Visual Dominance of Touch and the Somatosensory Homunculus: Does the Amount of Cortical Space Matter?

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Visual dominance has been a popular research topic in perceptual psychology because of Rock and Victor’s (1964) landmark study demonstrating vision’s dominance over touch. The results of many more studies over the years have supported the hypothesis that vision is dominant over touch in conflict situations (Colavita, 1974; Kinney & Luria, 1970; Miller, 1972; Pavani, Spence, & Driver, 2000). However, no study thus far has examined the possibility that visual dominance over touch may be moderated by the amount of cortical representation a body part occupies on the somatosensory cortex. For example, would a body part with relatively high cortical representation be less prone to visual dominance than a body part with relatively low cortical representation?

Pavani et al. (2000) examined participants’ ability to determine the location of a vibrotactile stimulus with both congruent visual information (when the visual stimulus indicated the same location as the vibrotactile stimulus) and incongruent visual information (when the visual stimulus indicated a different location than the vibrotactile stimulus). Participants received the vibrotactile stimulus through either the thumb or the forefinger, between which there was no significant difference in cortical representation (Sutherling, Levesque, & Baumgartner, 1992). The experimenters’ choice to have participants use the thumb and forefinger was a good one, as the study was not intended to examine the moderation of cortical representation. Otherwise, the results may have been confounded. If the thumb and middle finger had been used instead (between which there is a significant difference in cortical representation, according to Sutherling et al.), the thumb may have responded significantly faster and with greater accuracy.

In a study examining the cortical space devoted to the human hand, Sutherling et al. (1992) found that the index finger (hereafter, digit 2) had significantly...
greater cortical representation than the little finger (hereafter, digit 5).

Based on the findings of Sutherling et al. (1992), the present study sought to examine any difference in visual dominance that may exist between digit 2 and digit 5. Six hypotheses were tested:

Hypothesis 1: With congruent visual and tactile stimuli, response time will be shorter for digit 2 than for digit 5.

Hypothesis 2: With congruent visual and tactile stimuli, there will be no significant difference in accuracy between digit 2 and digit 5.

Hypothesis 3: Responses will be more accurate for congruent stimuli than for incongruent stimuli.

Hypothesis 4: Responses will be faster for congruent stimuli than for incongruent stimuli.

Hypothesis 5: With incongruent stimuli, response time will be shorter for digit 2 than for digit 5.

Hypothesis 6: With incongruent stimuli, digit 2 will be more accurate than digit 5.

The first hypothesis was based on the idea that digit 2’s greater cortical space would lend itself to faster response time. The second hypothesis assumed that congruent stimuli should present no difficulty to the participant in terms of accuracy. Hypotheses 3 and 4 (that responses would be faster and more accurate for congruent stimuli) are consistent with the results of Pavani et al.’s (2000) study. Hypotheses 5 and 6 propose that a larger amount of cortical space reduces visual dominance of touch.

Method

Participants

A sample of 45 students from California State University, Stanislaus (Turlock, CA), was recruited (43 women and 2 men). Some students received extra credit for their participation. All students were treated in accordance with the “Ethical Principles of Psychologists and Code of Conduct” (American Psychological Association, 1992). Two participants’ scores were excluded from the data analysis. One of these participants was left-handed; the other achieved such low accuracy on the incongruent trials (25%) so as to be an extreme outlier from the rest of the group.

Materials

The Briggs and Nebes Handedness Inventory (1975) was used to determine handedness in the participants. This inventory included 12 items describing various tasks (e.g., throwing a ball to hit a target, writing a letter legibly, etc.). The participant responded on a 5-point Likert scale as to which hand she/he used for each task (always left, usually left, no preference, usually right, always right). Possible scores ranged from -24 (strong left-handedness) to +24 (strong right-handedness). The authors of the scale classified scores from +9 to +24 as indicating right-handedness. Participants in the present study had scores ranging from +10 to +24 ($M = 20.79, SD = 3.78$).

