The consequences of wax-resin linings for the present appearance and conservation of seventeenth century Netherlandish paintings on canvas

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CONCLUSION

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The purpose of this thesis was to examine the influence of material composition on the colour change of ground layers of seventeenth century Netherlandish paintings after wax-resin lining. The study included an assessment of the present condition of wax-resin lined paintings and compared samples from selected works with samples of ground reconstructions whose material composition were based on evidence found in seventeenth century Netherlandish paintings. The conclusions, based on the research carried out, are summarised here alongside a discussion of the implications for the conservation of paintings from this period. The chapter also provides a critical evaluation of the experimental methods and criteria for interpretation used, as well as identifying areas for future research.

1. Colour change of ground reconstructions after wax-resin impregnation: causes and behavioural trends

1.1 Main trends

Results from the experiments carried out showed that wax-resin impregnation caused colour change in several of the grounds reconstructions. Comparative colour measurements showed that, in most of the cases, the L*, a* and b* values of the grounds decreased after wax-resin impregnation, indicating that the colour of grounds became darker and cooler in hue.
Study of the results of colour measurements showed that the extent of change was influenced by the binding medium and inorganic components as well as the proportion of the latter, thus supporting the initial hypothesis that ground composition is likely a crucial factor for changes that paintings undergo after wax-resin treatment.
In addition to this, the degree to which the ground layers obliterate the darkened underlying canvas support was also considered a key parameter in the colour change of ground layers. This hypothesis had already been formulated during the study of Van Gogh's grounds that suggested that the visibility of the underlying canvas may contribute to the colour change measured after wax-resin impregnation. In order to clarify this assumption, the present study examined the hiding power of the grounds by carrying out colour measurement on ground samples applied in varying thicknesses on opacity charts. The results of the hiding power study showed that all grounds types that underwent colour change after impregnation had poor (or worse) hiding power, supporting the hypothesis this is a cause of colour change. The change in hue of the reconstructions toward cooler tones also supports this as it might be due to a turbid medium

effect that is typically perceived when a light toned thin paint layer covers a darker and warmer layer underneath.[1]

1.2 Influence of the kind of binding medium in the ground

Experiments that investigated the influence of binding medium on the colour change of ground reconstructions showed that the glue-bound grounds changed colour more significantly than oil-bound grounds. This result corroborates historical observations by conservators who reported that the wax-resin impregnation of paintings with absorbent water-based grounds resulted in darkening and increased transparency. The results also confirmed trends already identified in studies of the grounds used for paintings by Vincent van Gogh, composed of chalk in animal glue, linseed oil and emulsions.[2] The present research showed that the vulnerability of glue-bound preparation layers to colour change occurs in grounds that contain a broad range of pigments including yellow and red iron oxide, as well as raw umber, tile red and charcoal black.

Study of the hiding power of the grounds was also able to explain differences in magnitude of the colour change depending on whether the ground is bound in animal glue or linseed oil. Observations during the impregnation process revealed that the wax-resin adhesive passed through the reconstructions with animal glue-bound grounds, while it did not for the oil-bound grounds. It was therefore assumed that the increased absorbency of glue-bound grounds compared with oil grounds caused this difference in colour change.

Animal glue-bound grounds are inherently porous (i.e. with a high pigment volume concentration) due to their drying process that involves the evaporation of the water, which leaves voids in the dried material.[3] This physical characteristic allows the wax-resin adhesive to penetrate into the ground layer, a phenomenon proven during practical experiments by the staining of the paper tissue placed in contact with the surface of the glue containing aqueous grounds. The presence of wax-resin in areas previously occupied by air causes the relative difference in refractive index between the pigments and the surrounding to decrease.[4] This reduces the hiding power of the ground, facilitating light transmission to under-layers such as the darkened canvas. The filling in of the voids also resulted in a smoother surface texture contributing to the darkening of the colour.[5]

Since the wax-resin adhesive did not pass through the oil-bound grounds, it was assumed that these ground layers did not undergo a change in refractive index and therefore the colour change measured after wax-resin treatment was caused principally by the degree to which the ground layers obliterate the underlying canvas support. This assumption was supported by the hiding

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[1] David Bomford, "Rembrandt's Materials and Technique," in David Bomford, Jo Kirby, Ashok Roy, Axel Rüger, Raymond White, *Art in the Making, Rembrandt* (National Gallery Company: London, 2006), 33.

