Psychon Bull Rev (2014) 21:1444–1451
DOI 10.3758/s13423-014-0617-2

BRIEF REPORT

Seeing and liking: Biased perception of ambiguous figures consistent with the "inward bias" in aesthetic preferences

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Published online: 29 March 2014
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Abstract Aesthetic preferences are ubiquitous in visual experience. Indeed, it seems nearly impossible in many circumstances to perceive a scene without also liking or disliking it to some degree. Aesthetic factors are only occasionally studied in mainstream vision science, though, and even then they are often treated as functionally independent from other aspects of perception. In contrast, the present study explores the possibility that aesthetic preferences may interact with other types of visual processing. We were inspired, in particular, by the *inward bias* in aesthetic preferences: When an object with a salient "front" is placed near the border of a frame (say, in a photograph), observers tend to find the image more aesthetically pleasing if the object faces inward (toward the center) than if it faces outward (away from the center). We employed similar stimuli, except that observers viewed framed figures that were ambiguous in terms of the direction they appeared to be facing. The resulting percepts were influenced by the frames in a way that corresponded to the inward bias: When a figure was placed near a frame's border, observers tended to see whichever interpretation was facing inward. This effect occurred for both abstract geometric figures (e.g., ambiguously-oriented triangles) and meaningful line drawings (e.g., left-facing ducks or right-facing rabbits). The match between this new influence on ambiguous figure perception and the previously studied aesthetic bias suggests new ways in which aesthetic factors may relate not only to what we like, but also to what we see in the first place.

Keywords Ambiguous figures · Bistable images · Aesthetics · Inward bias

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Our visual experience of the world is deeply, intrinsically imbued with aesthetic content. Sometimes this content is at the forefront of our experience, as when we visit an art gallery or a museum. But even in everyday life, it is hard to see many kinds of objects and scenes without also liking or disliking them to some degree—often without trying—and this form of seemingly automatic visual evaluation may even be adaptive in some contexts (e.g., Hurlbert & Ling, 2007; Palmer & Schloss, 2010).

Aesthetic visual experience may be salient and ubiquitous, but you wouldn't necessarily know that from reading most textbooks or journals in either vision science or cognitive psychology. With only a few exceptions (such as research on facial attractiveness), research on the nature of aesthetic perception seems especially scarce. This may be in part because aesthetic experience is influenced not only by cognitive and perceptual factors, but also by a rich and messy combination of historical, cultural, and societal factors that are not obviously amenable to psychophysical study. Indeed, it might be possible even in principle to explain only a relatively small percentage of our aesthetic experience in terms of underlying regularities of visual processing. Nevertheless, researchers have made some impressive progress in identifying visual factors that have a robust influence on aesthetic judgments (for a recent review, see Palmer, Schloss, & Sammartino, 2013).

The cognitive psychology of aesthetic visual preferences

Most studies of the possible visual roots of aesthetic preferences have involved variations in the color, shape, or location of objects within scenes. For example, people prefer colors linked to objects that they like (e.g., Palmer & Schloss, 2010); they prefer shapes that are symmetrical (e.g., Gartus & Leder, 2013) and that are certain sizes (e.g., Linsen, Leyssen, Gardner, & Palmer, 2011); and they prefer objects that are oriented in certain ways (e.g., Avrahami, Argaman, & Weiss-Chasum, 2004; Bertamini, Bennett, & Bode, 2011) and that are located at the center of a frame or along axes of symmetry (e.g., Palmer & Guidi, 2011).

These and other results have also inspired several more global theories of the nature of aesthetic preferences. For example, researchers have suggested that we tend to aesthetically prefer those image elements that we have been exposed to most often (e.g., Zajonc, 1968), those that are most typical of their categories (e.g., Halberstadt, 2006), and/or those that we can process most fluently (e.g., Reber, Schwarz, & Winkielman, 2004). Still, none to our knowledge have attempted to account for the effect on which we focus here: the inward bias.

