## Research Article

# PERCEPTION-ACTION DISSOCIATIONS OF A WALKABLE MÜLLER-LYER CONFIGURATION

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**Abstract—***These studies examined the role of spatial encoding in inducing perception-action dissociations in visual illusions. Participants were shown a large-scale Müller-Lyer configuration with hoops as its tails. In Experiment 1, participants either made verbal estimates of the extent of the Müller-Lyer shaft (verbal task) or walked the extent without vision, in an offset path (blind-walking task). For both tasks, participants stood a small distance away from the configuration, to elicit object-relative encoding of the shaft with respect to its hoops. A similar illusion bias was found in the verbal and motoric tasks. In Experiment 2, participants stood at one endpoint of the shaft in order to elicit egocentric encoding of extent. Verbal judgments continued to exhibit the illusion bias, whereas blind-walking judgments did not. These findings underscore the importance of egocentric encoding in motor tasks for producing perception-action dissociations.*

A growing body of empirical evidence suggests that the human visual system comprises two separate but interacting processing streams (e.g., Held, 1968; Milner & Goodale, 1995; Schneider, 1969; Ungerleider & Mishkin, 1982). Initial accounts proposed a division between the processes of object recognition and spatial localization (e.g., Ungerleider & Mishkin, 1982). More recently, Milner and Goodale (1995) have posited a division between phenomenal awareness, or perception, and visually guided action. The proposed segregation between streams is not only functional, but also neuroanatomical. Visual information for perceptual processing runs ventrally from the primary visual cortex to the inferior temporal cortex, whereas information for visuomotor control runs dorsally to the posterior parietal cortex. Moreover, the two streams are thought to process visual information differently (Haffenden & Goodale, 1998; Milner & Goodale, 1995). The ventral stream encodes the relative sizes and distances among features of an object or groups of objects using various reference frames, including environmental or object-relative frames. For example, the object-relative encoding of the handle of a cup with respect to its base allows its identification as a coffee cup. In contrast, the dorsal stream must encode information with respect to the appropriate egocentric reference frame for a given action. In order for someone to pick up the coffee cup, it must be encoded with respect to the coordinate system of the person's hand. The goal of this article is to highlight the importance of appropriate encoding strategies in assessing perception-action dissociations. We illustrate that egocentric encoding is a necessary component for an action response to be dissociated from perception.

The perception-action dissociation has been demonstrated quite clearly with neurological patients. Patients with damage to the temporal lobe usually exhibit impairment in object recognition, whereas visuomotor control is spared (Goodale, Meenan, et al., 1994; Goodale, Milner, Jakobson, & Carey, 1991; Milner & Goodale, 1995). In contrast, patients with damage to the parietal lobe usually show deficits in visually guided actions such as reaching toward and grasping objects, but show normal object recognition performance (Jakobson, Archibald, Carey, & Goodale, 1991; Jeannerod, Decety, & Michel, 1994).

For normal observers, the perception-action dissociation is demonstrable when a mismatch occurs between perceptual and motoric judgments about some dimension of the environment. For example, Loomis, Da Silva, Fujita, and Fukusima (1992) found that observers' verbal judgments of perceived distance were foreshortened in depth. In contrast, when the observers blind-walked (i.e., walked without vision) to the targets, the foreshortening bias disappeared. Similar dissociations have been found with verbal and pointing discriminations of target movement (Bridgeman, Lewis, Heit, & Nagle, 1979; Goodale, Pelisson, & Prablanc, 1986) and with verbal and haptic estimations of geographical slant (Creem & Proffitt, 1998; Proffitt, Bhalla, Gossweiler, & Midgett, 1996).

Another perception-action paradigm that has been used with apparent success involves visual illusions (e.g., Aglioti, DeSouza, & Goodale, 1995; Gentilucci, Chieffi, Daprati, Saetti, & Toni, 1996; Haffenden & Goodale, 1998; cf. Franz, Gegenfurtner, Bülthoff, & Fahle, 2000; Pavani, Boscagli, Benvenuti, Rabuffetti, & Farne, 1999). Participants typically view two-dimensional depictions of an illusory figure and make verbal and motor responses to some characteristic of it. For example, Aglioti et al. (1995) found that participants' verbal estimations of the width of the inner circle of an Ebbinghaus figure were biased by its surrounding circles in a predictable manner.[1] In contrast, grasps made toward the same inner circle were unaffected by the illusion. Similar dissociations have been demonstrated with the Müller-Lyer illusion (Gentilucci et al., 1996), the Roelofs effect (Bridgeman, Gemmer, Forsman, & Huemer, 1998; Bridgeman, Peery, & Anand, 1997), and illusions of induced motion (Abrams & Landgraf, 1990; Bridgeman, Kirch, & Sperling, 1981).

