Video Article

Testing Tactile Masking between the Forearms

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Abstract

Masking, in which one stimulus affects the detection of another, is a classic technique that has been used in visual, auditory, and tactile research, usually using stimuli that are close together to reveal local interactions. Masking effects have also been demonstrated in which a tactile stimulus alters the perception of a touch at a distant location. Such effects can provide insight into how components of the body's representations in the brain may be linked. Occasional reports have indicated that touches on one hand or forearm can affect tactile sensitivity at corresponding contralateral locations. To explore the matching of corresponding points across the body, we can measure the spatial tuning and effect of posture on contralateral masking. Careful controls are required to rule out direct effects of the remote stimulus, for example by mechanical transmission, and also attention effects in which thresholds may be altered by the participant's attention being drawn away from the stimulus of interest. The use of this technique is beneficial as a behavioural measure for exploring which parts of the body are functionally connected and whether the two sides of the body interact in a somatotopic representation. This manuscript describes a behavioural protocol that can be used for studying contralateral tactile masking.

Video Link

The video component of this article can be found at http://www.jove.com/video/53733/

Introduction

Tactile masking is where a tactile stimulus at one location on the body alters the perception of a touch at another location. This is a technique pioneered by von Bekesy[1] to reveal location interactions, especially lateral inhibition, between areas of skin that are adjacent on the body surface. While tactile masking has been studied extensively over the years, research has mainly investigated ipsilateral tactile masking using electrical stimulation[2,3], pressure[4], and vibrotactile stimulation[5,6]. In contrast, few studies have looked at contralateral tactile masking in which the masking and probe sites may be far removed. Long-range tactile masking effects have been shown between mirror-symmetric points on the hand and arm[5,7-9] but these studies have been largely restricted to looking at the hands and fingers[7,10], with more extensive parts of the whole body being largely ignored. A goal of such long-range masking experiments is to indicate how components of the body's representation in the brain may be functionally linked. Here, the phenomenon of long-range tactile masking is explored by investigating how vibration applied to one forearm might affect tactile sensitivity thresholds on the opposite forearm. Threshold refers to the minimum stimulus that is needed to detect a stimulus. We define this as the intensity at which the stimulus is detected 75% of the time. We used a tactile masking technique in which tactile sensitivity (the reciprocal of threshold) on one forearm is measured in the presence of a vibrating stimulus (the mask) on another part of the body. Effective masking is revealed by an increase in the detection threshold *i.e.*, a reduction in sensitivity. The technique can be used in conjunction with other manipulations such as varying limb position or movement to explore their effects on the effectiveness of masking.

Here we used vibrotactile stimuli as the masking stimulus. The advantage of this is that the frequency, and hence the receptor type that it stimulates can be controlled. The technique could be extended to look at pain using electrical stimuli as the probe or mask or both. Also, any site can be used as the masking site allowing the investigation of acupuncture sites for example.

Protocol

All of the experiments were approved by the York Ethics board and all participants signed informed consent forms. The experiments were performed in accordance with the Treaty of Helsinki.

1. Stimuli

1. Tactile Detection Stimulus
    1. Use a tactor (1.17" diameter and 0.30" thick) to deliver tactile stimuli of 250 Hz vibration for 100 msec. Using a purpose-built tactor provides a linear relationship between the amount of travel and the voltage applied.
    2. Control tactile stimulus delivery with a 64 bit sound card.

        1. To drive the tactor, treat it as a loudspeaker. Connect a stereo audio amplifier to a 64-bit computer stereo sound card. Connect the tactor to one of the outputs of the amplifier (*e.g.*, the 'left speaker out'). Connect the second channel (*e.g.*, the 'right speaker out') of the amplifier to a regular loudspeaker to provide auditory signals to the participant.
        2. In the computer code that is controlling the experiment, generate the waveform that will be used to vibrate the tactor (*e.g.*, a 250 Hz sinewave of duration 100 msec), and another waveform for the auditory signal (*e.g.*, a 3,000 Hz sinewave with a duration of 100 msec). See Example Code 1 in the Supplemental Code File.
        3. Put each of these two waveforms into a two-dimensional array. For the tactor array put the signal in the first dimension and set the second dimension to all zeros. For the sound array put the signal in the second dimension and set the first to all zeros. Play the appropriate array to the soundcard at the appropriate point in the program. See Example Code 1 in the Supplemental Code File for a demonstration of how this is done.

