Measurements on Pacinian corpuscles in the fingertip

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Introduction

A detailed understanding of tactile perception is important to the investigation of multimodal human interaction with real or virtual environments. In this study the distribution of Pacinian corpuscles in the human index fingertip was investigated using high-resolution magnetic-resonance imaging (MRI). Further experiments measured the variation over the index fingertip of the vibrotactile threshold at 250 Hz. The hypothesis was that the threshold would be lower in regions where the density of Pacinian corpuscles is higher.

There have been few previous studies of the number and distribution of Pacinian corpuscles in the fingers. In a cadaver study on elderly specimens (69-89 years old), Stark *et al.* (1998) observed 10-20 corpuscles in each fingertip, generally clustered round the digital nerves. It is probable (Cauna, 1965) that the number of corpuscles in the fingertip decreases with age, and it may be conjectured that young adults have 25-50 corpuscles in each fingertip.

Data are available for vibrotactile threshold as a function of frequency at various body sites, for example, the thenar eminence on the palm of the hand (Bolanowski *et al.*, 1988) and the distal pad of the fingertip (Verrillo, 1971). For vibration frequencies in the range 200-300 Hz, tactile thresholds at most body sites are determined by the Pacinian response. In general, it appears that vibrotactile thresholds are higher for areas with lower densities of mechano-receptors, such as the torso or forearm, and lower for areas with higher densities of receptors, such as the fingertip and palm. It may be hypothesised that this relation should be valid when comparing localised stimulation sites within a single fingertip. However, the literature for comparison of sites within the hand is limited (Löfvenberg and Johansson, 1984).

MRI investigation

Images of the index fingertip were acquired from two subjects, ages 22 and 24 years. Imaging was performed with a Philips whole-body imager at 1.5 T. A fat-suppression MRI technique was used to produce 3D data sets with a slice thickness of 140 μm and an in-plane resolution of 140 μm × 140 μm. The data sets were examined manually to identify structures with the ovoid shape of a Pacinian corpuscle and of appropriate size (i.e., major-axis length ~ 1 mm). Figure 1 shows 2D projections of the locations of the identified objects – 32 for subject A and 30 for subject B. The range of major-axis lengths was 0.7 – 1.3 mm for subject A and 0.7 – 1.8 mm for subject B; the range of minor-axis lengths was 0.2 – 0.7 mm for subject A and 0.4 – 0.7 mm for subject B. Figure 1 shows that the objects identified as Pacinian

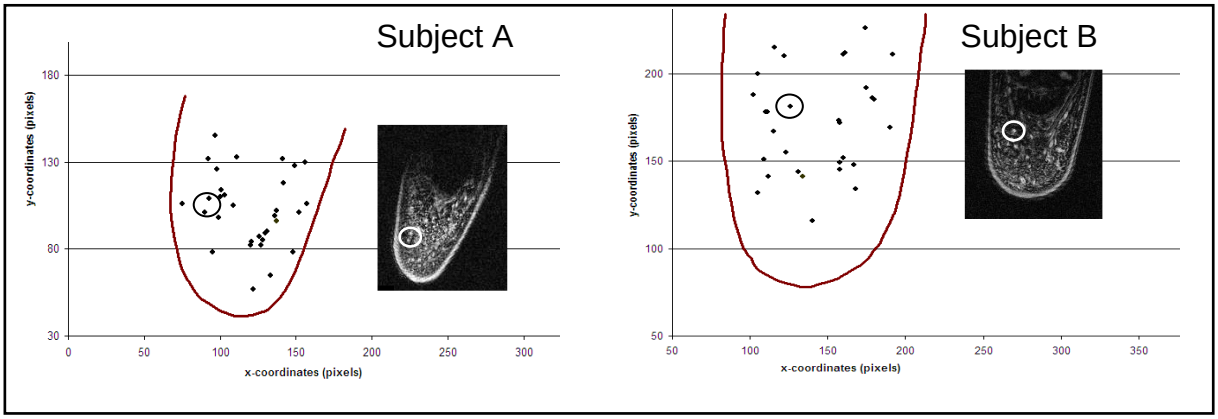

Figure 1. Identified locations within the right index distal phalange of the two subjects. The U-shaped lines indicate the outlines of the fingers at their widest points. The insets are single slices from the 3D MRI data sets, with corresponding features circled.

corpuscles are clustered off the midline of the fingertip, in close proximity to the expected locations of the digital nerves, matching the distributions described by Stark *et al*. (1998).

