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# Integration of Action and Size Perception Through Practice

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39 **Abstract**

40 Size perception is known to influence our usual interactions with environment. Numerous studies  
41 highlighted that during the visual presentation of an object, the properties of manual actions vary  
42 as a function of this object's size. In order to better understand the dynamic variations of  
43 relationships between size perception and action, we used an experimental paradigm consisting in  
44 two phases. During a previous implicit learning phase, a manual response (right or left) was  
45 specifically associated with the appearance of a large or small stimulus. During further test phase,  
46 participants were required to prepare a response while discriminating the color of a stimulus  
47 (GO/No GO task). We observed that the response execution was faster when the size of the  
48 stimulus was congruent with the size that had been associated to this response (during implicit  
49 learning phase). These results suggest that when a response usually co-occurs with visual stimuli  
50 characterized by a specific size pattern, the response and the size pattern become integrated. Any  
51 subsequent preparation and execution of this action are therefore influenced by the reactivation of  
52 this visual pattern. This result brings out new insights on how sensorimotor interactions may  
53 modulate the ability to anticipate perceptive size variations in the environment.

54

55 **Keywords:** sensorimotor integration, size perception, perception/action, stimulus-response  
56 compatibility, perceptual learning.

57

## 58 **Introduction**

59 For several decades, a growing body of works has been exploring the relationships between  
60 visual perception and action (Bridgeman & Tseng, 2011; Creem-Regehr & Kunz, 2010; Gibson,  
61 1979; Heurley & Ferrier, 2015; Proffitt & Linkenauger, 2013). In this framework, some authors  
62 have specifically focused on the importance of size perception for appropriate interactions with  
63 the environment. On the one hand, the perception of an object's size allows a better evaluation of  
64 its distance, speed and movement. Therefore, it strongly constrains our dynamic interactions with  
65 it (e.g., interception: DeLucia, 2005; Hosking & Crassini, 2010, 2011; Paivio, 1975). On the  
66 other hand, the perception of the object's size also influences hand-related actions like reaching  
67 or grasping. During reach-to-grasp movements for instance, the movement kinematics and the  
68 amplitude of hand opening during the reaching phase are closely correlated to the size of to-be-  
69 grasped objects (Corradini, Gentilucci, Leo, & Rizzolatti, 1992; Jeannerod, 1984). In the same  
70 vein, the object's size (i.e., small vs. large) determines the kind of grasp used for its manipulation  
71 (e.g., a precision grip between the thumb and the forefinger vs. a power grip with the whole hand;  
72 Napier, 1956; Newell, Scully, Tenenbaum, & Hardiman, 1989). Several studies recently  
73 demonstrated that the mere perception of an object potentiates the optimal grasp necessary to  
74 interact with it, even without any intention to reach-and-grasp it: A small object (e.g., a cherry)  
75 would potentiate a precision grip while a larger object (e.g., an apple) would rather potentiate a  
76 power grip (Ellis & Tucker, 2000; Olivier & Velay, 2009). Similarly, Borghi et al. (2007) found a  
77 compatibility effect between the hand visual prime posture (precision vs. power) and the grip  
78 required to grasp the target-object (precision grip vs. power grip). When the prime was a hand  
79 mimicking a precision grip action, participants responded faster and more accurately when the  
80 subsequent target objects were graspable with a precision grip (e.g., key, grape) than with a  
81 power grip (e.g., bottle, banana). When the hand mimicked a power grip action, the reverse  
82 pattern was observed. Comparable results were observed using video-clip of hands rather than  
83 static images (Vainio, Symes, Ellis, Tucker, & Ottoboni, 2008). Taken together, these researches  
84 point out close and automatic links between size perception and action. The present study aims at  
85 better understanding how these links may develop through practice and the implicit learning  
86 related to our usual interactions with environment.