The inward bias

Recent research has identified an *inward bias*: When an object is near a border of a rectangular frame, people judge the image to be more aesthetically pleasing when the object is facing inward rather than outward (Palmer, Gardner, & Wickens, 2008). This result is consistent with various previous prescriptive thoughts on how the objects in photographs (for example) should be balanced, and it also seems to capture how actual art is in fact most typically constructed (at least when the objects are animals; Bertamini et al., 2011). This bias holds for both animate objects (such as people) and inanimate objects with clear "facing" directions (such as teapots; Palmer et al., 2008), as well as for the spatial envelope of multiobject arrays (Leyssen, Linsen, Sammartino, & Palmer, 2012)—and for both horizontal and vertical borders (Sammartino & Palmer, 2012). (At the same time, though, this research has not yet explored just what can "count" as a frame, beyond simple continuous linear borders.) In the present experiments, we replicate the inward bias, but instead of using objects with unambiguous facing directions, we use ambiguous figures that can be seen as facing in multiple directions.

Perceiving ambiguous figures

External cues underdetermine the nature of the local environment, so that percepts are in effect the result of "unconscious inferences" (e.g., Gregory, 1980; Rock, 1983). Perhaps the most powerful demonstrations of such inferences are ambiguous images, in which the same unchanging pattern of light yields an alternation between multiple different percepts (for a review, see Long & Toppino, 2004). The prevalence of perceptual switching in such figures can be influenced by variables such as stochastic noise (Taylor & Aldridge, 1974), voluntary effort (van Ee, van Dam, & Brouwer, 2005), changing patterns of eye movements and/or covert visual attention (Peterson & Gibson, 1991; Toppino, 2003), unconscious transient visual cues (Ward & Scholl, 2014), and consistency with stimulation from other modalities (Hsiao, Chen, Spence, & Yeh, 2012). Here, we suggest what is, to our knowledge, a new type of influence on the perception of ambiguous images, based on how figures that can be seen with multiple "facing" directions are placed relative to a surrounding frame.

The present study

Observers viewed figures that were ambiguous in terms of the direction that they seemed to be facing and pressed keys to continuously indicate which interpretation they perceived during each 15-s trial. Experiment 1 employed a figure with semantic content (a duck/rabbit; modified from Torrey, 1970) placed in a rectangular frame (as in Fig. 1a); Experiment 2 employed an abstract geometric figure (a triangle; cf. Attneave, 1968) placed in a triangular frame (as in Fig. 1b); and Experiment 3 employed a triangle placed in circular frame (as in Fig. 1c). Of interest was whether figures near frame borders would be seen more often as facing inward.

Experiment 1: Ducks and rabbits

We first tested whether and how the perception of a duck/rabbit figure depended on its horizontal proximity to a rectangular border.

Method

Participants

Thirty-two naïve observers from the Yale/New Haven community (all with normal or corrected-to-normal acuity) participated in exchange for course credit or a small monetary payment. Pilot testing revealed that a sample size of 20 or more observers was sufficient to produce the observed effects, but we tested 32 in this first experiment so that we could effectively balance the design employed here (see Footnote 1).

Apparatus

Stimuli were presented via custom software written in Python with the PsychoPy libraries (Peirce, 2007), presented on a display subtending approximately 14.53° × 11.73°. Observers sat approximately 65 cm from the display (without restraint), with this distance used to calculate all of the reported spatial extents.

Stimuli

Observers viewed a modified version of the duck/rabbit figure (2.25° × 2.08°), presented as a black silhouette embedded in a grass field background (as in Fig. 1a), surrounded by a rectangular frame (9.20° × 5.79°, drawn with a stroke of 0.06°,

