Detecting oil paint through canvas using near-infrared reflectance and x-ray fluorescence

A copy of the renown Hungarian impressionist painter Jozsef Rippl-Ronai's Parisian Interior is shown in Figure 1. On the back of the canvas, two sets of oil paint swatches, white, blue, red and green and black, white, blue, red, and green (see Figure 2) were applied. The impasto technique utilized in the painting and the heavy foundation layer on the commercially purchased canvas on which it is painted made this painting a challenging test for detecting the test pattern painted on the back side of the canvas through the thick paint, the primed layer, and the canvas itself. The painting was tested with tree different imaging techniques: x-ray fluorescence (XRF), hyperspectral infrared, and multispectral infrared, to see if any of the squares on the back are detectable from imaging the front side. This painting was meant as an extreme test case, as in most cases, the hidden layer of paint or underdrawing is on the same side of the canvas as the outer visible image.

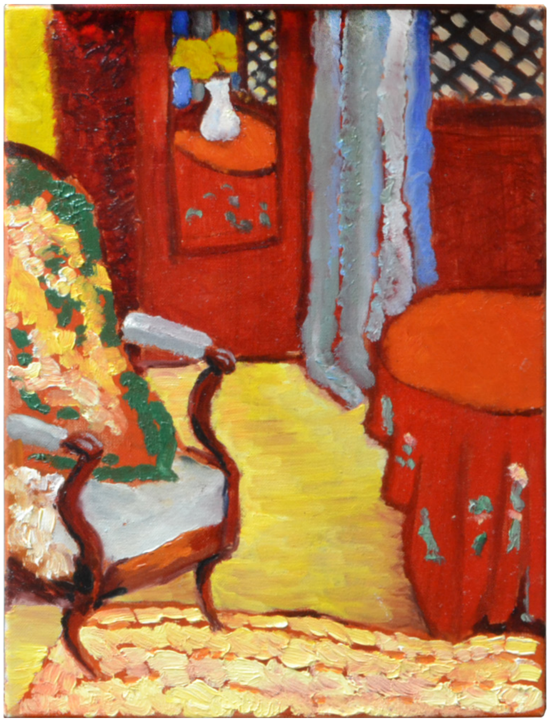

Figure 1. Jozsef Rippl-Ronai, Parisian Interior, oil on canvas, 16" x 12", copy section

Figure 2. a. Back of the canvas showing the oil paint test swatches b. Squares indicating where the paint swatches on the back of the canvas are located relative to the front of the painting

Capturing the painting with the RevealScan™-M multispectral system in the near infrared and visible range in reflection mode, the raw wavelength images did not appear to show any of the paint swatch squares through the canvas. Once the series of spectral images was processed with RevealScan™ Analysis software, however, the automatically generated principal components from Principal Component Analysis (PCA) did show a slight hint of the paint swatches for both the squares at the bottom and the ones at the top. Combining the second and third infrared component (Figure 3a), the lower white square closest to the chair becomes apparent and some of the green square right below it was visible as well. For the top portion of the painting, a similar combination of the second and third infrared component clearly shows the black swatch but none of the other colors (Figure 3b). The benefit of RevealScan™-M Analysis software is that PCA is applied separately for the visible wavelengths and the infrared wavelengths, which makes it easier to detect small differences among just the visible and just the infrared images. This separation is what enables the paint swatches to be detectable in the infrared components without being overwhelmed by visible signal.