    3. Attach the tactor to a strap with a mechanical-based fastening product.

2. Masking Stimulus
    1. Provide the masking stimulus by an electric, hand-held vibrator (4 cm diameter; 83 Hz when set on "low").
    2. Based on the areas where masking is to be tested, select the sites where the masking stimulus is to be applied.

2. Experimental Setup and Design

1. Arrange the computer and equipment on a desk, with a chair in front of it, for the experimenter.
2. Set up a table on which participants rest their left (test) arm. Place a chair to the right side of the table. Put an armrest stand next to the chair on which the participants rest their right (masking arm) elbow. Add cushioning to the table and armrest for comfort.
3. Arrange a loudspeaker on a mechanically isolated surface. Arrange foot pedals (connected to the left and right buttons of a computer mouse) so that the participant's feet will rest comfortably on them (**Figure 1**).
4. Choose the parameters of the study, including the appropriate number of trials required to obtain a reliable estimate of the threshold (typically, between 40-50 trials) and the number of blocks into which the experiment is to be divided (*e.g.*, two blocks of 20-25 trials per condition).
5. Make a list of the order in which the conditions will be run. Use this list to determine where to hold the masking stimulus for each block.
6. Enter the number of trials directly into the computer program code (*e.g.*, ntrials = 25; See Supplemental Code File). Ensure that each block is no longer than 10 min to maintain attention.
7. Program a two-alternative-forced-choice tactile detection task[11]in which stimulus intensity is controlled with a Bayesian adaptive psychophysical staircase psychometric procedure[12].
    1. For each trial, present two 1 sec intervals, marked by three beeps (5 kHz, 3 kHz and 5 kHz, duration 100 msec), with the tactile stimulus presented in the middle of one of the intervals. Have the participant indicate in which interval the stimulus was presented by means of foot pedals (left for first, right for second). See Example Code 2, which shows how the intervals are run and scored.
    Note: The computer scores the response as "correct" or "wrong" and the adaptive staircase chooses the next value to be presented accordingly.
    Note: This method determines a threshold value for detecting the vibration at the test site.

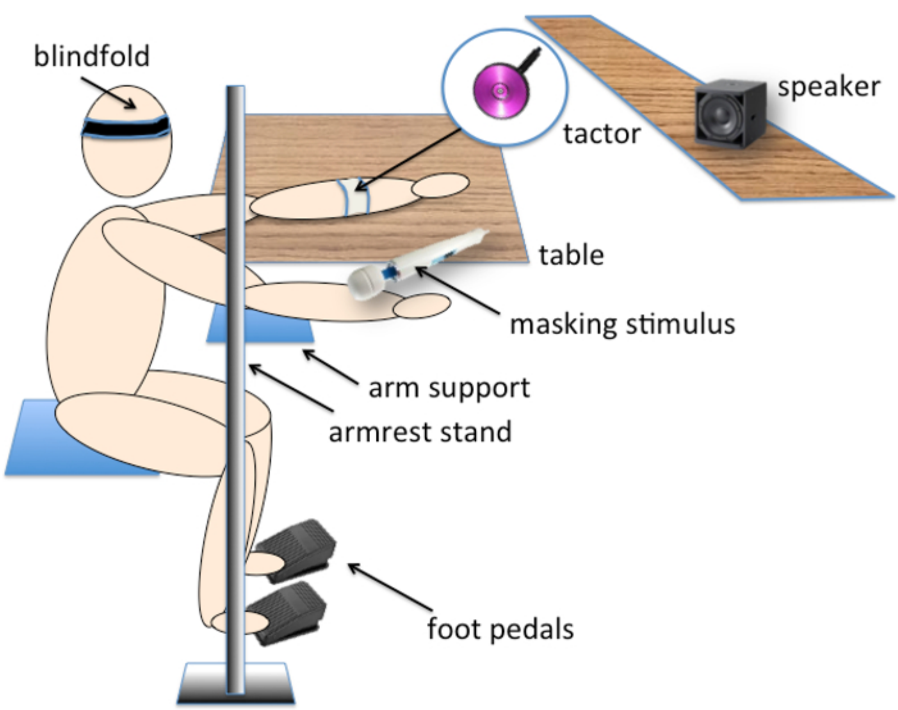

Figure 1. Experimental Design. This figure shows the set up of the experiment and the materials used. See text for details.

