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Big People, Little World: The Body Influences Size Perception

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Abstract

Previous research has shown that changes to the body can influence the perception of distances in near space (Witt et al 2005). In this paper, we question whether changes to the body can also influence the perception of extents in extrapersonal space, namely the perception of aperture widths. In experiment 1, broad-shouldered participants visually estimated the size of apertures to be smaller than narrow-shouldered participants. In experiment 2, we questioned whether changes to the body, which included holding a large object, wearing a large object, or simply holding out the arms would influence perceived width. Surprisingly, we found that only when participants' hands were widened was extrapersonal space rescaled. Experiment 3 explored the boundaries of the effect observed in experiment 2 by asking participants to hold their arms at different positions to locate the arm width at which apertures appeared smaller. We found that arm positions that were larger than the shoulder width made apertures appear smaller. The results suggest that dimensions of the body play a role in the scaling of environmental parameters in extrapersonal space.

Keywords

body size; aperture perception; perception of spatial layout; embodied perception

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Driving into a parking space in an SUV (sport utility vehicle) can be a somewhat complicated and daunting task when compared to parking a small sports car. Anecdotally, we have experienced situations in which driving a larger vehicle than we are accustomed to makes parking spaces appear much smaller. This paper will provide experimental evidence that suggests that this anecdotal experience is a perceptual reality. Instead of manipulating the width of the observer by placing them in a large or small vehicle, we had them hold objects of different sizes or simply hold out their arms to be wider than normal. We then asked them to estimate a series of aperture widths. We believe that when the body is widened (by holding a large object or by holding out the arms) observers' will adaptively rescale the perceived size of the environment to be smaller.

The Body and the Perception of Near Space

Previous research has shown that the ability to act on or perform actions within an environment contributes to the perception of the body. This perception of the body can be altered by changing the action abilities of the observer, like giving them a rake to retrieve food or a baton to reach a target (Iriki et al 1996; Kinsbourne 1995; Reed and Farah 1995; Witt et al 2005). These alterations, among others, can result in a change in the perceived space surrounding the observer, known as peripersonal or near space (Cutting and Vishton

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1995; Rizzolatti et al 1997). These claims are supported by both behavioral and neuroscience studies.

Recent research shows that preexisting differences in perceived body size can influence the perception of size and length. Linkenauger et al (forthcoming) found that right-handed observers perceived their right hands to be larger than their left, and therefore estimated that they could grasp larger objects with their right hand. Also, right-handers perceived their right arms to be longer than their left, which translated to increases in the extent to which they believed they could reach to objects with their right arm as opposed to their left. The authors argued that asymmetries in the sizes of the sensory cortices for the right and left hand (right-handers have a larger representation in their sensory cortices for their right hand than their left) could underlie the perceptual differences observed in their studies.

Other work has shown that overt changes to the size of the body can also influence the perception of space. For example, when arm length is extended by asking an observer to hold a baton, near space is rescaled in order to take this extension into account when planning or performing actions. Specifically, Witt et al (2005) showed that when participants held a baton (which extended their reach) the distance to an object was perceived as shorter than when they did not hold a baton. Also, this decrease in distance estimation only occurred when the observer *intended* to use the baton to reach towards the object. Their research suggests that the perception of near space is influenced by changes in the actions a body can perform, but only when the observer intends to use an object that changes the dimensions of the body.

Similarly, neurological and electrophysiological research supports the claim that a change in the body's ability to act can result in a change in the spatial representations that may underlie the perception of near space (Imamizu et al 2000; Inoue et al 2001). Iriki et al (1996) conducted an electrophysiological study with monkeys, which found evidence for changes in spatial representations in the brain when the body was altered. Certain neurons within the intraparietal lobe fired only when a specific target (in their study, a raisin) was in reach. After training monkeys to use a rake to reach for the raisin (which now put former out-of-reach raisins in reach) they found that the same neurons fired when the raisin was placed within reach of the rake. This research suggests that the brain may be able to quickly integrate changes in body size in order to act in reachable space (but see, Holmes et al 2004 for an argument that neurons may be remapping space, rather than integrating a tool). Evidence from patient research in humans also suggests that holding a tool remaps the perception of far-to-near space in cases of visuospatial neglect, a disorder that results in a tendency to ignore part of the visual field, (Berti and Frassinetti 2000).

The Body and the Perception of Apertures

The aforementioned studies suggest that changing the abilities of the observer rescales the perception of near or peripersonal space. Is there evidence to suggest that the same holds true for objects or dimensions in *extrapersonal* space? J.J. Gibson (1979) stated that perception is the pick up of information about opportunities for action. Recognizing what the environment *affords* the observer necessarily involves perceiving complementary environmental and body characteristics (Gibson 1979; Warren 1984). The organism must be capable of perceiving the action opportunities that the environment affords to adjust their behaviors and actions accordingly (Oudejans et al 1996).

A number of studies examining affordance judgments for aperture widths (specifically doorways of various sizes) have suggested that the size of one's body can influence judgments of passage through the aperture. One such study by Warren and Whang (1987) recorded different sized men walking through a variety of aperture widths. They found that broad-shouldered men needed to rotate their shoulders at larger aperture widths than narrow-shouldered men. However, both broad- and narrow-shouldered men began to rotate their shoulders when walking through an aperture that was 1.3 times the size of their shoulders, which suggests that both groups scaled their actions to their body dimensions. This rotation also suggests that individuals allow for a margin of safety appropriate to their body size when acting on an aperture.