[2] Emily Nieder Ella Hendriks and Aviva Burnstock, "Colour Change in Sample Reconstructions of Vincent van Gogh's Grounds Due to Wax-Resin Lining," *Studies in Conservation* 56 (2011): 97 and 99.

[3] The porosity of water-based grounds is well visible on X-ray tomography images, Claire Gervais, Jaap J. Boon and Federica Marone, "Characterization of Porosity in a 19th Century Painting Ground by Synchrotron Radiation X-ray Tomography," *Applied Physics A* 111 (2013): 33-38.

[4] Refractive index of the air = ca. 1, beeswax = 1.5, glue = 1.516-534, colophony = 1.525-548, linseed oil = 1.5. http://cameo.mfa.org.

[5] Feller and Kuntz in 1981: R. L Feller and N. Kunz, "The Effect of Pigment Volume Concentration Paint on the Lightness and Darkness of Porous Paints" in *AIC preprints* (Washington, D.C: American Institute for the Conservation of Historic and Artistic Works, 1981), 66–74.

power study that showed that each of the oil-bound grounds that changed colour after wax-resin treatment were at least poorly hiding.
The change in refractive index and surface texture of the porous grounds after wax-resin impregnation were assumed to alter considerably the visual properties of these layers, thus exacerbating the colour change measured in the animal glue-bound grounds compared with oil-bound grounds into which the wax-resin did not penetrate.

1.3 Influence of the grounds inorganic composition and pigment proportion

Comparative colour measurements of the reconstructions showed that the degree of colour change varied depending on the type of pigments and on the proportion of different inorganic materials. Occasionally, the type of pigment also influenced the change in hue.
Of the ground reconstructions bound in animal glue, the one composed of chalk changed the most after wax-resin impregnation. This reconstruction is the only case where the change in hue resulted in a more yellow and more red colour, as all other reconstructions changed toward cooler tones. Of the ground reconstructions bound in linseed oil, those composed of either chalk or ball clay measured the most significant alteration after lining, followed by lead white and Mass river clay containing grounds that changed only slightly, while the grounds composed of either red iron oxide, yellow iron oxide, raw umber or charcoal black did not undergo a change.
The research also found that the ratio of chalk to either yellow iron oxide, raw umber, lead white or yellow iron oxide and raw umber used in combination, was a significant factor in the colour change of oil-bound ground layers. Colour measurements showed that, in general, the higher the concentration of chalk, the more significant the colour change. Importantly, comparative colour measurements suggested that the impact of the inclusion of chalk on the degree of colour change was dependent on the pigment that it was mixed with. For example, the colour of the grounds composed of chalk and lead white was significantly altered after wax-resin impregnation, while the colour of those composed of chalk and yellow iron oxide or chalk, yellow oxide and raw umber changed only very slightly. No colour change was measured in ground reconstructions composed of chalk and raw umber. The hiding power study supported these results as it showed that the proportion of chalk was an influential factor on the hiding power of oil-bound grounds composed of chalk with either lead white, yellow iron oxide, or combination of yellow iron oxide and raw umber in equal ratios. Trends indicated that the higher the proportion of chalk the more poorly the ground hid the substrate it was applied on.
The minimum proportion of chalk at which colour change was measured varied depending on the other components in the ground. For example, for reconstructions composed of chalk and lead white, colour change was perceptible in reconstructions composed of more than 50% chalk, while the effect of wax-resin impregnation in ground reconstructions composed of chalk and yellow iron oxide was recorded only when the chalk content was 90%. Grounds composed of mixtures of yellow iron oxide and raw umber in equal ratios combined with chalk did show a slight colour change, but only when the chalk comprised 98% of the mixture. Comparative colour measurements also showed that the inclusion of 10% raw umber to the ground composed of lead white and chalk completely prevented colour change, as no colour difference was measured when the proportions of chalk in the ground were 50 and 70%.

