Illusory Shrinkage and Growth: Body-Based Rescaling Affects the Perception of Size

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Abstract
The notion that apparent sizes are perceived relative to the size of one’s body is supported through the discovery of a new visual illusion. When graspable objects are magnified by magnifying goggles, they appear to shrink back to near-normal size when one’s hand (also magnified) is placed next to them. When objects are “minified” by minifying goggles, the opposite occurs. The rescaling effect also occurred when participants who were trained in tool use viewed the tool next to the objects. However, this change in apparent size does not occur when familiar objects or someone else’s hand is placed next to the magnified or minified object. Presumably, objects’ apparent sizes shift closer to their actual sizes when one’s hand is viewed because objects’ sizes relative to the hand are the same with or without the goggles. These findings highlight the role of body scaling in size perception.

Keywords
size perception, embodied perception, affordances, handedness

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When people perceive the sizes of graspable objects, it is possible that they use their dominant hand as a “perceptual ruler” with which to measure the objects’ apparent sizes. If so, the apparent sizes of graspable objects would be scaled relative to the size of one’s dominant hand. Supporting this notion through the discovery of a new visual illusion, we show that an object will appear to shrink or grow depending on whether the viewer’s own hand can be viewed simultaneously. Specifically, when someone views an object while wearing magnification goggles, placing the viewer’s hand next to the object makes the object appear to shrink. Conversely, when someone wears “minification” goggles, placing the viewer’s hand next to the object makes the object appear to grow. This illusion illustrates the important role of body-relative scaling in the perception of object size.

The relation between one’s body and the physical sizes of objects is crucial during the execution of actions and in determining what actions are possible. Several lines of research show that this relation may be the basis for the perceptual measurement of sizes and extents (Fajen, 2005; Witt, Proffitt, & Epstein, 2005). According to this perspective, individuals likely perceive the sizes of graspable objects as a proportion of the maximum extent of their grasping ability in a given context (Linkenauger & Proffitt, 2008). For example, the width of a soda bottle would appear smaller to someone with larger hands than to an individual with small hands, because the soda bottle is a smaller proportion of the larger hands’ maximum grasp.

A well-known example of such body scaling of size can be seen in the movie Honey I Shrunk the Kids (Spielburg, Smith, Allen, & Johnston, 1989), in which a quirky scientist accidentally shrinks his children to the size of matchsticks with his newly invented shrinking machine. From the perspective of the shrunken children, their tiny backyard becomes a massive jungle, where a blade of grass appears to be the size of a tree. Interestingly, this example parallels the experience of individuals with neurological conditions that sometimes accompanies chronic migraine syndrome, appropriately called “Alice in Wonderland” syndrome; these patients experience the growth (or shrinkage) of their body followed by the shrinkage (or growth) of the world around them (Todd, 1955). In both of these examples, the size of the physical world is perceived in relation to the real or apparent size of the perceiver’s body.

This relation between the body and perceived size can possibly be mapped onto neural mechanisms that combine proprioceptive and visual information. Single-cell recording studies have found neurons that code for the relation of objects to an animal’s effectors. For example, in macaque monkeys, neurons in the anterior intraparietal area code for objects that are in grasping distance of the hand, regardless of the position.
of the hand or object in the visual field (Murata, Gallese, Luppino, Kaseda, & Sakata, 2000). Also, some neurons in this area code for the specific grasp required because of the shape and size of the object in addition to the position of the object relative to the hand (Murata et al., 2000; Taira, Mine, Georgopoulos, Murata, & Sakata, 1990). These cells also code for the orientation of the object relative to the orientation of the hand (Murata et al., 2000). In fact, when processing in the anterior intraparietal area is inhibited, monkeys’ ability to open their hands to an appropriate size to grasp a target is impaired (Gallese, Murata, Kaseda, Niki, & Sakata, 1994). Presumably, these neurons code for the ability to grasp a specific object, and they are likely responsible for scaling visual information about the object to the body and its action capabilities.

In the experiments reported here, we explored size perception in conditions in which participants wore magnification or minification goggles. If perception is based on the relation between visual information and the body, and if only the target is magnified, then the optical magnification will specify that the target is larger than it is, and, in turn, it will appear larger. However, if the body (e.g., the hand) and the target are viewed together under magnification, then the relative size relation between the body and object is reestablished. Consequently, the target should not appear as magnified, because the magnified target can be rescaled to the magnified body.

