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LAST BUT NOT LEAST

The jaggy diamonds illusion

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Abstract. We report a new illusion in which the edges of diamonds placed at the intersections of grids are perceived to be jaggy (the jaggy diamonds illusion). Interestingly, the illusion disappears when the stimulus is rotated by 45°, when the stimuli are observed at a close distance, and on the diamond at which the observers stare. Luminance contrast between diamonds, grids, and background is a strong determinant for this illusion.

Visual illusions induced by intersecting grids (grid illusions) have been reported in the past. For example, illusory smudges are perceived at the intersection of bright grids on a dark background (Hermann grid illusion). Scintillating smudges are also perceived within disks placed at the intersection of grey grids with a dark background (scintillating grid illusion). These anomalous percepts of illusory smudges are affected by luminance and geometrical relationships between the grids, the background, and the disks.

Here we report a new grid illusion: the edges of diamonds placed at the intersections of grids are perceived to be jaggy (figure 1a). This illusion was found when we conducted experiments on the scintillating grid illusion with diamond patches (figure 1b). However, stimulus conditions inducing the illusion of diamonds with jaggy edges are still unclear. This paper briefly reports two experiments on this finding.

In experiment 1, six observers were presented with an image of the type shown in figure 1a on a 20-inch display at a viewing distance of nearly 70 cm. The stimulus extended 27.5 cm horizontally and 21.0 cm vertically (a 20×16 diamond matrix with crossing grids). The width of each diamond subtended 0.6 cm and the width of each grid was 0.4 cm. The task of the observers was to freely scan the stimulus image and draw the perceived shape of diamonds with a pen. No time limit was imposed.

The results are shown in figure 1c. Though the perceived shapes of diamonds differed between the observers, one common feature of patches they drew was the jaggy or star-like edge of the diamonds. Therefore, we call this illusion 'the jaggy diamonds illusion'.

Informal observation showed that the jaggy diamonds illusion disappeared when the stimulus was rotated by $\sim 45°$ (try this with figure 1a), suggesting the dependence of this illusion on retinal image. These observations also ruled out the possibility that small image artifacts, such as physical notches along an edge, caused this illusion. Importantly, the illusion could be seen in the peripheral visual field. Moreover, a stronger illusion was reported when the viewing distance was increased and when the observers scanned the stimulus with eye movements.

Compare figures 1a and 1b. A potential source of the jaggy diamonds illusion seems to be a luminance contrast between the diamonds and the background, which is the only difference between figures 1a and 1b. Therefore, in experiment 2, we investigated how the luminance contrast of the diamonds against the background affected the illusion.

Five observers participated in this experiment. Stimuli were presented on a γ-corrected CRT display (RDF193H, Mitsubishi). A Mac Pro (Apple Inc.) controlled stimulus presentation and data collection. A head-and-chin rest was used to stabilise the visual field of each observer. The stimulus image in each trial was composed of 8×8

