriate stimulation. We found that trains of 3 impulses within the available pps range are perceived as short and distinct taps easily adjustable in calibration procedures to intensity values that yield clearly supraliminal but painless percepts. We decided to choose these taps as the basic elements for generating complex stimulus patterns (ref 2). The central question of establishing categorical perception within the tactile sense was investigated within the next series of experiments (ref 3). Although steep identification boundaries were found along a continuum varying the intertap interval, the discrimination curves did not show the 'predicted' peaks. The discrimination behaviour has been subject to further investigations (ref 4). Nevertheless, the identification results have been sufficient to define intertap interval ranges for producing taps sequences with different perceptual qualities. If a tap sequence is delivered to various electrodes placed linearly along the skin, then according to the phenomenon of tactile saltation (ref 5) there is a strong interference between temporal intertap intervals and the perceived tap localisation: the taps are equidistantly spread to virtual points along the line between the edge electrodes ('rabbit'-phenomenon). In a further series of experiments those results were used to construct an articulation-based system for the tactile coding of isolated (C)V(C)-syllables. The left forearm was selected as the stimulation area where the 16 electrode pairs were placed (figs 3-5).

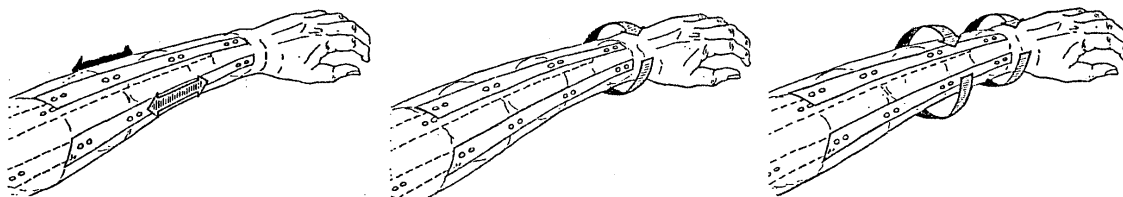


Fig. 3: /ə/-Pattern      Fig. 4: /f/-Pattern      Fig. 5: /s/-Pattern  
(/ʃ/ is constructed like /f/, and /ç/ like /s/. Lenis-Patterns differ from Fortis-patterns only in inter-tap interval values.)

The arrangement allows tap sequences to move along and around the arm, thus mapping consonantal places of articulation as well as vocalic tongue positions. (Front articulations are coded as distal sequences, back articulations as proximal ones, high vowels as dorsal patterns, low vowels as volar ones.) Different manners of articulation are represented by temporal properties of the sequences (so fortis and lenis patterns are distinguished by faster and slower moving sequences). Our experiments showed that the spontaneous identification of tactile vowels was high and better than that of tactile consonants. Learning experiments revealed that the identification of C-patterns approximates the vowel level after a few sessions, whereby the locally coded features were recognized somewhat better than the temporally coded ones (refs 6 and 7).

## EXPERIENCED VS. INEXPERIENCED SUBJECTS

According to the coding criteria tactile syllables representing /fə:/, /sə:/, /ʃə:/, /çə:/, /və:/, /zə:/, /ʒə:/, /jə:/ and their VC-equivalents were constructed. Eight Ss underwent a five-session feedback test procedure. After a short exposition of the inventory at the beginning of each session the Ss had to identify 240 randomized presentations of each tactile CV-syllable. In a sixth session the CV-syllables were

changed to their VC-equivalents. Successive sessions were separated by two or three days. We wanted to know whether and to what extent the significant learning effect of our previous experiments depended on the experience our Ss acquired during a long period of tactile stimulus judging. Therefore, in this experiment two groups of Ss were tested, a control group of four well experienced Ss and a test group of four Ss who had never undergone a tactile experiment before. The results (fig 6) reveal that experienced subjects have a constant advantage in their identification curves, but that both groups show a similar increase in their learning curve for sessions one to five. In session six both groups show a similar decrease when being forced to transfer their knowledge of initial C-features to VC-patterns.

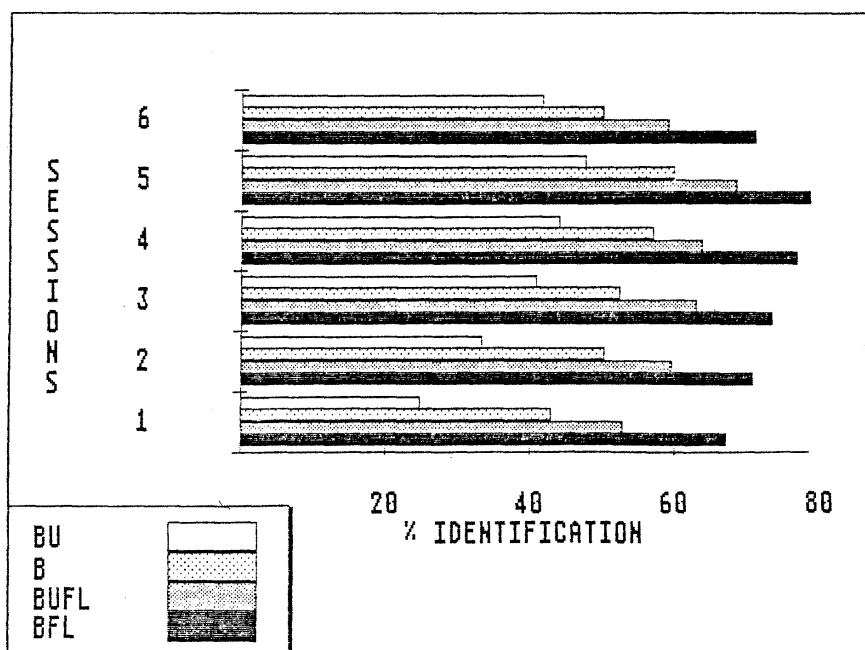


Fig. 6: Results of the Experiment (Mean Identification Rate: B Experienced Ss, BU Unexperienced Ss, Fortis-Lenis Recognition: BFL Experienced Ss, BUFL Unexperienced Ss)

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