87 According to the Theory of Event Coding (TEC), strong relationships exist between perception  
88 and action. More precisely, the perception goes along with both sensorial and motor components

89 to be integrated in an episodic memory trace, or Event-file (Hommel, 1998; see Zmigrod &  
90 Hommel, 2013, for a review). The perception of a visual object would therefore require the  
91 integration of its visual characteristics, the motor responses usually associated to it and the  
92 sensorial consequences of such motor responses (Hommel, 1998, 2004). For instance, the mere  
93 presentation of a stimulus activates a response spatially congruent with the stimulus even if the  
94 stimulus location is irrelevant for the task (Hommel, 2011; Kornblum, 1994; Proctor, 2011).

95 The co-occurring of sensorial and motor components (i.e., of stimulus-response combinations) is  
96 thought to be sufficient to strengthen the link between them, suggesting that such coupling could  
97 evolve across practicing (cf. Kühn, Keizer, Colzato, Rombouts, & Hommel, 2011). Elsner and  
98 Hommel (2001) notably developed an experimental paradigm allowing highlighting this dynamic  
99 link between perception, action, and consequences of action. During a first phase, the participants  
100 heard a sound right after having to randomly press one of the two available buttons (right or left).  
101 The sound was either a high- or low- pitched one, depending on the mapping with the previous  
102 button. According to Elsner and Hommel (2001), this phase created an association between an  
103 action (button press) and a sensorial consequence (sound presentation), although the sound was  
104 not relevant to the task. During the second phase, half of the participants were required to press  
105 either the right button when a high-pitched tone was presented or the left button for a low-pitched  
106 tone (i.e., situation compatible with the first phase). The other half received the opposite  
107 instructions (i.e., situation incompatible with the first phase). Results showed that reaction times  
108 were shorter for the group in compatible situation than for the other one. According to the  
109 authors, the repeated occurrence of a stimulus (i.e., sensorial consequences) just following a  
110 specific manual response (i.e., an action) induced their integration into a particular event. Further  
111 presentation of the stimulus thus potentiated the associated action. It is important to note that  
112 such integration creates bidirectional links between the various sensory components: The  
113 sensorial consequences and the object properties are both potentiated when an action toward the  
114 object is planned (Fagioli, Hommel, & Schubotz, 2007; Wykowska, Schubö, & Hommel, 2009).  
115 In this paper, the term action planning refers to the mechanisms that prepare the system to reach a  
116 goal, that is, to produce an intended effect (Hommel, Müsseler, Aschersleben, & Prinz, 2001).

117 With regard to those researches, the question remains to what extent the arbitrary association  
118 between a response and the size of a stimulus may also result in their integration in a unified  
119 event-file across interactions. More precisely, since a particular action followed by the

120 presentation of a stimulus should result in the integration of their various sensory components (cf.  
121 Camus, Brouillet, & Brunel, 2016), we therefore expect that any further planning of that action  
122 should reactivate the size of the previously associated stimulus, leading to a compatibility effect  
123 only when a stimulus with a compatible size is presented.

124

## 125 **Method**

### 126 **Participants**

127 Twenty-eight right-handed students ( $M = 21.4 \pm 2.4$ ) participated in the study. All of them gave  
128 their informed consent. They were not aware of the purpose of the experiment and they all  
129 reported normal or corrected-to-normal vision as well as no learning disabilities or psychiatric  
130 history.

131

### 132 **Materials and Procedure**

133 The work was carried out in accordance with the Code of Ethics of the World Medical  
134 Association (Declaration of Helsinki).

135 This experiment was divided into two successive phases: a learning and a test phase. During both  
136 phases, participants were seated in front of a 17-in. screen at a viewing distance of 60 cm. In  
137 addition, the screen was positioned in order that the stimuli appeared at eye level. The  
138 experimental procedure was controlled by E-Prime software (Psychology Software Tools, Inc.,  
139 Sharpsburg, PA).

140 During the learning phase, participants had to place their right index and middle finger  
141 respectively on the 4 and 6 of the numeric pad, while having their left index on space bar of a  
142 usual AZERTY keyboard (Figure 1). Herein, each trial started with the presentation of a number  
143 (4 or 6) in the center of the screen. Participants were instructed to press the corresponding button  
144 on the numeric pad. Immediately after pressing the button, the number was replaced by a red or a  
145 blue circle in the center of the screen (Figure 1). This circle was either visually larger ( $\varnothing = 100$   
146 mm) or smaller ( $\varnothing = 28$  mm) than the number (73 x 48 mm). When this circle was blue, the  
147 participant had to press the space bar.

