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SHORT AND SWEET

Koffka's effect is mediated by figure thickness at the joining region

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Abstract. Three-quarters of a century ago Gestalt psychologist Kurt Koffka described a remarkable effect: when a contiguous gray ring is placed on a background half one shade of gray, half another, the ring appears homogeneous. However, if the ring is divided, the two halves of the ring appear different shades of gray, the half of the ring on the darker background appearing lighter than the half of the ring on the lighter background. The Gestalt principle of continuity is used to explain this effect. But what microscopic principles might be mediating this effect? Recently we found sufficiently thin rings (annuli) appear heterogeneous even when geometrically continuous. Here, using crescent-shaped figures instead of the circular annuli used for the traditional Koffka effect, we show that this effect of thickness of the ring is mediated by the thickness at the boundary of the region where the halves of the figure are joined.

Over 70 years ago Gestalt psychologist Kurt Koffka (1935) described a striking effect: When a gray ring is placed on a background half of one shade of gray (different from the ring) and half of another shade of gray, the ring appears to be homogeneous. However, if the ring is slightly divided, the two halves of the ring appear different shades of gray with the half of the ring on the darker background appearing lighter than the half of the ring on the lighter background. The Gestalt explanation for this effect is that the good continuity of the ring—geometric continuity—of the undivided ring, begets continuity or homogeneity in shade or color. The effect is striking, and the Gestalt explanation consistent with what is observed. But what does 'good continuity' really mean? Do all planar figures topologically equivalent to Koffka's ring share the same degree of 'good continuity' in the context of Koffka's display? The answer is no. Recently, for example, we noticed (Huang et al 2008) that, if the ring is sufficiently thin, then even when undivided the ring looks heterogeneous. Here we show that this effect depends strongly on the width of the ring where it crosses the light – dark boundary in the background of the Koffka display. Instead of the regular annuli used for the traditional Koffka effect, we use annuli whose outer boundaries are circular but whose inner boundaries are elliptical, producing rings whose thickness varies in a crescentlike fashion. Some of our rings grow thin where they cross the light – dark boundary (and thick in those regions where the background is homogeneous light or dark gray), and other of our rings grow thick where they cross the boundary (and thin in those regions where the background is homogeneous). As we demonstrate, a continuous ring that grows thick where it crosses the light – dark boundary of the background appears homogeneous (as in Koffka's original effect); by contrast, however, a continuous ring that grows thin where it crosses the light – dark boundary breaks apart in brightness: the portion of the ring set against the dark background appears substantially brighter than the portion of the ring set against the bright background.

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Koffka's effect is shown in figure 1 along with our variation showing the effect of thickness of the ring. Figure 2 shows rings that are (a) wide where they cross the bright – dark boundary, and thin at the regions far from the boundary, and vice versa, (b) thin where they cross the bright – dark boundary and thick at the regions far from the boundary. We see that, when the ring is thick at the boundary region, the figure appears homogeneous when joined, but the left and right sides differ in brightness when the halves of the figure are separated. However, conversely, when the ring is thin where it crosses the light – dark boundary, the left and right sides of the figure appear to be different shades, whether the figure is continuous or not.

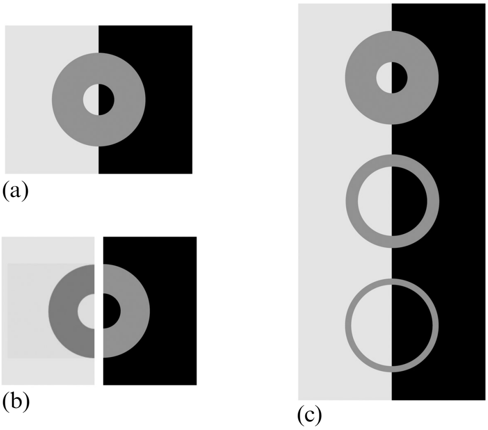

Figure 1. (a), (b) Koffka's original effect; (c) thin rings, even when connected, appear heterogeneous.

