Tempera Painting 1800–1950

Experiment and Innovation from the Nazarene Movement to Abstract Art

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Edited by Patrick Dietemann, Wibke Neugebauer, Eva Ortner, Renate Poggendorf, Eva Reinkowski-Häfner and Heike Stege

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Foreword

From the 15 to 17 March 2018, Munich and its 'Kunstareal' was the location for three days of exchange and experiment on 'Tempera Painting between 1800 and 1950'. The Doerner Institut of the Bayerische Staatsgemäldesammlungen had the pleasure of hosting this international conference with over 270 participants from 22 countries, which took place in close cooperation with the Academy of Fine Arts, Munich, and the Technical University Munich, Chair of Conservation-Restoration, Art Technology and Conservation Science, as well as museum partners Villa Stuck and the Lenbachhaus.

Munich has a long history as a hotspot for artists and scholars interested in painting techniques. All the above-mentioned institutions share an unbroken tradition of theoretical and practical engagement with art-technological questions reaching back into the 19th and early 20th century. Prominent painting technicians including Ernst Berger and Max Doerner researched and taught in this field, and chemists such as Alexander Eibner studied the properties and durability of artists' materials. This milieu inspired influential artists including Franz von Lenbach and Franz von Stuck as well as members of 'Der Blaue Reiter' to experiment with new materials and techniques. In this period, 'tempera' and experiments on new binding media systems were among the most debated and complex topics of painting techniques.

For about 10 years, intense academic research and exchange on this fascinating history of tempera painting has been ongoing among numerous institutions and independent scholars, both in Germany and elsewhere. However, good research always leads to more questions and we felt that this was the moment to share the manifold views and research activities among a broader, international audience, bringing together scholars from the fields of conservation, technical art history, science and art history. The two days of lectures covered a broad range of questions such as: What were the artists trying to achieve? Which materials did they use and how did they prepare and apply them? How can we examine and understand their techniques? In addition to theoretical disputes, the conference offered a day dedicated to practical workshops and guided gallery tours allowing participants to gain hands-on experience of the making of paints and their application as well as a splendid opportunity to study works of tempera painting preserved in Munich museums.

The following is an attempt to provide a résumé of these three days which again revealed so many different facets of tempera painting at the dawn of modernity. Where do we stand with our research and where will it possibly lead us in the future? Some of the expectations regarding this conference might have been to achieve a confirmed definition of the term 'tempera', perhaps to learn how to discriminate between tempera and oil paints by their visual appearance and how to identify tempera paints using scientific analysis. However, it became clear that such expectations could not be met straightforwardly. Written sources between 1800 and 1950 reveal a vast complexity of tempera paints and no general definition. It was shown that their defining feature was often the miscibility with water – at least in the majority of cases. But at the same time, there were exceptions to this rule such as the commercial brand of Wurm's tempera. It became evident that the term 'tempera' held different meanings in different languages and countries: in the United States and the United Kingdom it was confined to egg, while in Germany it was clearly used as an umbrella term for many varied systems. Tempera is of course a very old technical term dating back to antiquity. Its meaning changed even in the short period between 1921 and 1938 in different editions of Max Doerner's *Malmaterial und seine Verwendung im Bilde*. Clearly, the time span and geographical region of a specific topic of research has to be taken into account, for example, by querying what the term tempera meant in this period in general and for the individual artist under consideration in particular. Even having carefully combined documentary sources, technical examinations and analysis, open questions still remain as to how a specific artist discriminated tempera and other paints in his terminology, as has been shown in the case of Paul Klee.

How can tempera paintings be recognized by their visual appearance during technical examinations? The lectures and workshops demonstrated that there is an immense variety of visual appearances, some of which match our models and expectations as to how tempera paints are supposed to look, but others do not. For instance, the painting by Spencer Stanhope, *Love and the Maiden*, looked like tempera but contained no protein binder at all. The best we can do is to carefully describe what we see and observe, combining it with source research, reconstructions and medium analyses.

Even with respect to the allegedly 'hard facts' of scientific analyses, we now have to be aware that their possibilities are also limited in the discrimination of tempera and oil paints. Obviously we need sophisticated chromatographic and spectroscopic techniques in order to identify the individual materials in tempera mixtures. These analytical techniques provide important hints with regard to ageing phenomena and conservation decisions. Analysing complex tempera mixtures has always been a challenge, but in the future we need to integrate aspects of rheology and colloid chemistry that consider complex microstructures of pigments, medium components and solvents – these are the key aspects in correlating the material composition, the original properties of the liquid paints and the visual appearance of paintings created with them.

The conference demonstrated that various methodologies, perspectives and approaches of different professional disciplines need to be combined to obtain the full picture of tempera. For reliable interpretations, we need to intensify exchange and discussions between the many disciplines in the future. This conference could not answer all questions, but hopefully it helped to enhance awareness of the complexity of tempera painting and create enthusiasm and ideas for future research!

Patrick Dietemann, Wibke Neugebauer, Eva Ortner, Renate Poggendorf, Eva Reinkowski-Häfner and Heike Stege

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PAPERS

The paragone between oil and tempera painting in the 19th and 20th centuries

Matthias Krüger

ABSTRACT This paper analyses the art-theoretical, art-historical and art-critical discussion of painting techniques during the 19th and early 20th century. The focus is on the French debate that has received very little attention in the research on the tempera revival, the kinds of insight artists, art theoreticians, art historians and art critics possessed in the practical aspects of painting, and the meaning they attached to different painting techniques. It also examines how they interpreted the historical shift from oil to tempera in early modern times and their reaction to the tempera revival in the 19th century.

New York, 1946

'The first new painting medium in 500 years': these were the words of the slogan used by the Bocour Artist Colors Company in the late 1940s to advertise the newly developed acrylic paint that came onto the market in 1946 under the name Magna Paint (Ball 2001: 369–70). Not only was Magna Paint used by a number of avant-garde artists, such as Morris Louis, who would later be involved in the further development of the paint, it also ushered in a new era of artists' paints, even though it is arguable as to whether, as the advertisement suggested, the invention could be said to match the introduction of oil paint in the fifteenth century. Magna Paint was a product of a booming American paint industry, a veritable colour revolution, to quote the historian Regina Lee Blaszczyk – a colour revolution which since the 1930s had the entire spectrum of American consumer goods from cars to household appliances shine forth in the most vibrant colours (Blaszczyk 2012). At that time, many painters, instead of using paints specially made for artistic needs, turned to paints used in industry. For example, for his famous drip paintings Jackson Pollock used Duco paint, a lacquer developed by the DuPont Company in the 1920s for the automotive industry.

Artists usually choose their painting medium for very practical reasons: in the case of both Magna and Duco Paint, it was the speed with which they dried that made the new paint so attractive. Industrially produced paint, supplied not in tubes but cans, also had the advantage of being much cheaper than conventional artists' paints. However, such practical reasons are usually flanked or overlaid by ideological motives. America had emerged from the Second World War as the new economic, political and military superpower. From then on, the United States claimed to be the leader of the 'free world' – a claim that was also to be consciously expressed through the arts. As Serge Guilbaut has pointed out in his now classic study *How New York Stole the Idea of Modern Art*, the Abstract Expressionism of Jackson Pollock seemed almost tailor-made to meet this requirement (Guilbaut 1983).

Figure 1 Jean-Auguste-Dominique Ingres, *Romulus, vainqueur d'Acron, porte les dépouilles opimes au temple de Jupiter*, 1912, tempera on canvas, 276 × 530 cm, Paris, École des Beaux Arts.

In the construction of a distinctively American art, the new paints provided by the US paint industry offered an opportunity to also break with European tradition in the field of painting technique. Presumably this was precisely the reason for the sudden end of that last significant tempera revival which had come to the fore in American art between 1930 and 1950 (Boyle *et al.* 2002), a revival whose leading representatives included Pollock's teacher Thomas Hart Benton.

The imagery of Pollock's paintings can be interpreted as a utopian attempt to bring into harmony the values of a pre-industrial economy, based on physical labour and craftsmanship, and the technological progress of an industrial age. In the same nostalgic spirit, Benton attempted to revivify the craft of painting as practised by the pre-modern masters. He executed his paintings in egg tempera, a technique which he had taught himself by reading Cennino Cennini's *The Craftsman Handbook* (*Il libro dell'arte*) in 1925–1926 (Griffey and Kornhauser 2015: S.13; Wolff 2012: 203). In this respect, the shift from Benton to Pollock meant not only the transition from a figurative to an abstract style, but also a change from egg tempera to an automotive finish – from a painting medium based on a natural raw material, egg, to an industrially manufactured medium. In an interview given in 1950 Pollock programmatically proclaimed: 'New needs need new techniques … It seems to me that the modern painter cannot express his age, the airplane, the atom bomb, the radio, in the old forms of the Renaissance or of any other past culture' – a statement that has often been interpreted as the final severing of the umbilical cord linking him with his former teacher (Doss 1989: 214).

This paper on the competition between oil and tempera painting, which took place between 1800 and 1950, is concerned primarily with the ideological reasons for taking a position for or against tempera or oil, a competition that may not have come to an end with the arrival of the new painting media made available by American industry to artists in the 1950s, but which had certainly lost much of its relevance. Admittedly, the distinction between practical and ideological reasons is purely analytical because in many cases it is not possible to make a clear differentiation between them. To narrow down the topic, this paper focuses on French art and the French art discourse. This may appear surprising, as the tempera revival was mainly a German, English and American affair, but since Paris was the undisputed centre of the art world during this period, before it relinquished this supremacy to New York in the post-war era, it seems to make sense.

Rome, 1812

In 1800, at the beginning of the period in which the tempera revival took place, Europe was in the midst of major political events in the form of the French Revolution and the Napoleonic Wars, leading to profound political upheavals. One such was secularization. The occupation of Rome in 1808 by French troops, which was followed by the political disempowerment of the pope and the annexation of the Papal State, sent out an unmistakable signal. Yet not only did the age witness a political upheaval, but also the industrial revolution, leading throughout Europe to lasting economic and social change. It was not without consequences for artistic production either, since it gave rise to the production of synthetic paints. There was also a 'colour revolution'.

The tempera revival is linked to all this. However, its supporters did not see themselves as revolutionaries – on the contrary, they were often hostile to the developments mentioned above. This is especially true of the Nazarenes who, opposed to secularism, sought their ideals in the Christian Middle Ages. This attitude led them to found the Brotherhood of St Luke (Lukasbund), and in 1810 to move to Rome, where they led a life of monastic seclusion in the former convent of San Isodoro. Their favoured painting technology can also be seen in this light. Advocating a return to medieval craftsmanship, their main concern was the renewal of the fresco technique, to which they attached greater importance than to easel painting because of its more public character. Nevertheless, besides fresco, they were also interested in other painting techniques, first and foremost encaustic, but also tempera. Strictly speaking, the tempera revival is only one strand within a more general revival of forgotten techniques.[1] Above all, the tempera revival usually went hand in hand with a fresco revival – indeed, tempera was used at first by the Nazarenes merely for the secco retouching of their frescoes; only decades later was it to emancipate itself from the shadow of fresco (Reinkowski-Häfner 2014: 98–110).

In the practice of tempera painting as an independent medium, the Nazarenes were preceded by Jean-Dominique-Auguste Ingres, who had already resorted to the tempera technique in Rome in 1812, using it for his monumental painting *Romulus's Victory over Acron* (Fig. 1), and therefore, as it were, in the immediate vicinity of the Nazarenes. The painting was part of a programme for the Palazzo Quirinale, the former papal summer residence that Napoleon had appropriated and converted for use as his Roman headquarters thereby symbolically claiming political supremacy over the city.

It is an irony of history that in 1848 Pope Pius IX commissioned Friedrich Overbeck, a founding member of the Brotherhood of St Luke, to execute a monumental ceiling painting in the building, which was now once again in church ownership. According to Overbeck's early biographer Camillo Laderchi, it was stipulated that the painting was to be done '*in tempera, figendo una specie d'arazzo*' ('in tempera, simulating a kind of tapestry').[2] For Overbeck, this also meant the opportunity to enter into indirect competition with Ingres with his painting, for which he chose the subject of *Christ Escapes the Pharisees* (Fig. 2) (Thimann 2013).

That Ingres should turn to tempera painting in the same place and at the same time as the Nazarenes began to deal with historic painting techniques is probably mere coincidence – after all, recent research has demonstrated that there was at least sporadic contact between the colony of French artists in Rome and the Nazarenes (Frank 2006; Fastert 2003). In addition, Ingres and the Nazarenes shared a number of artistic convictions that in both cases influenced their recourse to tempera. Ingres and the Nazarenes were convinced that there was no such thing as progress in art. Ingres, for example, saw himself as '*un conservateur des bonnes doctrines, et non un novateur*' ('a conservator of good doctrines, not an innovator'). In a similar spirit Overbeck castigated '*die Sucht nach Originalität in unsren charakterlosen Zeiten*' ('the obsession with originality in our characterless times').[3] Accordingly, Ingres and the Nazarenes took their stylistic bearings from the art of the past. Their models were almost the same – they shared a veneration for Raphael and the masters of the early Renaissance. Ingres's large-format painting, with its frieze-like array of warriors bearing weapons and trophies, is reminiscent of models from the Italian Quattrocento, such as Piero della Francesca's battle scenes from the *Legends of the True Cross* cycle in the basilica of San Francesco in Arezzo, or Andrea Mantegna's *Triumph of Caesar*, executed in tempera, while Overbeck's *Christ Escapes the Pharisees* evokes, for example, Raphael's *Transfiguration*.

Figure 2 Friedrich Overbeck, *Christ Escapes the Pharisees*, 1848–49, tempera on canvas, 296 × 300 cm, Vatican, Palazzo Apostolico, Aula delle Benedizioni. (Photo © Vatican Museums.)

This orientation to historic models dating from the time prior to Raphael also explains why both the Nazarenes and Ingres confronted the topic of tempera painting: yet another reason that was to play an important role in the art-technical paragone throughout the century and may have impressed the artists when considering the tempera technique. The stippled application typical of late medieval tempera painting demanded a highly disciplined approach that did not allow the artist to develop an artistic signature. This had to wait until the more supple technique of oil painting created the condition for the demonstration of manual dexterity that lies at the heart of the early modern concept of bravura (see Suthor 2010). Both the Nazarenes and Ingres strictly rejected such a display of technical skill as it distracted the beholder from the actual content of the picture. Thus, for example, Franz Pforr saw the 'noble simplicity' of Old German painting expressed in its deliberately unpretentious execution: '*hier war keine Bravur des Pinsels, keine kühne Behandlungsart*' ('here was no bravura of the brush, no bold treatment')[4] whereas Ingres took the view: '*Ce qu'on appelle "la touche" est un abus de l'exécution. … Au lieu de l'objet représenté, elle fait voir le procédé; au lieu de la pensée elle dénonce la main*' ('What is called "touché" [or brushmark] is an abuse of execution. … Instead of showing the represented object, it shows the painting technique; instead of the thought, it exhibits the hand') (Delaborde 1870: 150).

Romulus's Victory over Acron, however, was to remain the only painting executed by Ingres in tempera, despite the fact that, according to his biographer Henri Delaborde, the artist's notes included the resolution: '*II faut exécuter tous mes grands tableaux à la détrempe, et puis vernir a l'huile*' ('I should do all my large paintings in tempera and then varnish them with oil') (Delaborde 1870: 215). The fact that *Romulus's Victory over Acron* would nevertheless remain an exception in Ingres's oeuvre does not detract from its significance in the history of painting technique. Although oil remained the dominant painting medium during the 19th century and the first half of the 20th, since then this supremacy has not been as unchallenged as it was from the High Renaissance to the end of the 18th century. Moreover, Ingres also contributed indirectly, through his students, to the revival of historic painting techniques, especially Victor Mottez, to whom is due the first French translation of Cennino Cennini's *Il libro dell'arte*, published in 1858.

Mottez was one of the most vehement critics of oil painting, against which, in spite of the fact that he himself worked mainly in oil on canvas, he carried on a caustic polemic in the annotations to his Cennino edition:

> Oil painting has doubtless produced many masterpieces, but it has destroyed monumental painting, not only by developing a taste for little things and small means, but also by making the work so long and laborious that any major enterprise using it must seem to be impracticable (Tambroni 1858: 33).[5]

Mottez's reservations with regard to oil painting were practical: it was simply too time-consuming to produce anything large.[6]

Charles Blanc on Ingres, 1867

Charles Blanc, one of the most influential art critics, theorists and historians of his time, argues similarly in his biography of Ingres. He recognizes in the picture *Romulus's Victory over Acron* a demonstration of the view expressed by 'eminent connoisseurs': '*que Ingres n'était pas fait précisément pour la peinture à l'huile; qu'il avait* été *créé plutôt pour la fresque ou la détrempe, qui sont les procédés les plus convenables au grand art*' ('that Ingres was not exactly made for painting in oils; that he had been created, rather, for fresco and tempera, which are the techniques most convenient to art on a large scale') (Blanc 1870: 20).

According to Blanc, oil painting had already completed the entire cycle of development which made it possible to judge it from a historical perspective. In Blanc's view, while the three indisputably greatest painters of all time – Leonardo da Vinci, Michelangelo and Raphael – had already painted in oils, they had not yet known how to fully exploit the resources of the new technology. The technique was perfected only in the next generation of artists:

> To tell the truth, the material and indisputable progress that was made in oil painting by Giorgione, Titian and Veronese, and even by Andrea del Sarto, added charm, voluptuousness, intimacy, if you will, and even an additional optical interest; but it is none the less certain that what is most elevated, greatest, and purest in the human mind and heart, the noblest thoughts, the proudest feelings, and also the most beautiful forms of the body were expressed either by fresco, or by oil painting before it was yet perfected, so that it can be said that the improvements brought about first by the Venetians, and later by the Flemings and the Dutch served only to give more pomp to the mise-en-scène, to increase the brightness of the spectacle and the amusement of the eyes. They doubtless redoubled and embellished the feast for the eyes; but the figures became less heroic, the intentions less lofty (Blanc 1870: 21–2).[7]

That oil painting has, allegedly, a stronger sensual appeal than tempera painting is one of the recurrent motives of the painting-technical paragone. Because of the variety of ways in which oil paint can be applied, it is particularly good for the reproduction of tactile qualities such as the depiction of human flesh tints, which was traditionally considered one of the most complex and distinguished tasks of painting (see Bohde and Fend 2007).

There were many who thought only oil painting was *vollkommen tauglich* (entirely suited) for the representation of flesh because of the delicate fusion of hues and the transparency that could be achieved by this technique (Hegel 1838, III: 73).[8] Advocates of tempera painting, however, generally refused to recognize any advantage in oil's greater suitability for rendering flesh. For example, for the Nazarenes, nude painting as practised at the academies was not compatible with their Christian views and was therefore rejected by them as immoral. Undoubtedly the 'unfleshly beauty' later attributed to tempera painting by Christina Herringham, the English translator of Cennino Cennini's painting manual (Herringham

Figure 3 Claude Monet, *Rouen Cathedral. Facade (Sunset)*, 1891–94, oil on canvas, 100 × 65 cm, Paris, Musée Marmottan.

1899: 191), was far more to their liking than the voluptuousness with which oil, according to Charles Blanc, enriched painting.

Charles Blanc too understood the greater sensuality of oil painting only as a relative value, seeing the gain in sensual effect as being associated with a loss of intellectual depth. The greater the appeal it offered to the eyes, the further its standards had sunk. Thus, for Blanc, technical progress had gone hand in hand with a moral decline. The vocabulary he uses in this context – 'pomp', 'spectacle' and 'amusement' – are terms that suggest debauchery and inane pleasures.

While for Blanc, the examples of Michelangelo, Leonardo and Raphael demonstrated that oil painting could be carried out responsibly, the possibilities offered by the painting medium to the painter still constituted a temptation to which most succumbed. The deficit of the tempera technique proved to be an advantage in that it prevented painters from straying from the right path. Blanc was convinced that the less a painting was endowed with 'sensual' appeal, the more it appealed to the 'mind' of the beholder.

More original is Blanc's discussion of the optical surplus that was achieved by the introduction of oil paint. While tempera painting was spiritual in its nature, for him oil painting was above all an art for the eyes. Leonardo had already used the resources offered by oil paint to simulate the laws of visual perception by painterly means, most famously in his *sfumato* technique used to plunge the backgrounds of his paintings into that haziness in which things appear that we perceive from a great distance. But the fact that Blanc talks of optics may well be due to more recent events; after all, he made the comments at a time when pioneering discoveries were being made in the field of physiological optics. Not least, they were to influence Charles Blanc's own colour theory: in the colour chapter of his 1867 *Grammaire des arts du dessin*, he goes into detail on simultaneous contrast and the *mélange optique*, two relatively recent findings in optics (Blanc 1867: 594–610). In the end, his remarks influenced the theory of Impressionism – a style whose programme was not to capture the object itself in its pictures, but the fleeting image that the eye receives from it (Roque 1997; Zimmermann 1991).

André Michel on Claude Monet and Puvis de Chavannes, 1895

André Michel's 1896 essay '*Quelques manières de peindre. Huile et détrempe*' makes Impressionism the subject of the painting-technical paragone, interestingly as a foil to a tempera revival observed by the author. One of the founding fathers of French art history, Michel viewed the art of his time as a hopeless cacophony, ranging from the arch-conservative academic painter William Bouguerau to the uncompromising revolutionary Claude Monet (Michel 1896: 285).

In this stylistic pluralism, however, Michel recognized the culmination of a development that had begun centuries earlier: when Brother Dionysos collected the recipes of religious painting for his fellow monks on Mount Athos, and Cennino Cennini wrote his *Libro dell'arte*, there was still general agreement on the aims and means of art. A hundred years later, however, this harmony was already a thing of the past, and individualism had taken its place. This development was encouraged by the introduction of oil painting, a technique which, precisely because it gave artists more freedom in the execution, had led to the most diverse, not to say contradictory, interpretations of the ideal and of reality. For Michel, Leonardo da Vinci serves as a devastating example; he felt tempera to be unsuitable for the imitation of nature, but instead of relying on tried and tested means, he preferred to mix his paints using his own recipes – a procedure with which, as Michel smugly states, Leonardo predestined his works to early decay (Michel 1896: 285–8).

According to Michel, there were signs that after 300 years of almost absolute dominance, the hegemony of oil painting was gradually coming to an end. In the form of tempera painting, it was now being challenged by the technique that it had once dethroned. Michel regarded Impressionism as a symptom of the decline of oil painting and declared the *Cathedrals* by Claude Monet (Fig. 3), which were then on display in an exhibition at the Galerie Durand-Ruel, as the '*"dernier cri" de la peinture à l'huile*' (the 'swan song of oil painting'). In order to capture the light in its vibrations, *plein-air* painting was, he believed, gradually leading to a complete dissolution of all drawn forms, to be replaced by a universal flickering of coloured molecules. In Impressionism, this had become the principle, a principle that Claude Monet with his *Cathedrals* had driven to such a point that it necessarily drowned in its exaggeration: '*Après un tel effort et une si* étonnante *gageure, un tel abus et une telle dislocation du métier, la peinture à l'huile n'a plus rien à dire, elle a parcouru le champ tout entier des expressions possibles; la sensibilité frémissante et lassée demande grâce et aspire au repos*' ('After such an effort, and such an astonishing enterprise, such an abuse and such a dislocation of the craft, oil painting has nothing more to say, it has run the whole course of possible expression; trembling and weary, sensibility asks for mercy and seeks repose') (Michel 1896: 288–93).

In Michel's view, oil painting had maxed out its options. It therefore aroused, as a natural backlash,

Figure 4 Pierre Puvis de Chavannes: *Concordia (Peace)*, 1861, oil on canvas, 340 × 555 cm, Amiens, Musée de Picardi.

the need for a new, salutary simplicity that Michel finds expressed in the works of Puvis de Chavannes and in the resurgence of tempera painting (Michel 1896: 293). If Puvis de Chavannes is made the guiding light of the forces rebelling against the dominance of oil painting, it was not because he himself was one of the tempera revivalists. His preferred medium was fresco, whose matt, chalky surfaces he sought to imitate in his oil paintings. By doing so, he had confused the critics at an early date.

In fact, as early as 1861, the coloration of his two Salon exhibits *Bellum* and *Concordia* (Fig. 4) had given the critic Théophile Gautier cause to puzzle whether they were cartoons, tapestries or perhaps frescoes:

> What medium was used? Tempera, wax, oil? One can hardly tell, so strange is the gamut of hues, so far outside the usual range; these are the neutral or skilfully muted tones of mural painting of the kind that covers buildings without introducing elements of gross vulgarity and, rather than represent objects, he gives birth to the idea of them (Gautier 1861: 102).[9]

Art criticism repeatedly stylized Puvis de Chavannes as being the antithesis of Realism, Naturalism and Impressionism – trends that stood for contemporary positivism. For precisely this reason Puvis de Chavannes was to become the great role model for the Symbolists.

Since Vasari, oil painting had been regarded as superior to tempera in its imitation of nature. In the course of the 19th century, however, the mimetic function of art radically declined in importance – a process that accelerated catalytically with the invention of photography. Although the new medium was long denied artistic status, at the same time no one disputed that photography surpassed painting in its rendering of reality. But as painting turned away from the imitation of reality, oil painting increasingly lost its monopoly position. This is particularly evident in Symbolism – its disciples' creed was that the less the extent to which painting technique recalls traditional oil painting, the greater its spiritual content. The methods used to achieve this goal could be very different, as Reinhold Heller explained, using the paintings of Paul Gauguin, Edgar Degas, Edvard Munch and Fernand Khnopff as his examples:

> The efforts to construct surfaces as surrogate frescoed walls, the accentuation of unorthodox or orthodox mediums perceptibly used in an unorthodox fashion, and the placing of transparent but reflective glass over the painted images all function to deny the presentation of art as an extension of visible nature. By affirming the material existence and composition of the art work, its non-illusionistic, decorative and symbolic function as the subjective expression of ideas was also affirmed (Heller 1985: 151).

