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# Aesthetic preference for spatial composition in multiobject pictures

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**Abstract.** Five experiments examined preferences for horizontal positions in multiobject pictures. In Experiment 1, each picture contained a fixed object and an object whose position could be adjusted to create the most (or least) aesthetically pleasing image. Observers placed the movable object closer to the fixed object when the objects were related than when they were unrelated (a relatedness bias) but almost never overlapped them (a separation bias). Experiment 2 showed that these results were not due to demand characteristics by replicating them almost exactly in a between-participants design. In Experiment 3, preference rankings revealed a strong relatedness bias together with an inward bias toward the spatial envelope of objects to point into the frame. A weak balance effect was evident in a multiple regression analysis. Experiment 4 replicated the inward bias for the spatial envelope using multiobject groups. Experiment 5 generalized the above findings for different objects when observers had to choose between image pairs that differed only in interobject distance or degree of balance. Strong relatedness effects were again present, but there was no evidence of any preference for balance.
**Keywords:** spatial composition, aesthetic preference, balance, semantic relatedness, visual perception, spatial structure, object perception.

## 1 Introduction

The problem of how to compose an image within a rectangular frame in aesthetically pleasing ways is one that faces virtually every painter, photographer, and graphic artist in almost every creative endeavor. Previous research has shown that numerous factors are relevant, including not only the positions of the elements within the frame, but also their colors (eg, Bullough 1907; Pinkerton and Humphrey 1974; Locher et al 2005), their orientations (Locher and Stappers 2002), and their sizes and shapes (Pierce 1894; Puffer 1903; Berlyne 1966; Wilson and Chatterjee 2005). Among the many factors that influence the aesthetic success of a spatial composition, the one that has been studied most frequently, however, is balance. Arnheim (1954) famously proclaimed that an image that is balanced is more aesthetically pleasing than one that is not, but he did not test this claim empirically.

The primary focus of the research described in this article is how preference for spatial composition is influenced by the semantic relatedness of meaningful objects, particularly in terms of the optimal distance between objects and their balance within the frame.[1] To

[1] We take "semantic relatedness" to be a general term that encompasses categorical relatedness (eg, boats and bicycles are both members of the category of vehicles, but they are seldom used together), functional relatedness (eg, a paint roller and a can of paint are typically used together, but are not members of the same category—other than "things used for painting") as well as their combination (eg,

foreshadow the results, we find a robust preference for closely related objects (eg, a wine bottle and a cake, or a bottle of liquid soap and a sponge) to be close together within the frame and for unrelated objects (eg, a wine bottle and a sponge, or a bottle of liquid soap and a cake) to be far apart. Moreover, we find these relatedness effects on aesthetic preference to be much stronger than balance effects on preference, which proved to be surprisingly difficult to document at all. Although balance is not the primary focus of our findings, we will begin with a brief review of some of the relevant literature on the perception of balance and its effect on people's judgments of aesthetic preference.

Some of the earliest empirical studies of balance investigated rectangular images containing a fixed line of some particular length, width, and color, and a second line of some particular length, width, and color (Pierce 1894; Puffer 1903). Observers adjusted the position of the second line to make the entire display appear balanced. All else being equal, test lines were placed further from the center than the fixed line if they were shorter, thinner, and/or lighter than the fixed line, but they were placed closer to the center if they were longer, thicker, and/or darker. These results are consistent with physical concepts of balance, provided that darker colors were treated as if they were heavier, even though colors have no physical weight. The aesthetic value of balanced versus unbalanced compositions was not assessed, however.

More recently, McManus et al (1985) examined balance in images by asking observers to move a fulcrum left and right under each image until the image appeared balanced with respect to the fulcrum. In the first experiment studying works of art, there were large differences between images, but overall the pictures were balanced near the center of the frame, with more images being balanced slightly left of center. In the second experiment, McManus used abstract displays of one or two colored squares (red, green, or blue) in an extension of the displays used by Pierce. Like Pierce, McManus found that position was very important for balance judgments but that there were also significant interactions with color, with red affecting balance more than blue, for example. More recently, McManus et al (2011) tested a highly quantified version of a theory of balance proposed by Arnheim (1954), as derived from Ross (1907), based on finding the center of mass in black and white photographs using a physicalist model of pixel "weight," in which black is maximally heavy and white maximally light. The data from observers' judgments of balance did not support the model, however. Like many researchers who have studied balance, McManus concentrated on understanding how balance is perceived rather than assessing how or whether it actually contributes to aesthetic preference.

Locher (2003) and colleagues examined the importance of balance in several ways. Locher et al (1998) recorded the actions of adults, some naïve and others trained in graphic design, as they tried to construct aesthetically pleasing displays with nine differently sized paper cutouts of abstract geometrical shapes (circles, squares, or rectangles) or identically shaped leaves. These elements were thus largely abstract and compositionally unconstrained by meaning. The participants were told to create a display that was "both interesting and pleasant" by arranging the shapes within an empty frame. Video recordings were analyzed to determine the role of balance both during the creative process and in the final product. About half of the designs displayed symmetry at some point in the creation process, and the physical weight was equally distributed around the center in many of the final designs. Locher et al (2001) replicated these results with adults who were trained in the visual arts. Although these results tend to support the relevance of balance for aesthetic value, they may

salt and pepper containers). We have not attempted to distinguish between them in this manuscript, but see this as an important issue for further research.

or may not generalize to situations in which the elements of the composition are meaningful objects.

Subsequently, Locher et al (2005) examined the perception of balance in six abstract paintings by Piet Mondrian together with variations of those paintings in which the colors (red, blue, and yellow) were interchanged. They found that Mondrian's originals were all judged to be balanced near the center, whereas the manipulations were generally perceived as less well balanced. No data on aesthetic preference or response were collected, however, and the elements of the images were, once again, abstract and meaningless.

Wilson and Chatterjee (2005) actually measured aesthetic preference for spatial compositions that varied in balance and found a significant, positive relation. Their images were configurations of abstract geometrical elements (circles, squares, and hexagons) whose spatial distribution was manipulated to produce a wide range of values on a mathematically defined index of balance (the Assessment of Preference for Balance, or APB) based on Arnheim's (1954) structural skeleton of symmetry axes. They found that aesthetic preference ratings were reliably correlated with this measure of balance, primarily because highly imbalanced configurations were disliked more than moderately balanced ones, rather than because highly balanced works were liked more than moderately balanced ones. These studies did not include images of any meaningful objects, however, so they do not speak to the central issues we study here. Further studies of balance by Gershoni and Hochstein (2011) with brief exposures of Japanese calligraphy suggest that first-fixation balance depends on different visual features than the APB, but once again aesthetic preferences were not measured.

Palmer et al (2008) investigated compositional preferences in pictures of single, meaningful objects. They assessed the role of balance in aesthetic judgments of pictures that contained just one, easily recognizable, common object (eg, a person, flower, chair, dog, etc) whose horizontal location within the frame was varied. Using a variety of measures, they found robust evidence of a strong "center bias" in people's preference for the locations of forward-facing symmetrical objects. This is a strong bias toward balance. However, they also found a powerful "inward bias" for left- and right-facing objects, resulting from the fact that left-facing objects were preferred when positioned reliably to the right of the frame's center, and right-facing objects were preferred when positioned reliably to the left of the frame's center. Given that there was only one object in the picture, this inward bias clearly goes against balance. Bertamini et al (2011) investigated the horizontal position of animals in paintings and drawings, and reported the same basic effect, which they renamed the "anterior bias."

In the present studies we extended our previous research on aesthetic response for pictures of meaningful objects by examining the horizontal placement of two common objects when their individual positions could vary independently, both in relation to each other and in relation to the frame. In particular, we sought to understand the role of separation, semantic relatedness, and balance in compositional preferences. Our specific concern was in how such factors influence aesthetic preferences for images in which these factors could be tightly controlled. We therefore did not study art works, but rather created multiobject images that specifically allowed us to make valid scientific inferences about these variables. We believe that people's aesthetic responses to these images are nevertheless relevant to understanding how people perceive art, but we leave to future research the application of the principles we report here to the structure of existing art works.

## 2 Experiment 1

The first experiment was aimed at understanding the role of object separation and relatedness in people's preference for the horizontal position of two symmetrical objects in a frame. As illustrated in Figure 1a, the related object pairs were a bottle of wine and a cake, or a liquid-soap container and a sponge. The unrelated object pairs were the same objects differently paired, thus keeping both the relative size and approximate shape of the object pairs consistent with the related pairs (ie, a wine bottle and sponge, or a liquid-soap container and cake). Participants' aesthetic responses to such images were measured by fixing the position of one object in the frame and asking them to adjust the position of the other object to make the picture *most* aesthetically pleasing. (This task is analogous to that used by Locher et al (1999) in some of their studies of "visual rightness" of art works, but using much simpler pictures containing just two objects.) After all of those measurements were made twice, observers were asked to place the movable object in the *least* aesthetically pleasing position. (We will henceforth use the terms "preferred" and "aesthetically pleasing" interchangeably.)

We expected that people would prefer any pair of objects to be separated by some minimum distance in the picture. We also expected that related objects would be preferred when separated by a smaller distance than unrelated objects, because people would prefer a spatial composition that is similar to the relative distances of those objects in real life. Such a pattern would be consistent with other "ecological biases" that we have found in previous research (Palmer et al 2012). We were unsure, however, how this bias might interact with compositional biases such as the center bias (Palmer et al 2008) and balance (eg, Arnheim 1983).