The illusion paradigm has recently come under some criticism, however. In particular, three issues have been raised. One point pertains to whether the perception and motor tasks used in some of these studies address the same physical characteristics of the illusory figure being tested (e.g., Gillam, 1998; Gillam & Chambers, 1985; Mack, Heuer, Villardi, & Chambers, 1985; Post & Welch, 1996; Welch, Post, Lum, & Cohen, 1996). For example, Mack et al. (1985) demonstrated that pointing to the vertices of a Müller-Lyer shaft (motor task) involves the perceived location of the shaft's endpoints, whereas verbal estimations of the same shaft's length (perception task) involve its perceived extent. A second concern is the possibility that the physical characteristic under examination (e.g., extent) could be con-

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[1] The Ebbinghaus figure consists of two target circles of equal size, one surrounded by a ring of smaller circles and the other surrounded by a ring of larger circles. People typically report seeing the target circle in the former scenario as larger than the target circle in the latter.

founded with another characteristic (e.g., location). For example, in testing perception-action dissociations of the extent of a Müller-Lyer shaft, Welch et al. (1996) used a finger-span response for a motor task, in which observers matched the distance between thumb and forefinger to the shaft length. So that the measure of shaft extent would be dissociated from the fingers' location relative to the shaft's endpoints, performance of the finger-span task was physically offset from the location of the figure. This manipulation, however, leads to concerns about a necessary egocentric component of visually guided responses, an issue to which we return soon. A final issue is that motor tasks must be performed open loop (i.e., without visual feedback) so that placement of the limbs is not aided by visual matchup with the stimulus. Indeed, when Welch et al. (1996) took these issues into account, the judged extent of the Müller-Lyer shaft showed a similar bias in both motor and perception tasks. Welch et al. concluded that controlling for these three factors was necessary for accurate tests of perception-action dissociations.

More recent studies suggest that additional methodological issues should be considered. Although a task may be motoric in nature, it is not always the case that the action is driven purely by the visual guidance system. Motoric responses often do not remain independent from perception. For example, the perceptual encoding system has been shown to influence motor judgments after a temporal delay (e.g., Creem & Proffitt, 1998; Gentilucci et al., 1996; Goodale, Jakobson, & Keillor, 1994).

As mentioned earlier, an important factor in distinguishing the perception and action processing streams is the way each encodes information. In particular, for a dissociation to occur, the action task must rely on egocentric encoding. Haffenden and Goodale (1998) have used this criterion to demonstrate a dissociation within two motor tasks: open-loop finger-span adjustments of the inner disk of an Ebbinghaus figure and open-loop grasps directed toward the inner disk. Grasping the disk was found to be unaffected by the surrounding circles of the Ebbinghaus figure, whereas finger matching exhibited the usual illusion bias. Haffenden and Goodale argued that the latter motor task was informed by object-relative encoding from the perceptual system. Support for this claim can be found in a study on a patient with an impaired perceptual system, who was able to perform accurate grasps toward blocks but had difficulty indicating widths of the same objects via finger-span adjustment (Goodale, Meenan, et al., 1994). These findings collectively suggest that the manner in which the visual system encodes a given action task is an important consideration for accurate tests of the perception-action dissociation.

The present studies examined these issues further by comparing perception and action judgments of a walkable Müller-Lyer configuration. We used a dumbbell version of the Müller-Lyer (Delboeuf, 1892), which was constructed of ribbon lines of varying lengths placed on the ground and surrounded by hoops. The tasks were designed to take into account all of the issues for testing perception-action dissociations previously raised by illusion researchers. Both tasks involved judgments of extent, the measure of extent was not confounded with location, and the motor task was open loop. In the perception task, participants made verbal estimates of the extent of the Müller-Lyer shaft. In the motor task, they walked the extent of the shaft without vision, in a path offset from the configuration itself. To test effects of encoding on perception and motor judgments, we constructed two variations of the Müller-Lyer configuration. In Experiment 1, the configuration was designed to elicit object-relative encoding (i.e., encoding of the lines' endpoints with respect to each other and possibly to the hoops). In Experiment 2, we altered the Müller-Lyer configuration so that it would elicit egocentric encoding (i.e., encoding of the lines' endpoints with respect to the participant). We predicted that the former scenario would result in an illusion effect in both perception and action tasks. However, we predicted the latter task would show a perception-action dissociation.