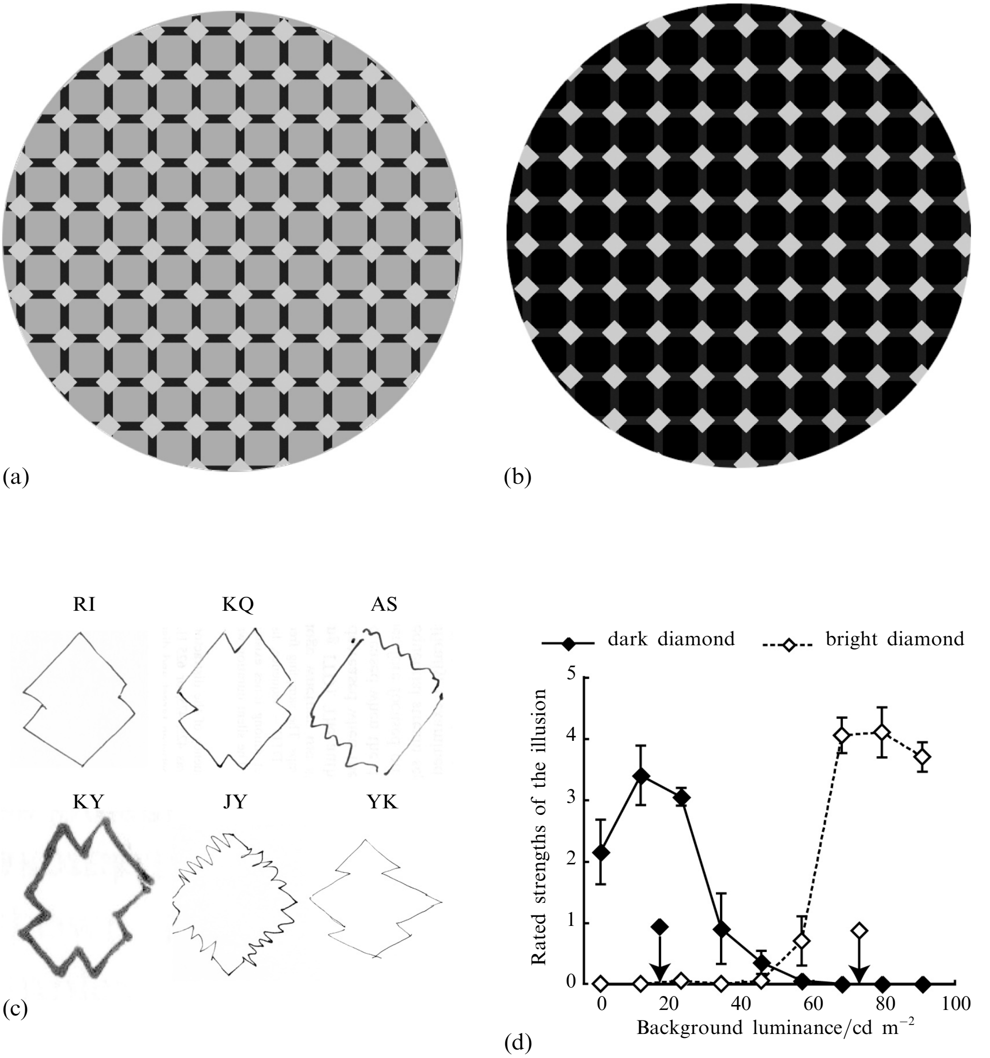

Figure 1. (a) The jaggy diamonds illusion. The observers typically perceive the edge of the diamonds to be jaggy. However, when this image is rotated by 45°, the illusion disappears. (b) The scintillating grid illusion with diamond patches, reported in Qian et al (2009). (c) The results of experiment 1: the individual drawings of typically perceived shape of diamonds are shown. (d) The results of experiment 2: arrows with black and white diamonds indicate luminance values in dark and bright diamond conditions, respectively. Error bars denote ±1 SEM ($N = 5$).

grid diamonds, 8×8 grid intersections, and background. The side of each diamond was 1.0 deg long. The width of each grid line was 0.4 deg. The distance between the diamonds was 2.8 deg. Each diamond was placed at a grid intersection. The luminance of patches was set at either a low (17.0 cd m^{-2}) or a high (73.8 cd m^{-2}) level. The luminance of background was randomly selected from nine alternatives (0.0, 11.5, 23.0, 34.0, 45.5, 57.0, 68.0, 79.5, or 91.0 cd m^{-2}). The grid luminance was 45.5 cd m^{-2} (neutral grey). The task of the observers was to rate the strength of the illusion on a 6-point scale ranging from 0 (no illusion) to 5 (strongest illusion). Before the experimental session, the observers conducted a task similar to that in experiment 1, and all drew the patch with jaggy edges. No temporal limit was imposed. The rating score in each trial was determined by pressing assigned keys. After conclusion of one trial the next trial was started by pressing the space bar of the keyboard. Each observer performed 72 trials:

2 (diamond luminance conditions) × 9 (background luminance conditions) × 4 (repetitions). The trial order was randomised across observers.

The results are shown in figure 1d. For each observer, the rated strengths were averaged in terms of each experimental condition. These data were submitted to a two-way ANOVA with diamond luminance and background luminance as factors. The main effect of diamond luminance was not significant ($F_{1,4} = 4.1$, $p > 0.1$). The main effect of background luminance was significant ($F_{8,32} = 13.3$, $p < 0.0001$). Importantly, the interaction between the two factors was significant ($F_{8,32} = 62.0$, $p < 0.0001$). Tests of simple main effects showed that rated strengths were significantly different in the two diamond luminance conditions when background luminance was 0.0, 11.5, 23.0, 68.0, 79.5, and 91.0 cd m^{-2} ($p < 0.0001$). When the diamonds were dark (17.0 cd m^{-2}), the rated strengths in background conditions with 0.0, 11.5, and 23.0 cd m^{-2} luminance were significantly higher than those in background conditions with more than 34.0 cd m^{-2} ($p < 0.003$). On the other hand, when the diamonds were bright (73.8 cd m^{-2}), the rated strengths in background conditions with 68.0, 79.5, and 91.0 cd m^{-2} luminance were significantly higher than those in background conditions with less than 57.0 cd m^{-2} luminance ($p < 0.0001$).

The results showed that the rated strength of the illusion was high when the difference in luminance between the diamonds and the background was small, indicating that luminance contrast was a strong determinant of the jaggy diamonds illusion. In particular, low luminance contrast between the diamonds and the background strongly elicited the illusion.