In 1977, Percival-Prescott had already suggested that chalk containing oil-bound grounds were vulnerable to colour change after wax-resin impregnation.[6] More than thirty years later, the Vincent van Gogh's ground research project provided evidence to support this hypothesis. Colour measurements carried out as part of the study found that chalk containing oil-bound ground reconstructions were the most prone to colour change after wax-resin impregnation, while grounds composed of lead white were less affected. The effect of chalk in lead white containing ground reconstructions resulted in different behavioural trends depending on the application technique of the size layer. When considering reconstructions prepared using gelled size, comparative colour measurements from Van Gogh's grounds reconstructions recorded inconsistent results compared to the those gathered in the present study where there was a smaller colour difference in the ground composed of chalk and lead white than in the ground composed of lead white only.[7] In Nieder's study, measurements on reconstructions with other types of size, however, recorded a greater magnitude of colour change when the ground was composed of lead white with chalk, a result that is in line with the results of the present study.
In this study, each quartz containing oil-bound ground showed substantial colour change including darkening as well as a decrease of yellowness and redness following wax-resin impregnation. The colour change in grounds of this type was amongst the most significant of all oil-bound grounds tested. Trends indicated that the higher the concentration of quartz the greater the colour change of the ground after impregnation. Although the inclusion of 3% yellow iron oxide tended to reduce this effect, the colour change of the grounds remained significant. The concentration of quartz in ball clay and quartz containing grounds was proven to be influential on the hiding power, since colour measurements indicated that the higher the concentration of quartz, the poorer the hiding power. These results supported the influence of hiding power on the colour change of the reconstructions on canvas support.
It is worth noting that some ground types that were assessed as having poor hiding power did not undergo colour change. This was particularly seen in the ground composed of raw umber and chalk, as well as the one consisting of lead white and chalk in a ratio of 1:1.

1.4 Influence of the ground layer thickness

Bomford and Staniforth suggested that ground layer thickness also influenced the degree of colour change on wax-resin lining.[8] The present research examined this factor and found that the influence of thickness varied according to the kind and proportion of the inorganic components. For example, the ground composed of chalk in animal glue changed colour more significantly when applied thinly. Similar trends were found for oil-bound grounds composed of either ball clay or lead white, 98% chalk mixed with either yellow iron oxide or combinations of yellow iron oxide and raw umber in equal amounts, as well as 80% chalk with lead white. On the contrary, layer thickness did not influence the degree of colour change of oil-bound ground reconstructions composed of lead white and raw umber (even when 70% chalk was included).

[6] Westby Percival-Prescott, "The Lining Cycle: Causes of physical deterioration in oil paintings on canvas: lining from the 17th century to the present day" in *Lining Paintings: Papers from the Greenwich conference on comparative lining techniques,* ed. Caroline Villers (London: Archetype Publications, 2003), 11.
[7] Nieder et al., "Colour Change in Sample Reconstructions of Vincent van Gogh's Grounds Due to Wax-Resin Lining," 100.
[8] David Bomford and Sarah Staniforth, "Wax-Resin Lining and Colour Change: An evaluation," *National Gallery Technical Bulletin* 5 (1981): 63.

Finally, the quartz and ball clay containing oil-bound grounds changed colour to a similar extent regardless of the thickness of application. Colour measurements of samples of these grounds on opacity charts showed that layer thickness considerably influenced the hiding power. A general trend was that the thinner the ground the less hiding it was, therefore supporting results of colour measurements from the reconstructions on canvas support. An exception was the ground composed of chalk and yellow iron oxide in linseed oil for which colour measurements were not decisive.

2. Implications for the conservation of wax-resin lined paintings

2.1 Identifying paintings that are likely to have changed colour following wax-resin impregnation

Analysis of the research enabled the identification of trends that can predict the likelihood that paintings with certain ground characteristics have been visually altered by wax-resin impregnation. For example, glue-bound grounds are prone to significant colour change, while oil-bound grounds are less susceptible. The effect of wax-resin impregnation on oil-bound grounds is heavily dependent on pigment composition as well as layer thickness. When considering pigment mixtures bound in linseed oil, the ground types at most risk are those composed of lead white mixed with at least 50% chalk. Oil-bound grounds consisting of mixtures of 90% chalk with yellow iron oxide and 98% chalk mixed with combinations of yellow iron oxide and raw umber in equal amounts, are also prone to change colour, though to a lesser extent than lead white mixtures. Quartz and clay containing oil-bound grounds are prone to significant colour change after wax-resin impregnation even with the addition of 3% yellow iron oxide.