148 When it was red, he or she had to wait (1500 ms)<sup>1</sup>. The intertrial interval was 1000 ms long. For  
149 14 participants (Group 1), large circles were always presented after pressing the 6 whereas small

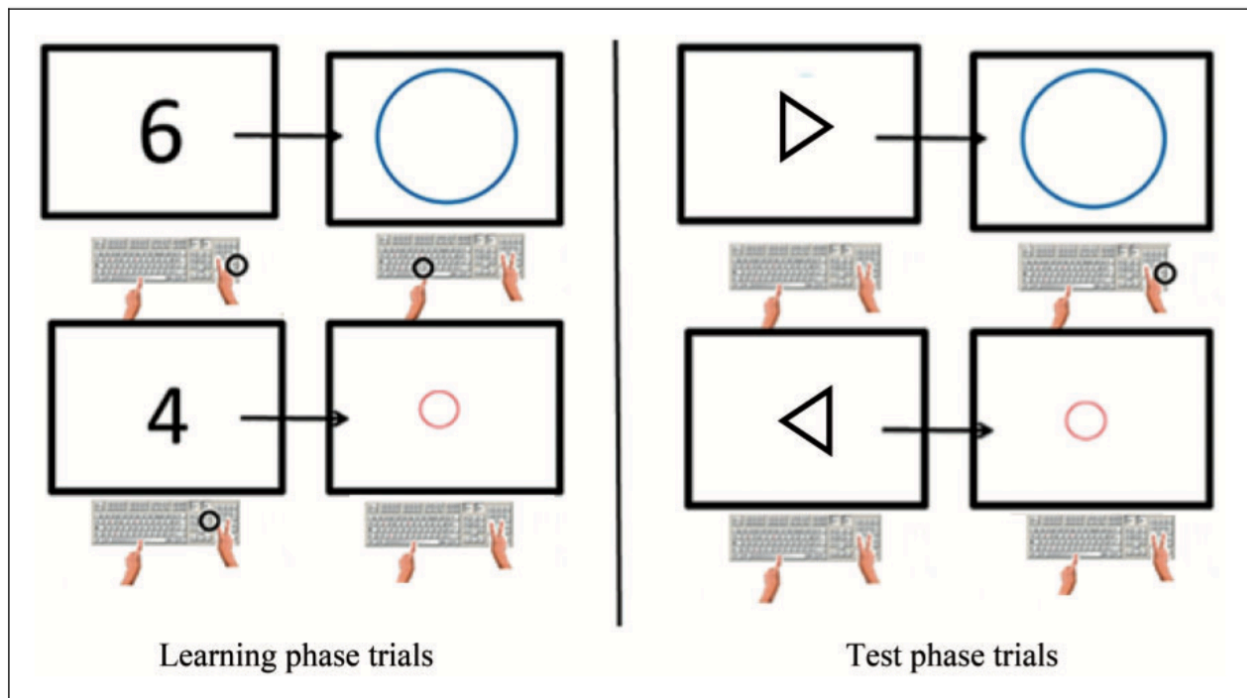
---

<sup>1</sup> The response on the space bar aimed at controlling whether the participants perceived the circle (i.e., press the space bar only when the circle is blue).

150 circles were presented after pressing the 4. For the other half (Group 2), this presentation pattern  
151 was counterbalanced: The small circles were always presented after pressing the 6, whereas large  
152 circles were presented after pressing the 4. For both groups, the learning phase consisted of 80  
153 randomly ordered trials resulting from the possible combinations of the circle's color (blue vs.  
154 red), its size (large vs. small) and the number (4 or 6).