## EXPERIMENT 1

### Method

#### *Participants*

Twenty-four undergraduate students (12 female, 12 male) participated in the experiment as part of a research-credit requirement.

#### *Materials*

The Müller-Lyer configurations were constructed of ribbon lines (shafts) surrounded by two hoops (tails) 71 cm in diameter (see Fig. 1). The ribbon lines were 175, 225, 275, and 325 cm long and 1.6 cm wide. The hoops were either turned in toward a line (hoops-in configuration) or turned out from its ends (hoops-out configuration).

#### *Procedure*

The Müller-Lyer configurations were presented on the floor, with the hoops-in and hoops-out configurations appearing in random order. Participants stood 1.5 m away from the endpoint of the line closest to them. Participants performed either a verbal or a blind-walking response task.

For the verbal task, participants estimated the length of the line by giving a verbal response in any unit of measurement. The experimenter recorded responses.

In the blind-walking task, participants viewed the configuration, turned 90° to their left, and were fitted with a blindfold. They then

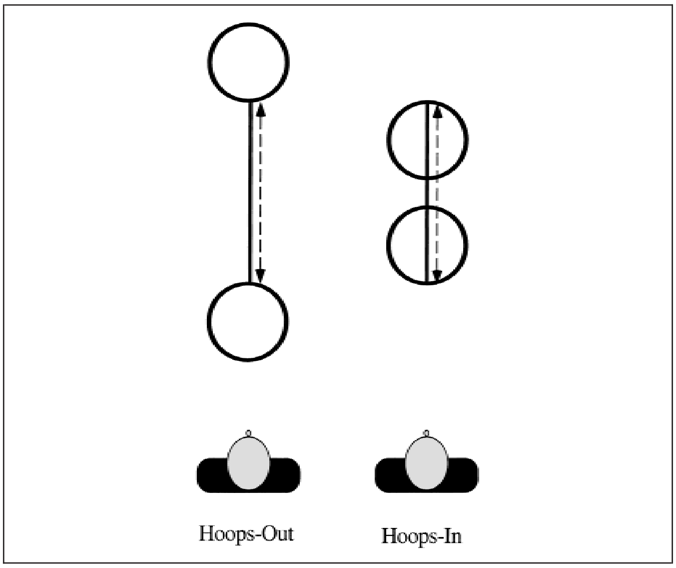

**Fig. 1.** Overhead view of the hoops-out and hoops-in Müller-Lyer configurations used in Experiment 1. The dotted lines represent the object-relative encoding of distance between line endpoints.

walked the extent of the line while using their left hand to hold onto a guide rope held taut by two experimenters. This measure ensured that participants walked in a straight line down the hallway. Once a participant had walked the line's extent, he or she stopped and stood in place. The experimenters then used a tape to measure the heel-to-heel distance from the start to endpoint of the walk. The participant was then led back to the test site, where the blindfold was removed.

Between judgments, participants were instructed to look away from the test site so they could not see the experimenters arranging the next stimulus configuration.

The verbal and blind-walking tasks were analyzed as between-subjects variables, whereas the hoops-in and hoops-out configurations were analyzed within subjects.

### Results and Discussion

The principal finding was that the illusion bias was present in the verbal and blind-walking tasks: In both, participants gave greater estimations of line extent with the hoops-out configuration than with the hoops-in configuration. A 2 (configuration) × 2 (task) × 4 (line length) analysis of variance revealed a main effect of configuration, $F(1, 22) = 25.21$, $p < .0001$, but no Configuration × Task interaction, $p = .56$ (see Fig. 2). There was also a significant effect of line length, $F(3, 66) = 378.37$, $p < .0001$, indicating that both verbal and blind-walking estimations increased linearly with line length.