Similarly, Wagman and Taylor (2005) investigated judgments of passage through an aperture when observers held wide objects. They asked participants to either hold T-shaped objects of varying size or to view the objects (without holding them) and to judge whether they could pass through an aperture when holding the objects. They found that participants were sensitive to the object width (indicating they could not pass through when they wielded large objects) when judging locomotion through an aperture in both the vision and touch conditions. The results suggest that judgments of passage through extrapersonal space (apertures) are scaled to the widest dimension of the participants (when holding or anticipating holding an object).

Collectively, these results suggest that the perception of the environment, specifically decisions about action, can be influenced by a change in the body's width. However, these observed changes in action may be due, in part, to a rescaling of perceived layout. For example, Warren and Whang (1987) found broad-shouldered men turned more when walking through a doorway than smaller men. In addition to acting as if the aperture was smaller, did these larger men actually *see* the aperture as smaller?

Overview of Current Studies

The current studies address several open questions derived from the previous research on the perception of affordances for apertures in extrapersonal space. First, the research on perceiving affordances for aperture crossing is rich, but none of the studies measured participants' visual perception of the width of the aperture outside of a motor decision or judgment of affordance for passage. Therefore, we examined whether participants of different widths and participants who experienced a change in body size would perceive the aperture widths to be different sizes. We used a visual matching task to obtain participants' perceptions of the size of aperture widths across multiple trials. We hypothesized that people with larger bodies would estimate apertures to be smaller than those with smaller bodies. Similarly, increasing the size of the body may result in a decrease in the perceived size of the aperture. If the body is used to rescale the perception of the environment, then we suspect it will be used for all situations in which the body is altered. We believe this is important to test because the perception of the aperture width could influence later motor decisions as measured in the experiments on the affordances of apertures.

Experiment 1

In this experiment, we tested whether broad- and narrow-shouldered participants would estimate the size of apertures to be different given their different sizes. Warren and Whang (1987) found that broad- and narrow-shouldered participants scaled their judgments of passage from a static viewing position to the sizes of their bodies. We sought to confirm that the perceived size of apertures, as assessed with a visual matching task, would also be affected by the size of the observer's body. We hypothesized that broad-shouldered observers would visually match the size of apertures to be smaller than narrow-shouldered observers.

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Method

Participants—Thirty-six (21 female, 15 male) College of William and Mary students participated in the experiment for credit in an introductory psychology course. All participants were naïve to the purpose of the experiment and gave written, informed consent to participate. All participants were randomly selected; we did not screen for broad- and narrow-shouldered participants.

Apparatus—Participants judged aperture widths in a 3.05 m × 3.05 m room with a solid colored carpet. Two wooden poles, each 2.54 cm thick and 159 cm tall, were moved to display different aperture widths for the participants who stood 95 cm from the poles (home position). The aperture was adjusted to different widths around a center point, which was directly in front of home position. The aperture was placed in front of a cinder block wall. We do not believe that the grooves in the cinder block wall influenced the results because they were present in all conditions. However, to allay concerns that participants may have used the grooves, the experimenter extended the tape measure for the matching task in front of a solid colored wall to reduce the possibility that participants could use the blocks as a strategy for making their estimates. Participants were asked to stand at the home position for the duration of the experiment.

Design—Aperture widths were shown at 5.08 cm intervals ranging from 30.48 cm to 60.96 cm. Aperture widths were randomly presented. Each participant made a total of seven judgments of aperture width (one for each aperture size).

Procedure—Participants were asked to imagine walking through the aperture without rotating their shoulders prior to making size estimates because previous research has shown that the perceived distance to an object was only affected when the participant intended to act on the distance (Witt et al 2005). Then, participants completed a visual matching task to estimate the perceived size of the aperture. For the visual matching task, the experimenter stood to the side of the participant. The experimenter told the participants to adjust the length of a tape measure (that the experimenter pulled open) to be the same as the width of the aperture (see figure 1). The participants were instructed to continuously adjust the length of the tape until it was the most accurate representation of the aperture width. The experimenter always asked if the width was correct when participants seemed satisfied, and would keep his gaze focused on the participants rather than the tape measure in order to provide no feedback about accuracy. After making their estimate, participants turned 180 degrees away from the aperture so that a new test width could be set. Upon completion of the experiment, participants' shoulder widths were recorded. The total experiment took about 10 minutes to complete.

Results and Discussion

Participant Selection—Eighteen participants (10 female, 8 male) were selected for analysis from the sample of 36. They were selected for analysis because they represented the largest 25% and smallest 25% of the 36 participants who participated. There were 9 (1 female, 8 male) broad-shouldered participants (M = 48 cm, SD = 4.01) and 9 (9 female, 0 male)[1] narrow-shouldered participants (M = 39.09 cm, SD = 1.56).

[1]Due to recent findings that gender influences judgments of passage through an aperture, one might be concerned that any differences between the groups in this experiment, especially because the broad- and narrow-shouldered group membership covaried with gender, reflect a difference between genders (Lopresti-Goodman, Kallen, Richardson, Marsh, & Johnston, 2009). To test this possibility we ran a 2 (gender) × 7 (aperture width) analysis of covariance where aperture width was a within-participants factor and shoulder width was the covariate. The analyses revealed no main effect of gender, F (1, 15) = 0.67, p = 0.43. Therefore, we conclude that the differences seen between broad- and narrow-shouldered participants are likely not due to gender.

Size Estimates—A 2 (shoulder width: broad, narrow) × 7 (aperture width) repeated-measures ANOVA revealed a significant main effect of body width, F (1, 16) = 4.64, MSE = 71.31, p = .047, $\eta_p^2 = 0.23$. Broad-shouldered participants estimated the aperture widths to be significantly smaller, on average, (M = 44.07, SE = 1.06) than narrow-shouldered participants (M = 47.31, SE = 1.06). There was also a main effect of aperture width, F (1, 16) = 824.07, MSE = 11.87, p < .0001, $\eta_p^2 = 0.98$.