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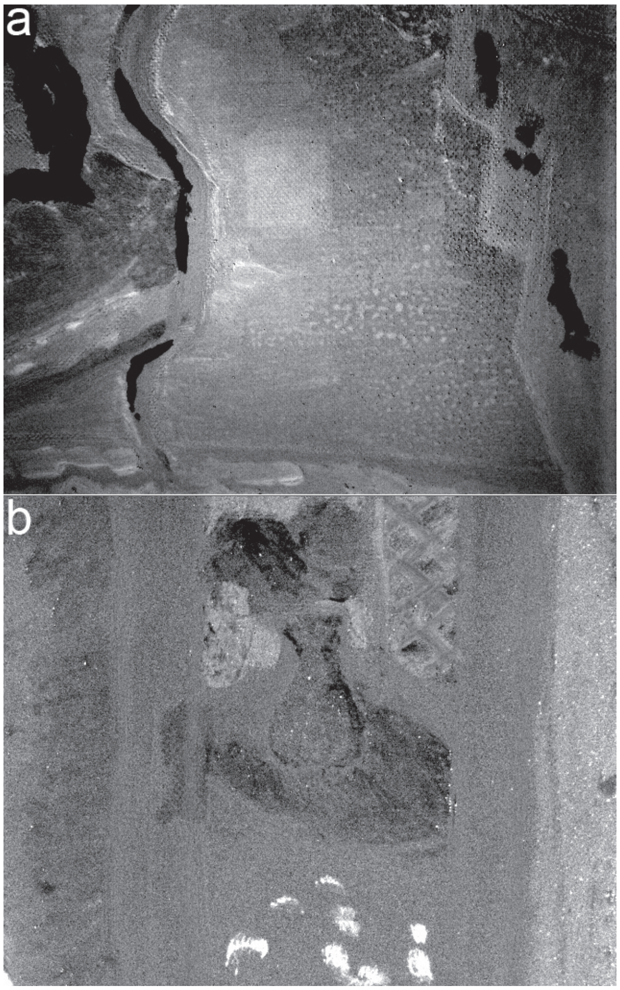

Figure 3. a.Combination of infrared principal component 2 and infrared principal component 3 showing the lower white square and part of the green square as they appear through the canvas and painting b. Combination of infrared principal component 2 and infrared principal component 3 showing the black swatch behind the upper part of the painting

For a comparison, two scans done on the same painting with a near infrared hyperspectral imaging system, a Specim Fx17 with a ViaSpec-III scanner, one on the bottom squares and one on the top squares. Unfortunately, none of the paint squares on the back were readily apparent in the mean image of all wavelengths or in any wavelength images created by averaging the bands every 50 nm.

Using KemoQuant™ Analysis software to run PCA on the data cube of the bottom squares, the white square appears in the 28th factor, see Figure 4a-b. In contrast to the multispectral images, the black and white squares from the top set are visible in the 7th factor from the scan of the top of the painting (Figure 4c). In hyperspectral imaging, typically only the first 5-10 factors are usable and the subsequent ones are mostly just noise. In this case, it was known that there were paint swatches on the back of the canvas, so many more factors were calculated and visualized. Both the Fx17 and the RevealScan™-M system are capable of detecting the lower white square by the chair and the black rectangle by the vase, with the hyperspectral being slightly more sensitive to detect the white swatch by the vase as well.