To measure the magnitude of the illusion bias, we calculated the mean proportion of overestimation between the hoops-out and hoops-in conditions (i.e., [out − in]/out) for each subject. The mean difference in percentage of overestimation between verbal (9.6%) and blind-walking (5.6%) judgments was not significant, $p = .18$.

We propose that the apparent perception-action association found in Experiment 1 was due to the type of encoding afforded by our experimental setup. The fact that participants were spatially separated from the Müller-Lyer configuration may have induced encoding of line extent with respect to the hoops rather than to the participants themselves, regardless of task. Object-relative encoding is thought to underlie the typical illusion bias found with perception tasks (Milner & Goodale, 1995). As evidenced in the findings of Goodale and colleagues, such a strategy can also lead to illusion effects in motor tasks (Goodale, Meenan, et al., 1994; Haffenden & Goodale, 1998). An alternate interpretation is that the perception-action dissociation in illusions may be spurious (Welch et al., 1996). We examined this possibility in Experiment 2.

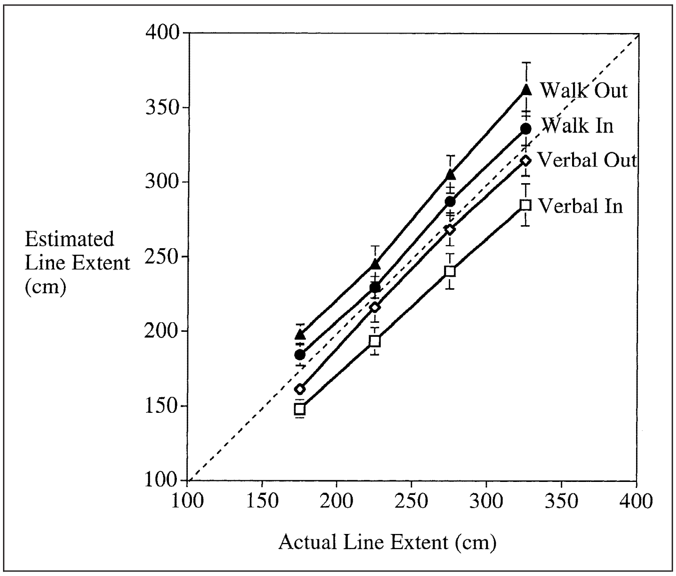

**Fig. 2.** Mean estimations of line extent and standard errors as a function of actual line extent, for the blind-walking and verbal tasks in Experiment 1. "In" and "out" refer to the hoops-in and hoops-out Müller-Lyer configurations, respectively. The dotted line represents perfect accuracy.

## EXPERIMENT 2

Experiment 2 was designed to make egocentric encoding of the Müller-Lyer configuration a more efficient strategy in the blind-walking task. We accomplished this by altering two aspects of the experimental setup. First, we eliminated one hoop (the one nearest the participant) from the configuration.[2] Second, participants stood directly at the near (i.e., hoopless) endpoint of the line. The resulting setup afforded encoding of the line's extent with respect to the participant in a straightforward manner. As in the previous experiment, participants judged the line's extent by either verbal estimation or blind-walking. We predicted that if egocentric encoding is a necessary criterion for accurate movement, judgments in the blind-walking task would show no effect of the Müller-Lyer illusion. In contrast, because perceptual size estimations typically elicit object-relative encoding (Haffenden & Goodale, 1998), we still expected to find an illusion bias in verbal judgments.

### Method

#### *Participants*

Thirty-three undergraduate students (20 female, 13 male) participated in the experiment as part of a research-credit requirement. The data of 1 additional participant (from the verbal task) were excluded when the difference between values for the hoop-in and hoop-out configurations was found to be more than three times the standard deviation of the mean difference.

#### *Materials*

The Müller-Lyer configurations differed from those of Experiment 1 in that the ribbon lines were affixed to only one hoop, which was placed at the end farthest from the participant (see Fig. 3).

#### *Procedure*

The procedure was identical to that of Experiment 1, except that in both the verbal and the blind-walking tasks, participants initially viewed the stimuli by standing with their toes directly on the ribbon's near endpoint.

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[2] Previous research has shown that the Müller-Lyer illusion effect can be elicited from single-tail configurations (Greene & Nelson, 1997; Tausch, 1962).