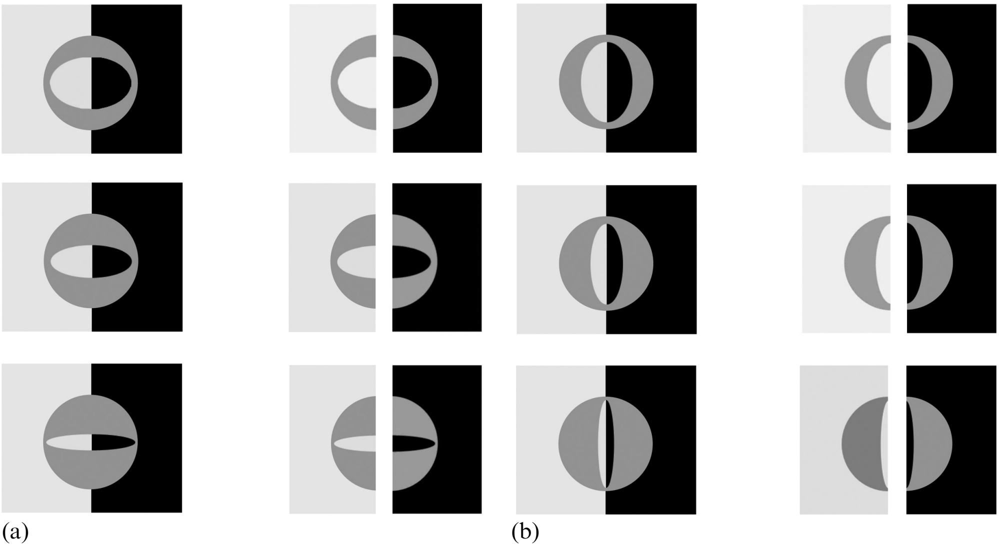

Figure 2. Figures which are thick at the joining region (horizontal ring – center) look homogeneous when unbroken (left column), and different shades only when broken (right column). The top, middle, and bottom rows of (a) and (b) correspond to the same rows in figures 4a and 4b. The figures in these rows we describe as most elongated (top row), semi-elongated (middle row), and least elongated (bottom row). (b) Figures which are thin at the joining region (vertical ring – center) look heterogeneous when unbroken (left column) or broken (right column).

To test our observations, we studied sixteen healthy subjects (ages 20 – 30 years, six female, with normal or corrected to normal vision) who were naive as to the purposes of the experiment. The study was approved by the UMDNJ IRB, and all subjects gave written informed consent. Examples of testing stimuli are shown in figure 3.

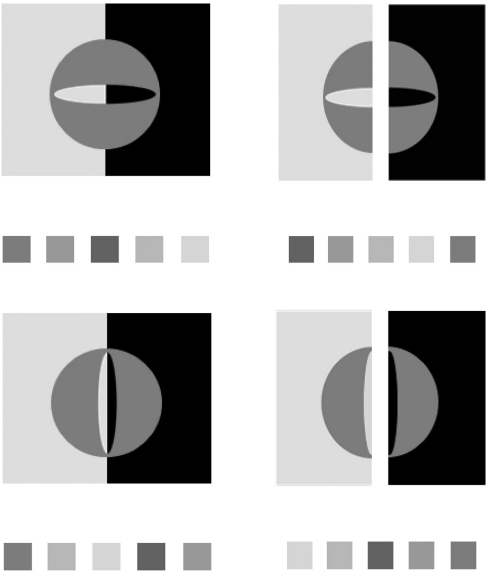

Figure 3. Examples of testing stimuli.

Subjects sat 53 cm from a standard Macbook LCD screen (visual angle 4 deg) set at 5 units on the brightness calibration bar with the screen elevated to eye level. Subjects were asked to indicate which of the five test squares on the bottom best matched in shade (a) the left half and (b) the right half of the crescent figure. The various subfigures in figure 2, joined and unjoined, were all arranged in random order in two sets. Sets were used alternately for successive subjects. The order of the brightness squares was randomized on a per slide basis.

Results are shown in figure 4. Figure 4a gives the results for the horizontal – center conditions (in which the ring grows thick as it crosses the boundary). On the left are the results for the conditions in which the ring is unbroken, and the corresponding results for the conditions in which the ring is broken are on the right. The top, middle, and bottom rows of figure 4a give the results for the conditions in which the ring – center is most-elongated (producing the largest variation in ring width), semi-elongated, and least-elongated. The analogous results for the vertical – center conditions are given in figure 4b.