These results indicate that larger individuals saw the aperture as smaller in addition to acting as if the aperture was smaller (see Warren and Whang 1987). Warren and Whang (1987) found that both broad- and narrow-shouldered males required apertures to be at least 1.3 times their own shoulder width in order to walk through without rotating their shoulders. However, this necessarily means that larger individuals also required a larger margin of error, the space on either side of their shoulders, when walking through[2]. We believe that the larger men in Warren and Whang (1987) may have required a larger margin of error than narrow-shouldered men because, in part, they *saw* the apertures as smaller.

Experiment 2

The purpose of this experiment was to test participants' perception of aperture width when the width of their body was widened, by holding an object or by holding out their arms. The WEAR group wore a rod that extended their width but their hands were at their sides. The HANDS ONLY group positioned their hands as wide as the rod was in the WEAR group but did not hold any object. In the third condition, the HOLD group, participants held the rod with their hands placed at its widest extent. The fourth group (CONTROL), acted as a control; participants did not hold an object or reposition their hands to widen their side-to-side extent. Multiple aperture sizes were presented. All participants viewed all aperture widths, imagined walking through the aperture, and completed a visual matching task to provide an estimate of the width of the aperture. We hypothesized that when participants' width was widened they would estimate the aperture to be smaller. However, we had no specific predictions about whether the manner in which participants were made wider would impact their judgments of aperture width.

Method

Participants—Forty (23 female, 17 male) College of William and Mary students participated in the experiment for credit in an introductory psychology course. All participants were naïve to the purpose of the experiment and gave written, informed consent to participate.

Apparatus—All apparati were the same as Experiment 1 except that only one pole moved parallel to the wall to create the different aperture sizes; the other pole remained stationary. The participants stood 152.4 cm from the aperture's center point at the home position. Once again for the visual matching task the tape measure was extended in front of an adjacent wall 90° perpendicular to the aperture, which was covered by a solid-colored curtain (see figure 1 for diagram). A curtain rod was used to extend the participants' body sizes in the two object conditions. It was light weight and 114.3 cm in length.

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[2]Warren and Whang (1987) reported that, on average, the larger participants in their study were 48.4 cm wide. Multiplying the average shoulder width (48.4 cm) by 1.3 cm results in the average aperture width required to pass through without rotating the shoulders (62.92 cm). If we take this aperture width (62.92 cm) and subtract out participants average shoulder width (48.4 cm) we get an average margin of error for larger participants (14.52 cm). Using this same procedure for the smaller group in Warren and Whang's study, we find that narrow-shouldered participants required a margin of error that was 12.12 cm. Larger individuals required not only larger aperture widths in order to pass through but also more space on either side of their shoulders (14.52 cm > 12.12 cm). If we assume that individuals act according to this 1.3 pi number, it is a mathematical certainty that larger individuals will require more space. It is, however, unclear if this difference is significant.

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Design—Participants were randomly assigned to condition. For each condition, the aperture width was adjusted to seven target sizes, 76.2, 88.9, 101.6, 114.3, 127, 139.7, and 152.4 cm, and one of pair of distracter distances, 63.5 and 165.1, 81.28 and 144.78, or 93.98 and 134.62 cm. Both target and distracter aperture widths were randomly presented. Distracter widths were included because each of the target distances was equidistant from each other and there was concern that participants would scale their responses accordingly (e.g., in regular, rounded intervals). The distracters made it seem like the distances were not regularized. The pair of distracter widths kept the mean of all target distances the same. For each distance participants imagined walking through the poles and visually matched the length of a tape measure to the aperture width.

Procedure—All procedures were the same as in Experiment 1. However, in this experiment participants donned an object or adjusted their arm width depending upon the condition to which they were randomly assigned.

If they were randomly assigned to the HOLD condition, participants were asked to hold the rod in front of their body with their hands clenched around the ends of the rod, but not extending past the ends (see figure 2a). If they were assigned to the HANDS ONLY condition, participants were asked to hold their hands in a fist (like they were holding an object) at the same extent as the rod (see figure 2b). The rod was used by the experimenter to place their hands in the correct location before each aperture width was presented. Participants in the WEAR condition donned a backpack that was light weight (empty), with the rod attached to it through loops on a carabiner so that the rod extended equally out to the right and left of the participant (see figure 2c). The participants' arms remained at their side, but their body size was enlarged by wearing the rod. Finally, in the CONTROL condition, participants simply made judgments of the size of the aperture with their arms at their side.

The participant was then given approximately 15 seconds to get comfortable and walk around with the rod before any judgments were made. Participants tended to walk around, approach the doorway into the room, or bump the extent of the object into a wall. They did not get experience walking through the test aperture as it was only set up after this familiarization phase. The rod was held throughout the experiment and participants kept it close to their torso and did not extend it out in front of them. After estimating all widths, participants' shoulder widths were recorded. Participants showed no signs of fatigue. The experiment lasted no longer than 10 minutes.

Results and Discussion

Perceptual Estimates—We ran a 2 (object: rod or no rod) × 2 (arm position: in or out) × 7 (aperture size) repeated measures analysis of variance (ANOVA) with estimates of the size of the apertures as the within-participants dependent variables. The object and arm position factors were between-participants. There was a main effect of arm position, $F(1, 36) = 8.70$, $MSE = 637.04$, $p = .006$, $\eta_p^2 = 0.20$. Participants who had their arms out (whether holding a rod or not) estimated the aperture to be smaller, on average (M =103.41, SE = 2.10) than participants who did not hold the rod or their arms out (M = 112.42, SE = 2.22; see figure 3). However, there was no main effect of object, $F(1, 36) = .02$, $p = .90$, and no object x arm position interaction, $F(1, 36) = .06$, $p = .84$. Finally, there was a main effect of aperture size, $F(6, 126) = 462.31$, $MSE = 49.63$, $p < .0001$, $\eta_p^2 = 0.93$, suggesting that participants did perceive the apertures as different across trials.

