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Within Reach but not so Reachable: Obstacles Matter in Visual Perception of Distances

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Abstract

A large number of studies show that effort influences visual perception of reaching distance. These studies mainly focused on the effect of reach-relevant properties of the body and the object that people intend to reach. However, the influence of reach-relevant properties of the surrounding environment remains still speculative. We investigated this aspect through the role of obstacle width in perceived distances. Participants had to estimate the straight-line distance to a cylinder located just behind a transparent barrier of varying width. Results showed that participants perceived the straight-line distance to the cylinder as being longer when they intended to grasp it by reaching around a wide transparent barrier than by reaching around narrower ones. Interestingly, this effect might be due to the anticipated reaching effort. Together our results show that reach-relevant properties of the surrounding environment influence perceived distances, thereby supporting an embodied view of visual perception of space.

Keywords. Distance perception, peripersonal space, economy of action, effort, perception-action link

Within Reach but not so Reachable: Obstacles Matter in Visual Perception of Distances

When you reach around a water bottle to grasp a soda placed just behind it, the distance you have to cover depends on the bottle width. Even if variations of the bottle width imply different reaching distances, the distance in a straight line between your hand and the soda (i.e., the Euclidean distance) remains identical. According to modular approaches (e.g., Pylyshyn, 1999), the intended reaching distance should not influence your visual perception of the Euclidean distance since effort or intentions are not supposed to influence vision. Researchers from these approaches argued that if there is any influence of action capabilities it necessarily operates at the response stage and not at the perceptual one (Durgin et al., 2009; Woods, Philbeck, & Danoff, 2009).

In contrast, an embodied view (e.g., Glenberg, 2010) of perception, namely the economy of action account (Proffitt, 2006; for somewhat similar views see also Coello & Delevoye-Turrell, 2007; Jackson & Cormack, 2007), posits that the effort associated with intended actions influences visual perception of space. The rationale of this account is that sensory motor systems have evolved under evolutionary pressures that promote minimizing action costs like energy expenditure. For instance, reducing arm’s reach with wrist weights (Lourenco & Longo, 2009), or making an object harder to grasp by manipulating the orientation of its handle (Linkenauger, Witt, Stefanucci, Bakdash, & Proffitt, 2009) leads people to perceive it as being farther away. Conversely, people perceive an object beyond reach as being closer when they intend to reach it with a baton extending their arm’s reach than when they intend to reach without this tool (Witt, Proffitt, & Epstein, 2005). These results suggest that modifications of reach-relevant properties of the body (i.e., arm’s reach) and the objects people intend to reach (i.e., handle orientation) influence perceived Euclidean distances. However, it remains speculative to argue that these results can be generalized to the influence of reach-relevant properties of the surrounding environment.

Studies about the influence of tool use on perceived distance provides preliminary insights into this question. Tools are objects from the surrounding environment that can improve ability to act, influencing space perception even in situations where these objects are not explicitly defined as tools (Osiurak, Morgado, & Palluel-Germain, 2012). However, such effects of tool use probably rely on an extension of arm's reach associated with an updating of the body schema (e.g., Cardinali et al., 2009), that is, a reach-relevant property of the body but not a property of the environment per se. Unlike tools, obstacles are part of the surrounding environment, so they are not supposed to directly affect body or target properties. Instead, obstacles mediate the relationship between the body and the target. For this reason, obstacles are particularly relevant to study the influence of reach-relevant properties of the surrounding environment without modifying body and target properties. In line with the economy of action account, we expected and we observed that intending to grasp a cylinder by reaching around a transparent barrier lead participants to estimate differently the Euclidean distance to this cylinder depending on the barrier width.

Method

Participants

Twenty right-handed undergraduates (19 females, M_{age} = 21.75, SD_{age} = 3.34) from the University of Grenoble took part in this experiment for course credit. The handedness of the participants was assessed by self-report and with the Edinburgh Handedness Survey (Oldfield, 1971; M = 85.47, SD = 16.26). Participants had normal or corrected-to-normal vision as indicated by self-report. The present study was conducted in accordance with the Declaration of Helsinki and with the understanding and the written consent of each participant. It was approved by the local ethics committee of the LPNC (CNRS and University of Grenoble).