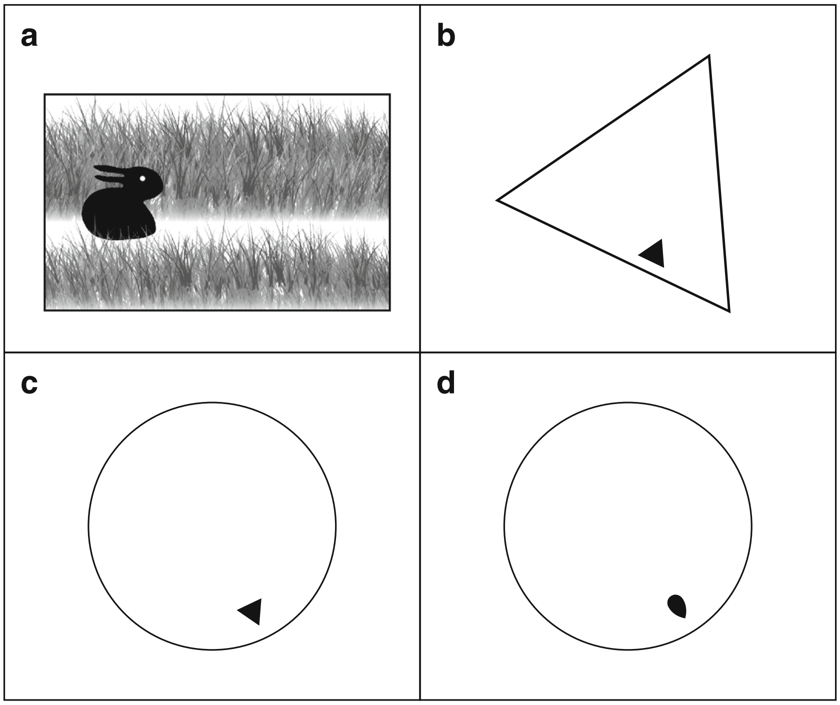

Fig. 1 A sample screenshot of: **a** an ambiguous duck/rabbit near the left border, from a trial from Experiment 1; **b** an upright-triangle trial from Experiment 2; **c** an inverted-triangle trial from the ambiguous figure test of Experiment 3; and **d** an outward-facing "drop" figure from the aesthetic preference test of Experiment 3. In each case, the relevant experiment varied whether the shape was facing inward or outward relative to the frame

centered on the display). Each of the conditions reported below used the duck/rabbit figure from Fig. 1a or its mirror image equally often, and this was also true for the background (with these factors counterbalanced independently). The duck/rabbit figure appeared in the center of the frame or near the right or left border (shifted 2.55° to the right or left, respectively).

Procedure and design

Observers completed individual 30-min sessions in a dimly lit room. Each trial began with the frame appearing for 1 s, followed by the duck/rabbit embedded in the background for 15 s, followed by a blank screen for 2 s before the start of the next trial. Whenever the duck/rabbit was visible, observers reported their percept by pressing one of two keys ("y" for duck, "b" for rabbit, or vice versa, counterbalanced across observers).[1]

Observers completed 4 practice trials (the results of which were not recorded), followed by 60 experimental trials, separated into five blocks of 12 trials each (with a self-paced rest period between each block). The 12 trials within each block were fully counterbalanced in terms of the three possible positions (left, center, right), the two possible figures (duck/rabbit or its mirror image), and the two possible backgrounds (the "grass field" or its mirror image).

Results and discussion

First interpretation on each trial

We first tested whether observers' initial percepts on each trial were likely to match the inward bias. These data are depicted in Fig. 2a, in terms of the percentage of total trials for each figure location that were initially seen with the figure facing to the left. Inspection of this figure reveals a clear pattern, wherein proximity to the border dramatically influenced observers' percepts—with more left-facing percepts for figures near the right border (58.6 %, $SD = 18.5$ %) than for figures near the left border (40.5 %, $SD = 16.1$ %), $t(31) = 3.96$, $p < .001$, $d = 0.70$.

Total duration

As is depicted in Fig. 2b, this same contrast was replicated in an analysis of the summed duration of each percept throughout each trial (again analyzed as a percentage of the total trial

[1] All of the reported analyses involve these trials. Before this main phase of the experiment, however, we first tested observers' initial percepts: The duck/rabbit first appeared for 1 s near either the right or the left border (counterbalanced across observers), after which observers were asked to "write down what you saw." The coded responses did not yield any significant initial bias to perceive the figure in one way or the other, and so these data are not reported here. Because of this, we initially chose our sample size to fill out a 2 × 2 × 2 × 2 design (initial position of the duck/rabbit [left vs. right], which image of the animal was initially used [original vs. mirror-image], which background was initially used [original vs. mirror image], and response key assignment [initial key mapping vs. reversed]), although these factors were not varied within subjects in the data reported in the main text.

