Perception, 2015, volume 44, pages 219–221

doi:10.1068/p7910

SHORT AND SWEET

A new illusion at your elbow

Peter Brugger, Rebekka Meier
Neuropsychology Unit, Department of Neurology, University Hospital Zurich,
Frauenklinikstrasse 26, 8091 Zurich, Switzerland; e-mail: peter.brugger@usz.ch
Received 10 November 2014, in revised form 3 February 2015

Abstract. On experiencing distal-proximal tactile motion on the volar side of the forearm starting at the wrist, subjects significantly anticipate touch of the elbow crook. This illusion, popular as a children's game, was quantified in ninety participants (forty-seven women) on both arms. As a top-down explanation of the illusion, we discuss a model of Bayesian inferences. As a bottom-up contribution, we consider afterdischarges of cortical neurons, which receive input from skin mechanoreceptors specifically driven by slow-motion tactile stimuli. Like previously described illusions, the elbow crook illusion is larger on the nondominant arm. Women showed a smaller illusion than men, giving testimony to their reportedly superior cutaneous sensitivity.

Keywords: cutaneous illusion, neurophysiology, children's game

Among the manifold illusions of the cutaneous sense (Lederman & Jones, 2011), some are not readily amenable to playful experimentation as they require substantial technical equipment (Hayward, 2008). One exception is a game Swiss children typically enjoy in playgrounds. They stimulate the inner side of a friend's forearm by slowly moving a finger from the wrist towards the crook of the elbow. Eyes closed, the friend has to shout "stop!" on feeling the crook being reached. On opening the eyes, there is much amazement about an anticipation error, frequently in the order of several centimetres. We investigated the crook-of-the-elbow illusion under controlled conditions (figure 1) and speculate about its potential origin on psychological and physiological levels.

Our measurements confirm a powerful and robust illusory anticipation of touch at the elbow crook when the tactile stimulus is slowly moved in a proximal direction starting at the wrist. In other words, the track on the skin appears subjectively enlarged. This is in contrast to most previously described cutaneous motion illusions that consist of a subjective length *contraction*. These have been accounted for by a model of Bayesian inference (Goldreich, 2007), which views the most probable cutaneous percept as "a compromise between imprecise sensorineural information and the observer's expectation of slow movement" (page 2), arguing that, under natural circumstances, object motion on the skin is slow. In the case of movements faster than those encountered in natural scenarios, as applied in many laboratory situations, Bayesian slow-motion priors would be violated and thus give rise to an illusory length contraction. The cutaneous motion illusion studied here occurs in response to a stimulation velocity at or even below the velocities typically experienced in everyday life (eg during caressing movements or the crawling of an insect). Hence, if violated at all, a participant's expectations of the speed of a tactile motion would lead them to experience an *enlarged* track on the skin. Such a top-down effect would be compatible with the anticipation error our subjects reported. On the neurophysiological level, we might consider the characteristics of skin mechanoreceptors and their (sub)cortical projection areas. C and Aδ fibers innervating mechanoreceptors are prominently driven by slow-moving (< 5 cm s^{-1}) stimuli, and the corresponding neurons in S1 are known for their exceptionally long afterdischarges (McKenna, Light, & Whitsel, 1984; Whitsel et al., 1986).

