An Evaluation of Color Change in Nineteenth-Century Grounds on Canvas upon Varnishing and Varnish Removal

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ABSTRACT. Color changes in prepared samples of grounds based on those used by Vincent van Gogh were measured before and after varnishing with dammar and artificial aging. Sections of the samples were lined using wax-resin. Varnish was removed using solvents, and practical observations were made about the influence of the ground composition and lining on the reversibility of varnish. Quantitative measurements of color change and qualitative observations made during varnish removal showed that wax-resin lining facilitated varnish removal, whereas varnishing of absorbent grounds was irreversible. Consultations with conservators and treatment reports of paintings cleaned at the Van Gogh Museum, Amsterdam, provided some theoretical context and practical guidelines for the removal of nonoriginal varnishes from Impressionist paintings.

INTRODUCTION

The application of varnish can significantly alter the appearance of paintings. By the mid-1880s many avant-garde French painters chose not to varnish (Swicklik, 1993; Schaefer, 2009; Callen, 2000). Later, Neo-Impressionists and twentieth-century artists relinquished varnishing in favor of a matte aesthetic (Miller, 1983; Jirat-Wasiutynski and Travers Newton, 1998). Following his arrival in Paris in 1886, Vincent van Gogh was influenced by the works of Camille Pissarro, Paul Gauguin, and Emile Bernard, whose preferences for unvarnished surfaces are well known (Hendriks, 2008). For example, notes declaring that the painting was not to be varnished can be found on the reverse of paintings by the Pissarros (Callen, 1994; Schaefer, 2009), and it has been inferred that van Gogh chose to leave many of his paintings unvarnished (Hendriks and van Tilborgh, 2006; Peres, 1990; Schaefer, 2009). Once out of the artists’ hands, many paintings were varnished in keeping with academic norms or contemporary taste, rendering them more sellable (Callen, 1994). Most Impressionist and Post-Impressionist paintings have been subsequently varnished, and some have been lined by dealers, collectors, and conservators for protection from dirt and pollutants or in keeping with a preference for the saturated surface (Bruce-Gardner et al., 1987).

The present study focuses on the use of dammar, a natural resin varnish that was used by the conservator J. C. Traas to varnish paintings at the Van Gogh Museum, Amsterdam, in the 1920s and 1930s and was used by dealers and colormen for varnishing paintings in the nineteenth and twentieth centuries. The aims of this study were to provide data on color change in Impressionist grounds on varnishing and subsequent removal of the varnish and to explore, by consultation with experienced conservators of Impressionist paintings.
paintings, some of the practical problems of removing varnish, with the ultimate goal of displaying the works in their original unvarnished condition.

**EXPERIMENTAL SAMPLES**

The 42 experimental ground samples used in this study were one of three sets prepared as part of the Historically Accurate Reconstruction (HART) project in 2005 and have been stored since their completion at the Rijksdienst voor Cultureel Erfgoed in Amsterdam. The preparation of the samples was based on the results of analyses of the grounds used for paintings by Vincent van Gogh and contemporary historical recipes (Hendriks and Geldof, 2007; Van Bommel et al., 2005). They included a range of canvas and hemp fiber supports, different methods of applying the size layer, and combinations of binding media and inorganic materials. The composition of the samples used in this study is given in Table 1. For a detailed description of the procedures and materials used to make the samples, see Carlyle (2005:85).

In a previous study (Nieder et al., 2011) each sample was wax-resin lined and varnished with dammar in quadrants, illustrated by the example shown in Figure 1. This set of samples was reexamined in the present study following a subsequent campaign of light aging.

**LIGHT AGING**

Light aging of the lined and dammar varnished samples was undertaken at the Stichting Restauratie Atelier Limburg, Maastricht, Netherlands, using 36W Philips color 96.5 fluorescent lamps with UV filtering (transmission 15 W/lm) and an average temperature of 25°C and 60% RH. Samples were exposed for 2250.5 hours at 10,000 lux illumination, corresponding to 38.5 years equivalent museum light exposure assuming reciprocity (based on 200 lux illumination for 8 hours per day). Together with the initial aging of the samples by Nieder (2008), the samples received the equivalent of 62.5 years of museum light exposure.