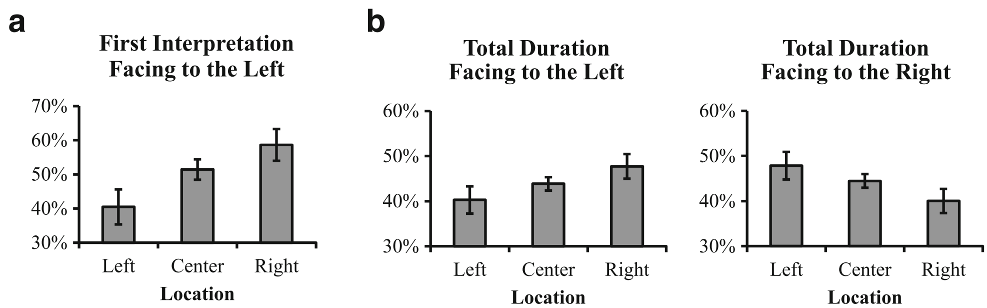

Fig. 2 Results from Experiment 1: **a** Percentages of trials in three conditions (left, center, and right positions) on which observers initially interpreted the figure as facing to the left; **b** percentages of total duration for left- and right-facing percepts in the three conditions. Error bars are 95 % confidence intervals after subtracting out the shared variance

duration): Left-facing percepts were seen for longer when figures were near the right border (47.7 %, *SD* = 10.0 %) than when figures were near the left border (40.3 %, *SD* = 8.5 %), $t(31) = 2.72$, $p = .010$, $d = 0.48$; and similarly, right-facing percepts were seen for longer when figures were near the left border (47.8 %, *SD* = 11.0 %) than when figures were near the right border (40.0 %, *SD* = 9.9 %), $t(31) = 2.89$, $p = .007$, $d = 0.51$. (Note that these two contrasts must be calculated separately for total duration for a technical reason: Because observers may spend some time not seeing either percept at the very start of the trial—i.e., because it may take them some short time to press the first key—the left-facing vs. right-facing durations can be subtly different.)[2]

The analyses of perceptual bias in this experiment—in terms of both the initially perceived interpretations and the total duration of the possible interpretations—aligned with the inward bias. In short, for bistable figures near the display borders, observers tended to see those interpretations corresponding to the inward bias more often.

Experiment 2: Ambiguous triangles

Is the inward bias in ambiguous figure perception specific in any way to left- vs. right-facing figures in rectangular frames, or perhaps to semantically meaningful objects? To find out, we replicated the effect with a simple geometric figure — a triangular figure in a triangular border (as in Figure 1b).

Method

This experiment was identical to Experiment 1, except as noted here. Twenty-two new observers participated. (This sample size was chosen to be the end of the first experimental session that exceeded 20 subjects.) The ambiguous figure was an equilateral triangle (with a side length of 0.93°), which observers can see as pointing in any of the three directions (Attneave, 1968). The triangle figure was always presented inside an equilateral triangular frame (with a side length of 8.07°, drawn with a stroke of 0.06°). The position of the figure within the frame was initially calculated by assuming that the frame was upright (i.e., with a horizontal lower contour), with the figure placed (either upright or inverted, counterbalanced within each block) with its nearest edge 0.35° from the frame's bottom contour and its horizontal position chosen randomly along the middle 5.05° of the frame's bottom contour. (Inverted trials were included simply to control for the fact that the inward direction for upright figures was also the only direction that was perpendicular to the nearest frame border.) Before being presented on each trial, however, both the figure and its frame were rotated together by a randomly chosen angle—so that the triangle figure was always facing inward or outward relative to the frame but its absolute angle on the display could vary between 0° and 360°.

Instead of pressing keys, the observers reported their percepts continuously by clicking the mouse in "front" of the figure, corresponding to whichever direction the triangle seemed to be pointing. Observers completed 2 practice trials (the results of which were not recorded), followed by 64 experimental trials, separated into four blocks of 16 trials each.

Results and discussion

First interpretation on each trial

The percentages of total trials for each figure orientation (upright vs. inverted) that were initially seen with the figure pointing perpendicular to the nearest frame border are depicted in Fig. 3a. For upright figures, this perpendicular direction also corresponded to the inward bias and was seen much more than would be predicted by chance (62.4 %, *SD* =

[2] Inspection of Fig. 2a, b reveals that the initial percepts and total durations for centered duck/rabbits were always numerically between the extremes for figures near the borders, but these contrasts were only sporadically statistically significant. We do not report these six contrasts here, though, since none of our conclusions involve (or are influenced) by them.

