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Brief article

The plasticity of near space: Evidence for contraction

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ABSTRACT

The distinction between near space and the space farther away has been well established, as has the relation of this distinction to arm length. Recent studies provide evidence for the plasticity of near space, showing that it is possible to expand its extent ("size") through tool-use. In the present study, we examine the converse effect, whether contraction of near space results from increasing the effort involved on a line bisection task. Adult participants bisected lines at different distances, while, in some cases, wearing weights. In Experiment 1, the arms, specifically, were weighted (wrist weights), and in Experiment 2, more general body weights were used (heavy backpack). As in previous studies, unencumbered participants showed leftward bias when bisecting lines at the closest distances and a rightward shift in bias with increasingly farther distances. With wrist weights, but not a heavy backpack, participants showed more rightward bias at the closest distances, and a more gradual rightward shift with increasing distance, as if the nearest locations were represented as being farther away. These results suggest that increased effort, when specifically related to the arm, can serve to reduce the size of near space, providing support for the generally symmetrical plasticity of near space representations.

1. Introduction

It has long been known that the space surrounding the body is represented differently than the space farther away (Brain, 1941; Hall, 1966; Sommer, 1969). Many researchers have suggested that the transition between near and far space may be related to the length of the arm (e.g., Halligan, Fink, Marshall, & Vallar, 2003; Longo & Lourenco, 2007; Rizzolatti, Matelli, & Pavesi, 1983; Weiss, Marshall, Zilles, & Fink, 2003). Little is known, however, about the nature of this transition. Of particular importance is the plasticity of near space, that is, the extent to which it is possible to alter its "size", and, hence, how it transitions to far space. Several recent studies provide evidence for plasticity, showing that near space can be expanded (e.g., Berti & Frassinetti, 2000; Farnè & Làdavas, 2000; Holmes, Calvert, & Spence, 2004; Iriki, Tanaka, & Iwamura, 1996; Longo & Lourenco, 2006; Maravita, Husain, Clarke, & Driver, 2001). The present paper concerns the converse effect: contraction of near space.

1.1. Expansion of near space

Neurophysiological and neuropsychological studies have shown that near space representations can be dynamically expanded (e.g., Fogassi et al., 1996; Iriki et al., 1996). Iriki and colleagues, for example, found that visual receptive fields of parietal neurons of monkeys expanded to incorporate the space surrounding a wielded tool. There was some specificity, however. Only active intentional use of the tool resulted in expansion; passive grasping did not. Tool-use effects have also been found in humans. Berti and Frassinetti (2000) described patient P.P. who exhibited hemispatial neglect for the left side of space using a laser pointer to bisect lines in near, but not far, space. In contrast, when responding with a tool, neglect

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also appeared in far space, suggesting that near space expanded to include that within range of the tool (although, see, Holmes et al., 2004). Similar tool-use effects have been reported in patients with visuotactile extinction (e.g., Maravita et al., 2001), although there may be cases when prior exposure to the tool is necessary for expansion (Farnè & Làdavas, 2000).

In healthy participants, the extent to which tool-use modulates the representation of near space has been examined via lateral attentional biases on line bisection tasks (Gamberini, Seraglia, & Priftis, 2008; Longo & Lourenco, 2006). On these tasks, participants indicate the perceived midpoint of lines while standing at different distances. In near space, participants generally show a slight leftward bias, known as *pseudoneglect* (for review, see, Jewell & McCourt, 2000). When participants bisect lines at farther distances with a laser pointer, the bias shifts rightward (Longo & Lourenco, 2006, 2007; Varnava, McCarthy, & Beaumont, 2002). In contrast, when sticks are used to respond, there is no rightward shift in bias with increasing distance; leftward bias occurs in near and far space (Gamberini et al., 2008; Longo & Lourenco, 2006). Others have reported similar effects of tool-use with cross-modal paradigms (e.g., Holmes, Calvert, & Spence, 2007; Maravita, Spence, Kennett, & Driver, 2002). Together, the existing data show that near space can be expanded through the use of tools, sometimes in real-time and on a trial-to-trial basis (e.g., Holmes et al., 2007; Longo & Lourenco, 2006), and, in cases of expertise with specific tools, perhaps resulting in long-term change (Serino, Bassolino, Farnè, & Làdavas, 2007).