The results showed that altering the width of participants' bodies changed the perception of aperture width, but only when their hands were at the widest point. When participants were holding a 114.3 cm rod (HOLD condition) or when they simply stood with their hands 114.3 cm apart (HANDS ONLY condition), they judged the aperture to be smaller than participants whose arms were not far apart (WEAR and CONTROL conditions). All depth cues were constant between viewing conditions; therefore the differences in perceived aperture width are likely due to the arm and/or hand positions of participants in the HOLD and HANDS ONLY conditions. However, it is possible that wearing the rod produced a confound that was not present in the other conditions because of the way that the rod was attached to the body. An alternative for future studies would be to have participants hold the rod in the middle (as done by Wagman and Taylor 2005).

This experiment gives good support to our hypothesis that participants who are wider will see apertures as smaller. The results also suggest that the manner in which the body is widened is important for realizing this potential change in perception. Wearing an object that was large did not alter the perception of apertures in this experiment. Thus, the position of the arms and hands seems important for a change in the body to influence perception. We decided to investigate this further by having participants hold their arms at different locations to see if we could replicate the results of this experiment, but also to pinpoint the locus at which perception begins to be altered by arm position.

Experiment 3

The purpose of this experiment was to further explore the effects observed in experiment 2. Specifically, we decided to test the boundaries of the effect of arm and hand location on the perception of aperture width by asking participants to vary the location of the arms during the course of the experiment. Participants held their arms at 4 widths, one that was as close together as the hands could go, one with their hands at 38.1 cm, one with their hands at approximately 76 cm, and one with their hands at 114 cm as in the previous experiment (see figure 4). However, no objects were held in this experiment. For each arm/hand location, they judged the same aperture widths as in experiment 2. Therefore, we could also assess whether changes in perception due to arm location could occur within-participants.

Method

Participants—Ten (8 female, 2 male) College of William and Mary students participated in the experiment for credit in an introductory psychology course. All participants were naïve to the purpose of the experiment and gave written, informed consent to participate.

Apparatus—All apparati used were the same as in experiment 2. However, no object was held.

Design—A within-participants design was used; therefore all participants completed all four arm/hand positions (0 cm, 38.1 cm, 76.2 cm, and 114.3 cm apart). The hand positions were four equally incremented extents that were chosen to more precisely test the relative influence of body width on perceived aperture width. Hand positions were blocked and randomized between participants. For each condition, the aperture width was randomly adjusted to the same seven target sizes used in experiment 2.

Procedure—As in experiment 2, participants imagined walking through the aperture and then visually matched the length of a tape measure to the aperture width. Participants' arms and hands were positioned appropriately by the experimenter. The distance between participants' hands was checked before each trial and participants kept their elbows extended. After all distances were judged for one position, the experimenter asked the participants to position their hands and arms in the next position, and so forth until participants completed judgments for each position. Participant shoulder width was recorded at the end of all blocks.

Results and Discussion

Size Estimates—A 3 (order) × 4 (arm position) × 7 (aperture width) repeated-measures ANOVA was run; all factors except order were within-participants. The analyses revealed a main effect of aperture width, F (6, 42) = 222.22, MSE = 88.39, $p < .0001$, $\eta_p^2 = 0.97$ and hand position, F (3, 21) = 5.14, MSE = 134.43, $p = .01$, $\eta_p^2 = .42$ (see Figure 5) There was no main effect of order, F (2, 7) = 2.4, $p = .16$.

We ran 3 planned contrasts in order to further assess the influence of hand position on the perception of apertures. First, we tested whether participants estimated the aperture widths to be different sizes when there hands were not the widest part of their body (0 cm, 38.1 cm) as compared to when their hands were the widest part of their bodies (76.2 cm, and 114.3 cm)[3]. The analysis revealed a main effect of hand position, F (1, 9) = 11.81, MSE = 81.99, $p = .007$, $\eta_p^2 = .57$. On average, participants judged the aperture to be smaller when their hands were the widest part of their bodies (M = 112.77, SE = 3.3) than when their hands were not the widest part of their bodies (M = 116.48, SE = 3.93). A second planned contrast revealed that participants judged the apertures, on average, to be significantly smaller when their hands were positioned 114.3 cm apart (M = 111.1, SE = 3.06) than when their hands were positioned 76.2 cm apart (M = 114.44, SE = 3.57), F (1, 9) = 8.39, MSE = 46.516, $p = .02$, $\eta_p^2 = .48$. A final planned contrast revealed that participants judged the aperture to be no different when their hands were positioned 0 cm apart (M = 118.64, SE = 3.75) as compared to when their hands were positioned 38.1 cm apart (M = 114.33, SE = 4.5), F (1, 9) = 2.74, $p = .13$. However, we concede that there was a trend for participants to see the aperture as wider when the hands were moved closer together.

The results indicate that participants began to see the aperture as smaller when their hands were positioned at least 114.3 cm apart. We believe this may be due, in part, to the fact that the hands may normally operate within 76.2 cm of one another. For example, people tend to swing their arms when walking or to gesture when talking. If this is true, it would suggest that changes to perception in this normal range of operation may be negligible.

General Discussion

In a series of experiments, we showed that the perception of spatial layout, specifically the size of apertures in extrapersonal space, was affected by observers' body size and their abilities to act within the space. In other words, we believe that observers use the size of their bodies as perceptual metrics for estimating the size of apertures. Our results suggest that participants who are large may perceive the environment to be different than participants who are small. Furthermore, when the body is larger than normal, participants rescale their perception of the environment, possibly to inform their actions.

