Preserving the Painted Image: The Art and Science of Conservation

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Summary

Colour is integral to art and particularly to paintings. When considered from a materials perspective, the ageing of pigments and dyes affects colour and thus how a painting is viewed. In addition to this, varnish and dirt layers obscure detail and change tonality. Conservation attempts to prevent such changes from occurring at the earliest stages. Nevertheless, ageing is a natural process for artist materials, and various more invasive treatment techniques such as cleaning and varnish removal may be considered. This has historically resulted in public controversy when the process is not adequately understood or communicated. More commonly now, scientific research is routinely applied to the analysis of pigments, colour measurement and treatment which reduces risk and aims to preserve the artist's original intent.

Introduction

Colour plays a prominent role in art, expressing and communicating the artist's vision. From the earliest rock art to contemporary installation art, colour has been a key component. Understanding its material composition and potential deterioration helps to preserve the original appearance of the object.

Colour in paintings

Colour is the most important element in a painting but also the most sensitive to degradation. Whether fading, darkening or yellowing, colour changes can alter the entire appearance and perception of a painting [1]. Historically, the choice of colour has been influenced by tradition: treatises, manuals and training in workshops guided the artist's selection. Until the Renaissance, particular colours and their order of application were prescribed and had particular significance. One of the first such treatises was the *Craftsman's Handbook* by Cennino Cennini (c.1370–1440) [2]. Cennini included instructions about the use of particular pigments, which areas to use them for and how to prepare them. The Renaissance saw a move away from the artist as craftsman, and led to the artist as creative, individual genius with more freedom in terms of subject matter and colours. Subjects became more life-like and thus colours were also meant to be true to life. By the 19th century, the Industrial Revolution made available new technologies such as synthesised pigments, further adding to the artist's palette. Simultaneously, the new scientific world view attempted to formulate descriptions for light, colour and vision in scientific terms: such theories were picked up by Impressionists such as Paul Gauguin, Paul Signac and Vincent van Gogh, who increasingly applied abstract colours and forms.

Pigments and paint structure

Colours are produced in a variety of ways; however, in paintings the use of pigment or dye is most common. Both must be mixed into a medium before they can be applied by brush or spatula. In order to understand paintings, one must consider paint structures as layers, and the image is created by the interaction between these layers. In cross-section, the layers that make up a painting can be seen (Figure 1). These may consist of a complex system including support such as canvas or board, over which ground, a sequence of pigmented paint layers, and subsequent varnish is applied.

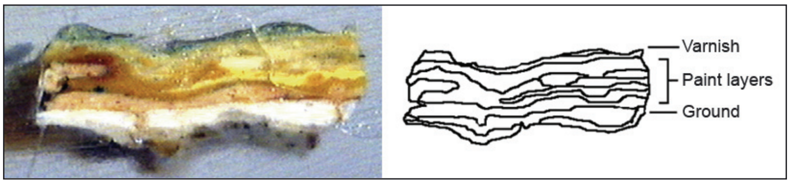

Figure 1 Cross-sectioned sample of paint, showing many layers of ground, colour and varnish that make up a section of landscape; from Alfred Munnings' *The Old Oak* (c.1927)

As red and yellow ochres in rock art (cave paintings) prove, certain pigments can remain in direct sunlight for thousands of years without any indication of fading [3]. These historical colours are part of the inorganic pigments based on earths and metals, and are known to be very light stable [4]. Paint chemistry is a constantly evolving field, and pigments used today are derived from different sources than they were fifty years ago. For example, safer complexes of cadmium and cobalt are being substituted for their toxic earlier counterparts, while lead and arsenic pigments have been phased out for health reasons.

As soon as a painting is finished, it begins to age and deteriorate. Materials become brittle; paint may flake and fall off the support, while supports warp, tear or crack. In the long term, the major reason for colour change is the inevitable chemical ageing of the paint layers. If the pigmented paint layer is sufficiently protected by binding media and varnish, it is protected against contact with other layers and exposure to the environment, slowing down any changes. Unfortunately these layers are also the most visible component of the painting.

Colour Change

Colour changes are particularly disturbing forms of deterioration, as they alter the original balance and interpretation of the image; these changes include alterations in optical properties of binders, and composition of pigments [1]. Paintings may darken to such an extent that the contrast is obscured. This may occur through dirt and pollution, or darkening of the medium. An increase in transparency can also affect darkening particularly with dark underlying paint. A fine network of cracks, called crazing, or blanching can also lead to different colour perception. Additionally, impurities or adulterations can cause darkening or bleaching, e.g. cadmium pigments in contact with sulphur [5]. By far the most common changes in pigment colour are caused by yellowing, fading or darkening of unstable paints.