1.2. Present study

Although it is well established that near space can be made larger, the symmetry of plasticity is presently unknown. Can near space also be made smaller? And, if so, what factors might serve to contract near space? One possibility is the amount of effort required to act. Proffitt and colleagues have found several effects of increased effort on perception (for review see, Proffitt, 2006). Bhalla and Proffitt (1999), for example, showed that participants who wore a heavy backpack reported a hill as steeper than those who did not. Such effort effects have also been found for perceived distance (Proffitt, Stefanucci, Banton, & Epstein, 2003; Witt, Proffitt, & Epstein, 2004) and motor imagery (Decety, Jeannerod, & Prablanc, 1989). Similarly, near space representations might change as a function of the amount of effort involved in particular actions.

Here we examine whether it is possible to induce contraction in the size of near space by increasing the effort involved on a line bisection task. As in previous studies, we measure the rightward shift in attentional bias with increasing distance to determine the rate at which near space transitions into far space. Participants bisected lines, while, in some cases, wearing weights. If increased effort serves to contract near space, wearing weights should lead to a relative rightward shift in bias at closer distances (as if the lines are perceived as being in far space), with little to no rightward shift as distance increases, since near and far space may be considered less distinct. Additionally, we examined the specificity of effort effects by comparing weighting of the arms (wrist weights, *Experiment 1*) to more general body weights (heavy backpack, *Experiment 2*). Previously, we suggested that the size of near space may be specifically related to arm length rather than to overall body size (Longo & Lourenco, 2007). Such specificity would predict that weighting the arms, but not wearing a heavy backpack, might influence the representation of near space.

2. Experiment 1: wrist weights

2.1. Methods

2.1.1. Participants

Twenty students (10 female) between 18 and 34 years participated for course credit or payment ($10). All were right handed (Edinburgh Inventory). Procedures were approved by the local ethics committee.

2.1.2. Materials and procedure

Participants bisected lines of 10, 20, and 30 cm (height: 1 mm) using a laser pointer at nine distances (30, 60, 90, 120, 150, 180, 210, 240, and 270 cm). Lines were centered on legal-sized paper (21.6×35.6 cm) and attached horizontally to a wall (145.3 cm above the floor). Distances were marked on the floor with tape. A laser pointer, constantly activated, was attached to the head of a tripod, with height of the tripod adjusted for each participant's comfort. The tripod was positioned to the participant's right side and at the same distance from the wall as his/her feet. Participants used their right hand to move the tripod, indicating the midpoint of the line with the laser beam. Responses were marked by an experimenter, who, until then, remained behind the participant.

There were four blocks of 27 trials, each was comprised of one line of each length at each of the nine distances (randomized order). On half the blocks, participants wore 5-pound (2.27 kg) wrist weights on each arm, fit snug to the wrist. The blocks were counterbalanced within-subjects in ABBA order (initial block counterbalanced across participants).

2.2. Analysis

Bisection responses were measured off-line by two coders who never disagreed by more than 0.25 mm. For each participant, mean percent deviations were calculated for each distance and for each condition (weights vs. no weights). In each condition, data were fit with multiple linear regression for each participant, and parameter estimates of slope and y-intercepts were used for subsequent analyses.

The slope in the analysis indexes the rate at which bias shifts rightward with increasing distance, a measure of the "size" of near space, whereas the intercept indexes bias at hypothetical distance zero. We previously showed that tool-use produces a reduction of slope without a corresponding change in intercept (Longo & Lourenco, 2006), indicating that closer and farther distances had become less distinct primarily via farther distances being treated as if they were nearer in space – an extension of near space. Contraction of near space should also make nearer and farther distances less distinct, but, in the opposite way, via nearer distances being treated as if they are farther in space. Thus, near space contraction should produce a reduction of slope with a corresponding increase in y-intercept.