**COLOR MEASUREMENT**

Color measurement was carried out using a Minolta Spectrophotometer CM 2600-d with a D 6500 (standard daylight) illuminant and was set to the medium aperture with the standard observation of 10°. A white standard number 7004487 was used for calibration. A template was used that facilitated repeated measurement of the same site on each sample that had been measured in the previous study (Nieder et al., 2011). The spectrophotometer was set to specular reflectance exclusion (SCE_0). The average of three measurements from each site was used to calculate \( L^*a^*b^* \) values. Reflectance measurements were taken at 10 nm intervals from 400 to 700 nm. The Commission International de l’Eclairage CIE2000 \( L^*a^*b^* \) values were recorded, and the color difference \( (\Delta E) \) was calculated: \( \Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \).

**PHOTOGRAPHY AND MICROSCOPY**

Samples were photographed using a Canon SD600 SLR digital camera. Each sample was photographed before and after varnish removal in the same lighting conditions for each sample in the study using daylight and ultraviolet lamps. Samples were examined using a binocular light microscope (LM) equipped with tungsten and UV illumination at 40x to 800x magnification. Observations were recorded and compared with qualitative observations made by Nieder et al. (2011), Carlyle (2006), and Carlyle et al. (2008) of the same samples.

**VARNISH SOLUBILITY**

The solubility of the dammar varnish in mixtures of isooctane, propan-2-ol, and ethanol were determined. The varnish was removed from three specific locations using cotton swabs in the areas where the comparative color measurements were made, noting the solvent mixture used and the number of rolls needed to complete the varnish removal for each quadrant. Removal of varnish was intended to return the appearance of the surface of the sample as closely as possible to the untreated quadrant (in the case of the varnished quadrants) or the lined quadrant (in the case of the lined and varnished quadrants). The success of removal was determined by examining the test areas in ordinary, UV, and raking light and using LM. This strategy was chosen to replicate as closely as possible the methods used by conservators.

**RESULTS AND DISCUSSION**

**Effects of Varnishing**

Varnishing produced significant visual darkening in some samples. Selected samples with a measured visible difference of \( \Delta E \) between varnished and unvarnished quadrants are shown in Figure 2. Darkening after varnishing was greatest in samples in glue medium, followed by emulsion; the least changed were the samples bound in oil. The change in \( \Delta E \) after varnishing of the unlined glue-bound samples ranged from 4.82 to 19.02, whereas the lined samples in the same medium changed less, with \( \Delta E \) ranging from 0.36 to 7.45. The glue-bound samples containing chalk absorbed the varnish and the surface remained matte. The varnished surface of the chalk in glue on jute samples had a superficial plastic appearance. The emulsion-bound samples were less darkened on varnishing (\( \Delta E \) of 2.44–4.05 for unlined and 1.12–2.65 for lined samples), and the smallest color change was measured in oil-bound samples (0.32–2.48 for unlined and 0.75–1.74 for lined samples).
<table>
<thead>
<tr>
<th>Binding Media</th>
<th>Sample Composition (size application, binding media, inorganic material, support)</th>
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| Hide glue binder | gelled glue size; chalk in hide glue binder on fine-weave linen  
fluid glue size; chalk in hide glue binder on fine-weave linen  
no size, chalk in hide glue binder on fine-weave linen  
gelled glue size; chalk in hide glue binder on open-weave linen  
no size, chalk in hide glue binder on jute canvas  
gelled glue size; chalk and bone black in hide glue binder on fine-weave linen  
fluid glue size; chalk and bone black in hide glue binder on fine-weave linen  
no glue size; chalk and bone black in hide glue binder on fine-weave linen  
gelled glue size; barium sulfate in hide glue binder on jute canvas  
no size; barium sulfate in hide glue binder on jute canvas |
| Emulsion | gelled glue size; chalk in glue-oil emulsion binder on fine-weave linen  
fluid glue size; chalk in glue-oil emulsion binder on fine-weave linen  
no size; chalk in glue-oil emulsion binder on fine-weave linen  
gelled glue size; chalk in glue-oil emulsion binder on open-weave linen  
no size; chalk in glue-oil emulsion binder on open-weave linen  
gelled glue size; barium sulfate in glue-oil emulsion binder on jute canvas  
no size; barium sulfate in glue-oil emulsion binder on jute canvas |
| Oil | gelled glue size; chalk in oil binder on fine-weave linen  
fluid glue size; chalk in oil binder on fine-weave linen  
no size; chalk in oil binder on fine-weave linen  
gelled glue size, double ground on open-weave linen; first ground: chalk in hide glue binder; second ground: lead white in oil binder  
gelled glue size, double ground on open-weave linen; first ground: chalk in glue-oil emulsion binder; second ground: lead white in oil binder  
gelled glue size, double ground on open-weave linen; first ground: chalk and lead white in oil binder; second ground: lead white and Barium sulfate in oil binder  
gelled glue size, double ground on open-weave linen; first ground: chalk in oil binder; second ground: lead white and Barium sulfate in oil binder |
| | gelled glue size, double ground on open-weave linen; first ground: chalk in oil binder; second ground: lead white and Barium sulfate in oil binder  
gelled glue size; chalk and lead white in oil binder on fine-weave linen  
fluid glue size; chalk and lead white in oil binder on fine-weave linen  
gelled glue size; lead white in oil binder on fine-weave linen  
no size; lead white in oil binder on fine-weave linen  
gelled glue size, triple ground on open-weave linen; first ground (applied twice): chalk and lead white in oil binder; second ground: lead white and chalk in oil binder  
gelled glue size, double ground on open-weave linen; first ground: chalk and lead white in oil binder; second ground: lead white and chalk in oil binder  
gelled glue size, double ground on open-weave linen; first ground: chalk and lead white in oil binder; second ground: lead white and chalk in oil binder  
gelled glue size; barium sulfate in oil binder on jute canvas  
no size; barium sulfate in oil binder on jute canvas  
gelled glue size; lead white and barium sulfate in oil binder on open-weave linen  
fluid glue size; lead white and barium sulfate in oil binder on open-weave linen  
no size; lead white and Barium sulfate in oil binder on open-weave linen |
The size layer affected the measured and observed darkening imparted by varnishing, and this was most pronounced in samples with chalk in glue binder. Grounds prepared with a cold size layer reduced absorption of the varnish into the canvas and concomitant darkening. Fluid sizing of the canvas provided some barrier to varnish absorption and darkening, whereas the unsized grounds darkened the most. A similar, though less pronounced, trend was observed and measured in samples in emulsion media. Samples containing bone black with chalk in a glue medium darkened more on varnishing than all the other samples in any medium, suggesting pigmented grounds such as those used by the Impressionists may be particularly vulnerable to darkening.