Fading

Fading of pigments is well known, and results in images that become visually out of balance. This is often seen in late 19th century paintings because of the use of paint with modern synthetic pigments that had poor colour fastness. Fading is most obvious in thin water colour washes, where there is low concentration of pigment, and in organic colours. Natural dyes and lakes in particular bleach quickly due to ultraviolet exposure. Early examples of such natural colours include sap green and indigo. Synthetic organic colours have been manufactured since 1857 [4], and have replaced many historical natural dyes but are themselves also fugitive; red lakes were often used as glazes over white and blue to give delicate pinks and mauves, but fading of red lakes has significant consequences for interpretation both aesthetically and iconographically. The pale portrait of *Anne, Countess of Albemarle* (c.1760) by Joshua Reynolds is an example of a fading red lake [6]. On examination of the face in cross-section, the skin colour consisted of lead white mixed with red lake and would have originally been pink. By reading through Reynolds' artist notes, he is known to have used Brasilwood or cochineal, fugitive pigments that have since faded at the surface and left the portrait in the pale hue seen today. Similarly, fading yellow lakes cause loss of green colour to blue where it is present in mixtures such as in foliage and fruit. Another well known fading pigment is indigo, historically the only organic blue pigment used in oil. By 1710, Prussian blue was invented as one of the earliest artificial pigments of the modern age, welcomed by artists as a stable alternative to indigo and the more expensive ultramarine [7]. Historic Prussian blue, however, has shown signs of fading when mixed with white pigment such as flake white. Kirby [7] noted this fading particularly in Gainsborough's skies, such as *Gainsborough's Forest* (c.1748), and *Mr and Mrs Andrews* (c.1750).

Darkening

Some pigments are prone to darkening, particularly on exposure to pollutants. One such example is lead white, which is unsuitable as a pigment in water colour and wall paintings, while protected by an oil medium or varnish it is very stable. Lead chrome yellows also darken on exposure to hydrogen sulphide, and chrome yellows tend to darken with age and become brown, a photochemical process even in the absence of oxygen [8]. Another pigment prone to darkening is vermilion, which can develop a disfiguring black or grey crust [9]. Examples of such darkening include the horse harness of Paolo Uccello's *Niccolo Mauruzi da Tolentino at the Battle of San Romano* (c.1440), where the border of the harness remains red but remainder is blackened. Slight reversing of the black state is seen when painting is allowed to rest in the dark [10]. Copper resinate pigments may become brown, affecting only the top surface exposed to light, which is presumably decomposition of copper resinate under ultraviolet (UV) light [11].

Yellowing

The last major factor in colour change discussed here is yellowing: a wide variety of natural resins, such as shellac and dammar, have been used as varnishes in addition to pure drying oils and gums. Natural varnishes oxidise with light and air, turning yellow or brown [4]. Over time, they can furthermore lose transparency through cracking, or blanch when in contact with water. Artists were aware of these darkening properties, and experimented to find the clearest one. Some colours were varnished separately or not at all. In addition, placing paintings near fireplaces or tobacco smoke provides a yellow/brown layer which masks and distorts the colour balance below. Dirt, dust and discoloured varnishes are removed as a matter of course within the gallery environment (Figure 2), often revealing a brighter, better resolved image underneath (Figure 3). On the part of the conservator, this requires great responsibility through skill, scientific and historical knowledge and humility.

Figure 2 Cleaning a painting, in progress

Figure 3 Effect of removing a discoloured yellow varnish (cleaning from left to right) from Charles Daubigny's painting *Snow Scene, Valmondois* (1875) (image reproduced by permission of the Art Gallery of Western Australia)

Cleaning Controversies

'There are two ways to destroy a painting – to restore it or not to restore it' [12].

Historically, there have been a number of ways to deal with changing surface appearance. Emphasis was traditionally put on restoring the appearance without consideration of the original, historical material. This led to patches and whole canvases being glued to the reverse, repainting part or all of the image, applying brown varnish to make it look old, and accidentally removing original paint during cleaning. These practices have been overcome through the introduction of scientific analysis and training, and modern conservation now concentrates on prevention and minimal, reversible intervention.

