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Observational drawing biases are predicted by biases in perception: Empirical support of the misperception hypothesis of drawing accuracy with respect to two angle illusions

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Observational drawing biases are predicted by biases in perception: Empirical support of the misperception hypothesis of drawing accuracy with respect to two angle illusions

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We tested the misperception hypothesis of drawing errors, which states that drawing accuracy is strongly influenced by the perceptual encoding of a to-be-drawn stimulus. We used a highly controlled experimental paradigm in which nonartist participants made perceptual judgements and drawings of angles under identical stimulus exposure conditions. Experiment 1 examined the isosceles/scalene triangle angle illusion; congruent patterns of bias in the perception and drawing tasks were found for 40 and 60° angles, but not for 20 or 80° angles, providing mixed support for the misperception hypothesis. Experiment 2 examined shape constancy effects with respect to reproductions of single acute or obtuse angles; congruent patterns of bias in the perception and drawing tasks were found across a range of angles from 29 to 151°, providing strong support for the misperception hypothesis. In both experiments, perceptual and drawing biases were positively correlated. These results are largely consistent with the misperception hypothesis, suggesting that inaccurate perceptual encoding of angles is an important reason that nonartists err in drawing angles from observation.

Keywords: Drawing accuracy; Angle illusion; Misperception hypothesis.

Realistic observational drawing involves creating a depiction of an external model stimulus with the goal of achieving [illegible]. A visually accurate drawing is "one that can be recognized as a particular object at a particular time and in a particular space, rendered with little addition of visual detail that cannot be seen in the object represented or with little deletion of visual detail" (Cohen & Bennett, 1997, p. 609). Years of training and practice are typically needed to achieve mastery in visual accuracy, which is evident in comparing the drawing performance of artists versus nonartists (Carson & Allard, 2013; Chamberlain, McManus, Riley, Rankin, & Brunswick, 2013; Cohen, 2005; Cohen & Earls, 2010; Kozbelt, 2001; Kozbelt, Seidel, ElBassiouny, Mark, & Owen, 2010; McManus et al., 2010; Ostrofsky, Kozbelt, & Seidel, 2012). Increasingly, experimental psy586.1i7(experimental)-1024.1(p sought to understand the cognitive processes related to individual variability in drawing performance. Here, we assess the influence of perceptual encoding of the stimulus being drawn on drawing

have been reported (Ostrofsky et al., in press; Ostrofsky et al., 2012). Such results suggest that the visual processes responsible for perceptual constancies also act on information guiding drawing behaviour, consistent with the misperception hypothesis. However, such studies do not directly demonstrate this point, for several reasons.

Although previous research demonstrated a relationship between perception and drawing, the influence was not well localized for two reasons. First, because judges typically are asked to make a single, holistic judgement about the accuracy of a drawing, this measure does not indicate what elements of a model were inaccurately depicted in a given drawing (e.g., line curvature, angles, proportions, and/or relative spatial positioning). Second, the perception and drawing tasks were not well matched, which weakened the ability of the research to test the prediction that specific perceptual errors would influence corresponding drawing errors.

To our knowledge, Mitchell et al. (2005) provided perhaps the strongest test of the misperception hypothesis to date. These researchers presented participants with two different versions of the well-known Shepard illusion. In one version, the stimuli were of plain parallelograms; in the other version, the parallelograms had legs attached to them, giving them the appearance of a 3D table. Previous reports suggested that when participants view these stimuli, lines are perceived to be longer when oriented vertically (versus horizontally), and that this illusion is exaggerated when the stimuli include 3D depth cues (Shepard, 1990). Mitchell et al. (2005, Experiment 2) presented subjects with Shepard illusion stimuli (either with or without the contextual cue of table legs) and asked them to draw the two models as accurately as possible. Since line length is an unambiguous property of drawing accuracy, the researchers were able to quantify drawing errors objectively by measuring the lengths of the reproduced lines. After completing the drawings, participants verbally estimated the lengths of the vertical and horizontal lines in each model, yielding an index of perceptual judgement errors. This paradigm represents a strong test of the misperception hypothesis, since the drawing stimuli were selected to allow well-defined predictions about the pattern of drawing errors, and the objective measurement of relative line-length drawing error allows this prediction to be cleanly tested.

Mitchell et al. (2005) replicated the Shepard illusion with respect to perceptual judgements using both versions of the stimulus and also found exaggerated illusion in the 3D contextual-cue condition. Analysis of line length drawing errors also showed that the signature pattern of errors associated with this illusion was only present in the 3D contextual-cue condition. Further, drawing and perceptual errors were correlated in the 3D contextual-cue condition, but not in the noncontextual-cue condition. This pattern of results supports a moderate version of the misperception hypothesis, in that drawing errors appear to have only been influenced by perceptual inaccuracies when the misperception was caused by encoding 3D depth cues.