Apparatus and Procedure

Participants sat approximately 5 cm away from the edge of a rectangular table (length: 144 cm, width: 125 cm, height: 77 cm). They had to estimate the Euclidean distance (43 cm, 40 cm, 37 cm, or 34 cm) between their right forefinger and a plastic cylinder (height: 9 cm; diameter: 3.2 cm) by a visual-matching task (for a similar measure see Osiurak et al., 2012; Witt et al., 2005). Using the arrows from a keyboard with their left hand, they adjusted the distance between their finger kept on a reference point and a comparison point projected onto the table until it matched the Euclidean distance between their finger and the cylinder (Figure 1). The reference point and the cylinder were aligned on the mid-sagittal axis of the participants. The comparison point was projected upon the table at a 45° angle from the mid-sagittal axis in the right or left hemifield of the participant. The initial distance between the comparison point and the reference point was randomly equal to either ± 25% of the distance between the cylinder and the reference point. The cylinder was presented at 10 cm behind a transparent barrier (height: 25 cm) of variable widths (wide: 30 cm, medium: 20 cm, or narrow: 10 cm). The transparent barrier allowed participants to clearly see the cylinder but was intended to increase the anticipated reaching effort depending on its width. It is important to note that before each distance estimation participants had to imagine a reach-to-grasp movement to the cylinder. This was done because some studies showed that the ability to perform an action influences perceived distance when people intend to carry out this action (Witt et al., 2005) and that imagined actions influence perceived distances in a same way (Witt & Proffitt, 2008).In order to reduce between-subject variability in the imagined movement, participants actually performed this movement five times before the visual-matching task. More precisely, on another table, they reached around a transparent barrier (height: 25 cm, width: 15 cm) to grasp the cylinder presented at 23 cm from a constant initial position. This movement was executed without leaning forward and with the shoulders against the back of the chair. Moreover, to avoid merely priming effort, this barrier width and this distance used during this task allowed participants to easily reach and grasp the cylinder with minimal reaching effort.

After this motor task, participants performed the visual matching task as described previously. They first performed four training trials randomly selected among the 12 of distance-width pairs. Then, they completed two estimations for each of these pairs, one with the comparison point in their right and one with the comparison point in their left hemifield. These 24 test trials were randomly presented. At the end of each trial, participants masked their eyes with their hands to allow the experimenter to adjust the apparatus for the next trial. To prevent the use of proprioceptive and kinesthetic cues of perceived distances provided by actual movements, participants never reach over the table during the 28 distance estimations. Cues projected onto the table allowed the experimenter to install the cylinder with the appropriate barrier width at the appropriate distance.

/insert Figure 1 about here/

After this visual-matching task, the experimenter interviewed the participants to determine whether they suspected the goal of the experiment using a post-experimental questionnaire[1]. Finally, participants also rated their anticipated reaching effort for each barrier width on a 4-point scale (1: no effort to 4: strong effort). For this effort manipulation check, the cylinder was randomly presented with each of the three barrier widths at 24 cm from the reference point. In addition, since perceived and actual size of the body influence space perception (Stefanucci & Geuss, 2009; van der Hoort, Guterstam, & Ehrsson, 2011;

[1] The experimenter asked two questions to the participants: (1) In your opinion what hypothesis is tested in this study? (2) Do you think that some aspects of the experiment could have influenced your responses? If so, what were these aspects?

Linkenauger, Witt, & Proffitt, 2011), the experimenter also recorded the perceived and actual length of the right and left arms of each participant. The arm length estimations were recorded following a visual-matching task used by Linkenauger, Witt, Bakdash, Stefanucci, and Proffitt (2009) in a counterbalanced order. For each of their arms, participants had to estimate the distance between the protrusion of their shoulder and the tip of their forefinger. Then, the experimenter measured this distance to obtain the actual length of each arm. The effort manipulation check and the measure of the actual and perceived arm's lengths were done after the post-experimental questionnaire. This aimed to ensure that the post-experimental questionnaire reflects as much as possible the suspicion resulting from the visual-matching task and not those potentially produced by these additional measures.