Note first that, irrespective of its center orientation, if the ring is broken, then participants show a strong tendency to judge the ring-half on the dark background as brighter than the ring-half on the bright background.

The conditions in which the ring is unbroken show a different pattern, however. Strikingly, across the three unbroken ring conditions in which the center is horizontal (figure 4a, left side), subjects judged both ring-halves to be the same shade in 46 of 48 trials. By contrast, however, in the three unbroken ring conditions in which the center is vertical (figure 4b, left side) there seems to be a stronger tendency for participants to see the half-ring on the dark background as brighter than the half-ring on the bright background.

We tested this trend separately for the conditions in which the ring – center is (a) most-elongated, (b) semi-elongated, and (c) least-elongated. Specifically, in a given center – elongation condition, for each participant, let d_{thin} be the difference between the brightness setting for the dark-background half-ring minus the setting for the bright-background half-ring for the vertical – center condition (in which the ring is thin at the bright – dark boundary), and let d_{thick} be the analogous difference for the horizontal – center condition (in which the ring is thick at the bright – dark boundary).

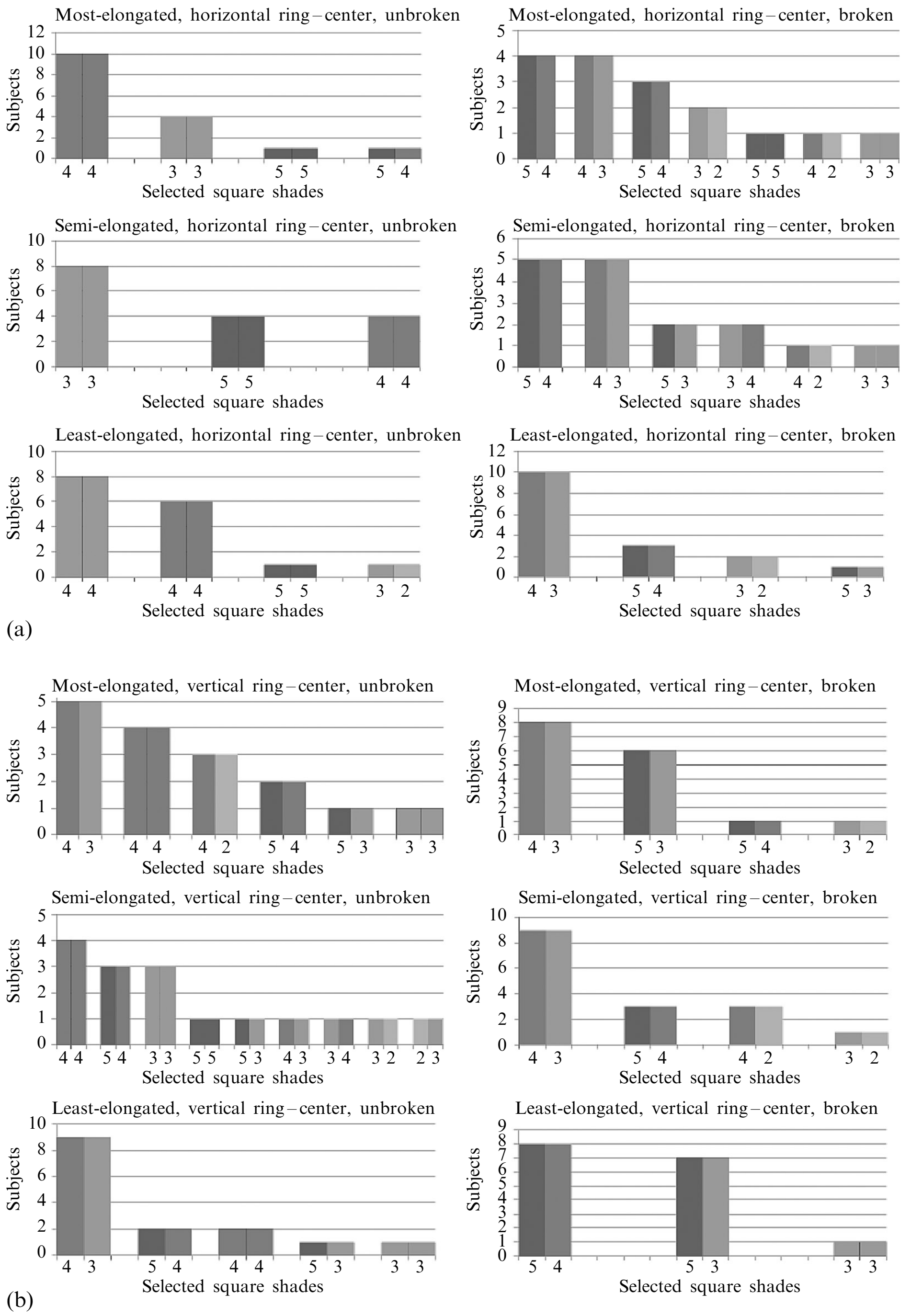

Figure 4. Results. See text for discussion. (a) and (b) top, middle, bottom show results for testing corresponding to figures 2a and 2b, respectively.

We conducted a one-tailed, Wilcoxon matched-pairs signed-ranks test of the null hypothesis that the median value of $d_{\text{thin}} - d_{\text{thick}}$ is 0. This test yields $p < 0.005$ ($W = 0$, $N = 10$) for the most-elongated ring-center condition, $p > 0.05$ ($W = 8$, $N = 8$) for the semi-elongated ring – center condition, and $p < 0.005$ ($W = 0$, $N = 12$) for the least-elongated ring – center condition.

We conclude that in the most-elongated and least-elongated ring – center conditions, our participants show a stronger tendency to judge the ring-half on the dark background brighter than the ring-half on the bright background in the vertical – center condition than in the horizontal – center condition. It is unclear why this effect fails to reach significance in the semi-elongated ring – center condition.