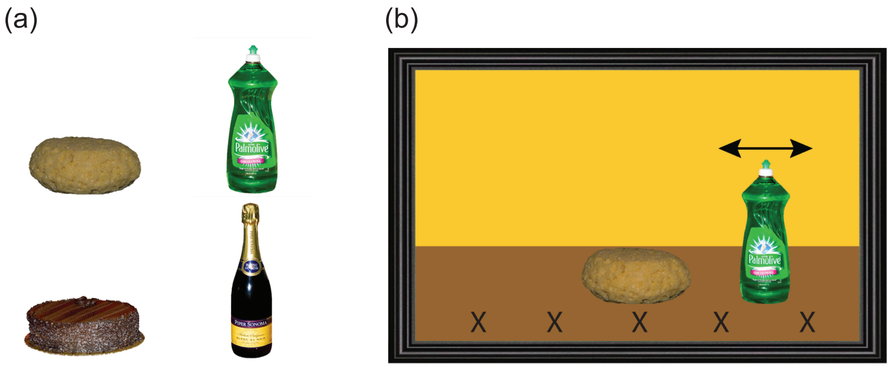


**Figure 1.** (a) Objects in Experiments 1, 2, and 3: a sponge, a plastic container of liquid dish soap, a cake, and a bottle of sparkling wine. (b) Example of a picture in which the sponge is fixed at the center position, and the plastic container of liquid dish soap is movable (indicated by the arrow). The other positions in which the fixed object could be located are indicated by "x"s (which were never shown in the pictures).

## 2.1 Methods

### 2.1.1 *Participants*

Eighteen (15 females, 3 males, ages 18–26 years) persons participated. All were students at the University of California, Berkeley, who participated in partial fulfillment of a course requirement. All were naïve to the purpose and nature of the experiment, and gave informed consent in accord with the policies of the University of California, Berkeley.

### 2.1.2 *Design and stimuli*

Each trial consisted of a single framed image containing two objects: one positionally fixed object and one movable object, whose position could be adjusted by the participant. The frame surrounding the image resembled a picture frame and was added to increase the aesthetic impact of the picture. An example of such a picture is presented in Figure 1b. The images all measured 1500 by 950 pixels. The fixed object was presented at one of five locations along a horizontal axis. The sizes and vertical positions of the objects within the frame were fixed by the experimenters such that they were consistent in size, and their bottoms were aligned (as if resting on the ground plane). One position was in the center of the screen, and the others were 250 or 500 pixels to the left or right. The movable object was first presented outside the boundaries of the screen on either the left or the right side. By moving the mouse, participants were able to slide the movable object into the frame and across the screen at a constant vertical level in a range of 500 pixels to the left and right of the center of the frame. On half the trials, the movable object would slide in front of the fixed object and behind it on the other half. Which of the two objects was movable was also balanced across trials. Each block of the experiment consisted of 80 trials, and there were three different blocks: in the first two blocks, the participants were asked to slide the movable object to the position in which they found the picture *most* aesthetically pleasing, and in the third block, participants slid the object to the position in which they found the picture *least* aesthetically pleasing. This resulted in a total of 240 trials.

Four vertically symmetrical objects without a strong facing direction were used: two short, wide objects (sponge and cake) and two tall, thin objects (plastic container of liquid dish soap and bottle of sparkling wine), as illustrated in Figure 1a. The objects were presented in pairs consisting of one short, wide object and one tall, thin object. The presented pairs could consist of related objects (sponge and liquid-soap container, or cake and wine bottle) or unrelated objects (sponge and wine bottle, or cake and liquid-soap container). The images of unrelated objects consisted of objects similar in size and shape to ensure that any effects we measured were not due to differences in these factors. Experiment 5 addresses the question of whether similar results would be obtained if both objects had similar shapes instead of different ones.

#### 2.1.3 *Apparatus*

The images were displayed using Presentation software (http://www.neurobs.com) on an LCD monitor that measured 20” diagonally, had a resolution of 1680 × 1050 pixels and refreshed at a rate of 60 Hz. The participants used a mouse to slide the movable object across the screen (without vertical deviation) to the position where they found the picture most (and later least) preferred. When they were satisfied, they pressed the left mouse button, which initiated the next trial.

#### 2.1.4 *Procedure*

Participants sat in a small, darkened booth. They were told that, in each trial, they would see one object on the screen that was fixed in position and another that was movable. They were asked to “slide the movable object into the frame and then to the position where they found the picture *most* aesthetically pleasing.” When they were satisfied with the composition of the picture, they were told to press the left mouse button, at which time the center point of the preferred position of the movable object was recorded.

On an instructional trial, the experimenter showed the participant how to slide the movable object across the screen with the mouse. They, again, were told that they could slide the object to any position on the horizontal axes within the boundaries of the frame and to click the left mouse button to make their response. After the instruction trial, the experimenter slid the movable object out of the frame and left the booth.

There were two identical blocks of trials such that each object in each pair was adjusted twice to create the most preferred picture. In a third block of trials, participants were asked to slide the movable object to the position where they found the picture least preferred. After each block, the experimenter read the instructions for the next block.

### 2.2 Results and discussion

To ensure that our assessment of the relatedness of the objects we used was accurate, we carried out a short questionnaire study with 12 additional participants. We presented a paper sheet with the names of the object pairs that were presented in the experiment, and participants were asked to indicate how related the different object pairs were on a scale ranging from 1 (not related at all) to 7 (very much related). The order in which the pairs were presented was randomized. The average rating for the related pairs (4.96) was reliably greater than for the unrelated pairs (1.96), $F(1, 11) = 49.50$, $p < 0.001$. We thus conclude that participants agreed with us about the relatedness of the object pairs.

To determine whether related objects were placed closer together than unrelated objects in the trials on which participants were asked to place the object in the most preferred position, we calculated the distance between the centers of the two objects for each pair of objects. To analyze the results, a 2 × 2 × 5 repeated-measures analysis of variance was used with most/least preferred position, relatedness, and the position of the fixed objects as within-participants' factors and the distance between the two objects as dependent variable. There was no significant difference between the most and least preferred placements for the related object, $F(1, 17) = 1.15$, $p = .300$ (see Figure 2a). However, Figure 2b shows that the unrelated objects were placed significantly farther from the fixed object in the most preferred placement trials than in the least preferred placement trials, $F(1, 17) = 15.09$, $p = .001$. This result indicates that they preferred unrelated objects to be farther apart. A comparison of the results in Figure 2a–b reveals that in the most preferred placement trials, people placed the related objects closer to the fixed object than they did the unrelated objects, $F(1, 17) = 42.49$, $p < .001$, but that in the least preferred placement trials, they placed the related objects farther from the fixed object than they did the unrelated objects, $F(1, 17) = 8.09$, $p = .011$.

Notice that, overall, there was a main effect of fixed-object position in which interobject distances were shorter for the central fixed-object position and larger as the fixed object was positioned farther from the center, $F(4, 68) = 40.78$, $p < .001$. There was also an interaction between the fixed-object position and semantic relatedness in which the positional effect of the fixed object was greater for some conditions than others, $F(4, 68) = 5.08$, $p = .001$. These effects probably are driven to a large extent by geometrical constraints imposed by the different fixed-object position conditions, given that the maximum distances (and therefore the range of possible distances) increase monotonically from the center position to the most laterally extreme positions.

We carried out analogous analyses of the degree of balance in the most and least preferred placements of the movable objects. We defined an index of balance—actually, an inverse index of balance, which we call Imbalance (IB)—and defined it as the absolute horizontal distance between the geometric center of the frame and the geometric center of the pair of objects, as calculated by the average horizontal position of the centers of the smallest rectangles that completely contained each object of the pair. This measure is zero pixels if the image is balanced (ie, if the centers of the two objects are equally distant from the center of the frame in opposite directions) and maximal (500 pixels) if both objects are next to the frame's edge on the same side.[2] Figure 3a shows a plot of the results for related

[2] We recognize that various other factors have been shown to influence the perceived balance point of a picture—eg, the color, orientation, size, and shape (see the references cited in the introduction)—but decided on the purely geometric measure as the simpler and more objective index. We acknowledge

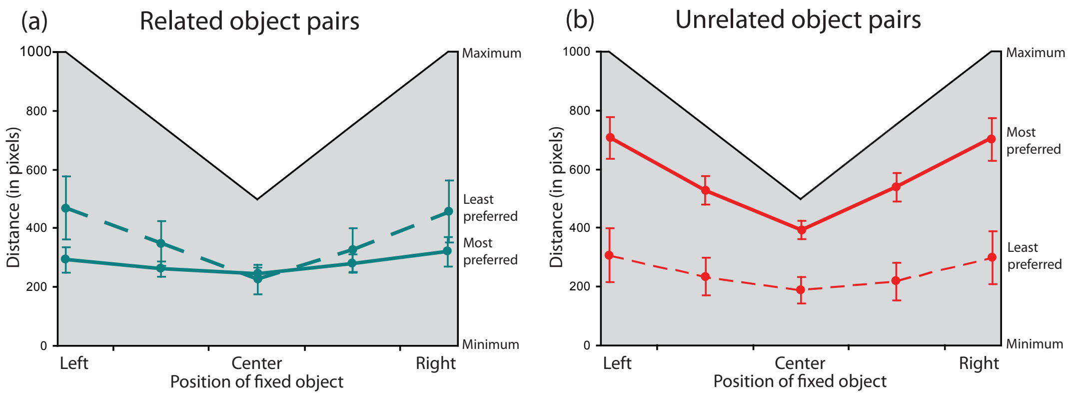


**Figure 2.** Absolute distance between two objects (in pixels) for each of the five positions of the fixed object in Experiment 1 for both related pairs (a) and unrelated pairs (b) when people were asked to place the movable object in the *most* aesthetically pleasing position (solid line) and when asked to place the movable object in the *least* aesthetically pleasing position (dashed line). The minimum and maximum distances possible between objects are shown as the bounds of the gray zone, which indicates the range of distances for all valid placements.