Previous studies have demonstrated handedness-related perceptual and behavioral effects in right-handed individuals, who favor the right side of their body (Gonzalez, Ganel, & Goodale, 2006; Linkenauger, Witt, Bakdash, Stefanucci, & Proffitt, 2009). Given these findings, we also hypothesized that hand dominance might influence the rescaling of objects’ sizes such that for right-handed people, the right hand would act as a more efficient perceptual ruler than the left. In this case, when right-handers viewed both their hand and the object under magnification, the object would be rescaled more and appear smaller when the right as opposed to the left hand was viewed next to the object.

Experiment 1: Magnification, Size Perception, and Hand Presence

Method

Participants. Forty-two (29 female and 13 male) right-handed University of Virginia students participated in Experiment 1. Handedness was assessed using the Edwards Handedness Survey (Oldfield, 1971; M = 93.74, SE = 1.59). All participants had normal or corrected-to-normal vision.

Design and procedure. Participants were randomly assigned to either the dominant- or the nondominant-hand condition. In both conditions, participants sat at a uniformly white table while wearing goggles with magnifying lenses (30.5-cm focal length, 1.8x magnification). Participants were instructed to close their eyes while an object was placed on the table in front of them. They then opened their eyes and made a verbal estimate of the apparent size of the object. Participants were instructed to estimate size using a 10-point scale in which 0 corresponded to the size of a pea and 10 corresponded to the size of a basketball. Participants were instructed to base these verbal estimates on how big the object appeared rather than how big they thought the object actually was. Then participants closed their eyes and another trial began. Participants estimated the sizes of six spherical objects: three familiar objects (baseball, 221 cm³; ping-pong ball, 33 cm³; tennis ball, 144 cm³) and three unfamiliar objects (wooden cylinder, 57 cm³; Wiffle ball, 178 cm³; Styrofoam ball, 113 cm³). After participants had made all six judgments, they were instructed to perform another block, of size estimates with the same objects, but in this block, they placed their dominant (or nondominant) hand next to the objects before making their verbal judgments.

Results and discussion

The verbal estimates were analyzed in a 2 (hand presence) × 6 (object size) × 2 (hand condition: dominant, nondominant) repeated measures analysis of variance (ANOVA) with hand presence and object size as within-subjects variables and hand condition as a between-subjects variable. Overall, participants’ estimates were smaller when their hand was present (M = 3.82, SE = 0.13) than when their hand was not present (M = 4.46, SE = 0.12), F(1, 40) = 33.75, p = .00, η² = .46 (see Fig. 1). In fact, at least 12 participants spontaneously reported that the object appeared to “shrink” when they placed their hand next to it. Object size also had a significant effect, with larger objects appearing larger, F(5, 200) = 67.32, p < .00, η² = .85. There was no Object Size × Hand Presence interaction, p = .50. As predicted, there was a significant Hand Condition × Hand Presence interaction, F(1, 40) = 4.12, p = .05, η² = .08. This suggests that the apparent size of the object decreased more for participants who saw the object in the absence of their hand (M = 4.39, SE = 0.17) and then placed their dominant hand next to the object (M = 3.53, SE = 0.19) than for participants who saw the object in the absence of their hand (M = 4.53, SE = 0.17) and then placed their nondominant hand next to the object (M = 4.12, SE = 0.19; see Fig. 2). Presumably, the objects appeared less magnified when the hand was visible than when no hand was visible, even though the hand was just as magnified as the target objects, because apparent object size was rescaled to the magnified hand. In other words, the relation between the target object and the hand was redefined to be more similar to that the target and hand were viewed without the magnifying glasses, so the object’s size appeared to be more similar to its unmagnified size. The fact there was no Object Size × Hand Presence interaction means that this effect cannot have been due to familiar size. If familiar size had played a role, then estimates of familiar objects, such as the baseball, would have been
affected by hand presence less than estimates of unfamiliar objects were.

Similarly, the observed effect of hand condition shows that people use the right hand more efficiently than the left to perceptually rescale the sizes of objects.

**Experiment 2: Minification, Size Perception, and Hand Presence**

**Method**

**Participants.** Twelve (6 female and 6 male) University of Virginia students participated in Experiment 2. All participants had normal or corrected-to-normal vision.