The Arachnimech SR-1 prototype (see Figures 1) was the apparatus used to deliver the visual and tactile stimuli to the participant and for the participant to respond to the stimuli. Two 5 cm × 10 cm × 15 cm experimenter’s boxes were mounted together in an “L” shape. Two red LEDs (the visual stimuli) were mounted on top of the posterior box 7.5 cm apart. Two rotating servos (the tactile stimuli) were mounted 7.5 cm apart and 2.5 cm back from the front end of the anterior box. Two response buttons were mounted 2.5 cm behind the servos on the anterior box.

Procedure

Students signed up to participate on the university’s online subject pool. Each participant came to the assigned room for the study at a designated time. When the participant arrived, she/he was presented with an informed consent form. The researcher reviewed this sheet orally and answered any questions that arose. The participant signed one copy of the informed consent form and returned it to the researcher. The participant was also given a blank, unsigned copy of the consent form for her/his records.

The participant completed the Briggs and Nebes Handedness Inventory (1975). The participant was
then instructed to place her/his right hand on the anterior portion of the SR-1 apparatus with the digit 2 resting on the left servo and digit 5 resting on the right servo. There was sufficient room on the SR-1 to rest the thumb, middle, and ring fingers naturally. The participant was instructed to stare at a focal point (a white, .5 cm square) during the two sets of trials, which was located halfway between the two LEDs.

The familiarization set consisted of four trials: one with congruent servo and LED activation for digit 5, one with congruent servo and LED activation for digit 2, one with servo activation for digit 5 and LED activation for digit 2, and one with servo activation for digit 2 and LED activation for digit 5. Preceding each trial, the participant was told which stimuli would be present and which button to press in response. This set of trials ensured that each participant understood the experimental instructions and was familiar with how to respond.

The experimental set consisted of the same types of trials presented in the familiarization set. Before the set began, the participant was told to respond according to the servo rotation, regardless of whether the LED stimulus was congruent or incongruent. The participant was asked to respond as quickly and accurately as possible by reaching slightly forward with the finger indicated by the servo and depressing the corresponding key, subsequently returning the indicated finger to the original servo position. There were 40 trials in this set: 20 congruent (10 indicating one finger, 10 indicating the other) and 20 incongruent (10 indicating digit 2 with the LED and digit 5 with the servo, and 10 indicating digit 5 with the LED and digit 2 with the servo) in a predetermined random order that was identical for all participants. There was a 5s pause between trials.

After the experimental set, the participant was orally debriefed and given a debriefing form that summarized the goals of the study, provided references for further reading, and indicated how she/he could learn about the results of the study.

**Results**

Table 1 shows the mean response times and accuracy scores for each condition of the experiment. To test the hypotheses, the data were analyzed using paired-samples t tests.

Regarding Hypothesis 1, with congruent visual and tactile stimuli, response time was significantly shorter for digit 2 than for digit 5, \( t(42) = 4.86, p < .01 \). There was no difference in accuracy between digit 2 and digit 5 (Hypothesis 2), as none of the participants made any errors in accuracy with congruent stimuli.

Regarding Hypothesis 3, responses were significantly more accurate overall for congruent stimuli than for incongruent stimuli, \( t(42) = 3.18, p = .01 \). Responses were also significantly faster for congruent stimuli than for incongruent stimuli (Hypothesis 4), \( t(42) = 6.99, p < .01 \).

Regarding Hypothesis 5, with incongruent stimuli, response times were significantly shorter for digit 2 than for digit 5, \( t(42) = 5.40, p < .01 \). With incongruent stimuli, there was no significant difference in accuracy between digit 2 and digit 5 (Hypothesis 6), \( t(42) = 1.06, p = .29 \).

**Discussion**

Five of the six initial hypotheses are supported by the results of the current study. Specifically, digit 2 was faster than digit 5 under congruent and incongruent conditions, and accuracy was not significantly different between the two conditions.