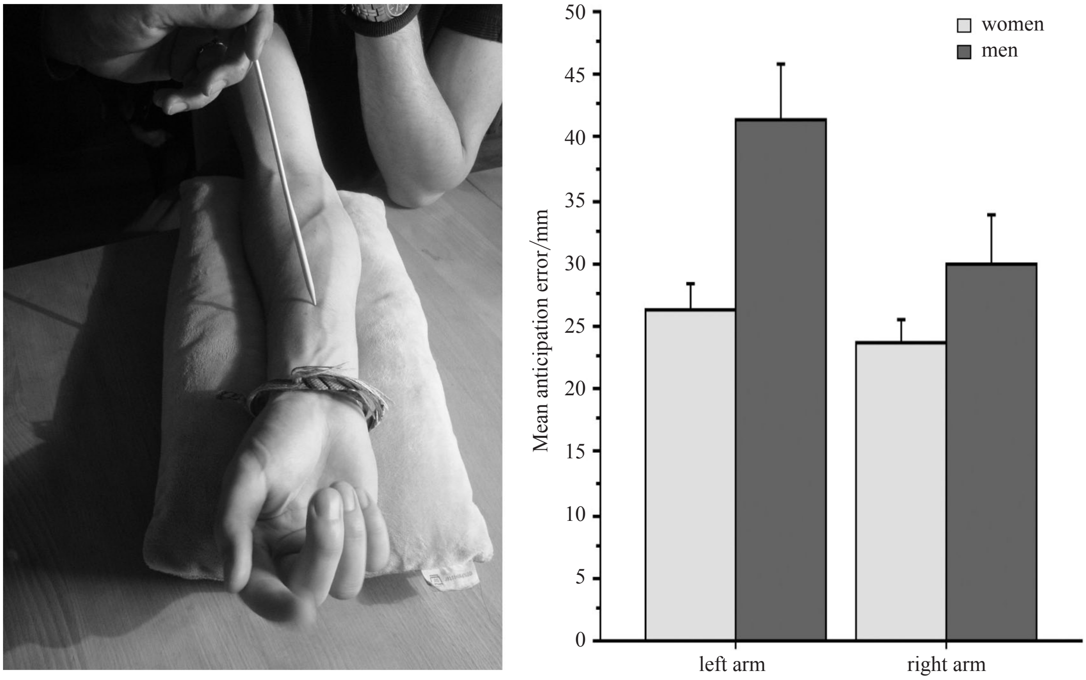

Figure 1. (a) The participant's arm was stretched out and stimulated on the volar side with a blunt stylus moving from the wrist towards the elbow's crook. A constant speed of ~2–3 cm s^{-1} had been practiced beforehand, and the constant soft pressure was determined by the stylus' weight (5 g). Skin stretching was carefully avoided. Eyes closed, the participant had to indicate verbally once touch was experienced in the crook. The deviation, measured to the nearest millimeter, could not be observed by the participant. (b) Forty-seven women and forty-three men gave written informed consent to participate in the experiment, approved by the ethics committee of the University of Basel. They were all right-handed and of comparable age (mean = 41.9 years, SD = 16.4 years). Participants were tested on both left and right arm (counterbalanced order). Overall, the anticipation error was significant (mean = 3.0 cm, SD = 2.2 cm; $t = 14.1$, df = 89, $p < 0.0001$). ANOVA revealed a main effect of sex ($F_{1,\,88} = 6.7$, p = 0.011) and arm ($F_{1,\,88} = 11.0$, $p = 0.001$). Women showed a smaller error than men, and the illusion was larger on the left than the right forearm. The interaction also reached significance ($F_{1,\,88} = 4.3$, $p = 0.042$), the arm difference being larger in men than in women. Fifty-eight of the participants (thirty-one women) were also tested in a proximal-distal direction and indicated when the moving stimulus approaching from the elbow crook seemed to have reached the wrist. The illusory anticipation of the wrist (mean = 1.4 cm, SD = 1.0 cm) was significantly smaller than that on the elbow ($t = 5.8$, df = 57, $p < 0.0001$; data not shown).

These afterdischarges were made responsible for the subjective enlargement of cutaneous motion tracks applied at velocities below 5 cm s^{-1} (Whitsel et al., 1986). These authors had their subjects indicate the offset point of a tactile motion on the dorsal aspect of the forearm and found a subjective overshooting at velocities below 5 cm s^{-1}, but an increasing undershooting with increasing stimulation velocities (between 25 cm s^{-1} and 250 cm s^{-1}). The displacement of the endpoint of a slow-motion track on the skin in the direction of movement may be equivalent to the error of anticipating a body landmark in the case of a continuing motion. The likely contributions of higher-order somatosensory areas including, for instance, area MT await to be investigated by functional neuroimaging.

