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# Double tactile sensations evoked by a single visual stimulus on a rubber hand

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ABSTRACT

The classical rubber hand illusion involves individuals misattributing tactile sensations 'felt' by their real hand hidden from view to a rubber prosthetic hand that they 'see' being tactilely stimulated in synchrony. However, from previous studies, it is not clear whether individuals actually feel the tactile sensation in the rubber hand, real hand, or both because the same part of the rubber and real hands were stimulated simultaneously. Here, we attempted to isolate subjects' sensations attributed to the rubber hand from those sensed in the real hand by placing the rubber and real hands in opposing orientations (e.g., palm up versus dorsum up). Interestingly, half of the subjects reported two tactile sensations for one visual stimulus, that is, one in the rubber finger stimulated visually with a light source and one in the real finger overlapping the rubber finger. This finding suggests that the tactile sensation induced by the visual stimulus is referred to the rubber hand and real hand simultaneously. Thus, both visuo-spatial and somatic codes are used in the localization of tactile sensation in the rubber hand illusion.


## 1. Introduction

In the rubber hand illusion (Botvinick and Cohen, 1998; Rorden et al., 1999; Farne et al., 2000), a realistic life-sized rubber prosthetic hand is placed on a table in front of the subject while their real hand is hidden from view on or under the table, and the subjects continuously watches the rubber hand. When the rubber hand and real hand are touched simultaneously, the subject 'feels' a tactile sensation in the rubber hand as though the rubber hand was their own hand. The brain interprets the rubber hand as the real hand because the visual sense can override tactile sense when tactile input on the real hand is consistent with the visual input.

Previous research on the rubber hand illusion has measured perceptual location errors in the classical form of the illusion and has shown that subjects can discriminate between coordinated and mismatched touch (e.g., Pavani et al., 2000; Ehrsson et al., 2004; Holmes and Spence, 2005; Tsakiris and Haggard, 2005). Recently, Durgin et al. (2007) reported that subjects 'felt' tactile sensations from a light source, without any tactile stimulation. Such evidence suggests that visual input strongly influences tactile sensation. However, the illusion was weakened or disappeared in cases of physically impossible mismatch situations between rubber and real hands, such as misorientation between the front and heel of the hand (Pavani et al., 2000; Durgin et al., 2007). Thus, it is postulated that body state (somatic) inputs also influence tactile sensation.

To examine how visual and tactile inputs contribute to the rubber hand illusion, we attempted to isolate subjects' sensations attributed to the rubber hand from those felt in the real hand by placing the rubber and real hands in opposing orientations. The present study therefore set up congruent and incongruent conditions. The congruent condition consisted of placing the real and rubber hands in identical orientations, a condition which was selected in order to verify the results of Durgin et al. (2007) who reported that the rubber hand illusion is induced by visual stimulus alone. We examined whether subjects could accurately ascertain the location where they felt tactile sensation (palm or dorsum of the hand and which of the five digits) under the condition of visual stimulus alone. The incongruent condition differed only in the orientation of the rubber and real hands, that is, palm up versus dorsum up (Fig. 1B).

We made three predictions as follows: (1) when only visuo-spatial coding is used to localize the tactile sensation, tactile sensation should occur on the finger of the rubber hand where a light spot is presented; (2) when only somatic coding is used to localize the tactile sensation, tactile sensation should occur on the finger of the actual hand (hidden from view) when a light spot is presented on the rubber hand; (3) when both codings are presented simultaneously, two tactile sensations should be perceived, one on the rubber hand and the other on the actual hand.

Previous investigations have measured skin conductance response (SCR) to verify sensation in the rubber hand illusion

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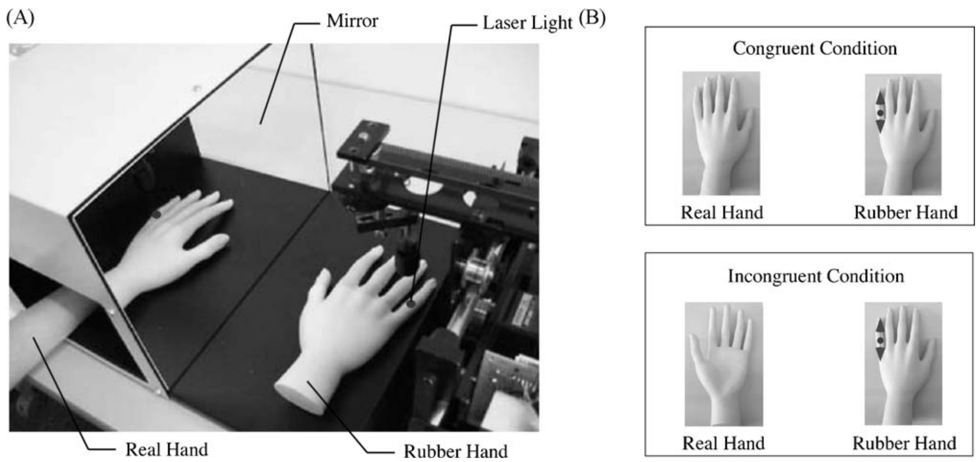


