ON USING INTENSITY AS A CODING PARAMETER IN TACTILE SPEECH STIMULI
PSYCHOPHYSIOLOGICAL DISCRIMINABILITY EFFECTS

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ABSTRACT
In preparation of a system that uses intensity as a coding parameter for tactile speech this paper reports an investigation of two general psychophysiological effects that show to be involved in intensity perception, namely the order effect and masking.

1. INTRODUCTION
Not only in psychophysiology, but also in application-oriented research establishing electrotactile speech transmission systems for the deaf questions concerning the human ability for tactile intensity perception have an important rate.

In developing an electrocutaneous speech-to-skin communication aid that transmits articulation-based features (13) we assume that a suprasegmental component (stress, intonation) could be added to the feature coding method by superimposing intensity variations on the segmental stimuli (93).

Classical investigations on electrocutaneous intensity perception discuss the number of possible steps that can be discriminated between absolute threshold and pain. Lindner 1937/51 has reported that the pain threshold is reached at approximately 50 times absolute threshold.

A pilot experiment with more complex stimuli using simultaneous pulse train sequences showed that at least two different intensity levels can be identified after a short training period. The present experiment was conducted to gain more knowledge on the discriminability of tactile intensities in complex stimuli. Especially, dependency effects of intensity perception on the temporal and spatial stimulus structure were investigated.

2. APPARATUS
The test stimuli were constructed and presented with the 16-channel System for Electrocuteaneous Stimulation SEHR-2. Four rows of electrode pairs were fixed along the dorsal, ulnar, volar, and radial sides of the S's left forearm. (See [13] for details and illustrations.)

3. STIMULI
Four complex stimuli were constructed with pulse train sequences as their basic parts consisting of three bipolar pulses with a rectangular part in one and hyperbola-shaped part in the other polarity, resulting in a d-c. component equaling 0. The pulse repetition rate was 400 Hz. In stimulus I eight pulse trains were delivered surrounding the arm at four distal electrode pairs with two succeeding pulse trains at each place and a constant interval of 15 ms after each of the eight pulse trains. The pattern started at the ulnar side and proceeded to the dorsal side. Then, without a longitudinal sequence of pulse trains was presented oscillating between the dorsal electrode pair on the dorsal side and the neighboring dorsal electrode pair fixed 4 cm apart in proximal direction. This sequence started at the more proximal place and consisted of eight pulse trains separated by an interval of 20 ms after each pulse train.

In stimulus II the order of the two parts was changed, thus it started with the longitudinal part and ended with the surrounding one. For stimulus III the complete surrounding part of the pattern was presented to the ring of electrode pairs placed 4 cm apart from the distal end in proximal direction. The longitudinal part that followed remained the same as in stimulus II, but started from the distal electrode pair.

In stimulus IV again, the order of the two parts of stimulus III was altered.

According to the feature coding method described in [13] stimuli I to IV are the tactile equivalents of /fi:/, /fi:/, /fi:/, and /fi:/. To determine stimulus intensities each S underwent a calibration procedure before the test. The Ss had to adjust absolute threshold and the threshold of annoyance four times for each place of stimulation in a mixed ascending and descending procedure using the basic parts of the stimuli presented repeatedly and separated by an interval of 50 ms. Nine intensity-distance intensity values were calculated corresponding to the absolute threshold +5%, +10%, +20%, +30%, +40%, +50%, +60%, +70%, +80%, +90% of the difference between both thresholds. Accordingly, seven versions of the five stimuli were defined with the intensities of the rectangular parts of the pulses in the vowel pattern (i.e. the longitudinally moving part) set to the 3rd to 9th intensity value as calculated corresponding to the absolute threshold +10%...+90% of the difference between both thresholds. Accordingly, seven versions of the five stimuli were defined with the intensities of the rectangular parts of the pulses in the vowel pattern (i.e. the longitudinally moving part) set to the 3rd to 9th intensity value as calculated corresponding to the absolute threshold +10%...+90% of the difference between both thresholds.

4. PROCEDURE AND SUBJECTS
Stimuli were arranged in pairs to yield a two-step discrimination test for stimulus intensities. All pairs contained two repetitions of the same stimulus with an interval of 1 s within the pair. Five pairs were built for each stimulus with higher intensities in the second stimulus (intensity values 3-5, 4-6, 5-7, 6-8, 7-9) and the five corresponding pairs with lower intensities in the second stimulus.

In this way a 4x2x5-factorial test design was constructed with 4 stimuli, 2 orderings (ascending and descending intensities) and 5 intensity levels.