The fact that, in the subset of participants stimulated in a proximal-distal direction, the anticipation error was only small may be accounted for by a proximal-distal gradient of increasing tactile sensitivity (Weinstein, 1968) and a locognosic acuity which is especially pronounced around the wrist (Cody, Garside, Lloyd, & Poliakoff, 2008). The observation that men showed a stronger illusion than women corroborates previous findings of a better cutaneous sensitivity in female compared with male participants (Chen et al., 1995; Peters, Hackeman, & Goldreich, 2009; Weinstein, 1968). The laterality effect—that is, the larger illusory anticipation on the *left* forearm—was unexpected, as for stationary stimuli no marked side differences in tactile sensitivity are apparent (Weinstein, 1968). It is in line, however, with a stronger multisensory (visual–tactile–proprioceptive) illusion on the nondominant compared with the dominant hand after dynamic tactile stimulation (slow-motion brushing; Ocklenburg, Ruther, Peterburs, Pinnow, & Gunturkun, 2011). The more pronounced arm differences in men compared with women may reflect their stronger functional cerebral hemispheric laterality (McGlone, 1980) and the absence of modulating effects of the menstrual cycle (Hausmann, 2005).

Explaining the mechanisms of an illusion should never aim at diminishing our amazement on experiencing it. In this sense, the surprise by the little playground game investigated here will hopefully remain at your elbow.

Acknowledgments. We thank Daniel Goldreich and Gregory Essick for helpful discussions and advice.

References

Chenn C. C., Essick, G. K., Kelly, D. G., Young, M. G., Nestor, J. M., & Masse, B. (1995). Gender-, side- and site-dependent variations in human perioral spatial resolution. *Archives of Oral Biology*, **40**, 539–548.

Cody, F. W., Garside, R. A., Lloyd, D., & Poliakoff, E. (2008). Tactile spatial acuity varies with site and axis on the human upper limb. *Neuroscience Letters*, **433**, 103–108.

Goldreich, D. (2007). A Bayesian perceptual model replicates the cutaneous rabbit and other tactile spatiotemporal illusions. *PLoS ONE*, **2**(3): e333.

Hausmann, M. (2005). Hemispheric asymmetry in spatial attention across the menstrual cycle. *Neuropsychologia*, **43**, 1559–1567.

Hayward, V. (2008). A brief taxonomy of tactile illusions and demonstrations that can be done in a hardware store. *Brain Research Bulletin*, **75**, 742–752.

Lederman, S. J., & Jones, L. A. (2011). Tactile and haptic illusions. *IEEE Transactions on Haptics*, **4**, 273–294.

McGlone, J. (1980). Sex differences in human brain asymmetry: A critical survey. *Behavioral and Brain Sciences*, **3**, 215–227.

McKenna, T. M., Light, A. R., & Whitsel, B. L. (1984). Neurons with unusual response and receptive-field properties in upper laminae of cat SI cortex. *Journal of Neurophysiology*, **51**, 1055–1076.

Ocklenburg, S., Ruther, N., Peterburs, J., Pinnow, M., & Gunturkun, O. (2011). Laterality in the rubber hand illusion. *Laterality*, **16**, 174–167.

Peters, R. M., Hackeman, E., & Goldreich, D. (2009). Diminutive digits discern delicate details: Fingertip size and the sex difference in tactile spatial acuity. *Journal of Neuroscience*, **29**, 15756–15761.

Weinstein, S. (1968). Intensive and extensive aspects of tactile sensitivity as a function of body part, sex, and laterality. In D. R. Kenshalo (Ed.), *The skin senses* (pp. 195–222). Springfield, IL: Charles C Thomas.

Whitsel, B. L., Franzen, O., Dreyer, D. A., Hollins, M., Young, M., Essick, G. K., & Wong, C. (1986). Dependence of subjective traverse length on velocity of moving tactile stimuli. *Somatosensory Research*, **3**, 185–196.