2.3. Results and discussion

Significant rightward shifts in bias were observed both with wrist weights (mean slope, $\beta = 0.229\%$ line length/meter), $t(19) = 2.67$, $p < .02$, and without (mean slope, $\beta = 0.605\%$ line length/meter), $t(19) = 9.20$, $p < .0001$, significantly correlated across conditions, $r(19) = .609$, $p < .005$[1]. This shift, however, was significantly reduced when participants wore weights, $t(19) = 5.43$, $p < .0001$ (Fig. 1). Further, the mean y-intercept was significantly higher (i.e., rightward) with weights than without (0.377% vs. −0.390% line length), $t(19) = -5.51$, $p < .0001$, suggesting that the reduced slope selectively affected the nearest distances. Data analyzed separately for males and females revealed significant effects both for slopes ($t(9) = 5.61$ and 2.65, $ps < .05$) and intercepts ($t(9) = -5.36$ and -3.43, $ps < .01$).

The data were also analyzed using analysis of variance (ANOVA) with condition (weights vs. no weights) and distance (30–270 cm) as within-subjects factors. There were significant main effects of distance, $F(8, 152) = 11.84$, $p < .0001$, condition, $F(1, 19) = 6.55$, $p < .02$, and, importantly, a significant interaction of distance and condition, $F(8, 152) = 4.63$, $p < .0001$, confirming that the rightward shift in bias across distance was affected by the weights manipulation (Fig. 1). Furthermore, one-tailed comparisons at each distance for the two conditions revealed significant differences at 30 and 60 cm, $t(19) = 5.59$ and 3.05, $p < .05$ (Bonferroni corrected), confirming the effect of wrist weights at the nearest distances. Even when data from the nearest distance was excluded (30 cm), significant modulations as a function of weights were found both for regression slopes, $t(19) = 3.74$, $p < .005$, and intercepts, $t(19) = -3.58$, $p < .005$, demonstrating that the effect of wrist weights is not limited to a shift in bias at the nearest distance.

Although bias shifted rightward with increasing distance in both conditions, the shift was more gradual when participants wore wrist weights. Furthermore, at the nearest distances, participants showed more rightward bias while wearing weights. That the intercept was shifted rightward for the weight-wearing trials suggests a selective influence on the representation of near space. Together, these results indicate that the increase in effort, when bisecting lines with wrist weights, served to contract near space.

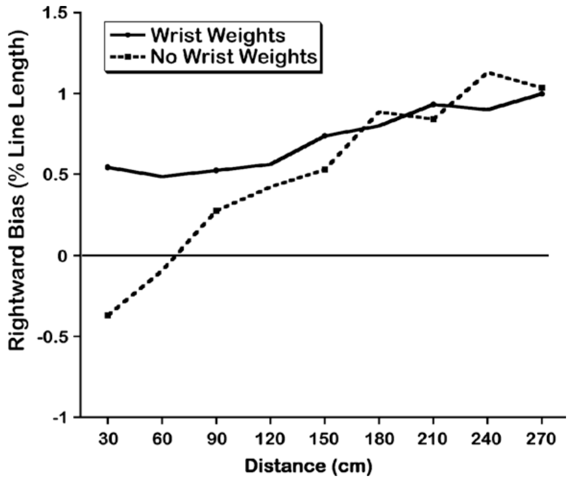

Fig. 1. Mean rightward bisection bias in Experiment 1 for wrist weights and no weights conditions.

Could these effects arise from motoric interference? Because fine motor control might be impaired when wearing wrist weights, participants' movements could have been more conservative than when without weights. A consequent reduction in variance across distance could account for a reduction in slope. To address this issue, we examined within-distance variance, which should also be reduced by more conservative responses. There was no significant difference in mean standard deviation between conditions (weights: 1.17% line length; no weights: 1.21% line length), $t(19) = 1.39$, $p > .10$, with a trend in the opposite direction, suggesting that wearing wrist weights did not result in more conservative movements.

