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Brief article

Looking into the future: An inward bias in aesthetic experience driven only by gaze cues

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ABSTRACT

The inward bias is an especially powerful principle of aesthetic experience: In framed images (e.g. photographs), we prefer peripheral figures that face inward (vs. outward). Why does this bias exist? Since agents tend to act in the direction in which they are facing, one intriguing possibility is that the inward bias reflects a preference to view scenes from a perspective that will allow us to witness those predicted future actions. This account has been difficult to test with previous displays, in which facing direction is often confounded with either global shape profiles or the relative locations of salient features (since e.g. someone's face is generally more visually interesting than the back of their head). But here we demonstrate a robust inward bias in aesthetic judgment driven by a cue that is socially powerful but visually subtle: averted gaze. Subjects adjusted the positions of people in images to maximize the images' aesthetic appeal. People with direct gaze were not placed preferentially in particular regions, but people with averted gaze were reliably placed so that they appeared to be looking inward. This demonstrates that the inward bias can arise from visually subtle features, when those features signal how future events may unfold.

1. Introduction

When you aim your camera at a scene you wish to capture, you face a problem that artists have faced for centuries: How can you best frame your composition? There is no easy answer to this question, since people's aesthetic preferences vary dramatically. Aesthetic taste can be extremely individualized and is influenced by personal history, countless sociological factors, and seemingly arbitrary cultural conventions. Some regularities, nevertheless, are powerful enough to persist across people, contexts, and time. One such example is the "inward bias" in aesthetic experience.

1.1. The inward bias in preference and perception

When an object in a frame is facing to one side, people prefer compositions in which that object is facing inward (i.e. toward the center, and thus away from the frame's nearest vertical edge) rather than outward (i.e. away from the center, and thus toward the nearest vertical edge). For example, most people prefer the composition in Fig. 1a compared to that in Fig. 1b. This inward bias is extremely pervasive: It is observed in typical compositions of amateur photographers (Palmer, Gardner, & Wickens, 2008), professional photographers (Gardner, Fowlkes, Nothelfer, & Palmer, 2008), visual artists (Bertamini, Bennett, & Bode, 2011), and cinematographers (Bode, Bertamini, & Helmy, 2016). It also holds in aesthetic preferences of naïve observers across a wide variety of displays, from depictions of objects and animals (Palmer et al., 2008) to abstract geometric shapes (Chen & Scholl, 2014; Guidi & Palmer, 2015). The inward bias also remains robust across different types of compositions—including both single objects (Palmer et al., 2008) and multi-object arrays (Leyssen, Linsen, Sammartino, & Palmer, 2012), for both horizontal and vertical dimensions (Sammartino & Palmer, 2012a), and even with circular frames (Chen & Scholl, 2014). (Semantic factors can sometimes overpower this preference, however; see Sammartino & Palmer, 2012b.)

Initial studies of the inward bias were focused solely on aesthetic experience, in a way that may seem relatively unconnected to other aspects of visual processing. Recently, however, a similar preference for inward-facing objects was discovered in the perception of ambiguous figures. In particular, when images with ambiguous orientations (e.g. a bistable duck/rabbit figure; Fig. 1c) are placed off-center in frames, people tend to see the interpretations that are facing inward—in terms of both their initial percepts and their most dominant percepts (Chen & Scholl, 2014). This suggests that the inward bias may not be just an

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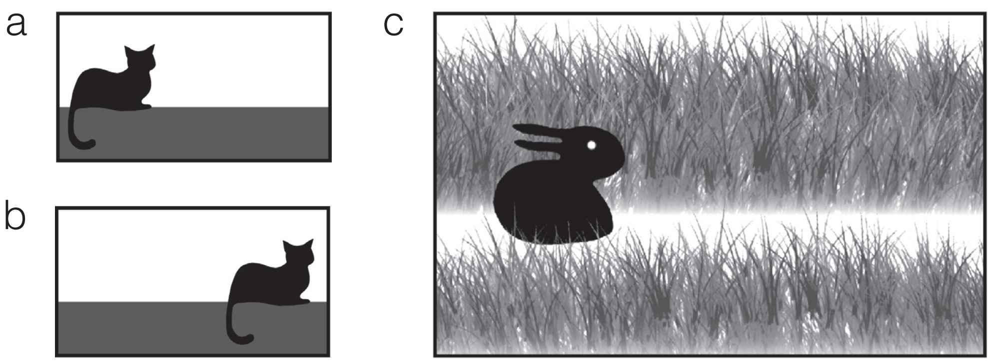