Large scale cleaning projects often face public scrutiny. Complaints that valuable paintings were ruined by removal of glazes have been reported as early as the 17th century [13]. Art galleries too have been accused of harming the paintings they should protect; the National Gallery in London came under great scrutiny in the 1840s with the hasty cleaning of masterpieces by Rubens, Titian, Velazquez and Canaletto. Critics at the time considered them to have been 'flayed, scoured, scrubbed, laid bare and smudged' [14]. The subsequent public outrage resulted in the UK government setting up a parliamentary committee of enquiry, and the keeper of pictures was sacked. The National Gallery repeated the controversy a hundred years later, when paintings were evacuated for safekeeping. During the 1940s, over 60 paintings were cleaned by two restorers in a secret cave in Wales. In 1947, an exhibition of the newly cleaned paintings was held to show the results of this 'scientific' conservation, receiving criticism in *The Times* and *Sunday Telegraph* as well as from distinguished art historians [15]. For a third time, the National Gallery in London raised concerns, when in 1962 Titian's *Bacchus and Ariadne* was cleaned [12]. More recently, media attention has similarly focused on cleaning of the Sistine Chapel [16] and da Vinci's fresco of the Last Supper in Milan.

Conservation practice has changed over time, and many of the arguments against cleaning are no longer valid. In fact, science has increasingly led to more and more caution in the use of treatments, with many conservators now practicing minimal intervention and preventive conservation such as environmental control. In cleaning varnish and dirt, the conservator has a number of choices; to retain the old varnish, to thin it, remove it entirely or clean some areas more than others. Different ways of cleaning conditions the way we see a painting, and each of these options involves a particular emphasis on aesthetics such as harmony, colour or the effects of age. This relativity exists as long as paintings continue to change over time.

Measuring Colour Change

Regular examination is important to detect early signs of deterioration. Documentation in the form of condition reports and photography is heavily relied on by galleries as a reference standard. With the advent of digital photography, better white balance and colour calibration against colour check charts is made possible. While colour perception depends on many factors such as the illumination, the observer and surrounding conditions, measuring the spectral reflectance of an object surface objectively provides a description of the surface's inherent physical characteristics [17]. The application of colorimetry can be used to identify pigments and monitor colour change. Colour data is measured through spectral reflectance and converted to tristimulus values expressed in CIE (Commission Internationale de l'Eclairage) L^*, a^* and b^* based on hue (wavelength), saturation (purity) and luminosity (intensity of reflected light) values, respectively [18], while change is measured through colour difference (ΔE) [19].

Investigation of the colour of artists' pigments was undertaken by the Fogg Art Museum at Harvard University as early as 1939 [20], where pigments in oil- and water-based binding media were analysed using a recording photoelectric spectrophotometer. More recently, Bradley *et al.* [21] used a spectrophotometer to monitor darkening in Lindow Man, a preserved peat body on display in the British Museum. Not surprisingly, their results showed that the largest colour change occurred when light exposure was highest. The limitation of spectrophotometers is that only a single point is measured at any one time, which is difficult for repeat testing over time, and may not be representative of the remaining image. Hyperspectral imaging overcomes this limitation through simultaneously measuring the entire image with millions of pixels [3]. This is achieved through capturing pictures with a charge-coupled device (CCD) camera through specific wavelength narrow band filters (Figure 4). Each image is assigned reflectance values between 0 and 100% based on a reflectance standard captured alongside the painting. Once a series of specific wavelength images is accumulated, software is used to precisely stack the images and obtain a three-dimensional image data cube. Drawing a point through this stacked cube allows extraction of a spectrum based on individual reflectance values for each wavelength. The resolution of the reflectance curve is limited by the number of filters used, but with new liquid crystal tuneable filter technology, an image may be collected for every wavelength in the visible and near infrared spectrum. Hyperspectral imaging reflectance curves compare well to more traditional bench top or fibre optic probe spectrometers, and allow an entire painting to be studied simultaneously [3]. Digital imaging may also assist in the restoration of artwork, where computer-aided comparison of before and after images have provided superior results.

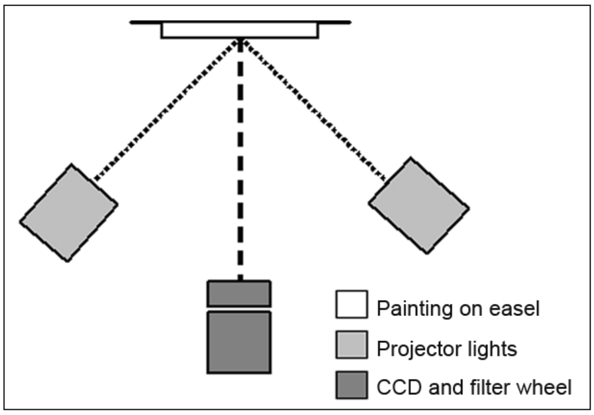

Figure 4 Hyperspectral imaging system setup, seen from above

The yellowing of varnish too may be monitored by collecting reflectance spectra (Figure 5). As comparison between yellowed and clean paint surface, a partially cleaned painting with aged dammar varnish was tested. When the reflectance spectra of varnished and cleaned regions are compared, it can be seen that the varnish causes not only a drop in reflectance, but also a red shift to a wavelength of 550 nm, describing the yellowed effect. Thus the gradual yellowing of a varnish layer, colour changes, as well as its cleaning, may be monitored objectively using hyperspectral imaging.

