Effects of spatial factors on tactile roughness perception
—A study based on signal detection theory—

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Our previous studies demonstrated that spatial factors, such as finger position (hand posture) and distance from the stimulated finger to the head modulate tactile roughness perception. Herein we investigate whether spatial factors influence the sensitivity or response bias of tactile roughness discrimination using signal detection techniques. Participants were asked to discriminate the roughness of two-sided stimuli between two fingers in a variety of postures. When the stimuli were presented close to the head, the discrimination sensitivity for the finger located on the back surface of the stimuli was lower than that for the finger on the front surface. Furthermore, judgments by the finger on the back-side were biased toward the same direction as the roughness of the front surface regardless of the distance of the hand from the head. These results indicate that spatial factors differently modulate the sensitivity and the response bias of roughness discrimination.

**Key words:** touch, roughness discrimination, peri-head space, sensitivity, response bias

Our previous study found that when participants were asked to discriminate the roughness of one side of a two-sided abrasive paper pinched with the thumb and index finger, the discrimination ability was impaired especially when the distractor was the inside relative to the head rather than the outside of the two sides of stimuli (Kakizaki, Suzuki, & Gyoba, 2011). In addition, this effect was observed only when the hand was located in the peri-head space. Herein we aim to clarify whether spatial factors modulate the sensitivity or response bias of tactile roughness discrimination using signal detection analysis. We conducted two experiments in which the stimulus signal was rougher or smoother than the noise signal.

**Methods**

**Participants** Twelve graduate and undergraduate students participated both in Experiment 1 and Experiment 2.

**Stimuli** Each stimulus was a thick paper (3 × 9 cm) with abrasive paper (3 × 6 cm) attached to both sides. The grit values of the abrasive papers were #4000 (average particle size of 3 μm: smoother stimulus) and #1200 (12 μm: rougher stimulus). The smoother (rougher) stimulus was regarded as the signal (noise) in Experiment 1 and vice versa in Experiment 2.

The distractor stimulus was the same (noise) throughout the experiment. The target stimulus was either the signal in the SN condition or the noise in the NN condition (Fig. 1A).

**Procedure** Participants sat on a chair and placed their chins on the chin-rest. They were blindfolded by eye-masks and wore headphones through which white noise (55 dB) was delivered during the experiment. They pinched a two-sided stimulus with their right thumb and opposing index finger. Their fingertips pointed toward the left. The stimuli were moved 6 cm toward their fingertips by an experimenter at a speed of approximately 4 cm/s.

Stimuli were presented near or far from the head (12 cm or 50 cm in front of the base of the participant's nose, Fig. 1B). The participants were randomly divided into two groups with respect to the side of the target stimulus that was assigned to the index finger or thumb. Accordingly, the participants in one

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Figure 1. Configuration of tactile stimuli (A) and location of stimulus presentation (B).

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group were asked to judge the roughness of stimuli presented to the thumb (thumb group), while the other group responded to the stimulus presented to the index finger (index finger group). The participants were then instructed to verbally judge whether the roughness of the stimulus on the target side was 'smooth' or 'rough'. The judgment of each trial was scored as either a hit or miss in the SN condition and correct rejections or false alarms in the NN condition. Forty trials were conducted for each of the eight conditions, which consisted of stimulus position (near/far from the head) × type of stimuli (SN/NN) × side of target stimuli (inside/outside relatively to the head).

Results

For each participant, the $d'$ (discrimination sensitivity) and $c$ (response bias) in each condition were calculated and analyzed using two-way repeated ANOVAs with distance (near/far) × target side (inside/outside) as factors (Fig. 2). Regardless of the condition, the thumb and index finger groups did not differ significantly.

The $d'$s had significant main effects for the target side (Exp. 1: $F(1, 11) = 42.85, p < .001$; Exp. 2: $F(1, 11) = 6.65, p < .05$) and significant distance × target side interactions (Exp. 1: $F(1, 11) = 17.90, p < .005$; Exp. 2: $F(1, 11) = 13.27, p < .005$). Post hoc comparisons revealed that the sensitivity scores in the near condition were higher in the inside condition than that in the outside condition (Exp. 1: $ps < .005$; Exp. 2: $ps < .001$).

The $c$s had main effects for the target side (Exp. 1: $F(1, 11) = 33.67, p < .001$; Exp. 2: $F(1, 11) = 31.61, p < .001$) and significant distance × target side interactions (Exp. 1: $F(1, 11) = 5.79, p < .05$; Exp. 2: $F(1, 11) = 5.46, p < .05$). Post hoc comparisons revealed that the judgments in the outside condition were biased toward the rougher (Exp. 1: $ps < .01$) and smoother (Exp. 2: $ps < .005$) sides than those in inside condition, suggesting that the biases in the outside conditions were in the same direction as the distractors' roughness. Furthermore, only in the outside condition was the bias in the near condition stronger than that in the far condition (Exp. 1: $ps < .005$; Exp. 2: $ps < .10$).

Discussion

We investigated the effects of spatial factors on roughness discrimination tasks when participants grasped double-sided abrasive paper between their thumb and index finger. When the participants discriminated the stimuli in their peri-head space, the discrimination sensitivities on the outside finger were lower than those on the inside finger. In addition, the analyses for the response bias revealed that the distractor on the inside finger misled judgments of the outside finger irrespective of the distance from the head, although the degree of the response bias changed depending on the distance from the head.

In summary, the response bias toward the inside stimuli was smaller as the distance from the head was larger, while the discrimination sensitivity on the outside finger decreased only in the peri-head space.

Reference