A note concerning the relationship between the Adelson’s Argyle Illusion and Cornsweet edges

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Adelson’s Argyle illusion and the Craik-O’Brien-Cornsweet illusion are two noteworthy brightness illusions. In the Argyle illusion two identical gray areas are perceived to have radically different brightness levels when they are surrounded by a pattern similar to an argyle clothing design. The Craik-O’Brien-Cornsweet (C-O-C) illusion shows two identical gray areas appear different brightness when they are separated by a “Cornsweet edge.” The C-O-C illusion is remarkable for the large distances over which the effect holds even though the Cornsweet edge is relatively narrow. Here we draw a connection between these two illusions by extending the columns of the Argyle illusion to produce what we refer to as long range Argyles (LoRAs). We show that LoRAs have many similar properties to Cornsweet edges and they are capable of producing brightness effects over a large spatial range. It therefore seems that part of the strength of the Argyle illusion arises from a combination of standard simultaneous brightness effects and edge effects like those produced by the C-O-C illusion. Lastly, we discuss a curious difference between the effects of LoRAs and Cornsweet edges.

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The Argyle illusion (Adelson, 1993) takes the form of an arrangement of diamonds in a grid; it is so named because the form of the diamonds resembles the argyle pattern found on sweaters, socks, and other clothing (see figure 1). In the illusion, diamonds in a grid arrangement are divided into triangles of gray, white, gray, and black, with black and white on the opposite quadrants. Columns of these diamonds change the perceived shade of the surrounding mid-luminance background to appear darker or lighter, depending on whether the background is surrounded by the black or white quadrants. Adelson (1993) explains this effect in the context of “higher-order” mechanisms of transparency perception, as if the darker-looking gray appears covered by a translucent sheet. Others, for instance Shapiro and Lu (2011) and Todorović (2006) have suggested that the brightness effect could be due to low-level processes. Here we show that the Argyle illusion contains within it multiple components that contribute to the strength of the effect; one of these components is a Craik-O’Brien-Cornsweet (C-O-C) edge.

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In the Craik-O’Brien-Cornsweet illusion (figure 2), a gray rectangle with a slight gradient toward white on its right edge is connected horizontally to a gray rectangle with a slight gradient toward dark on its left edge. The luminance profile of gray-light-dark-gray is called a Cornsweet edge, and it results in observers describing the background as being non-uniform in appearance; the background adjoining the dark part of the edge appears darker than the parts of the background adjoining the bright part of the edge. The Cornsweet illusion is remarkable because the contrast effect produced by a thin edge appears to spread outward over the entire background. The effect works for edges of very low contrast levels where the gradients within the rectangles are barely noticeable. There are many explanations for this effect, ranging from brightness/contrast processing models (Dakin & Bex, 2003; Grossberg & Todorović, 1988) to models based on knowledge from past experiences (Purves, Shimpi, & Lotto 1999).
of gradual luminance changes divided by a high contrast edge, known as a Cornsweet edge. This configuration of gradients causes the identical gray rectangles to appear different from each other.

To show the connection between the Argyle illusion and the C-O-C edge, we introduce long range Argyles (LoRAs)—depicted in Figure 3. A version of the original Argyle illusion is shown in Panel A. The illusion can described as three columns of five triangle pairs. In panels B and C, the outer columns are moved away from the center column, but the main effect remains — that is, the homogeneous background appears inhomogeneous; the area between the center and left area looking a brightly illuminated dark surface, and the area between the center and right column looks like a bright surface in a shadow. The images in panels 3B and C have some precedence in the literature (Todorović, 2003) although no one directly connected these images to the Argyle illusion.

Figure 3. Long Range Argyles (LoRAs). The variation of the basic configuration of the Argyle illusion with columns of triangles (see figure 1) is shown in panel A. The configuration results in two thin columns of mid-luminance gray background appearing different from each other. Panels B and C show that when the columns of triangles are spread apart, the effect remains, and the now larger areas of background continue to appear different. Panel D shows that the effect remains even if the outer columns of triangles are removed and only the center column remains. This panel is analogous to the Cornsweet illusion.

