Imperfect Copies. Reconstructions in Conservation Research and Practice[1]

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Introduction

Reconstruction plays an important role in the conservation of cultural heritage. While most of us are familiar with reconstructions of missing parts of statues or missing areas in paintings, the role of reconstructions in the investigation of degradation processes, treatment methods and insight into future changes to objects is less well known. Conservators investigate and care for works of art of the past and the present that are often unique, i.e. of which only a single or very few copies exist. It is this uniqueness that makes conservators resort to reconstructions in research, as all interfering with or altering 'the original' in conservation or restoration places this original in danger of losing part of its uniqueness or significance.

Art conservation[2] makes use of a range of reconstruction types, the choice of which depends on the purpose of the reconstruction. In this chapter I describe the different uses of reconstructions within the field, discuss the methods developed by conservators to deal with the use and limitations of reconstructions in conservation research, and reflect on the role and practices of reconstruction in this field. Reconstruction is the term used throughout, as this is a term that is generally employed within the field of conservation.[3] Yet, the cases discussed in this chapter show that re-enactment or replication are an integral part of the performative processes used in this field.

The conservation Code of Ethics and the invisibility of the conservator

As a paintings conservator, I follow the professional Code of Ethics of the European Confederation of Conservator-Restorers Organizations (E.C.C.O.). In this document, a conservator's obligations towards Cultural Heritage have been formulated (see Appendix 1). These obligations reflect current thoughts about ethically responsible conservation and reconstruction practice. Some of the principles described relate directly to the use of reconstructions in this field. Reconstructions can help minimize danger to the physical integrity when they replace an original during tests and they play a role in restoring symbolic meaning and aesthetic significance when they are employed to fill in missing pieces or areas in damaged objects (article 5). When objects are kept in an unsuitable environment, replacement with a reproduction will remove the object itself from danger of being damaged (article 16).[4] The conservation Code of Ethics also implicitly warns against limitless reconstruction. Articles 6 and 8 draw attention to the principle of minimal conservation treatments. If reconstruction or 'improvement' of an object by reconstruction goes too far, it harms the spiritual significance, physical integrity, historic, and often aesthetic values contained within it.[5]

The Code of Ethics places the main focus on the object and not on the practitioner, in this case the conservator. This emphasis reflects the attitude that many conservators, including myself, were infused with during training. We were trained to be minimally 'visible' as a person in our work, because a conservator is supposed to put the interests of the object first with the goal of making the object speak for itself. The idea of the conservator pushing aside his own personality to follow the artist has a long history. For example, in 1829, when French author Jacques Nicolas Paillot De Montabert wrote about retouching, he stated that 'the tint, the tone and the touch should resemble the work by the master; while the taste, the ideas and the manner of the repairer should not be at all apparent'.[6]

As discussed by Étienne, investigating painting restoration in France 1750-1850, historic references such as these, to the restorer imitating the 'hand' or capturing the 'spirit' of the master are numerous. While one might assume that such an attitude would lead to modest interventions, this was not necessarily the case. Out of one and the same spirit completely different restorations could flow, drastic reconstructions that would 'help' the artist or work of art by 'improving' certain areas. Étienne includes a quote by Italian restorer Bedotti (1837), who wrote 'it sometimes happens to even the most skilful painters to make mistakes that are too gross and too visible. In that case, one must not fear to seek and to remedy; whenever possible, and to improve the painting by eliminating or concealing the most shocking mistakes.'[7]

Recent conservation theory justly challenges the notion that a neutral intervention is possible and that such an intervention can be achieved by placing the artist or the work of art before the individuality of the conservator. Conservation and restoration influence the life trajectory of an object, changing the story contained within it. Therefore, being invisible or 'neutral' as a conservator is simply impossible. Even though not always visible at first sight, I, as a conservator, cannot prevent that my choices, my interventions, change the life trajectory of an object. If I remove a varnish, I may reveal more of the colours the artist used in his painting, but I also take away part of the history of the painting.

In modern conservation discourse, the term 'legibility' is often used in this context, the argument being that conservation is needed to make the object understandable for an audience. However, as conservator and philosopher Salvator Muños Viñas writes in his *Modern Theory of Conservation*, while reconstructions or retouching in conservation are often defended as a method of increasing the legibility of an object, the conservator is in fact not increasing legibility. Instead, the conservator is deciding which legibility prevails over different possible ways to read or understand an object.[8] For why would an object that before conservation is read as very damaged or broken, be *more* legible when it is less damaged or completed? The legibility does not increase, it only changes.

Reconstruction terminology

Notwithstanding the impossibility of being a neutral party, the profound way in which our aim to be invisible in conservation interventions is integral to the profession may in fact be why conservation terminology to describe methods that replicate artistic processes equally focuses on the object. Conservators will immediately recognise terms like reconstruction, replication, model paint, test panel or dummy – the first two terms employed mainly for illusionistic reconstructions that replicate the pictorial effects created by the artist and the last three used as alternative terms in reconstructions in conservation research. However, the conservation field is less familiar with process-related terms like re-enactment or reworking, terms that are employed in other fields discussed in this publication, fields that investigate human history with performative methods. And yet, reconstruction research within the conservation field does often include some form of performance or enactment, as we are also studying historical actions and processes in order to reconstruct historical materials or objects. An example is research into the effects of historical recipes to clean oil paintings that I am currently involved in.[9] In this research, in which we investigate the visual, chemical and physical consequences of the use of historical methods for cleaning oil paintings, we use reconstructions to test and evaluate what actually happens when a historical cleaning agent like wood ashes and water touches a paint surface. And while we use modern methods to document the effects of such exposures (e.g. microscopy, UV induced fluorescence photography, electron microscopy and analysis to investigate chemical changes), we investigate the circumstances of the use of historical methods described and base our approach to

tools or the production methods of ingredients on those available at the time of writing of a recipe. Equally, in our field notes and publications, we document and describe the sensations that we experience while using such methods (the time it takes and the difficulty of making cleaning solutions, the feel of the surface during application, the sounds made by the ashes touching a paint surface, etc.). In short, the process is as important as the final effects.