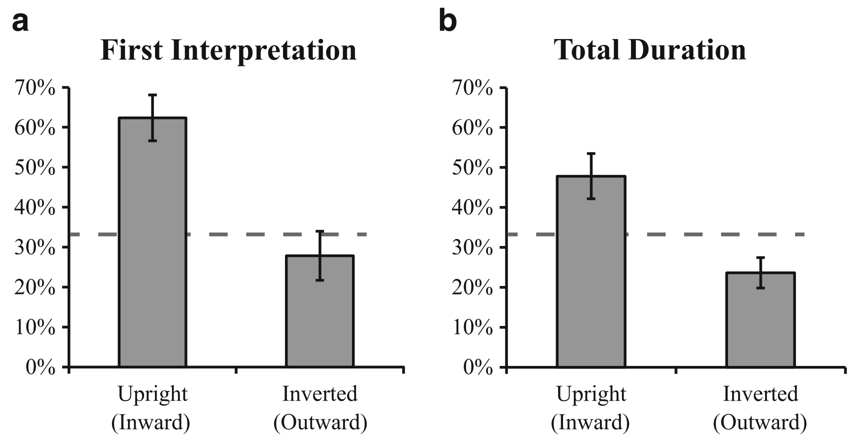

Fig. 3 Results from Experiment 2: **a** Percentages of trials in upright and inverted conditions on which observers initially interpreted the figure as pointing in the perpendicular direction; **b** percentages of total duration for which observers saw the figure pointing in the perpendicular direction. Error bars are 95 % confidence intervals

13.0 %), $t(21) = 10.48$, $p < .001$, $d = 2.23$. (Recall that the "inward" direction here, with the triangular frame, did not map onto a simple left or right direction, as in Experiment 1.) For inverted figures, this perpendicular direction corresponded to the triangle facing outward and was seen no more (and in fact marginally less) than would be predicted by chance (27.8 %, $SD = 13.8$ %), $t(21) = 1.86$, $p = .077$, $d = 0.40$.

Total duration

As is depicted in Fig. 3b, this same contrast was replicated in an analysis of the summed duration of each percept throughout each trial (again analyzed as a percentage of the total trial duration): The inward-pointing percept (on upright trials) was seen for longer than would be predicted by chance (47.8 %, $SD = 12.8$ %), $t(21) = 5.32$, $p < .001$, $d = 1.13$, and the outward-pointing percept was seen for shorter than would be predicted by chance (23.6 %, $SD = 8.5$ %), $t(21) = 5.33$, $p < .001$, $d = 1.14$.

These results collectively replicate the inward bias for triangular figures and borders, with the differing patterns of results for upright versus inverted figures ensuring that the inward bias was not simply a bias to perceive whichever pointing direction was perpendicular to the nearest frame border.

Experiment 3: Inward bias in aesthetic preferences

Although the results of Experiments 1 and 2 are consistent with the general notion of an inward bias in aesthetic preferences, this aesthetic bias has not previously been observed with simple geometric shapes. As such, we replicated the inward bias in ambiguous figure perception again (now using a triangle figure within a circular frame, as in Fig. 1c), while also testing the same observers' aesthetic preferences for inward- versus outward-facing unambiguous geometric figures matching the stimuli in the perception task as closely as possible.

Method

This experiment was identical to Experiment 2, except as noted here.

Participants

Twenty-two new observers (matching the sample size of Experiment 2) participated.

Stimuli

To test ambiguous figure perception, an equilateral triangle (with a 1.14° side length) was presented upright or inverted within a circular frame that had a radius of 5.19° and a line width of 0.06°. The triangle always appeared in a randomly chosen location along the frame border, 1.28° away (measuring from the triangle's centroid). In the upright condition, one of the triangle's vertices was pointing inward to the center of the frame. In the inverted condition, one of the triangle's vertices was pointing directly away from the center of the frame. Each randomly chosen location was used twice (once for each condition), presented in a different random order for each observer.

To test aesthetic preferences, the same circular frame was presented, but observers viewed an unambiguously oriented "drop" figure (matched in area to the triangle; 0.75° × 1.15°) that was presented in the same frame positions as was the ambiguous triangle (see Fig. 1d).