However, on comparing figures 2a and 2b, in which the contrast between the grids and the background is greater in the former than the latter with the contrast between the diamonds and the background fixed, one finds that the illusion is stronger in the former than the latter figure. This observation suggests that the illusion is also influenced by the relationship of luminance contrast between the grids and the background.

This study demonstrated that luminance contrast alters perceived shapes of diamonds, though it is still not clear exactly what kind of mechanism underlies this illusion. An earlier study has shown that local processing for luminance contrast between the central region and background strongly affected perceived size of the central region (van Erning et al 1988). Also, the relationship of contrast polarity between adjacent regions determines the perceived tilt of a line in the Café Wall illusion (Kitaoka et al 2004). However, none of these previous studies can provide a straightforward explanation for the jaggy diamonds illusion.

It is interesting to compare the jaggy diamonds illusion with other grid illusions. Consistent with the jaggy diamonds illusion, the Hermann and scintillating grid illusions are greatly reduced with oblique grids (De Lafuente and Ruiz 2004; Qian et al 2009) and with the curved grids (compare figures 2c and 2d—Geier et al 2008). The scintillating grid illusion is also sensitive to the relationship in luminance contrast between the disks, the grids, and the background (Schrauf et al 1997). Moreover, one critical aspect of the jaggy diamonds illusion is that jaggy edges of diamonds are perceived to twinkle or scintillate with eye movements or attention shifts, which is a prominent characteristic of the scintillating grid illusion (Schrauf et al 1997; VanRullen and Dong 2003). Hence, the underlying mechanism of the jaggy diamonds illusion is possibly shared by other grid illusions. The large individual differences of perceived shapes of diamonds (figure 1c) may be due to this twinkling/scintillation that likely induces uncertainty about the shape of the diamonds. Still, it is surprising that all our observers report jaggy edges of the diamonds.

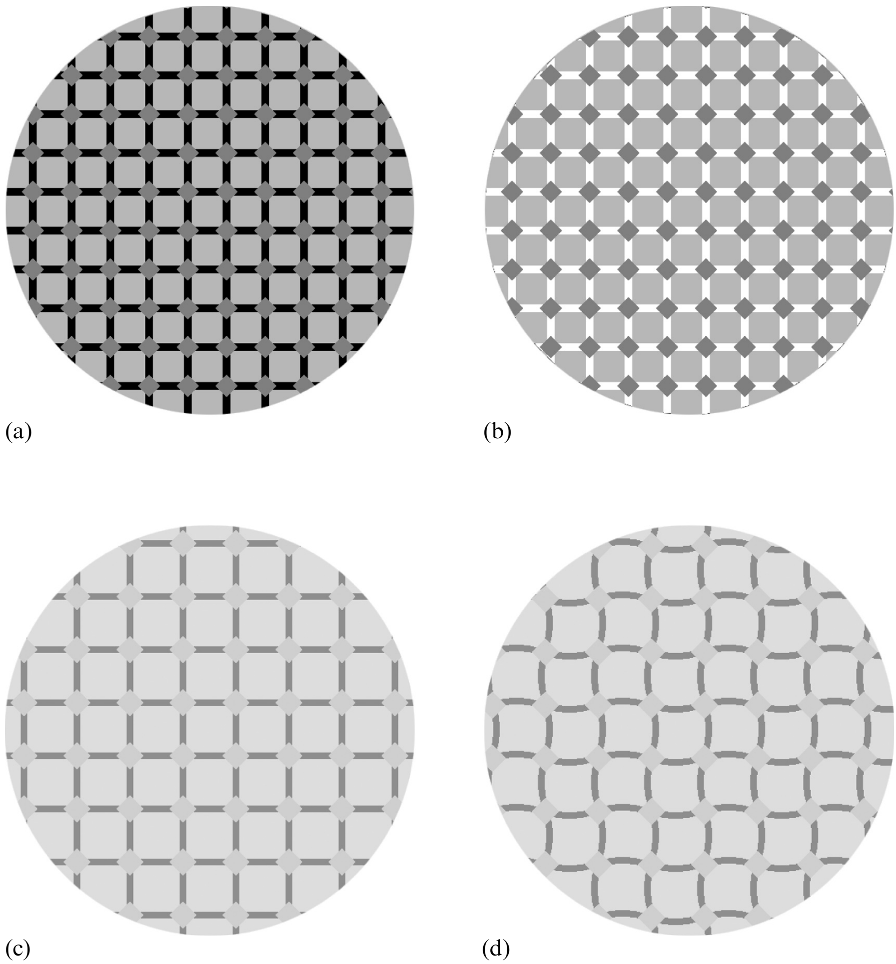

Figure 2. Demonstrations of the modulation of illusion strength by luminance contrast between grids and background: the illusion is stronger in (a) than in (b). The illusion disappears when grids in (c) are curved as in (d).

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