Fig. 1. (a) and (b) An example of the inward bias in aesthetic experience (adapted from Palmer et al., 2008): Observers prefer the image with the inward-facing cat to the image with the outward-facing cat. (c) An example of the inward bias in ambiguous-figure perception (Chen and Scholl, 2014): Observers tend to see the interpretation of the duck/rabbit figure that is facing inward.

artistic convention or an isolated aesthetic curiosity, but that it may rather be connected to mechanisms of visual processing.

1.2. Why does the inward bias exist?: Looking into the future?

Why does the inward bias exist? One intriguing possibility is that it is rooted in an adaptive property of our minds: Objects (e.g. cars, dogs, tools, and people) tend to act in the direction in which they are facing—and they tend to move forward more often than they move backward. Thus, the inward bias may reflect a preference to view scenes from a perspective that will allow us to witness those predicted future behaviors: When objects face inward (in a frame), for example, they will more likely stay in view if they move—whereas an outward-facing object might simply move out of view, especially if the relevant ‘frame’ is the observer's field of view. (And even for objects that do not move on their own, we often interact with their fronts more than their backs—from chairs to smartphones.)

As explored in the General Discussion, this account—in which the inward bias arises due to an adaptive preference to “look into the future”—can be considered as a sort of variant of the ‘affordance space’ hypothesis, in which observers prefer centered representations, but those representations are themselves asymmetric affordance spaces (Palmer & Langlois, 2017; Sammartino & Palmer, 2012a). It seems especially difficult to test this view with the typical stimuli used in previous experiments, however: Facing direction, after all, is often confounded with either global shape profiles or the relative locations of salient features. (A person's face will generally be more visually interesting than the back of their head.) Thus, an inward bias based on the likely direction of behaviors and interactions will typically be confounded with the direction of brute visual salience.

Teasing apart the “looking into the future” hypothesis from the role of visual salience thus requires a stimulus that is visually subtle but that nevertheless has a clear facing direction (and thus a clear likely path for behaviors/interactions). Here we employed one such stimulus that has special social significance: averted gaze.

1.3. Averted gaze

The most salient stimuli in our lives may be other people's eyes (for reviews, see Emery, 2000; Grossmann, 2017). Eye gaze reliably signals the direction of attention (e.g. Hoffman, 1998), intention (e.g. Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), and future actions (e.g. Land & Hayhoe, 2001). As a result, our visual systems are especially sensitive to gaze. Within about 100 ms of seeing another person's gaze, our own attention is oriented in the direction they are looking (e.g. Driver et al., 1999; for a review, see Frischen, Bayliss, & Tipper, 2007). And in fact, gaze direction is processed (and can direct attention) even when it is not consciously perceived (e.g. Chen & Yeh, 2012; Sato, Okada, & Toichi, 2007; Stein, Senju, Peelen, & Sterzer, 2011), and even when gaze cues aren't actually reliable (as is the case in most such experiments). Sensitivity to gaze is also present from the very beginning of life (e.g. Farroni, Csibra, Simion, & Johnson, 2002), and it guides infants' attention starting at around 3 months (e.g. Hood, Willen, & Driver, 1998). (This phenomenon isn't even specific to humans, since gaze cueing can also be observed in other social species; e.g. Povinelli & Eddy, 1996.)

The effects of gaze are especially impressive given that the eyes (despite their immense social significance) are actually quite visually subtle stimuli. Indeed, people detect averted gazes with eye rotations that are as small as 0.75°, when viewed from about 1 m away (Cline, 1967). Averted gazes thus enable us to test the idea that the inward bias in aesthetic experience reflects the importance of “fronts” in signaling future behaviors, while minimizing the influence of brute visual salience.