objects, and Figure 3b for unrelated objects. Here, again, a 2 × 2 × 5 repeated-measures analysis of variance was used with most/least preferred position, relatedness and the position of the fixed objects as within participants' factors and Imbalance as dependent variable. There is no difference in Imbalance between the most and least preferred placements of the movable objects when they are related, $F(1, 17) = 2.06$, $p = .169$, and also no interaction with the position of the fixed object, $F(4, 68) = 1.78$, $p = .143$. When the fixed object was in the most lateral positions, the most preferred placements of related objects were actually more *imbalanced* than the least preferred placements. This makes it unlikely that balance was itself the primary factor influencing people's placements of the related objects. For unrelated objects, however, the most preferred placements were reliably more balanced (ie, less imbalanced) than the least preferred placements, $F(1, 17) = 14.65$ $p = .001$. There was also an interaction between most and least preferred placements as a function of the position of the fixed object, $F(4, 68) = 13.73$, $p < .001$, such that the lateral positions of the fixed object produced larger differences in imbalance than did the center positions. We note, however, that the imbalance results could also be explained by a bias toward people placing unrelated objects far apart. That is, when the fixed object is at extreme positions, placing the movable object at the most distant possible position (on the other side of the center of the frame) would have also created a relatively balanced composition for essentially spurious reasons. We return to this issue in Experiments 3 and 5, where the contributions of distance and balance are teased apart.

To gain a more complete understanding of people's choices when they were asked to create the most aesthetically pleasing picture, the positions of the centers of the movable object were categorized according to the proportion of trials on which its center fell into each of nine equal-sized horizontal bins. A 2 × 5 repeated-measures analysis of variance was used with relatedness and the position of the fixed objects as within-participants' factors and the position of the moveable object as dependent variable. Analyses of these data showed that there was a significant difference between the distribution of positions chosen for the movable object in the related and the unrelated pairs, and that it was different for different

that such factors might change the precise values of an imbalance measure, but we doubt they would change them by enough to invalidate the conclusions we reach here.

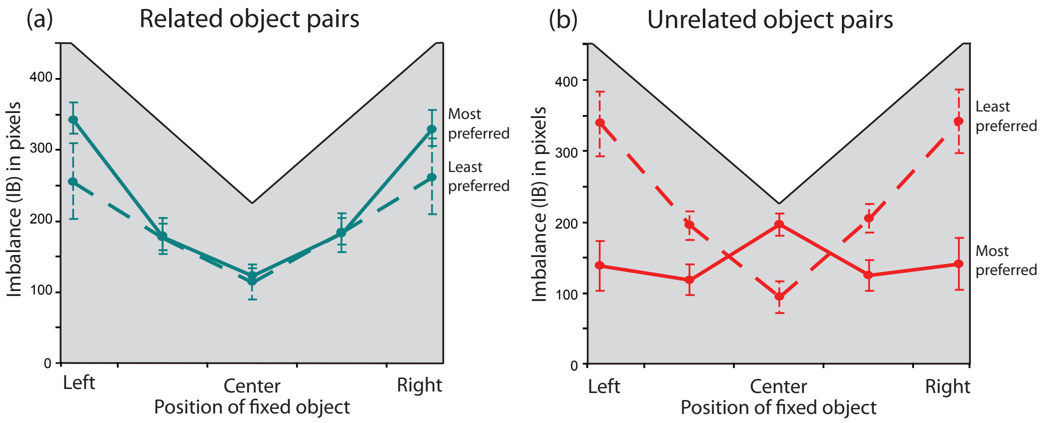


**Figure 3.** Absolute horizontal distance between the geometric center of the object pair (as calculated by the average horizontal position of the centers of the smallest rectangles that completely contained each object of the pair) and the geometric center of the frame (in pixels) for each of the five positions of the fixed object in Experiment 1 for both related pairs (a) and unrelated pairs (b) when people were asked to place the movable object in the *most* aesthetically pleasing position (solid line) and when asked to place the movable object in the *least* aesthetically pleasing position (dashed line).

positions of the fixed object, $F(4, 68) = 40.32$, $p < .001$. The results are plotted as frequency histograms in Figures 4a–c when the fixed object was located at the most extreme positions (a), the off-center positions (b), and the center position (c). The data from trials in which the fixed object was located on the right side of the frame were averaged with the data from symmetric positions in which the fixed object was located on the left side of the frame because these pairs of functions were almost exact mirror images of each other ($F < 1$ in both cases).

The most important and general features of the data plotted in Figure 4 are as follows. Clearly, the bin containing the fixed object (indicated by vertical gray bars in Figure 4) is almost never chosen as the most preferred location for the movable object. People apparently do not want either related or unrelated objects to overlap, at least in pictures containing just two objects of this size relative to the frame. This "separation bias" can be conceptualized metaphorically as a repulsive force that operates at close distances for all objects independent of their relatedness. Equally clear is the fact that the most preferred positions (ie, the global maxima of the histograms) for the related objects are quite close to the fixed object, with maxima in the bins just ±2 bins away. Unrelated movable objects, however, are preferred much farther from the position of the fixed object than those for the related objects. Indeed, the single most frequent placement of an unrelated object is always in the most distant bin possible. As the distance between related objects increases, the repulsive force away from overlapping positions is eventually counteracted by an "attractive force" operating between them, presumably due to their semantic connection. No such attractive force is apparent for unrelated objects. We note, however, that for unrelated objects in the extreme and off-center fixed-object positions, there is a slightly smaller local maximum in the same bin as the global maximum for related object. This may represent some observers' tendency to treat all object pairs as related.

There is surprisingly little evidence of the importance of balance in these data, if balance is conceived as a preference for the movable object to be placed at a position symmetrical with the fixed object in relation to the center of the frame. The only case in which balance is robustly preferred is for the unrelated objects in the extreme fixed-object positions, a case

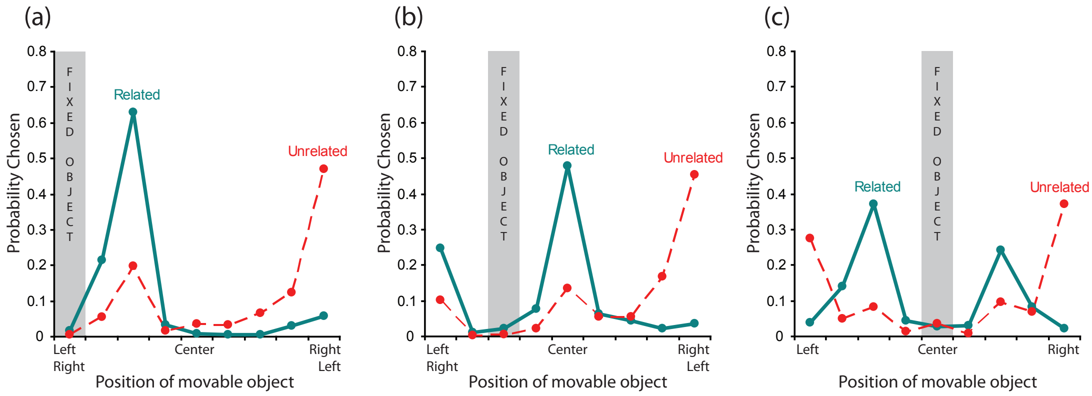


**Figure 4.** Proportion of the positions chosen for the related (solid line) and unrelated (dashed line) movable object in Experiment 1 when participants were asked to place the movable object in the position at which they found the picture to be *most* aesthetically pleasing when the fixed object (indicated with a gray bar) was located at the most extreme positions (a), the off-center positions (b), and the center position (c). The data from trials in which the fixed object was located on the right side of the frame were averaged with the data from symmetric positions in which the fixed object was located on the left side of the frame.

that may simply reflect the tendency for people to place an unrelated movable object as far as possible from the fixed object. There is some evidence toward balance in the off-center conditions with the related objects (Figure 4b), in the sense that when the fixed object is halfway between the center and the most extreme position (ie, at ±250 pixels from the center), people place the related object much more frequently in the center bin than in the most extreme bin, thus favoring the more balanced composition at the same distance from the fixed object, even though it is not the most balanced overall composition possible. Once again, there are alternative interpretations, however, in that the preferred position is to place the movable object at the center of the frame, which can be interpreted as an example of the center bias, or to place it away from the edge of the frame, which can be interpreted as arising from a repulsive force due to the frame edge itself. We return to the role of balance in Experiments 3 and 5, where its role is examined in greater detail and with better controlled conditions.