Tempera painting can easily be added to this catalogue of technical resources, but at the same time it was only one alternative to conventional oil painting in a field that was becoming ever wider and more confusing. On the one hand, this was due to a rapidly developing chemical industry, which provided artists with a rich palette of newly developed synthetic paints – including since 1875 industrially manufactured tempera paints for the first time (Reinkowski-Häfner 2014: S.366). On the other hand, it was also due to the multiplication of experimental and often highly individual painting techniques, as can be observed in painting on the threshold of the 20th century. In this context, the competition between oil and tempera increasingly lost its theoretical importance before finally disappearing in the post-war period, when acrylic paint became a more serious rival of oil paint than tempera had ever been since its Renaissance in the early 19th century.

Acknowledgements

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Notes

1. See Karoline Beltinger, 'The tempera revival 1800–1950: historical background, methods of investigation and the question of relevance', in this volume.
2. C. Laderchi, *Sulla vita e sulle opere di Federico Overbeck*, Roma, Menicanti, 1848, cited in Thimann 2013: 86 n. 3.
3. F. Overbeck, letter to his father, 8 February 1815, cited in Hasse 1888: 159.
4. Geschichte des Studiums in Wien von F. Pforr an seinen Vormund Herrn Sarasin in Frankfurt geschrieben, cited in Howitt 1886, I: 83. Pforr considered brushstrokes as '*notwendige Uebel und Mittel zu dem Zweck*' ('a necessary evil and an expedient'). Later advocates of tempera painting voiced similar ideas; see Herringham 1899: 219: 'The beauties of tempera are not those of preciseness of values and gradations, nor of dexterous brushwork. The charm is in its simplicity and carelessness of effect, with complete absorption in the subject, which the picture is the means of realising to the spectator.'
5. '*La peinture à l'huile … a certainement produit bien des chefs-d'œuvre; mais elle a détruit la peinture monumentale, non seulement en développant le goût des petites choses et des petits moyens, mais encore en rendant le travail si long et si pénible qu'une grand entreprise semble avec elle impraticable.*'
6. Mottez's interest, however, was more in fresco than tempera. As he wrote in a letter, he had tried to convert Ingres to fresco, but feared that Ingres would instead yield to the urge of Hippolyte Flandrin, also a student of the maestro, to take up tempera once more.
7. '*A vrai dire, les progrès matériels et incontestables qui ont été accomplis dans la peinture à l'huile par Giorgion, Titien et Véronèse, et même par André del Sarte, y ont ajouté du charme, de la volupté, de l'intimité, si l'on veut, et même un surcroît d'intérêt optique ; mais il n'en est pas moins certain que ce qu'il y a de plus élevé, de plus grand et de plus pur dans l'esprit et dans le cœur humain, les pensées les plus nobles, les sentiments les plus fiers et aussi les plus belles formes du corps ont été exprimés, ou par la fresque, ou par la peinture à l'huile non encore perfectionnée, de sorte qu'on peut le dire, les améliorations apportées par les Vénitiens d'abord, plus tard par les Flamands et les Hollandais, n'ont servi qu'à donner plus de pompe à la mise en scène, qu'à augmenter l'éclat du spectacle et l'amusement des yeux. On a doublé sans doute et embelli les fêtes du regard; mais les figures sont devenues moins héroïques, les intentions moins hautes.*'
8. As late as 1953, when many of his fellow Abstract Expressionists had already abandoned oil colour for acrylic or enamel, Willem de Kooning stated: 'Flesh was the reason oil color was invented', W. De Kooning, *The Renaissance and Order*, 1951, cited in Hess 1968.
9. '*Quel procédé a-t-on employé pour les peindre? la détrempe, la cire, l'huile? On ne sait trop, tant*

la gamme est étrange, en dehors des colorations habituelles; -ce sont les tons neutres ou savamment amortis de la peinture murale, qui revêtent les édifices sans réalité grossière, et font naître l'idée des objets plutôt qu'ils ne les représentent.' English translation by Dorra 1994: 38.

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Author's address

Matthias Krüger, Ludwig-Maximilians-Universität, Munich, Germany (matthias.krueger@kunstgeschichte.uni-muenchen.de)

The tempera revival 1800–1950: historical background, methods of investigation and the question of relevance

Karoline Beltinger

ABSTRACT This paper begins by examining the broader phenomenon of 19th-century craft revivals, listing some relevant examples. It continues with a summary of various investigation methods into the tempera revival that have so far been employed by researchers, commenting on their possibilities and limitations. This is followed by a comparison between other 19th-century craft revivals and the tempera revival. The final part of this paper discusses current knowledge of the geographical spread and relevance of the tempera revival in its time.

Historical background: some observations on 19th-century craft revivals

In art history, the spectrum of stylistic periods from which the 19th century liked to draw was exceptionally broad, spanning classical antiquity, early Christian, Romanesque, Gothic and Baroque periods. As an integral part of what today is referred to as 19th-century historicism, artistic genres, crafts and techniques, which had fallen out of use in the fine arts, were forced back into focus. By listing the most obvious examples in the field of fine and decorative arts, the first part of this paper looks at the broader phenomenon of 19th-century craft revivals, of which the tempera revival was only one.

Stained glass

A rather conspicuous example is stained glass. After its heyday in France in the Middle Ages, the genre had almost disappeared into oblivion. However in the early 19th century, medieval stained glass windows – often badly damaged due to neglect – began to be restored. A workshop for stained glass, the Königliche Glasmalerei Anstalt, was set up in Munich where new stained glass windows were produced following historicist designs. Founding of similar workshops soon followed, most importantly in France, but also in England. The once again popular genre made it into modern times as an integral part of modern architecture (Hofstätter 1965–1967, 2: 143–6).

Mosaic art

Also in the early 19th century, new workshops for mosaic art were established in a number of Italian cities and the education of mosaicists was institutionalized in Italy. New workshops were also established in Munich (1848), Berlin (1896) and Vienna (1908). From the late 1870s onward a successful Italian company, headed by the lawyer and businessman Antonio Salviati, fulfilled innumerable commissions all over

Europe and America. Mosaic art continued to be in demand in the 20th century for large commissions in contemporary styles (Meyer 1990: 490–91).

Graphic arts

The revival of silverpoint drawing in 19th-century Britain was recently discussed by Stacey Sell, who claimed that the main stimulus for the revival of this technique, which had last flourished in the 16th century, was Merrifield's translation of Cennini's *Il libro dell'arte*. The silverpoint revival spread to the Continent and in the 20th century to America also (Sell 2015). Among the first revivalists of the ancient woodcut printing method at the end of the 19th century was Félix Vallotton. In the 20th century the method retained its importance in the context of German Expressionism.[1]

Decorative mural techniques

The craft knowledge and skills for mural painting and decorating had, until the 18th century, been mostly in Italian minds and hands, but 19th-century attempts to revive them were undertaken outside Italy. Manfred Koller's impressive German language reference work *Wandmalerei der Neuzeit* provides a fascinating collection of evidence of 19th-century efforts to track down and reintroduce lost crafts with Italian names to contemporary building in Central and Western Europe (Koller 1990: 218, 246–379).

One example is *sgraffito* decoration: employed since the Middle Ages and first described by Giorgio Vasari, *sgraffito* had later been abandoned. In the 1830s it was reintroduced by historicist architects, among them the German Gottfried Semper, who reported in an article in the German art journal *Zeitschrift für Bildende Kunst* how he had been able to reconstruct it by way of experiments (Semper 1868: 45–8). He also disclosed instructions he had given his workforce for the decoration of the polytechnic in Zürich which, according to Koller, is why Semper's article became an important guideline for other *sgraffito* revivalists (Koller 1990: 364).

Stucco, a crucial element of a number of revived mural techniques, became a focus of revivalist research. In the mid-1830s, the Austrian architect Ludwig Förster published in the trade journal *Allgemeine Bauzeitung* a recipe he had discovered for the ancient stucco type *marmorino.* This stucco is extremely versatile: it can be used white, tinted or painted, it can be finished and polished and is essential for techniques such as *stucco lustro* (used to imitate natural coloured marbles) or *sgagliola* (used to imitate costly marble inlays). As pointed out by Koller, an example of the continuation of the *stucco lustro* revival well into the 20th century and into Expressionism is the work of the Austrian artist Sepp Mayrhuber (Koller 1990: 348–9).

Monumental mural painting

Theoretical debate as to the nature of antique encaustic, which had started as early as the 16th century, intensified in the 19th century. Research and experiments were carried out to test its suitability for monumental murals, especially in France where official attempts to introduce fresco had failed (Koller 1984: 373). When Jacques-Nicolas Paillot de Montabert published up-to-date descriptions of how to use the technique for this purpose, two of his recipes – one with, the other without the use of heat – were put into practice by his fellow artists in Paris for monumental works (Koller 1990: 356).

More important than encaustic as a process for monumental painting was the revival of fresco. The first to struggle with fresco were the Nazarenes. Although they and successive fresco artists were often frustrated by its difficulties, it continued to be employed for public commissions well into the 20th century throughout Europe, North America and Mexico (Koller 1990: 361).

The poor durability of the plaster substrates used in monumental mural painting was a problem and another focus of 19th-century revivalist research. Because the Roman wall paintings of Pompeii were well preserved despite their age, the German scholar, painter and architect Rudolf Wiegmann investigated their substrates. He made plaster reconstructions and apparently monitored their behaviour over a number of seasons. When he published his findings in 1836, he had concluded that one of the keys to their durability was their considerable thickness (Wiegmann 1836: 184). Wiegmann's book had significant impact: Koller states that 19th-century plasters executed after its appearance tend to be up to four times thicker than previously (Koller 1990: 349).

Easel painting

Interest in ancient techniques for (easel) painting was not by any means new, but experienced an unprecedented upsurge in the 19th century. There was a strong desire to learn from the Old Masters, in particular the early Dutch and Venetian schools, and an urge to uncover the secrets of their binding media in order to emulate them.

One of many influential contemporary texts is that first published in 1830 by Léonor Mérimée who, based on his scrutiny of early sources and Old Master paintings, had come to believe that both these schools had added copal to their oily medium (Mérimée 1830: 39). Like other competing hypotheses, Mérimée's suggestions were transferred into practice. Thanks to research at the Tate Gallery we know, for example, that in mid-19th-century England, the artists of the Pre-Raphaelite Brotherhood (who were aware of Mérimée's work) added copal to their oily medium (Carlyle 2004: 47). The combination of oily and resinous components as a formula used in earlier periods remained popular among revivalists (e.g. Knirim 1839: 168–86). In the 1870s, the Italian artist Cesare Mussini developed his own recipes for such a combination, which he sold to the German company Schmincke. Even today, Schmincke's 'Mussini colours' are described as 'based on the Old Masters' formulations'.[2]

In the early 19th century, alternative theories on ancient painting techniques were developed, many of which involved a type of tempera, such as the so-called 'Venetian method': artists including Titian, Giorgione and others in 16th-century Venice were generally believed to have worked with a combination of absorbent groundwork and oil paint. Although there was no complete consensus, according to some revivalists' theories the absorbent groundwork could well have included a tempera underpaint. As pointed out by Guerreiro *et al.* (2011), the British artist George Frederic Watts declared that he used the 'Venetian method' in the 1840s for the monumental work on canvas, *King Alfred Inciting the Saxons to Prevent the Landing of the Danes*. Watts glue-sized his canvas but applied no ground, and then employed an egg-oil emulsion as underpaint for subsequent oil layers (Guerreiro *et al.* 2011: 4, 5). One of several other variants on the 'Venetian method' is evidenced in a copy executed in the 1860s by the German artist Franz von Lenbach after a work by Titian. According to Neugebauer, Lenbach attempted to paint the copy in the original's technique, alternating layers of oil with multiple layers of a tempera composed of egg, copaiba balsam, drying oils and some glycerine (Neugebauer 2016a: 297–308; 2016b: 173–4). Decades later, Max Doerner also described a version of the Venetian method, again a combination of tempera and oil, which also became known as Doerner's 'mixed technique'. After the English translation of his book became available in 1934, Doerner's 'Venetian method' (or 'mixed technique') became popular in America (Brown 2002: 131). Applying tempera together with oil paint according to these and other theories on early schools of painting continued in 20th-century art practice, both in Europe and North America, and is an important aspect of the tempera revival. However, from *c.*1890 onwards, working exclusively in tempera rather than combining it with layers of oil paint became the trend, marking a new chapter in the history of the tempera revival.

Methods of investigation

Research into the historical phenomenon of the European and North American tempera revival probably began in the early 1990s. During that period, Eva Reinkowski-Häfner began to investigate the discovery, study and interpretation of ancient texts on the materials and techniques of painting in tempera by 18th- and 19th-century German-speaking scholars (Reinkowski-Häfner 1994). Around the same time the Brandywine River Museum of Art in Chadds Ford, Pennsylvania, started to investigate the 20th-century American tempera revival (Boyle *et al.* 2002; Brown 2002). Since these and other pioneering achievements, the research has gained momentum. The second part of this paper examines the various methods that have been (and still are) employed in the investigation of the tempera revival which have led to important results, especially when used in combination.[3]

Interpretation of written sources

An important tool of enquiry is the interpretation of texts originating from the tempera revival, such as manuals and technical journals on painting, paint manufacturers' pamphlets on tempera products, patents for historic tempera brands, artists' workshop notes, diaries and correspondence, and contemporary scholarly publications. Nineteenth-century editions of early manuscripts, such as the *Schedula diversarum artium*, Jehan Le Begue's scripture collection and

Cennini's *Il libro dell'arte* are also of interest, although the focus is less on the early sources themselves and more on how the revivalists interpreted them.

A fact that is often deplored by tempera researchers is that unfortunately these sources contain very little information on the exact composition of 19th- and 20th-century temperas. Their formulas, or parts of them, were sometimes kept secret, and the imprecise and shifting meaning of the term 'tempera' can be a problem – even products featuring the term as part of their brand names, such as Pereira Tempera, Wurm Tempera and Tempera Fortuny can represent purely aqueous, purely oily or emulsified systems.

Interviewing artists

Another method of investigation tempera researchers have utilized is artists' interviews. In the early 1990s, Richard J. Boyle and Hilton Brown made exemplary use of this approach when they worked towards the exhibition *Milk and Eggs: The American Revival of Tempera Painting* (Boyle *et al*. 2002; Brown 2002). Around the same time, Lance Mayer and Gay Myers interviewed the American artist William McCloy for their excellent paper on the impact of Max Doerner and Jacques Maroger in North America (Mayer and Myers 2002: 28–9).

Optical examination of tempera paintings

The optical examination of tempera paintings is another useful approach. Through careful scrutiny of the paint layer, experienced conservators may discern the layer build-up employed by an artist. This can provide a better understanding of the tempera paint's properties when it was manipulated by the artist's brush thereby shedding light on an artist's motivation for choosing one particular type of paint over another.

Unfortunately the very basic question as to whether a painting was executed in tempera or oil often cannot be answered on the basis of its appearance alone. In less enlightened times, mattness and luminosity were considered distinctive markers for tempera. Based purely on this misguided interpretation, Ferdinand Hodler's works, for example, were incorrectly believed to be painted in tempera (Doerner 1965: 360–61). In order to distinguish more reliably between tempera and oil on the basis of appearance, researchers have begun to search for subtler clues. In the catalogue for the exhibition *Milk and Eggs* for example, Brown describes being able to identify the difference between oil and tempera in the case of the American artist N.C. Wyeth. Because egg tempera had enabled Wyeth to work in a technique distinctly different from his oil technique, through optical examination it is actually possible to distinguish his works in tempera from those in oil (Brown 2002: 94–7). In other cases this remains difficult if not impossible, especially when the types of turn-of-the-century commercial tempera paints employed were those that had been deliberately designed to behave like and resemble oil paints.[4]

Chemical analysis of tempera paintings

Until recently, the identification of one aqueous component in the binding medium of a paint sample was considered as a marker for a tempera system. However, we now know that the types of tempera that behaved like oils may not contain an aqueous component at all. The struggle to interpret these often complex mixtures can only be resolved by adopting a multi-analytical approach. But even then, the basic question as to whether a work was created in tempera or oil may be hard or impossible to answer.[5]

Chemical analysis of reference materials

The chemical analysis of historic tempera reference materials can be an invaluable tool to provide information on the composition of historic tempera paint products. The reason why this path has rarely been followed is probably the scarcity of such materials. To date, no 19th-century tempera reference materials have come to light, and only a handful from the early 20th century. Wurm Tempera is one of the few historic brands that have been analysed to date.[6]

Reconstructions of tempera paints and painting techniques

A number of reconstructions of tempera paints and painting techniques have been carried out in recent years based on written sources, both printed and archival, and on the visual evidence offered by paintings from the period. In some instances, reconstructed tempera paints were submitted to controlled ageing and analysed during several stages of the ageing process. Analytical strategies were then developed for their identification in samples from paintings (Ferreira *et al*. 2016: 206–16). In other instances, appreciation of the crucial role of individual components for the tempera's behaviour was enhanced, and actually painting with them enabled their properties when fresh to be experienced (Neugebauer 2016b: 171).

A comparison of 19th-century craft revivals with the revival of tempera

Common features

Some of the craft revivals listed in the first part of this paper share common features with each other and with the revival of tempera. One such feature is that, contrary to the impression given by some 19th-century sources, some of the crafts had not actually been lost prior to being 'rediscovered' – they had just drifted out of the technical repertoire employed by academic artists and architects. Craftspeople, builders and decorators had quietly passed on the crafts from generation to generation. For example, when *marmorino stucco* was tracked down by the architect Ludwig Förster, it was still in use in the building trade in Venice (Koller 1990: 348) and mosaic had survived in the pontifical workshops in Rome (Meyer 1990: 489). When the academic painters of the Nazarene brotherhood began to grapple with fresco, the technique was still being used by house painters in Bavaria and the Tyrol (Reinkowski-Häfner 2016: 55, n. 4), as was the *sgraffito* technique in Engadin, Valtellina and South Tyrol (Knoepfli and Emmenegger 1990: 107). When painting in tempera was 'rediscovered', it was still a living tradition in contemporary decorative painting such as the work of the Italian Ippolito Caffi (Perusini and Perusini 2016: 28, 29).

Having been 'rediscovered', the ancient crafts and technologies were soon adapted to modern times and tastes, the most striking example being mosaic, which quickly became a mass production craft (Hansen 1899). Fresco was also used differently from its heyday: fresco revivalists tended to finish their frescoes off with secco retouchings (Reinkowski-Häfner 2016: 41–3) and just before the turn of the 20th century, the Danish artist Oskar Matthiesen, believing that fresco was in need of improvement in terms of beauty and durability, even patented a revised fresco technique (Anon. 1899). Tempera revivalists also adapted materials and techniques to modern times, combining historical principles with creative modification. As recently discussed by Albrecht Pohlmann, from 1893 onwards there was even a progressive tendency in tempera studies inspired by the processes employed in photography (Pohlmann *et al.* 2016: 139–44). In the 20th century, chemically produced biocides, anti-foaming agents and other types of modifiers were added to refine the performance of tempera mixtures. All the revivals proved to be durable – they outlived historicism and lasted well into the 20th century but not into the 21st.

Differences

There also exist fundamental differences between the tempera revival and other revivals. Firstly, the reintroduction of techniques such as silverpoint drawing, woodcut printing, stained glass windows, mosaic art, etc., was inseparable from the revival of a genre. Even in the cases of encaustic and fresco, the revival of the techniques cannot be separated from the revival of a genre (here monumental painting). The renaissance of tempera was different; it was not tied to the revival of a genre, as painting (i.e. easel painting) had always remained prominent. Tempera 'invaded' painting and the changes it caused to the genre are not immediately obvious, which is why the tempera revival as a historic phenomenon has long been overlooked.

Secondly, in contrast to other craft revivals, tempera was not merely driven by the historicist movement, but also by a crisis that had befallen the genre of easel painting: modern paintings tended to age badly. Many artists believed that tempera was more durable than oil and that their works would not last unless they used it. A third very special feature of the tempera revival was that it met with fundamental opposition from outside the movement. Influential figures such as Adolf Wilhelm Keim in Munich, Heinrich Ludwig in Rome and William Holman Hunt in London did not believe in the superiority of tempera.[7] A particular feature of the German tempera revival was the fierceness of the debate on the pros and cons of tempera as an alternative to oil (Kinseher 2016: 59–62, 68–9).

Lastly, the tempera systems developed and propagated by scholars, scientists, artists, restorers and paint manufacturers are heterogeneous, multifaceted and inconsistent. The complexity of the materials employed must be seen as another fundamental difference.

Relevance and impact of tempera between 1800 and 1950

We have seen that other craft revivals were inseparable from the revival of a genre. Because the artworks created in the wake of those revivals are easily recognizable, their number is an effective measure of relevance and impact. Paintings, in contrast to these artworks, do not readily disclose their materials and techniques. The number of works created in (or partially in) tempera – and therefore the relevance and impact of tempera in its own time – is much more difficult to assess. This last section discusses what we have discovered so far as to the true extent of the tempera movement's relevance and impact in its own time.

Some information on the geographical spread of tempera, which may be regarded as one indicator of its relevance and impact, can be gathered from sources relating to ready-to-use commercial tempera paints. Pohlmann *et al.* (2016) published a useful list of tempera brands available up to the mid-1940s in Europe including a small number of products made in Italy and France, one brand each made in Switzerland and Hungary, and a large number produced in Germany – indeed in the first decade of the 20th century, tempera brands from Germany flooded the market. It is reasonable to assume from product pamphlets and advertisements in French and Italian that they found buyers in both France and Italy. Further evidence of their geographical spread is extant correspondence between paint manufacturers and their customers. For example, in the case of Pereira Tempera, correspondence to the Stuttgart-based manufacturer originated primarily from Germany and France, but also from Austria, Hungary, Switzerland, Italy, Poland, Belgium, the Netherlands, Denmark, Finland and North America (Beltinger 2016: 102–16). Correspondence relating to Wurm Tempera indicates a similar spread, with the addition of England, Bohemia and Norway to the list of countries in which those products were used by artists (Berberich 2012: 99–119).

Nevertheless even this type of information is not necessarily an indicator of the proliferation of tempera at the time, as there are very good reasons to believe that the number of oil-paint products on sale at the time must have been greater still. Of course, certain tempera revivalists did not buy commercial products, but made their tempera binders themselves. Evidence for this has to be sought in individual artists' estates and by tracking down private notes and correspondence – not an easy task. While the number of North American artists using home-made egg-tempera binders in the 20th century must have been considerable, it is interesting to note that in 1935 the American artists Vaclav Vytlacil and Rupert Davidson Turnbull wrote in the introduction to their book on egg tempera painting: 'This method of painting … is a more craftsmanlike, more permanent, and more beautiful method of painting' – and now comes the interesting part – 'than the ordinary oil painting as practised today' (Vitlacil and Turnbull 1935: 2). So clearly, at least two American tempera revivalists saw themselves as belonging to a minority.

The answer to the question as to how widespread and relevant the movement really was will no doubt emerge through future research.

Notes

1. A useful summary of the revival of woodcut, not to be confused with the invention of wood engraving, is given in Hofstätter 1965–1967, 1: 153–6.
2. https://www.schmincke.de/en/company/about-cesare-mussini.html (accessed May 2018).
3. The usefulness of a combined approach is demonstrated, among others, by publications such as Boyle *et al.* 2002, Brown 2002, Mayer and Myers 2002, Ferreira *et al.* 2016 and Neugebauer 2016a.
4. An example of this type of commercial tempera is Syntonos paint; see Neugebauer 2016b: 172.
5. For some of the challenges encountered by scientists in the chemical analysis of works created by tempera revivalists in the period between 1800 and 1950, see the following contributions in this volume: Patrick Dietemann, Wibke Neugebauer, Cedric Beil, Irene Fiedler and Ursula Baumer, 'Analysis and interpretation of binding media from tempera paintings'; Annika Hodapp, Patrick Dietemann and Norbert Willenbacher, 'Flow behaviour and microstructure of complex, multiphase fluids'; Kristin deGhetaldi, 'Past, recent, and future developments in the analysis and interpretation of tempera-based systems'.
6. See Wibke Neugebauer, Patrick Dietemann and Ursula Baumer, 'The exception to the rule: reconstructing Richard Wurm's *Temperafarbe*', in this volume.
7. Keim and Ludwig polemicized against tempera; see Kinseher 2016: 60; Ludwig 1887. Hunt, who was extremely concerned with the longevity of painting materials, became fond of a combination of drying oil and copal resin; see Katz 1995: 161.

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Author's address

Karoline Beltinger, Swiss Institute for Art Research, Zürich, Switzerland (karoline.beltinger@sik-isea.ch)

Tempera: narratives on a technical term in art and conservation

Eva Reinkowski-Häfner

ABSTRACT The definition 'tempera is an emulsion' was developed in Germany during the course of the 19th century, fuelled by researches into painting technique, interpretations of technical source texts, the endeavours of painters to copy the tempera painting of the Old Masters, and by the efforts of paint manufacturers struggling with the difficulty of filling tubes with tempera paints. In Max Doerner's last authentic edition of *Malmaterial und seine Verwendung im Bilde* in 1938, tempera is described as emulsion, whereby he included an oil/water as well as a water/oil emulsion which was only miscible with fatty or volatile oils. Influenced by Doerner's book, today the definition of tempera as an oil/water emulsion is accepted in most European languages. This paper discusses the differences in the definition of tempera prior to and after 1800, and between German and other languages. The debate makes clear that when engaged with tempera and tempera painting, the historical development of the term must be taken into consideration and a definition of tempera specific to the period, the region and the individual artist determined.