Where the difficulties lie

As any other researcher who employs re-enactment, replication or reconstructive methods to learn about the past, researchers in conservation are keenly aware of the challenges of bridging the gap between the present and the past in reconstruction projects. It is only very rarely that we know exactly under which circumstances certain materials or methods were employed in conservation treatments. This uncertainty forms the basis of the development of visible retouches or replacements of missing areas, methods that go from 'neutral' retouchings that aim to make damage less obvious without filling in for the artist, to integral retouches that aim to be invisible to the naked eye but still detectable with additional techniques (see discussion below).

The same challenge also influences the way we set up research reconstructions and how we describe the outcomes of reconstruction experiments in publications. Authors reporting on research that involves reconstruction may choose formulations like 'the painting may well have been subjected to this type of handling',[10] or indicate general connections, as in: 'comparison with reconstructions make it possible to read the surface of a painting with enhanced understanding of what that paint must have been like in order to behave as it has',[11] or the description of reconstructions as offering 'flavours and insights'[12]. Verissimo Mendes et al. pointed out in their research into the cleaning of unvarnished contemporary oil paintings that their reconstructions 'are not necessarily representative when compared to the variability of "real, natural" dirt and naturally aged painted surfaces'. As they had available real objects for their research, in this case deaccessioned fragments of original and naturally aged paintings, they were able to draw comparisons between their tests performed on reconstructions and on a real aged object, concluding that 'tests performed with the same cleaning material show that the well cured and aged deaccessioned surface suffered less abrasion and polishing than the relatively young albeit light aged surfaces of the prepared panels'. Yet, they concluded that 'cleaning test results on these [reconstruction] surfaces give a good insight on the potential use of the cleaning materials' on specific young surfaces.[13] I myself have described reconstructions as 'approximations' and pointed out that 'today's researchers lack long-term experience of handling historic materials'.[14]

A specific difficulty in undertaking research into the effects of conservation methods using reconstructions, is the fact that we not only need to consider the distance between the present and the past but must multiply that distance by two. For example, when my colleague Joen Hermans investigates the way solvents used in conservation treatments interact with – or maybe damage – seventeenth-century oil paints, he needs to perform his tests with reconstructions that firstly, represent the composition of the original seventeenth-century oil painting, and secondly, also compare chemically to this same oil painting after three hundred years of ageing, i.e. he requires a reconstruction of an *aged* original. And chances are that a centuries-old painting may even have been cleaned or restored during its lifetime, further complicating the chemical and physical characteristics of the object that he wishes to replicate.

Regarding reconstructions used in conservation research, chemical and physical comparability are of particular importance because these reconstructions function as stand-ins for tests of conservation methods, usually followed by application on original objects themselves,

necessitating sufficient chemical and physical resemblance to make the tests on the replicate relevant for actual conservation practice.

Different approaches have been developed to deal with the complexity of producing reconstructions or test samples that are comparable to *aged* oil paintings. Research into the topic of cleaning water-sensitive paints by Klaas Jan van den Berg and Aviva Burnstock, among others,[15] shows the complexity of, and the necessity to, include reconstruction processes in research that aims to design suitable conservation methods for such fragile paintings.

Reconstruction as conservation treatment: Aesthetic enhancement

Replication processes are introduced into conservation trajectories for two reasons: Firstly, to replace an original, for instance when the decision is made to remove an object from harmful weathering, and when an original is lost, and secondly, to fill in damaged or lost areas and segments of works of art, in a process that is referred to by Muños Viñas as 'aesthetic enhancement'. A famous example of the first category is the lower left panel of the altarpiece by Jan van Eyck in the St. Bavo Cathedral in Ghent. The copy panel of the *Righteous Judges*, painted by Jan van der Veken, art dealer, artist and painting restorer, after the theft of the original in 1934, is still in place.[16]

In processes primarily aimed at aesthetic enhancement, visual comparability is considered more crucial than chemical and physical similarity with the original. In fact, chemical and physical dissimilarity is even considered a positive trait in the filling of lost or damaged areas, as is discussed below.[17] The evaluation of reconstructions as conservation treatments rests on a number of primary criteria, the thoroughness of the research that precedes the reconstruction, the ethical and aesthetic qualities of the result, and a balanced approach to notions of authenticity. In the field it is felt that a replicate(d area) is only acceptable if sufficient evidence can be found to support its visual characteristic, and when the reconstruction is aesthetically and structurally suitable; ideally it should also age in a manner that is comparable to that of the original in order to prevent future dissimilarities.