Thus far we have argued that an ideal empirical approach to misperception hypothesis would involve examining specific predictions about drawing errors rooted in earlier perceptual research, which could be tested using identical stimuli in the perceptual judgement and drawing tasks. In the remainder of this paper, we report and discuss two experiments that test the misperception hypothesis—specifically with respect to the drawing of .

Angle drawing as a test case of the misperception hypothesis

Perhaps the most basic spatial relationships rendered in drawing involve angles, which define how two lines intersect or coterminate. Like other kinds of visual information depicted from observation, the drawing of angles is associated with individual variability in accuracy; further, this variability appears to be associated with drawing ability in general (Carson & Allard, 2013; Chamberlain, McManus, Riley, Rankin, & Brunswick, 2014; McManus et al., 2010). These findings suggest that the accurate drawing of local angles is an essential component in producing visually accurate drawings of more complex objects and scenes.

Applying the misperception hypothesis to angles yields the prediction that errors in drawing angles should be accounted for and related to mimic the process that nonartists have been observed to engage in when producing observational drawings: Tchalenko (2009) observed that nonartists, while producing drawing marks, fixate on the emerging drawing as opposed to the model they are trying to reproduce. Thus, having nonartist participants reproduce the target angles from memory is arguably quite ecologically valid.

Method

Participants

Fifty individuals with no formal training in drawing [40 females, 10 males, ( ) age = 21.9 (6.6) years] were recruited from the Brooklyn College Psychology undergraduate subject pool and participated for course credit.

Stimuli

. In both the perceptual reproduction task and drawing reproduction task, participants were presented with four target angles measuring 20, 40, 60, and 80° (see Figure 1). In each task, half of the trials depicted the target angle embedded in isosceles triangles; on the other half, it was in scalene triangles. In isosceles triangles, the two lines defining the target angle were equal in length, each measuring 111 mm on the screen. In scalene triangles, the two lines defining the target angle were unequal in length, measuring 26 mm and 148.2 mm on the screen, a ratio of 1:5.7.

Stimuli were presented to participants as they appear in Figure 1. All triangles were composed of three black lines, shown in the centre of the screen against a white background. For all stimuli, one line defining the target angle (the base line) was always presented horizontally; the second line defining the target angle (the angle line) deviated in orientation above the base line. For target angles embedded in the scalene triangles, the base line was always longer than the angle line. On each trial, a red arrow identified the target angle.

. In this task, participants adjusted the size of a single angle presented on the screen with the goal of matching the size of the previously presented target angle. The was composed of two black lines, each measuring 100 mm on the screen, presented on a white background. One line (the base line) remained horizontal; the second (the adjustment line) always formed an angle with the base line at their left endpoints. Participants changed the orientation of the adjustment line to adjust the size of the angle. On the screen above the adjustment angle, participants were instructed: "Adjust the size of the angle on the screen to match the size of the target angle you just saw. Click the left and right arrows on the scroll bar to adjust size. When finished, click anywhere else on the screen to move to the next trial."

The adjustment angle was created using the software program Radpix Multiple Image Capture (Version 1.0.23). This program allows one to create an image stack embedded in a Microsoft Office Powerpoint slide. The stack was composed of individual images of angles varying in size between 1° and 179° in 1° increments, displayed one at a time. Participants could change the image being displayed by using the mouse to click the left and right arrow buttons on the scrollbar near the bottom centre of the Powerpoint slide. The adjustment angle size started at 1°, with the starting position of the scrollbar set to its leftmost point. Moving the to the right the size of the adjustment angle in 1° increments maximum of 179°; size adjustment left to the angle. always angle adjustment movdn the adjustment line in attention to the size of the indicated target angle and accurately reproduce it in a series of trials. After participants indicated that they understood the task, they completed the perceptual reproduction and drawing reproduction tasks. Task order was counterbalanced across participants.

identical to the perceptual reproduction task. The experimenter first explained the instructions and administered a single practice trial. Participants were instructed to pay attention only to the target angle pointed to by the red arrow. They were explicitly instructed not to begin their drawing while the stimulus was still present on the screen, but rather to wait until the image disappeared. Participants were told that their goal was to draw the size of the target angle as best they could. They were also instructed not to draw the entire triangle. Participants were allowed to erase and modify their drawings. After these instructions were given, participants completed the single practice trial under supervision of the experimenter. Once the practice trial was over, the task began.

Each trial of the drawing reproduction task began with a screen that read, “

intermediate range between 0° and 90°. Finally, we found that the average extent to which participants were biased to perceive the size of a given angle differently across the two triangle conditions was reliably correlated with the extent to which participants drew the size of a given angle differently across the two triangle conditions. This suggests that transformational processes operating on the bottom-up information inherent in the stimuli similarly affected the information guiding perceptual judgements and drawing reproductions of angles. Thus, the results generated by the correlational analysis is generally consistent with the proposition of the misperception hypothesis that inaccurate perceptual encoding of angles is a major source of error in drawing angles.