Introduction

Around 1900, painting technology researchers in the Deutsche Gesellschaft zur Beförderung rationeller Malverfahren (German Society for the Promotion of Rational Painting Techniques) in Munich – such as the painter Ernst Berger (1857–1919), the painter and academy professor Max Doerner (1870–1939) and the scientist Alexander Eibner (1862–1935) – investigated the history and characteristics of the various painting techniques and their binding mediums. Eibner was concerned to create definitions based on material sciences, and took into consideration chemical compositions, binding and drying processes. He attempted to clarify the confusion with regard to tempera definitions and in his strict distinctions between the painting techniques he defined, for example, watercolour as a painting system using only water-soluble binders, while tempera had to use water-miscible binders. Eibner worked on the assumption that egg yolk as exemplary emulsion should be the paradigm for all temperas and defined tempera as an oil/water emulsion which could be thinned with water and dried resistant to water (Eibner 1906, 1909: 263–9, 1926). Doerner's definition of 1921 is identical with the exception of his emphasis that only *natürliche Emulsionen* (natural emulsions) with egg or casein would dry resistant to water (Doerner 1921: 183–97).

Eibner wanted to establish a universal definition for 'tempera' from the antique to the 20th century. His strict categorization of painting systems was torpedoed when water/oil emulsion was introduced as a paint as the result of new colloid and emulsion research (Clayton 1924). In 1938, in the last authentic edition of his book, *Malmaterial und seine Verwendung im Bilde* (*The Materials of the Artist and their Use in Paintings*), Max Doerner even included among the temperas a water/oil emulsion, namely *ölmischbare, fette Tempera* (oil-miscible fat tempera) or simply

Öltempera (oil tempera), alongside the *magere, wassermischbare Eitempera* (lean, water-miscible egg tempera) (Doerner 1938 [1992]: 173–88). In 1940 Kurt Wehlte distinguished between water-soluble oil/water emulsions and non-water-soluble water/oil emulsions as *Öltempera* (Wehlte 1940: 55, 136–137). Since then the term 'tempera' has been used in Germany to refer to water-miscible and oil-miscible emulsions (Kühn 1981) or for any mixture of aqueous and oily binders in ignorance of the actual emulsion processes. This definition cannot be regarded as universally valid as it does not match the definitions in the source literature up to 1800.

Tempera as used in textual sources before 1800

The word 'tempera' comes from the Latin *temperare*, meaning simply binder or mixing of paint. In the most important source on tempera painting, the *Trattato della pittura* by Cennino Cennini (*c.*1390), the term 'tempera' was also used in this sense but in particular for egg paint, for which Cennini provided two recipes. The first 'tempera' consisted of the whole egg mixed with the milky sap of the fig tree, while the second was a mixture of pure yolk added to pigments which had been ground with water. Furthermore, Cennini used the term 'tempera' or *temperare* for animal glue, egg white, for oil or varnish, and he even described fresco plaster as tempera.

In 16th-century sources, such as Giorgio Vasari and Giovanni B. Armenini, *la tempera* referred exclusively to the mixture of whole egg with the milky sap of the fig tree. However tempera still meant binder and the term was even used for oil paint: Michel Angelo Biondo's '*tempera d'oglio*' and Vasari's '*questi olii che è la tempera loro*' described oil-based binders or oil paints. For Vasari and Armenini, painting *a la tempera* was considered the general painting technique of the Old Masters before the invention of oil painting by Van Eyck, as handed down in Vasari's account of the life of Antonello da Messina.

In 17th-century sources a tradition of using egg, glue and gums for tempera can still be observed especially in the field of wall painting, emphasizing the contrast between water-miscible tempera and oil painting. In the 18th century, formulations with animal glue for decorative wall painting and house painting came to the fore. Often whole eggs or egg yolks were no longer mentioned as a binder, but rather, and above all, egg whites, gums and glue (see Table 1) (Reinkowski-Häfner 2014: 345–52). In his 1847 work, *Materials for a History of Oil Painting*, the English painter Charles L. Eastlake (1793–1865) summarized the term 'tempera' thus: in its most general sense 'tempera' could simply mean 'binding medium', in a narrower sense aqueous binding media, and in its narrowest sense it could be used to designate egg yolk or whole egg mixed with fresh fig sap (Eastlake 1847 [1960]: 100–101).

Definitions of tempera in various countries in the 19th and 20th centuries

The term 'tempera' was subject to historical conditions not only in the period before 1800 but also from 1800 to 1950 when the development varied in different European countries, influenced by often poor source research, individual painting practice and by the industrial production of paints in tubes (see Tables 2 and 3, pp. 26–8).

Germany

Around 1800, art historians, restorers, painters and chemists began to study medieval art and painting technique, especially the age of oil and tempera painting. Art-technical source literature, the original paintings and initial attempts at analysis formed the basis for this research (Reinkowski-Häfner 2014: 24–69). Jakob Schlesinger, restorer in the Royal Museum of Berlin, described Italian tempera paintings in 1828 in his article '*Ueber Tempera-Bilder und deren Restauration*' ('On tempera pictures and their restoration'). He examined original paintings and evaluated Cennini's *Trattato*, describing a tempera of egg yolk with a possible addition of vinegar (Schlesinger 1828). The University of Heidelberg drawing master, Jakob Roux, started instead from Vasari's tempera recipe, translated into German by Joachim von Sandrart in 1675. This had laid great emphasis on the mixture of egg with the milky sap of the fig tree (see Table 1). According to an 'analysis' by the chemist Philipp Lorenz Geiger (Geiger *et al.* 1827), Roux mistakenly interpreted the resins contained in the fig sap as the essential component of this tempera.

Table 1 Tempera as used in the textual sources before 1800.

Cennini, C. *Il libro dell'arte*, *c.*1390, F. Frezzato (ed.). Vicenza: Neri Pozza, 2011, 120–21, 141, 154, 200, 203.	**Tempera** Whole egg with fig sap: *binder for mural painting, mixed with water.* Egg yolk: *binder for painting on wall, for easel painting and painting on iron. Pigments are ground in water.* Glue: *binder for blue pigments.* Egg white: *binder for gildings.* Oil and varnish *as strong tempera*. Fresco plaster *as the most noble and strong tempera*.
Biondo, M. *Della nobilissima pittura, et della sua arte, del modo, e della dottrina di conseguirla, agevolmente et presto, opera di Michel Angelo Biõdo.* Venice: Alla Insegna di Appolline, 1549, 20.	**Tempera** Egg, glue. Binding medium in general. Even oil as binder: *tempera d'oglio.*
Vasari, G. *Le vite de' più eccellenti pittori e architettori nelle redazioni del 1550 e 1568*, R. Bettarini (ed.) (6 vols), vol. 1 (1966), 132–4. Florence: Sansoni, 1966–1987.	**Tempera** Whole egg and fig tree sap. Binding medium in general. Even oil as binder: *olii che è la tempera loro.*
Armenini, G.B. *De veri precetti della pittura*, Ravenna 1586, M. Gorreri (ed.), Turin: Einaudi, 1988, 139–40.	**Tempera** Whole egg and fig tree sap.
Sandrart, J. von, *L'Academia Todesca della Architectura, Scultura & Pittura oder Teutsche Maleracademie der Edlen Bau-, Bild- und Mahlerey-Künste* (5 vols), vol. 2, 66. Nuremberg: Matthaeus Merian, 1675.	**Tempera** Egg yolk and fig tree sap.
Pacheco, F. 'Arte de la pintura, su Antiguedad y Grandezas, Sevilla 1649', in Z. Véliz (ed. and trans.)., *Artists' Techniques in Golden Age Spain.* Cambridge: Cambridge University Press, 1986, 45–9.	***Temple*** Size, paste, or whole egg and fig tree sap *for 'sargas' or 'Tüchlein'.* Whole egg and fig tree sap or egg yolk or goat's milk *for the application of smalt in fresco painting.*
Pernety, A. *Dictionnaire portatif de peinture, sculpture et gravure.* Paris: Bauche, 1757, XXIV, 139.	***Peinture à détrempe*** Glue or gum. Size or egg yolk and fig tree sap. *Technique of the Old Masters before van Eyck.*

Roux believed that the resins were transformed into a water-miscible state by the addition of a small amount of egg yolk to create a mixture similar to emulsions (Roux 1828: 10–11). He invented an early non-water-miscible *künstliche Temperamalerei* (synthetic tempera painting technique) by using a mixture of caoutschouc, copal varnish and egg yolk as binder. As a vehicle he used egg yolk, drying oil or varnish but no water (Reinkowski-Häfner 2016: 15–16).

In his 1895 article on Van Eyck's tempera, Ernst Berger described the artist's invention as consisting of converting oil paint into a water-miscible state, a misinterpretation derived from Vasari's formulation '*questi olii che è la tempera loro*'. He introduced the notion of *Öltempera* (oil tempera) , a water-miscible emulsion consisting of egg or gum and oil (Berger 1895). About 10 years later, in 1906, Karl Lupus achieved a patent for a mixture of oil and egg whose vehicle was a mastic varnish; he called this paint *neue Oeltemperafarbe* ('new oil tempera paint') (Anon. 1911; Dietemann *et al.* 2014: 39). In a next step, oil-miscible, water-in-oil mixtures were defined as water/oil emulsions and designated as Van Eyck medium, for example by the German painters Richard Lindmar and Ruhrmann-Remscheid (Lindmar 1935; Ruhrmann 1934).

In the 19th century, as in former centuries, painters expanded the tempera recipes from the source literature by calling on their own practical experience. Arnold Böcklin (1827–1901), who engaged with tempera painting as early as the 1850s, began in 1888 with experiments on a tempera based on a description in the 12th-century *Schedula diversarum artium*, which was considered a reference to painting technique in Northern Europe. In the summer of 1888, he painted *Vita somnium breve* with whipped egg white in close accordance with the source (Neugebauer 2016: 127–35, 248–65). In 1889 Böcklin began to produce mixtures of aqueous cherry-gum solutions allegedly based on a recipe taken from the *Schedula*. Because of a misinterpretation he mixed the gum with oil and balsams. Böcklin failed to produce a stable emulsion: he painted his 1893 self-portrait[1] using a tempera consisting of cherry gum, walnut oil and copaiba balsam, which separated even while he was working with it (Reinkowski-Häfner 2014: 177–8).

Further factors influencing ideas of what tempera was supposed to be were the constraints to which manufacturers of tempera paints in tubes were subject. To avoid separation and degradation, tempera paint makers overcame the difficulties of filling tubes with tempera paints by preparing them as thick pastes of oil and water mixtures, using stabilizers and emulsifiers. The tempera tube paint by the Dresden company Neisch & Co., sold from 1875, was a mixture of egg and oil. Wurm Tempera, by the paint maker Richard Wurm in Munich, available by 1877, was called a *verseifte Oelfarbe* (saponified oil paint).[2] Pereira Tempera was an oil-free multi-component system based on the binders honey, glue, starch and gum, but each paint layer had to be varnished. By contrast, the Syntonos paints introduced in 1893 contained a mixture of gum arabic and oil as binder. Glycerine, wax, tallow and green soap were added as humectants, stabilizers and emulsifiers (Pohlmann *et al.* 2016).

Oil-miscible forms of tempera tube paints such as the Wurm Tempera occur frequently in Germany in the period from 1870 to 1945.[3] Fritz Gerhard supplied oil-miscible forms of casein paint. *Weimar Farbe* (Weimar Paints), an oil-resin paint, was mixed with a *Feigenmilch, künstlich* (synthetic fig tree sap), a wax soap, to produce a tempera that was miscible with turpentine and water (Reinkowski-Häfner 2014: 375–6, 2018: 143–5).

England and the United States

Around 1800, the usual English term for aqueous binders was 'distemper'. Even in Mary Merrifield's (1804–1889) translation of Cennini's *Treatise on Painting*, his 'tempera' was translated as 'distemper' (Merrifield 1844). As previously mentioned, the term 'tempera' was introduced to English technical painting literature in 1847 by Eastlake. In his first edition of *The Chemistry of Paints and Painting* of 1890, the English chemist Arthur Church (1834–1915) described 'tempera painting or painting in distemper'. The binding media egg yolk he called an 'oily emulsion', which should be mixed with water or egg white. Church treated 'painting in distemper' and 'painting in tempera' as equivalent (Church 1890: 63, 239–41), although by the second edition of 1892 he was applying the term 'distemper' to wall paints with size or starch as well as primings (Church 1892: 276, 288).

Tempera painting had been widespread in England since the 1870s. Painters such as Joseph Southall (1861–1944) and members of the Society of Painters in Tempera, founded by Christiana Jane Herringham (1852–1929) in 1901,[4] felt obliged to follow Cennini's recipes with pure egg yolk.[5] The influence of the German idea of tempera can be seen in the oil/water emulsions introduced by Percyval Tudor Hart (1873–1954) in 1922, although he termed these mixtures 'emulsion' and not 'tempera' (Tudor Hart 1925). In 1924 Maxwell Armfield (1881–1972) came up with an 'egg and varnish tempera', which contained in addition to egg yolk and water, four drops of varnish (Armfield 1925). Today British technical paint literature only cites oil-free tempera recipes – a mix of oil and egg is not considered 'normal' tempera (Seymour 2007: 214–19, 226–7).

In the United States, at Harvard and Yale, there is a tradition of education in painting techniques by Edward Waldo Forbes (1873–1969) and his pupil Daniel Thompson (1902–1980) (Galassi 2009). In his book *The Practice of Tempera Painting* of 1936, Thompson described in particular a tempera binder consisting of egg yolk and water. A chapter on 'artificial emulsion' painting at the end of the book was appended where, for example, water-miscible mixtures of egg and oil were described (Thompson 1936 [1962]: 96–8, 129–31). The translation of Max Doerner's book into English in 1934, in which Doerner's 1921 definition was adopted, may have had an influence in this case.

In their *Short Encyclopaedia* of 1942, the American chemist Rutherford J. Gettens (1900–1974) and the restorer George L. Stout (1897–1978) described distemper as glue painting for theatre scenery and walls. The entry 'tempera' followed the explanations of Eastlake and Church. In the entry on 'egg tempera' they referred to Thompson's pure egg recipes, as well as to 'present-day recipes' by Max Doerner and Kurt Wehlte, which were mixtures of egg with oil or varnish. An additional entry, 'emulsion', described oil/water and water/oil emulsions and the interpretations of the Van Eyck technique (Gettens and Stout 1942 [1966]: 18–23, 69–71).

The American artist Ralph Mayer in the first edition of *The Artist's Handbook of Materials and Techniques* (1940) defined distemper as the use of glue-size or casein binder for wall painting and decoration, and tempera as an emulsion of egg yolk and water. Mayer was familiar with emulsions of egg and oil and water and noted that 'most of the published formulas for egg/oil emulsions are apparently of German origin'. What was new was his discussion of the term 'oil tempera', which he did not categorize among the tempera techniques on account of its oil miscibility (Mayer 1943: 181–4, 187–8, 195–7, 503).

The British and Americans seemed closer when it came to the commercial tube paints on offer: Daler-Rowney offered tubes of Egg Tempera Colour, which contained an egg yolk and linseed oil emulsion (Daler-Rowney 1994: 32) and today the company advertises a paint containing 'liquid egg yolk, according to a formulation dating back to 1906'.[6] The American Martini Artist Color Laboratories produced tempera paints in tubes that contained both egg and oil (Mayer and Myers 2013: 206).

Spain

In 1837 Soler i Oliveras described *temple* as painting in which pigments ground in water were mixed with binding media such as glue, gum or *temple de huevo* (egg tempera) (Soler i Oliveras 1837: 163). In the 19th century, Spaniards held to the tradition of producing *tüchlein* or *sargas* (tempera on fine linen),[7] which Francisco Pacheco (1649) named the binder consisting of animal glue, paste and whole egg, mixed with the milky sap of the fig tree (see Table 1). The Spanish also changed their concept of *temple*, which was already influenced by the translation of Max Doerner into English in 1934. Bontcé put forward oil/water emulsions as the '*version actual*' of *temple* (Bontcé *c.*1940: 105). The Spanish translation of Ralph Mayer's book followed in 1948. Although the Spanish translation of Max Doerner's seventh edition of 1941 appeared in 1946, the current Spanish technical painting literature describes *temple* as only a water-miscible emulsion of aqueous and oily binders, which should dry in a non-water-soluble state (Alegre Cavajal 2016: 218).

France

In France, the term tempera was not used, but always translated as *détrempe*. In 1829, Jacques Paillot de Montabert (1771–1849) emphasized that *détrempe* simply meant the action of mixing and for this he preferred the terms *peinture à la colle* and *peinture à l'œuf*. In contrast to the English, Montabert knew how to modify pure egg paint by emulsifying it with resins. He also listed several drying retardants, including an emulsion of gum and wax oil (Paillot de Montabert 1829: 437–50).

In 1891, the French painter Jehan George Vibert (1840–1902) followed Montabert's definition. In a modern reconstruction of *détrempe à l'œuf*, Vibert recommended a combination of casein, resin dissolved in egg oil, and wax saponified with ammonia. Vibert's formulation was probably used in the production of tempera paints in tubes by the Lefranc company, which were available from 1890. Vibert was not aware of any definition as an emulsion (Vibert 1891: 239–47).

André Béguin's *Dictionnaire technique de la peinture* of 2001 discusses the development of tempera. He uses the term *détrempe* like Montabert but the term 'tempera' is new, defined first as an emulsion of egg yolk and water, and secondly as a mixture of aqueous and non-aqueous media. *Tempera d' huile* (oil tempera) is referred to as an oil/water emulsion (Béguin 2001: 380–82, 420–21, 1257–8). This shows that Eibner's water-miscible tempera recipes also found their way into French sources. Since the French had, in the person of the technical director of the Musée du Louvre, Jacques Maroger (1884–1962), someone who had searched for the Van Eyck medium, they were also aware of oil-miscible, water-in-oil mixtures (Maroger 1948: 41).

Italy

In Italy, Lorenzo Marcucci described his tempera recipe with egg yolk and a small addition of lemon juice but he was also aware of additions of oil or resins to casein paint (Marcucci 1813: 192–4). Eastlake's tempera definition was also known in Italy from his Italian translation of 1849. The Italian painter and

Table 2 Tempera: German, British and American definitions.

German		British		American	
Schlesinger 1828: 35	***Tempera*** Egg yolk + vinegar.				
Roux 1828: **10–11** **Roux before 1830** **(Reinkowski-Häfner** **2016: 15—16)**	***Tempera*** Emulsion of 3 parts 'resins' (fig tree sap) + 1 part egg yolk, water-miscible. ***Synthetic tempera technique*** Caoutschouc, copal varnish and egg yolk. Vehicle is egg yolk, drying oil or varnish, no water.				
		Merrifield 1844	***Cennini's tempera*** Distemper.		
		Eastlake 1847 **[1960]: 100—101**	***Tempera in the sources until 1800*** *General sense:* binding medium. *Specific sense:* aqueous binders. *Restrictive sense:* yolk or whole egg mixed with fresh fig sap.		
Berger 1895	***Van Eyck's invention (new tempera)*** Egg/gum + oil. Emulsions (O/W). Oil tempera (O/W!).	**Church 1890: 63, 239–41** **Church 1892: 276, 288**	***Distemper*** Paint with size for primings, grounds and walls. ***Tempera*** Paint with egg. ***Emulsion*** Egg yolk + egg white + water.		
Lupus 1906 **(Anon. 1911)**	100 parts egg + 75 parts oil, ground under reduction of water = 'new oil tempera paint'. As vehicle: mastic varnish	**Laurie 1913**	***Van Eyck medium*** 'Emulsion (O/W) of egg and varnish' ≠ tempera.		
Doerner **1921: 183—97**	***Tempera*** Emulsion (O/W). ***Natural tempera*** Egg, egg yolk, egg white, casein + oil + water. ***Artificial emulsion*** Gum, glue, paste + oil + water Wax soap	**Tudor Hart 1925**	Emulsions (O/W) ≠ tempera.		
Lindmar 1935	***Van Eyck medium*** 'Oil miscible emulsion paint'.	**Armfield 1925**	***Tempera*** Emulsion = egg + water + 4 drops of varnish.	**Doerner 1934**	***Tempera*** Emulsion (O/W).
Doerner 1938 **[1992]: 173–88**	***Tempera*** O/W emulsion = lean, water-miscible. W/O emulsion = oil-miscible. Fat tempera, oil tempera.			**Thompson** **1936 [1962]:** **96–9, 129–31**	***Tempera*** Egg yolk + water. ***Artificial emulsion (O/W)*** Egg yolk, glue, casein + oil, water-miscible.

Wehlte 1940: 16	***Tempera*** O/W emulsion, water-miscible. ***Oil tempera*** W/O emulsion, oil-miscible.			**Gettens and Stout 1942 [1966]: 18–23, 69–71**	***Distemper*** Glutinous medium for walls, scenery paintings. ***Tempera*** See Eastlake's definition. ***Egg tempera*** Egg + water. Egg + oil/ varnish + water. ***Emulsion*** O/W and W/O emulsion.
				Mayer 1943: 181–4, 187–8, 195–7, 503	***Distemper*** Glue-size or casein binder for wall painting and decoration. ***Tempera*** Emulsion. Egg yolk + water. Egg and oil. ***W/O emulsion*** Oil tempera ≠ tempera [due to 'use, behaviour, and effect, it is classed among the tempera media'].
Wehlte 1967: 604—10	***Tempera*** O/W emulsion. ***Oil tempera*** W/O emulsion. ***Soap emulsions***				
Kühn 1981: 46–7	***Tempera*** O/W emulsion. W/O emulsion.	**Seymour 2007: 214–19, 226–7**	***Tempera*** Pigments with a water-thinnable binding medium: gum, glue, casein, glair, egg yolk. ***Egg-oil emulsion***	**Mayer 1982: 228–54**	See Mayer 1943

Table 3 Tempera: Spanish, French and Italian definitions.

Spanish		French		Italian	
				Marcucci1813: 192–4	***Tempera*** Whole egg, with some lemon juice. Milk + lime. Milk + lime + oil or resin.
Soler i Oliveras 1837: 163	***Temple*** Pigments ground in water, glue, gum and *temple de huevo* (tempera of egg) as binders.	**Paillot de Montabert 1829: 437–50**	***Peinture à l' oeuf*** Egg + varnish. Retarder: emulsion of wax oil and gum.		
				Eastlake 1849	
		Vibert 1891: 239–47	***Détrempe*** Gelatine, casein, gum. ***Peinture à l'oeuf*** Egg yolk + water or egg yolk + varnish + saponified wax.	**Secco Suardo 1858: 51; 1894, 2: 280, 321–5**	***Tempera*** Pigments ground in water + glue and egg. ***Tempera dura* or *molle*** Milk, paste, gum, fig sap and other plant saps. Oil-free recipes of parchment glue, egg, milk or gum, egg and milk.
				De Chirico 1928 [1983]: 28–49	***Tempera magra*** Water-miscible binders without oil. ***Tempera grassa*** Water-miscible binders with resins or oils, emulsified with water.
Bontcé *c.*1940: 105	***Pintura al temple*** Emulsion (O/W).	**Maroger 1948: 41**	***Tempera*** Glue, egg, gelatine, cheese, blood, gum arabic, cherry gum, fecula. ***Van Eyck medium*** Oil paint + emulsion of egg and oil, thinned with essential oil and water.		
Doerner 1946; Mayer 1948					
Alegre Carvajal 2016: 218	***Temple*** Emulsion (O/W) with oil- and water-miscible binders, drying to water-resistant state.	**Béguin 2001: 380–82, 420–21, 1257–8**	***Détrempe*** Diluting the pigments with a binder. Contrary to oil paint. '*Peinture à la colle*'. Binder: gum, glue, egg + water. ***Peinture à l'oeuf*** Emulsion. Egg yolk + water + varnish. ***Tempera*** Egg + water. Egg + oil. ***Emulsion*** Egg yolk + water. Aqueous and non-aqueous media. ***Tempera à l'eau*** Aqueous binders. ***Tempera d'huile*** Emulsion (O/W).	**Piva 1984: 392–408**	***Tempera commune*** With glue, gum, egg yolk, wax.

restorer, Giovanni Secco Suardo, in his 1858 book on the discovery of oil painting, defined tempera as a painting system in which the pigments are ground in water and bound with glue and egg. In 1894 he provided oil-free recipes using parchment size, egg and milk or gums (Secco-Suardo 1858: 51; 1894, 2: 280, 321–5). Nevertheless, the Italians were influenced by German research into painting technology. In 1928, in his *Piccolo trattato di tecnica pittorica*, Giorgio de Chirico (1888–1978), who studied at the Academy in Munich from 1906 to 1909, gave recipes for a water-thinnable *tempera grassa*, which corresponded to the oil tempera of Ernst Berger. De Chirico claimed to have painted the 1924 picture *Autoritratto con la tavolozza* with a *tempera grassa* (De Chirico 1928: 28–49).[8]

Italian tempera paints in tubes consisted of aqueous and oily components, but were always water-thinnable, namely the Tempera Muzii and the Tempera grassa di Maimeri (Baroni *et al.* 2016). In their painting practice, however, Italian painters also encountered oil-miscible tempera paints when ordering the non-water-miscible Wurm Tempera from Munich in the 1890s (Berberich 2012: 162–4, 211–15).

Considerations on the use of the term tempera

Variations in historical and regional developments confirm the failure of Eibner's attempt to provide a universal definition of tempera from antiquity to the present. The problem can be solved by tracking down the prevailing idea of tempera for each period, region and artist under consideration and taking into account a number of perspectives (Neugebauer 2016: 397–426):

- the use of the term in the art-technical writings
- the assessment of the visual appearance of tempera painting
- tempera as a paint material and the way artists and paint manufacturers handled it
- the possibilities of, and difficulties in, detecting tempera by chemical analysis.