Historically, aesthetic enhancement was the domain of artists who were hired to restore paintings because of their painting skills. Depending on the context of an object, aesthetic enhancement was not always restricted to reconstruction, but could go much further and cover original surfaces. It could even include the addition of certain elements, for example to adapt a work of art to a new role, a new aesthetic or changed morals.[18] Because for cases in this last category the term reconstruction does not apply, these are not considered in this chapter.

However, with the rise of the conservation profession in the eighteenth century the role of professional artists in conservation slowly decreased, although both professions remained closely related for a long time.[19] With the establishment and professionalization of conservation came the development of conservation theory, and conservation professionals developed conservation ethics. This had its effect on the degree of reconstruction in conservation, as conservation theory started to question the ethical validity of reconstruction as a conservation treatment. In fact, the conservation field has struggled and is still struggling to define the role of reconstruction and its principles as a method. In particular the tension between concept and material, the connection between a reconstruction and its original, the subjective versus the objective, the role of the conservator in the interpretation of the original, and the way in which the public may be informed about replicated areas are central to this discussion.

In the case of severely damaged paintings, conservators have sought and are seeking methods to reconstruct missing areas without falsification of the object: they feel that ideally, the audience should be able to distinguish original from restoration. Nadolny[20] provides a complete overview of the retouching – or 'visual compensation' – systems the field has developed for this

purpose and discusses the historical context of their development. Methods range from fully mimetic or integrated retouches to the application of a 'neutral' tone, neutral in this case being an even tone that is considered suitable for the surrounding painted areas. Between these extremes we find a number of techniques that mimic the original to a different degree, but that can be distinguished visually from close by. Such methods include several stippling (or *pointillism*) and stripe (*tratteggio*) techniques, or the use of fully mimetic or integrated retouches that have a slightly lower surface level than the object's surface, etc.[21] The choice in material used for aesthetic enhancement also plays a role; modern retouching binders having different solubilities than those of the original. This is considered particularly important ethically, because such differences allow for later removal of the retouches without destruction of or damage to original material.[22]

The degree to which the effects of ageing are reconstructed during aesthetic enhancement varies. In fully integrated reconstructions, signs of age such as craquelure in paintings or surface dirt are mimicked using different techniques. Craquelure patterns can for instance be scratched into the paint, a cast can be made of an intact area and used as a mould to impress texture in a filling. The effect of dirt can be created using semi-transparent brownish or greyish paints.

An interesting case illustrating the effects of different approaches to reconstructing severely damaged paintings is the *Holy Kinship* by Geertgen tot Sint Jans (*c.* 1495). This painting, which was restored by Luitsen Kuiper, from 1983-1989 and Gwen Tauber, from 1991-2001, paintings conservators at the Rijksmuseum, Amsterdam, had suffered severe water damage in the past. Overall, approximately fifteen percent of the painted layers was lost, and in particular the painting's bottom half was very damaged, with many areas of exposed wooden support and ground (Figure 7.1). <insert figure 7.1 here> As filling in the losses would have required extensive reconstruction, Kuiper and Tauber started exploring some of the techniques mentioned above, Tauber using as a test panel a fragment of a fifteenth-century panel painting given to the museum for research (Plate 7.1). On this test panel, different techniques with stripes and stipples were explored, each executed to different degrees of fineness and colour resemblance. After careful deliberation and discussion with studio colleagues, museum curators and an advisory commission including external conservators, the choice was made to reconstruct missing areas using a stripe and stipple technique that would only be visible to the trained eye from very close by. The more visible techniques were considered too disturbing, as the conservator and curators thought that they would draw the public's attention away from the preserved original areas. The idea was to restore the losses to such a degree that the unity of the whole composition would be regained, guiding primary attention to the original (intent), before the damage. Craquelure patterns were not imitated. Tauber explained that as such patterns were not very visibly dominant in the original, she did not find their absence in reconstructed areas visually disturbing.[23] The lengths conservators go to in such a difficult reconstruction process is illustrated by the reconstruction of the brocade pattern of saint Elizabeth in this painting. So much of the original gold brocade was lost that it was extremely difficult to reconstruct its folds on the basis of what remained. Tauber finally made her reconstruction using a visual aid fabricated by a colleague, a cloth marked with horizontal and vertical lines, stiffened with glue and pushed into shape following the remnants of the original cloth (Figure 7.2 and Plate 7.2). <insert figure 7.2 here>

Tauber still feels only partly satisfied with some of the reconstructed areas: 'It is better than it was, but the chance that you choose exactly the method of the artist is near zero. You may get close, but never reach it completely. This is a heavy responsibility'.[24] These mixed feelings are why Tauber emphasises the fact that the museum audience can at least learn about the degree of loss in this painting and its restoration treatment in a museum tour and in a book dedicated to this painting and its restoration, as well as the importance of using materials which can be removed

later without damage to the original paint.[25] This means that Tauber's interpretation of the painting can be changed in a new conservation or restoration treatment if information surfaces that necessitates a change, or if our general vision of such paintings or their restoration changes. The term 'retreatability' is commonly used in this context. As discussed by Appelbaum, retreatability can be read both as 're-treatability' or as 'retreat-ability', both terms indicating that reversing or withdrawing should remain possible. The term was adopted by practitioners in the field to replace the earlier term 'reversibility' in conservation ethics, the idea being that current conservation measures should not diminish future options for restoration or interpretation.[26] The issue with reversibility is that absolute reversibility is unattainable in practice, as nearly every conservation measure removes, adds or changes an object in such a manner that it is impossible to remove every trace of this measure. Retreatability is seen as a more practical aim, which also takes into account the fact that the idea of the conservator as a neutral mediator for the object (as an independent entity) is oxymoronic.