In experiment 1, we selected for broad- and narrow-shouldered participants and compared their estimates of aperture width. As hypothesized, participants who were broad-shouldered visually matched the size of the apertures to be smaller than participants who were narrow-shouldered. In experiment 2, we found that participants who held a large object or held their arms out wide perceived aperture widths to be smaller than those who did not hold an object or whose hands were at their sides when wearing an object. These findings are novel and interesting, given previous work has shown that wielding an object provides enough information to discover its length, even when it may be out of view (Burton and Turvey 1990; Kingma et al 2004; Turvey 1996) or when the limb that wielded the object was numb due to peripheral neuropathy (Carello, Kinsella-Shaw, Amazeen, and Turvey 2006). Our

[3]Participants' shoulder widths, (M = 41.73, SD = 2.97), ranged from 37.85 cm to 47.63 cm. Only one participant's shoulder width was less than 38.1 cm.

findings suggest that, at least for the rescaling of perceived aperture width, the location of the hands and arms are important in predicting alterations in perception. Furthermore, as observed in experiment 3, these alterations in perception are different depending on the location of the arms and hands. When the body was enlarged by holding the arms out, apertures appeared smaller. However, when the arms and hands were held close together, the apertures trended toward appearing wider.

These studies add to the literature on aperture perception, in that they showed that observers use their bodies to visually match the size of apertures. Previous work clearly found that the body is used as a metric for making affordance judgments about passage (Wagman and Taylor 2005; Warren and Whang 1987). Our work replicated these findings with a different measure of perception. Furthermore, this measure is influenced by a change to the observer's body, which results in a perceptual rescaling of apertures in extrapersonal space. Witt et al (2005) showed that increasing observers' reaches (by having them hold a baton) resulted in a rescaling of the perception of distance in near space. Linkenauger et al (forthcoming) found that differences in perceived arm length influence estimates of reachable extents. Likewise, differences in perceived hand size altered the perception of what was considered graspable. Our paper adds to this growing body of literature, which suggests that the body is used to scale the perception of space, by extending the previous findings to the perception of extrapersonal space, specifically to the perception of aperture widths. Furthermore, the position of the hands and arms seem to be particularly important in producing these effects.

Recent research in visual attention reveals a plausible reason for why the position of the hands and arms may have resulted in a change in perception that was different from wearing the object. Abrams et al (2008) found that, in three experiments, participants were slower to disengage attention when their hands were near the visual display (holding the sides of the screen) rather than far from the display (in their laps). These results suggest that visual perception was enhanced when participants' hands were closer to the objects being processed. Similarly, Reed et al (2006) have found that participants who had one hand on the side of a display were faster to detect targets closer to the hand, even though the location of the targets was randomized across trials. This bias in attention toward areas or objects close to the hands could result from neurons that code for hand-centered space in the parietal cortex (see Graziano 2001; Makin et al 2007). Furthermore, Davoli and Abrams (2009) showed that the hands do not need to physically be near the display to produce an enhancement. They found that imagining the hands being near the display resulted in the same search enhancements observed in Abrams et al (2008). We tentatively suggest that a similar mechanism could underlie the current findings. Again, participants may have attended more to the area around their hands, which influenced perceived aperture size when the hands were wide because this awareness provided useful information with which to scale the size of the aperture. Abrams et al (2008) mention in their article that enhanced visual awareness near the hands would be important when wielding or carrying objects to avoid collisions. When participants held the objects in our experiments or held out their arms, they may have had an enhanced awareness of the extent, which resulted in reduced perceptions of aperture width.

Thus, our findings suggest that adding a large object to the body may only result in a decreased perception of aperture width when participants have salient feedback about the size of the object from the position of their arms or hands. In our experiments, perceived aperture width was reduced when holding a wide object or holding the arms out, but not when wearing the object or when the hands were at the sides of the body. These findings may also be related to claims that touch can reveal the length and width of objects to observers who are wielding, or even just holding those objects (Carello 2004; Carello et al 2006; Carello and Turvey 2004; Wagman and Malek 2007; Wagman and Taylor 2005). If our participants had better knowledge about the length of the rod when holding it as opposed to wearing it, then this could have affected their perceptual estimates. Holding the arms open may have also provided more reliable proprioceptive cues for the length and extent of participants, such that participants were better able to understand the size of their body in order to use it to scale aperture width.

Future research should test the influence of the body on other parameters of extrapersonal space. One could imagine that changes to the body could influence the perception of farther distances (holding a long rake could make leaves on the ground appear closer), sizes (wearing a large glove or holding a large object could make an aperture appear smaller for reaching, see Ishak et al 2008), and heights (wearing high heels could make steps look shorter, or holding an umbrella could make heights look shorter, see Stefanucci and Geuss 2009). Recent work by Wagman and Malek (2008) showed that affordance judgments for walking under a horizontal barrier were affected by the eye-height of the observer. Participants rescaled their judgments of passage under a barrier when they were sitting on the floor or standing on a stool. Moreover, the effect of the body on space perception may extend to sensitivity around other limbs, like the legs and feet. Hajnal et al 2007 showed that when participants wielded rods with their feet, their perception of the length of the rod was comparable to that of their hands.