Dealing with source texts

Around 1900, Eibner's definition of tempera as an oil/water emulsion in Germany was considered standard and can still be found today in all languages as a result of the international dissemination of Doerner's book of 1921. However, Eibner's and Doerner's definition cannot be transferred to earlier centuries – this applies not only to the period before 1800, but also to the 19th century. For example, Eibner and Doerner excluded from their tempera definition the oil-free Pereira Tempera, a painting system used by an international art community (Beltinger 2016: 102–17). Furthermore, even a term such as 'emulsion' can conjure up different ideas. For English and French readers 'emulsion' signifies egg with water, while every German thinks immediately of a mixture of egg and oil. Another ambiguous term is *Öltempera* (oil tempera) as used by Berger in 1895 for a water-miscible emulsion. When research into emulsions described water/oil emulsions (Clayton 1924), the term 'oil tempera' assumed a different meaning and was used by Doerner in 1938 to refer to a water/oil emulsion. Since oil-miscible tempera forms have been known from the 1870s, it is not always clear which definition the respective author, artist or paint producer is following: water-miscible or oil-miscible. In other languages, the water/oil emulsion definition is generally not accepted as tempera because of its oil miscibility.

Paintings: visual appearance

The best-known tempera effect is the brushwork of Italian early Renaissance paintings. British painters and the Pre-Raphaelites tried to imitate it accurately with paint comprising egg yolk but John Stanhope (1829–1908) in 1877 copied this effect successfully with oil paint.[9] The visual appearance of tempera paintings from the period 1800–1950 does not always display an obvious feature of tempera painting such as matt and light colours or the typical brushwork of a water-miscible paint (Doerner 1921: 182–90). Stuck's *War* (*Der Krieg*) was painted with Syntonos paints, which sought to emulate oil paints, but this painting cannot be recognized as a tempera work by its visual appearance (Neugebauer 2016: 146–56, 321–40).[10] By contrast, the *Nude Child* (*Kinderakt mit Goldfischglas*) by Paula Modersohn-Becker,[11] which is painted with the non-water-thinnable Wurm Tempera, evidences a matt and dry paint application, which is commonly meant to be characteristic of tempera (Kruppa 2011: 107–25). For these reasons the American Ralph Mayer stated that although water/oil emulsions are not covered by the tempera definition, 'yet, from the point of view of its use, behavior, and effect, it is classed among the tempera mediums' (Mayer 1943: 196).

As conservators, we can often identify when an artist may have used tempera, not by the surface appearance of the painting but by its water sensitivity. This fact also refutes definitions that assume all temperas to be water-resistant when they are dry.

Paints

When using tempera, it was of primary importance to artists that the paints were water-miscible, in contrast to the oil-miscible oil paints. However, artists often modified their binders to make them more durable or supple, producing unstable mixtures that caused difficulties when painting, as can be seen with Böcklin's so-called *Kirschharz* (cherry gum) tempera. Just how much the artist's opinion of tempera must be taken into account can be demonstrated by Paul Klee's use of the term 'tempera'.[12]

Tempera tube paints, with their diverse combinations of binders, additives and auxiliary agents, did not always achieve a typical tempera paint application. In England, Syntonos paints were advertised as a 'perfect substitute for oil paints', allowing a 'continuous working process' without drying times.[13] The Italian painter Cesare Laurenti, on the other hand, complained about Wurm Tempera as, probably contrary to expectations, these paints were not water-thinnable (Berberich 2012: 211–15). Tempera paint products around 1900 usually claimed, like homemade paints, that they combined the properties of the water-based and oil paints. While not guaranteeing specific material properties, they did promise a wealth of variants that allowed a wide variety of qualities ranging from impasto to translucent applications and surface appearances from matt to glossy (Wehlte 1940: 16). Nevertheless, miscibility with water was a primary requirement, even if in Germany oil-miscible forms were no exception.

Analysis

Due to the German definition of tempera, until the end of the last century results of chemical binder analyses were prematurely interpreted as tempera when mixtures of oily and aqueous binders were detected. Patrick Dietemann demonstrated the possibilities of producing such mixtures both in oil and tempera painting, namely as an oil/water emulsion and possibly a water/oil emulsion, as an aqueous additive to oil paint, as unstable mixtures, or as coating for the pigments (Dietemann *et al.* 2014). Here, too, lie the difficulties of chemical analysis to confirm whether the paint has been applied in aqueous or oily form, and if it should be called a tempera or an oil paint.

Conclusion

With regard to tempera and tempera painting, the historical development of the term must be taken into consideration and a definition of tempera specific to the period, region and the individual artist determined based on source research, examination of the paint material, painting surfaces and scientific analysis.

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Notes

1. Arnold Böcklin, *Selbstbildnis im Atelier*, 1893, 120.5 × 80.5 cm, Kunstmuseum Basel, inv. no. 113; A 437.
2. Letter from Max Klinger to Hermann Prell, August 1885, Sächsisches Staatsarchiv, Dresden, Archivbestand 12755 Personennachlass Hermann Prell.
3. See Wibke Neugebauer, Patrick Dietemann and Ursula Baumer, 'The exception to the rule: reconstructing Richard Wurm's *Temperafarbe*', in this volume.
4. See Herringham 1899 for a translation of Cennini's *Il libro dell'arte*.
5. See George Breeze, 'Joseph Southall and the tempera revival' and Michaela Jones, 'If there is no struggle there is no victory': Christiana Herringham and the British tempera revival', in this volume.
6. http://www.daler-rowney.com/en/egg-tempera (accessed 27 May 2018).
7. See Esther Aznar Franco, Susana Martín Rey and María Castell Agustí, 'Studies on the consolidation treatment of a collection of 19th-century *tüchlein* from the Palau Ducal of Gandia, Valencia, Spain', in this volume.

8. Giorgio de Chirico, *Autoritratto con tavolozza*, 1924, Kunstmuseum Winterthur, inv. no. 904. For other Italian painters who used emulsions as tempera, see Teresa Perusini, Giuseppina Perusini, Francesca C. Izzo and Giovanni Soccol, 'Tempera painting in Veneto at the beginning of the 20th century', in this volume.
9. See Elise Effmann Clifford, '*Love and the Maiden* by John Roddam Spencer Stanhope: assumptions and the importance of analysis', in this volume.
10. Franz von Stuck, *War* (*Der Krieg*), 1894, 245.5 × 271 cm, Bayerische Staatsgemäldesammlung, Neue Pinakothek, inv. no. 7941.
11. Paula Modersohn-Becker, *Nude Child* (*Kinderakt mit Goldfischglas*), 1906–1907, 105.5 × 54.5 cm, Bayerische Staatsgemäldesammlung, Pinakothek der Moderne, München, inv. no. 13468.
12. See Patrizia Zeppetella, Stefan Zumbühl and Nathalie Bäschlin, '"Then egg, then watercolour or tempera paints, then alcohol resin": Paul Klee's tempera painting techniques', in this volume.
13. Advertisement for 'Syntonos Colours', Archive Museum Stuck, Munich.

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Author's address

Eva Reinkowski-Häfner, Universität Bamberg, IADK, Bamberg, Germany (eva.reinkowski-haefner@uni-bamberg.de/eva.reinkowski@t-online.de)

Colour and form in highest perfection: teaching tempera in the early 20th century

Kathrin Kinseher

ABSTRACT The revival of tempera painting in the late 19th and early 20th century was accompanied by an increasing knowledge in the use of tempera paints. This paper discusses the teaching of tempera painting in the early 20th century, when painting techniques and materials became integral to the training of artists, and presents a selection of schools in London, Vienna, Berlin and Munich. Teachers of these new subjects included chemists Arthur Herbert Church, Friedrich Linke, Ernst Täuber and Alexander Eibner, and artists Albert Wirth, Ernst Berger and Max Doerner. The investigation reveals the academic knowledge of tempera in the early 20th century and presents different practices and ideas of tempera painting.

Introduction

Pohlmann *et al.*'s (2016) overview of commercial tempera paints confirms the popularity of these paints, which were distributed by many different companies and used by a number of artists. Given the widespread use of this technique, the question arose as to whether technical knowledge of tempera paints was included in the training of artists. This paper examines the dissemination of tempera painting and investigates what was taught in technical painting classes at art academies.

Technical painting classes

In general, little is known about technical painting classes but it is clear that lessons were introduced as an independent subject during the latter part of the 19th century. An important initiative to promote their implementation in Germany was the first major congress of painting techniques in Munich in 1893, which took place concurrently with the *Ausstellung für Maltechnik* (*Exhibition of Painting Techniques*) (Kinseher 2006). Several art academies and art schools sent delegates and representatives (Anon. 1893: 412–13) (Table 1). During this congress a resolution was passed which demanded instruction in painting materials, their use, properties, production, ageing and chemical effects (Anon. 1893: 481). Ten years later, Adolf Wilhelm Keim (1851–1913) discussed the outcomes of this resolution in *Ueber Mal-Technik* (*On Painting Technique*). He referred to the academies in Berlin, Vienna, Munich, St Petersburg and London as commendable and exemplary institutions where classes and lectures on painting materials and techniques were already established (Keim 1903: 21–31). This contribution presents the academies and some of the teachers mentioned by Keim with the exception of St Petersburg.

Table 1 Delegates from art academies at the Munich *Maltechnik Congress* 1893.

Location	Institution	Delegate
Antwerp	Académie des Beaux-Arts	Albrecht de Vriendt (1843–1900) painter, director
Berlin	Kgl. Akademische Hochschule für die bildenden Künste	Max Koner (1854–1900), painter
Budapest	Kgl. Landes-Muster-Zeichenschule	Gustav Keleti (1834–1902) painter, director
	Kgl. Landes-Muster-Zeichenschule und Zeichenlehrer-Seminar	Robert Nadler (1858–1938), painter
Kassel	Kgl. Kunstakademie	Louis Kolitz (1845–1914), painter, director
Munich	Kgl. Akademie der Bildenden Künste	Rudolf Seitz (1842–1910), painter
	Kgl. Kunstgewerbeschule	Emil von Lange (1841–1926), architect, director
Prague	K.K. Kunstgewerbeschule	Karl Kruis (1851–1917), chemist
		Franz Zenisek (1849–1916) painter
Stuttgart	Kgl. Kunstschule	Claudius von Schraudolph (1843–1902), painter, director
Vienna	K.K. Akademie der Bildenden Künste	August Eisenmenger (1830–1907), painter
		Josef Mathias Trenkwald (1824–1897), painter
		Friedrich Linke (1854–1914), chemist
	Kunstgewerbeschule des K. K. Österreichischen Museums für Kunst und Industrie	Friedrich Linke (1854–1914), chemist
		Karl Karger (1848–1913), painter

London

Royal College of Art

Keim reprinted a list, translated into German, of 35 exam questions on painting materials and techniques, which provided evidence of technical classes at the South Kensington School (National Art Training School), today the Royal College of Art (RCA)[1] (Keim 1903: 27–30). The original 46 questions can be found in Henry C. Standage's work *The Artists' Manual of Pigments* (Standage 1887: 100–108). They reveal interesting information on the expectations of students' state of knowledge on the subject of painting technique and technical art history. Several questions referred to the topic of tempera painting, for example: 'Describe the gradual change of method from tempera to oil painting, the vehicles employed, and their composition. Was more than one vehicle employed in the same picture?' (Keim 1903: 30 [question 34]; Standage 1887: 108 [question 42]).

Although Standage's book was widely used, he is not very well known (Diependaal *et al.* 2013: 175). The archive records of the National Art Training School and the RCA show no evidence that he was one of the lecturers and instructors there.[2] Later records from the turn of the 20th century reveal further information on the subject of tempera painting. Evidently the use of tempera paint was commensurate with oil paint for studies in colour. Candidates were required to present a 'study in colour from the life in oils or tempera in eight days'.[3] As a practical example for students, a tempera painting by John Dickson Batten (1860–1932), a member of the Society of Painters in Tempera, using a method suggested by Cennino Cennini (*c.*1370–*c.*1440), was acquired by the Victoria and Albert Museum in 1906 (Fig. 1) on the recommendation of Walter Crane (1845–1915): 'As tempera painting is now being revived, and is practised in the Royal College of Art, it would be desirable to have such good modern examples available for students, and I should advise its purchase.'[4]

Royal Academy of Arts: Arthur Herbert Church

Keim mentioned Arthur Herbert Church (1834–1915) who was professor of chemistry at the Royal Academy of Arts from 1879 to 1911 (Kurzer 2006). Church's research, based on his lectures and earlier papers, was originally published in 1890 in *The Chemistry of Paints and Painting*. The third enlarged and updated edition was translated into German in 1908. A note in *Technische Mitteilungen für Malerei* (*Technical Communications on Painting*) reveals that Keim already held a translated manuscript of the second edition prior to the publication of Ostwald's translation (Anon. 1919: 55). Church described egg yolk emulsion, size and prepared egg white as binders employed in tempera painting. The binders were explained in detail in a table that gave the composition and proportions of the yolk and white for ordinary hens' eggs (Church 1890: 61). Church explained the egg yolk as 'an oily emulsion, in which innumerable minute globules of a thick, fatty oil are suspended in an albuminous solution'. Although he regarded egg yolk as the best vehicle for tempera painting, in his opinion it provided less protection than varnish and oil for the incorporated pigments (Church 1890: 63, 241). As a painter himself, Church provided several useful tips when working with tempera, referring specifically to the importance of proper grounds and the right pigment selection. He recommended the use of a protective varnish made of sandarac in oil and described an uncommon application of egg white as a binder.[5] In the German translation Ostwald, on his own initiative, added casein and starch as useful vehicles for tempera (Church 1908: 294–5).

Figure 1 John Dickson Batten, *St Christopher and the Christ Child*, tempera on plaster, before 1906. (Photo © Victoria and Albert Museum, London.)

Vienna

Academy of Fine Arts (Akademie der bildenden Künste): Friedrich Linke

Friedrich Linke (1854–1914) was a regular full-time professor at the Chemisches Laboratorium (chemical laboratory) at the Academy of Applied Arts in Vienna (Patka and Vogelsberger 1986: 397) and taught paint chemistry at the Academy of Fine Arts (1883–1909). The exam questions set in Vienna were even published by Keim (1892 and 1903: 23–6). Among a chorus of questions – the majority on pigments – tempera painting is treated in only one question (no. 72): '*Welche Bindemittel verwendet die Temperatechnik? Woraus bestehen und wie verhalten sich diese Bindemittel?*' ('Which binding agents are used with the tempera technique? What do they consist of and how do they behave?') (Keim 1892: 8; 1903: 26). The answer can be found in *Die Malerfarben, Mal- und Bindemittel und ihre Verwendung in der Maltechnik* (*Paints, Vehicles and Binders and their Use in Painting Technique*) (Linke 1904). The topic of tempera is outlined in the chapter *Wasserfarben* (water-based colours).

Linke divided tempera into three categories: *Eitempera* (egg tempera), *Leimfarben* (size paints) and *Kaseinfarben* (casein paints) (1904: 106). He explained that the original kind of tempera was essentially egg yolk, whereas in contemporary painting the meaning of tempera involved a variety of binders. Two characteristics would determine the term 'tempera': firstly, paints with a water-miscible binder and secondly, a painting technique which was related to oil painting to the extent of employing the same pigment selection using opaque white and a moderate impasto application. The chemical composition of egg yolk and egg white was explained using the same table and list of composition as Church (Linke 1904: 106). Unlike Church however, Linke described the emulsifying property of egg yolk, which allows dilution with water as well as the further addition of a drying oil. The visual effect of egg tempera was compared with oil paint as 'half oil paint, half watercolour' (Linke 1904: 107) which dries to a semi-glossy surface and can be protected by the application of mastic varnish. The emulsifying property of egg yolk was illustrated by a recipe given in the third edition (Linke and Adam 1913: 117) (Table 2). In comparison to egg yolk, an effect similar to 'water-soluble oil paints' could be achieved by artificial emulsions such as gum arabic mixed with linseed oil. Artificial emulsions often contained many different ingredients designed to

Table 2 Selected recipes.

Author	Recipe	Reference
Ernst Berger	*Oil tempera* 1 part gum arabic 2 parts linseed oil or boiled linseed oil 2 or more parts water	Berger 1897: 258
Max Doerner	*Egg tempera* 1 volume egg ¾ volume linseed oil ¼ volume dammar varnish Dammar diluted in turpentine 1:2	Doerner 1921: 166–7
F. Linke and E. Adam	*Egg tempera* 50 g egg yolk 20 g boiled linseed oil 10 g mastic varnish (*Mastixlack*)	Linke and Adam 1913: 117
Ernst Täuber	2 parts (by weight) egg 1 part linseed oil 1 part water Small addition of camphor is recommended	Täuber 1934/35: 51
	10 parts (by weight) casein powder 50 parts water 2 parts borax in 50 parts water = casein solution + 50 parts linseed oil Small addition of camphor is recommended	Täuber 1934/35: 51
Albert Wirth	*Egg tempera, matt, for wall painting* 100 parts egg yolk or the whole egg 50–70 parts linseed or poppy seed oil 20 parts water 6 parts glycerin	Wirth 1916: 77
	Resin tempera for easel painting 100 parts gum arabic 100 parts poppy seed oil 50 parts copal or mastic or dammar varnish (*Kopal-, Mastix- oder Dammarlack*) 120 parts water Resin is diluted in 30 parts turpentine	Wirth 1916: 81; 1928: 84. Doerner recommended egg or casein instead of gum arabic

help overcome their deficiencies, as in Syntonos paint – in Linke's opinion a complicated and absurd artificial mixture (Linke 1904: 107–8). In the section on *Leimfarben* (size paints), Linke criticized the composition of Pereira Tempera which included vinegar that affects pigments such as lead white, zinc white and ultramarine.[6] The chapter on casein refers to the risks of outdoor application and ends with a short digression on egg white, another animal protein binder, which was used in photography and becomes insoluble on exposure to light. Finally Linke introduced formaldehyde as an effective vehicle to achieve insolubility of animal glue, casein and egg white (Linke 1904: 111).

Berlin

Royal Art Academy (Königliche Akademische Hochschule für die bildenden Künste)

Thanks to the director Anton von Werner, the Royal Art Academy in Berlin was the first academy in Germany to offer a technical class in painting materials, founded in 1895 (Anon. 1901). The painter Albert Wirth taught colour theory and the preparation of paint. The chemist Ernst Täuber from the Technical University (Technische Hochschule)[7] was additionally engaged to give lectures on fundamental terminology in chemistry and physics.

Figure 2 Professor Albertus (Albert) Wirth teaching his class in colour theory and paintmaking at the Art Academy in Berlin. (Photo © akg-images, Berlin.)

Anton von Werner

In 1908, Anton von Werner (1843–1915) published *Über Farben und Mal-Technik* (*About Paints and Painting Techniques*), a small guide[8] based on the lessons of the abovementioned class, which contained a section on tempera painting that referred both to matt tempera paints in decorative painting and varnished easel paintings. In contrast to glue and casein paints, tempera paints were described as emulsions in which water and oil were mixed together: 'The emulgent is egg, especially egg yolk, or gum arabic, or also casein. The simplest tempera binder is a mixture of water, vinegar, and a little oil. Other tempera binders are made by adding fig-tree sap, resins, wax, cherry gum, alum, honey etc.' (Werner 1908: 24). For decorative painting on walls the combination of glue and tempera paint was recommended, starting with glue paint and finishing with tempera. Furthermore, tempera was used to complete the fresco technique as a kind of secco finish (Werner 1908: 25–6). A short section dealt with varnished tempera paints for easel painting. This technique was regarded as quite difficult for beginners and doubt was cast on its permanence (Werner 1908: 26).

Albert Wirth

Albert Wirth (1848–1923) (Fig. 2), who originally trained as a decorative painter, was already an experienced teacher of glue-size painting before he started teaching at the academy (Werner 1896: 279). Wirth's interest in decorative wall painting is evidenced in his book *Technik der Malerei nebst kurzgefaßter Farbenlehre* (*Painting Technique Together with a Summarized Theory of Colour*), originally published in 1916. Wirth also distinguished between tempera for wall painting – matt without varnish – and tempera for easel painting that he referred to as oil-tempera and which could be matt or varnished (Wirth 1916: 75–83) (see Table 2). Wirth provided several tempera recipes for wall and easel painting together with

Figure 3 Ernst Berger, study painting in the technique of Cennino Cennini after Sandro Botticelli, *Primavera* (detail), Uffizi Gallery, Florence, Deutsches Museum inv. No. 11564 (Berger 1897: 114). (Photo: Bayerische Staatsgemäldesammlungen © Deutsches Museum.)

Figure 4 Alexander Eibner (first row in the middle) at the Versuchsanstalt- und Auskunftsstelle für Maltechnik (Research Institute and Information Centre for Painting Technology) at the Technical University of Munich. The person on his left is probably presenting Eibner's book *Malmaterialienkunde als Grundlage der Maltechnik*. (Photo: estate of Prof. Anton Dietl, made available by Ingo Rogner, Akademische Chemiker Verbindung.)

some varnish recipes. A comparison between the 1916 and 1920 editions of *Technik der Malerei nebst kurzgefaßter Farbenlehre* and the 1928 edition revised by Max Doerner after Wirth's death, reveals several changes in the tempera recipes. For example, Doerner removed glycerine, vinegar and honey previously used by Wirth and recommends egg and casein instead of gum arabic (see Table 2).

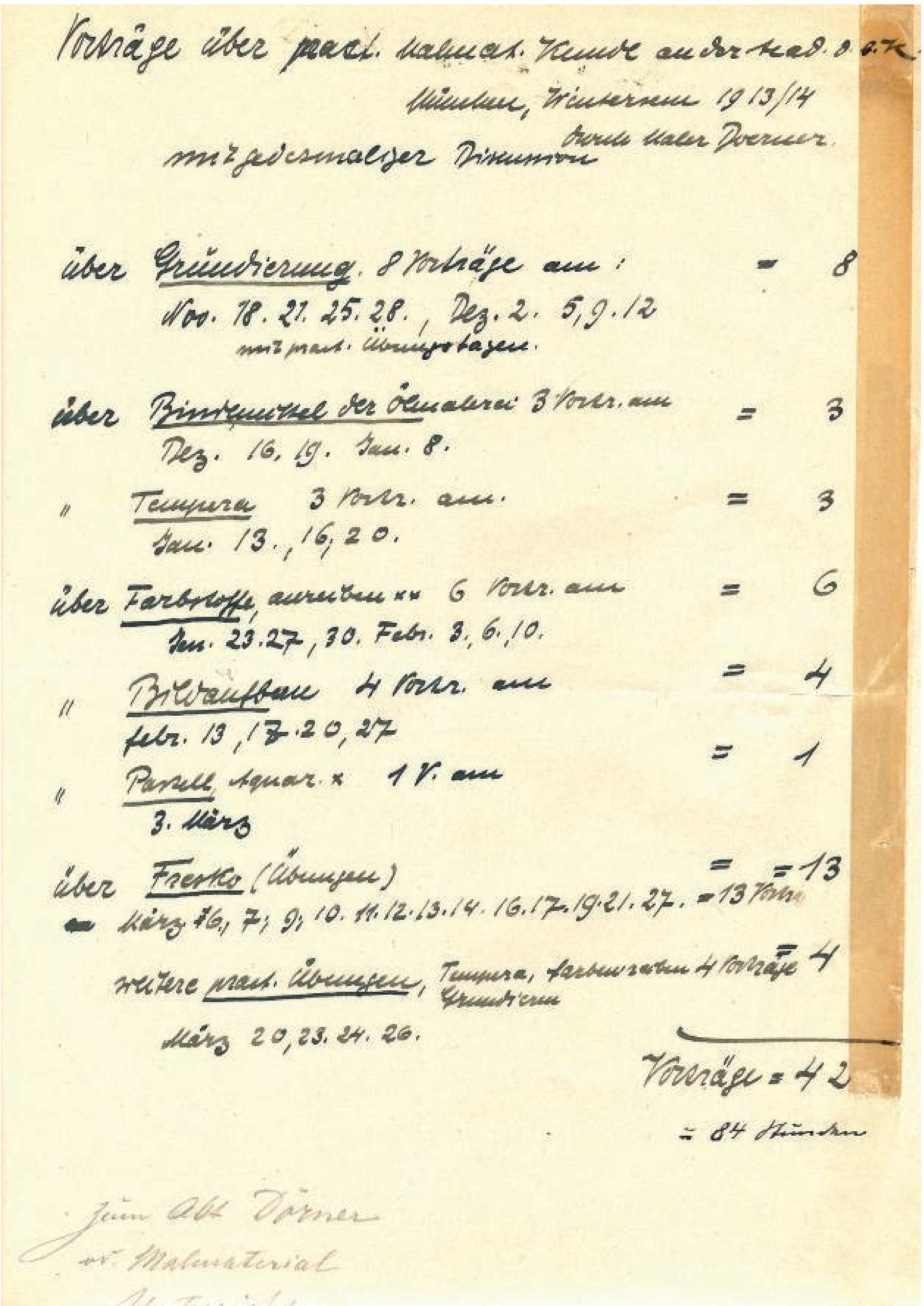
Ernst Täuber

Contributions in *Technische Mitteilungen für Malerei* and *Münchner kunsttechnische Blätter* (*Munich Art Technology Newssheets*) by Ernst Täuber (1861–1944) evidence a deep research interest in oils, resins, wax and pigments with less emphasis on tempera. After retiring in 1934 Täuber published the article '*Kleiner Ratgeber in künstlerischen Materialfragen*' ('Concise manual of questions of artists' materials') (Täuber 1934/1935; 1935) as a condensed outcome of his teaching, which also contained a very short passage on tempera binders. Täuber provided recipes for an egg-linseed-oil and a casein-linseed-oil emulsion (Täuber 1934/35: 51) (see Table 2). He considered it acceptable to add resin solutions in small quantities and advised that the addition of wax emulsions might have some positive effect but additions such as glycerine and vinegar were rejected categorically. To avoid colour change induced by varnishing, the application of a solution of casein or zapon was recommended before applying a dammar matt varnish (*Dammar-Mattlack*). Whereas in Berlin Täuber and Wirth seemed to have cultivated a peaceful and harmonious coexistence, the situation in Munich was affected by rivalries and competition.