The choice of a retouching or reconstruction approach is inherently a personal choice, the restorer deciding which characteristics of the object should be revealed to the audience, which values of the object should be most noticeable, of course within the borders of what is considered ethically defendable and the limitations of what is practically possible, as skill plays an undeniable role. Should the audience know exactly which parts of the object have the same age as the original, or should the audience not know this as visible retouches are considered too disturbing for the visitor experience? Muños Viñas argues that conservation is in essence a creative profession, exactly because of this subjectivity,[27] something that is confirmed by Tauber's account. Even when based on much scientific research, aesthetic enhancement depends as much on the conservator's feeling about what is *right for* or *needed by* an object and on the collection's curatorial policy, as on the conservator's research of the original materials, the state of preservation of the object and on the perceived intention of the artist.

Reconstructions in conservation research

Physical reconstructions in conservation research follow completely different trajectories. Visually, they are also a separate category. In conservation research, such reconstructions often look like long series of squares or rectangles of paint, without any reference to a pictorial image. <insert figures 7.3 and 7.4 here> Sometimes they are not applied by paint brush but with a paint applicator called a drawdown-bar that ensures paint layers of equal thickness (Figures 7.3 and 7.4). While reconstructions executed as aesthetic enhancement are physically connected or part of the original they are reconstructing/completing, reconstructions in conservation research are generally separate objects.

As explained earlier, reconstructions are needed in conservation research because conservators and scientists require surfaces for testing conservation materials and methods, materials and methods that may in the future also be used on original paintings. Also, in degradation studies investigating the way materials change through time, and in preventive conservation studies focused on improving the environment of an object, reconstructions are employed to help understand material degradation or change through time and to determine the factors that influence this change.[28]

A major problem that researchers identify in this approach is dealing with 'the chemical complexity of oil paint and the great variation in paint formulation and paint history', as Hermans writes. In order to find 'true explanations of the phenomena that are observed in real paintings', chemists like Hermans work with model systems and vary a single factor. According to Hermans, such model systems cannot be classified as reconstructions. Yet, the approaches share similarities,

as in using such model systems researchers do try to reconstruct the steps in chemical processes that occur in art objects themselves, even though their experiments are performed out of context, in a situation that differs enormously from that surrounding the creation of a real oil painting. And always the chemist is left with the immense challenge to 'relate this knowledge of paint models to actual paints', which Hermans attempts 'by gradually reintroducing complexity'.[29]

The time gap between the present and the past, and back again from the past to the present needs to be bridged in some way in conservation studies, as replicates of originals are relevant only if they possess certain ageing and degradation features that are similar to those of the original. Two approaches have been developed for the creation of such reconstructions, one making use of a process described as artificial or accelerated ageing, the other directly preparing materials using chemicals that have compositions similar to those that have been detected in the aged original by chemical analysis.

Artificial or accelerated ageing uses extreme environmental conditions to speed up degradation processes that would normally take much longer. Depending on the type of accelerated ageing, different effects are produced. Increased light levels result in the formation of radicals, which initiate further chemical reactions. By raising the temperature, all chemical processes accelerate. Exposing samples or reconstructions to cycles of high and low humidity and/or of high and low temperature creates physical stress, as objects respond to the changes in temperature and humidity through shrinkage and expansion. This leads to the formation of tears and cracks or in flaking paint, visually comparable to the kinds of physical changes seen in naturally aged objects. Accelerated ageing has long played an important role in the paint industry, where it is used to compare materials and their stability under different circumstances. Standards and protocols that have been developed for such industrial applications[30] and equipment built for these standardized ageing tests finds application in conservation research.

While accelerated ageing can be used to explore possible reactions that may occur in materials when exposed to extreme conditions, the use of accelerated ageing to age paint to a level where it resembles an ancient oil paint is problematic. The reason is that extreme environmental conditions do not necessarily result in the same chemical and physical degradation processes that would occur naturally. Different energy levels may lead to different reactions. Therefore, one cannot re-create Rembrandt's paint by simply making a fresh paint according to a seventeenth-century recipe and exposing this paint to high levels of light and temperature. The resulting paint will not necessarily resemble a real seventeenth-century paint, even more so because this seventeenth-century paint has probably been restored a number of times during its lifetime, which has added more uncertain factors to the equation.

Much is still unknown about natural ageing. Therefore, we cannot fully imitate natural ageing with accelerated processes. Robert Feller concluded in his 1994 overview of contemporary approaches to accelerated ageing that 'it is really too soon to expect to find extensive, well-founded recommendations for specific testing procedures.' He was hopeful that 'this may be possible in the not-too-distant future for specific materials such as paper, dyed textiles, and artists' pigments.'[31] Progress has been made since Feller's publication. For example, new insights have been obtained into degradation processes of oil paint. More knowledge about the chemical reactions that may occur during the natural ageing of oil paint can be used to improve protocols for accelerated ageing, which can aim to create circumstances under which such reactions are most likely to occur.