Results

According to the two questions asked to the participants about our hypothesis, no participant indicated that they suspected that we were testing the effect of reaching constraints on visual perception of distances. We conducted a two-way ANOVA with Actual Distance (43 cm, 40 cm, 37 cm, and 34 cm) and Barrier Width (wide: 30 cm, medium: 20 cm, and narrow: 10 cm) as within-subject factors, and Perceived Euclidean Distance as dependent variable. To avoid the frequent problem of sphericity assumption, we separate this ANOVA into a group of orthogonal contrasts with one degree of freedom (Judd, McClelland, & Ryan, 2009)[2]. This principle was also used for the subsequent analyses. The main effect of the Actual Distance was significant, as indicated by the significant linear contrast, $F(1, 19) = 847.79$, $p < .001$, $\eta^2 = .98$, and the non-significant quadratic and cubic contrasts tested together, $F(1,38) = 2.92$, $p = .096$, $\eta^2 = .07$. More interestingly, there was also a significant

[2] An omnibus ANOVA was also performed and yielded similar results for the effect of Actual Distance, $F(3, 57) = 348.26$, $p < .001$, $\eta^2 = .95$, and Barrier Width, $F(2, 38) = 3.34$, $p = .02$, $\eta^2 = .19$. However the interaction between Actual Distance and Barrier Width was not significant with this omnibus ANOVA, $F(6, 114) = 1.16$, $p = .33$, $\eta^2 = .06$, whereas it was marginal when testing it with contrast analysis which is known to be a more powerful and conservative test than the omnibus ANOVA (Judd et al., 2009).

effect of the Barrier Width as indicated by the significant linear contrast, $F(1, 19) = 4.43$, $p = .049$, $\eta^2 = .19$, and the non-significant quadratic contrast, $F(1, 19) = 3.81$, $p = .066$, $\eta^2 = .17$. Supplemental analyses using Bonferroni correction revealed that the distance overestimation was significant between the wide ($M = 41.62$ cm, $SD = 2.86$) and the narrow barrier ($M = 40.42$ cm, $SD = 2.69$), $p = .026$, and was marginal between the wide and the medium one ($M = 40.63$ cm, $SD = 2.51$), $p = .088$. However, distance estimation for the medium and the narrow barriers was not significantly different, $p > .9$. The interaction between the Barrier Width and the Actual Distance was marginal as indicated by the significant linear contrast, $F(1, 19) = 4.23$, $p = .054$, $\eta^2 = .18$, and the non-significant residual contrast, $F(1, 95) = 1.39$, $p = .24$, $\eta^2 = .01$. This was partly due to the fact that the effect of the Barrier Width was not significant for the shortest distance, $F(1, 19) = .32$, $p = .58$, $\eta^2 = .02$, whereas it was significant for the three longest distances, ps < .05 (Figure 2).

Concerning the effort manipulation check, we conducted a one-way ANOVA with Barrier Width as within-subject factor and with the rating of Anticipated Reaching Effort as dependent variable. We observed that the Anticipated reaching Effort increased significantly with the Barrier Width, $F(1, 19) = 69.28$, $p < .001$, $\eta^2 = .78$. However, this increase was significantly greater between the medium and the wide barrier ($M = 1.2$, $SD = .77$) than between the narrow and the medium one ($M = .7$, $SD = .66$), $F(1, 19) = 5$, $p = .038$, $\eta^2 = .21$. Additionally, we found a significant difference between the perceived length of the right arm ($M = 57.27$ cm, $SD = 8.33$) and those of the left one ($M = 54.76$ cm, $SD = 7.17$), $F(1,19) = 7.04$, $p = .02$, $\eta^2 = .27$. In contrast, such difference was not significant between the actual length of the right arm ($M = 68.12$ cm, $SD = 3.39$) and those of the left one ($M = 68.19$ cm, $SD = 3.53$), $F(1,19) = .06$, $p = .8$, $\eta^2 = .003$. Interestingly, this asymmetry in perceived arm length is consistent with those found by Linkenauger, Witt, Bakdash, et al. (2009). However entering the perceived or actual right arm length as covariate in the analysis did not significantly modify the results reported above concerning the influence of barrier width on perceived distances.