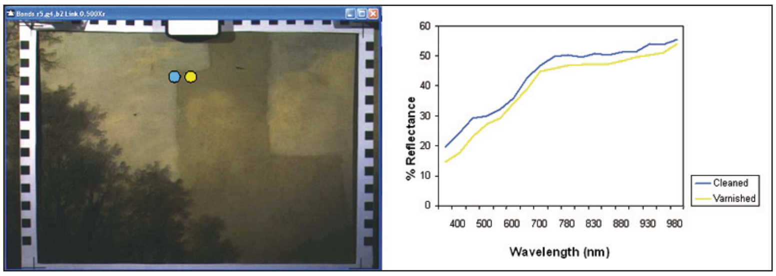

Figure 5 Partially removed varnish with tested areas in sky (blue dot = cleaned area), (yellow dot = aged varnish), and resulting hyperspectral imaging reflectance spectra

Making Painted Colours Last

Preventive conservation dictates that it is best to prevent damage such as colour change from occurring in the first place. This is achieved by understanding the mechanisms involved in the deterioration of paints, and undertaking steps slow or stop the process. Agents of colour deterioration in art include gaseous and particulate pollution and UV light.

Gaseous pollution

Pollutants which affect colour change include ozone, nitrogen dioxide, nitric acid, formaldehyde and peroxyacetyl nitrate. In addition, the main pollutant causing pigment change is sulphur dioxide SO_2, an air pollutant found even in urban museums through ingress of smog. Damage from sulphur dioxide has long been a recognised risk, so that the National Gallery of London glazed its paintings as early as 1850 for protection [22]. Potential for damage is a function of the pollutant concentration, the exposure duration and the magnitude of specific pollutant-colorant interaction. Prevention is achieved through filtration of air entering the museum environment, by using ‘safe’ materials inside the building that do not off-gas, through the use of activated carbon in display cases, by varnishing over sensitive pigments [10], or by glazing paintings to present a physical barrier against harmful gases. Pigment change can also be prevented by addition of stabilisers in the paint formula, such as barium sulphate, zinc oxide and titanium dioxide [4].

Particulates and surface dirt

Particulate pollutants settle onto a painting’s surface and mask the image, and may act as a further catalyst for breakdown of chemicals in paint and varnish. Deposits on the paint layer are known as surface dirt, and may include airborne dust, residues from previous restoration, finger prints, accidental food splashes, mold, insect accretions, soot and tobacco smoke. As with gaseous pollution, prevention is achieved by filtration, good house keeping, varnishing or glazing paintings, while cleaning of the paint surface may be undertaken by a conservator.

Light

Light, in particular at the UV end of the spectrum, can cause many pigments to fade: such damage is cumulative and irreversible, and depends on the wavelength, intensity and duration of exposure. The higher the energy of the photon, the more likely that damage will occur – thus, UV light is most harmful, followed by the blue/violet end of the spectrum [23]. Prevention is achieved through filtering out or eliminating direct sunlight which contains a high level of UV light, and choosing light sources with no UV light component. Exposure time can be limited through storage in the dark and limiting lighting to visitor hours only. Glazing behind UV barrier acrylic or varnishing with a light stabilised varnish also reduces fading. Lastly, stabilisers may be added directly to paint, such as the addition of zinc and antimony salts to lead chrome pigments [8].

Conclusion

Colour change in paintings appears in many forms through fading, darkening or yellowing, and affects the overall colour balance of the image. Changes result through a combination of the choice of artists' materials used, pollution, display and storage conditions, and begin as soon as the painting is completed. While ageing and the resulting patina is considered a natural process, there are various treatment techniques which can be considered including surface cleaning and varnish removal. In the past, public controversy and criticism of treatments has occurred where the process was not adequately consulted or communicated. More commonly now, collaboration with artists and curators will guide the conservator's choices. Scientific research is routinely applied to colour measurement and treatment which reduces risk and aims to preserve the artist's original intent. The key lies with ongoing research into materials and deterioration methods to ensure that the most suitable paints are used and artwork better preserved for the future. Insisting on better quality materials at the outset, and adequate housing in a gallery or museum will thus add to the life of any painting.

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