2. Experiment 1: An inward bias driven by averted gaze

We explored whether perceived gaze alone induces an inward bias in aesthetic experience, using a photo-adjustment task (adapted from Palmer et al., 2008). Each subject viewed a photo of a person with direct or averted gaze (as depicted in Fig. 2) and adjusted its horizontal position within the photo to maximize its aesthetic appeal. To avoid task demands, each subject completed only a single trial. An online demonstration can be viewed at http://perception.yale.edu/inward-bias-gaze/.

2.1. Method

2.1.1. Subjects

240 subjects (131 females; M_{age} = 35.1) were recruited through Amazon Mechanical-Turk (MTurk), and each completed a single trial in a 3–5 min session in exchange for monetary compensation. (For a

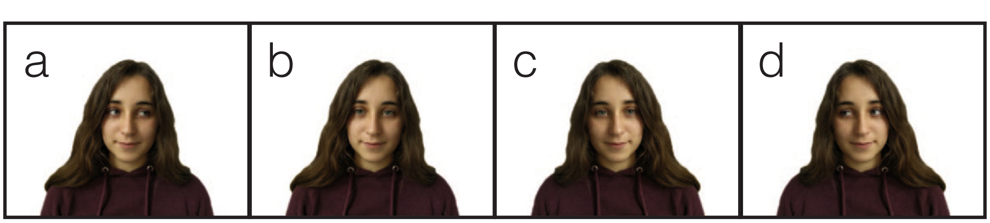

Fig. 2. Examples of the stimuli used in the photo adjustment task. A photo of a person gazing straight at the camera was taken and the background was removed (c). The eye region of the image was then replaced with the eye region (and only the eye region) from a photo of the same person gazing to the left (d). The images were then mirrored to create the rightward gaze stimulus (a) along with its matching direct-gaze counterpart (b) as another matched pair of direct vs. averted figures.

discussion of this pool's nature and reliability, see Crump, McDonnell, & Gureckis, 2013. All subjects were from the U.S., had at least a 90% MTurk task approval rate, and had previously completed at least 50 MTurk tasks.) This sample size was chosen before data collection began (based on pilot testing), and was fixed to be identical across both experiments reported here.

2.1.2. Stimuli and procedure

Subjects were redirected to a website controlled by custom software written in HTML, JavaScript, CSS, and PHP. (Since the experiment was rendered on subjects' own devices, viewing distance, screen size, and display resolutions could vary dramatically, and so we report stimulus dimensions using pixel [px] values.)

As in the examples depicted in Fig. 3, each subject viewed a photo (600 × 450 px) centered in their browser window with a centered person (one of two possible identities, either 214 × 218 px or 214 × 208 px) on a background (a bookshelf or hallway). As depicted in Fig. 2, the person was gazing either straight ahead or to the side. Photographs of two people gazing straight ahead were taken for the *direct-gaze* condition (e.g. Fig. 2c). The eye regions were then replaced with eye regions from photographs of the same two people gazing leftward for the *averted-gaze* condition (e.g. Fig. 2d). Both the original photos (e.g. Fig. 2c and d) and mirrored photos (e.g. Fig. 2a and b) were used, to control for asymmetries in the images that could produce any leftward/rightward bias in preferences. There were thus 16 images (2 backgrounds [bookshelf/hallway] × 2 identities × 2 gaze directions [direct/averted] × 2 versions [original/mirrored])—and each was viewed by 15 unique subjects.

Subjects used their cursor to adjust the horizontal position of the person in the photo until they thought the photo looked maximally aesthetically pleasing, and then pressed a key to submit their response and advance to the next page.[1] They then answered questions that allowed us to exclude subjects who guessed the purpose of the experiment (e.g. mentioning gaze; $n = 14$), misunderstood the instructions ($n = 67$),[2] or encountered technical problems ($n = 12$). (For example, some subjects indicated during the debriefing phase that they had forgotten the instructions, or that they had difficulty figuring out how to make the figure move.) 88 unique excluded subjects (some of whom triggered multiple criteria) were replaced without ever analyzing their data.