One might imagine that Panels B and C simply show that the Argyle illusion extends over a large distance—an impression that would be consistent with models of brightness-based inferences about illumination of the scene. However, in Panel D, we can see that the effect still arises when the outer columns are removed completely from the image. That is, when only one central column of triangles remains, one half of the display looks darker than the other half of the display. The extent of the effect is analogous to the C-O-C edge shown in figure 2. Indeed, the gray-light-dark-gray pattern from the Cornsweet edge is also present in the columns of triangles: a cut through the diagonals of the Argyle stripes shows a similar gray-light-dark-gray pattern (although in the Argyle the luminance changes are more abrupt).
The Argyle illusion and LoRAs seem to sum across several coarser, Cornsweet-like edges. For instance, in Figure 3A-C the effect of the center is stronger, as if there is a summative effect of the surround columns. In figure 4A and B we show this directly. Figure 4A is a LoRA illusion (like figures 3B and C) and in figure 4B the center column is flipped so that the white triangles pairs are now on the left side. Notice that the brightness effect is much weaker (if not absent) in Figure 4B. The reason for this is that in 4A the area marked as I is between two white triangles; the background is darker to the right of column 1 and also darker to the left of column 2. Similarly the area marked as II is between the dark triangles in columns 2 and 3 and thus appears different from area I. In 4B, column 2 is horizontally flipped so that Area I is bordered by white triangles from column 1 on its left and by dark triangles from column 2 on its right. The same is the case for area II flanked by columns 2 and 3. The effect of the white triangles to the left is canceled out by the effect of the dark triangles to the right. This results in areas I and II looking the same as each other and the effect of the illusion is destroyed.

Figure 4. A comparison between LoRAs and Cornsweet edges. Panel A shows a long range Argyle (LoRA) as designed by Shapiro. The gray areas labeled I and II appear different because of the summed effects of columns, 1, 2, and 3. Panel B shows that when column B is reversed, the effects of the columns cancel each other out, and areas I and II appear to be the same. Panels C and D show the same effect using Cornsweet edges. In C, areas I and II appear different, but in D they appear the same. This shows the individual contributions of each column (1, 2, 3) to the effect and the analogous effects of the Argyle illusion and the Cornsweet edge.

The manipulation displayed in figures 4A and B can be applied equally well to the Cornsweet illusion. In 4C, the effects of three different Cornsweet edges
(labeled 1, 2, 3) combine to create the effect of areas I and II appearing different.
While area I is immediately flanked by two gradients which turn dark, area II is
flanked by two gradients which become lighter. As a result, areas I and II appear
different. Conversely, in 4D, the center Cornsweet edge has been reversed so that
areas I and II are each flanked by a triangle to dark and a gradient to light. The
two effects of these gradients work against each other and cancel out the effects of
each individual Cornsweet edge. As a result, areas I and II look the same.

Figure 5. A single-column LoRA in panel A is compared to a normal, single-column
Cornsweet in panel B. The displays are arguably analogous because the luminance
profile of the center area of each figure follows a gray-lighter-darker-gray pattern either
through coarse edges (LoRA) or gradients divided by a center edge (Cornsweet). Different
observers, however, see different combinations of areas (I and II) from panels A and B
as matching up. Some see the “illuminated” area I in panel A as brighter than area II and
comparable to area I in panel B. Others see panel A area I as darker than area II and thus
c omparable to panel B area II.

A curious aspect of figure 4 is that most (but not all) observers report that the
effects of LoRA are opposite the effects of the C-O-C edge. That is, in panel A, area
I appears dark and area II appears light, but in panel C area I is light, but area II is
dark. In figure 5, we show the same relationship but for a single LoRA (panel A)
and C-O-C edge. We do not have a good explanation for why this should be so, but
we can tentatively hypothesize that the flipped percepts concern the multifaceted
perceptual aspects of the LoRA displays. As stated above the LoRAs (as well as the
original Argyle illusion) can be described in terms of both the illuminant and the
surface—so, one field (for instance, area I in figure 4A) looks like a dark surface
in a bright illuminant and the other field (area II in figure 4A) looks like a light
surface in a shadow. In the C-O-C illusion, however, the two aspects of the display are not nearly as apparent. For those who are amenable to inference based theories of brightness it is conceivable that observers who match area I in 4A to area II in 4C are making judgments based only the appearance of the surface, whereas the observers who match area I in 4A and 4C are making judgments based on the properties in the stimulus that correspond to the description of the illuminant.

LoRAs are robust phenomena that seem to be a component of the Argyle illusion. Here we have noted some similarities to the C-O-C effects and at least one possible difference. Other demonstrations of the LoRA can be seen at http://shapirolab.net/LoRA. One of the demonstrations allows the observer to adjust the flicker rate of the white and black triangles in the LoRA display. We note that the speed of the induction effects can occur at rates much higher that those reported for standard induction by De Valois and colleagues (1986). It therefore seems likely that the effects found in LoRA do not represent a slow cortical filling-in-like response.

References