Hypothesis 6 is not supported by the results as there is no significant difference in accuracy between digit 2 and digit 5 (although accuracy is slightly higher

<table>
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<tr>
<th>TABLE 1</th>
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<td><strong>Mean Response Time and Accuracy of Each Condition</strong></td>
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<table>
<thead>
<tr>
<th>Digit Response time (in milliseconds)</th>
<th>Accuracy*</th>
<th>Overall response time (in milliseconds)</th>
<th>Overall accuracy*</th>
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<tbody>
<tr>
<td><strong>Congruent stimuli</strong></td>
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<tr>
<td>2</td>
<td>923.81</td>
<td>10.00</td>
<td>957.21</td>
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<tr>
<td>5</td>
<td>990.62</td>
<td>10.00</td>
<td></td>
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<tr>
<td><strong>Incongruent stimuli</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1062.11</td>
<td>9.72</td>
<td>1101.25</td>
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<tr>
<td>5</td>
<td>1140.40</td>
<td>9.58</td>
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*Maximum score = 10.00
for digit 2). This result is not unexpected in light of the evidence in support of Hypothesis 5; one cannot expect both to be supported simultaneously. Participants invariably will choose between sacrificing speed for accuracy or accuracy for speed. Most choose accuracy above speed when they are told that both are important. If the researcher had instead emphasized that speed was more important than accuracy, we would expect Hypothesis 6 would be supported. This may also have been the result if the participant’s hand had been hidden from view. As it was, the participant may have been made aware of imminent mistakes (by the ability to see her/his finger reaching for the incorrect button) and been able to correct them before actually depressing the incorrect button. This would logically result in higher accuracy and slower responses, as the data show.

The results of the present study in support of Hypotheses 3 and 4 are consistent with previous research in terms of vision’s apparent dominance over the sense of touch (Colavita, 1974; Kinney & Luria, 1970; Miller, 1972; Pavani et al., 2000). However, the performance comparison of digit 2 and digit 5 is novel in this field of research. It would appear from the results that visual dominance may indeed be moderated by varying amounts of cortical representation.

However, the present study does have certain limitations that should be considered. First, the response keys on the SR-1 were a bit stiff, and thus required a certain amount of strength to depress. This may have been slightly more difficult for the weaker digit 5 than for the stronger digit 2, which may in turn have adversely affected the response times for digit 5. The use of more flexible response keys would make the present results more reliable.

Second, the support of both Hypothesis 1 and Hypothesis 5 is a possible confound. If it is a fact that digit 2 responds faster to a stimulus than digit 5, perhaps that may be the only reason Hypothesis 5 is supported. The fact that digit 2 responds faster did not necessarily mean it is more independent of visual dominance.

Third, there was no way for the experimenter to know for sure if the participants were keeping their eyes on the focal point as opposed to looking away or defocusing to circumvent distraction. It is reasonable to assume that, at least subconsciously, the desire to perform well at the task may outweigh verbal instructions, even with participants who understand the instructions and genuinely intend to follow them. If this is the case, the results may show only that digit 2 is capable of responding faster than digit 5, and that Hypothesis 5 really measures the same variable as Hypothesis 1. This can be remedied by making the visual stimulus more salient so that the visual distraction can not be easily averted.

Fourth, 95% of the participants were women. Therefore, it is not certain whether or not the results are generalizable to men, whose brain structure may be slightly different with regards to the somatosensory cortex.

Future research may compare the performance of several different age groups to determine any interaction effect between cortical representation and age in terms of visual dominance. It may also be worthwhile to explore any differences that may exist between typists and non-typists with regards to cortical representation of the fingers. Perhaps cortical representation is more equalized in typists (as typing requires more extensive use of digit 5 than other activities), and thus we may notice more pronounced results in a non-typist population. Future research can also investigate the role of the regional proportions of the motor homunculus as it relates to visual dominance. If cortical representation on the somatosensory cortex moderates visual dominance, one will expect the same of cortical representation on the motor cortex.

A follow-up study can investigate whether or not allowing the participant to see her/his hand would affect speed or accuracy. If a significant difference in accuracy truly does exist between digit 2 and digit 5, hiding the participant’s hand from view might accentuate this difference by preventing participant self-correction based on visual cues.

References