2.2. Results and discussion

The average image placements are depicted separately for direct-gaze and averted-gaze trials in Fig. 3a—in terms of the horizontal displacements from the center, scaled as a percentage of the largest possible displacement (which was 193 px to either side). A positive value indicates a displacement that caused an averted-gaze figure to be gazing inward, and a negative value indicates a displacement that caused her to be gazing outward. (To conduct this analysis, we treated direct-gaze stimuli as if they had averted gazes, using the corresponding averted-gaze figures, as e.g. is depicted in Fig. 2. In essence, this just ensures that any inward-bias we observe for averted-gaze figures must be due to the averted gazes per se—and not to anything else about the images or the task—since that is all that varied between the averted- and direct-gaze stimuli.)

Inspection of Fig. 3a suggests a clear pattern of results: Averted-gaze figures were preferentially placed so that they appeared to gaze inward, but no such directional bias occurred for direct-gaze figures. These impressions were confirmed by a highly reliable positive (i.e. inward) bias for averted-gaze figures ($t(119) = 5.16$, $p < .001$, $d = 0.47$), no positive bias for direct-gaze figures ($t(119) = 0.21$, $p = .836$, $d = 0.02$), and a reliable difference between these two conditions ($t(238) = 3.74$, $p < .001$, $d = 0.48$).[3] These effects could also be observed by directly looking at the individual placements, as depicted in Fig. 3b (in which placements for one example averted-gaze figure are depicted in orange, and placements for the corresponding direct-gaze figure are depicted in teal).[4]

The physical difference between the averted-gaze and direct-gaze figures in this experiment was minute—implemented by a mere 5-pixel shift of the irises (and pupils) to one side (a difference of roughly 1 mm on a typical screen). Nevertheless, this difference was socially powerful, and was sufficient to induce a highly reliable inward bias in aesthetic experience. And the fact that this was observed (for the first time) with only one trial per subject confirms that this bias cannot be explained by appeal to strategies (or task demands, or response biases) that develop over the course of repeated aesthetic judgments with obvious contrasting manipulations.

3. Experiment 2: Color inversion control

To ensure that the inward bias observed in Experiment 1 was truly based on perceived gaze (and not on subtle differences in geometric cues or spatial frequency profiles) we inverted the colors of the images in a second experiment. This manipulation (as illustrated in Fig. 3d) effectively reverses the perceived gaze direction by reversing the luminance contrast between the sclera and the pupil and the iris, while holding geometric and spatial-frequency properties constant (e.g. Sinha, 2000; cf. Ando, 2002). (For example, the sclera may be treated as a sort of 'ground' for the iris and pupil 'figures' in such stimuli, in which case there is a larger region of uncovered 'ground' for averted eyes. But this will be held constant for color-inverted images, which nevertheless reverse the direction of perceived gaze.)

3.1. Method

This experiment was identical to Experiment 1, except as noted here. A new factor was added: In addition to the original *color-intact* images, we included a set of otherwise-identical *color-inverted* images, created by inverting the color polarity of all the images from Experiment 1. The conditions using color-intact images are thus a direct replication of Experiment 1. The overall sample size was doubled (to 480; 219 females; $M_{age} = 34.1$) to maintain the same number of subjects per cell as that in Experiment 1. 121 unique additional subjects were excluded and replaced (6 guessed the experiment's purpose, 97 misunderstood the instructions, and 22 had technical difficulties).

3.2. Results and discussion

The average image placements for both color-intact and color-inverted images are depicted separately for direct-gaze and averted-gaze figures in Fig. 3c. Inspection of this figure suggests two clear patterns of results: (a) The results with color-intact images replicated the inward

[1] The exact instructions were: "We would like you to adjust the horizontal position of the person in the photo until you think the photo overall looks the most visually pleasing. For example, if you were to take this photo, where would you ask the person to stand (e.g. to the left, to the right) to make the photo look good?"

[2] The full probe used to assess whether subjects had understood the instructions is included in the supplementary raw data file.

[3] One might also wonder whether there was a 'center bias' for the direct-gaze images. This is an independent question, since such a bias could not explain the *directional* (i.e. inward) bias just reported. (The inward bias is in effect not an 'away-from-center' bias, but rather an 'away-from-center-*in-one-particular-direction*' bias.) However, no such effect existed. Here, the unsigned displacements to the center for direct-gaze images were no smaller than for averted-gaze images, ($t(238) = 1.11$, $p = .268$, $d = 0.14$). And, to foreshadow, no such effect was observed in Experiment 2 either—for the same images ($t(238) = 0.86$, $p = .389$, $d = 0.11$) or for that experiment's control images ($t(238) = 0.66$, $p = .510$, $d = 0.09$). (And in any case, Fig. 3b and d make it clear that the image placements—even for the direct-gaze stimuli—were often highly dispersed.)