**COLOR CHANGE ON VARNISH REMOVAL**

\( \Delta E \) and the percentage color change in samples after varnish removal from lined and unlined quadrants are illustrated in Figures 3 and 4. The measurable “recovery” of the unvarnished surface after varnish removal was measured by calculating the percentage change:

\[
\frac{[\Delta E_u - \nu_a] - [\Delta E_v - \nu]}{[\Delta E_u - \nu]} \times 100
\]

where \( u \) is the untreated quadrant, \( v \) is the varnished quadrant, and \( a \) is the area after varnish removal.

The larger the percentage change is, the more “successful” the varnish removal was in recovering the original surface. A larger percentage also reflects a significant difference in color between untreated and varnished grounds. Oil-bound samples changed the least on varnishing and lining, and thus, the small

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**FIGURE 1.** Template for sample treated and untreated quadrants. This example is composed of unsized fine-weave linen, with a single priming of chalk in hide glue.

**FIGURE 2.** Selected \( \Delta E \) values of samples after varnishing and varnish removal.
percentage changes represent a reversal of this shift. Although removing varnish from the lined samples was practically more straightforward, the darkening imparted by lining was greater than the recovery of the surface after varnish removal.

Glue-bound samples showed the greatest changes (on varnishing and after varnish removal). The ΔE values after varnish removal for all the other samples (with the exception of the lined samples in emulsion medium) were below 1ΔE and thus were not detectable by the eye. However, there were significant changes in these samples that are reflected in the calculated percentage change. The most successful varnish removal in terms of visible change was from glue-bound samples. The recovery of the surface was greatest in the lined samples, reflected in the percentage change. This follows practical observations that lining facilitated the removal of varnish in these samples, whereas it was more difficult to remove the varnish from the more absorbent unlined samples in glue medium. The greatest changes were measured between the untreated quadrants and the lined and varnished quadrants of the glue-bound samples. The average ΔE value of the untreated quadrant versus the lined and varnished quadrant was 14.11, reflecting the color change due to both lining and varnishing. The average ΔE value of the same quadrants following varnish removal was 10.06, demonstrating a visually significant reduction in darkening. Incomplete recovery of the unlined quadrant on varnish removal was evident from the comparison between the untreated quadrant and the varnished quadrant following varnish removal. Thus, it was not possible to recover the appearance of the unvarnished surface of the most absorbent samples, and varnishing of these samples was not reversible.

