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Abstract. In the Mausoleum of Galla Placidia (Ravenna, Italy), the *San Lorenzo lunette* shows two peculiar visual effects: a transparency effect of gold seen through gold and perceptual collinearity between two parts of a cross which are physically misaligned. Both effects are found within the area of the halo surrounding the saint's head. In this work we addressed the problem posed by the physical misalignment of the cross. Our hypothesis is that the physical misalignment went unnoticed throughout history because the artist produced a perceptual alignment to correct for the Poggendorff illusion. Hence, we asked observers to align two ends of a cross in a reproduction showing the silhouette of San Lorenzo's torso holding the cross. Results support our hypothesis: both direction and magnitude of adjustments comply with the alignment in the original mosaic.

Keywords: Poggendorff illusion, history of art.

San Lorenzo lunette (first half of the 5th century, Mausoleum of Galla Placidia) is a rather peculiar work of art within the collection of Byzantine mosaics in Ravenna. Every detail shows dynamism, something that contrasts with the rather static representations of sacred figures of the same period. From left to right: the cabinet holding the four gospels is left wide open; a blazing fire under the martyrdom grid is casting its own vivid shadow against the wall; the saint's toga is flustered in a baroque fashion while he proceeds toward the centre of the scene, peering at the visitor. San Lorenzo is holding an open book of Psalms in his left hand and a long cross over his right shoulder (Figure 1).

Figure 1. *San Lorenzo lunette*. The lunette measures 313 × 187 cm (base length × height). The perpendicular distance from the mausoleum's floor to the base is 290 cm; the perpendicular distance from the mausoleum's floor to the saint's head is 445 cm. This means that the saint is practically portrayed with a 1:1 ratio (considering the average height of men at the time). Given such dimensions, the sinopia used by the artist to trace the geometrical layout of the scene must have been created with the aid of drawing tools, especially for tracing straight lines and the halo.

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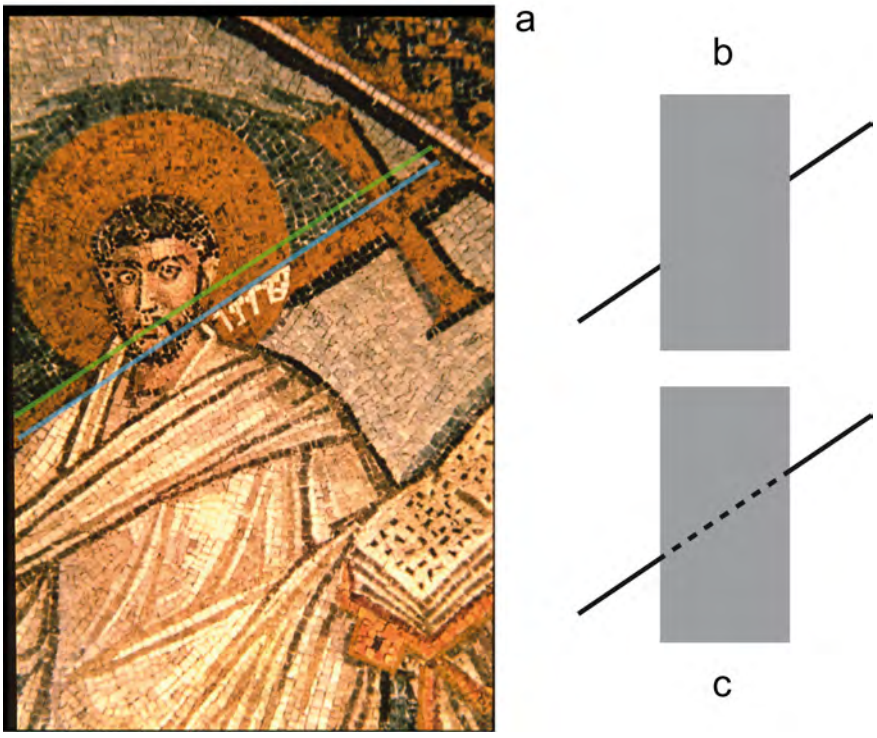

Figure 2. (a) Detail of San Lorenzo. The blue and green lines show the entity of the geometrical misalignment. Notice the different density of the tesserae in the region comprised between the halo and the cross, and the simulation of transparency with a coarse placement of the white tesserae: should these be interpreted as cues of a *pentimento* (a technical term to refer to a visible trace of an artist's change of mind concerning some detail of a work of art)? (b) The Poggendorff illusion. (c) The two visible parts of the line are geometrically aligned.

All portrayed objects are pertinent to the saint's iconography, but within the context of the mausoleum the cross is a core feature. The building is charged with sepulchral meanings, with particular reference to the theme of resurrection and eternal life (Ricci 1914). Inside this iconological programme the cross stands out as an emblem of faith and salvation. This is probably the reason why the artist had to be sure that the long cross held by San Lorenzo was recognizable in its whole extent, being also a symmetric representation of the cross held by the *Good Shepherd* on the opposite wall. Careful observation of San Lorenzo's cross reveals two details that are particularly fascinating to the vision scientist (Zavagno 1996).