In addition, research showed that the “abraded look” of the surface of a ground could be a phenomenon resulting from wax-resin impregnation. This effect was observed after impregnation in ground reconstructions composed of chalk in animal glue or linseed oil as well as the oil-bound grounds composed either of ball clay or lead white, as well as chalk and lead white mixtures. The hiding power study helped explain the cause of this phenomenon since for these specific ground types, colour measurements reported significant differences in the degree of hiding power as a function of layer thickness. As thickness varied considerably in the reconstructions due to the inherent irregular texture of canvas support, the colour change of these grounds was uneven. Furthermore, each of these grounds presented strong tonal contrasts with the darkened canvas, thus contributing to the typical “abraded look”. This surface effect was also observed in certain ground reconstructions produced for the Van Gogh research project.[9] Though this effect may have causes other than wax-resin lining, including lacunas in the ground layer due to harsh cleaning techniques, it is important to note that in the occurrence of an abraded look due to wax-resin impregnation, the ground layer remained on the canvas support. The abraded appearance is an optical effect caused by the darkening of the canvas, rather than actual abrasion of the ground layer.

[9] Nieder et al., “Colour Change in Sample Reconstructions of Vincent van Gogh’s Grounds Due to Wax-Resin Lining,” 100.

2.2 Remedial conservation treatment for wax-resin lined paintings

While it has been observed that the impregnation of an absorbent ground with an adhesive will cause colour change, the present research highlighted the influence of ground hiding power on the same occurrence. The penetration of wax-resin into the absorbent canvas caused changes in refractive index surrounding the fibers, resulting in the darkening of the textile. In the case of ground layers with poor hiding power, visual change may occur due to the darkened canvas support. Recent research has shown that the presence of wax-resin around canvas fibres can be an issue for the conservation of paintings.[10] It has been suggested that when wax-resin lined paintings are exposed to high humidity levels swelling of the fibres may cause increased contraction force, resulting in increased stress levels in paintings and thus enhancing the occurrence of mechanical damages such as fractures and distortions. Findings from the present research now show that the presence of adhesive in the canvas structure is also a cause for the alteration of the appearance of paintings.
Correction of this effect could involve extracting wax-resin from the painting's structure, assuming that this treatment might reveal the original colour of the priming. However, this strategy presents many obstacles, including the irreversibility of wax-resin impregnation. During the first half of the 1970s, Gustav Berger and Harold Zeliger examined the efficacy of wax-resin extraction from canvas supports and studied the resulting physical changes in paint films from fragments of old paintings.[11] They concluded that "wax impregnation of any and all the components of easel paintings must therefore be considered irreversible" and "some wax-resin mixtures might contribute to the decay of (canvas) supports." In 1990, subsequent research by Gunnar Heydenreich, paintings conservator, tested the combined action of gelled organic solvents and a suction table for extracting wax-resin from the textile support of a specific painting.[12] Once treatment was completed, comparative colour measurements recorded that the extraction resulted in a visibly lighter appearance of the painted image ($\Delta E = 1.03$ in a thinly applied mid-tone area, with a marked increased lightness and a slight increase in redness and yellowness).[13] However, when a section of the painting that had undergone extraction was reheated, darkening re-occurred, suggesting that was-resin was still present. The appearance that this zone had achieved after the first extraction could not then be recovered by a second extraction treatment.[14] This led Heydenreich to conclude that wax-resin impregnation had limited reversibility and also implied that the colour of the paint obtained after extraction treatment may not be how it appeared originally. Questions also remain as to whether a full extraction would really return the painting to pre-lining colour, as chemical interactions between paint layers and organic solvents, such as leaching, may occur. Finally, the implementation of this