**MONITORING VARNISH REMOVAL**

The extent of varnish removal from oil-bound samples was most effectively monitored by change in gloss that was visible in LM and ordinary light. In UV light, samples bound in oil and emulsion media that did not contain lead white exhibited a characteristic yellow green fluorescence in the unvarnished quadrants. This cast was slightly reduced on varnishing, and when the varnish was removed using polar solvents, the fluorescent material was disturbed, and the cleaned areas appeared purple. This suggests that the solvent affected a skin of fluorescent surface material on these samples. This hypothesis was supported by the results of testing a different solvent mixture for varnish removal that did not affect the superficial fluorescent layer.

**INFLUENCE OF BINDING MEDIUM ON VARNISH REMOVAL**

The glue-bound samples required the most polar solvents and most repeated swab rolling to satisfactorily remove the varnish. Isopropanol and mixtures of iso-octane:isopropanol (3:1 or 2:1) were required, with an average of 25 swab rolls. The unlined quadrant required the same or a more polar solvent to remove the varnish compared with the lined quadrant of the same sample. In general, ΔE values decreased after varnish removal, whereas unsized samples bound in glue containing chalk, bone black, and barium sulfate measured an increase in ΔE between the lined and the lined plus varnished quadrants. This change reflects the combined effects of impregnation of the samples, the abrasion of the most raised areas of ground on peaks in the canvas weave, and varnish removal.

Removal of varnish from samples in emulsion medium required a lower-polarity solvent mixture and less mechanical action than samples in glue medium. Mixtures of iso-octane:isopropanol (4:1 and 3:1) required 20 swab rolls, and the coarse texture of the samples on jute required 40 swab rolls to remove the varnish. Varnish removal from the unlined quadrants required the same or slightly more polar solvent mixtures than the lined quadrants of the same sample. Samples containing lead white in oil were...
glossy and relatively nonabsorbent and required an average of 25 rolls using a 3:1 mixture of iso-octane/isopropanol to remove the varnish from both the lined and unlined quadrants. Practically, varnish removal was most straightforward when it contained lead white as the surface was unaffected even using a solvent mixture of higher polarity. Notably, varnish from samples with multiple ground layers containing chalk and lead white mixtures was readily removable using a 4:1 mixture and 10 rolls, illustrating the influence of the underlying layers as well as the surface on varnish absorption and removal.

**Influence of the Size Layer on Varnish Removability**

The size layer acted as a physical barrier, preventing varnish and/or the lining adhesive penetrating the support. The gelled size was the most effective barrier, followed by fluid size, whereas varnish, adhesive, and solvents penetrated the sample most when no size was present. In removing varnish from unlined quadrants, particularly from samples bound in glue, the solvent was difficult to contain, and spreading beyond the swabbed area was visible on the reverse. This was less pronounced in samples where the canvas had a gelled size application. Varnish penetrated the structure of the unsized samples and was concomitantly more difficult to remove.

**Influence of Lining on Varnish Removal**

Lining adhesive provided a barrier to absorption of varnish and acted in a way similar to a gel sizing of the canvas. Varnish was easier to remove from lined samples than from the unlined quadrants because of reduced penetration of the coating. During varnish removal from wax-resin lined samples, the nonpolar component of the solvent mixture reduced the wax present on the weave tops, notably lessening the darkening effects of the lining. The influence of lining on varnish removal was most pronounced on unsized samples in glue medium. Samples in emulsion media showed a similar, though less pronounced, effect, and oil-bound samples were not affected.

**Influence of the Ground’s Inorganic Component on Varnish Removal**

Barium sulfate in glue (and to some extent in the emulsion) media was relatively porous and absorbent, and thus, varnish removal from samples with barium sulfate in glue was more difficult. There was no significant change in color in samples containing lead white on varnishing and after varnish removal, whereas the samples containing bone black in glue medium changed the most. The reversibility of varnishing of colored grounds and paint grounds requires further study.

**Influence of the Canvas Support on Varnish Removal**

The rough topography of jute canvases precluded complete removal of varnish from unlined samples in all media. Otherwise, there were no significant differences between the supports with regard to varnish removal.

