# On the Nature of the Background Behind Mona Lisa

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**Abstract 100 words**

One of the many questions surrounding Leonardo's *Mona Lisa* concerns the landscape visible in the portrait's background: Does it depict an imagination of Leonardo's mind, a real world landscape or the motif of a plane canvas that hung in Leonardo's studio, behind the sitter? By analyzing divergences between the Mona Lisa and her Prado double that was painted in parallel but from another perspective we found mathematical evidence for the motif-canvas hypothesis: The landscape in the Prado version is 10% increased but otherwise nearly identical with the Louvre one, which indicates both painters used the same plane motif-canvas as reference.

When the conservators of the Museo Nacional Del Prado in Madrid were asked by the Louvre to lend them their copy of "La Gioconda" to be presented in a special exhibition in 2012, they started to inspect the painting closely. Though the Prado's Gioconda and the Louvre's original Mona Lisa both depict a similar looking young lady in about the same pose, their resemblance was rather limited at first sight, particularly because of the dense black background of the Prado version. So it must have been kind of an "Aesthetic Aha!" [1] when the first infrared examination revealed a landscape hidden beneath the black color.

In the course of the subsequent restoration, the black overpainting was removed and it became visible that the landscapes in the Prado's Gioconda and the Louvre's Mona Lisa do very much look alike (see Fig. 1). Using infrared and x-rays, the Prado's conservators further analyzed and compared the portraits. They found that both share several corrections also in the tracing and lower paint layers why it is now assumed that the paintings were executed simultaneously in Leonardo's studio [2].

**Fig.1. La Gioconda/Mona Lisa: The Prado (left panel) and the Louvre (right panel) version.**

## On the perspective

The high visual similarity of the Prado and the Louvre versions could additionally be confirmed by means of bi-dimensional regression analysis. Applying this method to compare the coordinates of corresponding landmarks in the two paintings (e.g., the tip of Mona Lisa's nose), Carbon showed that the landmark configurations of the face areas do match to a degree of above 99.8% [3].

Still, there is a small systematic difference: The sitter is depicted from slightly different perspectives. As we revealed recently [4], this difference does not only allow for reconstructing the positions of Leonardo and the second artist relative to each other and the sitter, respectively. It also causes grounds for the hypothesis that the two versions together represent a stereo pair as the identified horizontal disparity between the two depictions of the sitter (about 69 mm) quite well reflects the perspectival difference resulting from human interocular distance. In fact, it is statistically not different ($p$=.13, *n.s.*) from the mean interocular distance of (Italian) Caucasians being approximately 64 mm [5]. Whether this was or was not intended by Leonardo is debatable indeed. Nevertheless, the Prado version and the Louvre version, generated in Leonardo's studio about 330 years before Wheatstone invented the stereoscope [6], can be combined to an image of Mona Lisa that has obvious stereoscopic qualities.

## On the background

The background is one of the much discussed aspects of Leonardo's Mona Lisa. The issue is whether it depicts just something Leonardo had imagined or rather something real, be it a real-world landscape (e.g., the Val di Chiana [7]) or simply the motif of a plane canvas that hung in Leonardo's studio behind the sitter. (The same question can also be asked with regards to the loggia, including balustrade and the columns to the right and left of the portrayed lady.)

In order to obtain further insights concerning the background, we utilized the above mentioned logic of analysis [3, 4]: We defined so-called landmark points, that is unique pictorial properties (such as a specific tear-off edge of a mountain) to be found in the background of both versions. Fig. 2 displays the linear trajectories between corresponding landmarks in the Louvre version (start) and the Prado version. Black arrows indicate trajectories for the landscape; light blue arrows indicate trajectories for the loggia.

Mere visual inspection of the trajectories reveals already that there is a constant pattern of expansion, except for a slight deviation concerning the upper left part of the mountainside. Most importantly, the expansion is *not* stronger for parts that seem to be nearer (e.g., the loggia should be the nearest while those bizarrely shaped higher mountains in the upper part of the painting should be the farthest). Following Gibson's ecological