As we have noted, if the ring is broken, then, irrespective of whether the ring is thick or thin at the boundary, the half-ring on the dark background tends to be much brighter than the half-ring on the bright background. This suggests that the median value of $d_{\text{thin}} - d_{\text{thick}}$ should be near zero. In line with these expectations, Wilcoxon matched-pairs signed-ranks tests fail to reject the null hypothesis that the median value of $d_{\text{thin}} - d_{\text{thick}}$ is 0 in the cases in which the ring is broken: for the most-elongated ring – center conditions, $W = 12$, $N = 8$, $p > 0.05$; for the semi-elongated ring – center conditions, $W = 7.5$, $N = 7$, $p > 0.05$; for the least-elongated ring – center conditions, $W = 4$, $N = 7$, $p > 0.05$.

We have found that Koffka's effect is influenced by the thickness of the ring at the boundary between the two sides of the figure. If the ring is thick where it crosses the boundary, the ring tends to be seen as homogeneous in brightness. If the ring is thin where it crosses the boundary, then it tends to break apart in brightness, with the half-ring on the dark background brighter than the half-ring on the bright background.

We observe that these findings might be accommodated by a 'filling-in' theory of brightness, such as that of Grossberg and Todorović (1988), in which the brightness assigned to a homogeneous region results from a diffusion of information throughout the region from its boundary. The one additional assumption required is that diffusion of brightness information is slower through narrow parts of the figure than it is through wider parts. Under this account, the brightnesses of the right and left halves of any one of our variants of the Koffka ring represent the equilibrium state of a dynamic process in which contrast signals are continuously being generated at the (inner and outer) boundaries of the ring and are diffusing throughout the ring. Thus, for example, the difference in brightness between the left and right halves of a ring with a vertical center results from the following factors: (i) all of the signals arising at the boundary of the ring-half on the dark background are positive (because the contrast across the boundary from background to figure is positive at all points), (ii) all of the signals arising at the boundary of the ring-half on the bright background are negative, and crucially, (iii) diffusion of this opposite-signed brightness information across the bright – dark vertical boundary is slow in comparison to the rate at which these boundary contrast signals are being generated, because the straits through which this information must pass at the top and bottom of the ring are narrow. Under this model, what we see constitutes the equilibrium state of this diffusion process.

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