155 During the test phase, participants had to keep on placing their right index and middle finger  
156 respectively on the keys 4 and 6 of the numeric pad. In this phase, each trial started with the  
157 presentation of a central arrow during 1500 ms. This arrow was oriented either to the left or to  
158 right side of the screen (73 x 48 mm). Participants were instructed to prepare to press the spatially  
159 corresponding button only if a blue circle then appeared. More concretely, after an arrow pointing  
160 to the left, participants had to press the key 4 of the numeric pad, whereas when an arrow  
161 pointing to the right was presented, they had to press the key 6. Then appeared a circle that could  
162 be either large ( $\text{Ø} = 100 \text{ mm}$ ) or small ( $\text{Ø} = 28 \text{ mm}$ ). When this circle was blue, participants had  
163 to execute the prepared response (Go). When it was red (No Go), they just had to wait (1500 ms).  
164 The intertrial interval was 1000 ms long (Figure 1). This phase consisted of 128 randomly  
165 ordered trials resulting from the possible combinations of the circle's color (blue vs. red), its size  
166 (large vs. small) and the direction of the arrow (right vs. left).

167



168

169 **Figure 1.** On the left, example of the two learning phase trials for a participant of Group 1. After having pressed the  
170 “6” button on keyboard (as required on the screen), the presented circle is always large. After having pressed the  
171 “4” button on keyboard, the presented circle is always small. The participant has to press the space bar only if the  
172 circle is blue (e.g., example in the top). On the right, example of the two test phase trials for a participant of Group 1.  
173 After the arrow, stimuli are equiprobable large or small. The participant has to respond exclusively to blue stimuli  
174 (e.g., example in the top). He is required to press either the “4” (i.e., left button) after a left arrow or the “6” (i.e.,  
175 right button) after a right arrow.

176

## 177 **Results**

178 During the learning phase, the participants made less than 1% of incorrect responses. We  
179 computed an analysis of variance (ANOVA) on the times to respond on the space bar, in which  
180 (a) the circle’s size (large vs. small) is a within-subjects factor and (b) instructions (Group 1 vs.  
181 Group 2) is a between-subjects factor. The participants of Group 1 responded in 464 ms ( $SD =$   
182 45) to large circles (i.e., presented after pressing the right button), whereas they responded in 484  
183 ms ( $SD = 45$ ) to small circles (i.e., presented after pressing the left button). Participants of Group  
184 2 responded in 442 ms ( $SD = 36$ ) to large circles (i.e., presented after pressing the left button),  
185 whereas they responded in 479 ms ( $SD = 32$ ) to small circles (i.e., presented after pressing the  
186 right button). The participants of both groups responded faster to large circles than small circles,  
187  $F(1, 26) = 18.75, p < .01 (\eta^2 = .41)$ . The ANOVA revealed no significant effect of instructions  
188 ( $F < 1$ ), nor interaction between instructions and the circle’s size,  $F(1, 26) = 1.75, p = .20$ .

189 In order to test our hypothesis, the statistical analyses on the data of the test phase were  
190 performed on the data collected for blue circles during the test phase. More precisely, we  
191 computed an ANOVA on response times (hereafter RTs) in which (a) circle’s size (large vs.  
192 small) and (b) compatibility between response and circle’s size (compatible vs. incompatible) are  
193 both within-subjects factors and (c) instructions (Group 1 vs. Group 2) is a between- subjects  
194 factor. The compatible condition refers to trials in which the circle’s size and the response were  
195 associated with regard to the learning phase. Conversely, the incompatible condition refers to  
196 trials in which the size and the response were not associated with regard to the learning phase. A  
197 series of one-sample Kolmogorov–Smirnov tests revealed that participants’ performance was  
198 distributed normally around the group means (all  $p > .05$ ). We excluded from the analyses the  
199 trials in which (a) incorrect responses were given (less than 1% of data of the test phase)<sup>2</sup> and (b)

---

<sup>2</sup> During the test phase, an incorrect response is defined as the action to press a key that was opposite to the arrow.