[10] C. Krarup Andersen, M. Scharff, J. Wadum and M. Mecklenburg, "With the Best Intentions: Changed response to relative humidity in wax-resin lined early 19th century canvas paintings," in *Preprints of the 17th ICOM Committee for Conservation triennial meeting Melbourne*, ed. Janet Bridgland (Paris: ICOM, 2014).
[11] Berger and Zeliger, "Detrimental and irreversible Effect of Wax Impregnation on Easel Painting," in *Preprints Meeting ICOM-Committee for Conservation 4th Triennial Meeting Venice (*Paris: ICOM, 1975), 75/11/2-10.
[12] The painting is: *Water Park, Highgate, 1920* by Rodney Burn (1899-1984) in the collection of the Tate Gallery London.
[13] Gunnar Heydenreich "Removal of a Wax-Resin Lining and Colour Changes: A Case Study," *The Conservator*, 18 (1994), 27.
[14] Ibid, 26.

approach may expose paintings to high risks of delamination, since wax-resin impregnation was in many cases used to re-adhere flaking paint layers. Confronted with these challenges in correcting visual alteration due to wax-resin impregnation through chemical processes, alternative solutions using corrective light projections were installed in the galleries of the Royal Palace Amsterdam in 2010 and are still in use today.[15] Tailor-made lighting has also been used for the presentation of *The Night Watch* in the Rijksmuseum since 2011.

3. Evaluation of the approach and methods

3.1 Making and lining the reconstructions

The methods and materials used for making and lining the reconstructions in the present study were based on both material evidence found in historical paintings and contemporary documentary sources. Historical accuracy in the experiments was however not fully realised due to a series of obstacles that included the limitations of analytical techniques, imprecisions in data provided in historical texts and challenges in sourcing historical accurate materials today. Nevertheless, the efforts made to produce reconstructions that replicate as closely as possible the material and technical characteristics of grounds layers in seventeenth century Netherlandish paintings lined with wax-resin, resulted in novel data that can inform the changes that have occurred in the works investigated.
Although the kind of materials used for making the reconstructions was based on findings in the ground layers of the paintings selected for the present study, the experimental variables included the exclusion of minor components found in the grounds and the testing of a limited number of different proportions of inorganic pigments. Therefore the reconstructions were representative of a range of works made in this period rather than a precise replication of the works investigated. This approach allowed trends to be identified in a broader range of grounds than those used in the paintings.
For future research it would be very interesting to broaden the type of grounds studied, by further investigating, for example, lead white containing oil-bound grounds with varying pigment mixtures and proportions of chalk. Variations of red grounds would also be worth examining, as they are often found in seventeenth century Netherlandish paintings. Double-ground layers also remain an unexplored category. Finally, since the condition of ground layers is influenced by the paint applied on top, this parameter could also be taken into account. This aspect is especially important when considering glue-bound grounds due to the sinking in of oil medium from the paint.
Analysis of cross-sections taken from reconstructions showed that the use of a drawdown bar was not a guarantee for obtaining a specific layer thickness. This is primarily due to the flexibility of canvas that tends to bend under the pressure of the instrument. It is also due to drying processes, an effect that could not be anticipated. In addition, the tool created parallel lines in relief, some of which were thicker than the grounds found in paintings. The use of a palette knife

[15] Margriet van Eikema Hommes and Emilie Froment, "The Decoration Programme in the Galleries of the Royal Palace Amsterdam: An harmonious interaction between painting, architecture and light?" in *The Batavian Commissions,* ed. Marianna van der Zwaag (Royal Palace Amsterdam, 2011): 3.

or a brush with the intention of obtaining a thin layer that still obscures the canvas weave now seems to be a better technique.

3.2 Interpretation of physical phenomena

Key in the present research was the correlation of colour measurements of ground reconstructions on canvas support with measurements of the same grounds applied on opacity charts. The latter samples were essential, as they provided measurements of the degree of hiding power in relation to thickness and composition on a substrate with standardised coloured backgrounds and texture. The interpretation process was, however, not as straightforward as anticipated. For example, some of the grounds that showed poor hiding on the opacity charts did not change colour after impregnation when applied on canvas. Equally confusing were grounds registered as extremely poorly hiding that only slightly changed colour after lining with wax-resin. It is possible that a difference in thickness between the two samples may have caused this effect. The difference in background colour may also have influenced this result as the strong tonal contrast of the opacity charts enhances the visual consequences of a poor hiding power compare with the grey coloured canvas.