3. Experiment 2: backpack with weights

3.1. Methods

3.1.1. Participants

Twenty students (seven female), between 18 and 28 years, participated. The majority were right handed ($N = 16$, Edinburgh Inventory). Procedures were approved by the local ethics committee.

3.1.2. Materials and procedure

These were identical to Experiment 1, except that weights were placed in a backpack, fastened with a belt to the participant's waist. We assigned backpack weights to participants using the criteria of Bhalla and Proffitt (1999; see Table 1).

[1] We previously found that the rightward shift with distance occurred whether absolute size or visual angle was held constant (Longo & Lourenco, 2006). Because we used three line lengths (10, 20, and 30 cm) and nine (equally-spaced) distances (30–270 cm), visual angle can be held constant by examining responses to a single line length at each of the three distances that involve a similar ratio. There are three subsets of distances on which these analyses can be conducted: (a) 30, 60, and 90 cm (18.92°), (b) 60, 120, and 180 cm (9.46°), and (c) 90, 180, 270 cm (6.31°). Across conditions and subsets, a significant rightward shift in bias was observed on the subset of data holding visual angle constant (mean slope, $\beta = 0.278\%$ line length/meter), $t(19) = 3.04$ $p < .01$, confirming our previous finding that the rightward shift with distance is not an artifact of differences in visual angle (Longo & Lourenco, 2006).

Table 1
Criteria used to determine weight of backpack for each participant, and the number of participants in each group. No participant weighed less than 100 pounds (45.36 kg) or more than 210 pounds (95.25 kg).

Backpack weight lb (kg)	Participant weight lb (kg)	Number of Participants
20 (9.07)	100–120 (45.36–54.43)	4
25 (11.34)	121–150 (54.88–68.04)	1
30 (13.61)	151–180 (68.49–81.65)	11
35 (15.88)	181–210 (82.10–95.25)	4

3.2. Results and discussion

As in Experiment 1, rightward shifts in bias with distance were observed both with weights (mean $\beta = 0.749\%$ line length/meter), $t(19) = 5.54$, $p < .0001$, and without (mean $\beta = 0.796\%$ line length/meter), $t(19) = 6.43$, $p < .0001$, significantly correlated across conditions, $r(19) = .776$, $p < .0001$[2]. In contrast to Experiment 1, there were no significant differences for slopes, $t(19) = 0.56$, or y-intercepts (weights: -0.924% line length; no weights: -0.922% line length), $t(19) = 0.01$, across condition (see Fig. 2). Similarly, an ANOVA with condition (weights vs. no weights) and distance (30–270 cm) as within-subjects factors revealed a significant main effect of distance, $F(8, 152) = 23.78$, $p < .0001$, but no significant main effect of condition, $F(1, 19) = 1.18$, or interaction of condition and distance, $F(8, 152) = 0.70$.

Thus, unlike Experiment 1, wearing a heavy backpack did not alter the pattern of bias across distance. Why might this result differ from that in the previous experiment? One possibility is that the contraction of near space depends on the specificity of task-related effort. To investigate the relation between near space contraction and wrist weights, we conducted between-experiment ANOVAs on regression slopes and y-intercepts with type of weights (Experiment 1: wrist weights vs. Experiment 2: backpack) and condition (weights vs. no weights) as factors. There were significant interactions between weight type and condition both for slopes, $F(1, 38) = 8.95$, $p < .005$, and intercepts, $F(1, 38) = 15.39$, $p < .0005$, providing direct support for the specificity of near space contraction to changes in effort that relate specifically to the arm. Proffitt and colleagues have suggested that the extent to which effort impacts spatial perception is determined by the intended action (e.g., Proffitt et al., 2003; Witt et al., 2004). Witt and colleagues, for example, found that participants who threw a heavy ball to a target judged the distance to the target as greater than participants who blind-walked to the target. Similarly, the contraction of near space may depend on the specificity of increased effort, as it relates to the arm (discussed below).