/insert Figure 2 about here/

Discussion

In the present study, participants perceived longer Euclidean distances to the cylinder in presence of the wide barrier than in presence of the medium and the narrow barriers. As suggested by the effort manipulation check analysis, this might reflect that the difference of anticipated reaching effort between the wide barrier and the two others was greater than those between the medium and the narrow barriers. However, further studies will have to confirm this interpretation by using a more subtle measure of the anticipated effort (e.g., Rosenbaum & Gaydos, 2008). In contrast, one could argue that our results might be explained in terms of demand characteristics. Against such an explanation, it could be argued that the post-experimental questionnaire would have allowed us to detect participants suspecting our hypothesis. Moreover, a difference in perceived distance between the medium and the narrow barrier would have been observed and we should not have observed a marginal interaction between barrier width and actual distance. In spite of these arguments, we agree that the potential implication of demand characteristics in such experiments remains an important concern (Durgin et al., 2009). Notably, the use of implicit manipulations of effort, the use of indirect measures of perceived distances, and the use of a different type of post-experimental questionnaire might be relevant to deal with this concern in future studies. The absence of difference in perceived distance between the medium and the narrow barrier also rules out an interpretation in terms of distance segmentation produced by the barrier as shown in previous study on environmental effects on distance perception (e.g., Nasar, 1983; Witt, Stefanucci, Riener, & Proffitt, 2007).

Consistent with the economy of action account, the marginal interaction between the actual distance and the barrier width could reflect that the effort required to reach around the wide barrier increases with the actual distance. Such interaction effect was also observed by Lessard, Linkenauger, and Proffitt (2009) who showed that increasing physical constraints of an intended action influences distance perception merely when the constraints substantially affect action capabilities. Further studies are needed to directly test this hypothesis. In addition, our results corroborate previous studies on motor control indicating that biomechanical costs associated with going around or above obstacles play an important role in motor planning for reaching (Cohen, Biddle, & Rosenbaum, 2010) as well as for walking (Patla & Rietdyk, 1993). More generally, as stated by Sparrow and Newell (1998), planning and performing adaptive action seem to be function of the organism's propensity to minimize energy expenditure regarding the task, environment, and organism constraints to action. Consistent with this statement, perceptual effects such as found in the present study could have an important role in an economic action planning (Proffitt, 2006).

Detractors of the economy of action account argued that such variability of space perception is unlikely to occur independently of response bias since an illusory perception of the environment would be dysfunctional for an adaptive control of action (Durgin, Ruff, & Russell, 2012). However, recent studies suggest that such top-down effects of action on perception have an adaptive function by influencing action in return. For instance, Elliott, Vale, Whitaker, and Buckley (2009; see also Witt, Linkenauger, & Proffitt, 2012) showed that increasing the perceived height of a stair by a visual illusion lead people to adopt a safer stepping strategy to avoid tripping. Therefore, perceptual effects resulting from the tendency to minimize action costs might be highly adaptive for action planning by promoting larger safety margin. Conversely, perceptual effects resulting from the overestimation of one own capabilities might have many detrimental effects by increasing risky behaviors. Luyat, Domino, and Noël (2008) provided a compelling example of such tendencies by observing that older adults tend to overestimate their ability to stay in an incline surface without falling, suggesting that this perceptual tendency could lead to an increase of falling risks.

Perceived Euclidean distances are influenced by modifications of reach-relevant properties of the body and the objects people intend to reach, like arm's reach (Lourenco & Longo, 2009; Witt et al., 2005) or handle orientation (Linkenauger, Witt, Stefanucci, et al., 2009) respectively. Here, we observed that obstacle width plays a role in this perception as a reach-relevant property of the surrounding environment. These results provide a strong support to the claim that action costs influence visual perception (Proffitt, 2006) which appears as a more penetrable process than it is usually assumed. Of course, further studies will have to determine exactly what cognitive processes underlie the effect observed in the present study. It has been shown that both motor simulation (Witt & Proffitt, 2008) and visual attention (Cañal-Bruland, Zhu, Van der Kamp, & Masters, 2011) are implicated in action effect on space perception. How these processes interact with visual perception to produce these effects remains an open issue. Another interesting research perspective consists in extending the rationale of the economy of action account to social cognition. Recent evidences suggest that this perspective is promising since it was reported that psychosocial resources and costs influence visual perception (Harber, Yeung, & Iacovelli, 2011; Morgado, Muller, Gentaz, & Palluel-Germain, 2011; Schnall, Harber, Stefanucci, & Proffitt, 2008; for reviews see Balcetis & Lassiter, 2010; Schnall, 2011; Stefanucci, Gagnon, & Lessard, 2011).