An example of conservation research using artificial ageing is found in the work of Van den Berg with different co-workers on the cleaning of modern oil paintings. Within this context, Volk and Van den Berg published on cleaning methods suitable for surfaces that were covered with epsomite crystals. Epsomite crystals occurring on modern oil paints are thought to be the result of

a chemical reaction between magnesium carbonate, a paint constituent, and sulphurous gases that were abundant in city air during periods of high pollution in the past.[32] Epsomite is very water-sensitive, and severely limits the conservator's ability to clean non-varnished paint surfaces. Volk and Van den Berg worked with reconstructions, or as they call them, 'artificial test paints' in which epsomite crystals were created by exposing paints containing magnesium carbonate to sulphurous gases inside a custom-built box. For their subsequent surface-dirt removal tests, they applied 'artificial soiling', dirt made up of powdered pigments and fillers (ivory black, ochre, silica, kaolin, cement) and organic materials (gelatin powder, starch, olive oil and mineral oil).[33] They explain that reconstructions allow for 'well defined systems', which, for this research is considered an advantage, but they also see limitations and note problems. For instance, in their experiments, the raised temperatures used to speed up degradation during accelerated ageing led to a softening of the relatively fresh paint films, which had the result that the artificial soiling was adhered too strongly to the paints.[34]

The second approach to the problem of bridging the age gap in conservation reconstructions is to eliminate accelerated ageing from a reconstruction protocol altogether and directly create aged paints, as done by Baij and colleagues in their model-system-based experiments into the penetration layers of solvents used in conservation into paint layers. This penetration of solvents is an important concern of conservators, as solvents-on-the-move may 'drag along' small molecules in paint layers that are thus pulled out of place, which may play a role in promoting unwanted short- and long-term chemical reactions within paint layers, and may result in swelling of paint films, which in turn can make paint layers more vulnerable to damage when rubbed or pressed when swollen. To answer the question of how quickly solvents penetrate into aged paint layers, and what effects such penetration may have, Baij et al. chose not to use artificially aged paint films. They rejected this approach for their research because they felt that such paint films would be too complex, obscuring insights into the process they wish to investigate, as every additional variable could play a role in changes, thus confusing their results. Secondly, they asked themselves, why follow the indirect approach of starting with new materials and ageing them to make our test materials (which leads to problems itself), if we can combine the molecules we are interested in investigating directly in the lab? Thus, they set about combining chemical compounds that are found within aged paint films and created their model system. They worked with linseed oil co-polymerized with lead or zinc sorbate complexes, as they found in previous studies that these compounds gave readings in instrumental investigations that are comparable to those of original aged paint films.[35] Their 'paint films' were exposed to different solvents in an ingenious set-up: they placed an ATR-FTIR detector (Attenuated Total Reflection – Fourier Transform Infrared Spectroscopy) on one side of their paint film and distributed the solvent on the other side. The solvent would only become detectable with the ATR-FTIR after having travelled through the paint film. By taking measurements with the ATR-FTIR equipment at different intervals, they were able to determine how long it took the solvent to travel through a paint film. They measured its effects on the paint film, while the same set-up also allowed them to determine the swelling of the paint film (Figure 7.5).[36] <insert figure 7.5>

The above examples underscore the difference between reconstructions in conservation practice that need to visually replace or complement an original, and in conservation research, where a high degree of abstraction is sometimes accepted, and is even considered crucial by researchers who wish to get to the bottom of the chemical or physical changes that underlie degradation effects known to occur in paintings. These researchers lift out single processes from the complexity of the paint layer and re-enact and analyse them.

In this simplification lies the main complicating factor of the approach, for in order for such experiments to have relevance for actual paintings conservation, the results need to be translated to the more complex reality of the conservation studio. Indeed, researchers find this translation extremely challenging and acknowledge that at the moment it is often only partly possible. Due to this issue, the main value of such performative experiments is that they help paintings conservationists understand the principles that lie at the basis of processes we experience in conservation practice. This type of experiment does not lead to tailor-made solutions for individual cases. Therefore, conservation practice is still characterized by extensive testing procedures, practical tests where original paint layers are exposed to different chemicals in order to test their suitability. Trial-and-error still plays a big role in conservation practice, even though trials are executed according to protocols that are designed to minimize risk to the original object, and that rest on an ever-growing scientific foundation.

Recent developments

The last decades have seen the introduction of new reconstruction methods in conservation, both in research and in conservation practice. In particular, digitization plays an important role. Trumpy et al. describe early uses of digital image processing methods to virtually reconstruct what paintings look like without signs of age or degradation, by digitally removing discoloured varnishes or craquelure patterns. Their work aims to check the reliability of digital reconstructions as tools to visualise the effects of the removal of yellowed varnishes. While earlier studies did this by correcting the blue, red and green values, Trumpy et al. train neural networks to make predictions. As the paintings involved are actually undergoing varnish removal at the same time, they can compare their virtual varnish removals with actual varnish removal, concluding that while their approach gives good results, the match is not perfect. They believe that this is due to small local variations in the degree of discolouration and craquelure formation of the varnish, and differences in surface roughness of the paint that influence light absorption and scattering. This indicates the difficulty of digitally modelling or reconstructing variations that exist in the real world.[37] More recently, Kirchner et al. used a different approach, applying the Kubelka Munk theory, in a study focusing on varnish removal from Van Gogh's *Field with Irises*. They had more promising results when comparing the digital varnish removal and the actual varnish removal.[38]