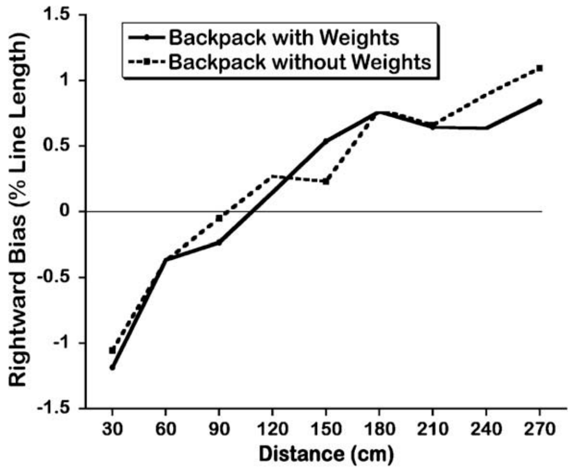

Fig. 2. Mean rightward bisection bias in Experiment 2 for weights (heavy backpack) and no weights conditions.

4. General Discussion

Previous studies have emphasized the plasticity of near space, describing cases of *expansion* via tool-use (e.g., Berti & Frassinetti, 2000; Iriki et al., 1996; Longo & Lourenco, 2006). To our knowledge, the present study is the first to show *contraction*, indicating that the size of near space is plastic in generally symmetrical fashion. Participants bisected lines, while, in some cases, wearing weights (wrist weights in *Experiment 1*, or a weighted backpack in *Experiment 2*). When participants were unencumbered, they showed leftward bias in near space (pseudoneglect) and rightward shifts in bias with increasingly farther distances. In contrast, when participants wore wrist weights, predominantly rightward bias was observed, with more gradual shifts with increasing distance. Like tool-use effects (Longo & Lourenco, 2006), wrist weights made responses at nearer and farther distances less distinct. This decrease in distinctiveness occurred in opposite ways, however. Tool-use altered responses at distant locations, making them seem more like closer locations (i.e., shifting bias leftwards). Conversely, wrist weights altered responses at closer locations, making them seem more like farther locations (i.e., shifting bias rightwards). More specifically, tool-use led to a decrease in slope, without any substantial change in intercept, suggesting that it selectively affected farther locations. Wearing wrist weights also led to a decrease in slope, but with an associated increase in intercept, suggesting that (unlike tool-use) this effort manipulation affected the nearest locations.

Although near space contraction was found when the effort required to act was increased, this effect was specific to the arm. Wearing a heavy backpack, while known to modulate perceived steepness (Bhalla & Proffitt, 1999) and distance (Proffitt et al., 2003), as well as locomotor imagery

[2] As in our previous study (Longo & Lourenco, 2006) and Experiment 1, significant rightward shifts were observed for the subsets of data holding visual angle constant (mean slope, $\beta = 0.236\%$ line length/meter), $t(19) = 4.23$, $p < .001$.

(Decety et al., 1989), did not appear to influence the representation of near space. This specificity is consistent with findings that active wielding of a tool, rather than passive holding, is needed to alter perception (e.g., Farnè & Làdavas, 2000; Witt, Proffitt, & Epstein, 2005), as well as with our previous finding that the size of near space is systematically related to arm length (Longo & Lourenco, 2007). It should be noted that although participants did not directly interact with the stimuli (lines) to be bisected (always responding via a laser pointer), the wrist weight manipulation in the present study can nevertheless be considered active in nature. Participants actively used their weighted arm to make bisection judgments. Future research might examine whether there is still contraction of near space under passive conditions, such as when wrist weights are worn but bisection responses involve verbal judgments.

With respect to the specificity related to the arm, this specificity may not be intrinsic to the representation of near space. It may arise, in part, from particular task demands (i.e., manual line bisection). With tasks that involve actions not related to the arm, there may be a different pattern of effort-related specificity. An alternative (although not mutually exclusive) explanation is that weighting the arm may have altered its *perceived* length. Consistent with this interpretation, Wapner, McFarland, and Werner (1963) found that participants perceived their arms as longer when positioned in front of an open space than when standing in front of a wall. Because perceived arm length was not measured in the present study, this possibility cannot be excluded.