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References

Balcetis, E., & Lassiter, G. D. (2010). *Social Psychology of Visual Perception*. New York: Psychology Press.

Cañal-Bruland, R., Zhu, F. F., Van der Kamp, J., & Masters, R. S. W. (2011). Target-directed visual attention is a prerequisite for action-specific perception. *Acta Psychologica, 136*(3), 285-289.

Cardinali, L., Frassinetti, F., Brozzoli, C., Urquizar, C., Roy, A. C., & Farnè, A. (2009). Tool-use induces morphological updating of the body schema. *Current Biology, 19*(12), R478-R479.

Coello, Y., & Delevoye-Turrell, Y. (2007). Embodiment, spatial categorisation and action. *Consciousness and cognition, 16*(3), 667-683.

Cohen, R. G., Biddle, J. C., & Rosenbaum, D. A. (2010). Manual obstacle avoidance takes into account visual uncertainty, motor noise, and biomechanical costs. *Experimental Brain Research, 201*(3), 587-592.

Cousineau, D. (2005). Confidence intervals in within-subject designs: A simpler solution to Loftus and Masson's method. *Tutorial in Quantitative Methods for Psychology, 1*(1), 42-45.

Durgin, F. H., Baird, J. A., Greenburg, M., Russell, R., Shaughnessy, K., & Waymouth, S. (2009). Who is being deceived? The experimental demands of wearing a backpack. *Psychonomic Bulletin & Review, 16*(5), 964-969.

Durgin, F. H., Ruff, A. J., & Russell, R. (2012). Constant enough: On the kinds of perceptual constancy worth having. In G. Hatfield & S. Allred (Eds.), *Visual Experience*: Oxford University Press.

Elliott, D. B., Vale, A., Whitaker, D., & Buckley, J. G. (2009). Does my step look big in this? A visual illusion leads to safer stepping behaviour. *PloS One, 4*(2), 2159-2168.

Glenberg, A. (2010). Embodiment as a unifying perspective for psychology. *Wiley Interdisciplinary Reviews: Cognitive Science, 1*(4), 586-596.

Harber, K. D., Yeung, D., & Iacovelli, A. (2011). Psychosocial resources, threat, and the perception of distance and height: Support for the resources and perception model. *Emotion, 11*(5), 1080-1090.

Jackson, R. E., & Cormack, L. K. (2007). Evolved navigation theory and the descent illusion. *Attention, Perception, & Psychophysics, 69*(3), 353-362.

Judd, C. M., McClelland, G. H., & Ryan, C. S. (2009). *Data analysis: A model comparison approach*: Routledge/Taylor & Francis Group.

Lessard, D. A., Linkenauger, S. A., & Proffitt, D. R. (2009). Look before you leap: Jumping ability affects distance perception. *Perception, 38*(12), 1863-1866.

Linkenauger, S. A., Witt, J. K., Bakdash, J. Z., Stefanucci, J. K., & Proffitt, D. R. (2009). Asymmetrical Body Perception: A possible role for neural body representations. *Psychological Science, 20*(11), 1373-1380.

Linkenauger, S. A., Witt, J. K., & Proffitt, D. R. (2011). Taking a hands-on approach: Apparent grasping ability scales the perception of object size. *Journal of Experimental Psychology: Human Perception and Performance, 37*(5), 1432-1441.

Linkenauger, S. A., Witt, J. K., Stefanucci, J. K., Bakdash, J. Z., & Proffitt, D. R. (2009). The effects of handedness and reachability on perceived distance. *Journal of Experimental Psychology: Human Perception and Performance, 35*(6), 1649-1660.

Lourenco, S. F., & Longo, M. R. (2009). The plasticity of near space: Evidence for contraction. *Cognition, 112*(3), 451-456.