Psychophysics investigation

Further experimentation was undertaken using a purpose-built vibrotactile stimulator [Figure 2(a)] to measure the detection threshold at two positions on the right index fingertip: in the centre of the fingerpad and towards the side (displaced from the midline by 7.0 mm). Vibratory stimulation was at 250 Hz and detection of stimuli was investigated over a range of displacement amplitudes (i.e., using the method of fixed stimuli for threshold determination). Figure 2(b) shows psychometric curves (mean data over each stimulation site) for 14 young-

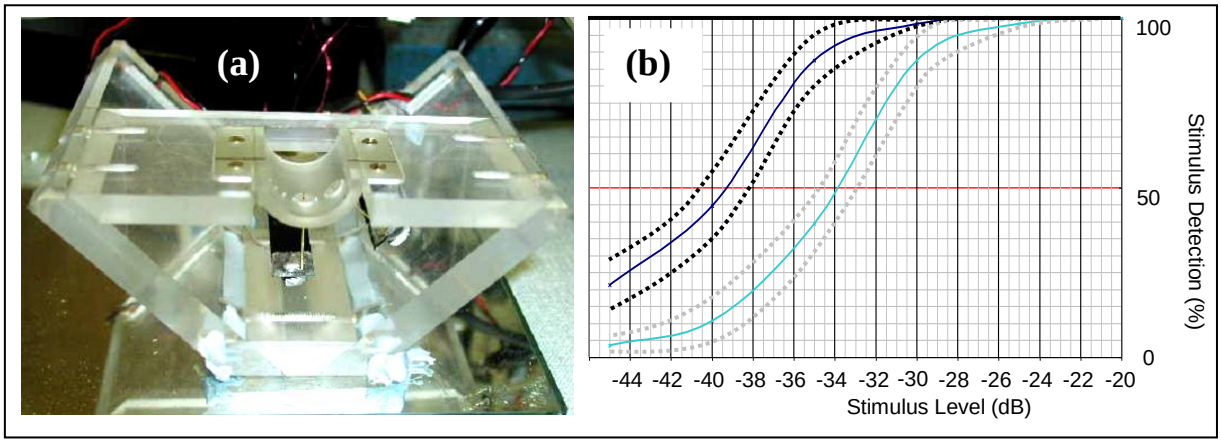

Figure 2. (a) The vibrotactile stimulator, showing the curved surface on which the finger rests and the two stimulation sites within this surface; (b) psychometric curves – the full dark-blue line shows mean data from the side of the finger and the full light-blue line shows mean data from the centre of the finger pad. The dotted lines indicate the ranges of standard error.

adult subjects. The difference in threshold (defined as 50% detection rate) between the two sites was determined to be (5.4 ± 1.8) dB. The threshold at the side of the finger was ~ 1.0 μm and the threshold at the midline was ~ 2.0 μm.

Conclusions

The MRI results indicate a non-uniform distribution of Pacinian receptors in the fingertip, with a lower density towards the centre of the fingerpad than toward the sides. The psychophysics results indicate a non-uniform vibrotactile sensitivity over the fingertip, with a higher threshold on the midline and a lower threshold toward the side. This lends support to the hypothesis that higher receptor density is associated with lower threshold, and *vice versa*.

Acknowledgement

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References

Bolanowski, S.J., Gescheider, G.A., Verrillo, R.T., Checkowsky, C.M. (1988). Four channels mediate the mechanical aspect of the sense of touch. J. Acoust. Soc. Am., 84, 1680–1694.

Cauna, N. (1965). The effects of aging on the receptor organs of the human dermis. In: Montagna, W. (Ed.). Advances in biology of skin, - aging, pp. 63-96. Pergamon, Oxford.

Löfvenberg, J., Johansson, R.S. (1984). Regional differences and interindividual variablity in sensitivity to vibration in the glabrous skin of the human hand. Brain Research, 301, 65-72.

Stark, B., Carlstedt, T., Hallin, R.G., Risling, M. (1998). Distribution of human Pacinian corpuscles in the hand. A cadaver study. J. Hand Surg. [Br.], 23, 370-372.

Verrillo, R.T. (1971). Vibrotactile thresholds at the finger. Percept. Psychophys., 9, 329–330.

Appendix (not in published paper): End view of finger to show distribution in third dimension