First of all, the cross and the saint's halo determine a peculiar transparency effect: both objects are of a gold colour, and the transparency effect, which works marvellously when viewed at a distance, is sketched inside the halo using only white tesserae. Due to this graphic solution, the halo appears transparent only where it intersects with the cross (Figure 2).

The second curiosity concerns the long arm of the cross, which is subject to amodal completion behind the saint's neck. However, a more careful inspection reveals that the two parts of the long arm are not geometrically aligned (Figure 2). We believe that this detail went unnoticed throughout history because the artist corrected for a perceptual misalignment that would have occurred if the two ends of the cross were geometrically collinear. Given the size of the lunette (see Figure 1), the geometrical elements of the sinopia of the mosaic must have been created with the aid of drawing tools. At this point a problem arises: Why did the artist use drawing tools to trace perfectly straight lines everywhere except when it comes to the cross, which is indeed straight but made of two physically misaligned parts? To answer this question and to test our aforementioned hypothesis, we designed an experiment

in which participants were asked to adjust the upper-right part of a cross until it appeared collinear to the lower-left part in silhouette configurations reproducing the saint's head, halo, torso, and cross (Figure 3). Such types of configurations were used to limit the stimuli to the essential features that we considered part of the problem: the head/halo/torso of the saint, two portions of the cross, and a portion of the upper-curved border of the lunette. We believe that our configurations in some sense mimic the sinopia, holding equivalent those geometrical features pertinent to the problem.

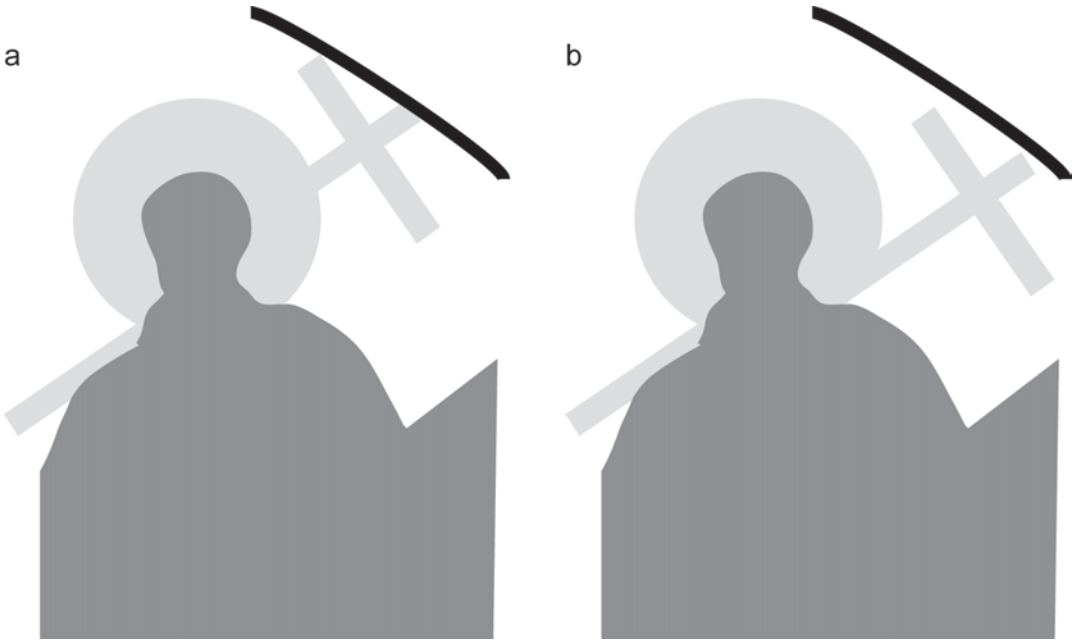

Figure 3. The psychophysical method of adjustment was used to estimate a participant's point of subjective equality (ie, the perceptual alignment of the two ends of the long cross). The figure shows two typical starting points for cross adjustments. Task: adjust the right end of the cross until it appeared collinear to the left end. Stimuli were displayed on a 2-in CRT. Thirty-six participants performed 12 adjustment trials, (a) half of which starting from a point, variable from trial to trial, always well above the point of geometric alignment (0) and (b) the other half starting similarly from a point always well below the point of alignment set by the artist (−25 pixels from 0). Trials were randomised.

Results are displayed in Figure 4 and reported in detail in its caption. Results support the hypothesis that the artist preferred a perceptual alignment to a geometrical one. Of course, we are aware that our study has at least four limitations: 1) adjustments were performed using greyscale silhouettes that reproduced only a small portion of the scene; 2) we omitted the transparency effect; 3) silhouettes were heavily scaled to fit the CRT; and 4) adjustments were performed at eye-level.

All four limitations were imposed by the experimental set-up. While we think that our configurations reproduce most of the geometric information available in the sinopia, they do not represent the 3D information that would have been available to the artist as he portrayed the head of the saint. Hence, the actual mosaic may induce greater or different effects due to its 3D rendering (Koning and van Lier 2007), its size, and also due to the presence of the transparency effect.