Comparable attempts have also been made to reconstruct areas in paintings that have suffered discolouration due to the instability of particular pigments, such as the blue pigment smalt, organic yellow and red lakes.[39] The effects of such discolourations can be huge, as for instance in the paintings of Vincent van Gogh, who is known to have worked with a red pigment called geranium lake, a pigment that discolours from exposure to daylight and UV-radiation. In paintings like Van Gogh's *Bedroom*, the role of complementary colours is described by the artist in his letters, like the red floor against the green windows and the purple walls against the yellow bed. However, currently, these purple walls have faded to light blue and the red floor has turned pink. While the current state does not reflect the artist's intent, re-colouring the painting (and certainly scraping off the discoloured surface of the paint!) is considered highly unethical because of the invasiveness of such a treatment. Therefore, reconstructions have been chosen to inform the public about the painting's changed state. Described as 'approximations' or 'visualisations' by the researchers involved (Berns et al.), digital reconstructions were carried out, based on what the researchers could find out about paths of discoloration through recipe reconstructions,[40] measurements of the colours in areas that did not discolour – as they had been protected from light by the frame, and the colours of pigments present below the surface, as seen in paint samples. The reconstructions were illustrated in museum catalogues, published in scientific papers and also incorporated into museum

displays (Plate 7.3a and 7.3b). Researchers have also used these digital reconstructions to explore the future discolouration of the *Bedroom*. For, having approximate knowledge of the influence of fading in the past, they project these changes into the future to digitally simulate further colour changes expected in the painting.[41] The Van Gogh museum used these approximations as part of their move towards a new museum lighting system, based – amongst other reasons – on what were considered acceptable future discolouration levels (Fading continues and its rate depends on the amount of light the painting receives.) In an experiment, they showed these simulations with progressive colour fading to several groups of museum staff members and stakeholders and asked them what level of change they would consider acceptable, and within which time range. This information was taken into account in the decision-making process towards new LED museum lights as well as the formulation of new lighting instructions for paintings that go on loan to other museums, and played a role in raising staff awareness and acceptance of a new museum lighting system which lowered the light dosage received by the paintings in the Van Gogh Museum.[42]

In the case of Van Gogh's *Bedroom*, colour change was different for each area, depending on the way the artist mixed and applied his paints. For more homogeneous and well-defined colour changes, another approach has been introduced into conservation: digital retouching with light. This was the method used by Stigter (2016) in the conservation treatment of Dutch artist Ger van Elk's sculpture *Roquebrune* (1970, Frans Hals Museum Haarlem).[43] This triangular sculpture consists of a chromogenic print of a rock on the right side, and a painted version of the same pattern and colour on the left side. Because the photo print had faded, the relationship between the two elements was no longer as originally intended by Van Elk. Stigter describes the decision-making process around the conservation, which involved conservators, curators and the artist himself, discusses the ethical, conceptual and practical consequences of different options, ranging from a complete reproduction or reconstruction of the work to a non-intervention. The action chosen was to use a ceiling spot with coloured light to illuminate the faded plane, light that added such colour to the photographic print that both sides were visually similar again, thus 'retouching' the statue with light to reconstruct its unity.

In the case of Van Gogh's *Bedroom*, 2D reconstructions were used as a tool to restore or reconstruct original colour, and for *Roquebrune* light 'retouching' was introduced. Also, 3D, digitally printed reconstructions are being explored in conservation. [44] An example is research carried out by Beentjes et al. in relation to the restoration of August Rodin's 'Thinker' of the Singer Museum in Laren. When recovered after a brutal theft from the museum garden, the bronze was severely damaged, having suffered attempts to cut it into pieces with a chainsaw and having received blows with a sledgehammer. Distortions, saw cuts and a missing lower leg needed to be dealt with in the conservation treatment. Research led to the discovery of the original casting mould in the Musée Rodin in Paris. A full 3D scan of this mould and of the mutilated statue were made and digitally overlain to identify changes (Plate 7.4). These scans were used by metal conservators as a guide during the re-bending of distorted areas. The 3D scan of the missing lower leg was used to 3D print a mould to cast the replacement part in a mixture of brass powder and synthetic resin (Plate 7.5). Colouring and retouching was carried out by hand, as this was considered the most practical option by the restoration team.

Conclusion

As the cases discussed in this chapter exemplify, in conservation some kind of reconstruction is often part of a treatment. During the act of conserving, a conservator may attempt to improve or optimise the relationship between the current state of an object and its intended appearance as perceived by the conservator and stakeholders. Conservators do not always feel comfortable with

this creative aspect of their profession, as exemplified by the example of the *Holy Kinship*. Here the conservator in particular stressed the importance of telling the whole story to the public, including the reasoning behind the choices and illustrations of the damaged original to avoid falsification. Digital reconstruction techniques that have entered the field recently offer new possibilities to inform the public about what remains of an original and what has been added through reconstruction. This is an area that will no doubt develop further in the future, also because of the interest of museum audiences in this type of information.

Will digital methods replace 'traditional' reconstruction in conservation? It is expected that in some areas their role will increase. For example, do-it-yourself 3D scanning is developing rapidly and future availability of simple tools for scanning objects will offer interesting possibilities for the field. Applications such as computer-designed shaped fillings that can be printed, inserted into an object and subsequently finished on the spot do not seem far away.