3. Experimental Procedure

1. Obtain written informed consent. Seat the participant in the chair with their feet resting comfortably on the response foot pedals and explain the experimental procedure.
2. Measure and record the length of the dorsal surface of the left forearm. Apply the strap so the tactor is positioned in the middle of the arm halfway between the inner angle of the elbow and the wrist crease.
3. Wrap a tensor bandage loosely around the arm several times to hold the tactor in place.
4. Instruct participants to place their left arm on the table and rest their right elbow on the armrest. Blindfold the participant to prevent them looking at the stimulus or masking location and instruct them to look straight ahead throughout the experiment.
5. Start with a block of 20 practice trials (without the masking stimulus) in order to familiarize participants with the tactile detection task and to allow them to become familiar with the tactile stimuli.
6. Following the practice trials, begin the experiment, running the blocks of conditions in a random, counterbalanced order. Before beginning each block, ensure that the arms and the masking stimulus are in the correct positions.
    1. For each condition, hold the masking stimulus on the chosen site, referring to the list of conditions made earlier. Cross off each condition as it is run. Hold the masking stimulus throughout each block of data collection trials maintaining approximately constant pressure. The masking stimulus can be applied through thin clothing.
    2. Run the experimental program which will run through a set number of trials as previously selected. Introduce a 2 min rest period after each short block of trials. After a given block of trials is completed, select the next site for the masking stimulus and run the program again. Repeat until all trials are completed.

4. Data Analysis

1. To visualize and confirm the estimate of the threshold value returned by the adaptive staircase program[12], fit the participants' data with a cumulative Gaussian The formula for a cumulative Gaussian (sigmoid) that goes from 50% (chance level - equal number of 0s - wrong and 1's- correct) to 100% (all 1's, all correct) is:
   probability of a correct response = 0.5 + 0.5/(1+exp(-(x-x0)/std))
   where x is the intensity value tested, x0 is the 75% threshold value, and std is the standard deviation of the estimate. This formula can be fitted to the data using any curve-fitting software and the resulting x0 value compared to the adaptive staircase value.
    1. Ensure that the curve goes between 50% (chance performance) and 100%. Conduct statistical analyses (*e.g.*, t-tests or ANOVAs) on the 75% threshold values obtained under each condition of the experiment (*e.g.*, between different masking sites) to determine if there are any differences between the conditions tested.

2. In order to identify outliers, calculate the mean and the standard deviation for a given condition. Compare each participant's score with the mean and if an individual score is more than 2 standard deviation from that mean then regard this score as an outlier and remove it from the analysis. Alternative criteria may be used if desired.
3. To standardize the values of the intensity of the tactors (which are in in arbitrary units), convert them to decibels relative to the control thresholds (measured when the masking stimulus is applied to the control site, *e.g.*, the shoulder). Use this formula:
   dB = 10 x $\log_{10}$ (threshold value/control threshold value).

Representative Results

Analyses of the data was reported in[13]. Tactile sensitivity (expressed relative to the thresholds measured in the control condition) on the forearm was significantly reduced (thresholds were significantly increased) when vibrotactile masking stimulation was applied to the opposite arm (**Figure 2A**), demonstrating a contralateral masking effect between forearms. The effect depended on the position of the masking stimulus on the masking arm, with the largest effect occurring when the mask and test sites corresponded. **Figure 2B** shows that posture also plays a role on the effectiveness of masking. The masking effect was considerably stronger when the arms were touching compared to when they were parallel (3.3 dB compared with 0.52 dB).