Also, changes to the body may not be necessary to alter space perception. Anorexics who exhibit distorted body schemas may show similar distortions of perceived environmental layout as in the current studies. Given that anorexics perceive themselves to be larger than the average person (Sands et al 1997; Zellner et al 1989) they may estimate apertures to be smaller when considering acting on them. In fact, recent research showed that anorexics required a larger margin of error when estimating if they would fit through an aperture than normal, size-matched controls (Luyat et al 2009). Another population that could be affected is people who have claustrophobia (fear of enclosed or small spaces). Previous work has shown that claustrophobics exhibit fears of restriction and suffocation, especially in small, enclosed spaces (Rachman and Taylor 1993). However, they are usually bothered by bodily restrictions as well, especially restriction of the hands. Therefore, they could perceive apertures to be even smaller than normals when their body is restricted or the aperture is in an enclosed space. By studying these populations, methodological issues that arise when adding an object to a person, such as whether the object is seen or touched, could also be avoided.

When approaching an aperture, the perceptual system dynamically updates the perceived size of the aperture in reference to the size of the body and the actions that body can perform. The system then uses the information about the size of the aperture and the person plus any object he is holding or the position of his body to make one of three decisions: to walk through without rotating the body, to walk through and rotate the body, or to find an alternate route (Warren and Whang 1987). Often, the perceptual system must signal to the individual to find an alternate route before the individual is close to the aperture. Obviously, deciding on an alternate route early is important so that the observer does not walking into area, get stuck, and then have to find an alternate route.

In contrast, people may decide to change the size of their body in response to their perception of the physical environment. Informally, we have observed people in crowds making their bodies smaller in order to fit through tight spaces. This work suggests that this bodily adjustment might not only serve to create more space in which to maneuver, but it may also enlarge the space perceptually, thus providing possible reprieve from the crowding.

The purpose of these studies was to measure the information on which the system bases these action decisions before the action is imminent. The results suggest that the body is an important source of information for action decisions, and that the position of the hands, in particular, may be privileged in informing the final decision to act.

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References

Abrams RA, Davoli CC, Du F, Knapp WH, Paull D. Altered vision near the hands. Cognition. 2008; 107:1035–1047. [PubMed: 17977524]

Berti A, Frassinetti F. When far becomes near: Remapping of space by tool use. Journal of Cognitive Neuroscience. 2000; 12:415–420. [PubMed: 10931768]

Burton G, Turvey MT. Perceiving the lengths of rods that are held but not wielded. Ecological Psychology. 1990; 2:295–324.

Carello C. Perceiving affordances by dynamic touch: Hints from the control of movement. Ecological Psychology. 2004; 16:31–36.

Carello C, Kinsella-Shaw J, Amazeen EL, Turvey MT. Peripheral neuropathy and object length perception by effortful (dynamic) touch: A case study. Neuroscience Letters. 2006; 405:159–163. [PubMed: 16884850]

Carello C, Turvey MT. Physics and the psychology of the muscle sense. Current Directions in Psychological Science. 2004; 13:25–28.

Cutting, JE.; Vishton, PM. Perceiving layout and knowing distances: The integration, relative potency, and contextual use of different information about depth. In: Epstein, W.; Rogers, S., editors. Handbook of Perception and Cognition: Vol 5: Perceiving Space and Motion. Academic Press; London: 1995. p. 69-117.Perceiving space and motion

Davoli CC, Abrams RA. Reaching out with the imagination. Psychological Science. 2009; 20:293–295. [PubMed: 19222813]

Gibson, JJ. The ecological approach to visual perception. Erlbaum; Hillsdale NJ: 1979.

Graziano M. Is reaching eye-centered, body-centered, hand-centered, or a combination? Reviews in the Neurosciences. 2001; 12:175–185. [PubMed: 11392457]

Hajnal A, Kinsella-Shaw J, Fonseca S, Carello C, Harrison S. Comparison of dynamic (effortful) touch by hand and foot. Journal of Motor Behavior. 2007; 39:82–88. [PubMed: 17428754]

Holmes NP, Calvert GA, Spence C. Extending or projecting peripersonal space with tools? Multisensory interactions highlight only the distal and proximal ends of tools. Neuroscience Letters. 2004; 372:62–67. [PubMed: 15531089]

Imamizu H, Miyauchi S, Tamada T, Sasaki Y, Takino R, Putz B, et al. Human cerebellar activity reflecting an acquired internal model of a new tool. Nature. January 13. 2000 403:153–154. [PubMed: 10646587]

Inoue K, Kawashima R, Sugiura M, Ogawa A, Schormann T, Silles K, Fukuda H. Activation in the ipsilateral posterior parietal cortex during tool use: A PET study. NeuroImage. 2001; 14:1469–1475. [PubMed: 11707103]

Iriki A, Tanaka M, Iwamura Y. Coding of modified body schema during tool use by macaque postcentral neurons. NeuroReport. 1996; 7:2325–2330. [PubMed: 8951846]

Ishak S, Adolph KE, Lin GC. Perceiving affordances for fitting through apertures. Journal of Experimental Psychology: Human Perception and Performance. 2008; 34:1501–1514. [PubMed: 19045989]

Kingma I, van de Langenberg R, Beek PJ. Which mechanical invariants are associated with the perception of length and heaviness of a nonvisible handheld rod? Testing the inertia tensor hypothesis. Journal of Experimental Psychology: Human Perception and Performance. 2004; 30:346–354. [PubMed: 15053693]

Kinsbourne, M. Awareness of one's own body: An attentional theory of its nature, development, and brain basis. In: Bermudez, JL.; Marcel, A.; Eilan, N., editors. The Body and the Self. MIT Press; Cambridge, MA: 1995. p. 205-244.

Linkenauger S, Witt JK, Bakdash JZ, Stefanucci JK, Proffitt DR. Asymmetrical body perception: A possible role for neural body representations. Psychological Science.