Munich

Ernst Berger

Ernst Berger (1857–1919) experienced this atmosphere of intrigue when his lectureship at the Academy of Fine Arts (Akademie der Bildenden Künste) came to an end in 1904 after two winter semesters. Berger's research into the history of painting techniques and his extensive teaching exerted a remarkable influence on the reception of tempera painting (Kinseher 2016). Berger supplied a series of tempera recipes (see Table 2),[9] even including some from standard works on decorative painting (Berger 1897: 258–60),


Vorträge über prakt. malmat. Kunde an der Akad. d. b. K.
München, Wintersem 1913/14
mit jedesmaliger Diskussion durch Maler Doerner.

über Grundierung. 8 Vorträge am: = 8
Nov. 18. 21. 25. 28., Dez. 2. 5, 9. 12
mit prakt. Übungstagen.

über Bindemittel der Ölmalerei 3 Vortr. am = 3
Dez. 16, 19. Jan. 8.

" Tempera 3 Vortr. am. = 3
Jan. 13., 16, 20.

über Farbstoffe, anreiben 6 Vortr. am = 6
Jan. 23. 27, 30. Febr. 3, 6, 10.

" Bildaufbau 4 Vortr. am = 4
Febr. 13, 17. 20, 27

" Pastell, Aquar. 1 V. am = 1
3. März

über Fresko (Übungen) = = 13
am März 6, 7, 9, 10. 11. 12. 13. 14. 16. 17. 19. 21. 27. = 13 Vortr.

weitere prakt. Übungen, Tempera, Farbenreiben, Grundieren 4 Vorträge = 4
März 20, 23. 24. 26.

Vorträge = 42
= 84 Stunden

Zum Akt Dörner
Malmaterial

Figure 5 Max Doerner, list of lectures at the Academy of Fine Arts, Munich, during the winter semester 1913–14. (Photo: Kathrin Kinseher © Akademie der Bildenden Künste München.)

and described some of the commercially available tempera paints that already included paints mixable both with water and oil.[10] His study paintings on technique served as teaching aids as well as exhibits in the Deutsches Museum's painting room (Kinseher 2018) (Fig. 3).

Alexander Eibner

Starting from the winter semester 1905, before regular technical lessons were established at the Academy of Fine Arts, painting students were required to attend the lectures by the chemist Alexander Eibner (1862–1935) at the Technical University of Munich (Technische Hochschule München). The programme and dates of Eibner's lectures were announced in *Technische Mitteilungen für Malerei* (Anon. 1905, 1906). Different types of tempera were explained in lecture 9 (of a course of 12) among a variety of subjects that included coal tar pigments as well as inorganic and organic

Figure 6 Max Doerner, study painting demonstrating the *Mischtechnik*. Notes on the edge of the painting explain each step of the technique as well as the composition of the egg tempera and resin-oil paint. (Photo: Bayerische Staatsgemäldesammlungen, Doerner Institut © Bayerische Staatsgemäldesammlungen, Doerner Institut.)

binders (Keim 1905: 18). Eibner presented two categories: natural tempera such as milk and egg yolk, and artificial tempera including egg yolk, casein or gum arabic mixed with drying oil and water. Again, in April 1913, a series of Eibner's lectures was published in more detail (Keim 1913: 177–8). The subjects corresponded with the chapter *Eidotter und Tempera* (egg yolk and tempera) in his comprehensive book *Malmaterialienkunde als Grundlage der Maltechnik* (*Painting Materials as the Foundation of Painting Technique*) (Eibner 1909: 263–74) (Fig. 4). In an explanation of the function of emulsions, Eibner referred to Friedlein's book *Tempera und Tempera-Technik* (*Tempera and Tempera Technique*) from 1906, and like other authors identified Pereira's glue-tempera as a non-authentic tempera. He also criticized Beckmann's Syntonos paints and included new research by the Austrian chemist and future Nobel Laureate Richard Zsigmondy (1865–1929), who had focused on colloid chemistry (Zsigmondy 1905). Eibner's programme was announced by Keim when potential competition arose at the academy in the person of Max Doerner, who had been appointed as lecturer on painting materials (Doerner 1913).

Max Doerner

During the winter semester 1913–14, Max Doerner (1870–1939) gave 42 two-hour lectures, three of which were devoted to tempera, three to oil painting and four that included practical exercises devoted to tempera, preparing paints and grounds. Doerner's lectures (Fig. 5) were complemented by practical exercises and visits to museum collections. In common with other lecturers, Doerner published material based on his teaching. *Malmaterial und seine Verwendung im Bilde* (*The Materials of the Artist and their Use in Paintings*) has undoubtedly proved one of the most successful technical manuals since its first edition in 1921. The extensive chapter on tempera painting reveals that the subject had been elaborated in detail which can be attested by study paintings preserved in the Doerner Institut's collection. Judging by the recipes noted on the paintings, a significant number of these studies relate to tempera painting. Doerner supplied recipes (see Table 2) and described the different kinds of tempera on the basis of his own practical experiences, and provided advice on the proper grounds, brushes, palette and correct preparation of self-made tempera paints (Doerner 1921: 165–82). Some of the tempera emulsions are mentioned again in the context of secco painting on plaster: egg, casein and wax-tempera (Doerner 1921: 231–2, 234).

A unique and characteristic aspect of Doerner's book is that he supplied a considerable amount of practical information on the application and characteristics of the different techniques using tempera paints (Doerner 1921: 182–91). Included are methods for unvarnished tempera, varnished tempera, tempera as an underpainting for an oil painting, and a combination of tempera and oil painting described as the '*Mischtechnik*' (mixed technique): a means of mixing tempera paint, especially oily emulsions, into a wet oil-resin layer. The *Mischtechnik* exploited all the advantages of tempera and oil paint by underpainting with egg or casein tempera and proceeding with very thin oil-resin layers (Fig. 6). Precise details, such as the sharpness of drawing with an impasto brushstroke, could be achieved (Doerner 1921: 186). The colours do not mix, unlike what happens when oil paint is applied on a wet underlayer of oil paint. Doerner regarded this technique as allowing paintings of '*höchster Vollendung in Form und Farbe*' ('form and colour in highest perfection') (Doerner 1921: 247). He compared the *Mischtechnik* to the painting method of the Flemish and German masters, and described it as the analogue of the technique of Van Eyck and Albrecht Dürer. However, during the 1930s water-in-oil emulsions (oil-mixable, fat tempera paints) were introduced by the painters Walter Ruhrmann (1897–1968) and Richard Lindmar (1867–1956) as the new Van Eyck medium (Schmidt 1935: 9–14) and discussed in *Technische Mitteilungen für Malerei* (Reinkowski-Häfner 2016: 20–21). Although this theory represented a riposte to the *Mischtechnik*, Doerner included water-in-oil emulsions in the sixth updated edition of his book (Doerner 1938 [1992]: 176–8; Burmester 2016: 347–8).

Conclusion

From the beginning of the introduction of technical classes on painting materials and techniques, tempera painting was included in the subsequent publications by the teachers and formed part of the course for easel as well as wall painting. While the artists provided recipes, test paintings and practical painters' experience, the chemists investigated and described chemical properties and composition.

There was a distinct shift from the 'old', 'lean' kind of tempera painting based on egg and size as described by A.H. Church to modern types based on oil-in-water emulsions using egg or gum arabic, or casein in combination with drying oils and resins and soaps. Although Ernst Berger was a pioneer in the teaching of this modern type of tempera, it was Eibner who explained the characteristics and principles of emulsions. Tempera emulsions represented a modern 'scientific' material which, due to the new chemical understanding of the surface action between water and oil, also appealed to artists. Max Doerner's *Mischtechnik* method of combining oil and tempera could also be transferred to contemporary painting. Doerner succeeded in calming the debate, triggered by Keim and Linke, on the 'proper painting technique' (i.e. either tempera or oil) which had been conducted with considerable animosity while Doerner himself was a young artist in Munich.

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Notes

1. The Royal College of Art was founded as the Government School of Design in 1837, later renamed the National Art Training School, due to its location informally known as South Kensington School of Art. It was renamed the Royal College of Art in 1896. For more information see: https://www.rca.ac.uk/more/about-rca/our-history/ (accessed 6 June 2018).
2. Victoria and Albert Museum, Word and Image Department and Neil Parkinson, Archives and Collections Manager, Royal College of Art, personal communication.
3. Prospectus of the Royal College of Art 1901: 5; older prospectuses (1887–1895) of the National Art Training School use the term watercolour.
4. See http://collections.vam.ac.uk/item/O131393/st-christopher-and-the-christ-tempera-painting-batten-john-dickson/ (accessed 6 June 2018).
5. 'We may coat a piece of fine linen cloth with albumen-solution, and before it is quite dry we may paint upon it with pigments which have been previously ground up with a weak solution of tannin. If the work be carefully done, the colours will, when dry, be found to have been fixed by the reaction between the tannin and the albumen' (Church 1890: 62).
6. Linke and his friend Keim shared an antipathy to Syntonos paint and Pereira's tempera system. For a bibliography on Pereira Tempera and Syntonos paint see Pohlmann *et al.* 2016: 156–7, 164–5.
7. See https://cp.tu-berlin.de/person/1759 (accessed 15 November 2018). Further information on Täuber is hard to find. Universitätsarchiv TU Berlin, personal communication.
8. With contributions from Albert Wirth and Ernst Täuber.
9. See Kathrin Kinseher, 'Ernst Berger #tempera emulsions: tempera networks in Munich *c.*1900', in this volume.
10. On oil-miscible tempera forms such as Wurm Tempera: see Berberich 2012: 53–4 and Reinkowski-Häfner 2016: 20–21.

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Author's address

Kathrin Kinseher, Akademie der Bildenden Künste München, Munich, Germany (kathrin.kinseher@adbk.mhn.de)

Past, recent, and future developments in the analysis and interpretation of tempera-based paint systems

Kristin deGhetaldi

ABSTRACT While the conservation and scientific communities have made excellent strides in pigment research, the history of media analysis in conservation should be considered when assessing the literature concerning the characterization of tempera-based paints. Instrumentation and analytical methods (such as sample preparation) have greatly improved since the early efforts of conservation scientists. However, as with most technological improvements, unforeseen complications can arise. Contamination from restoration materials such as resin/oil-containing varnishes, proteinaceous adhesives, migration of fatty acids, the presence of reactive pigments, and the formation of degradation products (e.g. metal soaps) are now known to affect the detection of many key chemical markers – markers that are often used in the characterization of paint binders. These complications call for a re-evaluation of the findings reported in early technical studies. While this paper explores the evolution of various analytical techniques traditionally used to characterize tempera-based paints, it seems that a more accurate assessment of these paints can be accomplished only if the original stratigraphy of the paint and ground layers is maintained throughout the analytical procedure. Imaging techniques combined with certain analytical methods (such as ATR-FTIR and ToF-SIMS) now allow for the characterization of inorganic and organic materials within discrete layers present in cross-section paint samples. Such methods can aid in differentiating between restoration and original materials without consuming the sample during the process, allowing it to remain preserved for future analysis.

Introduction

Tracing the history of binding media analysis can help to elucidate some of the discrepancies encountered in the literature relating to the characterization of tempera-based paint films. This article aims to provide a summary of analytical techniques that have been commonly used to identify binding media in easel paintings since the early 20th century, outlining the benefits and limitations associated with each method as well as investigating potential directions for future research. A survey of relevant scientific publications, both past and present, reveals that this area of research has witnessed significant progress since the turn of the century. It is impossible to include a comprehensive bibliography on this subject given the length constraints of this article; however, there are a number of texts and survey articles that readers can now consult for in-depth information (Vallance 1997; Domenech-Carbo 2008; Colombini and Mudugno 2009; Dallongeville *et al.* 2016). Groups of scientists who specialize in binding media analysis have also begun to meet on a regular basis (such as the MaSC Users Group for Mass Spectrometry and Chromatography and the Infrared and Raman Users Group (IRUG)). Recently, scholars have identified a number of factors that can hamper organic analysis including pigment interference, detection limits, the migration of mobile chemical markers (e.g. fatty acids), the formation of degradation products, and the potential contamination of restoration materials (e.g. oil-resin coatings, protein glue, various adhesives, etc.). In addition, studio practices and methods of paint handling and other techniques are often overlooked in scientific publications focusing on tempera-based paint films, leading to misinterpretation and false conclusions regarding the use of binding media. Finally, aside from technological advancements in instrumentation and data processing, it is equally important to place these early case studies into context, considering how art-historical theories and debates of the past may have influenced the direction and even the outcome of scientific testing.

Early methods of characterization: chemical and heating tests

The early history associated with the analysis of tempera-based paint films was generally influenced by two art-historical debates: (1) how did the transition from egg tempera to oil painting transpire during the Quattrocento and (2) what was the binding medium commonly used by Jan van Eyck and his contemporaries? Early attempts to identify the presence of glues, gums, oils, resins, and waxes were limited to chemical and heating tests (recording the temperature at which a paint sample began to liquefy and/or burn). These were minor improvements over 'wiping' tests that had been used previously, a procedure that involved wiping the surface of a painting with water, organic solvents, acids, and/or alkalis. Nadolny (2003) has identified a number of early reports that demonstrate the wide range of results generated by such tests – chemical/heating tests performed in 1828 may represent the first instance of binder characterization carried out on a tempera-based paint film. Chemical and heating tests were employed up until the 1960s/70s, although they frequently led to oversimplified or even incorrect judgments relating to binding media.

Cross-sectional microscopy and related techniques

Early improvements in cross-sectional microscopy and chemical testing

While some chemical tests would continue to be used throughout the early 20th century, scientists eventually realized that a more sophisticated approach was needed to analyze easel paintings consisting of multiple paint/ground layers. A.P. Laurie employed a hypodermic needle to collect samples and as early as 1905 Ostwald was one of the first to apply stains to intact cross-sections in an attempt to characterize proteinaceous materials (Plesters 1956; Ostwald 1936). By 1932, Eibner's publication provided a step-by-step approach to identifying and characterizing binding media, including some of the earliest schematics of cross-sections. During this same period, Gettens and Stout designed an elaborate 'micro-sectioner' for sampling tempera and/or oil-based paintings (Gettens 1932, 1936; Stout 1938; Khandekar 2003). In his 1938 article, Stout included images of cross-sections as well as results from chemical tests, concluding that 15th-century Italian artists would occasionally apply their tempera paints directly atop a layer of un-pigmented oil sizing. While Stout's early assessment is unlikely, his article still marks an extremely important turning point for the analysis and examination of tempera-based easel paintings in general. Gettens continued to improve methods used to characterize binding media and mount cross-sectional samples in collaboration with Coremans (Coremans *et al.* 1952). Gettens also explored the use of methyl methylacrylate for mounting cross-sectional samples as opposed to the more traditional wax. A total of nine different spot and staining tests were used on samples in order to identify oils, egg, and glue (Lefève and Sneyers 1950; Coremans *et al.* 1952). Plesters was perhaps one of the first to express apprehension regarding the accuracy of some of these early tests. Although she included a list of chemical tests and staining solutions in her 1956 article, she described these tests as 'rather rough and ready', questioning whether they should even be classified as analytical methods.

De Silva demonstrated foresight regarding future problems relating to the organic analysis of artworks. His study focused primarily on binders encountered in wall paintings; however, his work can also be extrapolated to the analysis of tempera paints (de Silva 1963). By using an extensive set of known references, he found that nearly all tests could generate false positive reactions and false negatives. He attributed many of these discrepancies to the presence of trace components and/or impurities that could give rise to misinterpretation. De Silva's observations relating to egg tempera predicted challenges relating to the analysis of tempera-based paint films in general, particularly as he recognized that both egg yolk and drying oils share the same 'fatty matter' (de Silva 1963). His additional prescient concerns included the possible interference of pigments, insufficient sample size, and the impact of degradation products, all of which have shown to have an impact on the organic analysis of paintings in recent times.

Cross-sectional staining techniques

In contrast to chemical 'spot' tests, staining solutions offered the advantage of creating a distinct visual effect based on changes in color depending on the presence of certain materials within the paint and ground layers. In the 1970s, several scientists began to embrace cross-sectional microscopy and staining techniques to assist in the characterization of tempera-based paint systems; however, there was no consensus as to which stains generated the most accurate and consistent results, and even then a scientist might abandon one staining technique in favor of another from year to year (Mills and White 1994; Spring and Morrison 2017). Johnson and Packard (1971) described the general benefits and drawbacks of cross-sectional staining citing complications that remain relevant today. These include the quality of water used to dissolve the solutions (the presence of metal ions and other substances can affect staining), the 'age' of the staining solutions, interactions with the mounting resin, the presence of certain inorganic materials, and the time required before a staining reaction was considered 'complete'. Gay and Martin soon followed with publications that questioned Packard and Johnson's findings (Gay 1976; Martin 1977). While Gay's own staining results were problematic, she noted that stains were unable to differentiate between whole egg, egg yolk, and egg white, and that such materials could be identified by applying fluorescent antibodies to thin-sections of paint samples. Martin also found that Sudan Black was no longer considered reliable and instead presented three new classes of stains, two of which offered the promise of distinguishing between the various categories of proteins (e.g. glue, egg, and casein).

Cross-sectional microscopy continues to be combined with staining or other analytical methods. Recent tests on cross-sectional reference samples containing egg tempera, oil, and glue, confirm some of the early criticisms conveyed by Plesters, de Silva, and others. Wolbers *et al.* (2012) summarized some of the problems associated with past staining solutions, describing them as 'cumbersome' to apply, requiring frequent rinsing, and pointing out the irreversible damage that might be caused by stains delivered in alcoholic or acidic solutions. Theoretically, fluorochrome stains offer an improvement in both selectivity and sensitivity. By 1987, a number of fluorochrome stains used in the biomedical field were shown to be potentially useful for the identification of proteins, carbohydrates, and fatty substances within discrete paint/ground layers. This work continued over subsequent decades and was also used in the characterization of tempera-based paint systems (Wolbers and Landrey 1988; Golikov and Kireyeva 1990; Schäfer 1997; Wolbers 2000). Fluorochrome stains are not always able to produce reliable results as they are prone to quenching or photo-bleaching and, as with traditional stain solutions used in the past, some fluorescent stains are delivered in solvents that may cause portions of the sample to alter or dissolve. In addition, if handled improperly, extraneous oils or proteinaceous materials can contaminate the surface and produce a false positive result or prevent a stain from reacting with the substrate. In addition, stains may not always produce consistent results with aged materials and reactions may be further inhibited by certain pigments. Recent publications have demonstrated the efficacy of fluorescent stains but there remains a consistent lack of comprehensive and systematic testing on both fresh and aged reference samples save for a handful of publications (Schäfer 2007, 2013; Dietemann *et al.* 2016). Indeed this issue has prompted some scholars to reconsider or even retract earlier conclusions made regarding the characterization of proteinaceous binding media (Gifford *et al.* 2017). However, cross-sectional staining techniques still offer the possibility of analyzing intact cross-sections, something that other analytical methods are not always capable of achieving.

Cross-sectional microscopy and immunobiological techniques

During the 1970s, Johnson and Packard began tagging fluorochome stains to secondary antibodies (Johnson and Packard 1971). Antibodies can be tailored to bind to epitope sites associated with certain materials that fall within the same class, helping to differentiate casein, glue, and egg. The presence of a secondary antibody can then be observed using the appropriate excitation wavelength of the attached fluorochrome. By the late 1980s, scientists and conservators were using immunofluorescence microscopy (IFM) techniques to identify proteinaceous materials in easel paintings and polychrome sculptures dating from the 12th to the 17th century (Kockaert *et al.* 1989). As with other staining techniques, a few samples were found to generate false negative results and problems were encountered with porous samples, autofluorescent pigments and/or binders, and with fluorochromes that fluoresced colors similar to certain pigments in a sample. Nearly two decades later, IFM was employed to assist with the characterization of binding media in cross-sections (Vagnini *et al.* 2008; Cartechini *et al.* 2010). Initial results seemed promising: IFM did not appear to be hampered by most pigments or artificial ageing but scientists occasionally struggled with the autofluorescence produced by cross-sectional samples.

The potential problems with IFM and autofluorescence have since inspired scientists to explore the applicability of enzyme-linked immunosorbent assay (ELISA) techniques to the identification of proteinaceous binders (Cartechini *et al.* 2010; Palmieri *et al.* 2011; Lee *et al.* 2015; Ren *et al.* 2016). Similar to IFM, ELISA relies on the use of an enzyme-conjugated secondary antibody to generate a spectrophotometric reading (Klausmeyer 2009). While some of these studies cite promising results, ELISA is still not able to provide spatial mapping of the components in an intact cross-section. Furthermore, additional studies have demonstrated the potential issues caused by ageing processes as well as the presence of certain pigments, with egg-tempera paints in particular often generating fairly low to poor protein signals.[1] Future research may focus on techniques, such as immuno-SERS Raman spectroscopy, which have recently generated promising results with regard to the characterization of proteinaceous binding media (Perets *et al.* 2015).

Spectroscopic techniques

Beginning in the mid-1980s, photoluminescence spectroscopy has been used occasionally for the characterization of tempera-based paint systems. The technique relies on the unique fluorescent (or photoluminescent) properties associated with certain materials when temporarily excited with an ultraviolet light source (Bottiroli *et al.* 1986, 2005; Mancuso and Gallone 2004). In more recent years, laser-induced fluorescence (LIF) has been used to successfully differentiate between classes of proteins (egg and glue); various UV lasers can be coupled with an optical multichannel analyzer to produce spatial maps of the fluorescence imaging at specific excitation wavelengths (Nevin and Anglos 2006; Nevin *et al.* 2008, 2014). However, preliminary studies have found that the presence of certain pigments can significantly influence the shape and position of spectra. While more 'traditional' spectroscopic methods such as UV-vis are no longer employed to characterize proteinaceous binders, newer techniques still require additional research in order to assess the effects of natural ageing, pigments, and/or the presence of mixed media.

Since the 1970s, Fourier transform infrared (FTIR) spectroscopy has become one of the most widely adopted methods used to characterize organic binding media in easel paintings (Mills and White 1994; Derrick *et al.* 1999). Although FTIR can be employed to identify classes of organic and inorganic materials, the technique is typically unable to differentiate between materials of the same class, especially in mixed media paints (e.g. egg tempera and animal glue), or distinguish original binding media from restoration material (Pilc and White 1995; Townsend and Boon 2012). Throughout the 1990s, more museum laboratories began to invest in FTIR technology and comprehensive databases. Soon after the formation of IRUG in 1993, Pilc and White developed a novel mounting system that allowed them to preserve the stratigraphy of cross-sections during FTIR analysis. In their 1995 article, Pilc and White also warned about the challenges associated with the analysis of mixtures, emulsions, and the potential complications caused by overlapping peaks. In the late 1990s, additional spectroscopic techniques, such as fiber optics reflectance spectroscopy (FORS), was applied to tempera-based paint films, focusing on information gathered from the middle and near IR regions of the spectrum. As the technology improved, scientists started to recognize how peaks (or lack thereof) might be attributed to the presence of certain pigments (e.g. red lakes extracted from dyed silks or wool), degradation components (e.g. metal soaps), and/or influenced by materials from adjoining layers (Kirby *et al.* 2005; Higgitt *et al.* 2003; Spring and Higgitt 2006). In some instances, these complications have potentially led to erroneous conclusions relating to the characterization of tempera-based paint systems.

In transmitted mode, all stratigraphic information is typically lost. Conversely, if cross-sections are analyzed using attenuated total reflection FTIR (ATR-FTIR), it is possible to collect spectra from discrete locations. Furthermore, if a system is equipped with an imaging system, spatially resolved 'maps' can also be produced (van der Weerd *et al.* 2002; Spring *et al.* 2008; Mazzeo *et al*. 2008). Using this technique, scientists have been able to establish that metal soap formation occurs not only in oil-rich paint films but also in egg tempera-based paints (Spring *et al.* 2008; Mazzeo *et al.* 2008). As the resolution of an ATR-FTIR system is directly dependent on the type and/or size of the crystal that is pressed directly into the sample, the technique may not be able to successfully differentiate one layer from another (Townsend and Boon 2012). However, advancements in synchrotron radiation FTIR (SR-FTIR) now offer dramatic improvements in overall spatial resolution. ATR-FTIR systems coupled to various detectors (e.g. focal plane array detectors, etc.) can also improve spatial results and allow for imaging of cross-sections (Salvado *et al.* 2005; Zumbühl *et al.* 2014; Dietemann *et al.* 2016; Ferreira *et al.* 2016). On the other hand, FTIR systems still cannot reliably distinguish between protein sources (egg vs. animal glue) or accurately characterize certain mixtures, both of which are particularly relevant to the identification of binding media encountered in tempera-based paintings. While some progress has been made using near-IR reflectance imaging spectroscopy combined with FORS, additional research is needed to address the potential contamination of layers through restoration campaigns (e.g. varnishing of egg-tempera films) in addition to the problems posed by the possible presence of mixed media.

Chromatography coupled with mass spectrometry

Early developments in chromatography methods

By the 1960s and 70s, thin-layer chromatography (TLC) and gas chromatography (GC) were the preferred chromatographic methods for the characterization of tempera-based paint systems (Striegel and Hill 1996; Mills and White 1975). A relatively simple and inexpensive technique, TLC can be used to separate and identify different components present in a mixture by dissolving the sample in a solvent; patterns left behind on the TLC plate/bed are then compared to known references. Although White later recalled his reservations with the technique, stating that TLC 'sometimes gave sort of falsely possible things', the method continued to be used well into the 1990s to characterize a wide range of binding media, culminating in the 1996 text *Thin-Layer Chromatography for Binding Media Analysis* (White 2009; Striegel and Hill 1996).

The inability of TLC to successfully identify different drying oils likely provided more incentive for Mills and White to continue their work involving GC. Mills had been using capillary column chromatography to characterize natural resins since his arrival at the National Gallery, London, in 1951; however, around 1962/3 he began to apply GC to the analysis of paint samples following Nathan Stolow's pioneering work that focused on the characterization of drying oils (Stolow 1965; Mills 1966; Mills and White 1975, 1976, 1978). Developed in the late 1960s, GC is a separation technique based on the boiling point and polarity of individual compounds present in a sample as it makes its way through a tube/column. Mills and White were finally able to develop a more systematic analytical approach and published some of their first GC results collected from tempera-based paintings by 1976 (Mills and White 1976; Thompson *et al.* 1977). The following year marked the establishment of the annual *National Gallery Technical Bulletin* with each subsequent publication including tabular summaries of binding media analyses.