One limitation of Experiment 1 relates to a confounding variable pertaining to the length of the lines of the adjustment angle that was used by participants to make their response in the perceptual reproduction task. Since the adjustment angle was composed of two lines of equal length, there was a greater similarity between the adjustment angle and the angles embedded in the isosceles triangle than those embedded in the scalene triangle. Thus, it is possible that the differences in perceptual judgement of angles embedded in the isosceles and scalene triangles were caused by differences in the similarity of target and adjustment angles as opposed to differences of the type of triangle the angles were embedded in. However, the pattern of perceptual bias we observed here (angles embedded in isosceles triangles are perceived larger than the same-sized angle embedded in a scalene triangle) has been previously observed in studies employing the psychophysical method of constant stimuli (Kennedy et al., 2008). So, we suspect that the pattern of bias observed in this experiment was caused by the contextual variable of isosceles versus scalene triangle rather than the confounding variable of similarity between the target and adjustment angles.

Another possible limitation of the drawing task (also relevant to Experiment 2) is that participants always drew one horizontal line and one oblique line. One potential critique of this method is that the drawing biases we observed could have been due to motor biases that are known to influence the drawing of oblique lines (Broderick & Laszlo, 1987). However, by assessing the difference in how an angle of a given size is drawn between when it is embedded in an isosceles versus a scalene triangle (Experiment 1), we are controlling for such motor biases. If any motor bias contributes to error in drawing the oblique line of an angle of a given size (e.g. 60°), then that motor bias should affect performance equally in the isosceles versus scalene triangle conditions. Therefore, any difference in drawing an angle of a given size across the two contextual conditions would then be assumed to be isolating influences of the perceptual processing of the different global-shapes of the stimuli on angle drawing biases.

Limitations aside, the similar perceptual and drawing reproduction biases observed in Experiment 1 were induced by the processing of 2D visual information that did not contain any available depth cues to be processed, in contrast to findings relating the perception and drawing of relative line length (Mitchell et al., 2005). The next experiment tests the robustness of the relationship between perceptual and drawing angle biases by aiming to determine whether biases in perceiving angles caused by the processing of 3D depth

Experiment 2 tests the misperception hypothesis with respect to this shape constancy effect on angle drawing. Participants were shown target angles embedded in cubes and parallelograms and then provided perceptual judgements and drawings of the target angles. The misperception hypothesis predicts a greater regression to right angle effect for angles embedded in cubes than for those in flat par-

(_ . _ . , also always measuring 45 mm in length on the screen) defining the angle joined perceptual reproduction and drawing reproduction tasks. Task order was counterbalanced across participants.

. This task was composed of 32 trials. Each target angle was presented four times each, twice while embedded in the cube stimulus and twice while embedded in the parallelogram stimulus. Cube and parallelogram stimulus trials were organized into blocks; within-block presentation order was randomized for each participant with the constraint that a given target angle could not be presented in two consecutive trials. Half of the participants completed the cube trials first, and the other half of participants completed the parallelogram trials fi