Several lines of evidence suggest anisotropy in the perception of body size. Perceived increases of body size are more frequent and robust than perceived decreases. Such effects have been obtained for proprioceptive biases induced by the rubber hand illusion (Pavani & Zampini, 2007), tactile effects produced by the 'Pinocchio' illusion (de Vignemont, Ehrsson, & Haggard, 2005), as well as delusions of body size associated with migraine (Podoll & Robinson, 2000) and somatosensory epilepsy (Mauguiere & Courjon, 1978). Although there was always a general rightward shift in bias with increasing distance in the present study, this shift was more gradual when participants wore wrist weights, demonstrating a reduction in the size of near space and paralleling the increase we found previously with tool-use in the same paradigm (Longo & Lourenco, 2006). The parallel suggests that the anisotropy between increases and decreases of body size may not apply to the representation of near space.

One intriguing possibility is that this difference may reflect the distinction between explicit and implicit body representations, such as that between *body image* and *body schema* (cf. Gallagher, 1986). Whereas body image refers to a conscious representation of the physical structure of the body, body schema refers to a generally unconscious representation of the position of body parts in space used to guide action. The effects related to the anisotropy in the perception of body size involve changes to the conscious perception of the body, suggesting a connection to the body image. The representation of near space, however, may be unconscious and related to more implicit body representations, which may function to guide visuomotor action (Farne, Iriki, & Ladavas, 2005) or defend the body surface (Graziano & Cooke, 2006). Although not necessarily mutually exclusive, these two proposed functions provide very different perspectives on the nature of near space representation. In showing that changes to the body itself (i.e., weighting the arms) alter the perception of external space, the present results highlight the role of near space in guiding visuomotor action. It is unknown, however, how visuomotor representations overlap or interact with representations subserving reactions to noxious or threatening stimuli (Graziano & Cooke, 2006), suggesting an important area for future research.

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References

Berti, A., & Frassinetti, F. (2000). When far becomes near: Remapping of space by tool use. *Journal of Cognitive Neuroscience, 12*, 415–420.
Bhalla, M., & Proffitt, D. R. (1999). Visual–motor recalibration in geographical slant perception. *Journal of Experimental Psychology: Human Perception and Performance, 25*, 1076–1096.
Brain, W. R. (1941). Visual disorientation with special reference to lesions of the right cerebral hemisphere. *Brain, 64*, 244–272.
de Vignemont, F., Ehrsson, H. H., & Haggard, P. (2005). Bodily illusions modulate tactile perception. *Current Biology, 15*, 1286–1290.
Decety, J., Jeannerod, M., & Prablanc, C. (1989). The timing of mentally represented actions. *Behavioural Brain Research, 34*, 35–42.
Farne, A., Iriki, A., & Ladavas, E. (2005). Shaping multisensory action-space with tools: Evidence from patients with cross-modal extinction. *Neuropsychologia, 43*, 38–248.
Farnè, A., & Làdavas, E. (2000). Dynamic size-change of hand peripersonal space following tool use. *NeuroReport, 11*, 1645–1649.
Fogassi, L., Gallese, V., Fadiga, L., Luppino, G., Matelli, M., & Rizzolatti, G. (1996). Coding of peripersonal space in inferior premotor cortex (area F4). *Journal of Neurophysiology, 76*, 141–157.
Gallagher, S. (1986). Body image and body schema: A conceptual clarification. *Journal of Mind and Behavior, 7*, 541–554.
Gamberini, L., Seraglia, B., & Priftis, K. (2008). Processing of peripersonal and extrapersonal space using tools: Evidence from visual line bisection in real and virtual environments. *Neuropsychologia, 46*, 1298–1304.
Graziano, M. S. A., & Cooke, D. F. (2006). Parieto–frontal interactions, personal space, and defensive behavior. *Neuropsychologia, 44*, 845–859.
Hall, E. T. (1966). *The hidden dimension*. Garden City, NY: Doubleday.
Halligan, P. W., Fink, G. R., Marshall, J. C., & Vallar, G. (2003). Spatial cognition: Evidence from visual neglect. *Trends in Cognitive Sciences, 7*, 125–133.
Holmes, N. P., Calvert, G. A., & Spence, C. (2004). Extending or projecting peripersonal space with tools? Multisensory interactions highlight only the distal and proximal ends of tools. *Neuroscience Letters, 372*, 62–67.
Holmes, N. P., Calvert, G. A., & Spence, C. (2007). Tool use changes multisensory interactions in seconds: Evidence from the crossmodal congruency task. *Experimental Brain Research, 183*, 465–476.
Iriki, A., Tanaka, M., & Iwamura, Y. (1996). Coding of modified body schema during tool use by macaque postcentral neurons. *NeuroReport, 7*, 2325–2330.
Jewell, G., & McCourt, M. E. (2000). Pseudoneglect: A review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia, 38*, 93–110.
Longo, M. R., & Lourenco, S. F. (2006). On the nature of near space. Effects of tool use and the transition to far space. *Neuropsychologia, 44*, 977–981.
Longo, M. R., & Lourenco, S. F. (2007). Space perception and body morphology: Extent of near space scales with arm length. *Experimental Brain Research, 177*, 285–290.