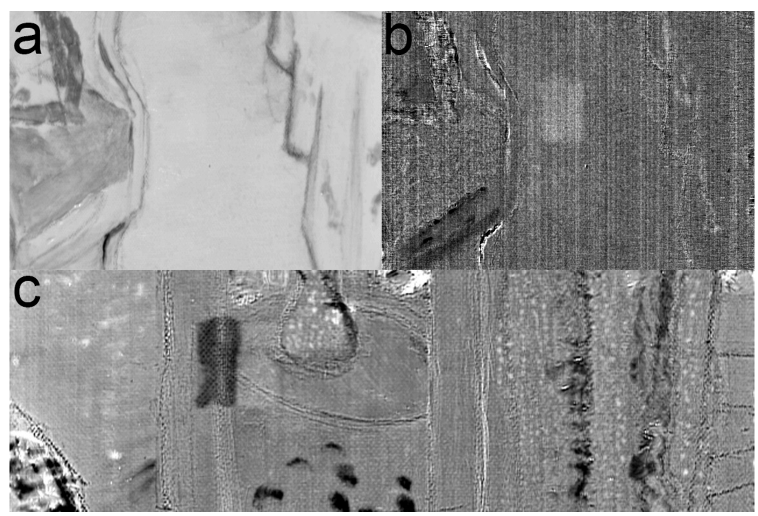

Figure 4. Selected components from PCA on the hyperspectral scans of the painting. a. Factor 1 from the scan of the bottom squares b. Factor 28 from the scan of the bottom squares showing the white swatch close to the armchair. No factors up until factor 28 show the white square. c. Factor 7 from the scan of the top squares showing the black and white swatches. Hyperspectral imaging collects huge amounts of data, several hundred spectral channels, but due to nonlinearities many factors do not contain that many independent specifically identifiable information. The number of usable factors is generally limited by the available signal-to-noise and factors beyond a certain threshold only contain various noise factors.

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A Bruker M6 Jetstream, a high-resolution X-ray fluorescence imager, was also used to scan the entire painting point by point and analyze the elemental composition and to see if any of the test paint squares were detectable. Analyzing the elemental maps of the painting, the image was almost entirely dominated by the visible outer painting for a given element, see the zinc map shown in Figure 5a for example. The notable exception is the cobalt elemental map where there are two distinct squares with a high amount of cobalt and none anywhere else in the painting, see Figure 5b. These two squares corresponded with the location of the two blue swatches on the back of the canvas, indicating that the blue pigment on the back is likely cobalt blue that was apparently not used elsewhere in this painting.

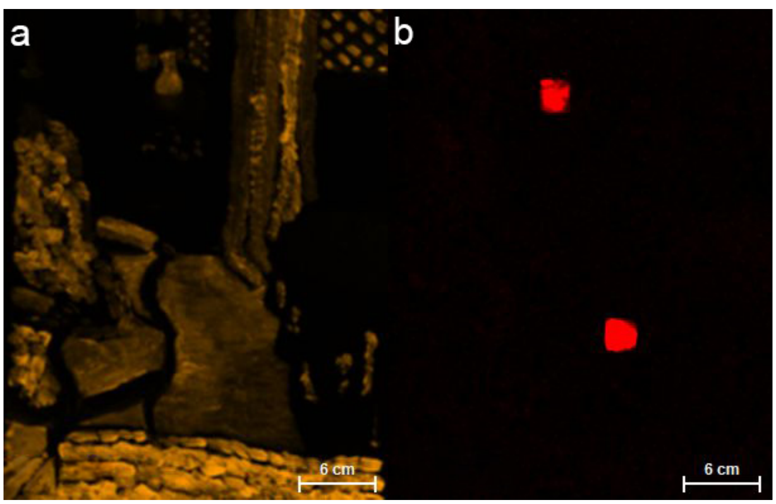

Figure 5. XRF Cobalt concentration maps of a. zinc and b. cobalt. Zinc white was used as a color dilutant and distributed widely in the painting whereas cobalt only appeared in the location of the blue swatches.

This example shows the strengths and weaknesses as well as the complementary nature of IR imaging and x-ray fluorescence (XRF). XRF can detect elemental composition whereas the infrared detects material differences. Certain pigments like the cobalt blue square stand out dramatically in XRF but were not detectable in either multispectral or hyperspectral imaging. The cobalt stands out because none of the pigments in the surface painting contained cobalt, so the only cobalt signal came from the back blue squares. In contrast, after some data processing, the white squares were visible with IR. This is likely because the white square reflects more of the light back compared to the other colors and thus white shows up as a faint detectable feature in IR. The white likely doesn't show up in XRF because XRF averages the signal over a large volume, and the small increase in zinc signal from the paint on the back doesn't appear as a substantial increase in zinc signal compared to the signal coming from the white vase or the yellow floor. In terms of comparing penetration depths, the x-ray excitation clearly crosses the thick paint, the primer layer, and the canvas. The backscattered fluorescence however sometimes is absorbed by the same layers and are consequently not detectable. In this case, spectral infrared and a-ray flourescence, the two common non-destructive test techniques, were clearly complementary to detect the paint pattern applied to the verso side.