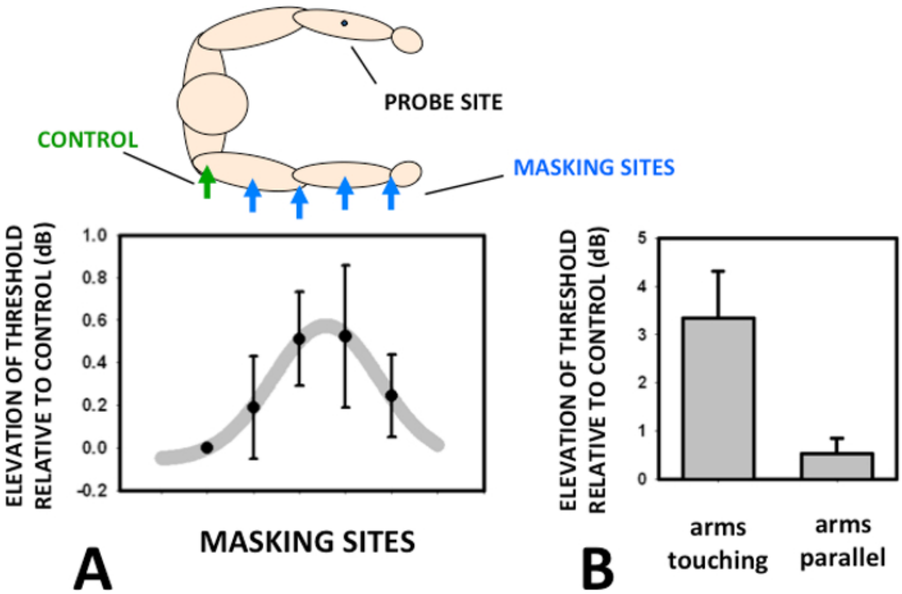

Figure 2. Typical data obtained using this technique. (**A**) The elevation in threshold is plotted as a function of the position of the mask (shown as blue arrows in the cartoon above the graph). (**B**) The elevation in threshold at the probe site on the left arm caused by a masking stimulus on the corresponding site on the right arm depends on whether the arms are touching or parallel. All data are expressed in dB relative the thresholds obtain with vibration applied to a control site on the shoulder (green arrow). Standard errors are shown. N = 15. Data redrawn from D'Amour and Harris, 2014.

Supplemental Code File 1. (Please click here to download this file.)

Discussion

Here, a detailed protocol for contralateral tactile masking is described and previously published results using the technique to test tactile detection thresholds are shown. The advantage of this method is that thresholds are measured using a psychophysically rigorous technique. The two-alternative forced choice (2AFC) procedure is relatively insensitive to response bias and therefore from attentional effects. The adaptive staircase procedure for honing in on the actual threshold value is very efficient as most of the data are collected with stimulus intensities close to the threshold level. Blindfolding the participant and having them look straight ahead throughput the data collection period further reduced attentional effects.

It is technically very demanding to measure the actual pressure applied by a tactor. It is not sufficient to calibrate the device beforehand because the pressure exerted will also depend on how tightly the tactor is bound to the skin surface. Thus we are only able to make statements about changes in thresholds rather than the absolute values. Since in this experiment we are only looking for changes brought about by the masking stimulus, this is not a concern in this design.

By interleaving relatively short blocks (about 10 min) for each condition (*i.e.*, each position of the masking stimulus) and presenting them in a sequence that was counterbalanced between participants the alertness of the participant is maintained.

Contralateral masking can be useful for exploring the representation of the body in the brain by revealing details of which parts are functionally connected to others. This technique provides behavioural[5,7,8,13-15] evidence to support neurophysiological[16-18] and neuroimaging data[19-23] that suggest that the integration of somatosensory inputs from the two sides of the body occurs in a somatotopic representation. In these experiments, the effect of arm location was briefly examined by comparing masking when the hands were touching or parallel. Though a difference was found, it cannot be concluded whether it is caused from actual skin contact or arm position. In a set of new experiments, we have taken these methods and tested a variety of different arm positions of both the test and masking arms. These findings will help address whether long-range masking effects occur before or after postural information has been added.

The technique is extremely flexible and can be used to investigate any manner of interactions between different parts of the somatosensory system. For example, the frequency content of masking or testing stimulation can be varied to optimally stimulate rapidly adapting or slowly adapting sub-systems. A potential limitation of these methods is the tactile stimuli used. Using different detection and masking stimuli (such as size, frequency, duration, *etc.*) might reveal different results especially when measuring the spatial tuning of the masking effect. A smaller masking stimulus would allow for better precision and allow for more accurate measurements of specific areas. For future applications, this protocol could be modified by testing the masking effect using a wide range of tactile stimuli.

Research has typically concentrated on studying masking and tactile perception on the hands and fingers with relatively few studies examining the whole body[14,24-27]. Future directions could include testing contralateral masking on more extensive areas of the body, which might reveal unexpected connections between other body parts or within a limb that could shed light on how the three-dimensional body is represented within the brain.

Disclosures

The authors declare that they have no competing financial interests.

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