**Design and procedure.** We repeated the same design as in Experiment 1 except that participants wore minifying goggles (inverted paper binoculars with 3x minification) instead of magnifying goggles, which made the surrounding environment appear smaller rather than larger. Also, all participants used their dominant hand. Verbal estimates were made as in Experiment 1 except that the scale was modified to accommodate the smaller appearance of the objects; 0 was the size of a pea, and 10 was the size of a softball.

**Results and discussion**

The verbal estimates were analyzed in a 2 (hand presence) × 6 (object size) ANOVA. Participants estimated the sizes of the objects to be larger when their hand was present ($M = 6.23$, $SE = 0.45$) than when their hand was not present ($M = 5.08$, $SE = 0.36$), $F(1, 11) = 8.17$, $p_{rep} = .94$, $\eta^2_p = .43$ (see Fig. 3). At least 4 participants spontaneously commented that the target objects appeared to “grow” when they placed their hand next to the objects. Object size also had a significant effect, with larger objects appearing larger, $F(5, 55) = 17.00$, $p_{rep} = .99$, $\eta^2_p = .43$. There was no Object Size × Hand Presence interaction, $p_{rep} = .81$. 

![Fig. 1. Mean size estimates for the six objects in Experiment 1. Estimates were made in two blocks: with and without the participant’s hand placed next to the object. Error bars represent 1 SEM, calculated within condition.](image1)

![Fig. 2. Mean size estimates, collapsed across all six objects, as a function of hand condition (dominant or nondominant hand) and hand presence (i.e., whether or not the participant’s hand was placed next to the object) in Experiment 1. Error bars represent 1 SEM, calculated within condition.](image2)
Presumably, the apparent size of objects was rescaled when the hand was viewed, so that their sizes appeared more similar to their unminified sizes. Experiments 1 and 2 both demonstrate that perceived size is not independent of the body, but rather is dependent on use of the body as a metric to scale (or rescale) apparent size.

**Experiment 3: Magnification, Object Size, and Another Person's Hand**

To expand on these findings, in Experiment 3 we investigated whether similar rescaling would occur when the perceiver viewed target objects in the presence of someone else’s hand.

**Method**

**Participants.** Twelve (10 female and 2 male) University of Virginia students participated. All participants had normal or corrected-to-normal vision.

**Results and discussion**

The verbal size estimates were analyzed in a 2 (hand presence) × 6 (object size) ANOVA. Participants estimated the objects to be the same size when a hand was present ($M = 4.06, SE = 0.17$) as when a hand was not present ($M = 4.31, SE = 0.17$), $F(1, 11) = 2.39, p_{rep} = .76$. As expected, object size had a significant effect, with larger objects appearing larger, $F(5, 55) = 53.53, p_{rep} > .99, \eta^2_p = .83$. Surprisingly, participants’ size estimates did not differ depending on whether or not the research assistant’s hand was visible (see Fig. 3), which suggests that rescaling is contingent on viewing one’s own body rather than someone else’s.

![Fig. 3. Mean ratio of size estimates with the hand (or tool) visible to size estimates without the hand (or tool) visible in Experiments 1 through 4. Error bars represent 1 SEM, calculated within condition.](image-url)
Experiment 4: Magnification, Object Size, and Tool Use

Several studies have found that with practice, hand tools can become an extension of the body (Berti & Frassinetti, 2000; Maravita, Husain, Clarke, & Driver, 2001). Neurons that code for objects within reach will expand their receptive fields to include previously unreachable space that has been made reachable through tool use, and neurons coding for hand-centered space will expand their receptive fields to include space accounted for by a tool (Iriki, Tanaka, & Iwamura, 1996). Inspired by these studies, in Experiment 4, we explored whether the perception of size could be based on the relation between the size of a tool and the target object.

Method

Participants. Twenty-four (12 female and 12 male) University of Virginia students participated. All participants had normal or corrected-to-normal vision.

Design and procedure. Participants were randomly assigned into either the practice or the no-practice condition. In the practice condition, participants used a pair of kitchen tongs to transfer several different round objects from one box to another. Participants made a total of 40 lifts with the tongs. In the no-practice condition, participants were given no experience using the tongs. Participants in both conditions then put on the magnifying goggles and repeated the procedure used in Experiment 1 except that they only used the dominant hand. However, participants placed the tongs rather than their hands next to the objects. The hand holding the pair of tongs was occluded from view by a piece of white felt that was attached to the tongs and covered the hand.