Although the field benefited from advancements in chromatographic technologies throughout the 1970s, the successful characterization of proteinaceous materials and complex mixtures remained challenging. Eventually mass spectrometry (MS) provided a more accurate method of identifying compounds, reducing scientists' dependency on GC retention times. Masschelein-Kleiner's (1976) research marked a turning point for GC analysis, as she was one of the first to employ MS to calculate amino acid profiles of proteinaceous materials in an easel painting. Some years later, the National Gallery acquired its first gas chromatography-mass spectrometry (GC-MS) system, which further improved the characterization of tempera-based paintings (Mills and White 1982, 1994; White 1986). Simultaneously, the advent of computerized systems during the 1980s allowed for automated calculation of the ratios associated with peak areas of specific markers, making it possible to rely on the calculation of peak ratios of specific free fatty acids (palmitic and stearic) as well as dicarboxylic acids (azelaic, suberic, and sebacic) (Mills and White 1982, 1994). Determining the precise origin (e.g. drying oils vs. egg yolk vs. wax, interference of restoration materials) of these markers, however, remained challenging (Mills and White 1976).

High performance liquid chromatography

Advancements in high performance liquid chromatography (HPLC) eventually allowed for the analysis of smaller paint samples, a technique that was further adapted by Halpine at the National Gallery of Art in Washington during the 1990s (Steele and Halpine 1993; Halpine 1995, 1997). Halpine improved earlier HPLC methods and was able to recover more amino acids. She warned against relying solely on fatty acid ratios 'as some animal glue preparations can contain up to 10% of these non-drying oils, and a large enough sample could possibly be interpreted as egg yolk' (Halpine 1992: 23). Halpine's work also confirmed that amino acids could be present in other organic materials including natural resins and gums (e.g. gum arabic) and that samples with multiple layers remained challenging (Halpine 1992, 1995, 1997). While Halpine relied on amino acid profiles to identify glue, egg tempera, and casein in works of art, it was later discovered that (1) recovery of amino acids can be hampered due to the formation of metal ion-amino acid complexes and (2) the presence of lake pigments can inadvertently give rise to amino acids in the paint layer(s) due to various methods of preparation/extraction (Schilling *et al.* 1996a; Colombini *et al.* 1999; De la Cruz-Canizares *et al.* 2004; Kirby *et al.* 2005; Gautier and Colombini 2007; Bonaduce *et al.* 2009).

Since the 1990s, HPLC analysis of paint samples has focused primarily on the identification of dyestuffs rather than proteinaceous materials. However, it has also been found that liquid and gas chromatographic techniques can be useful for the analysis of complex tempera-based paint samples containing combinations of resins, glues, casein, oils, and/or waxes, due to the improved sensitivity of HPLC towards aqueous binders (Newman and Konefal 1993; Koller *et al.* 1998).

Recent advancements in chromatography/mass spectrometry

Improvements in analytical technology and the development of specialized databases have enabled scientists to explore numerous enhanced methods including sample preparation and developing multi-step extraction protocols that can potentially be used to detect a wide range of organic materials present in a single paint sample. Beginning around the 1990s, some efforts were made to apply pyrolysis-GC-MS to the characterization of complex binders but the technique is not well suited for the identification of protein- or gum-containing materials (Bonaduce and Andreotti 2009). Over the last three decades, an increasing number of derivatizing agents and silylating reagents (used for identifying the presence of fatty acids and amino acids, respectively) have become available (Vallance 1997). Additionally, several sample preparation protocols for GC were developed in order to allow for the simultaneous detection of fatty acids and amino acids in complex samples (Witold 1995; Schilling *et al.* 1996a, 1996b; Schilling and Khanjian 1996; Koller *et al.* 1998, 2004; Andreotti *et al.* 2006; Bonaduce *et al.* 2009). Schilling's team and the Colombini group in particular have helped to demonstrate and quantify the extent to which certain pigments interfere with the recovery of amino acids. The latter has developed several protocols in an attempt to suppress possible interference from problematic colorants (such as copper-containing pigments) (Schilling 2005; Colombini *et al.* 1999; Gautier and Colombini 2007; Bonaduce *et al.* 2009). Of particular relevance to the characterization of tempera-based paint systems are protocols for sample preparation involving multi-step extraction processes (Koller *et al.* 1998, 2004; Andreotti *et al.* 2006; Bonaduce *et al.* 2009). While some of these protocols focus on the separation of chemically different species, the Doerner Institut approach was developed in an effort to also interpret varying quantities of fatty acids in each extraction step (Koller and Baumer 2006; Dietz *et al.* 2010: 94).

The last two decades of research involving chromatography/mass spectrometry techniques have revealed an important discovery that directly affects our past and current understanding of tempera-based easel paintings. Comparison of analytical results generated by various protocols is often problematic and additional research is needed, possibly in the form of round-robin exercises which invite multiple laboratories to report their results based on the blind analysis of the same reference sample (Colombini *et al.* 2011). In addition, several factors can alter expected and measurable trends in both amino acid and fatty acid ratios including biological/fungal growth, the presence of restoration materials, pigment interference, the migration/leaching of specific markers (e.g. selective leaching of fatty acids during cleaning campaigns), and/or the difficulties involved when sampling artworks with complex stratigraphies. Furthermore, a relationship has often been identified between the relative amounts of dicarboxylic acids (azelaic, suberic, and sebacic) and whether an oil is pre-treated using heat. However, the various methods of refining oils include a wide range of processes aside from heat (such as water washing, sun bleaching, etc.) and the presence of driers, pigments, and even natural ageing processes can also lead to unforeseen deviations in fatty acid ratios (Colombini and Modugno 2009: 8–9; Bonaduce *et al.* 2012). Boon and his colleagues have also explored some of these issues in great detail, carrying out several studies that expose the inconsistencies associated with the successful recovery of dicarboxylic acids in oil-based paints and thus questioning preconceived notions involving the identification of 'heat-bodied' and 'partially-heat bodied' oils (Boon *et al.* 2002, 2007; Keune *et al.* 2008).

Interestingly, it seems that ratios of chemical markers are still occasionally used to characterize tempera-based paint films although it appears that there continues to be confusion as to how fatty acid ratios should be interpreted. FTIR and even staining have been used to help clarify results obtained using GC-MS, particularly when intermediate or low levels of azelaic acid are obtained. However, it is now known that various degradation components (e.g. oxalate-rich crusts, smalt degradation, etc.) or certain colorants (e.g. the silk or wool clippings that may be associated with lake pigments) can generate false positive results using both FTIR and staining. To date only a handful of publications have summarized some of these complications with some attempting to re-examine case studies using new approaches to analysis and interpretation (Spring and Higgitt 2006; Peggie 2014; Dunkerton 2014; Gifford *et al.* 2017; Spring and Morrison 2017). When attempting to characterize complex tempera-based paint systems, it has become abundantly clear that more sophisticated methods of analysis (e.g. GC-MS, HPLC) must be performed in order to confirm whether or not proteinaceous materials are present. Fatty acid ratios alone are no longer considered reliable to help in the identification of tempera-based paints.

Looking ahead: novel approaches used in the analysis of tempera-based paints

All of these recent efforts have begun to offer a more in-depth picture of the challenges scientists face when they attempt to characterize and identify original binding media present in aged paint films. As researchers now rely less on fatty acids ratios, there have been some promising advancements in the analysis of proteins present in tempera-based paint systems. Research has been carried out using proteomic techniques such as matrix-assisted laser desorption ionization mass spectrometry (MALDI-MS) in order to address challenges associated with the successful extraction and detection of amino acids (Leo *et al.* 2009; Kirby *et al.* 2011; Fremout *et al.* 2011). Techniques like MALDI are able to provide less ambiguous results, as recovery of intact peptide fragments (as opposed to individual amino acids) can aid not only in protein classification (e.g. egg yolk, casein, glue, etc.) but can also be used to identify the origin of the proteinaceous material (e.g. fish glue, hide glue from mammals, etc.).[2] Scientists have found, however, that the presence of certain synthetic consolidants or pigments may interfere with the successful detection of peptide chains obtained via digestion (often performed using trypsin) (Leo *et al.* 2009). Furthermore, it remains difficult to obtain spatial information from multilayered paint samples using proteomic methods, although recent advancements using MALDI imaging mass spectrometry may help to address this problem. On the other hand, imaging systems have been used successfully in conjunction with secondary ion mass spectrometry (SIMS) for over a decade in order to characterize organic binders present in artworks possessing complex stratigraphies (Keune and Boon 2004). Time-of-flight SIMS (Tof-SIMS) has been employed recently to generate spatially resolved organic mass spectrometric information from cross-sections collected from tempera-based paints encountered in artworks dating from the 14th century to the early 20th century (Kerr *et al.* 2014; Voras *et al.* 2015, 2016). However, as with other imaging techniques, it is best used in tandem with complementary methods, particularly for the identification of materials that SIMS has yet to successfully characterize.

Conclusion

When faced with the characterization of tempera-based paint systems, it is evident that various scientific departments in cultural institutions have developed unique approaches in order to address many of the analytical challenges summarized in this article. Yet this also makes it increasingly difficult to compare the results generated by different laboratories. While further research is still needed to assess and compare various scientific protocols, it seems that a more accurate approach to analyzing complex tempera-based paint systems involves sophisticated imaging techniques (e.g. ATR-FTIR, ToF-SIMS, MALDI) used in tandem with chromatography/mass spectrometry methods. An additional benefit to this approach is that older cross-sectional samples can be re-examined, extracting both organic and inorganic information simultaneously from a single sample. Conservators and scientists should continue to tackle this challenging subject in a collaborative manner, particularly when previous assumptions regarding the binding media present in an artwork require revisiting and further discussion. Finally, additional round-robin exercises involving the blind analysis of known references will likely help in directing researchers towards the right path when faced with the analysis of complex paint formulations that were used during the 19th and 20th centuries.

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Notes

1. Collaborative research performed recently between scientists at the Metropolitan Museum of Art, New York, and Professor Brian Baade at the University of Delaware, has found that commonly used pigments such as iron oxides and carbon black can cause significant interference with ELISA techniques, typically leading to false negative reactions.
2. Techniques like MALDI can differentiate between proteins associated with egg white and egg yolk; however, some researchers have suggested that artists employed whole egg as a binding medium based on results obtained with MALDI (see Kirby *et al.* 2011). As it is almost impossible to completely segregate traces of egg white when separating the yolk, some of these findings may be worth revisiting, particularly if pigments and other materials are known to interfere with the detection of specific peptides. Recent research has begun to address some of these issues (Kuckova *et al.* 2018). It should also be noted that traditionally egg white (glair) has been used as a varnish for hundreds of years.

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Author's address

Kristin deGhetaldi, Painting Conservator, Instructor Winterthur/University of Delaware Program in Art Conservation, University of Delaware, Newark DE, USA (kdeghetal@yahoo.com)

Flow behaviour and microstructure of complex, multiphase fluids

Annika Hodapp, Patrick Dietemann
and Norbert Willenbacher

ABSTRACT Artists' paints application behaviour, their flow during a brushstroke and the resulting texture of the painting are closely related to their rheology. Rotational and capillary rheometers are widely used to determine viscosity as a function of shear rate or shear stress. Since artists' paints are complex fluids they generally show shear thinning or shear thickening, but may also exhibit an apparent yield stress, thixotropic or viscoelastic behaviour. The simplest model system for an artists' paint is a suspension of hard spheres. Flow properties of more complex systems, including repulsive or attractive interactions among particles as well as particles of different size or shape, are discussed with reference to the hard sphere benchmark system. Furthermore, the class of capillary suspensions is introduced which reveals microstructures and flow properties similar to paints that could be considered to be tempera paints. Finally, preliminary results regarding the flow behaviour of artists' paint model systems are presented.

Introduction

Paints are mixtures of pigments and a binder. The latter can consist of many components including oils, resins and aqueous binders, as in tempera. Historically, it was often believed that mixtures of aqueous and oleaginous binders always form emulsions, irrespective of the added pigment. However, rheologists who study the flow behaviour of materials have a distinctly different view, as will be described in this paper. Pigment–pigment and pigment–binder interactions may result in a complex microstructure depending on the tempera paint composition. Accordingly, the flow properties of the liquid paints also depend strongly on the type of system, as does the appearance and texture of the dry paintings.

Emulsions are heterogeneous mixtures of two (or more) immiscible liquids. One liquid (the disperse phase) is dispersed as fine droplets in the other (continuous) phase. If the disperse phase is solid, the system is called suspension. A tempera paint consisting of pigments, oil and water forms a multiphase fluid, for example, a suspension of pigments in an emulsion of oil droplets in water. However, many other structures can be formed depending on the composition and preparation of the paint, as will be shown below. Minor components such as dispersing agents, flow control additives or others may be dissolved or suspended in water, oil or in a mixture of hydrophilic and/or hydrophobic liquids, and they may either be included in the disperse or the continuous phase. The flow properties of such a mixture cannot be inferred from the chemical composition of the paint alone – they are dependent on the volume fraction as well as the size and shape of the pigment particles, the microstructure of the multiphase system and the interactions between the ingredients.

Simple, one-phase homogeneous fluids consisting of low molecular weight components exhibit what is known as Newtonian behaviour, i.e. their flow resistance is given by a single number, viscosity η. In contrast, multiphase fluids can exhibit complex flow behaviour including shear thinning, yield stress, thixotropy or even viscoelasticity, i.e. they can store and release mechanical energy during deformation and flow.

In the conservation literature there is surprisingly little accurate information available on the rheological properties of paints. For example, de Viguerie *et al.* (2009) offer a very good introduction to rheology, but then continue the discussion on the properties of paints assuming that they are determined by the binder only, ignoring the effects of the pigments, which is clearly not applicable (see below). However, Salvant Plisson *et al.* (2014), who compared lead white and zinc white paints based on paintings by Vincent van Gogh, also studied the influence of pigment parameters.

In this paper we briefly describe how to measure the rheological properties of multiphase systems such as artists' paints, the flow phenomena that frequently occur in such systems and establish structure–property relationships for suspensions of spherical particles, addressing the dependence of flow behaviour on particle volume fraction ϕ, particle size (distribution) and particle interactions. This is followed by a discussion on the microstructure and flow of capillary suspensions, i.e. ternary systems comprising solid particles as well as two immiscible fluids. Finally, we present the first results on the rheology of tempera-type model pastes including oil, pigment and egg yolk, demonstrating that artists' paint rheology cannot be reduced to a simple viscosity number.

Basics and measurement techniques of rheology

The following is restricted to shear deformation and flow, i.e., to flow fields characterized by parallel streamlines and a velocity gradient perpendicular to the flow direction. For a fluid element sheared between two parallel plates (Fig. 1) moving at a relative velocity v and a gap height h the shear rate $\dot{\gamma}$ is given as

$$\dot{\gamma} = \frac{v}{h} \qquad \sigma = \frac{F}{A} \qquad \gamma = \frac{x}{h}$$

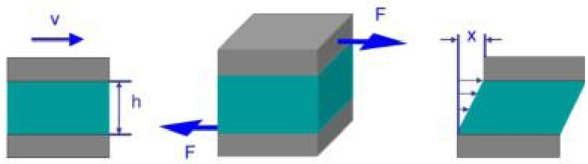

Figure 1 The fluid element sheared between two parallel plates.

Finally, Newton's law $\sigma = \eta\dot{\gamma}$ with the proportionality factor η, termed viscosity, establishes the simplest relationship between shear stress σ and $\dot{\gamma}$. For complex fluids η may depend on $\dot{\gamma}$ and/or time t. In other words, the flow behaviour of fluids such as artists' paints cannot generally be characterized by a single number because the viscosity is not constant – it is dependent on the conditions of application (see 'Rheological phenonema' below). A brief description of how rheological parameters can be measured follows.

Rheometry

The viscosity can be determined using different rheometers. The widely used rotational rheometers are versatile, easy to use and can be equipped with different sample cells such as concentrical cylinder, plate-plate and cone-plate fixtures depending on sample properties. This rheometer type operates in a shear rate range of 0.001–1000 s^{-1}. Capillary rheometers are used to extend the shear rate range up to 10^6 s^{-1}. Typical shear rates occurring during application of artisan paints range between 10^2 and 10^4 s^{-1}. For example, if a 100 µm thick paint layer is applied with a brush at a speed of 10 cm per second, the shear rate is 10 cm s^{-1}/100 µm, i.e. 1000 s^{-1}.

Rotational rheometry

Rotational rheometers can be operated in two different modes. If a constant rotational speed n is imposed the shear rate is controlled. Respectively, if a constant torque is applied the shear stress is controlled. The cylinder geometry is preferred for

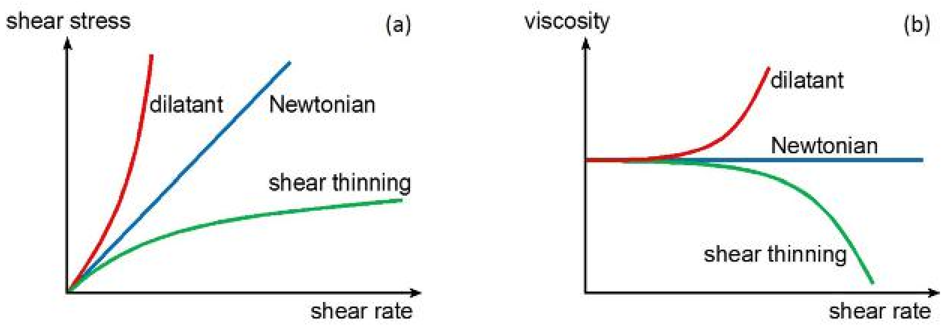

Figure 2 Shear thinning, Newtonian and dilatant flow behaviour: (a) shear stress as a function of shear rate and (b) viscosity as a function of shear rate.

low viscosity samples because it offers a large shear rate area and the sample cannot spill out of the shear gap. The advantage of the cone-plate geometry is that the shear rate is constant throughout the gap. The disadvantages are that particles can clog the small gap in the middle and the edge is sensitive to solvent loss. The plate-plate geometry is used to examine suspensions containing large particles because the gap height *h* can be chosen appropriately (*h* > 10× particle diameter). The disadvantage of this geometry is that the circumferential velocity *v* depends on the distance *r* from the rotational axis. Accordingly, the shear rate $\dot{\gamma}$ increases in the radial direction.

Rotational rheometers are also used frequently for dynamic tests probing the linear viscoelastic behaviour of fluids. In small amplitude oscillatory shear (SAOS) tests, the sample is loaded by a sinusoidally oscillating stress or strain. A sinusoidal deformation γ(t) is related to the amplitude γ_0 and an angular frequency ω applied to the sample by the equation:

$$\gamma(t) = \gamma_0 sin(\omega t)$$

If the deformation amplitude γ_0 is small enough, the measured stress σ(*t*) also varies sinusoidally at the same frequency ω but is phase shifted by an angle δ:

$$\sigma(t) = \sigma_0 sin(\omega t + \delta)$$

The shift angle can be between δ = 0° for ideal elastic materials and δ = 90° for ideal viscous liquids. From this, the storage and loss moduli G' and G" can be determined to characterize the linear viscoelastic properties of a fluid:

$$\sigma = \sigma_0 [G' sin(\omega t) + G'' cos(\omega t)]$$

G' is the specific energy stored by the material and represents the elastic behaviour of the material. G" corresponds to the energy dissipated or lost during an oscillation cycle and characterizes the viscous behaviour of the material. The accessible frequency range is typically 10^{-3} rad/s < ω < 10^{2} rad/s and the ratio G'/G" can strongly depend on ω, i.e. on the time scale of a considered process.

Capillary rheometer

In a capillary rheometer the fluid is forced to flow from a reservoir through a capillary die of radius *R* and length *L* using a piston moving at controlled velocity. Assuming a Newtonian liquid and a fully developed, incompressible, laminar flow, the shear rate at the wall is related to the flow rate *Q*:

$$\dot{\gamma} = \frac{4Q}{\pi R^3}$$

and the wall shear stress is related to the measured pressure drop Δp by:

$$\sigma = \frac{\Delta p R}{2L}$$

In general, the abovementioned conditions are not valid and the measured σ-$\dot{\gamma}$ data sets have to be corrected for pressure losses at the die entrance (Bagley 1957), wall slip (Mooney 1931) and deviations from the parabolic Newtonian flow profile (Macosko and Larson 1994).

Rheological phenomena

During painting, the paint is sheared between the brush and the canvas, therefore the brush applies a force to the paint that depends on the type of brush, the speed of application and the paint itself. This section describes the effect of the resulting force on the viscosity of the paint.

Newtonian flow behaviour

Fluids for which shear rate and shear stress are linearly dependent on each other and the viscosity is independent of the shear rate are termed Newtonian fluids. This also means that viscosity is constant during the time of shearing and shear stress relaxes immediately after the shearing is stopped. Most low molecular weight liquids such as water/glycerol mixtures, organic solvents and untreated drying oils are Newtonian fluids. However, many materials – in particular multiphase fluids such as pigment suspensions – exhibit deviations from this simple behaviour (Fig. 2).

Shear thinning

Shear thinning or pseudoplastic behaviour means that the viscosity decreases with increasing shear rate (Fig. 2, green line). Some examples of shear thinning liquids are polymeric solutions, dispersions and emulsions. Because artists' paints often exhibit shear thinning behaviour the viscosity in a brushstroke is much lower than expected from visual inspection while gently shaking a beaker or slightly tilting a palette.

Shear thickening

Shear thickening or dilatancy means that the viscosity increases with increasing shear rate (Fig. 2, red line). Examples of shear thickening fluids include highly concentrated dispersions and starch suspensions. Dilatancy is disadvantageous for painting because it hinders the paint take-up by the brush. The paint transfer from brush to canvas is also hampered due to the high viscosity during application. However, once the paint has been applied to the canvas the viscosity reduces and there is a risk that the paint might run if the canvas is not lying flat.

Yield stress

Certain fluids require a minimum shear stress to enable flow. This critical stress is called yield stress σ_y. Dispersions with attractive interactions, such as clay suspensions and densely packed emulsions and foams, typically exhibit a yield stress, which is of paramount importance for painting. There is a risk that the paint might run if it takes hours or days to dry, even if the viscosity is very high. This applies in particular to easel painting if the canvas is not lying flat and to sculpture polychromy. In glazes, even minor changes in layer thickness due to flow will result in a very obvious change of colour, which can easily ruin the appearance. To allow for a controlled paint application it is therefore highly advantageous if the viscosity of a paint is not just very high shortly after application, but reaches a yield stress and stops flowing entirely. The same effect is also crucial for impasto painting.

Thixotropy

Thixotropy – a gradual decrease in viscosity over time at a constant shear rate and subsequent recovery at rest or at lower shear rate – can be seen in differences between viscosity data obtained from shear rate ramps in upward and downward mode. Thixotropy promotes the levelling of artists' paints after application and is important for varnish or lacquer application on musical instruments or furniture for example.

Viscoelasticity

Complex fluids often encounter viscoelastic properties, i.e. they not only dissipate but can also store and release mechanical energy during deformation and flow. This can lead to embarrassing consequences such as rod climbing (the Weissenberg effect), die swelling, fibre spinning or the open syphon effect. Artists' paints are also prone to such phenomena. Paints able to form impasto are described as viscoelastic. For example, if an oil paint reaches a yield point, it will not flow despite the influence of gravity or its own weight. This means that the viscosity is not defined according to Newton's law. Although such an oil paint is still considered a liquid a few seconds after application, rheologically it has to be described as a (viscoelastic) solid: below the yield stress it is mainly elastic, above the yield stress it is predominantly viscous.

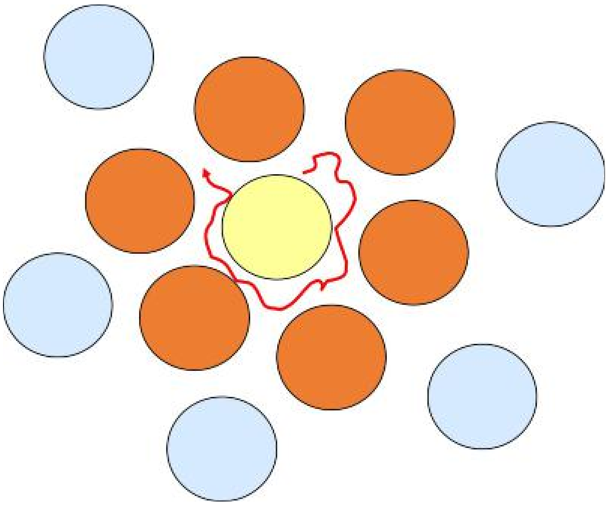

Figure 3 The cage effect.

Parameters controlling dispersion rheology

The most important parameter controlling the rheology of dispersions is the particle volume fraction ϕ, which is the volume of the particles compared to the total volume of the suspension. Other parameters include the particle size, shape and size distribution. For particles typically smaller than 1 μm Brownian motion is another phenomenon that affects flow behaviour. Thermodynamic interactions among particles, such as van der Waals attraction or electrostatic and steric repulsion, also have a strong impact on dispersion rheology. All these aspects are important for paints: artists may have manipulated these parameters in the past albeit unintentionally. Attractive or repulsive forces between mineral pigment particles, for example, may have been adjusted by a pigment coating with proteins, or the addition of acids such as vinegar might have influenced the electrical charges on pigment surfaces.