[4] Additional histograms (for all experiments) are included in the supplementary raw data file.

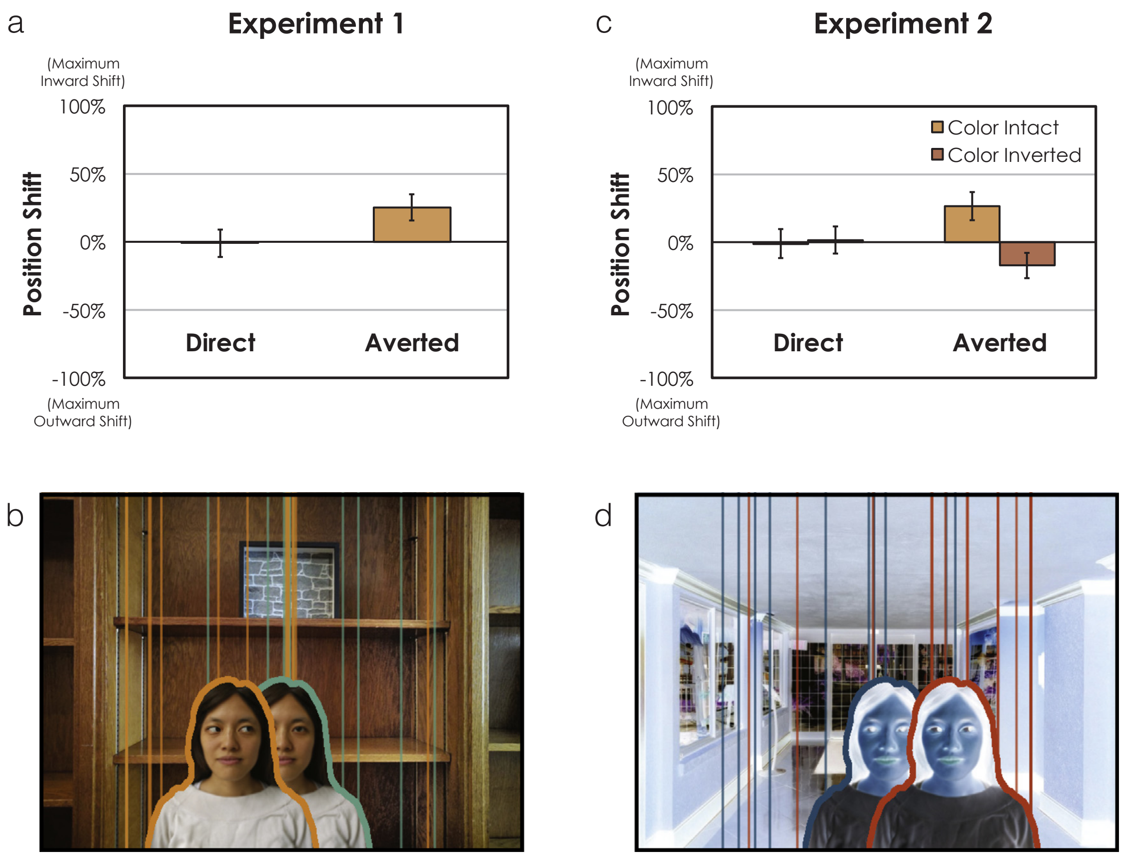

Fig. 3. Results from Experiments 1 and 2: (a) The average image placements depicted separately for direct-gaze and averted-gaze trials in Experiment 1—in terms of the horizontal displacements from the initial center point, scaled as a percentage of the largest possible displacement. A positive value indicates a displacement that caused an averted-gaze figure to be placed such that she was gazing inward, and a negative value indicates a displacement that caused her to be gazing outward—and these positive/negative assignments for the direct-gaze figures followed their corresponding averted-gaze figures. Error bars indicate 95% confidence intervals. (b) Placements for one example averted-gaze figure from Experiment 1 are depicted in orange, and placements for the corresponding direct-gaze figure are depicted in teal. (c) The corresponding results from Experiment 2, broken down by color-intact and color-inverted images. (d) Placements for one example color-inverted averted-gaze figure from Experiment 2 are depicted in red, and placements for the corresponding direct-gaze figure are depicted in blue. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