Figures 5a–c present histograms of the percentages of trials on which the moveable object was placed in each of the nine positional bins when observers were asked to choose the *least* aesthetically pleasing position. Analyses of these data show that there is a significant difference between the position of the movable object for the related and the unrelated pairs depending on the position of the fixed object, $F(4, 68) = 4.12$, $p = .005$. Although it is true that people find the picture to be least preferred when the related objects are placed far apart and the unrelated objects are placed closer together (ie, opposite to the pattern when choosing the *most* preferred position; see also Figure 2a versus 2b), the most notable feature of the distributions in Figure 5 is how similar the functions are for related and unrelated objects, particularly in comparison with those for the most aesthetically pleasing positions (Figure 4). This suggests that the least preferred compositions are dominated simply by inappropriate placement of the objects relative to each other and to the frame, largely independent of semantic relatedness. The other noteworthy feature of the data is that the least preferred compositions tend to be those in which the moveable object is placed either in the same positional bin as the fixed object or in the bin closest to the far edge of the frame. The former case violates the separation bias (see above) and the latter an edge-repulsion bias, suggesting that these effects are stronger than semantic relatedness.

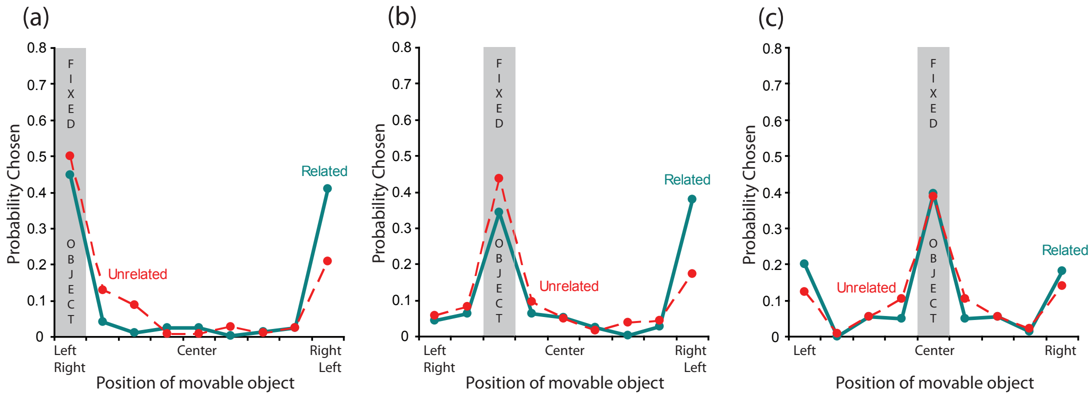


**Figure 5.** Proportion of the positions chosen for the related (solid line) and unrelated (dashed line) movable object in Experiment 1 when participants were asked to place the movable object in the position at which they found the picture to be *least* aesthetically pleasing when the fixed object (indicated with a gray bar) was located at the most extreme positions (a), the off-center positions (b), and the center position (c). The data from trials in which the fixed object was located on the right side of the frame were averaged with the data from symmetric positions in which the fixed object was located on the left side of the frame.

The overall pattern of results indicates that two factors dominate people's preferences for spatial compositions involving object pairs. First, both most and least preferred placements of the movable object depend strongly on the mere physical separation between two depicted objects, with compositions in which the two objects overlap in essentially the same position being, in general, least preferred. We call this tendency the "separation bias." The repulsion it implies appears to increase as the two objects get closer together. Second, people prefer objects that are related to each other to be closer together in a frame than objects that are not related to each other, with the reverse being true when people are asked to construct the least preferred picture. This relatedness bias may be another instance of an ecological effect in the aesthetics of spatial composition (Palmer et al 2012; Sammartino and Palmer no date): people prefer pictures to have a spatial composition in which the distances between objects mirror their likely corresponding distances in the environment, with related objects tending to be closer together than unrelated objects.

Somewhat surprisingly, participants seldom put the movable object in a position at which the picture was in balance—by which we mean that the distance from both objects to the center of the frame was the same or nearly so—as Arnheim's (1983) discussion tends to imply. It is true that previous research has shown color, size, and shape to influence the perception of balance in images (eg, Pierce 1894; Puffer 1903; McManus et al 1985) but these influences are relatively minor, and our images were largely controlled for shape and size effects, since each image contained a tall, thin and a short, wide object of approximately the same sizes. It is impossible that differences in color could lead to the conclusion that the most preferred images containing the fixed object at the most extreme position (Figure 4a) are balanced when the movable related object is most often placed at a position that is on the same side as the fixed object and only midway to the frame center. Such an image is hugely unbalanced. These considerations lead us to believe that both the separation and relatedness biases have stronger influences on the preferred positions of elements in two-object pictures than does balance. We return to this issue in Experiments 3 and 5.

## 3 Experiment 2

Experiment 2 was carried out to address the question of whether the results of Experiment 1 might be due to demand characteristics. That is, it is plausible that participants in Experiment 1 noticed that some of the object pairs were related and others unrelated, and therefore might have felt that this variable should somehow be reflected in their responses. It does not actually explain why they chose to place related objects closer together and unrelated objects farther apart, but given the opposite alternative, it is not surprising that this solution might have been chosen. To determine the extent to which the relatedness effects in Experiment 1 resulted from demand characteristics of the within-participants study, participants in Experiment 2 were divided into two different groups, one of which saw only related pairs and the other of which saw only unrelated pairs. If the results are essentially the same as those of Experiment 1, then the results of Experiments 1 are not due to demand characteristics.

### 3.1 Methods

#### 3.1.1 *Participants*

Thirty-six (18 females, 18 males, ages 16–24) persons who were naïve to the purpose of the experiment participated. Thirty-five participants were students at the University of California, Berkeley, who participated as a partial fulfillment of their course requirements. One participant was paid to participate in the experiment. All gave informed consent in accord with the policies of the University of California, Berkeley.

#### 3.1.2 *Design and stimuli*

As in Experiment 1, each picture contained one stationary object, whose position was fixed, and one movable object, whose position could be adjusted by the participant to create the most preferred picture. The objects used were again images of a cake, a wine bottle, a sponge, and a liquid-soap container (see Figure 1b). The entire design was identical to that of Experiment 1, except that subjects were divided into two different groups. One group saw only related pairs (cake and wine bottle, sponge, and liquid-soap container), whereas the other group only saw unrelated pairs (sponge and wine bottle, cake, and liquid-soap container). As a result, each participant had to complete only 120 trials.

#### 3.1.3 *Apparatus and procedure*

The apparatus and procedure were identical to those of Experiment 1.

### 3.2 Results and discussion

The overall correlation between the results for the most preferred positions of the two experiments was +.99, indicating that the data in the two experiments for these objects were almost identical. Correlations nearly as high were found when people were asked to create the least preferred pictures ($r = +.88$). When the results of Experiments 1 and 2 were analyzed in a single between-participants design, there was no significant difference between the two experiments, when participants were asked to create either the most preferred picture, $F(1, 17) = 1.73$, $p = .210$, or the least preferred picture ($F < 1$). These results show that demand characteristics arising from the same observer seeing both related and unrelated object pairs were not responsible for the compositional effects reported in Experiment 1.

Histograms of the placements of the movable object when people were asked to place the object in the most and least preferred position were constructed by categorizing them into nine equal-sized bins, as with the corresponding data from Experiment 1. We do not show the graphs because the patterns are almost identical to those shown in Figures 4 and 5. Indeed, the correlation between the 180 data points from the two experiments is +.94 ($p <$

.0001). Clearly, neither the separation bias nor the relatedness bias of Experiment 1 depend on observers seeing both related and unrelated object pairs.

## 4 Experiment 3

The results of Experiments 1 and 2 suggest that relatedness may be more important than balance when people make aesthetic judgments, at least when they concern simple pictures containing just two meaningful objects. Observers *could* have placed the movable object in such a position that it would have created a balanced picture, but they seldom chose to do so. Instead, they generally preferred the related objects to be close together and the unrelated objects to be farther apart, even if this created unbalanced pictures, as indicated by the peaks in Figure 4. A possible drawback of Experiments 1 and 2 is that the constraints of the fixed object positions may have made it difficult for observers to create balanced pictures without violating other powerful biases. For example, when the fixed object was positioned in the center, observers could create a balanced picture only by positioning the other object at the same location, which would violate the powerful separation bias. Moreover, Experiments 1 and 2 provided no information about people's relative preferences among the five most preferred images they created with the same objects.

In Experiment 3, we investigated how preference varies as the composition differs in systematic ways that specifically include both balanced and unbalanced compositions at a variety of different interobject distances with related and unrelated pairs of objects. The results should be sensitive to both balance and relatedness effects, if they are present. We expected that the most aesthetically pleasing composition would be the one in which the picture is balanced and separated by distances consistent with the relatedness effects reported in Experiments 1 and 2.

### 4.1 Methods

#### 4.1.1 *Participants*

Six males and 14 females, aged 18–38, volunteered to participate for payment. All were naïve to the purpose of the experiment and gave informed consent in accord with the policies of the University of California, Berkeley.

#### 4.1.2 *Design and stimuli*

Each trial consisted of 15 framed images containing the same two objects in the same left/right order. The objects within a single frame were located at one of six equally spaced locations in a frame of 350 by 221 pixels. There were three possible equally spaced locations on the left side of the picture (positioned 24, 72, or 120 pixels to the left of the center of the frame, which we will refer to as positions 1, 2, and 3, respectively) and three corresponding locations on the right side, which were symmetrical to those on the left (positioned 24, 72, or 120 pixels to the right of the center of the frame, which we will refer to as positions 4, 5, and 6, respectively). The two objects were never positioned at the same location within a trial because the results of Experiments 1 and 2 indicated so clearly that this composition is strongly disliked. Figure 6 shows an example image in which the cake is at position 3 and the wine at position 5. Each other location at which the objects could be positioned is indicated by an x.