Luyat, M., Domino, D., & Noël, M. (2008). Surestimer ses capacités peut-il conduire à la chute? Une étude sur la perception des affordances posturales chez la personne âgée. *Psychologie & NeuroPsychiatrie du vieillissement, 6*(4), 287-297.

Morgado, N., Muller, D., Gentaz, E., & Palluel-Germain, R. (2011). Close to me? The influence of affective closeness on space perception. *Perception, 40*(7), 877-879.

Nasar, J. L. (1983). Environmental factors, perceived distance and spatial behavior. *Environment and Planning B: Planning and Design, 10*(3), 275-281.

Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia*, *9*(1), 97-113.

Osiurak, F., Morgado, N., & Palluel-Germain, R. (2012). Tool use and perceived distance: When unreachable becomes spontaneously reachable. *Experimental Brain Research, 218*(2), 331-339.

Patla, A. E., & Rietdyk, S. (1993). Visual control of limb trajectory over obstacles during locomotion: effect of obstacle height and width. *Gait & Posture, 1*(1), 45-60.

Proffitt, D. R. (2006). Embodied perception and the economy of action. *Perspectives on Psychological Science, 1*, 110-122.

Pylyshyn, Z. (1999). Is vision continuous with cognition?: The case for cognitive impenetrability of visual perception. *Behavioral and brain sciences, 22*(03), 341-365.

Rosenbaum, D. A., & Gaydos, M. J. (2008). A method for obtaining psychophysical estimates of movement costs. *Journal of Motor Behavior, 40*(1), 11-17.

Schnall, S. (2011). Embodiment in affective space: Social influences on the perception of spatial layout. In A. Maas & T. Schubert (Eds.), *Spatial dimensions of social thought* (pp. 129-152). Berlin: De Gruyter.

Schnall, S., Harber, K. D., Stefanucci, J. K., & Proffitt, D. R. (2008). Social support and the perception of geographical slant. *Journal of Experimental Social Psychology, 44*(5), 1246-1255.

Sparrow, W. A., & Newell, K. M. (1998). Metabolic energy expenditure and the regulation of movement economy. *Psychonomic Bulletin & Review, 5*(2), 173-196.

Stefanucci, J. K., Gagnon, K. T., & Lessard, D. A. (2011). Follow Your Heart: Emotion Adaptively Influences Perception. *Social and Personality Psychology Compass, 5*(6), 296-308.

Stefanucci, J. K., & Geuss, M. N. (2009). Big people, little world: The body influences size perception. *Perception*, *38*(12), 1782–1795.

Van der Hoort, B., Guterstam, A., & Ehrsson, H. H. (2011). Being Barbie: The size of one's own body determines the perceived size of the world. *PloS One*, *6*(5): e20195.

Witt, J. K., Linkenauger, S. A., & Proffitt, D. R. (2012). Get me out of this slump! Visual illusions improve sports performance. *Psychological Science*, *23*(4), 397-399.

Witt, J. K., & Proffitt, D. R. (2008). Action-specific influences on distance perception: A role for motor simulation. *Journal of Experimental Psychology: Human Perception and Performance, 34*(6), 1479-1492.

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*(5), 880-888.

Witt, J. K., Stefanucci, J. K., Riener, C. R., & Proffitt, D. R. (2007). Seeing beyond the target: Environmental context affects distance perception. *Perception, 36*(12), 1752-1768.

Woods, A. J., Philbeck, J. W., & Danoff, J. V. (2009). The various perceptions of distance: an alternative view of how effort affects distance judgments. *Journal of Experimental Psychology: Human Perception and Performance, 35*(4), 1104-1117.

Figures

Figure 1. Schematic representation of the visual-matching task. Participants had to put their right forefinger on the reference point (R) throughout the visual-matching task. Then, they had to judge the Euclidean distance between their finger and the cylinder by a visual-matching task. Using the arrows from a keyboard with their left hand, they adjusted the distance between the reference point and a comparison point (C) projected onto the table until it matched the Euclidean distance between their finger and the cylinder. The cylinder was presented at 10 cm behind a transparent barrier (height: 25 cm) of variable widths (wide: 30 cm, medium: 20 cm, or narrow: 10 cm).