Results and discussion

For each condition, the verbal size estimates were analyzed in a 2 (hand presence) × 6 (object size) ANOVA. In the practice condition, participants estimated the sizes of the objects to be smaller when the tongs were visible (M = 3.67, SE = 0.19) than when the tongs were not visible (M = 4.18, SE = 0.26), F(1, 11) = 8.96, p<.01, ηp2 = .45 (see Fig. 3). Object size had a significant effect, with larger objects appearing larger, F(5, 55) = 53.57, p<.01, ηp2 = .83. In the no-practice condition, participants estimated objects to be the same size when their tongs were visible (M = 4.51, SE = 0.18) as when their tongs were not visible (M = 4.56, SE = 0.25), F(1, 11) = 0.96, p<.50 (see Fig. 3). Object size had a significant effect, with larger objects appearing larger, F(5, 55) = 54.71, p<.01, ηp2 = .83.

Participants who received tool-use training prior to performing the size-estimation task perceived the target objects as smaller when the tool was in view compared with when it was not. This result suggests that they rescaled the objects’ sizes to the tool. In contrast, participants who did not receive training with the tool did not perceive a change in the size of the target objects when they viewed the objects with the tool. These results support previous findings that tools become an extension of the body, but only after experience with their use.

Experiment 5: Magnification and Size Matching

In order to control for possible demand characteristics resulting from participants making multiple verbal reports on the same objects, we thought it necessary to show the rescaling effect using another, less explicit estimate of size. Therefore, in Experiment 5, we repeated the same procedure as in Experiment 1 except that participants used a visual matching task to estimate the size of the target objects.

Method

Participants. Fifteen right-handed students (10 female and 5 male) from the University of Virginia participated. All participants had normal or corrected-to-normal vision.

Design and procedure. The design was the same as in Experiment 1, and the procedure of Experiment 1 was changed as follows. First, all participants viewed their dominant hand next to the objects. Second, participants made their size estimates by adjusting the size of a circle presented on a laptop screen so that it matched the size of the objects. Participants adjusted the size of the circle on the laptop display by using their nondominant hand to press arrow keys on a wireless keyboard, which was below the table and out of the participants’ sight. The laptop keyboard was covered by white felt so that it was not visible to the participants, and the screen was positioned on the table approximately 30 cm diagonally away from the left side of the participants.

Results and discussion

The estimated diameters were analyzed in a 2 (hand presence) × 6 (object size) ANOVA. As expected, hand presence had a significant effect, with participants estimating objects to be smaller when their hand was present (M = 5.14 cm, SE = 0.31 cm) than when their hand was not present (M = 5.50 cm, SE = 0.35 cm), F(1, 14) = 13.65, p<.01, ηp2 = .49. Object size also had a significant effect, with larger objects being estimated as larger, F(5, 70) = 122.86, p<.01, ηp2 = .90. These findings show that the rescaling effect is generalizable to other estimates of apparent size.

Experiment 6: Magnification, Minification, and Apparent Hand Size

In Experiment 1, we found that the right hand acted as a more effective perceptual ruler than the left hand. If this holds true more generally, then the right hand should be less magnified...
Body-Based Rescaling

(or minified) than the left when viewed by someone wearing magnifying goggles (or minifying goggles), because the right hand is the anchor (perceptual ruler) with which relative size is perceived among right-handed people. If the left hand is not used often as a perceptual ruler (or is less efficient), then it should appear magnified (or minified) in much the same way that target objects are. We tested this hypothesis in Experiment 6.

Method

Participants. Thirty-two right-handed (12 female and 20 male) students from the University of Virginia participated. All participants had normal or corrected-to-normal vision.

Design and procedure. Participants were randomly assigned into either the magnifying condition or the minifying condition. In the magnifying condition, participants put on the magnifying glasses and were instructed to look at the sizes of their right and left hands (one at a time). After looking at both hands several times (approximately four times per hand), participants indicated whether their hands looked to be the same size or whether one hand looked larger than the other. If one hand looked larger, they were asked how much larger (as a percentage) the hand looked. In the minifying condition, participants performed the same task except that they wore minifying goggles rather than magnifying goggles.