The objects used in the experiment were the same as in Experiments 1 and 2 (see Figure 1b). The related pairs consisted of one tall, thin object and one short, wide object: a cake and a bottle of wine, or a sponge and a liquid-soap container. The unrelated pairs consisted of the same objects, but differently paired such that there was also always one tall,


**Figure 6.** Example of a picture in which the cake and the bottle are presented at positions 3 and 5. Each other position in which the objects could be located is indicated by an x.

thin object and one short, wide object: a liquid-soap container and a sponge, or a wine bottle and a sponge. The image of each object was slightly adjusted to ensure that they would not overlap when they were placed in adjacent locations.

#### 4.1.3 *Apparatus*

The pictures were displayed using Presentation software (http://www.neurobs.com) on the same monitor that was used in Experiments 1 and 2.

#### 4.1.4 *Procedure*

Participants sat in a small, darkened booth. They were told that, for each trial, 15 framed images containing the same two objects in the same left/right order would be presented on the screen in four different rows. The three top rows each consisted of four images, and the bottom row consisted of three images and a “Restart Trial” button at the bottom right corner. The positions in which the images were presented on the screen in each trial were randomized, and the eight trials consisting of different combinations of objects were presented in a random order.

Participants were instructed to use the mouse to click on the image they found most aesthetically pleasing of all the images on the screen. After each click, the selected image disappeared, and participants then chose the most aesthetically pleasing image from the remaining images. They repeated this procedure until there were no images left on the screen. The order in which they clicked the images was recorded with the first one chosen being scored as 15 and the last one chosen as 1. If the participant made a mistake and wanted to redo the trial, they could press the “Restart Trial” button, which initiated the same trial again with all the images being presented in the same positions on the screen as before.

### 4.2 Results and discussion

The data were averaged over participants to measure preference for each condition. The primary data are plotted in Figure 7 as a function of the location of the rightmost object (x-axis) and leftmost object (separate curves) for related objects (Figure 7a) and for unrelated objects (Figure 7b), averaged over specific object pairs and left/right object positions. Note that ranks have been inverted so that more preferred conditions are higher on the y-axis.

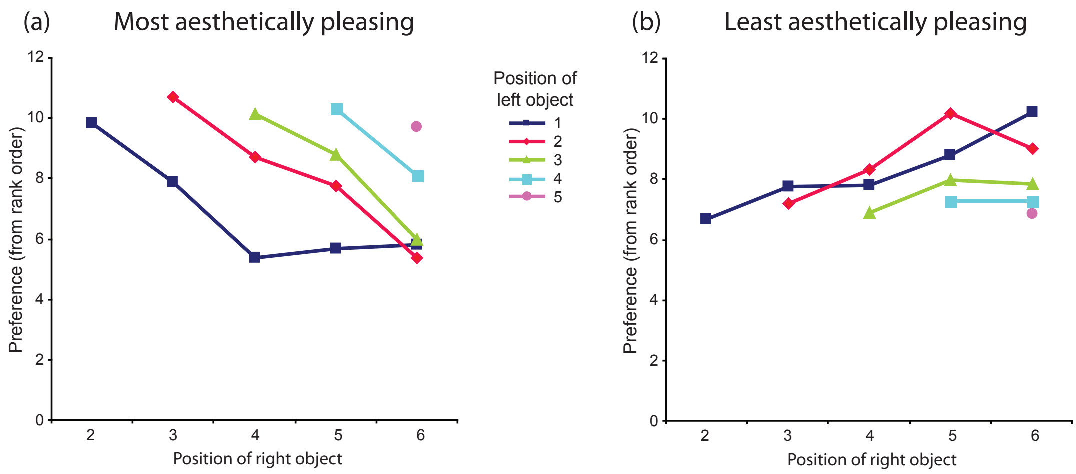


**Figure 7.** Preference for images in Experiment 3 plotted as a function of the different locations of the objects for (a) related pairs and (b) unrelated pairs. The position of the rightmost object is indicated on the x-axis, and that of the leftmost object is represented by separate curves.

The most obvious feature of the data for related objects (Figure 7a) is that the positions in which the objects are adjacent (the leftmost data point for each curve) are the *most* preferred, and the functions generally *decrease* as interobject distance increases (for points farther to the right). This pattern is consistent with the relatedness effects found in Experiments 1 and 2: people prefer related objects to be close together. The opposite pattern is evident for the unrelated objects (Figure 7b), where adjacent positions (again, the leftmost data point for each curve) are *least* preferred, and the functions generally *increase* monotonically as the interobject distance increases. These distance effects are isolated in Figure 8, which plots the interaction between interobject distance and relatedness, $F(4, 76) = 16.99$, $p < .001$. For related objects, preference decreases almost linearly with distance, whereas for unrelated objects, it increases almost linearly with distance. Clearly, relatedness matters a great deal in compositional preferences, with related and unrelated objects showing opposite effects of distance.

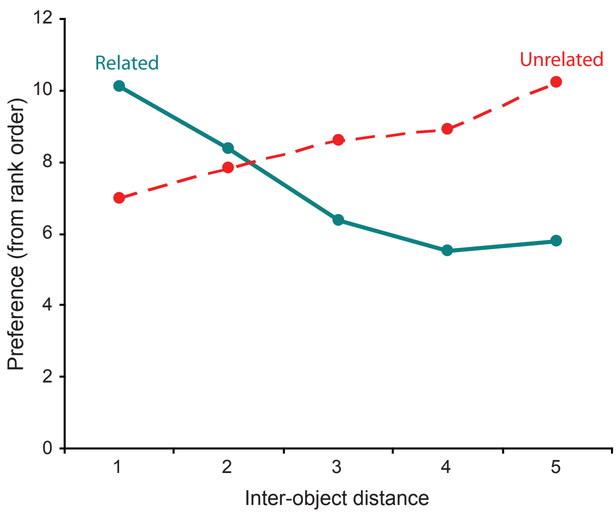


**Figure 8.** Preference for images in Experiment 3 for each interobject distance (x-axis) for both related pairs (solid line) and unrelated pairs (dashed line).

The effects of balance were assessed by the previously described index of imbalance (IB) as the distance between the center of the object pair (as calculated by the average horizontal position of the centers of the smallest rectangles that completely contained each object of the pair) and the center of the frame. When the two objects were equidistant from the center of the frame and thus maximally balanced at pair positions (1,6), (2,5), and (3,4), the IB was zero. The maximally unbalanced cases are those in which the two objects are in adjacent positions nearest to the edge of the frame at pair positions (1,2) and (5,6), which have an IB of 2.0. Because balance does not vary orthogonally with distance, we carried out a multiple linear regression analysis on the full set of data averaged only over participants and object types. For related pairs, both distance and IB were included in the equation, accounting for 77.1% of the variance, with distance explaining 73.5% or the variance ($p < .001$) and IB accounting for an additional 3.6% of the variance ($p < .05$). For unrelated pairs, both factors were also included and together explained 60.8% of the variance, with similar relative levels of significance: distance accounted for 54.4% of the variance ($p < .001$), and IB accounted for 6.4% ($p < .05$). Interestingly, the beta weights for IB were essentially identical for related and unrelated objects (–0.224 versus –0.297), whereas the beta weights for distance were wildly different and opposite in sign (–.975 for related pairs and +.582 for unrelated pairs.) This is consistent with what one would expect if the identity of objects were largely irrelevant for balance but highly relevant for distance.

A third factor of interest is the possible effect of the spatial envelope of the object pair. Each image contained one tall, thin object (bottle of wine or liquid-soap container) and one short, wide object (cake or sponge). Because both were resting on the same surface, the spatial envelope of the pair roughly defines a right triangle that points either left or right. Given the inward bias reported by Palmer et al (2008) for single objects, we wondered whether people might prefer the compositions in which the spatial envelope of the pair was directed into (rather than out of) the frame. Figure 9 plots the data as a function of this inward/outward "pointing" factor separately for interobject distances of 1, 2, 3, and 4 units. In each case, there is a significant interaction between the pointing direction of the spatial envelope and the position of the objects in the frame, $F(4, 76) = 8.05$, $p < .0001$; $F(3, 57) = 10.56$, $p < .0001$; $F(2, 38) = 3.60$, $p < .05$; and $F(1, 19) = 9.64$, $p = .006$, for interobject distances of 1, 2, 3 and 4 units, respectively. Clearly, there is an inward bias operating on the spatial envelope in these preference data.

## 5 Experiment 4

The results of Experiment 3 provided further evidence of the importance of semantic relatedness on people's preferences for spatial compositions. They also demonstrated systematic preferences due to the directedness of the object pair's spatial envelope, consistent with an inward bias that operates at the level of configurations of objects as well as for facing effects of individual objects (cf Palmer et al 2008). Surprisingly, however, there were only weak indications of a preference for balance, which would correspond to a center bias for configurations.