Loomis JM, Da Silva JA, Fujita N, Fukusima SS. Visual space perception and visually directed action. Journal of Experimental Psychology: Human Perception & Performance. 1992; 18:906–921. [PubMed: 1431754]

Lopresti-Goodman S, Kellen RW, Richardson MJ, Marsh KL, Johnston L. The influence of heightened body-awareness on walking through apertures. Applied Cognitive Psychology. 2009

Luyat, M.; Guardia, D.; Lafargue, G.; Thomas, P. Does false representation of body in anorexia nervosa affect visual perception of action possibilities?. Poster presented at the annual meeting of the Vision Sciences Society; 2009.

Makin TR, Holmes NP, Zohary E. Is that near my hand? Multisensory representation of peripersonal space in human intraparietal sulcus. Journal of Neuroscience. 2007; 27:731–740. [PubMed: 17251412]

Oudejans RR, Michaels CF, Bakker FC, Dolne MA. The relevance of action in perceiving affordances: Perception of catchableness of fly balls. Journal of Experimental Psychology: Human Perception and Performance. 1996; 22:879–891. [PubMed: 8756956]

Rachman S, Taylor S. Analyses of claustrophobia. Journal of Anxiety Disorders. 1993; 7:281–291.

Reed CL, Farah MJ. The psychological reality of the body schema: A test with normal participants. Journal of Experiment Psychology: Human Perception and Performance. 1995; 21:334–343.

Reed CL, Grubb JD, Steele C. Hands up: Attentional prioritization of space near the hand. Journal of Experimental Psychology: Human Perception & Performance. 2006; 32:166–177. [PubMed: 16478334]

Rizzolatti G, Fadiga L, Fogassi L, Gallese V. The space around us. Science. 1997; 277:190–191. [PubMed: 9235632]

Sands R, Tricker J, Sherman C, Armatas C, Maschette W. Disordered eating patterns, body image, self-esteem, and physical activity in preadolescent school children. International Journal of Eating Disorders. 1997; 21:159–166. [PubMed: 9062839]

Stefanucci JK, Geuss MN. The body influences the perception of a horizontal barrier. Manuscript in preparation. 2009

Stroop M, Turvey MT, Fitzpatrick P, Carello C. Inertia tensor and weight-percept models of length perception by static holding. Journal of Experimental Psychology: Human Perception and Performance. 2000; 26:1133–1147. [PubMed: 10884013]

Turvey MT. Dynamic touch. American Psychologist. 1996; 51:1134–1152. [PubMed: 8937263]

Wagman JB, Malek EA. Perception of whether an object affords walking under from different points of observation. Ecological Psychology. 2008; 20:65–83.

Wagman JB, Malek EA. Perception of whether an object can be carried through an aperture depends on anticipated speed. Experimental Psychology. 2007; 54:54–61. [PubMed: 17341015]

Wagman JB, Taylor KR. Perceiving affordances for aperture crossing for the person-plus-object system. Ecological Psychology. 2005; 17:105–130.

Warren WH. Perceiving affordances: The visual guidance of stair climbing. Journal of Experimental Psychology: Human Perception and Performance. 1984; 10:683–703. [PubMed: 6238127]

Warren WH, Whang S. Visual guidance of walking through apertures: body-scaled information for affordances. Journal of Experimental Psychology: Human Perception and Performance. 1987; 13:371–383. [PubMed: 2958586]

Witt JK, Proffitt DR, Epstein W. Tool use affects perceived distance, but only when you intend to use it. Journal of Experimental Psychology: Human Perception and Performance. 2005; 31:880–888. [PubMed: 16262485]

Zellner DA, Harner DE, Adler RL. Effects of eating abnormalities and gender on perceptions of desirable body shape. Journal of Abnormal Psychology. 1989; 98:93–96. [PubMed: 2708649]

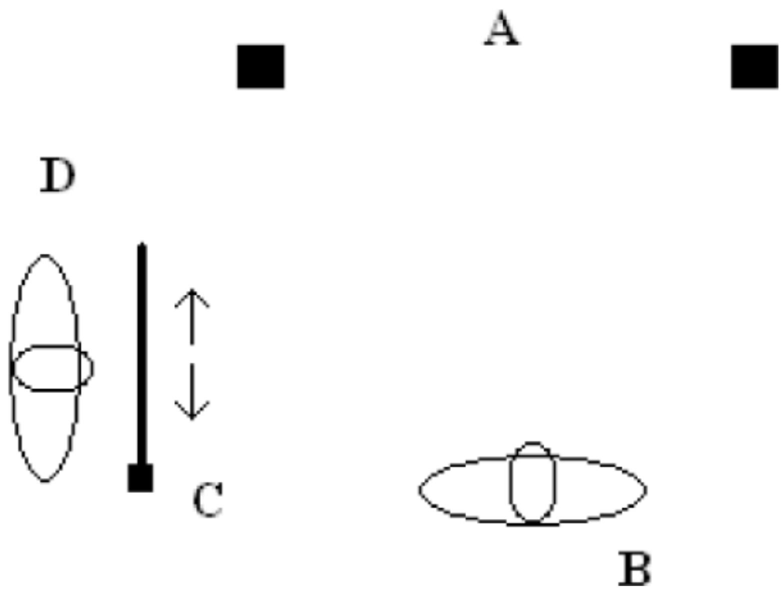

Figure 1.
A top-down view of the experimental setup. (A) denotes the location of the aperture. (B) represents the location of the observer (95 cm from the center of the aperture in experiment 1; 152.4 cm from the center of the aperture in experiments 2 and 3). (D) represents the location of the experimenter relative to the observer and aperture, and (C) is the tape measure that was adjusted in either direction to match the size of the aperture (A).

