Short Report

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Integration of Action and Size Perception Through Practice

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Abstract

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

Keywords

sensorimotor integration, size perception, perception/action, stimulus-response compatibility, perceptual learning

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Introduction

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

According to the Theory of Event Coding (TEC), strong relationships exist between perception and action. More precisely, the perception goes along with both sensorial and motor components to be integrated in an episodic memory trace, or Event-file (Hommel, 1998; see Zmigrod & Hommel, 2013, for a review). The perception of a visual object would therefore require the integration of its visual characteristics, the motor responses usually associated to it and the sensorial consequences of such motor responses (Hommel, 1998, 2004). For instance, the mere presentation of a stimulus activates a response spatially congruent with the stimulus even if the stimulus location is irrelevant for the task (Hommel, 2011; Kornblum, 1994; Proctor, 2011).

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

With regard to those researches, the question remains to what extent the arbitrary association between a response and the size of a stimulus may also result in their integration in a unified event-file across interactions. More precisely, since a particular action followed by the presentation of a stimulus should result in the integration of their various sensory components (cf. Camus, Brouillet, & Brunel, 2016), we therefore expect that any further planning of that action should reactivate the size of the previously associated stimulus, leading to a compatibility effect only when a stimulus with a compatible size is presented.

Method

Participants

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

Materials and Procedure

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

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

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

When it was red, he or he had to wait (1500 ms).[1] The intertrial interval was 1000 ms long. For 14 participants (Group 1), large circles were always presented after pressing the 6 whereas small circles were presented after pressing the 4. For the other half (Group 2), this presentation pattern was counterbalanced: The small circles were always presented after pressing the 6, whereas large circles were presented after pressing the 4. For both groups, the learning phase consisted of 80 randomly ordered trials resulting from the possible combinations of the circle's color (blue vs. red), its size (large vs. small) and the number (4 or 6).

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

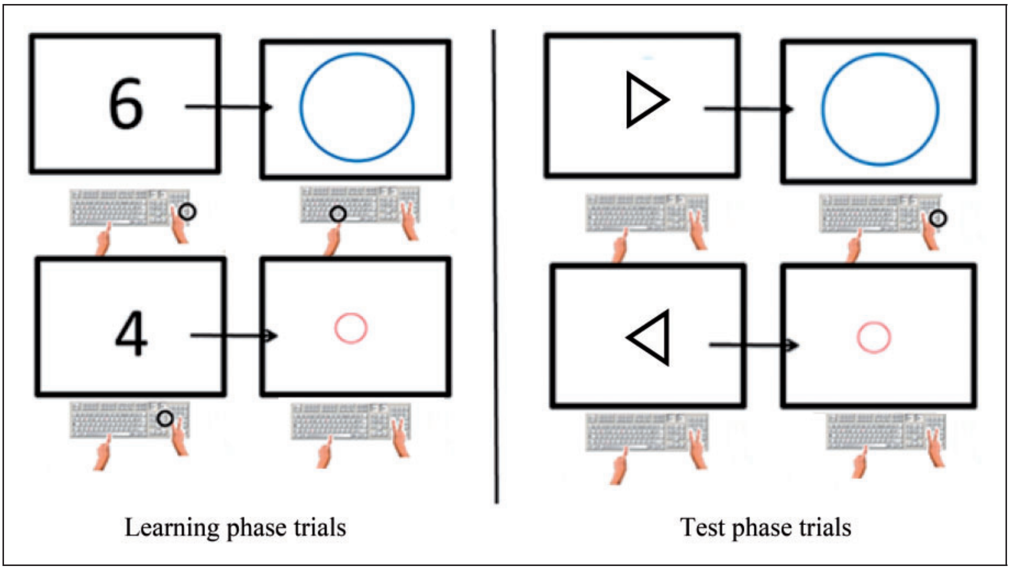

Figure 1. On the left, example of the two learning phase trials for a participant of Group 1. After having pressed the "6" button on keyboard (as required on the screen), the presented circle is always large. After having pressed the "4" button on keyboard, the presented circle is always small. The participant has to press the space bar only if the 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. After the arrow, stimuli are equiprobable large or small. The participant has to respond exclusively to blue stimuli (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., right button) after a right arrow.