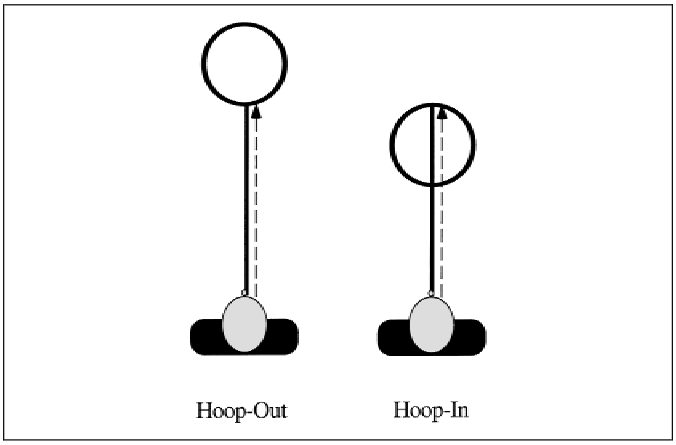

**Fig. 3.** Overhead view of the hoop-out and hoop-in Müller-Lyer configurations used in Experiment 2. The dotted lines represent the egocentric encoding of distance from the observer to the line's far endpoint.

## Results and Discussion

The principal finding was a difference in the illusion's effect across tasks. Participants in the verbal task gave greater estimations of line length in the hoop-out configuration compared with the hoop-in configuration. In contrast, participants in the blind-walking task showed no difference between hoop-in and hoop-out estimations (see Fig. 4). A 2 (configuration) × 2 (task) × 4 (line length) mixed design analysis of variance revealed significant effects of configuration, $F(1, 32) = 6.03$, $p < .02$, and line length, $F(3, 96) = 260.04$, $p < .0001$. Most important to our hypothesis, a significant Task × Configuration interaction was found, $F(1, 32) = 4.96$, $p < .034$. Post hoc analyses revealed that in the verbal task, estimations for the hoop-out configuration were greater than estimations for the hoop-in configuration, $F(1, 16) = 14.54$, $p < .002$; in the blind-walking task, this comparison yielded no difference, $p = .88$.

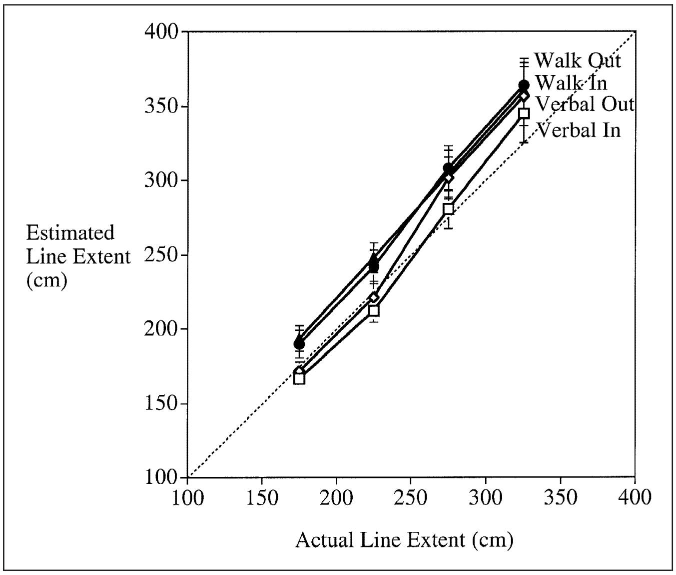

**Fig. 4.** Mean estimations of line extent and standard errors as a function of actual line extent, for the blind-walking and verbal tasks in Experiment 2. "In" and "out" refer to the hoop-in and hoop-out Müller-Lyer configurations, respectively. The dotted line represents perfect accuracy.

To measure the magnitude of the illusion bias, we calculated the mean proportion of overestimation between the hoop-out and hoop-in conditions for each subject. The mean difference in the percentage of overestimation was significantly greater in the verbal task (3.7%) than in the blind-walking task (0.15%), $F(1, 32) = 4.28$, $p < .05$. A between-experiment analysis revealed a reduced overestimation effect from Experiment 1 to 2, for both the verbal and the blind-walking conditions, $F(1, 54) = 12.86$, $p < .001$.