Another hypothesis is, however, worthy of consideration: the viewing angle and distance from which the artist checked how his work was proceeding might have something to do with the magnitude of the mismatch between the geometric alignment and the one chosen by the artist. Ours, of course, is just a conjecture; however, it is based on an objective element: the size of the lunette (see caption to Figure 1), because of which the use of tools to draw the

geometric parts of the scene in the sinopia was practically mandatory. Consider the sinopia to be a sketch, maybe something a bit more than a line drawing. It is quite plausible that the artist drew a straight line for the upper edge of the cross right across the saint's neck and halo (something similar to Figure 2c). If this were the case, only afterwards, while placing the tesserae and checking his work from a distance, would he have noticed the problem posed by gold against gold—the golden halo and the golden cross, which made the artist seek for a peculiar transparency effect (Zavagno 1996)—and also the problem posed by the unknown Poggendorff illusion, which made him reject the geometrical alignment of the sinopia in favour of a perceptual alignment in the mosaic.

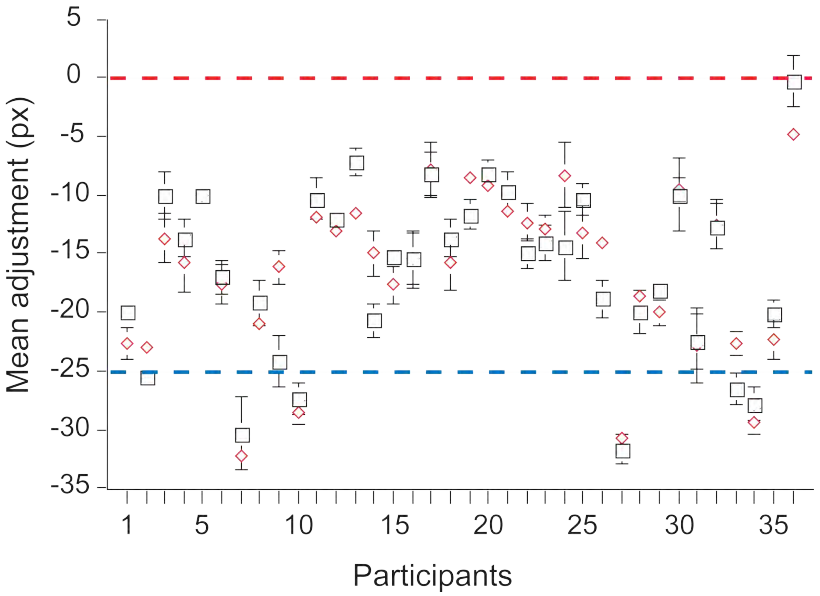

Figure 4. Mean perceptual alignment for each observer. '0' on the *y*-axis indicates the point of geometrical alignment, while the blue line indicates the artist's alignment. Squares refer to adjustments from above geometrical alignment; diamonds, to adjustments from below the artist's alignment. An ANOVA on adjustments with 'adjustment direction' (from above and from below, see Figure 3) and repetitions as within-subjects factors revealed no significant effects. The distribution of subjects' estimations is well below the geometrical alignment. In fact, all means, except one, statistically differ from the geometrical alignment. Some observers performed adjustments that were comparable to the artist's alignment.

Allow us to engage in an exercise of pure fiction, by picturing how the artist might have worked. Up on a scaffold, about 3 m from the ground, the artist would place the tesserae of the mosaic according to his plans, following the sinopia he created that allowed him to achieve, among other things, a round halo and very straight lines. Imagine the artist going up and down ladders to check his work from a distance, because he could not visually embrace the whole scene from the scaffold. At some point, viewing the mosaic from ground level, he realised that something was wrong: the long cross appeared 'broken', separated in two pieces. This outcome was a small catastrophe considering the iconological programme that informed the entire building, from its shape (a Latin cross) to its rich decorations (Ricci 1914). The saint's halo was responsible for the problem, but of course, it could not be deleted: if the cross and the book of psalms are Lawrence's diaconal attributes, the halo is the symbol of his holiness. The artist thus proceeded by trial and error to fix the appearance of the long cross, finally devising the stratagem of an improbable transparency effect and perceptually fixing the alignment of the cross to avoid an illusion of misalignment. The same illusion tormented another artist, Rubens (Topper 1984), more than 1000 years later; however, it took another

250 years before the phenomenon was finally discovered and acknowledged as an illusion, when Poggendorff observed it while inspecting yet another illusion, published by Zöllner in 1860 (Vicario 2008).

As stated above, ours is only an alluring conjecture. A fact, however, remains: the misalignment was made because of the Poggendorff illusion. The mosaic's sinopia would probably help to shed light on how 3D appearance, viewing distance, and angle influenced the choice of the artist, if only it were visible. Since the sinopia is not available, as an alternative, we plan to run a more ecological experiment in which not only some of the stimuli show a detailed reproduction of the mosaic, but the set-up also mimics the viewing distance inside the Mausoleum. If viewing distance and angle matter, observers' adjustments should roughly coincide with the alignment chosen by the artist more than 1500 years ago, regardless of whether stimuli are good renderings of the mosaic or sinopia-type of representations, somewhat similar to those portrayed in Figure 3.

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