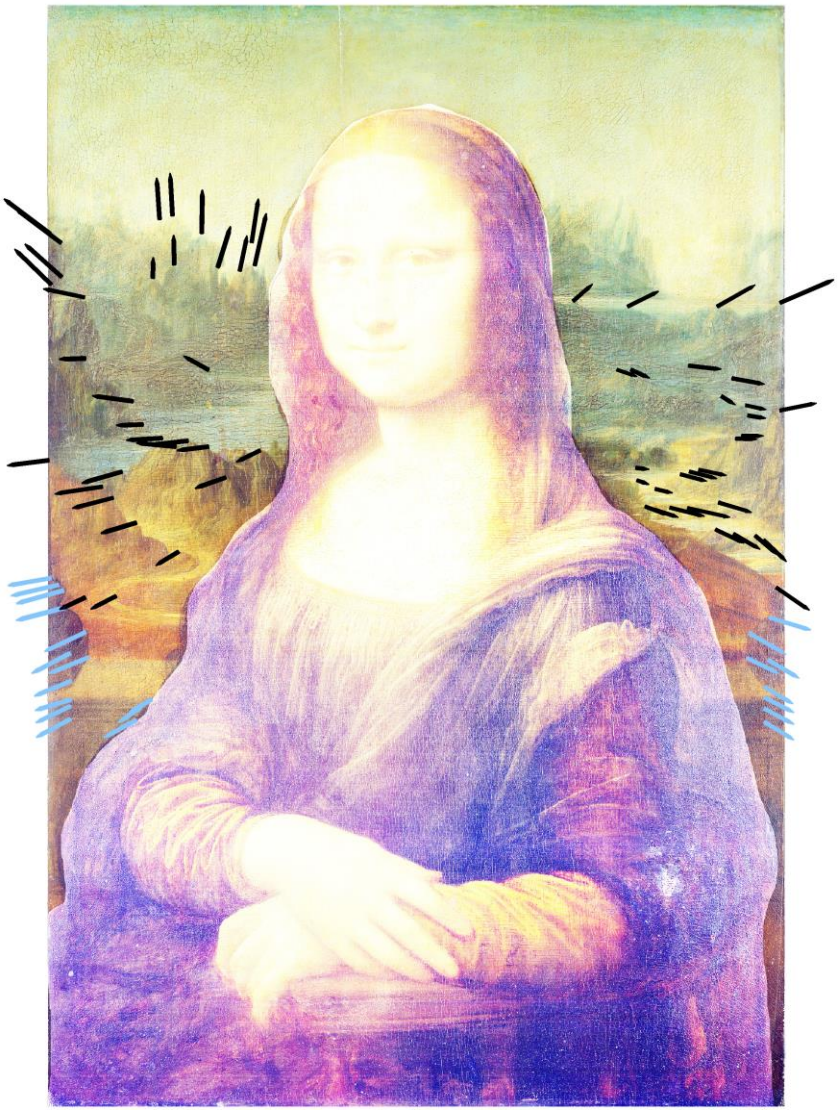

**Fig.2. The perspectival change between the backgrounds of the Louvre and the Prado versions is indicated by arrows showing the linear trajectories between corresponding landmark points, with the Louvre coordinates taken as starting points. The contrast and color spectrum have been modified in order to enhance visibility of the trajectories.**

approach to visual perception [8] such a constant pattern of expansion is incompatible with the actual depth provided by a real landscape.

Using bi-dimensional regression analysis, we revealed constant scaling factors that were around 10 % (Euclidean geometry approach; 10.4 % for the landscape and 10.2 % for the loggia; *p*s < .0001). This means that the backgrounds of the Prado and the Louvre versions are statistically not different with regards to shape, yet the background of the Prado version is zoomed in by a constant factor of 10 % as compared to the background of the Louvre version. (The zooming can be well observed in a movie to be retrieved elsewhere [4] showing the morphing transition between both versions. Interestingly, an inconsistency can be detected here as the foreground figure itself is not zoomed at all—this might reflect the process of painting the two portraits: while the same cartoon might have been used to transfer the outlines of the figures onto the panels, the outlines of the backgrounds were probably created using a different technique.)

In sum, our analysis of the trajectories revealed that Mona Lisa's background was not created after a real world landscape actually present during painting. This is indicated by the constant pattern of expansion to be found in the trajectories which does not fit the pattern that would arise from actually present depth information in a real-world setting. Most probably, the background was produced by reference to a plane landscape motif painted on canvas. Such a canvas may have hung behind the sitter in Leonardo's studio serving as scenery. Further, we showed that the background of the Prado version is zoomed in as compared to the background of the Louvre version. This means that the artist working on the Prado version must have stood closer to the motif-canvas than did Leonardo.

With the given data we can, however, not decide whether the landscape depicted on the motif canvas itself was of imaginary or real quality, but as several journeys to Northern Italy in the recent years have revealed, such landscapes do not seem to be too far away from what we can observe in parts of Tuscany or Lombardy. We will keep our eyes open to find the area finally.

## Concluding remarks

The present paper paradigmatically shows how methods from mathematics and natural sciences can enrich aesthetic and art (history) research. Integrating these multiple disciplines into a comprehensive framework provides a fascinating and promising approach for future aesthetics research. Such a joint "new science of aesthetics" will give the opportunity to recapitulate unsolved questions and opens new perspectives on issues awaiting investigation.

### References and Notes


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### Glossary

- Aesthetic Aha: The effect that patterns in which we detect objects or Gestalts are particularly aesthetically pleasing [1].
- Ecological approach (to visual perception): The psychologist J.J. Gibson [see 7] favored direct perception and direct realism instead of the information processing view of cognition.
- Stereoscopy: A technique for creating the illusion of visual depth in a plane image by means of binocular vision [see 6].
- Trajectory: A path through space [see 4].