In contrast to Experiment 1, Experiment 2 demonstrated a dissociation between verbal and blind-walking judgments of line extent using a setup conducive to egocentric encoding. When participants were positioned in such a way as to encode the Müller-Lyer configuration with respect to themselves, their blind-walking performance showed no effect of the illusion. However, their perceptual judgments continued to be biased, albeit to a lesser degree than with a two-hoop configuration. The latter result is consistent with the notion that the Müller-Lyer illusion bias decreases proportionately with elimination of the number of angles intersecting the line (Tausch, 1962). Taken together, the present findings suggest that egocentric encoding in motor tasks is a necessary criterion for eliciting perception-action dissociations.

An alternative explanation for the differences found between verbal and blind-walking judgments might be differential effects of attentional distribution across configurations in each task (e.g., Pressey & Pressey, 1992). For example, it might be the case that blind-walking judgments of extent generally involved a field of attention concentrated on the hoopless center of the configuration, whereas verbal estimations of extent did not. However, this argument cannot account for the change in blind-walking illusion biases found across experiments. A more tenable explanation is that the presence and absence of the bias in blind-walking judgments was driven by differences in encoding.

## GENERAL DISCUSSION

The present research supports the existence of perception-action dissociations in visual illusions. More important, it underscores the necessity of egocentric encoding in motor tasks if they are to produce such dissociations. Altering the Müller-Lyer setup from a configuration that was physically separate from the observer to a configuration that could be efficiently encoded with respect to the observer resulted in elimination of the illusion bias in the blind-walking task. In contrast, verbal judgments showed an illusion effect regardless of the configural setup. These findings support the idea of distinctive processing mechanisms for perception and action (Milner & Goodale, 1995).

One implication of our results, however, is that there is some flexibility in the way spatial information is processed by the human visual system. Although the mechanism providing cross talk between systems is presently not known, a number of circumstances in which action tasks are influenced by the perceptual system have been identified (e.g., Creem & Proffitt, 1998; Gentilucci et al., 1996; Goodale, Jakobson, & Keillor, 1994; Haffenden & Goodale, 1998). The results of the present study indicate that action tasks can be influenced by object-relative encoding as a result of environmental factors, such as the position of the observer with respect to the configuration. We illustrated that identical blind-walking actions can produce different results depending on the processing systems involved. The critical variable appears to be the spatial reference frame used to encode the scene.

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## REFERENCES

Abrams, R.A., & Landgraf, J.Z. (1990). Differential use of distance and location information for spatial localization. *Perception & Psychophysics*, *47*, 349–359.

Aglioti, S., DeSouza, J.F.X., & Goodale, M. (1995). Size-contrast illusions deceive the eye but not the hand. *Current Biology*, *5*, 679–685.

Bridgeman, B., Gemmer, A., Forsman, T., & Huemer, V. (1998). *Properties of the sensorimotor branch of the visual system*. Manuscript submitted for publication.

Bridgeman, B., Kirch, M., & Sperling, A. (1981). Segregation of cognitive and motor aspects of visual function using induced motion. *Perception & Psychophysics*, *29*, 336–342.

Bridgeman, B., Lewis, S., Heit, F., & Nagle, M. (1979). Relation between cognitive and motor-oriented systems of visual perception. *Journal of Experimental Psychology: Human Perception and Performance*, *5*, 692–700.

Bridgeman, B., Peery, S., & Anand, S. (1997). Interaction of cognitive and sensorimotor maps of visual space. *Perception & Psychophysics*, *59*, 456–469.

Creem, S.H., & Proffitt, D.R. (1998). Two memories for geographical slant: Separation and interdependence of action and awareness. *Psychonomic Bulletin & Review*, *5*, 22–36.

Delboeuf, J. (1892). Sur une novelle illusion d'optique [On a new optical illusion]. *Bulletin de l'Academic Royal de Belguique*, *24*, 545–558.

Franz, V.H., Gegenfurtner, K.R., Bülthoff, H.H., & Fahle, M. (2000). Grasping visual illusions: No evidence for a dissociation between perception and action. *Psychological Science*, *11*, 20–25.

Gentilucci, M., Chieffi, S., Daprati, E., Saetti, M.C., & Toni, I. (1996). Visual illusion and action. *Neuropsychologia*, *34*, 369–376.

Gillam, B. (1998). Illusions at century's end. In J. Hochberg (Ed.), *Perception and cognition at century's end* (pp. 95–136). San Diego: Academic Press.