Hard spheres

Hard sphere dispersions (radius *a*) are an idealized model system in which hydrodynamic (flow-induced) interactions are considered. Direct particle–particle interactions, however, are ignored except when particles come into contact (excluded volume). But even with this simplified model, complex rheological scenarios can be described. For infinitely diluted suspensions ($\phi < 0.01$) Einstein (1906) found that the particles increase the viscosity of the dispersion medium linearly with volume fraction:

$$\eta_r \equiv \frac{\eta}{\eta_s} = (1 + 2.5\phi)$$

In this equation, η_r is the relative viscosity, η is the viscosity of the suspension and η_s is the viscosity of the suspension medium. Batchelor (1977) continued to develop the Einstein equation, paying attention to the hydrodynamic interaction of two particles:

$$\eta_r = 1 + 2.5\phi + 6.2\phi^2$$

This covers the concentration range $\phi < 0.1$, which only corresponds to heavily diluted paints. For higher particle loadings numerous phenomenological equations have been suggested referring to the maximum packing fraction ϕ_{max} at which η diverges (approaches infinity), for example:

$$\eta_r = \left(1 - \frac{\phi}{\phi_{max}}\right)^{-\gamma}$$

with $\gamma = 1.6$ (Krieger and Dougherty 1959) or $\gamma = 2$ (Maron and Pierce 1956).

For non-colloidal particles it is $\phi_{max} \approx 0.64$ assuming random packing. For colloidal dispersions it has been observed that the viscosity diverges at a lower volume fraction, termed the colloidal glass transition $\phi_g = 0.58$. This is due to the cage effect (Fig. 3), reflecting that particles cannot diffuse over long distance when the gap between the surrounding particles is smaller than the particle diameter (Horn *et al.* 2000). Then $\phi_{max} = \phi_g$ and mode-coupling theory predicts $\gamma = 2.45$ (Russel *et al.* 2013).

Repulsive particles

Generally, technical dispersions are stabilized via short-range electrostatic or steric repulsion. Nevertheless, such systems can also be described as hard sphere dispersions using the true particle radius a and an effective radius a_{eff} or an effective volume fraction ϕ_{eff} taking into account the volume excluded for other particles due to the repulsive interaction:

$$\phi_{eff} = \frac{4\pi}{3} a_{eff}^3 = \phi \left(\frac{a_{eff}}{a}\right)^3$$

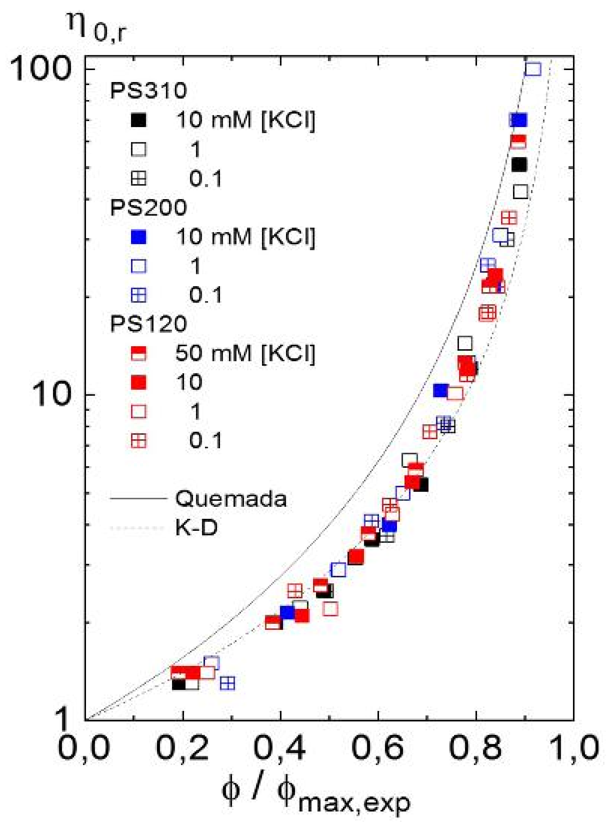

Figure 4 Relative zero-shear viscosity $\eta_{0,r}$ versus $\phi/\phi_{max,exp}$ for monodisperse polystyrene (PS) particles. Master curve including data obtained for different salt concentrations of potassium chloride [KCl] and particle size [PS]: 120, 200, 310 nm (Horn *et al.* 2000). Solid and dotted lines correspond to the model equations of Krieger and Dougherty (1959) as well as Quemada (1977).

The validity of this hard sphere mapping concept is demonstrated in Figure 4 for electrostatically stabilized dispersions with different particle size and salt content (i.e. varying range of electrostatic repulsion).

In dispersions with particle volume fraction $\phi_{eff} < 0.5$, particles are distributed randomly and in this concentration range the absolute value of viscosity and the degree of shear thinning are low (Fig. 5, blue symbols). In the concentration range $0.5 < \phi_{eff} < 0.55$, regions where particles are arranged in crystalline order and regions with randomly distributed particles co-exist result in thixotropic behaviour, i.e. the viscosity measured in a decreasing shear rate mode is lower than that measured in an upward ramp (Fig. 5, open and closed red symbols). At even higher concentrations $\phi_{eff} > 0.55$ dispersions exist in a uniform ordered state or in a disordered glassy, gel-like structure. This then results in a strongly shear thinning but non-thixotropic flow behaviour (Fig. 5, black symbols).

Bimodal dispersions

Highly concentrated dispersions ($\phi > 0.5$) with a bimodal or broad particle size distribution exhibit a lower viscosity than monomodal dispersions with the same ϕ (Farris 1968). Viscosity reduction is most pronounced at a small particle volume fraction ξ_s

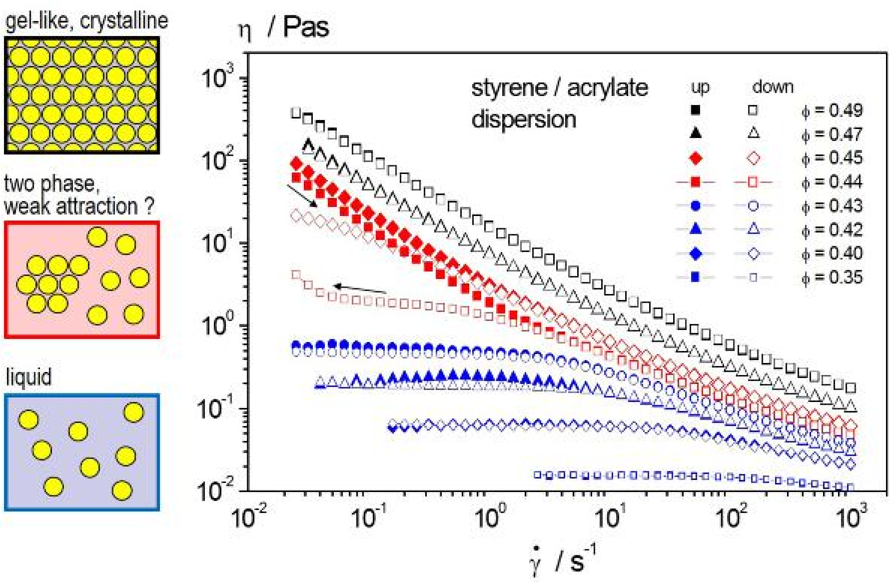

Figure 5 Viscosity vs. shear rate for styrene/acrylate dispersions at different particle volume fraction. These dispersions exhibit short range repulsion among particles, resulting in $\phi_{eff} = 1.15\phi$; the downward arrow indicates viscosity data measured at increasing shear rate and the upward arrow represents the decreasing shear rate ramp.

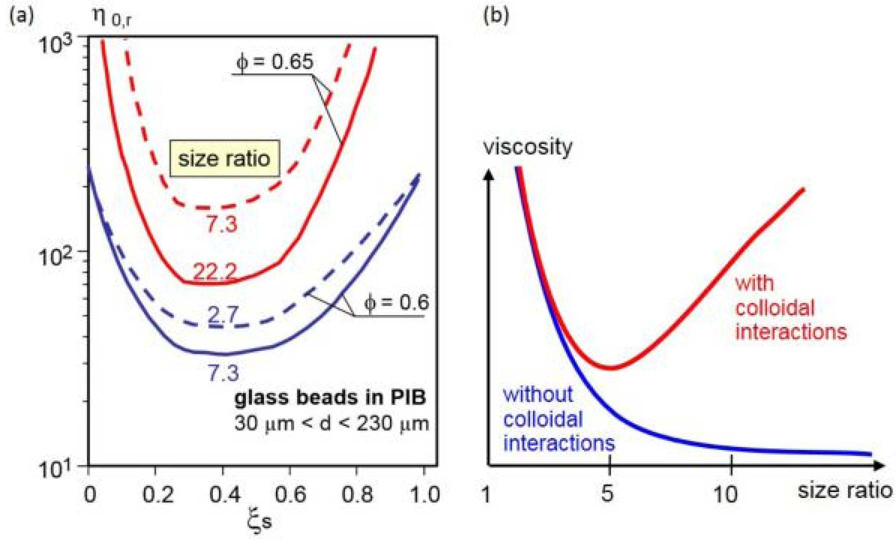

Figure 6 (a) Calculated relative viscosity as a function of small particle volume fraction ξ_s for a suspension of non-colloidal hard spheres suspended in polyisobutene (PIB) at different size ratios (adapted from Chong *et al.* 1971); (b) viscosity vs. particle size ratio for suspensions with (red line) and without (blue line) colloidal interactions (Dames *et al.* 2001).

of $0.25 < \xi_s < 0.4$. For non-colloidal particles, i.e. for particles for which electrostatic, steric or van der Waals interactions are of minor relevance, the viscosity reduction is more pronounced at higher ϕ and increases monotonically with increasing size ratio $\chi = a_{large}/a_{small}$ (Fig. 6a) (Chong *et al.* 1971). In colloidal dispersions it should be noted that at constant ϕ the effective volume fraction ϕ_{eff} increases with decreasing a_{small}. Hence viscosity exhibits a minimum and increases strongly around $\chi \approx 4\text{-}5$ depending on the range of repulsive interaction (Fig. 6b) (Dames *et al.* 2001).

Particle shape

Shape anisotropy has a strong effect on rheology. At a constant volume fraction the low shear viscosity increases with increasing anisotropy. The high shear viscosity, however, decreases due to flow alignment of the anisotropic particles.

Attractive particles

When attractive interactions (van der Waals attraction, capillary bridging and depletion attraction) among particles dominate in a dispersion, self-similar (fractal), sample-spanning particle networks may form resulting in distinct flow properties. Such dispersions or pastes typically exhibit a yield stress, strong shear thinning and often thixotropic properties. Moreover, they typically show gel-like, predominantly elastic behaviour (G' >> G") independent of frequency even at low ϕ. At high shear rates the network structure breaks down and the viscosity approaches that of hard sphere dispersions determined solely by the particle loading ϕ. Many artists' paints belong to this class of fluids (see 'Rheological data of artists' paint model systems' below).

Capillary suspensions

Capillary suspensions are three-phase systems consisting of one solid and two immiscible liquids. Adding even a small amount ($\phi_{sl} < 0.01$) of a second fluid to a low-concentrated suspension (ϕ_{solid} = 0.05 – 0.35) can dramatically change the texture and flow behaviour of such a system (Fig. 7a). A transition from a fluid-like to a gel-like behaviour or from a weak to a strong gel occurs, and typically such pastes exhibit a pronounced yield stress that increases with an increasing amount of secondary liquid until spherical agglomeration and phase separation occur. The effect exists even when this secondary fluid wets the particles to a lesser degree than the main fluid (Koos and Willenbacher 2011). This is called the capillary state (Fig. 7b). If the second fluid wets the particles more than the first fluid it is called pendular state (Fig. 7c) (Bossler and Koos 2016).

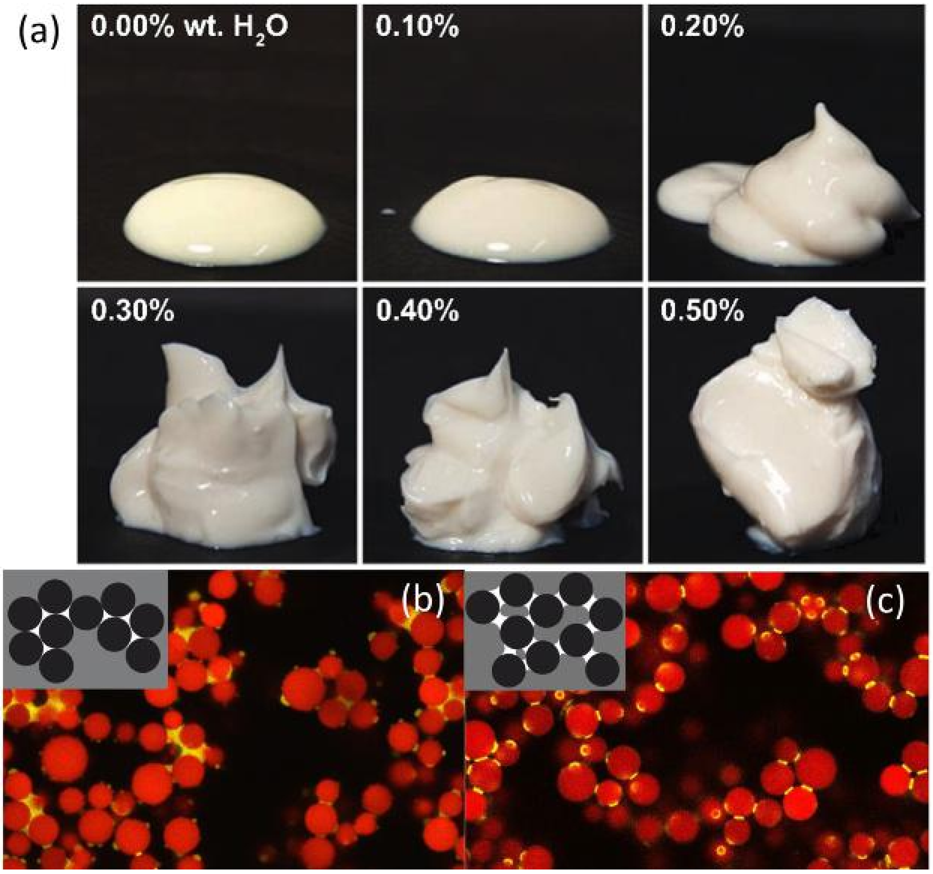

Figure 7 (a) Hydrophobic $CaCO_3$ (a = 0.8 mm, ϕ_{solid} = 0.111) in diisononyl phthalate (DINP) with added water (Koos and Willenbacher 2011); glass beads in DINP (a = 3.2 mm, ϕ_{solid} = 0.30) with 3% added water (Bossler and Koos 2016); (b) capillary state; (c) pendular state (confocal scanning microscopy images).

Capillary suspensions consisting of ceramic oxide particles, a paraffin oil/wax mixture as primary fluid and an aqueous sucrose solution have been used as pastes for 3D printing of porous ceramic due to their unique and easy to adjust flow properties (Maurath and Willenbacher 2017).

The analogy to tempera paints containing pigment particles, oil, water and an aqueous binder is obvious. Dietemann *et al*. (2014) discussed the fact that mixtures of oil and aqueous binders do not necessarily form emulsions (although without considering capillary suspensions), and in the presence of pigments, many more options are evidently possible. Clearly more work is needed to elucidate the microstructure of such paints – whether they form emulsions, capillary suspensions, Pickering emulsions (an emulsion that is stabilized by solid particles) or other microstructures – and how this relates to their flow behaviour and texture which is so important for painting.

Rheological data of artists' paint model systems

We studied artists' paint model systems containing TiO_2 pigment (Kremer Pigmente, a = 0.25 μm) suspended in linseed oil at various pigment concentrations between 20 vol% and 50 vol%. Additionally, egg yolk (1:1 diluted in water) was added to one of these suspensions (36 vol%). Pure suspensions are extremely shear thinning and the viscosity (a) as well as the yield stress (b) increase dramatically with increasing pigment concentration (Fig. 8). Strikingly, adding a trace amount of egg yolk to such suspensions results in a drastic increase in viscosity and the yield stress rises by almost one order of magnitude.

Oscillatory shear measurements (Fig. 8c and d) reveal that the suspensions are predominantly elastic (G' > G") and the moduli are essentially independent of frequency. The amplitude sweeps directly show

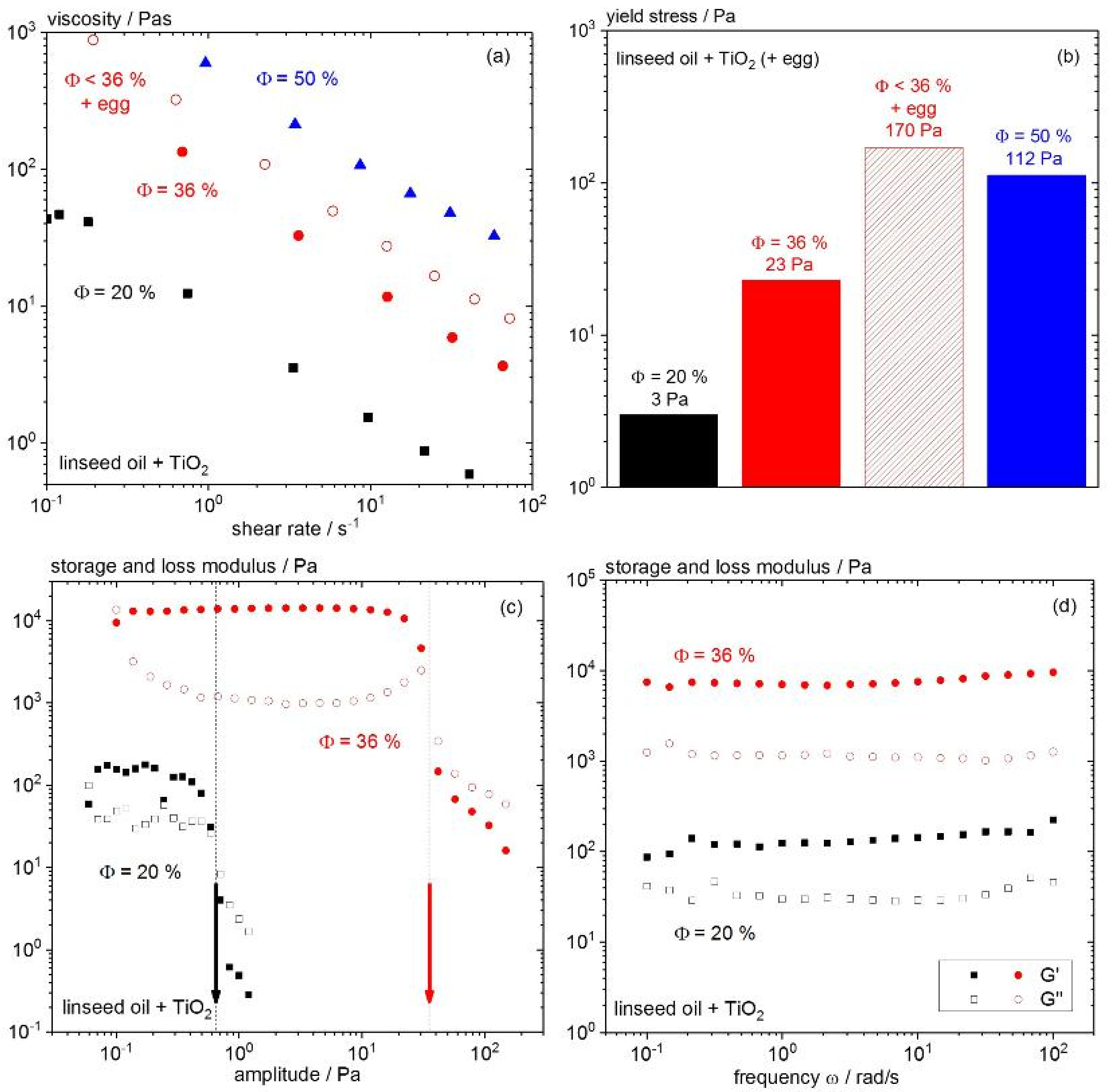

Figure 8 Results of experiments on suspensions of TiO_2 in linseed oil (and egg yolk): (a) viscosity vs. shear rate and (b) yield stress; (c) moduli G' and G" vs. stress amplitude at fixed frequency (f = 6.28 rad/s); (d) moduli G' and G" vs. frequency at fixed stress amplitude ($\sigma_{36\%}$ = 10 Pa, $\sigma_{20\%}$ = 0.4 Pa).

the structural breakdown at stress amplitudes roughly corresponding to the yield stress of the respective samples.

Effect of the brush on the rheology of paint

When paint is applied with a brush, it is squeezed between the canvas and the brush. The flow properties of the paint depend on the speed and force applied by the artist's hand and even more on the type of brush – its shape, size, thickness, length and stiffness of bristles/hair – which strongly influences the force transfer to the paint (Fig. 9). The applied force will exceed the yield stress thereby allowing the paint to flow. Depending on the amount of shear thinning, for example, the paint's viscosity will drop to a certain degree. At the same time, the resistance of the paint will deform the brush, especially if it is soft, that again limits the force that a brush can apply to the paint, which in turn influences the viscosity because paint is not a Newtonian fluid. It is obvious that a

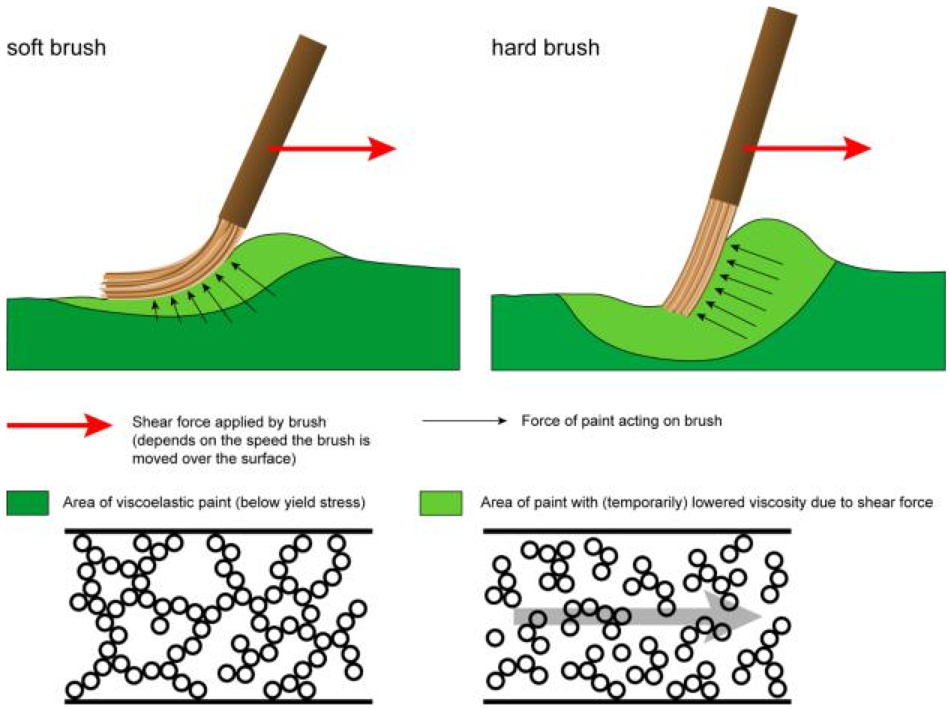

Figure 9 Interaction and force transfer of brush and paint during painting (top). Note the different black arrows due to the bending of the brush's hairs. The gel network in the paint, causing yield stress, is temporarily destroyed by the force applied by the brush and the paint is able to flow (bottom) (dimensions are not true to scale).

brush is a highly sensitive tool for the adjustment of a paint's viscosity through the modulation of the applied force and vice versa.

On the other hand, the microstructure of the paint will determine the absolute value of the yield stress and degree of shear thinning or dilatancy and, accordingly, the flow and appearance of the paint during and after application. A high yield stress is indispensable to obtain pronounced impasto. These factors are not only influenced by the properties of the binders, but also by the kind of pigment, the pigment:binder ratio, the shape and size distribution of the pigments and last but not least the gel structure of the evolving mixture. Because tempera paints consisting of oils and aqueous binders form not only emulsions but many other more complex gel networks, they provide artists with unlimited possibilities.

Conclusion

Considerable knowledge exists on the rheology of many kinds of emulsions, dispersions and pastes including technical inks, paints and coatings. The relationship between characteristic flow properties and the performance of such systems in technical processing and coating operations is well understood. In contrast, little is known about the correlation between the composition, microstructure and rheology of artists' paints, particularly when the paint comprises three or more components including non-synthetic, natural binders. Shedding light on this fascinating topic will be an interesting challenge for future research aiming at a better understanding of the painting process, paint appearance and texture, and eventually, of the changes due to ageing which might lead to improved restorations of unique and valuable artworks.

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Authors' addresses

- Annika Hodapp, Karlsruhe Institute for Technology, Institute for Mechanical Process Engineering and Mechanics, Karlsruhe, Germany
- Patrick Dietemann, Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich, Germany
- Norbert Willenbacher, Karlsruhe Institute for Technology, Institute for Mechanical Process Engineering and Mechanics, Karlsruhe, Germany (norbert.willenbacher@kit.edu)

Analysis and interpretation of binding media in tempera paintings

Patrick Dietemann, Wibke Neugebauer, Cedric Beil,

Irene Fiedler and Ursula Baumer

ABSTRACT Analysis of 19th–century tempera binding media is difficult for many reasons. Due to the colloidal nature of paints, the same materials can be mixed in various ways, resulting in very different paints with strongly varying properties. Reliable identification of the binder components is therefore only the first step in the identification of the binding medium system, i.e. the type of paint that was used for painting. Unfortunately it is often not possible to identify the binder system by chemical analysis alone therefore additional information from written sources and a technological study of the sampled paintings provides for a more comprehensive interpretation of the analytical data, possibly supported by paint reconstructions. This paper summarizes the conclusions drawn from a large project on tempera painting 1850–1914 and discusses three selected case studies. It demonstrates that the composition of tempera paints can be very complex, including many different materials from several classes of binders (oils, resins, proteins, polysaccharides, waxes) in just one sample. The layer build-up of the painting needs to be considered because materials from varnishes and top layers may penetrate lower layers and are not always easily distinguished from original binders of that paint. Reliable detection of (possibly degraded) minor components may be difficult but is crucial for the interpretation of the initial binding medium system.