One subtest included 10 repetitions of pairs of stimuli I and II (/fi:/, /fi:/) in randomized order, the other subtest of stimuli III and IV (/fi:/, /fi:/) in randomized order. The interval between the pairs was set to 4 s.

Eight Ss participated in the experiment. They received both subtests in different sessions with the order of subtests randomized over Ss. Each subtest was presented in two parts of 100 pairs with a short break in between. Ss were informed that the intensity differences were encoded in the "vocalic part" of the stimuli and had to mark the more intensive stimulus of each pair on an answer sheet.

5. RESULTS
Tab. 1 gives the results of a 4x2x5-factorial MANOVA (SPSS: 163 1975) with stimulus, ordering and intensity level as factors. The overall discriminability was 80.53% and intensity differences were well-recognizable. The MANOVA calculation yielded a significant stimulus effect (p<0.005) and a highly significant level effect (p<0.001). It can be seen from Fig. 1 that discriminability increases with intensity level for the second ascending pair (higher intensity in the second stimulus), but decreases with higher intensity level for descending pairs, thus producing the interaction effect. Concerning the main effect of the factor 'stimulus' a DUNCAN a posteriori test showed significant differences (p<0.05) between /fi:/ and /fi:/, as well as between /fi:/ and /fi:/, /fi:/ and /fi:/, /fi:/ and /fi:/. It showed a slight (p<0.10) tendency effect (Tab. 2).

Table 1 Results of the Statistical Analysis

<table>
<thead>
<tr>
<th>Factor</th>
<th>d.f.</th>
<th>p</th>
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</tr>
<tr>
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<td>0.09</td>
</tr>
<tr>
<td>LEVEL</td>
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<td>2.44</td>
</tr>
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<td>IT'S IE</td>
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</table>
could be explained under the assumption of forward masking. Since according to the earlier investigations there is a tendency to forward masking and since the intensity variations to be discriminated in the present experiment are encoded into the "vocalic" part of the stimuli, intensities of VC-stimuli should be more easily discriminated. The poor recognition of /fi/ could well be explained if /fi/ had a stronger masking effect than /fi/ or /fi/ itself. For such an explanation the central representations of the stimuli instead of their peripheral characteristics have to be taken into account. Within the frame of this experiment only a first speculative approach to such an explanation can be proposed: The basic units of the stimuli (pulse trains) were identical in all cases, but they differed in their temporal and spatial relations. Because of the somato-topical representation of body sites the spatial relations should be preserved in building the central representation. But since more distant and more proximal places were stimulated in the "consonantal" (circumferential) parts of the stimuli, the conduction velocity of the C-fibres may become relevant to determine the central temporal relations. In CV-stimuli the interval between the last pulse train of /fi/ or /fi/ and the first of /fi/ is 15 ms. The distance between the corresponding places of stimulation is 4 cm, but in /fi/ the place changes in proximal, in /fi/ in distal direction when proceeding from the "consonantal" to the "vocalic" part. Relying on the values given in the literature (2,33) conduction velocity in thick myelinated fibres is between 40 and more than 100 m/s, i.e., even with 40 m/s a distance of 4 cm in the distal—proximal direction produces a change of the temporal intervals of only 1 ms which is too small to cause an effect as observed. But if — as can be supposed — a part of the central representation of the stimulus is based on information processed via thin unmyelinated C-fibres with a conduction velocity of no more than 2.55 m/s the temporal intervals at the points of central occurrence of two successive pulse trains at places 4 cm apart from one another differ from the peripheral interval by at least 15.7 ms. Thus, in /fi/ with /fi/ being presented at more proximal places the inter—pulse—train interval is centrally doubled (15 ms + 15.7 ms = 30.7 ms), and the interval to starting at the distal places it is reduced to approximately 0 (15 ms - 15.7 ms = -0.7 ms). Based on this speculative assumption one could explain (CV—stimuli): (i) /fi/ and /fi/ cannot cause forward masking, since the vocalic part is presented first (81.00% and 83.88% correct discrimination). (ii) /fi/ produces a forward masking effect, since the central representation of /fi/ is built up before the representation of /fi/ is started (thus, only 75.75% correct answers). (iii) For /fi/, the representation of both parts are not separate, but as the central point of occurrence of the last pulse train of /fi/ is identical with that of the first in /fi/ the whole stimulus elicits a unique, more complex representation which is not affected by forward masking (81.49% correct answers).

To summarize, the stimulus effect can be explained in terms of central temporal characteristics if C-fibre conduction contributes to the representation of the stimuli used and if forward, but not simultaneous masking is involved in a perceptual process that separates the longitudinal and circumferential parts of the pattern. To evaluate this proposal, more specific electro- or psychophysiological experiments are mandatory.

7. REFERENCES