On the Possibility of Tactile Categorical Perception

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1. Introduction

If trials to develop devices enabling cutaneous transmission of speech have failed so far, the reason could well be that no adequate method has been found to transfer information via the skin with a velocity comparable to the values known for the auditory mode (e.g. Kirman, 1973). Furthermore, to evaluate the general possibilities for tactile transmission of speech it is necessary to compare the psychological phenomena underlying tactile perception with compatible effects in auditory speech processing. Since one of the most important effects discussed in this connection is 'Categorical Perception' (e.g. Repp, 1982) a series of tests was carried out to determine the possibility of establishing tactile phenomenal categories that also fulfil the conditions for categorical perception.

2. Stimuli and Procedure

The stimuli were constructed, produced, and presented under computer control (PDP 11/50) with the system SEHR-1 for electrocutaneous stimulation, consisting of two hardware and two software components: a 16-channel stimulus generation device producing current-controlled a.c.-impulses of the form in Fig. 1 (the impulse frequency is variable along the physiologically important range from 100 to 500 Hz), an interface to the computer, a MACRO-library for controlling the interface, and a FORTRAN-library for producting and presenting the test stimuli (Tillmann and Piroth, 1983).

Our test sequences were based on the 'rabbit phenomenon' (Geldard and Sherrick, 1972), which in its standard version is elicited when m tactile taps are presented with a constant temporal interval Δt to each of n equidistantly and linearly ordered loci. Each single tap was stimulated by three impulses repeated at a rate of 5 ms (cf. Fig. 1). Rabbit sequences with 9 taps at three different loci were used. The temporal interval separating the taps was varied to obtain two continua, each consisting of 8 stimuli. The intertap interval varied from sequence to sequence in steps of 20 ms. In continuum I a range from 5 to 145 ms was chosen, to enclose also intervals too short to be perceived as isolated taps, but eliciting the apparent movement phenomenon (Sherrick and Rogers, 1966). In continuum II the intertap interval varied

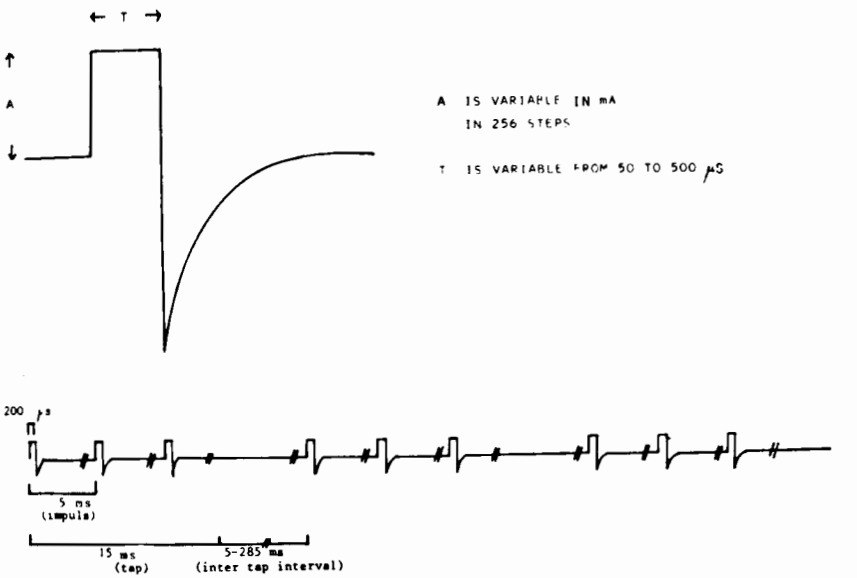

Fig. 1. Form of the stimuli used.

from 145 to 285 ms, to cover the point where the rabbit phenomenon breaks down and single taps at the veridical loci are perceived. As single rabbits could be discriminated by the parameter of total length, two different stimulus forms have been tested. In the first case the overall duration of each sequence was held constant: the stimuli were repeated for 3.6 s in continuum I and for approximately 6.4 s in continuum II. In this case the end locus of the stimulus sequence could not be held constant. Therefore a second stimulus form was realized by shortening the sequences to the amount necessary to make each sequence end at the same locus as it started at. 3 members and 1 student of the institute participated in the experiments, only 3 had previous experience of electrocutaneous stimuli. The stimuli were presented via a matrix containing 3 pairs of circular gilded brass electrodes, 9 mm in diameter each. The smallest distance between the two electrodes of a pair was 1 mm. The three electrode pairs were arranged linearly in such a way that the distance from the mid locus to each of the edge loci was 6 cm. The matrix was applied on the dorsal part of the left forearm, the distal electrode pair being placed about 3 cm from the wrist.

As there is an interference between stimulus intensity and the parameters that constitute the rabbit phenomenon - temporal interval and distance between loci – (Cholewiak, 1976), each test was preceded by a calibration procedure with the distal electrode as reference point. After the absolute threshold and the threshold of annoyance had been determined the intensity of the referent stimulus was set to the absolute threshold plus 60% of the difference to the threshold of annoyance. Then the subjects received the reference stimulus in alternation with one of the two proximal stimuli in

order to match the magnitude at these skin loci to that of the reference locus. It should be noted that the calibration was done with the taps used in the experiment that followed immediately. The stimuli described above were presented (in randomized order) in an identification test with an interstimulus interval of 5 s, in a one-step discrimination test with an interstimulus interval of 5 s between the pairs, and (in several cases) in a two-step discrimination test under the same conditions. In all tests each stimulus appeared three times.