200 RTs were below or above two standard deviations (6% of data).  
 201 As expected, we observed a significant effect of compatibility,  $F(1, 26) = 5.20, p < .05 (\eta^2 = .16)$ .  
 202 More specifically, RTs were shorter for compatible trials ( $M = 431$  ms;  $SD = 63.5$ ) than for  
 203 incompatible trials ( $M = 442$  ms;  $SD = 72$ ). The ANOVA also revealed a significant effect of  
 204 size,  $F(1, 26) = 4.46, p < .05 (\eta^2 = .14)$ . Indeed, RTs were shorter for large stimuli ( $M = 430$  ms;  
 205  $SD = 66$ ) than for small stimuli ( $M = 442$  ms;  $SD = 69$ ). Additionally, neither the main effect of  
 206 group ( $F < 1$ ), nor the interactions between size and group ( $F < 1$ ), between compatibility and  
 207 group ( $F < 1$ ), between compatibility and size ( $F < 1$ ), and between size, group and compatibility  
 208 ( $F = 1$ ) reached significance (see Table 1).  
 209

	Large		Small	
	Compatible	Incompatible	Compatible	Incompatible
<b>Group 1</b>	421 (41)	422 (63)	429 (57)	449 (72)
<b>Group 2</b>	431 (71)	446 (81)	441 (77)	449 (67)

210  
 211 **Table 1.** Mean (SD) in millisecond for the “Go condition” (blue circles) in the test phase.  
 212

213 **Discussion**

214 The present experiment aimed at testing whether the arbitrary association between a response and  
 215 the size of a stimulus may result in their integration across sensorimotor interactions. More  
 216 precisely, the experimental design investigated whether the preparation of a response would  
 217 induce the reactivation of the size variations (a circle either larger or smaller than the previous  
 218 stimulus) specifically associated to this response during a previous learning phase. Our results  
 219 notably showed that RTs were shorter for compatible trials than for incompatible trials. This  
 220 compatibility effect is in line with our hypothesis. In the theoretical framework of previous  
 221 studies (e.g., Elsner & Hommel, 2001; Hommel, 2011), such a compatibility effect suggests that  
 222 during the learning phase, each response became associated to the subsequent appearance of a  
 223 specific stimulus and more precisely to its size (e.g., for the Group 1, left and right responses  
 224 were associated respectively with a small or large circle, whereas the opposite association was  
 225 induced for the Group 2). The motor response and the circle’s size have thus become integrated  
 226 as a sensorimotor event, as if the action was associated to its visual and proprioceptive

227 consequences (for a similar interpretations, see Elsner & Hommel, 2001; Hommel, 2004; Kühn et  
228 al., 2011). During the test phase, planning the response seems to have reactivated the previously  
229 integrated stimulus properties, leading to faster response execution when a compatible stimulus  
230 was presented than when an incompatible one was presented. For instance, when a participant  
231 had to respond to a large circle, the response execution was more efficient if it had been  
232 previously associated with a large circle than with a small one. Noticeably, the present study  
233 showed that such a compatibility effect can be observed under minimalistic and arbitrary  
234 conditions. Indeed, the 80 trials of the learning phase were enough to implicitly integrate a  
235 specific manual response to a stimulus size (although the stimulus size was not relevant to the  
236 task) and furthermore influence any subsequent execution of this response. Thus even if the size  
237 of this compatibility effect was small in our study, it seems reasonable with regard to previous  
238 research (cf. Hommel, 2011) to assume its generalization to less constraining situations. Besides,  
239 our results also showed a significant effect of the stimulus size. This effect is in line with results  
240 previously described in the literature (cf. Tucker & Ellis, 2001). In fact, it could result from a  
241 faster discrimination of the blue color (i.e., the GO signal) for large circles compared to small  
242 ones (due to a larger quantity of color on the screen for large circles). RTs were thus shorter.  
243 To conclude, our results suggested that when a response is associated to a specific pattern of size,  
244 any subsequent preparation and execution of this action are influenced by the reactivation of this  
245 visual pattern. Further investigations using complementary methodologies (e.g., measures of  
246 movement kinematic properties) are necessary to better understand how this association between  
247 an action and a size pattern may influence subsequent the action planning and the initiation  
248 decision. But already, this result may have important implications to our understanding of how  
249 sensorimotor interactions can modulate the ability to anticipate perceptive size variations in our  
250 environment, especially when an object is getting closer or further. More generally, this study  
251 brings out concrete ways to explore the ontogenetic development of our abilities to adapt our  
252 manual movements to efficiently reach and grasp objects.

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