The choice of an absorbent type of chart also challenged the research due to inconsistent degrees of absorbency, which were occasionally reflected in the ground samples in the form of blanching or gloss differences. Although sealed charts did not develop these irregularities after drying, their use caused other difficulties during the comparison of colour measurements with the ground samples on canvas, due to marked differences in absorbency. For further research, systematic testing on various types of charts should be carried out with the aim of finding a form with even absorption across different background colours. Furthermore, the use of a form with a grey scale with subtler steps may provide a better substrate for comparison with reconstructions on canvas support.

The hiding power of oil-bound grounds was suggested as the primary cause for colour change after wax-resin impregnation This was assumed due to the non-absorbency of freshly made grounds, the sealing ability of which was evidenced by the wax-resin adhesive that did not pass through the samples (as it did in grounds composed of animal glue). However, no research was carried out on the degree of porosity of these layers and whether the wax-resin has penetrated to some extent is not clarified to date. A pilot-study completed over the course of this research investigated the possibility of visualising wax-resin in cross-sections using SEM-EDX. The adhesive was mixed with nano-particles of titanium white (particle size = 10 nm) easily identifiable with the element detector in the electron microscope without risking confusion with the materials used for the reconstruction (a lead white and iron oxide containing oil bound ground on canvas). Although titanium white was found in the canvas support, technical analysis was not able to find any particles of the white pigment in the ground, further supporting the assumption that the ground is non-absorbent. Having said that, tests were not performed with porous grounds to assess whether the labelling technique of the wax-resin was valid.

3.3 Results from reconstructions compared to results from historical paintings

Results of colour measurements of ground reconstructions rarely showed an exact match with the grounds of historical paintings. Though the composition of the reconstructions was based on material evidence found in seventeenth century Netherlandish paintings, factors that differentiate the reconstructions from the real paintings were significant and precluded inferences about the original colour of the ground of paintings before lining. These factors included minor components that were not reproduced in order to minimise variables and the varnish layers present on the paintings but not on the samples. Further the source of the iron oxide pigments and the proportion of inorganic materials were anticipated to contribute to discrepancies measured between paintings and reconstructions.

The complex ageing processes to which the paintings have been exposed while the reconstructions have not, may also have had an influence on their physical differences, for example the degree of absorbency and the lack of lead soap formations in the reconstructions versus the historical paintings. These factors are however anticipated to be influential regarding the occurrence and the degree of colour change in ground layers after wax-resin lining. Preliminary tests in this study were carried out on samples of naturally aged paintings (tacking-margins cut from seventeenth century paintings before lining) from which the varnish had been removed and oil paint was present locally on top of the ground. [16] After impregnation, wax-resin had stained the tissue placed in front of the paint layer, indicating that adhesive had passed through the sample. This never occurred to the reconstructions with oil-bound grounds. This observation supported the hypothesis that the ageing processes undergone by paintings including natural ageing, exposure to organic solvents in past restoration campaigns, and unstable levels of humidity and temperature, may have increased the porosity of the paintings' grounds, thus potentially increasing the chance of colour change after wax-resin lining. A pilot-study carried out in the present thesis aimed to replicate these changes on the reconstructions (chapter 3). Results of these experiments highlighted the challenges of replicating ageing effects which supported the decision not to expose the reconstructions to artificial ageing techniques and/or organic solvents. The question remains, therefore, whether increased porosity of paintings due to ageing has an influence on the degree of colour change after impregnation. This problem was also underlined by Bomford and Staniforth, who state in the conclusion of their study that "natural ageing played no part since the grounds were freshly prepared, but in real paintings deterioration of the binding medium becomes an important factor."[17] Tests on samples of naturally aged paintings create new questions which introduce further research approaches that might be valuable to consider in the future, such as the use of fragments from aged paintings and systematic comparative study of both lined and unlined paintings.

4. Perspectives

In her chapter written for *Conservation of Easel Paintings*, Mireille te Marvelde concludes by noting that "as far as research on the effect of wax-resin lining is concerned, the case is far from closed."[18] Since then scientific research on the impact of wax-resin lining on the present physical condition and conservation of paintings has been enriched by research on the mechanical

[16] Organic analysis did not confirm the identification of the binding medium of the ground layers, though oil was very likely.