Experiment 4 attempted to confirm the existence of a configural inward bias and to look more closely for a balance effect using a sensitive two-alternative forced choice (2AFC) preference task. Using such tasks, Palmer et al (2008) regularly found both center and inward bias effects for pictures of individual objects, so we reasoned that this method would be most effective here. We also thought that the balance effect might not have emerged in Experiment 3 because it was dominated by relatedness and interobject distance effects. In the present experiment, we therefore used only related object configurations and kept the distances between the objects fixed and small. Observers had to decide which of two images they

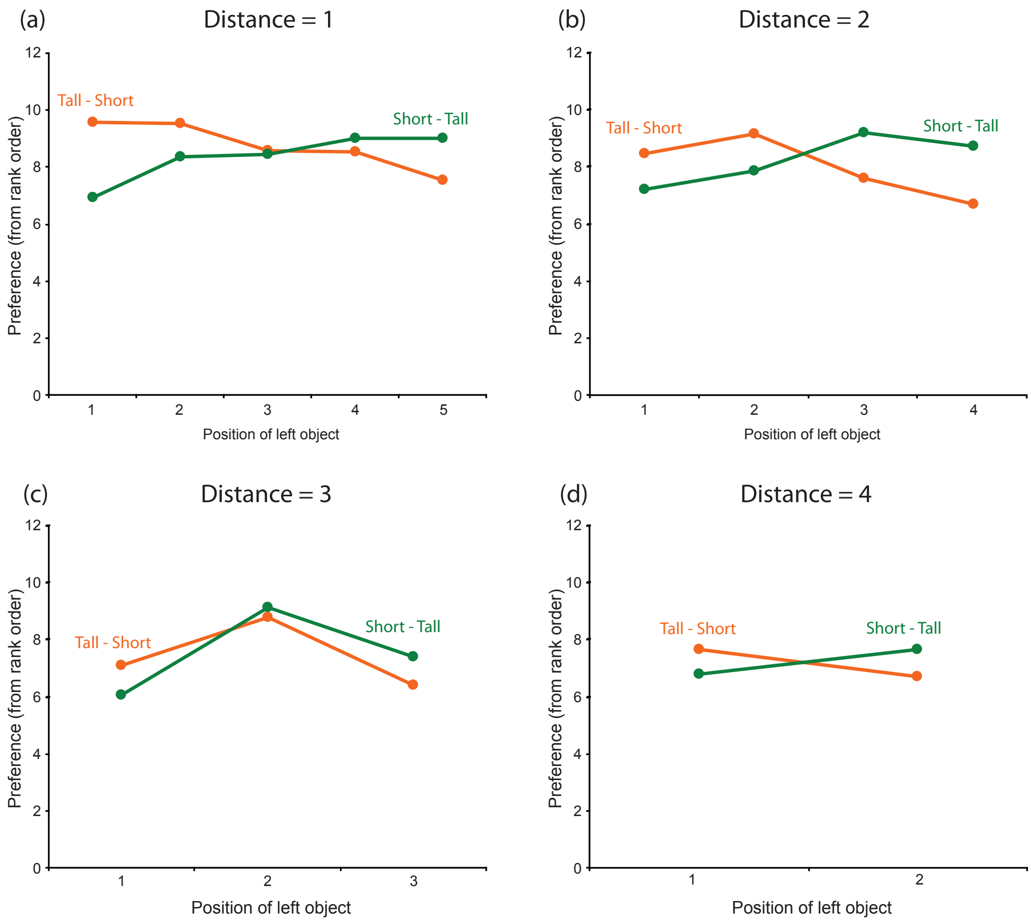


**Figure 9.** Preference for images in Experiment 3 as a function of the position of the left object (x-axis) and pointing direction of the composition separately plotted for interobject distances of 1, 2, 3, and 4 units. In right-pointing configurations, the short object was positioned to the right of the tall object, and in left-pointing configurations, the short object was positioned to the left of the tall object. These effects confirm the presence of an inward bias on the spatial envelope of the object pairs within the frame.

preferred aesthetically when the only variable that differed was the position of the whole configuration. We reasoned that this task would provide a definitive test of whether people prefer multiobject images that are compositionally balanced around the center and whether there is an inward bias in the spatial envelope of the objects. We note that Palmer et al (2008) only demonstrated an inward bias based on the facing direction of individual objects as defined by the fronts of objects rather than on the spatial envelopes of configurations, so an inward bias in the present experiment would generalize its nature in an interesting way.

## 5.1 Methods

### 5.1.1 *Participants*

All 15 participants were students at the University of California, Berkeley, who received partial course credit in their undergraduate psychology course. Their mean age was 19.3 years. All were naïve to the purpose and nature of the experiment, and gave informed consent in accord with the policies of the University of California, Berkeley.

### 5.1.2 *Design and stimuli*

Each trial consisted of two framed images depicting the same configuration of objects whose spatial envelope “pointed” in the same direction, at two different positions within the frame from a possible set of five positions. Two different configurations of related objects were used: either a configuration consisting of a wine bottle, a wine goblet, and a plate of grapes (see Figure 10a) or a ceramic pitcher and a basket of bread cubes (see Figure 10b). There were two different versions of both configurations: one in which the spatial envelope of the configuration was pointing to the left and one in which it was pointing to the right. These different versions were mirror images. Figure 10 shows two example images in which the horizontal component of all possible locations where the center of the configuration could be located are indicated by “x”s. The center of the configuration was defined as the center of the smallest bounding rectangle that included the entire configuration. The wine-goblet–grapes images had the general appearance of oil paintings, whereas the pitcher–bread images were high-resolution photographs.

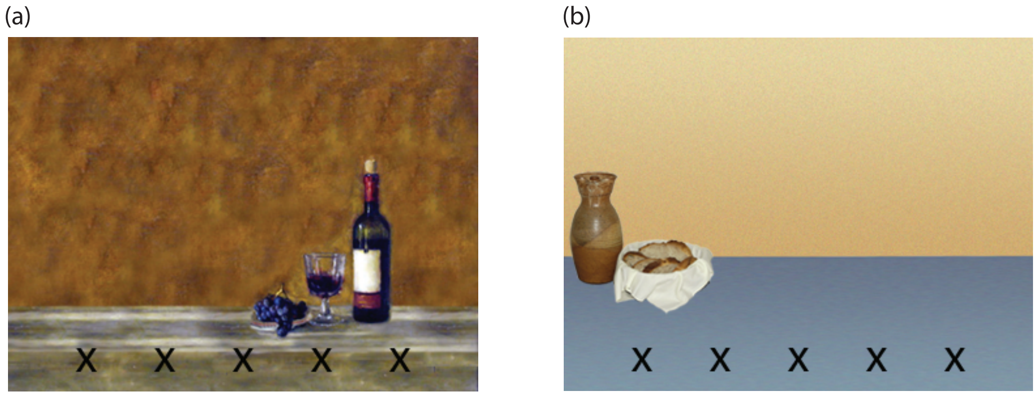


**Figure 10.** Examples of pictures in which the configuration of a wine bottle, a wine goblet, and a plate of grapes is pointing toward the left (a) and in which the configuration of a ceramic pitcher and a basket of bread cubes is pointed toward the right (b). Each location in which the center of the configuration could be located is indicated by an x.

Trials consisted of all 10 possible pairwise comparisons of the images depicting the same configuration of objects facing in the same direction at different positions for each of the two configurations of objects and both of the two possible pointing directions. The left/right position of the 2AFC pairs of images on the screen was counterbalanced within participants, and each trial was replicated three times. This resulted in a total of 240 trials.

#### 5.1.3 *Apparatus*

The pictures were displayed using Presentation software (www.neurobs.com) on the same monitor that was used in Experiments 1, 2, and 3.

#### 5.1.4 *Procedure*

Participants were instructed to choose the image they found most aesthetically pleasing on each trial by clicking the right mouse button for the right image and the left mouse button for the left image. Which mouse button they pressed was recorded. Participants were given the opportunity to take a break every 60 trials.

### 5.2 Results and discussion

We scored participants’ responses for the probability with which they chose each image in each of the 2AFC pairs of images for each object configuration. To create a composite measure of the aesthetic response to each image, we then computed the average probability of choosing that image across all of its pair-wise comparisons. The resulting probabilities, averaged over participants and object configurations, are plotted in Figure 11 as a function of location within the frame for the right- and left-pointing configurations.

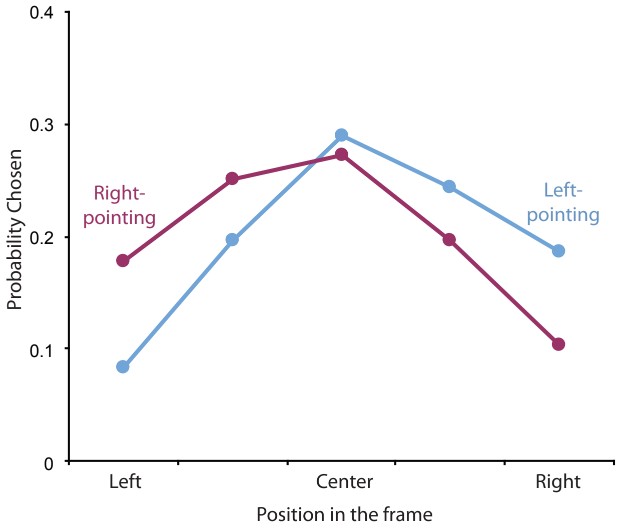


**Figure 11.** Proportion of trials in which the image of right-pointing and left-pointing configurations was chosen in Experiment 4 as a function of the position of the configuration in the frame.