Results

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

In order to test our hypothesis, the statistical analyses on the data of the test phase were performed on the data collected for blue circles during the test phase. More precisely, we computed an ANOVA on response times (hereafter RTs) in which (a) circle's size (large vs. small) and (b) compatibility between response and circle's size (compatible vs. incompatible) are both within-subjects factors and (c) instructions (Group 1 vs. Group 2) is a between-subjects factor. The compatible condition refers to trials in which the circle's size and the response were associated with regard to the learning phase. Conversely, the incompatible condition refers to trials in which the size and the response were not associated with regard to the learning phase. A series of one-sample Kolmogorov–Smirnov tests revealed that participants' performance was distributed normally around the group means (all $p > .05$). We excluded from the analyses the trials in which (a) incorrect responses were given (less than 1% of data of the test phase)[2] and (b) RTs were below or above two standard deviations (6% of data).

As expected, we observed a significant effect of compatibility, $F(1, 26) = 5.20$, $p < .05$ ($\eta^2 = .16$). More specifically, RTs were shorter for compatible trials ($M = 431$ ms; $SD = 63.5$) than for incompatible trials ($M = 442$ ms; $SD = 72$). The ANOVA also revealed a significant effect of size, $F(1, 26) = 4.46$, $p < .05$ ($\eta^2 = .14$). Indeed, RTs were shorter for large stimuli ($M = 430$ ms; $SD = 66$) than for small stimuli ($M = 442$ ms; $SD = 69$). Additionally, neither the main effect of group ($F < 1$), nor the interactions between size and group ($F < 1$), between compatibility and group ($F < 1$), between compatibility and size ($F < 1$), and between size, group and compatibility ($F = 1$) reached significance (see Table 1).

Discussion

The present experiment aimed at testing whether the arbitrary association between a response and the size of a stimulus may result in their integration across sensorimotor interactions. More precisely, the experimental design investigated whether the preparation

Table 1. Mean (*SD*) in millisecond for the "Go condition" (blue circles) in the test phase.

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

of a response would induce the reactivation of the size variations (a circle either larger or smaller than the previous stimulus) specifically associated to this response during a previous learning phase. Our results notably showed that RTs were shorter for compatible trials than for incompatible trials. This compatibility effect is in line with our hypothesis. In the theoretical framework of previous studies (e.g., Elsner & Hommel, 2001; Hommel, 2011), such a compatibility effect suggests that during the learning phase, each response became associated to the subsequent appearance of a specific stimulus and more precisely to its size (e.g., for the Group 1, left and right responses were associated respectively with a small or large circle, whereas the opposite association was induced for the Group 2). The motor response and the circle's size have thus become integrated as a sensorimotor event, as if the action was associated to its visual and proprioceptive consequences (for a similar interpretations, see Elsner & Hommel, 2001; Hommel, 2004; Kühn et al., 2011). During the test phase, planning the response seems to have reactivated the previously integrated stimulus properties, leading to faster response execution when a compatible stimulus was presented than when an incompatible one was presented. For instance, when a participant had to respond to a large circle, the response execution was more efficient if it had been previously associated with a large circle than with a small one. Noticeably, the present study showed that such a compatibility effect can be observed under minimalistic and arbitrary conditions. Indeed, the 80 trials of the learning phase were enough to implicitly integrate a specific manual response to a stimulus size (although the stimulus size was not relevant to the task) and furthermore influence any subsequent execution of this response. Thus even if the size of this compatibility effect was small in our study, it seems reasonable with regard to previous research (cf. Hommel, 2011) to assume its generalization to less constraining situations. Besides, our results also showed a significant effect of the stimulus size. This effect is in line with results previously described in the literature (cf. Tucker & Ellis, 2001). In fact, it could result from a faster discrimination of the blue color (i.e., the GO signal) for large circles compared to small ones (due to a larger quantity of color on the screen for large circles). RTs were thus shorter.

To conclude, our results suggested that when a response is associated to a specific pattern of size, any subsequent preparation and execution of this action are influenced by the reactivation of this visual pattern. Further investigations using complementary methodologies (e.g., measures of movement kinematic properties) are necessary to better understand how this association between an action and a size pattern may influence subsequent the action planning and the initiation decision. But already, this result may have important implications to our understanding of how sensorimotor interactions can modulate the ability to anticipate perceptive size variations in our environment, especially when an object is getting closer or further. More generally, this study brings out concrete ways to explore the ontogenetic development of our abilities to adapt our manual movements to efficiently reach and grasp objects.

Declaration of Conflicting Interests

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Notes

1. 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).
2. During the test phase, an incorrect response is defined as the action to press a key that was opposite to the arrow.

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