Procedure and design

Observers completed individual 45-min sessions. Observers first completed the ambiguous figure test (with four practice trials), and then (following new instructions) completed the test of aesthetic preferences, as follows. On each trial, observers pressed one of two keys to reveal the initial display, and subsequently they were allowed to freely press those keys to alternate between the two possible displays. Each display presented a drop in the same location, but facing in opposite directions. The initial orientation of the drop on each trial was chosen randomly to correspond to one of the three orientations of the matched triangle's vertices (so that it was facing directly in vs. out on one third of the trials—which we subsequently focused on during the analyses). Observers switched between the two displays freely (viewing each at least once) until they decided which looked more aesthetically pleasing, at which point they hit a third key to record their choice. After each choice was recorded, a "Strength: 1–7?" prompt appeared, and observers pressed a key from 1 (*very weak*) to 7 (*very strong*) to indicate the strength of their choice, after which the next trial began immediately.

Observers completed 3 practice trials of the preference task (the results of which were not recorded), followed by 96 randomly ordered experimental trials, separated (with no breaks) into four blocks of 24 trials each. The 24 trials within each block were fully counterbalanced in terms of the three possible initial orientations (corresponding to the matched triangle's three vertices), with each one testing 8 possible positions that had previously been used during the ambiguous figure test. There were thus 32 possible randomly chosen positions in total, each tested twice in the ambiguous figure task (for upright vs. inverted triangles) and three times in the aesthetic perception task (corresponding to the three possible orientations of the triangle).

Results and discussion

Ambiguous figures: First interpretation on each trial

The percentages of total trials for each figure orientation (upright vs. inverted) that were initially seen with the figure pointing perpendicular to the nearest point along the border are depicted in Fig. 4a. There were many more such trials for the upright figures (corresponding to the inward bias; 72.6 %, SD = 17.2 %) than for the inverted figures (corresponding to an outward bias; 45.5 %, SD = 19.3 %), $t(21) = 4.71$, $p < .001$, $d = 1.01$.

Ambiguous figures: Total duration

As is depicted in Fig. 4b, this same contrast was replicated in an analysis of the summed duration of each percept throughout each trial (again analyzed as a percentage of the total trial duration): The inward-pointing direction (i.e., the perpendicular orientation on upright trials) was seen for longer (55.8 %, SD = 14.5 %) than the outward-pointing direction (i.e., the perpendicular orientation on inverted trials; 34.7 %, SD = 14.4 %), $t(21) = 4.93$, $p < .001$, $d = 1.05$.

Aesthetic preferences

Analyzing those trials on which the drop figure was oriented perpendicular to the nearest point on the frame, we observed an inward bias in aesthetic preferences: Observers chose the inward-facing drops at a higher rate than would expected by chance (60.8 %, SD = 22.8 %), $t(21) = 2.22$, $p = .037$, $d = 0.47$. The average strength ratings (coded positive for inward-facing displays and negative for outward-facing displays), however, only marginally replicated the two-alternative forced choice (2AFC) data ($M = 0.87$, $SD = 2.21$), $t(21) = 1.85$, $p = .079$, $d = 0.39$. This suggests that 2AFC ratings (as also used in Palmer et al., 2008) may be a more sensitive test of the inward bias for aesthetic preference than are strength-of-choice ratings.

These results replicate the inward bias for triangular figures inside a circular frame, and for the first time, they show that this same inward bias occurs for ambiguous figure perception

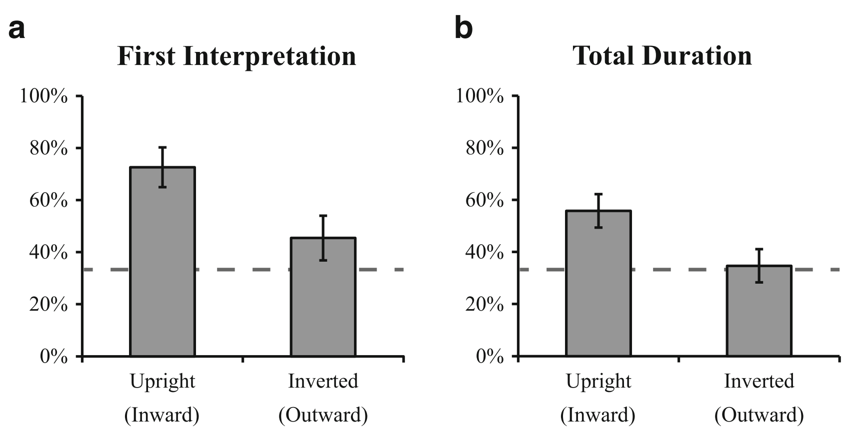

Fig. 4 Results from the ambiguous figure test of Experiment 3: **a** Percentages of trials in upright and inverted conditions on which observers initially interpreted the figure as pointing in the perpendicular direction; **b** percentages of total duration for which observers saw the figure pointing in the perpendicular direction. Error bars are 95 % confidence intervals

and for aesthetic judgments, when tested in the same observers, with stimuli that are as similar as possible.[3]