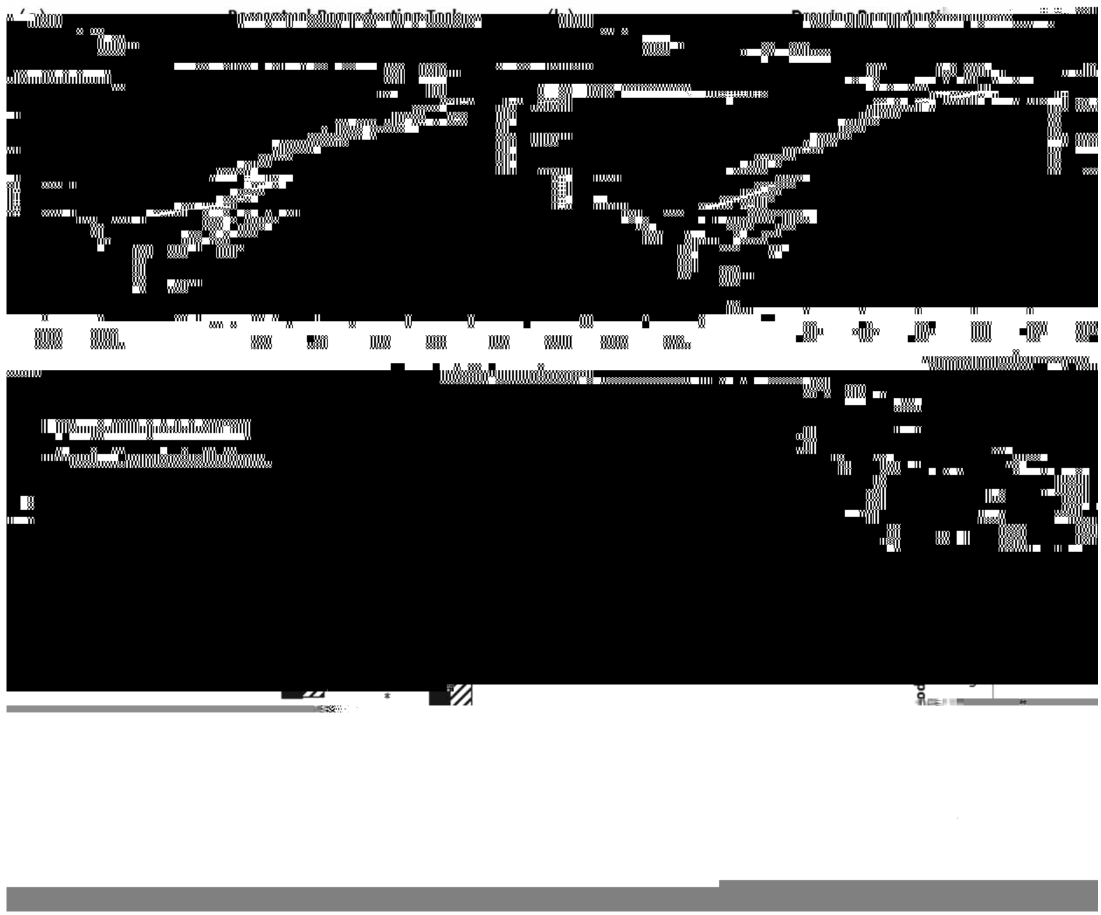

Figure 5. 2. ( ) y– ( ) ( ) y– ( ) ( ) *p < .05, **p < .01, ***p < .001.

angles, the target angles were perceptually reproduced as larger when embedded in cubes than when embedded in a parallelogram for the 29° target angle, (1, 99.9) = 17.83, $< .001$, for the 44° target angle, (1, 99.9) = 7.65, $< .01$, and for the 57° target angle, (1, 99.9) = 4.90, $< .05$. We did not observe a reliable difference on this comparison for the 83° target angle, (1, 99.9) = 1.45, $> .05$. With respect to the obtuse target angles, participants perceptually reproduced the target angle as reliably smaller when embedded in a cube than when in a parallelogram for the 123° target angle, (1, 99.9) = 3.71, $= .05$, and the 151° target angle, (1, 99.9) = 10.33, $< .01$. We did not observe a reliable difference on this comparison for the 97° target angle, = (1, 99.9) = 0.75, $> .05$, or the 137° target angle, (1, 99.9) = 0.73, $> .05$.

Overall, these results replicate the previously documented shape constancy effect. Since angles embedded in cubes are perceptually transformed to be closer to 90° than when embedded in parallelograms, this leads to a prediction derived from the

$(22) = .46$, , $< .05$. Therefore, the individual variability in how shape constancy biases vary across different target angle sizes are related between perceptual judgements and drawings of angles embedded in cubes versus parallelograms.

Discussion

The results of Experiment 2 were largely consistent with the misperception hypothesis of drawing accuracy. We observed a strong congruency in bias across the perceptual and drawing reproduction tasks using stimuli eliciting a perceptual illusion due to processing 3D depth cue information. Specifically, the typical pattern of regression to a right angle was evident both when participants made perceptual judgements and when they made drawings of the size of angles. Further, we observed a covarying relationship between the shape constancy biases that were observed in the participants' perceptual judgements and drawings of angles that were embedded in cubes versus parallelograms.

the component cognitive processes that support skill in that domain. This methodological approach has employed to understand drawing skill, with some studies demonstrating cognitive and perceptual advantages experienced by skilled artists relative to nonartists (Chamberlain et al., 2013; Kozbelt, 2001; Ostrofsky et al., 2012; Zhou, Cheng, Zhang, & Wong, 2012) and other studies failing to find such differences (Ostrofsky, Kozbelt, & Kurylo, 2013; Perdreau & Cavanagh, 2011).

It remains open to question whether individuals who are drawing experts experience the same angle-based perceptual biases that nonartists were observed to experience in this study. Although greater skill in drawing (assessed by both subjective accuracy ratings of drawings of complex images and objective measurements of drawn angles) appears to be associated with perceptual judgement accuracy of the size of angles (Chamberlain et al., 2014, but see Carson & Allard, 2013, for a lack of difference between artists and nonartists with respect to accuracy of verbal estimates of angle sizes), those studies analysed errors in the absolute judgements of the perceived size of a plain angle (e.g., the degree to which individuals misperceive the size of a plain 60° angle). It remains unclear whether

methodology for quantifying drawing accuracy. [illegible] Advance online publication. http://dx.doi.org/10.1037/a0035635

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