There was an overall main effect of position, indicating that participants preferred the configuration more in central locations than in ones closer to the edges of the frame, $F(4, 56) = 8.66$, $p < .001$. This preference for central positions is the clearest evidence we have obtained favoring balance in the present research on composition of multiobject compositions. Nevertheless, it is systematically modulated by the pointing direction of the configuration, as evidenced by the interaction between positions and pointing direction, $F(4, 56) = 4.16$, $p < .01$. The nature of this interaction is consistent with that reported in Experiment 3: people prefer right-pointing configurations to be located farther to the left in the frame and left-pointing configurations to be located farther to the right in the frame. The net result is that, overall, configurations are preferred when they point into (rather than out of) the frame. No reliable interactions were present between either of these effects and the two object configurations, $F(4, 56) < 1.5$, $p > .25$.

The results of this experiment thus clearly provide evidence of a center bias in images of multiobject configurations, which is essentially a bias toward balance. There are many reasons why balance might have been detected in the present experiment when it was not in the previous three experiments. The most plausible one is that, in Experiment 4, interobject distance and relatedness did not vary across the images participants had to compare. This fact may have allowed balance effects to emerge here, whereas they may have been swamped by other effects in the previous experiments.

## 6 Experiment 5

Experiments 1, 2, and 3 studied the same set of stimuli: two short, wide objects (a sponge and a cake) and two tall, thin objects (a plastic container of liquid dish soap and a bottle of sparkling wine). Are the results of these experiments due to using these specific objects and/or object shapes or are they more general than that? The final experiment answered this question by studying different objects of different shapes that can be found in different environments.

Experiment 5 was carried out as a maximally sensitive 2AFC experiment in which participants had to indicate which of two pictures they preferred. Only the key contrast comparisons were included: two pictures with the same degree of balance that differed only in the interobject distance and two pictures with equal distances between objects that differed only in balance. The results should thus be sensitive to both balance and relatedness effects, if they are present.

We expected to replicate the previous findings with these new objects. Most importantly, we expected participants to prefer the pictures in which related objects were closer together, but to prefer pictures in which unrelated objects were positioned farther apart. For the trials comparing two pictures that have the same interobject distance but vary in the degree of balance, we expected participants to prefer the balanced pictures over the unbalanced pictures for both the related and unrelated object pairs, because in these trials there was no conflict between balance and the relatedness effects, given that the distance between the objects was the same.

## 6.1 Methods

### 6.1.1 *Participants*

There were 20 participants (9 females, 11 males, ages 18–24 years) in this experiment. Seventeen participants were students who received partial course credit in their undergraduate psychology course at the University of California, Berkeley. The other participants were paid for their participation. All were naïve to the purpose and nature of the experiment, and gave informed consent in accord with the policies of the University of California, Berkeley.

### 6.1.2 *Design and stimuli*

Each trial consisted of two framed images containing the same two objects in the same left/right order. The objects within a single frame were located at one of six equally spaced locations in a frame of 680 by 430 pixels. There were three possible equally spaced locations on the left side of the picture (positioned 45, 135, or 225 pixels to the left of the center of the frame, which we will refer to as positions 1, 2, and 3, respectively) and three corresponding locations on the right side, which were symmetrical to those on the left (positioned 45, 135, or 225 pixels to the right of the center of the frame, which we will refer to as positions 4, 5, and 6, respectively).

For each pair of objects, there were seven different compositions in which the two objects were positioned in different locations. There were two different pictures in which the midpoint between the two objects was located to the left side of the center (which we call "left-unbalanced"), including pictures with objects at positions 2 and 3, and pictures with objects at positions 1 and 4. Likewise, there were also two "right-unbalanced" pictures in which the midpoint between the two objects was located right of center, located at positions 4 and 5, and positions 3 and 6. In addition, there were three balanced pictures, in which both objects were equidistant from the center on opposite sides, including pictures with objects at positions 3 and 4, positions 2 and 5, and positions 1 and 6. The distance between the objects in all of these pictures was equal to 1, 3, or 5 spatial units (of 90 pixels each). Figure 12 presents an overview of all the different locations in which the objects could be positioned for each pair of objects using the unrelated pair of a block of cheese and an American football helmet.

There were five kinds of trials designed to assess distance effects (distance-based comparisons): one in which left-unbalanced pictures were compared to each other at

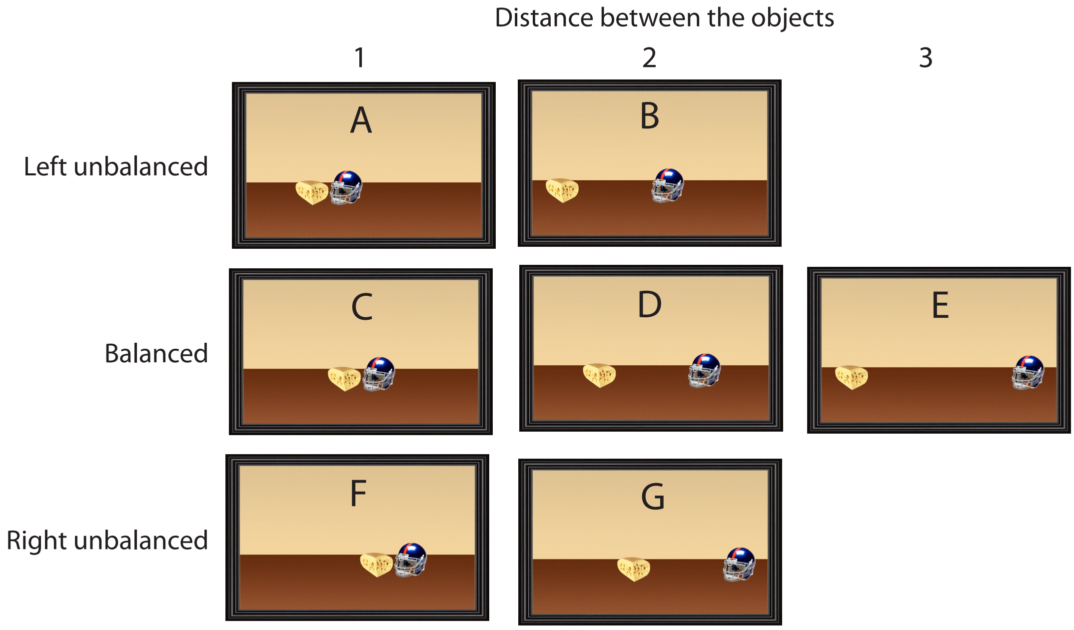


**Figure 12.** Overview of all the different locations in which the objects could be positioned for each pair of objects using the unrelated pair of a block of cheese and an American football helmet.

different interobject distances (A vs. B in Figure 12), one in which right-unbalanced pictures were compared to each other at different interobject distances (F vs G in Figure 12), and three in which balanced pictures were compared with each other (C vs D, C vs E, and D vs E). Four other kinds of trials were designed to assess balance effects in which the balanced pictures were compared to the left-unbalanced and right-unbalanced pictures (balance-based comparisons): two in which the distance between the objects was one unit (A vs C and C vs F) and two in which it was three units (B vs D and D vs G).

The objects used in the experiment were different from those used in Experiments 1, 2 and 3, but were analogously structured into quartets of objects that produced well-controlled sets of related and unrelated objects. There were four quartets, each of which could be combined into four different pairs of objects: two related pairs and two unrelated pairs. The left/right presentation of these different pairings was counterbalanced within participants, resulting in eight different pairings for each quartet. The quartets (see Figure 13) consisted of (a) a pair of shoes, a pair of slippers, a paint roller, and a paint can; (b) a hammer, a wrench, a wire whisk, and a spatula; (c) a loaf of bread, a block of cheese, an American football, and a football helmet; and (d) a salt shaker, a pepper grinder, a wallet, and a keychain. The left/right position of the 2AFC pairs of images on the screen was counterbalanced between participants. This resulted in a total of 288 trials for each participant.

6.1.3 *Apparatus*

The pictures were displayed using Presentation software (http://www.neurobs.com) on the same monitor that was used in the previous experiments.

6.1.4 *Procedure*

Participants sat in a small, darkened booth. On each trial, two framed images containing the same two objects in the same left/right order were presented on the screen. Participants were

**Figure 13.** Objects in Experiment 5: (a) a pair of shoes, a pair of slippers, a paint roller, and a paint can; (b) a hammer, a wrench, a wire whisk, and a spatula; (c) a loaf of bread, a block of cheese, an American football, and a football helmet; and (d) a salt shaker, a pepper grinder, a wallet, and a keychain.

instructed to choose the image that they found most aesthetically pleasing. If they preferred the image on the left side of the screen, they were instructed to press the left arrow key, and if they preferred the image on the right, they were instructed to press the right arrow key. They had to wait at least 2 s before they could make a response.

## 6.2 Results and discussion

As in the previous experiments, we wanted to insure that our assessment of the relatedness of the objects was accurate. Therefore, we carried out a short questionnaire study with 12 additional participants. We presented a paper sheet with the images of the object pairs that were presented in the experiment, and participants were asked to indicate how related the different pairs were on a scale ranging from 1 (not related at all) to 7 (very much related). In the questionnaire, we presented images of the objects, rather than their names, to be sure that the participants knew the visual appearance of the particular objects. The order in which the pairs were presented was randomized. The average rating for the related pairs (6.25) was reliably greater than that for the unrelated pairs (2.20), $F(1, 11) = 242.11$, $p < .001$. We thus, again, conclude that participants agreed with us about the relatedness of the object pairs within the quartets.

The distance-based and balance-based comparisons were analyzed separately. In distance-based comparisons, the interobject distance differed (1, 3, or 5 distance units), whereas the balance of the pictures was the same (as defined by the average of their center points), being either both balanced or both unbalanced with the center of the object pair being located at the same point. In the balance-based comparisons, the balance of the two pictured differed (balanced vs. unbalanced), whereas the distance between the objects was the same.