Results and discussion

In the magnifying condition, 62.5% of the participants responded that their left hand appeared larger, 25.0% responded that their right and left hands appeared to be the same size, and 12.5% responded that their right hand appeared larger. In the minifying condition, 6.25% of the participants responded that their left hand appeared larger, 43.75% responded that their right and left hands appeared to be the same size, and 50% responded that their right hand appeared larger (see Fig. 4a).

Participants’ responses of how much larger one hand appeared than the other were coded in the following way. If participants responded that their right hand appeared larger, the percentage was coded as a negative value, and if they responded that the left hand appeared larger, then the percentage was coded as a positive value. If participants responded that their right and left hands appeared to be the same size, then their response was coded as zero. One-sample t tests, which tested the mean responses against zero, were conducted for each condition. The t test showed that participants in the magnifying condition indicated that they saw their right hand as larger than their left hand ($M = 7.75, SE = 2.78$), $t(15) = 2.79$, $p_{rep} = .94$, two-tailed. Responses of participants in the minifying condition indicated that they saw their right hand as larger than their left hand ($M = -6.09, SE = 2.53$), $t(15) = -2.41$, $p_{rep} = .91$, two-tailed. An independent-samples t test with condition as the independent variable and the percentage response as the dependent variable showed that responses differed between the two conditions, $t(30) = 3.68$, $p_{rep} = .99$, two-tailed, $\eta^2_p = .31$ (see Fig. 4b). These data show that the right hand appeared less magnified than the left hand when participants wore magnifying goggles and less minified than the left hand when
participants wore minifying goggles. This pattern suggests that the right hand is the primary reference for apparent size scaling.

**General Discussion**

Combined, these results show that the dominant hand, and to a lesser extent the nondominant hand, is used to scale the apparent size of graspable objects. A tool can also serve to scale apparent object size, but only if the perceiver has experience with its use. These experiments demonstrate that the body may serve as a metric with which to scale optical information specifying spatial layout. Because optical information comes to the eye in angular form (i.e., visual angles and oculomotor adjustments, which are scaled as angles) this information needs to be rescaled into size-appropriate units. We propose that the perceptual system uses the body as a perceptual ruler, and thus the sizes of graspable objects are perceived as a proportion of the hand’s size. This proportion directly indicates to the perceiver how large objects are with respect to his or her hand’s grasping capabilities. Previous studies provided evidence for the body-based scaling of extent by showing that people perceive a reachable object to be closer when their reaching ability is expanded by using a tool (Witt, Proffitt, & Epstein, 2005). This likely occurs because the perceptual ruler, defined by reaching ability, is expanded by tool use. Objects at a given physical distance are measured as closer after the ruler is stretched. However, unlike previous studies on the role of body scaling on apparent extents, the experiments presented in this article show a phenomenally noticeable change in size perception attributable to body scaling. Objects appeared to shrink or expand before the participants’ eyes.

An alternative explanation for these findings is that in the presence of the hand, individuals used familiar size as a depth cue (Epstein, 1961, 1965). By such an account, the presence of any familiar object, not just the body, should lead to rescaling. If this were the case, then the presence of the hand would have had a smaller effect (or no effect at all) for familiar compared with unfamiliar objects. Recall that there were equal numbers of familiar and unfamiliar objects, but that there was no difference in the magnitude of the rescaling effect between familiar and unfamiliar objects. Moreover, people are equally familiar with the sizes of their two hands, yet results showed that the dominant hand served more efficiently as a perceptual ruler and led to a larger rescaling effect than the nondominant hand did. Another alternative account is that these findings are a result of demand characteristics. However, we find it extremely unlikely that viewing the left, right, or another individual’s hand would induce different demand characteristics that would account for the different findings in each of these conditions. In addition, we replicated these findings using a visual matching task, which is less susceptible to demand characteristics than are verbal reports.

In order to perceive the world in a way that supports interactions with it, people must relate bodily information to the visual angles that specify the spatial properties of the environment. We have shown here that in the case of graspable objects, optical information is transformed and scaled to the dimensions of one’s hands, especially the dominant hand. In summary, the dimensions of the body play the essential role of providing a perceptual ruler with which to scale the environment. To our knowledge, these are also the first experiments to demonstrate an observable change in the perception of an object’s size due to body-based scaling. Participants reported seeing objects shrink or expand as their hand came into view.

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