In conservation research the role of digital aid is also increasing. Steps are being taken towards the digital modelling of degradation, such as the recent work of Piet Iedema in the Predagio project, modelling oil paint networks and their degradation,[45] and by Akke Suiker, who models the ageing and degradation of wooden objects and their adhesives.[46] While much progress is being made towards representative models in these projects, the complexity of the different chemical and physical processes at play makes computer modelling a great challenge. Designing computer models that replicate all instances that influence degradation of actual objects also remains challenging. An interesting aspect of the approach employed by these researchers is the fact that they make use of physical model systems, i.e. reconstructions, to validate their modelling approach. They compare their computer predictions with laboratory tests to check the outcomes of their mathematical models. In return, the mathematical models aid in guiding the direction of laboratory tests. So, while the balance between reconstruction in the lab and reconstruction behind the computer may change, they play a complementary, mutually supportive role in such research.

Reconstruction projects within conservation are more interdisciplinary now than in the past. In particular the cooperation with philosophy, history of science and anthropology has increased, for instance within the RRR network. In the conservation of contemporary art such connections were established earlier,[47] as evidenced by the application of methods from anthropology, such as the interview, in conservation trajectories[48] or auto-ethnography inspired reflective trajectories.[49]

Such crossings of the disciplinary boundaries lead to a more profound articulation of discipline-related paradigms. Connections with other fields play an important role, as they result in increased attention to methodology that is required for reconstruction to fulfil its role as a mature scientific approach in conservation research and practice. These fields are welcome partners in discussing the way reconstructions themselves influence the way we experience art, in particular the questions they raise about authenticity and object value. For with all current advances towards in-depth understanding of the ageing of oil paint and the development of ever more precise reproductive techniques, we may need to prepare ourselves for the following question: Which do we consider to be the original? The aged three-hundred-year-old Rembrandt or the research-based 'perfect' copy of the painting as it must have left the artist's studio?

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Appendices

Appendix 1: Excerpts from the E.C.C.O. Code of Ethics

Article 5: The conservator-restorer shall respect the aesthetic, historic and spiritual significance and the physical integrity of the cultural heritage entrusted to her/his care.
Article 6: The conservator-restorer, in collaboration with other professional colleagues involved with cultural heritage, shall take into account the requirements of its social use while preserving the cultural heritage.
[…]
Article 8: The conservator-restorer should take into account all aspects of preventive conservation before carrying out physical work on the cultural heritage and should limit the treatment to only that which is necessary.
[…]
Article 15: The conservator-restorer shall not remove material from cultural heritage unless this is indispensable for its preservation or it substantially interferes with the historic and aesthetic value of the cultural heritage. Materials, which are removed, should be conserved, if possible, and the procedure fully documented.
Article 16: When the social use of cultural heritage is incompatible with its preservation, the conservator-restorer shall discuss with the owner or legal custodian, whether making a reproduction of the object would be an appropriate intermediate solution. The conservator-restorer shall recommend proper reproduction procedures in order not to damage the original.[50]

Endnotes

[1] Acknowledgements: Gwen Tauber, Laurent Sozzani, Leslie Carlyle, Joana Devesa, Ella Hendriks, Agnes Brokerhof, Kees van der Meiracker, Tonny Beentjes, Rozemarijn van der Molen, Lambert Baij, Joen Hermans, Katrien Keune, Piet Iedema.
[2] While conservators in cultural heritage care for art objects, they also conserve and restore applied art objects or structures, and artifacts that primarily carry historical value. For ease of reading, the term 'art' has been chosen here and should be seen to include these other categories as well in this chapter.
[3] Although the term 'visualisation' is preferred for colour 'reconstructions'.
[4] Although of course, removing an object to a different location in order to keep it safe may in fact remove meaning and identity from the object depending on its meaning in its original setting.
[5] An interesting discussion on the difficulties of applying such Ethical Codes in conservation practice is given by Smith, 'A Role'.