For the distance-based trails, we scored participants' responses for the probability with which they preferred the picture with the smaller distance between the objects. The resulting probabilities, averaged over participants, for the related and unrelated object pairs are plotted in Figure 14a. When the objects in an image were related, participants chose the picture with the smaller interobject distance much more often than expected by chance in every case, $F(1, 19) = 217.55$, 22.42, 17.50 and 17.69, $p < .001$, for quartets A, B, C, and D, respectively. When the objects were unrelated, participants showed no such preference for the alternative with the smaller interobject distance. Indeed, for quartets A and C, participants reliably preferred the alternative with the larger interobject distance, $F(1, 19) = 5.92$, 0.05, 5.32, and 0.01, $p =$ .025, .823, .032, and .934 for quartets A, B, C, and D, respectively. In general, participants were much more likely to choose the picture with the smaller interobject distance when the objects were related than when they were unrelated, $F(1, 19) = 32.73$, $p < .001$. This difference is clearly consistent with the relatedness bias reported in Experiments 1, 2, and 3. There was no difference between the left/right order in which the objects were positioned in the picture, $F(1, 19) < 1$.

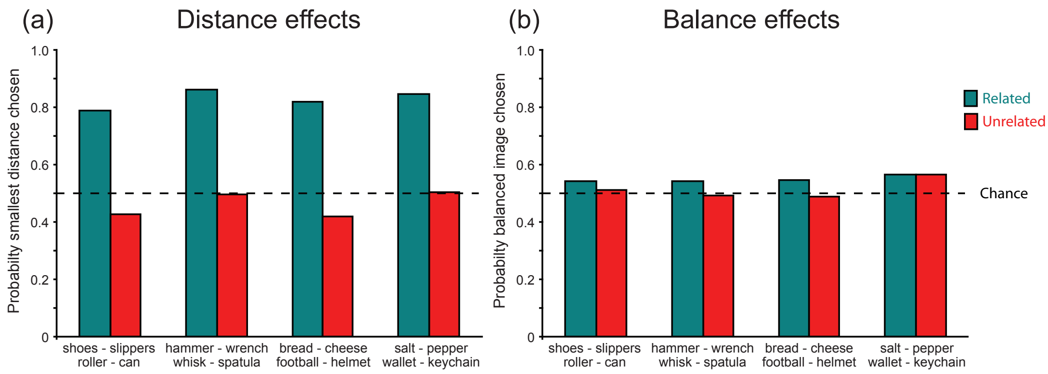


**Figure 14.** (a) Proportion of trials in which the picture with the smaller interobject distance was chosen in Experiment 5 for each object quartet. (b) Proportion of trials in which the picture that was in balance was chosen in Experiment 5 for each object quartet.

Similar analyses were carried out for balance-based trials in which the two pictures had the same interobject distance but differed in the degree of balance. For these trials, we scored participants' responses for the probability with which they chose the picture in which the objects were balanced (ie, positioned at the same distance from the center on opposite sides) over the unbalanced picture. The resulting probabilities, averaged over participants, for the related and unrelated pairs are plotted in Figure 14b. Participants did not prefer the pictures that showed balance over those that were unbalanced more often than expected by chance for any quartet, $F(1, 19) < 1$ for all quartets. There was no significant difference in the preference for balance between the related and the unrelated objects, $F(1, 19) = 1.18$, $p =$ .290, and also no difference between the left/right order of the objects in the picture, $F(1, 19) = 3.87$, $p = .064$.

The results obtained from this experiment are thus consistent with the results of Experiments 1, 2, and 3 in the sense that we again found strong evidence for objects to be preferred closer together when they are related than when they are unrelated. Moreover, this was robustly true for all four object quartets in Experiment 5 as well as for the quartet used in Experiments 1, 2, and 3. Because the present objects had different shapes than those in Experiments 1, 2, and 3 yet showed the same pattern of distance-dependent preferences, it is unlikely that the precise shape and/or size of the objects was responsible for the previous findings. Once again, however, we failed to find robust evidence of a preference for balanced over unbalanced pictures for either related or unrelated objects.

## 7 General discussion

The results of the five experiments reported above have shed considerable light on people's aesthetic preferences for spatial compositions of images that contain more than one meaningful object. Perhaps the most significant insight is the robust importance of the distance between two objects and how its effect depends on the semantic relatedness of the objects. From the results of the experiments reported here, it can be concluded that people tend not to like two-object images in which the two objects are very close together, regardless of their semantic relatedness. This "separation bias" may seem surprising, given that most still-life paintings depict objects that are tightly grouped and even overlapping. One relevant factor is that the objects of still-life paintings are typically very closely related to each other, such as a bowl containing apples, pears, and other fruit. Another factor is that the separation bias may depend importantly on other features that were not manipulated in our experiments, such as the number of objects in the picture and the size of the objects relative to the frame. Still-life paintings of the sort seen in museums and galleries, for example, tend to depict numerous related objects that together fill the frame much more densely than in the pictures we have studied, which were severely constrained in the number (ie, two) and sizes of the objects (ie, small) relative to the frame. It seems likely that even a painting of just two objects would tend to be composed with them positioned very close together or overlapping if they were large relative to the frame and/or if the occlusion of one by the other produces interesting shadows and partly occluded shapes that would not have been present if they had been separated.

The data further indicate very clearly that, beyond some minimum distance, people like related objects to be relatively close together, but unrelated objects to be relatively far apart. This relatedness bias was robustly present in the results of every experiment in which the interobject distance was varied (Experiments 1, 2, 3, and 5). The results of the fifth experiment enable us to generalize this finding beyond the objects studied in Experiments 1, 2, and 3, although we have not yet tested any scenes composed of quartets of large-scale outdoor objects. We have no reason to believe that they would produce a different pattern of results, however.

A third important finding is the existence of an inward bias for configurations whose spatial envelope points to the left or right, as in a series of objects that decrease regularly in height (Experiments 3 and 4). People generally prefer compositions in which this envelope points into (rather than out of) the frame, analogous to their preference for a single object to face into (rather than out of) the frame (Palmer et al 2008). It is not exactly clear why this inward bias exists for size gradients of objects. Artists frequently talk about structuring a composition so that it "leads the eye into the frame," and the inward bias we found for object-size gradients might be related to this practice. Another possibility is that people might prefer larger objects to be more peripheral than smaller objects to counteract the decease in visual acuity that occurs with eccentricity when they fixate on the center of the frame. Further research will be required to understand the reason for this bias, but even so, it is noteworthy that it is generally opposed to a bias toward gravitational balance. The center of "visual weight" for a pair of objects would actually be closer to the center of the frame if the larger object were closer to the center rather than farther from the center, as we find in our data. We therefore infer that the inward bias arises from factors other than those responsible for preferring balance.

In some ways, the most surprising result is the difficulty we had in finding any clear evidence of a preference for balance, which is the aspect of spatial composition that has been studied most extensively (eg, Pierce 1894; Puffer 1903; McManus et al 1985, 2011; Wilson and Chatterjee, 2005; Gershoni and Hochstein 2011). It was only when we used a fixed configuration of objects that varied solely in left–right position within the frame (Experiment 4) that clear evidence of a center bias consistent with balance was evident, and even here it was modulated by an inward configural bias that opposes "gravitational" balance. In general, it appears that balance is a much less important factor in spatial composition than interobject distance and semantic relatedness, both of which had robust effects in every experiment. Indeed, in Experiments 3 and 5, where distance and balance variables could be directly compared, the results showed that interobject distance was far more salient and influential than balance. In Experiment 5, for example, participants frequently had to choose between a balanced and an unbalanced picture that had the same interobject distance, such that balance was the only relevant relational factor that was different between the two pictures. The fact that participants did not exhibit a preference for the balanced picture in these comparisons is a clear indication that balance is less important than generally believed, at least in the kind of pictures we have studied here. It is again important to point out that the definition we used for balance is a purely geometric measure, without taking into account the color, orientation, size, and shape of the objects. We acknowledge that such factors might change the precise values of an imbalance measure, but we doubt they would change them sufficiently enough to invalidate the conclusions we reach here. It is noteworthy that most previous studies of balance have not actually assessed the importance of balance in aesthetic preference, but rather how perceivers judge balance when that is the task they are given. It appears to be generally assumed that balance is important for aesthetic judgment, perhaps due in large part to the influential writings of Arnheim (1983), without well-controlled studies of its actual impact, which we find to be minimal.

The results of the foregoing experiments provide significant insight into the factors that influence people's aesthetic response to the spatial composition of simple images consisting of two or three objects. Similar studies of single-object images showed that the primary variables influencing aesthetic response were those that related the object to the surrounding frame (Palmer et al 2008; Sammartino and Palmer no date). Perhaps the single most important take-home message of the present studies is that in images containing two or more objects, the relations between the objects (eg, interobject distance and semantic relatedness) matter more than their individual or even their collective relations to the frame (eg, balance and inward direction of configural pointing). Much work remains to be done, however, in specifying the precise nature of the spatial and semantic relations that influence aesthetic preference. Most of the present experiments simplified the problem by using two symmetrical objects, for example. What compositions might be favored if the two objects had a facing direction, such that they could face in the same direction, toward each other, or away from each other? And what would happen if the spatial relations among three or more independently variable objects were assessed? We are currently studying these and related questions, which we hope to report in subsequent articles.

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