Gillam, B., & Chambers, D. (1985). Size and position are incongruous: Measurements on the Müller-Lyer figure. *Perception & Psychophysics*, *37*, 549–556.

Goodale, M.A., Jakobson, L.S., & Keillor, J.M. (1994). Differences in the visual control of pantomimed and natural grasping movements. *Neuropsychologia*, *32*, 1159–1178.

Goodale, M.A., Meenan, J.P., Bülthoff, H.H., Nicolle, D.A., Murphy, K.J., & Racicot, C.I. (1994). Separate neural pathways for the visual analysis of object shape in perception and prehension. *Current Biology*, *4*, 604–610.

Goodale, M.A., Milner, A.D., Jakobson, L.S., & Carey, D.P. (1991). A neurological dissociation between perceiving objects and grasping them. *Nature*, *349*, 154–156.

Goodale, M.A., Pelisson, D., & Prablanc, C. (1986). Large adjustments in visually guided reaching do not depend on vision of the hand or perception of target displacement. *Nature*, *320*, 748–750.

Greene, E., & Nelson, B. (1997). Evaluating Muller-Lyer effects using single fin-set configurations. *Perception & Psychophysics*, *59*, 293–312.

Haffenden, A.M., & Goodale, M.A. (1998). The effect of pictorial illusion on prehension and perception. *Journal of Cognitive Neuroscience*, *10*, 122–136.

Held, R. (1968). Dissociation of visual functions by deprivation and rearrangement. *Psychologische Forschung*, *31*, 338–348.

Jakobson, L.S., Archibald, Y.M., Carey, D.P., & Goodale, M.A. (1991). A kinematic analysis of reaching and grasping movements in a patient recovering from optic ataxia. *Neuropsychologia*, *29*, 803–809.

Jeannerod, M., Decety, J., & Michel, F. (1994). Impairment of grasping movements following a posterior parietal lesion. *Neuropsychologia*, *32*, 369–380.

Loomis, J.M., Da Silva, J., Fujita, N., & Fukusima, S.S. (1992). Visual space perception and visually directed action. *Journal of Experimental Psychology: Human Perception and Performance*, *18*, 906–921.

Mack, A., Heuer, F., Villardi, K., & Chambers, D. (1985). The dissociation of position and extent in Müller-Lyer figures. *Perception & Psychophysics*, *37*, 335–344.

Milner, A.D., & Goodale, M.A. (1995). *The visual brain in action*. Oxford, England: Oxford University Press.

Pavani, F., Boscagli, I., Benvenuti, F., Rabuffetti, M., & Farne, A. (1999). Are perception and action affected differently by the Titchner circles illusion? *Experimental Brain Research*, *127*, 95–101.

Post, R.B., & Welch, R.B. (1996). Is there dissociation of perceptual and motor responses to figural illusions? *Perception*, *25*, 569–581.

Pressey, A.W., & Pressey, C.A. (1992). Attentive fields are related to focal and contextual features: A study of Müller-Lyer distortions. *Perception & Psychophysics*, *51*, 423–436.

Proffitt, D.R., Bhalla, M., Gossweiler, R., & Midgett, J. (1996). Perceiving geographical slant. *Psychonomic Bulletin & Review*, *2*, 409–428.

Schneider, G.E. (1969). Two visual systems: Brain mechanisms for localization and discrimination are dissociated by tectal and cortical lesions. *Science*, *163*, 895–902.

Tausch, R. (1962). Empirische Untersuchungen im Hinblick auf ganzheits und gestalt-psychologische Wahrnehmungser-erklaerungen [Empirical investigations concerning holistic and gestalt-psychological perceptual explanations]. *Zeitschrift für Psychologie*, *166*, 26–61.

Ungerleider, L.G., & Mishkin, M. (1982). Two cortical visual systems. In D.J. Ingle, M.A. Goodale, & R.J.W. Mansfield (Eds.), *Analysis of visual behavior* (pp. 549–586). Cambridge, MA: MIT Press.

Welch, R.B., Post, R.B., Lum, W., & Cohen, M.M. (1996, November). *Are vision and action dissociated with respect to pictorial illusions?* Paper presented at the annual meeting of the Psychonomic Society, Chicago.

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