In the case of identification the subjects were instructed to identify one of four categories: (i) 'continuous movement' (no single taps are perceived), (ii) 'rhythmically structured rabbit' (taps are perceived at more than 3 loci between the edge stimuli in a sequence having an intrinsic rhythmic structure), (iii) 'constant rabbit' (taps are perceived at more than 3 loci but separated by equal intervals and distances), (iv) 'single taps' (more than 1 tap is perceived at the same locus and only 3 loci are perceived at all). Additionally, the subjects were informed that not all of the categories had to appear in the same test. Before the test was executed, the stimuli were presented once in randomized order. The complete series of tests was carried out first using continuum I and then continuum II.

3. Results and Discussion

Fig. 2 and Fig. 3 show the results of identification for continua I and II and the respective one-step discrimination results. Both stimulus forms (constant duration vs. constant starting and ending points) are mixed in order to prohibit a significant evaluation according to those critical parameters. Fig. 4 and Fig. 5 show the same identification values, but categories (ii) and (iii)

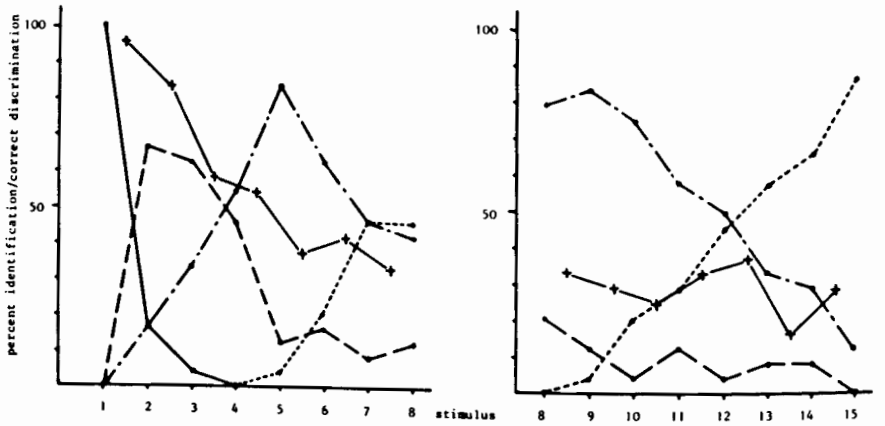

Fig. 2. Results for continuum I; ——: category (i), — —: category (ii), — · —: category (iii), ---: category (iv); *——* discrimination.

Fig. 3. Results for continuum II.

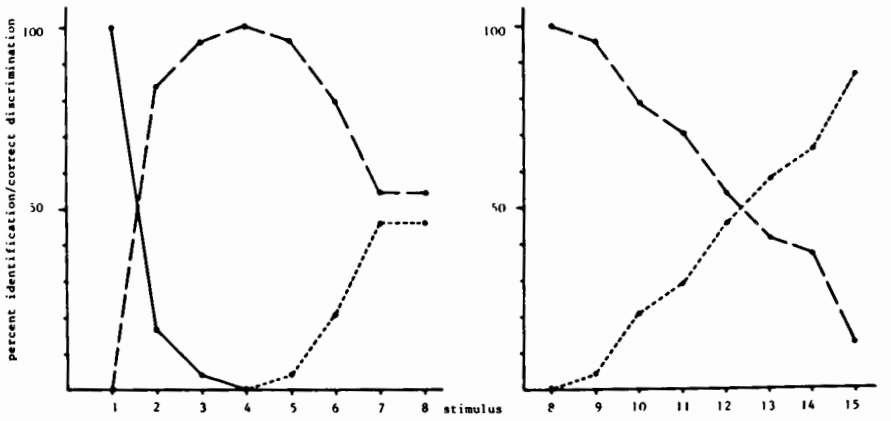

Fig. 4. Results for continuum I; ——: category (i) — —: categories (ii) and (iii), ---: category (iv).

Fig. 5. Results for continuum II.

are added together to form one category 'rabbit.' Only the category switch from 'apparent movement' to 'rabbit' at stimulus 1.66 (corresponding to an interval of 18.33 ms) shows steep boundaries with an adequate discrimination peak (95.83%). Discrimination decays continuously and reaches chance without being increased at category switches. Even two-step discrimination was not significantly better and is therefore omitted from the results. Concerning stimulus 8 which was part both of continuum I and II an important uncertainty is revealed. Whereas in continuum I categories (iii) and (iv) reach approximately 50%, category (iii) has a starting value of 79.17% in continuum II, and even category (ii) is present at chance level throughout the continuum. The most general conclusion to be drawn from the results is that the responses (i) - (iv) accumulate in certain sections of the continuum. A natural case of categorical perception only exists between 'apparent movement' and 'rabbits.' The identification of rhythmically structured and constant rabbits is much poorer. On the other hand, this additional category switch (cf. Fig. 2) could be established without any training phase simply by once exposing the subjects to the stimuli and by giving a phenomenal description of the categories. A 100% peak, of course, can only be reached if both categories are taken together (Figs. 4 and 5). In the context of the two continua, stimulus 8 is judged quite differently. This indicates relative uncertainty in category assignment which could probably be reduced by a learning phase: after having been presented in continuum I, stimulus 8 received 100% identification in continuum II. Slow taps show a much less clear category switch and therefore seem to be less adequate for the establishment of categorical perception.

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