Figure 2. Perceived distance as a function of actual distance and barrier width. Error bars denote standard errors of the mean corrected for between-subject variability (Cousineau, 2005).

Figure 1

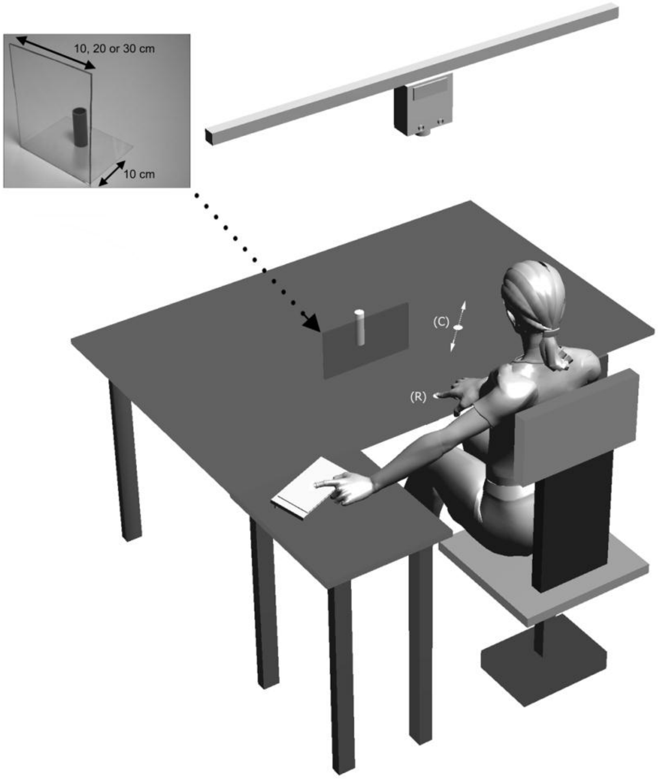
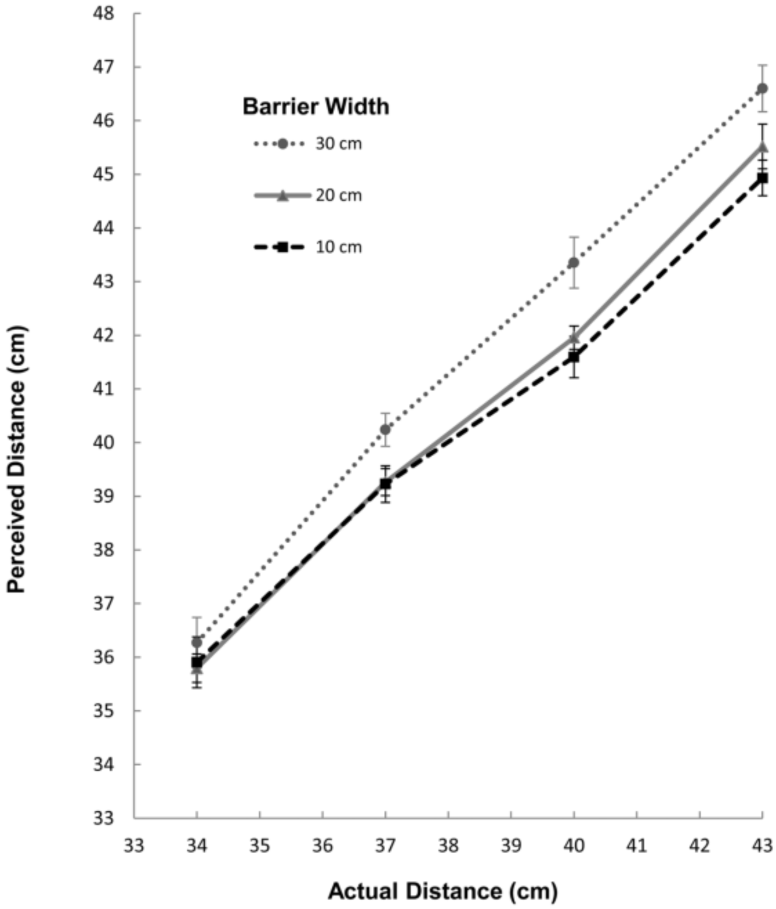


Figure 2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