**Fig. 1.** Equipment and experimental conditions. (A) Subjects placed their left hand behind the mirror, which was seen as the image of a rubber right hand reflected in the mirror. Subjects could not observe the laser light irradiator, although the cover had been removed for the photograph. (B) Upper panel shows the conditions in the congruent condition where the subject's hand was oriented identically to that of the rubber hand. Lower panel shows the incongruent condition where the orientation of the subject's hand and the rubber hand was in opposition. The circle point on the rubber hand indicates the location illuminated by the laser light, and arrows indicate the direction of laser movement.

(e.g., Armel and Ramachandran, 2003), where a subject who does not succumb to the rubber hand illusion will not display any change in SCR when the rubber hand is stimulated. Conversely, a subject who does experience the illusion will show a change in SCR. In this research, we measured SCR when the experimenter pricked the rubber hand with a needle.

## 2. Materials and methods

### 2.1. Subjects

Thirty-five volunteers (age, 18–35 years; mean age, 21.9 years) naïve to the purpose of the experiment and with normal or corrected-to-normal visual acuity were recruited to the study. All subjects were right handed. Written informed consent was obtained from all subjects prior to participation. The study protocol was approved by Rikkyo University Research Ethics Committee.

### 2.2. Apparatus and stimuli

The finger of a prosthetic rubber hand was exposed to a red laser light (630 nm) that moved a distance of 10 cm, at a right angle to the subject. The diameter of the laser light was 8 mm. The laser light did not stray from the rubber hand. The rubber hand was visible only through a mirror. Subjects received no tactile stimulation on their real hand. The apparatus was controlled using a pulse motor and drift speed was 10 cm/s. Viewing distance was approximately 50 cm (Fig. 1A). SCR was measured using electrodes (MLT116F; AD Instruments) and a data acquisition component (PowerLab 4/25; AD Instruments).

### 2.3. Procedure

Subjects placed their left hand behind a mirror and were asked to observe the image of the whole right rubber hand in the mirror reflection (Fig. 1A). They subsequently answered a questionnaire pertaining to the presence or absence of tactile sensations just minutes after viewing the stimulus (the rubber hand exposed to a light source) for 120 s. Subjects orally indicated the location where they experienced the tactile sensation; that is, at which of the 5 digits and whether the sensation was experienced on the palm or dorsum of the hand, for a total of 10 alternative choices. Multiple answers were allowed if a subject experienced tactile sensations simultaneously in different perceived locations (see Appendix A). Each subject participated in 8 trials (congruent/incongruent condition × palm/dorsum × first/fifth digit). Trials were conducted randomly and without repetition. In the congruent condition, the orientations of the rubber and real hands were consistent (Fig. 1B, upper). In the incongruent condition, conditions were the same as in the congruent condition except that the hands were placed in opposing orientations (Fig. 1B, bottom).

To record SCRs, an electrode was attached to the ring finger of the left hand, and the subject stood for 3 min in a resting state. After the subject indicated the perceived location of the stimulus, the experimenter pricked with a needle the second joint of the thumb or little finger of the rubber hand, at the position corresponding to the location of the laser light stimulus. The needle prick was performed once per trial. SCR was calculated by subtracting baseline from peak skin conductance. Subjects again indicated the location at which they experienced the tactile sensation for the needle prick.

## 3. Results

In the congruent condition, 27 of the 35 subjects experienced a tactile sensation. All subjects who experienced a sensation reported that the location of tactile sensation corresponded with movement of the laser light. The tactile sensation was experienced in their own hand, on the same finger as the rubber finger that was illuminated by the laser light (Table 1, left). For example, some subjects experienced a tactile sensation in the little finger of their real hand as the laser light was illuminating the little finger of the rubber hand.

In the incongruent condition, again 8 subjects experienced no tactile sensation (Fig. 2, Case 1) and 27 subjects experienced tactile sensation in the location corresponding to the location stimulated on the rubber hand. The 8 subjects who experienced no tactile sensation in the congruent and incongruent conditions were the same individuals. Tactile sensations in the 27 subjects who experienced tactile sensation were divisible into three types. All 27 experienced tactile sensations in the rubber hand (Table 1, right). For example, when the real left hand was palm up and the dorsum of the little finger of the rubber hand was illuminated by the laser light, 9 subjects experienced a sensation on the palm side of the index finger (Case 2), while 18 subjects described two sensations simultaneously (not successively), with one on the dorsum of the little finger and one on the palm side of the index finger (Case 3).