Maravita, A., Husain, M., Clarke, K., & Driver, J. (2001). Reaching with a tool extends visual–tactile interactions into far space. Evidence from cross-modal extinction. *Neuropsychologia, 39*, 580–585.
Maravita, A., Spence, C., Kennett, S., & Driver, J. (2002). Tool-use changes multimodal spatial interactions between vision and touch in normal humans. *Cognition, 83*, B25–B34.
Mauguiere, F., & Courjon, J. (1978). Somatosensory epilepsy: A review of 127 cases. *Brain, 101*, 307–332.
Pavani, F., & Zampini, M. (2007). The role of hand size in the fake-hand illusion paradigm. *Perception, 36*, 1547–1554.
Podoll, K., & Robinson, D. (2000). Macrosomatognosia and microsomatognosia in migraine art. *Acta Neurologica Scandanavica, 101*, 413–416.
Proffitt, D. R. (2006). Embodied perception and the economy of action. *Perspectives on Psychological Science, 1*, 110–122.
Proffitt, D. R., Stefanucci, J., Banton, T., & Epstein, W. (2003). The role of effort in perceiving distance. *Psychological Science, 14*, 106–112.
Rizzolatti, G., Matelli, M., & Pavesi, G. (1983). Deficits in attention and movement following the removal of postarcuate (area 6) and prearcuate (area 8) cortex in macaque monkeys. *Brain, 106*, 655–673.
Serino, A., Bassolino, M., Farnè, A., & Làdavas, E. (2007). Extended multisensory space in blind cane users. *Psychological Science, 18*, 642–648.
Sommer, R. (1969). *Personal space. The behavioral basis of design*. Englewood Cliffs, NJ: Prentice-Hall.
Varnava, A., McCarthy, M., & Beaumont, J. G. (2002). Line bisection in normal adults: Direction of attentional bias for near and far space. *Neuropsychologia, 40*, 1372–1378.
Wapner, S., McFarland, J. H., & Werner, H. (1963). Effect of visual spatial context on perception of one's own body. *British Journal of Psychology, 54*, 41–49.
Weiss, P. H., Marshall, J. C., Zilles, K., & Fink, G. R. (2003). Are action and perception in near and far space additive or interactive factors? *NeuroImage, 18*, 837–846.
Witt, J. K., Proffitt, D. R., & Epstein, W. (2004). Perceiving distance. A role of effort and intent. *Perception, 33*, 577–590.
Witt, J. K., Proffitt, D. R., & Epstein, W. (2005). Tool use affects perceived distance, but only when you intend to use it. *Journal of Experimental Psychology: Human Perception and Performance, 31*, 880–888.