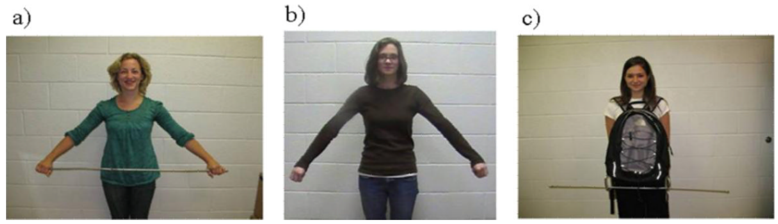

Figure 2.

Participants in experiment 2 either held the rod (a), placed their hands out to be the same distance when holding the rod (b), or wore the rod (c).

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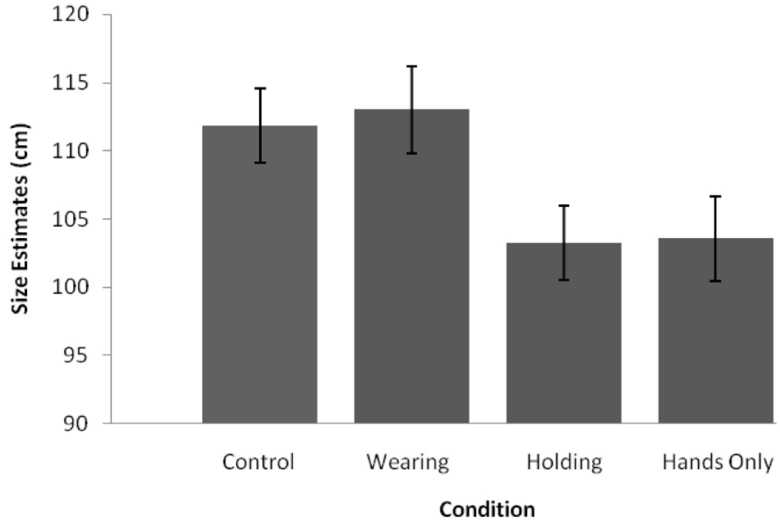

Figure 3.
Graph displays average size estimates for each experimental condition in experiment 2. Note that for the two conditions in which the hands are wider (holding & hands only), participants estimated the aperture to be significantly smaller than when their hands were not widened. Bars represent one standard error.

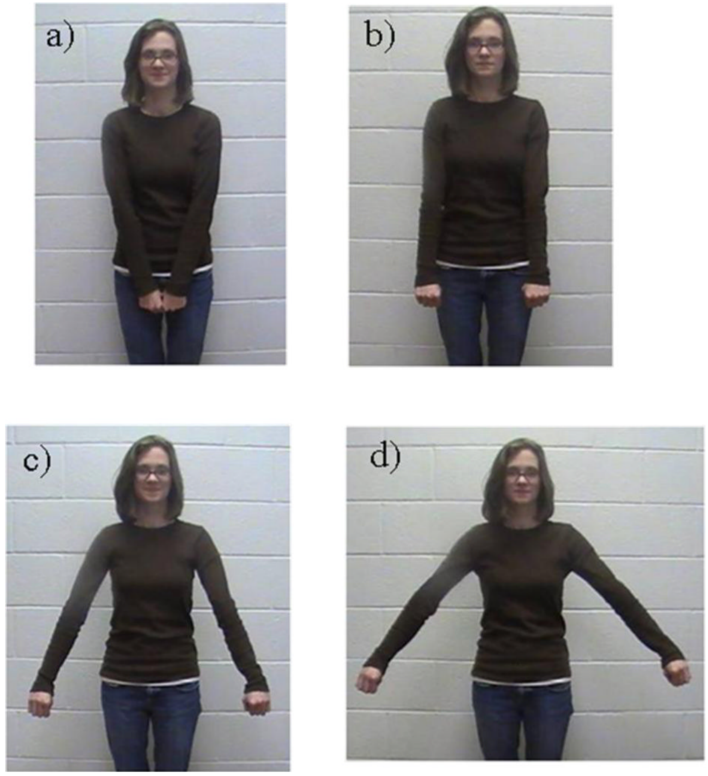

Figure 4.
Participants in experiment 3 held their hands as close as possible (a), 38.1 cm apart (b), 76.2 cm apart (c), and 114.3 cm apart (d).

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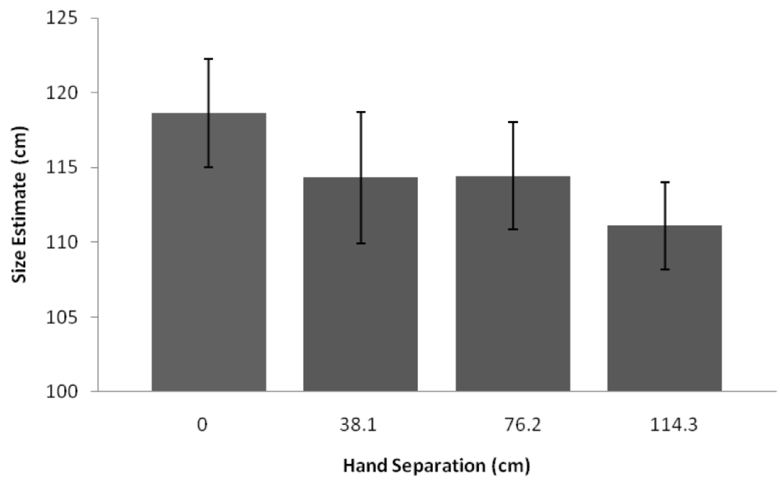

Figure 5.
Graph displays the average size estimate for each arm position. Generally, participants estimated the aperture to be smaller as their hands moved farther apart. Specifically, participants estimated the aperture to be significantly smaller when their hands were the widest part of their body (76.2 cm and 114.3 cm) than when their hands were not the widest part of their bodies (0 cm and 38.1 cm). Bars represent one standard error.