General discussion

This study was inspired by previous demonstrations of an “inward bias” in aesthetic preferences, as demonstrated with simple pictures (Palmer et al., 2008) and photographs (Sammartino & Palmer, 2012). In each case, observers seem to find figures near a border more pleasing when they are unambiguously facing inward instead of outward — and such choices may also have guided artists, as assessed in databases of paintings depicting animals (Bertamini et al., 2011). Here, we replicated this inward bias using simple geometric shapes (in Experiment 3). (Leysson et al., 2012, also demonstrated the inward bias using the abstract spatial envelope created by the configuration of a tall thin object and a flat object, but the objects in each case were still recognizable pictures with semantic content. And Palmer & Griscom, 2013, did not measure an inward bias.)

The primary result of this study, however, was a different kind of inward bias: Observers tend to see figures with ambiguous orientations as facing inward for longer (and also first, on each trial) when the figures were located near a border. This effect was demonstrated for duck/rabbit silhouettes placed near the borders of rectangular frames (in Experiment 1) and for ambiguously oriented triangles placed near the borders of triangular frames (in Experiment 2) or circular frames (in Experiment 3). Moreover, this inward bias occurred in Experiment 3 for the very same observers who also showed the inward bias in aesthetic preferences, using unambiguously oriented figures that were as well-matched as possible.

To our knowledge, these results reflect a new kind of contextual influence on ambiguous figure perception: What we see in such figures depends not only on the properties of the figure itself, but also on how the figure is situated with respect to its immediate environment. What causes this new kind of inward bias? The experiments themselves are unable to answer this question, of course, and we have been careful to note only that this new inward bias is (merely) consistent with the inward bias in aesthetic preferences (and so could be caused by some unrelated factor). (This is the same situation as that faced by the only other example we can think of that demonstrated the same sort of effect for both aesthetic preference and visual performance: Certain diagonal orientations are both more aesthetically pleasing and more readily found in visual search tasks, but the relationship between these effects remains unclear; Avrahami et al., 2004.)

Nevertheless, it is interesting to speculate on possible causal connections between the two sorts of inward biases. There are three possibilities. First, the aesthetic preferences may be driving the ambiguous figure perception: Perhaps we see the figures facing inward precisely because we like that interpretation better. Second, the bias for ambiguous figure perception may be driving the aesthetic preferences: Perhaps we simply process inward-facing figures more fluently, and this fluency leads to greater liking (Reber et al., 2004). Third, both inward biases may be caused by a third factor: Perhaps, for example, we tend to attend differently to inward- versus outward-facing objects, and this attentional difference influences both ambiguous figure perception and aesthetic preferences. This possibility could be explored, for example, by assessing the influence of attentional loads on each type of inward bias. Testing these sorts of possibilities may be an exciting avenue for future work on how what we like may be related to what we see.

Acknowledgments For helpful conversation and/or comments on earlier drafts, we thank Chaz Firestone, Brandon Liverence, and Aysu Suben.

[3] Future studies with vastly larger samples might also be able to correlate the magnitude of these two types of inward biases. To compute such a correlation here, we began in the ambiguous figure task by computing a “perpendicular bias” measure for total duration (the percentage seen perpendicular minus the average of the percentages seen in the other two directions), with the difference in perpendicular biases for upright versus inverted trials used as the measure of the strength of the inward bias. This measure was not significantly correlated with the inward bias for aesthetic judgment, measured in terms of either the percentage of inward choices, $r = -.073$, $p = .746$, or the strength ratings, $r = -.078$, $p = .731$. A null effect that persisted in an experiment designed with such correlations in mind (with much larger samples) might suggest that the relationship between perception and preference is categorical rather than continuous: Perhaps one tends to see the interpretation that is judged to be more aesthetically pleasing whenever that aesthetic preference is above a certain threshold.

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