bias observed for averted-gaze figures in Experiment 1; and (b) this bias reversed for the averted-gaze figures in the color-inverted images (i.e. to again produce an inward bias considering the reversed direction of perceived gaze). These impressions were confirmed by the following analyses. A two-way ANOVA revealed a main effect of color ($F(1, 476) = 16.26$, $p < .001$, $\eta_p^2 = 0.033$), no effect of gaze ($F(1, 476) = 0.79$, $p = .375$, $\eta_p^2 = 0.002$), and—most importantly—a highly reliable interaction between these factors ($F(1, 476) = 20.51$, $p < .001$, $\eta_p^2 = 0.041$). Specific comparisons with the color-intact images then confirmed a reliable inward bias for averted-gaze figures ($t(119) = 5.10$, $p < .001$, $d = 0.47$), but not any corresponding positive bias for direct-gaze figures (calculated as in Experiment 1; $t(119) = 0.20$, $p = .839$, $d = 0.02$), along with a reliable difference between these conditions ($t(238) = 3.69$, $p < .001$, $d = 0.48$). In contrast, the same comparisons with the color-inverted images revealed a reliable bias *in the opposite direction* for averted-gaze figures ($t(119) = 3.57$, $p = .001$, $d = 0.33$), no effect for direct-gaze figures ($t(119) = 0.29$, $p = .774$, $d = 0.03$), and another reliable difference between these conditions ($t(238) = 2.68$, $p = .008$, $d = 0.35$). These effects could also be observed by directly looking at the individual placements, as depicted in Fig. 3d.

The results of this experiment thus fully replicated Experiment 1, while also ensuring that the inward bias was due to perceived gaze per se (which was flipped in the color-inverted images—as you may be able to observe in Fig. 3d) rather than to any possible lower-level figural differences (which were equated across the color-intact and color-inverted trials).

4. General discussion

The inward biases observed in this study were exceptionally reliable, despite being driven by cues that are far more minimal than the global shape differences that have been used to elicit the bias in previous studies, in at least two ways. First, these inward biases were obtained with minimal experience, as we collected only a single response (to a single image) per subject. Second, and more importantly, the 'facing direction' that fueled the inward bias in these experiments was especially subtle—just a slight displacement (of approximately 1 mm) of two tiny regions (the irises and pupils) on faces that were otherwise equated. In all cases, averted-gaze figures yielded robust inward biases, whereas the same direct-gaze figures yielded no biases at all. And since the direction of the inward bias reversed with color-inverted images (which also reversed perceived gaze direction) in Experiment 2, we can be certain that the effects were due to perceived gaze, per se.

4.1. Looking into the future

These results support the possibility that the inward bias in aesthetic experience is not an isolated quirk of taste in framing compositions, but may rather be an adaptive feature of our minds. In particular, the inward bias may reflect a preference to "look into the future", by viewing objects from a perspective that will allow them to remain visible if they move in the predicted direction (i.e. in the direction in which they are facing). Previous experiments were unable to isolate this sort of factor, since they used figures in which facing direction was confounded with asymmetric visual salience (e.g. when facial features are depicted on one side of a profiled head but not the other) and/or asymmetric global shape envelopes (e.g. when the back of a chair looks radically different than its front). In contrast, the current results more readily isolated perceived facing direction per se—since that is nearly all that is changing between the direct-gaze and averted-gaze figures (given how otherwise-miniscule the relevant physical differences are). In this way, the inward bias may apply not only to the specific case of framing objects in artistic compositions, but may extend to (and be derived from) a more general preference to "frame" the world so that objects are seen to face inward in our field of view.

This "looking into the future" account also readily accommodates previous results that explored the inward bias with depictions of implied motions. In such cases, an object that implies a *backward* motion (e.g. a person about to dive backward into a pool) yields an especially strong inward bias consistent with that implied motion direction (Palmer & Langlois, 2017). This is exactly what we would expect if the inward bias is a mechanism that helps us to keep objects in view so that we can witness their impending behaviors.