**Practical and Aesthetic Issues for Varnish Removal from Paintings**

The removal of a varnish coating from paintings of the late nineteenth and twentieth centuries that were intended to be unvarnished with view to their display might be considered part of the conservation plan for these works. The question of whether it is possible to recover the original surface of an unvarnished painting or, failing that, how to evaluate a reinterpretation of the surface requires further investigation. The present study has provided some guidelines for some of the parameters that might be considered in evaluating the success of removing a natural resin varnish from a range of ground samples similar to those used for nineteenth-century paintings and the influence of wax-resin lining on the process and results of removal. Although this study has highlighted some of the issues, the practical problems of removing varnish from paint are more complex, where selective sensitivity to solvents and cleaning reagents and mechanical methods for varnish removal are points to be taken into account. For example, conservators of paintings by Van Gogh have reported sensitivity of dark blue and green paints, medium-rich paints, and paint containing chrome and cadmium yellow pigments in his works to a range of organic solvents used for varnish removal (Van Gogh Museum, Amsterdam, unpublished treatment reports for F293; van Bommel, 2005). In addition, the physical deterioration of some red-lake-containing paints, manifest in cracking, powdering, and flaking paint, can limit complete varnish removal (Van Gogh Museum, Amsterdam, unpublished treatment report for F370). Removing varnish evenly remains a challenge, and the selection of solvent or reagent for cleaning may influence the surface quality of the underlying paint or ground (L. Mayer, Mayer & Myers Conservation, New London, Connecticut, personal communication). The pronounced texture of some Impressionist paintings requires the use of a range of cleaning tools and methods tailored for the purpose (Van Gogh Museum, Amsterdam, unpublished treatment reports; E. Hendriks and D. Ormond, Van Gogh Museum, Amsterdam, personal communication; L. van der Loeff, Kroller-Muller Museum, Otterlo, Netherlands, personal communication; I. Duvernois, Metropolitan Museum of Art, New York, personal communication).

The treatment history of an individual painting influences its current appearance and subsequent treatment. The obtained results show that wax-resin lining adhesive may reduce the porosity of some paint films, preventing the varnish from penetrating and thus facilitating its removal, supporting observations made by conservators (Duvernois, pers. comm.; E. Steele, Philips Collection, Washington, D.C., personal communication; L. Hoogstrader, ICN, Rijswijk, Netherlands, personal communication). Residues from former treatments, including adhesives, consolidants, discolored retouchings, and, potentially, the nonvolatile components of cleaning reagents, further complicate treatment.
Paintings that have undergone multiple cleaning campaigns may be difficult to interpret visually as areas may be changed because of lining, paint-solvent interaction, and retouching (A. Hoenigswald, National Gallery of Art, Washington D.C., personal communication). Assessment of the surface during treatment may be informed by unvarnished examples of works by the artist; however, these paintings may have changed on aging, and the task remains interpretive. For example, Van Gogh’s *Garden of the Asylum* 1889 (Figure 5) has survived unlined and unvarnished.

Technical study of the painting has characterized but not quantified material changes in the paint, and thus, the use of this work as a benchmark for the appearance of the original surface is compromised. Few artists provide written accounts of their intention for the surfaces of their works, and these also require interpretation. The expertise of visually informed conservators and evidence from technical studies provide guiding principles that lead to a practical resolution that a painting looks “right” (Hendriks, pers. comm.). In some cases the relationship between compositional elements may be difficult to read once the varnish is removed, and this has been noted in paintings that have undergone several cleaning or lining treatments (Hoenigswald, pers. comm.). To regain the spatial sense of the composition after varnish removal, selective or complete revarnishing may be undertaken. For example, after varnish removal, dark passages of paint become unsaturated and require an application of a thinly applied local varnish (such as Regalrez) by brushing, spraying,

**FIGURE 5. Garden of the Asylum** Vincent van Gogh, 1889. Oil on canvas, 72 cm × 91 cm. (Van Gogh Museum, Amsterdam; Vincent van Gogh Foundation)
CONCLUSIONS

The removal of nonoriginal varnish from paintings by Van Gogh and contemporaries who valued the matte aesthetic may be desirable as part of a conservation campaign. The results of the present study highlight the changes in the grounds due to varnish and some of the practical difficulties in recovering the original appearance of the surface after varnish removal. The implications of these findings for the appearance of the recovered unvarnished painted surface present a significant challenge for the conservator. It is clear, from both conservators’ accounts and the results of the present study, that both the material composition of the work and former treatments (such as wax-resin lining) may influence the surface appearance and affect the ease of varnish removal. This study investigated the color changes imparted by varnishing and subsequent removal of varnish from prepared samples based on grounds used by Van Gogh. The results will also be relevant to the study of paintings by his contemporaries who used similar commercially prepared canvases. The problems with removing varnish from passages of paint of different composition and texture that have been noted by conservators were clearly critical, particularly where works are to be displayed unvarnished.

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