[17] Bomford and Staniforth, "Wax-Resin Lining and Colour Change: An evaluation," *National Gallery Technical Bulletin* 5 (1981): 63.

[18] Mireille te Marvelde, "Wax-Resin Lining," in *Conservation of Easel Paintings: Principles and practice,* Joyce Hill Stoner and Rebecca Anne Rushfield eds. (London and New-York: Routledge, 2012), 433.

behaviour of wax-resin lined Danish nineteenth century paintings at The Royal Danish Academy of Fine Arts in Copenhagen and the research presented in this thesis. The latter complements the research carried out on similar topics in the 1980s by the National Gallery in London and in the 2010s by the Van Gogh Museum in Amsterdam.

It should be noted that this thesis is only a start in a broader field of research. For example, the study of the impact of wax-resin lining is tightly connected with the practical history of the technique, in which the present study revealed gaps of knowledge despite the amount of research carried out over the last decennia. A history of the dissemination of the technique still needs to be written. These lines of research are somewhat urgent, as it is timely to collect the practical insights of paintings conservator(s) who are either still practicing or used to practice the technique. Furthermore, the chemical consequences of wax-resin lining on paint films is a critical area to investigate. Many historical documents include testimonies reporting the solvent sensitivity of paint layers on paintings that had been wax-resin lined. The assumption that "wax acts as a solvent for oil paint" can be read in literature though no systematic study has been carried out. Research into the potential risks of paint layers being exposed to organic solvent is therefore also needed, as varnishes are removed daily in conservation studios using organic solvents.[19] The research on varnish removal from nineteenth century ground reconstructions on canvas revealed that the cleaning was easier on the lined than the unlined samples and that the exposure to solvent reduced the amount of wax present on the weave tops.[20] This raises the question whether varnish removal may disturb the consolidation purposes of the wax-resin impregnation. To this end, the development of visualization techniques, allowing for a better understanding of the distribution of wax-resin adhesive in the paint film, would also provide an essential insight for designing suitable remedial conservation strategies. Finally, since the goal of wax-resin lining was full impregnation of the paint layer with the lining adhesive, questions remain as to whether the presence of the adhesive near/on the surface of the painting may interfere with the future appearance of wax-resin lined paintings. Research into the impact of the physical modification of the wax-resin adhesive for the future appearance and conservation of wax-resin lined paintings is therefore very relevant.

As it appears now, paintings conservators world-wide are often confronted with the conservation of paintings that have been wax-resin lined and are treating such paintings despite a lack of scientific research on the overall consequences of the technique for present conservation. More insight based on scientific research is therefore essential and timely. Research into the effects of wax-resin linings includes numerous lines of study, each of which having a high level of significance for paintings conservation, conservation history and art history. In order to maximize the benefits for different fields of interest, it is crucial to investigate these lines in an integrated and concerted manner. While new knowledge is required, one should not forget that significant aspects have already been investigated, especially with regard to the history of the technique. This information is, however, spread between various institutes and the creation of a place of reference for the conservation of wax-resin lined paintings could help to remedy this situation. It would centralize and coordinate existing information on the history and

[19] Berger and Zeliger, "Detrimental and Irreversible Effect of Wax Impregnation on Easel Painting," 75/11/2-10.

[20] Meredith Watson and Aviva Burnstock, "An Evaluation of Color Change in Nineteenth Century Grounds on Canvas upon Varnishing and Varnish removal," In *New Insight into the Cleaning of Paintings (Cleaning 2010)*, Marion M. Mecklenburg, A. Elena Charola and Robert J. Koestler eds. (Smithsonian Institution Scholarly Press, 2013): 82.

conservation of wax-resin lined paintings, as well as create new knowledge integrated with past research. The creation of such a centre in the Conservation-Restoration department at the University of Amsterdam is not only relevant because of the history of wax-resin linings that is tightly connected with the Netherlands but also due to the fundamental role of the University in carrying out scientific research and supporting the sharing and dissemination of knowledge.