4.2. Relationship to 'affordance spaces'

The current findings are also consistent with the "affordance space" hypothesis (Palmer & Langlois, 2017; Sammartino & Palmer, 2012b), which has been the most prominent interpretation of the inward bias to date. This view posits that the inward bias arises because people prefer to center in the frame not the object itself, but rather an abstract affordance space that surrounds it. This affordance space "reflects the extent and/or importance of functions that take place in that region around the object" (Sammartino & Palmer, 2012a, p. 876). For example, a teapot has an affordance space stretched toward its front because of its function, such that centering that space ends up making the teapot face inward.

The "looking into the future" account was inspired by the "affordance space" account, in that it preserves the idea that the location of likely future events plays a critical role—and as such it may be considered as a variant of this previous hypothesis. At the same time, it differs from this earlier account in some possibly substantial ways. First, the 'affordance space' account relies on a bias to prefer the (asymmetric) affordance space when it is centered in the image. In this sense, it posits a special role for the center of the image, but no special role for the edges of the frame. From the "looking into the future" perspective, in contrast, the aesthetic preferences are driven primarily by an aesthetic *aversion* to objects that are facing toward the edges of the frame, since this limits one's ability to directly witness their likely future behaviors. (In this sense the phenomenon might be better described as a 'not-outward' bias!) And so in this view, the center itself plays no special role. And this might not just reflect a difference in rhetorical framing, since the two views might make contrasting predictions in displays which emphasize or de-emphasize the frame's borders. In especially wide images with small objects placed only slightly off-center (and nowhere near the edges), for example, the affordance space view might still predict the usual effect, while the "looking into the future" perspective might predict a decreased bias, since there will be plenty of room to witness future behaviors in either direction.

Second, the nature of the 'affordance space' isn't precisely specified, which makes it difficult for this view to make strong predictions. When predicting the magnitude of any given bias, everything depends in this view on the precise (but unspecified, and hard to measure) size and shape of the affordance space itself, but there is no independent way to determine these values. (In stimuli such as ours, for example, does the affordance space stretch out from only the person's eyes, or from their entire body? And just what shape would it take, and how far would it extend?) In this way, the 'affordance space' view seems able to accommodate almost any pattern of results (except perhaps a clear outward bias), which seems dangerously flexible. Third, and most obviously, this earlier view must assume the existence of mental 'affordance space' representations in the first place—something that hasn't been directly empirically demonstrated, and that has remained quite controversial ever since Gibson's introduction of the notion of affordances. In contrast, our view requires no such assumptions, beyond the well-supported facts that future actions tend to follow gaze (e.g. Land & Hayhoe, 2001) and that gaze cueing is robust even when the cues aren't reliable (as in most such experiments). For all of these reasons, the "looking into the future" perspective might have some advantages over the "affordance space" hypothesis, even though they share the same root focus on how objects are likely to behave (or be acted upon) in the future.

4.3. Conclusion: Dynamic representations of static objects

From the "looking into the future" perspective, the inward bias may also constitute an example of how vision involves extracting not only the current state of the world, but also predicting how the future may unfold. Given that eye gaze signals attention and intention in such a salient way, viewing an averted gaze (even in a static image) may generate a dynamic expectation that the person is about to move or act in that direction—and that dynamic expectation may in turn fuel our aesthetic experience.

This sort of phenomenon—in which static images yield dynamic expectations (and possibly dynamic underlying representations)—may be more common than we suspect (cf. Craik, 1943). For example, this sort of effect may also lie at the root of phenomena of implied motion (e.g. Freyd, 1983), perceived causal history (e.g. Chen & Scholl, 2016), and the perception of physical instability (e.g. Firestone & Scholl, submitted for publication). In the current study, we show that this sort of dynamic predictive representation fuels not only spatial perception, but also our aesthetic experience.

Appendix A. Supplementary material

The supplementary file available online with this paper contains the raw data for each experiment, the full probe used to assess whether subjects had understood the instructions, and additional histograms depicting the binned distributions of responses for each experiment.

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2018.02.010.

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