[6] 'La teinte, le ton et la touche doivent sembler l'ouvrage du maître; cl le goût, les idées, la manière du réparateur ne doivent apparaître aucunement'. De Montabert, *Traité complet*, p. 717.
[7] See Étienne, *The Restoration*, p. 82 ; quoting Bedotti, *De la restauration*, p. 32.
[8] Muños Viñas, *Theory of Conservation*, p. 100.
[9] 'From Wood Ashes', PhD research at the New University of Lisbon by Joana Devesa, supervised by Dr. Leslie Carlyle and Dr. Stols-Witlox, provides a description of the project.
[10] Mengshoel, *In Artists' Footsteps*, p. 136.
[11] Carlyle, 'Exploring the Grammar', p. 37.
[12] Bucklow, *In Artists' Footsteps*, p. 25.
[13] Veríssimo et al., 'New Approaches', p. 387. The 'deaccessioned' in the first quote from this publication refers to the fact that the tests were performed on a painting that was first in a public collection, deaccessioned, i.e. removed from the collection, and donated to science.
[14] Stols-Witlox, *A Perfect Ground*, pp. 224-225.
[15] Both authors have published widely on this topic, with various other researchers. See for example *Issues in Contemporary Oil Paint*, ed. by Van den Berg et al. A full overview of publications is outside the scope of this paper, but a list of publications by Van den Berg can be found at http://www.uva.nl/en/profile/b/e/k.j.vandenberg/k.j.vandenberg.html, checked on February 17th 2019. See for publications on the topic by Burnstock: https://courtauld.ac.uk/people/aviva-burnstock, checked on February 17th 2019.
[16] http://closertovaneyck.kikirpa.be/ghentaltarpiece/#home/sub=panel23, checked on February 17th 2019.
[17] This comment about the emphasis on visual similarity generally applies to paintings produced within a Western European and North American tradition. In particular, in situations where objects have an important spiritual or religious meaning, the balance between material and visual similarity that is aimed at during treatment may be entirely different. See for instance the discussion of the restoration of Thai Stupa, 'Phra Pathom Restored'.
[18] One of the well-known examples of such interventions are the loincloths to cover the nudity of the figures in Michelangelo's *Last Judgement* (1536-1541) in the Sistine Chapel. Added by Daniele da Volterra *c.* 1565, a number of them were removed in the restoration campaign of 1980-1994.
[19] See Conti, *History of the Restoration*, for a discussion of historical restoration treatments and restorers from the sixteenth century onward, with emphasis on Italy and the UK, and Étienne, *The Restoration*, about the rise of the restoration profession in France. Varnish removal and retouching were estimated nobler than structural treatments of painting supports (tear mending, lining, transfer, etc.), and were often the domain of artists, although Étienne's sources did show that restoration was considered by many a last resort for professional artists who had too little success to earn their living with the selling of paintings.
[20] Nadolny, 'History of Visual Compensation'.
[21] Nadolny, 'History of Visual Compensation', pp. 573-585.
[22] Digney-Peer et al., 'The Imitative Retouching', p. 613.
[23] Gwen Tauber, paintings conservator Rijksmuseum Amsterdam, oral communication, 23-10-2018.
[24] Gwen Tauber, paintings conservator Rijksmuseum Amsterdam, oral communication, 23-10-2018.
[25] Wallert and Tauber, *The Holy Kinship*. Unfortunately, and ironically, currently out of print.
[26] Appelbaum, *Conservation Treatment*, pp. 353-359.
[27] Muños Viñas, *A Contemporary Theory*, p. 147.
[28] See the chapter by Carlyle in this publication.
[29] Hermans, *Metal Soaps*, p. 14.
[30] See for instance the accelerated aging tests described by the American Society for Testing and Materials: www.astm.org, checked on October 25th, 2018.
[31] See Feller, *Accelerated Aging*.
[32] Magnesium sulphate is used as an additive in certain modern oil paints. See Silvester et al., 'A Cause of Water-Sensitivity' for a detailed discussion on the formation of epsomite in oil paints.
[33] The recipe for this artificial dirt was introduced by Bronwyn Ormsby, who explains the reasoning behind its composition in Ormsby, 'An Empirical Evaluation', pp. 77-87.
[34] Volk and Van den Berg, 'Agar – A New Tool', pp. 390, 393, 402.
[35] A model system developed in the context of PhD research by Joen Hermans (defended in 2017) which aims to provide insights into chemical reactions between oil and pigments that take place in oil paintings and lead to degradation phenomena.
[36] Baij, et al. 'Time-Dependent ATR-FTIR', p. 7137.
[37] Trumpy, et al., 'Experimental Study'.

[38] Kirchner et al., 'Digitally Reconstructing, Part 1'.
[39] Dik, *Scientific Analysis*; Wrapson, *In Artists' Footsteps*; Kirchner et al., 'Digitally Reconstructing, Part 2'; Kirchner et al. 'Digitally Reconstructing, Part 3' and Geldof et al., 'Reconstructing Van Gogh's Palette'.
[40] Burnstock, 'Comparison'; Kirby, 'The Reconstruction'.
[41] Researchers acknowledge that their approximations of future change are no more than that, noting about that the fading experiments with painted reconstructions that they used for their predictions: 'Obviously, the behaviour of freshly prepared paint is not the same as that of paint more than a century old, but this was accepted as indicating a worst-case scenario'. Hendriks et al., 'Valuing Van Gogh's Colours', p. 2.
[42] Hendriks et al., 'Valuing Van Gogh's Colours'.
[43] Stigter, *Between Concept and Material*, p. 117.
[44] This chapter focuses on conservation applications, not on 3D scanning and printing of art in general. However, the techniques developed by Joris Dik at Delft University may have interesting conservation applications. Dik et al., together with Océ Technologies, have performed research into 3D scanning and printing of paintings, resulting in 3D prints of paintings by Rembrandt and Van Gogh, amongst others. See also Elkhuizen et al., 'Topographical Scanning'.
[45] Iedema et al., 'Mathematical Modeling'. Prof. Iedema is project leader of the project 'Predicting Ageing of Oil Networks', a project that uses multi-scale mathematical modeling to study the microstructure of oil paintings. See http://www.nicas-research.nl/full-projects/predagio/predagio.html, checked on November 26th, 2018.
[46] 'A multi-scale and uncertainty approach for the analysis of the ageing of timber art objects adhesively bonded by animal glues'. Project leader Akke Suiker, TU Eindhoven, Netherlands. This project uses modelling to investigate the physical changes that occur during the degradation of such objects. See: https://www.nwo.nl/en/news-and-events/news/2018/01/eight-projects-receive-funding-for-collaborations-between-scientists-and-museums-with-the-application-of-data-science.html, checked on November 26th, 2018.
[47] See for instance Hummelen and Sillé, *Modern Art*, the book published at the occasion of a seminal symposium on the conservation of modern art in 1997.
[48] Beerkens et al., *The Artist Interview*.
[49] Stigter, *Between Concept and Material*.
[50] *E.C.C.O. Professional Guidelines*, part II, Code of Ethics.