Introduction, questions and methods

Analytical characterization of tempera systems is difficult for a number of reasons. Some aspects have been discussed previously, such as the problem of terminology (Dietemann *et al.* 2015)[1] and the colloidal nature of paints and tempera paints in particular (Dietemann *et al.* 2014).[2] This paper discusses three case studies, each dealing with a further, analytical issue: the complexity of tempera paint composition and layer build-up, and the problem of detecting minor, potentially degraded compounds that may be crucial to the understanding and interpretation of (tempera) paints.

General considerations

A number of reasons, primarily the colloidal nature of paints, make the provision of a consistent definition of 'tempera' in such a short text impossible (Dietemann *et al.* 2015). This paper uses the term 'tempera' primarily to describe paints with a continuous aqueous phase, thus paints that can be diluted with water but not oil or oil of turpentine.[3] This usually means that the paint contains aqueous binders with or without oleoresinous binders, although there are also exceptions (e.g. *Weimarfarbe*) (Dietemann *et al.* 2015: 287). Consequently, the term 'oil paint' in this paper describes a paint with a continuous oil phase that can be diluted with oil or oil of turpentine but not water. It usually comprises an oleoresinous binder, i.e. a binder consisting of oil(s) with or without resin(s), but may also contain proteins or possibly polysaccharides. Accordingly, if both aqueous and oleoresinous binders are identified in a paint sample, it raises several questions of interpretation. First, it must be determined whether the identified materials all originate from the same layer and binding medium system (i.e. the system of all binders and diluents), if they represent binders from different layers sampled together or whether compounds from upper layers or varnishes penetrated the sampled layer and therefore do not constitute original binder components. These questions are discussed in the case studies.

Even if all components of a binding medium system are identified and attributed to one and the same system, further questions concerning interpretation of the results still remain. Thus, in a second step, the kind of binding medium system that may have been formed has to be evaluated. In the past it was commonly assumed that mixtures of aqueous and oleoresinous binders always form emulsions; depending on the relative amounts, the two phases are believed to constitute oil-in-water (O/W) or water-in-oil (W/O) emulsions ('symmetric emulsion theory'). It has been shown that this theory conflicts with basic principles of colloid chemistry (Dietemann *et al.* 2014) and is, therefore, clearly incorrect. Instead, many other systems may form, depending on the paint preparation. Paints made from pigments and two immiscible liquids, such as water and oil, should be described as ternary systems. These may form emulsions, but can also produce capillary suspensions or bicontinuous structures (Koos 2014).[4] It is also possible to coat the pigments with proteins before suspending them in oil.

Studying the literature cited above, it is clear that the type of system formed can be decisively influenced by minor compounds, for example emulsifiers, materials that coat the pigments, or even traces of solvents, be it as little as 1% water.[5] Of course, this is highly problematic when trying to correlate the results of binding media analysis with the composition of initial paints, sometimes even preventing a distinction between tempera and oil paints. For example, it has been shown that egg tempera with oil may consist of up to almost 90% lipids and only 10% egg protein when dry (Dietemann *et al.* 2014: 36). Nevertheless, such a mixture forms an O/W emulsion, therefore the aqueous phase forms the continuous phase, and the mixture can be diluted with water but not with oil or oil of turpentine (the latter diluents would need to be emulsified to form a homogenous mixture). This system therefore constitutes an aqueous tempera paint, although the decisive component, the protein, is only the minor component. Generally, the absolute content of protein remaining in a dried paint can be extremely low because aqueous binders consist mainly of water. If the protein degrades during ageing, the amount of detectable protein in a paint sample can be even lower as the sensitivity of most analytical methods is higher for aged oils than for aged proteins.

These examples demonstrate that the kind of binding medium system formed (emulsions, capillary suspensions, bicontinuous systems or protein-coated pigments in oil) has little dependence on the absolute amounts of the various binders. It is important to realize that the properties of the liquid paint are contingent on the type of system formed, and that this is what influences the artist to consider a system to be tempera or oil paint, as well as determining whether the artwork would be regarded as an oil or tempera painting (Dietemann *et al.* 2015). At present, an unambiguous determination of the initial system based on chemical analysis alone does not seem possible. Necessary complementary key information must be obtained both from written sources, if available, and technological examination of the paintings. In addition, paint reconstructions may also be very useful.

The 'Munich tempera project' and analytical methods

This volume is an excerpt from a larger study, the 'Munich tempera project', which focused on tempera painting between 1850 and 1914.[6] Of some 170 studied paintings, 19 were selected and sampled for binding medium analysis following careful, in-depth technological study and source research (Neugebauer 2016). Samples were extracted step-by-step with solvents of increasing polarity (Koller *et al.* 1998): isooctane, methanol, chloroform/methanol (7:3), anhydrous oxalic acid in methanol (10 wt%) and water. The first four extracts were analysed by gas chromatography-mass spectrometry (GC-MS) with and without derivatization with trimethylsulfonium hydroxide. The aqueous extract was first boiled with hydrochloric acid in methanol to hydrolyse the monosaccharides, which were then identified by GC-MS following a procedure published in Bonaduce *et al.* (2007). The residue of the aqueous extract, as well as that of the extracted sample, was subsequently analysed for proteins after hydrolysis with 'constant-boiling' (azeotropic) hydrochloric acid, using ion exchange (liquid) chromatography with post-column derivatization (amino acid analysis).

With this procedure, comprehensive, reliable and detailed identification of all classes of binders in a sample is possible. In addition to the chromatographic analyses, the distribution of the materials in the paints and the layer build-up of the paintings were studied in cross-sections by protein-selective fluorescent staining with SYPRO Ruby and in some cases with Fourier transform infrared focal plane array (FTIR-FPA) imaging.[7]

The complexity of samples: Franz von Stuck, *Portrait Gertrud Littmann* (1911)

Descriptions of the technique and materials of Franz von Stuck's painting (Fig. 1) are found in Neugebauer (2016: 350–65, 633–45). Due to complex stratigraphies with various intermediate varnishes, interpretation of the binding media analysis is difficult. However, it seems that Stuck placed his painting in its frame to check its appearance when the paints were still partially wet: residues of four different paints could be sampled from inside the frame, without touching the painting. It should be noted that, because no varnish residues were observed on the frame, we were able to obtain samples consisting of a single paint without any contamination from other layers or varnishes. Naturally, a single paint could have been mixed from two or more colours (tube paints), for example, violet from red and blue.

A black paint sampled from the furniture in the lower left corner (Fig. 1) consisted of gum arabic with animal glue and dammar/mastic with a little colophony. A dark blue paint from the top left corner contained gum arabic with animal glue. The bright red underpaint of the violet background comprised egg and oil, possibly walnut oil, with a little resin (as in black), and a dark blue-violet glaze on top of the red background (one of several) contained egg, animal glue, some gum arabic, possibly with some cherry gum (fruit tree gum), and a little dammar, mastic and colophony. All paints contained some animal fat, possibly from the egg yolk or animal glue, but the red and blue-violet paints of the background contained relatively large amounts of lauric and myristic acids, possibly an indication of a coconut-fat additive.

While the red paint is interpreted as an egg tempera with oil (and a little resin), the black, blue and blue-violet paints are essentially mixtures of gums with proteins, sometimes with oleoresinous additives. For all gum-based paints examined in the tempera project, proteinaceous binders were identified concurrently with the polysaccharides. Based on advice from numerous artists and art technologists such as Ernst Berger and Max Doerner (e.g. Doerner 1938: 182–3), the interpretation is that proteinaceous binders were used by artists to stabilize gum emulsions and improve wetting and adhesion to the support. Detailed discussion of this in relation to a painting by Arnold Böcklin and Stuck's use of Syntonos paint in the painting *Der Krieg* (*War*, 1894) is provided in Dietemann *et al.* (2016: 186–94) and Lutz (2011). While samples from Syntonos tube paints did not contain protein, which accords with the published composition, all the paint samples from the *Der Krieg* painting contained egg (sometimes with animal glue) in addition to the typical Syntonos tube-paint components. In both the Böcklin and Stuck case studies, it was demonstrated that the egg protein was evenly distributed in the paint layers and not a contaminant from intermediate layers or varnishes. In a questionnaire he completed in 1912, Stuck also explained that he used an egg emulsion as an additive/diluent for Winsor & Newton tempera paints (Beisiegel 2014: 92). Unfortunately, it is not known what kind of tempera he used.

Although the complexity of supposedly 'simple' tempera paints may seem surprising at first glance, from the viewpoint of colloid chemistry it is to be expected. Emulsions and suspensions require stabilization, especially in the case of commercial tempera paints, because phase separation in the tube during storage must be avoided at all costs. Furthermore, manufacturers also optimized the flow properties of commercial paints by including various additives (Dietemann *et al.* 2015: 288–9). It has been demonstrated that the flow properties of paints

Figure 1 Franz von Stuck, *Portrait Gertrud Littmann*, 1911, 114.2 × 99.5 cm, Bayerische Staatsgemäldesammlungen, Inv. No. 14450. (Photo: Sibylle Forster, Bayerische Staatsgemäldesammlungen, Munich.)

depend largely on the pigments they contain, and the type of interactions between the particles.[8] How these are influenced by the additives is very complex and not necessarily understood for the binders discussed here. However, it is clear that egg (yolk) was frequently recommended as a stabilizing additive for tempera paints, and its identification in many of the tempera paints studied in the 'Munich tempera project' confirms that artists used the emulsifying power of proteinaceous binders, mostly egg, but also animal glue.

As a consequence, sensitive and precise binder analysis can reveal many components in a single paint: an emulsion of drying oil with a plant gum and stabilizing proteinaceous material contains three main components; if the oil is further mixed with a resin, there are four main binders. Additional additives, such as wax, tallow or soap, could be added by the manufacturer to further modify paint properties, as seen for Syntonos paint (Dietemann *et al.* 2016: 186–94; Lutz 2011). If the artist mixes a violet from red and blue tube paints, the binders are mixed as well. Thus a blue paint bound with gum arabic-egg-walnut oil with dammar mixed with a red paint bound with cherry gum-animal glue-poppyseed oil with mastic will contain eight different binders from four classes of materials: gums, proteins, oils and resins. This might be one explanation for the composition of the blue-violet paint identified in Stuck's *Portrait Gertrud Littmann*, but of course it is unknown which components were initially mixed together.

Figure 2 Arnold Böcklin, *Venus Genitrix*, 1891–95, 104.6 × 149.8 cm, Kunsthaus Zürich, Inv. No. 1167. (Photo: Wibke Neugebauer.)

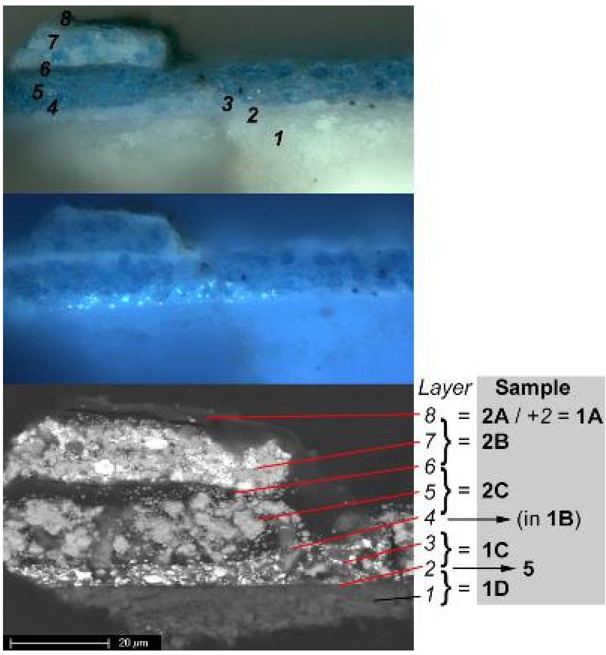

Figure 3 Arnold Böcklin, *Venus Genitrix*: cross-section taken from blue sky (left panel) shown in visible light, under UV illumination and as a backscattered electron image (detail of left part). The different layers are labelled 1–8 and a tentative attribution to samples taken from the painting (e.g. 2A etc.) is also provided. (Photo: Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich.)

The fact that tempera paints can contain many binder components poses several problems. The amount of each binder in a small sample can be very limited, which may generate problems of sensitivity. Even more problematic, some of the components may be abundant, while other components are only present in small quantities, either because they were only minor additives in the initial paint, or because they were the binders of a minor addition of another colour (tube paint). If only the main binders are identified, due to limited sample size and/or lack of analytical sensitivity, the initial complexity of the tempera binder is not fully recognizable. This can be particularly difficult if the minor compound is the decisive compound that determined the properties of the paint desired by the artist. As mentioned above, a mere 10% egg yolk protein can be indicative of a tempera paint, even though the main binder is oil, and the percentage of detected protein can be even lower if the protein is degraded or additional materials have penetrated the lean tempera layer (see below).

The complexity of layer build-up: Arnold Böcklin, *Venus Genitrix* (1891–95)

Aqueous binders are more or less lean (porous) because they dry by forming a gel network as the water evaporates, even when there is still a lot of water present. Gelatine, for example, can form gels at concentrations of less than 1%.[9] This means that the paint stops flowing despite the presence of a large amount of water. During further drying, the loss of volume cannot fully be compensated by shrinkage, causing voids, microscopic cracks and pores to develop. Binders from paints or varnishes applied later are therefore able to penetrate these voids, and are analysed together with the initial binders of the respective paint. Thus, any analytical interpretation must consider the layer build-up and painting technique(s) of each piece. The blue sky in Arnold Böcklin's *Venus Genitrix* (Fig. 2, top left) was chosen as an example.

Böcklin's painting technique is described in Neugebauer (2016: 266–79; 555–73). From the technical study it became obvious that the sky was painted with three blue paint layers and intermediate varnishes in between. The ground was isolated by a brownish liquid with orange fluorescence. In the cross-section of the sky (Fig. 3), the layer build-up is visible: three blue paints (layers 3, 5, 7) with intermediate varnishes (layers 2, 4, 6) can be seen on a white ground layer (1).

For binder analysis, samples were removed under the microscope by scraping with a scalpel and layers separated as far as possible. A routine cross-section was also taken. The intermediate layers could not be separated from the paint layers, but sometimes it was possible to sample single layers individually in separate locations, which eliminated contamination by materials from other layers. Samples taken at different locations are labelled with different numbers while succeeding layers at one location are labelled with letters, A being the top layer. Therefore the attribution of samples in Figure 3 shows that the individual layers were sampled at two different locations: the sample from location 2 comprised varnish (sample 2A), an upper blue layer (sample 2B) and a central blue-turquoise layer (2C), and the sample from location 1 contained varnish (sample 1A), a brown paint from a tree (1B, not contained in the cross-section), a lower blue paint layer (1C) and the ground layer (1D). The isolation of the ground was sampled in yet another location, where it was not covered by paint (sample 5). It is impossible to tell whether the intermediate varnishes were sampled together with the upper or lower paints, or both, however, it seems clear that the materials of each varnish were able to penetrate the lower layer(s).

The results of part of the binding medium analyses are shown in Table 1. It is obvious that most samples comprise more than one layer, and in order to interpret the table, it was necessary to label each sample in the first column not only with all the known layers but also with any possible layers that the sample might contain. Table 2 lists all the layers of the cross-section and correlates them with all the samples that contain (or might contain) this layer.

In a very intricate, elaborate and time-consuming process, the probable composition of each layer was elucidated and the results listed in Table 2 (right-hand column). Going back and forth, checks were made to see whether all the materials each layer was assumed to contain were in fact present in all the corresponding samples, and if all the samples that should comprise that layer also contained these materials. Only about half of the samples are discussed here and shown in Table 1, but all the samples taken from the entire painting needed to be included for this interpretation.[10] As for the distribution of proteins in the cross-section, FTIR-FPA imaging was not conclusive due to the spectral overlap of oils, resins and synthetic polymers (BEVA, embedding resin), lead soaps and calcium oxalates with amide bands I and II. However, protein-selective fluorescent staining of the cross-section revealed that, again, protein was evenly distributed in the paint layers and no proteinaceous intermediate layers were present.

In short, it was concluded that all three paints were bound with cherry gum[11] tempera stabilized with egg. The isolation of the ground and first intermediate varnish consisted of shellac with boiled oil and resin, mainly colophony, but also another copaiba balsam-type resin. The upper intermediate varnish also comprised boiled oil with resin; however it did not contain any shellac. Because these varnish materials penetrated the paints, unfortunately it is unclear whether the

Table 1 Arnold Böcklin, *Venus Genitrix*, left panel: results of the binding media analyses. Paints are marked in grey. The numbers of the layers contained in the individual samples corresponding to the numbers in Table 2 and the cross-section (Fig. 3). *Key*: +++ large amount; ++ significant amount; + small amount; (+) trace; ? quantification difficult due to high degree of degradation; n.a. not analysed.

			Possibly partially original			Original oleoresinous binders			Original aqueous binders		
Sample number (solid) and *numbers of layers (italic)* contained in the sample			dammar	mastic	larch turpentine	shellac	colophony[a]	oil/fat	‘cherry’ gum[b]	proteins	others
Left panel, sky (see cross-section in Fig. 3)	**1A**	Varnish *(8)* with isolation *(2)*	++	+	+	+	+++	++	yes	+? egg	BEVA, plasticizers
	2A	Varnish *(8)*	+	+	+		++	+	little	+? egg	BEVA, plasticizers
	2B	Light blue paint of the sky *(7)*, *(+8*, possibly *+6)*	+	(+)	+		++	+	yes	+? egg	BEVA
	2C	Turquoise blue paint *(5)*, *(*possibly *+6, +4)*	+		+		++	+	yes	++? egg	BEVA, plasticizers
	1B	Brown glaze of tree (not contained in cross-section in fig. 3), *(+4, +8*, possibly *+6)*	++	+	+	+	+++	++	yes	+? egg	BEVA, plasticizers
	1C	Blue paint, no craquelure *(3)*, (+ some **1B**, *2)*	+	(+)	+	+	++	+++	little	+? egg	BEVA
	1D	Light ground layer *(1)*, (possibly *+2)*						+	-	++ animal glue	
	5	Isolation *(2)* on ground layer, sampled in centre panel	+	+		+++	+	++	n.a.	n.a.	(cyclohexanone resin), plasticizers

[a] contains another resin, presumably a kind of copaiba balsam.
[b] ‘cherry’ gum is fruit tree gum (see note 11).

Table 2 Arnold Böcklin, *Venus Genitrix*, left panel: correlation of the layers of the paint build-up (Fig. 3) with the samples analysed in Table 1 and final interpretation of the individual layer composition (right column).

Layer (cross-section in Fig. 3)		Contained in sample no. (cf. Table 1) (**main** / minor component)				Simplified composition (interpretation)
8	Varnish	**1A**	(1B)	**2A**	(2B)	Dammar, mastic, oil/resin (possibly larch turpentine?) (BEVA, gum/egg contamination?)
7	Light blue			**2B**		**Cherry gum tempera (with oil/resin?) and egg**
6	Organic intermed. layer		1B?		2B?, 2C?	Boiled oil/resin
5	Turquoise blue			**2C**		**Cherry gum tempera (with oil/resin?) and egg**
4	Organic intermed. layer		1B?		2C?	Shellac with boiled oil/resin
3	Blue, not cracked	**1C**				**Cherry gum tempera (with oil/resin?) and egg**
2	Isolation	**5**	1A, 1C			Shellac with boiled oil/resin
1	Ground layer	**1D**	(1C)			Animal glue with some linseed oil

gum tempera with egg contained drying oils and/or resin as well, but according to very explicit sources, it is extremely likely that Böcklin used cherry gum tempera mixed with copaiba balsam (Neugebauer 2016: 266), which would also explain the need for stabilization of the emulsion with egg. It seems that Böcklin's copaiba balsam was heavily adulterated with cheaper resins such as pine resin or colophony.[12] The final varnish(es) comprised many materials that were possibly partly original (dammar, mastic, larch turpentine), but certainly also contained modern conservation materials: although meticulous checks were made to ensure that the sampling locations were not retouched or consolidated areas, the samples taken were contaminated with BEVA and cyclohexanone resin. Furthermore, small quantities of gum and egg were found, and it is unclear whether these, too, are contaminants or residues from original paints that migrated during conservation treatments.

As this case study shows, the layer build-up of 19th- and early 20th-century tempera paintings can be very complicated, and the composition of individual tempera paints highly complex. However, if analysis is combined with careful technical study, and the layers are meticulously separated as far as possible and compared to the stratigraphy in a cross-section, an assignment of specific components may still be possible, especially if written information on the materials and painting techniques of the painting in question survive.

The problem of (degraded) minor compounds: Arnold Böcklin, *Vita somnium breve* (1888)

Whether identification of binders is fully possible also depends on the degradation of individual materials, something that can severely hamper interpretation of the paint system. This is demonstrated for Böcklin's *Vita somnium breve* painted in 1888 (Fig. 4), which is described in two written sources as a tempera painting finished with oil paints or as painted in *Firnisfarben* ('varnish paints', i.e. oleoresinous paints) (Neugebauer 2016: 248–65; 2018). On the whole, we have detailed knowledge on the works of Böcklin's Zurich period (1885–1892), the materials he used, the historical recipes he tried to apply, and his general use of oil and tempera paints. For Böcklin, oil paints were ideal for depicting reality, whereas tempera paints were suitable for creating visionary pictures of the spirit or the soul.[13] Böcklin attempted to apply recipes described in Theophilus' famous *Schedula diversarum artium*, albeit in a 19th-century interpretation. For instance, recipes that describe the boiling of oil with a material called *gummi* in the Latin sources were translated as polysaccharide gum ('gum arabic' in Ilg 1874: 46), whereas today 'gummi' is often believed to denote amber or similar resins. In addition, Böcklin assumed that the painting technique employed by van Eyck, Holbein, Dürer, Perugino and Raffael was not actually oil painting but rather tempera with oil varnishes (Neugebauer

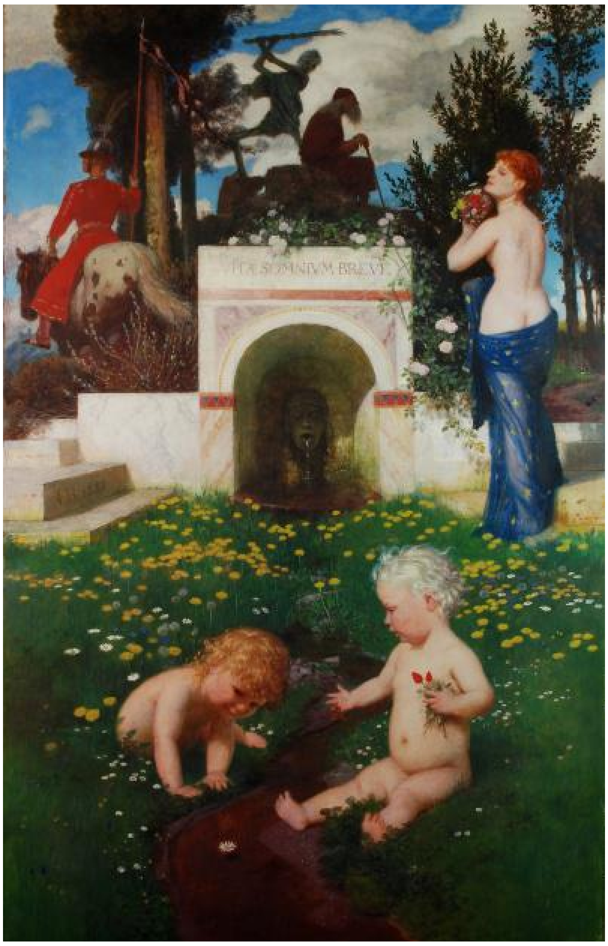

Figure 4 Arnold Böcklin, *Vita somnium breve*, 1888, 180 × 114 cm, Kunstmuseum Basel, Inv. No. 112. (Photo: Wibke Neugebauer.)

2016: 128–30; 2018). Böcklin's assistant, Albert Welti, was responsible for preparing and grinding his paints during the artist's time in Zurich. He was one of several who reported that Böcklin mainly used beaten egg white and cherry gum as binders during that time, in combination with oil and mixtures of oil with resins, such as copaiba balsam (Neugebauer 2016: 132–4). The colours of *Vita somnium breve* have a symbolic function: the technical study showed that they are pure and luminous, and were not mixed wet in wet, clearly indicating that tempera paints should be expected. Additional signs that are considered indicative of aqueous paint include little air bubbles in some colours or patterns that are typical indicators of aqueous paint contracting and slipping on an oily layer or intermediate varnish (Neugebauer 2016: 251–8). Fluorescent staining of cross-sections with SYPRO Ruby also confirmed the presence of proteins in paint layers, but not in intermediate varnishes,[14] which were accordingly interpreted as consisting of oils and/or resins.

As mentioned above, the written sources are somewhat ambiguous with regard to *Vita somnium breve*: it is said to be painted in tempera and finished with oil paints, or painted with oleoresinous paints (*Firnisfarben*). The analyses of a green paint and green glaze from the meadow and white and grey paint from a cloud revealed drying oil and resins as the main binders. The varnish(es) consisted of a possibly non-original dammar and, presumably, an amber varnish mixed with copaiba balsam from *Copaifera multijuga* Hayne, as this was also reported by Albert Welti (cited in Frey 1903: 81). Amber boiled with oils is sometimes difficult to identify. In this case study, the samples contained labdanes from the copaiba and abietanes from colophony and/or amber. Small amounts of succinic acid indicated the presence of amber. Because varnish materials may penetrate tempera paints (see above), it is somewhat unclear how much of the oil and resin components are original binders of the paints. However, it seems very likely that drying oil, copaiba, colophony (perhaps again as an adulteration of copaiba) and possibly amber are indeed important original components of the paints. While identification of the oil type in the green paints is somewhat uncertain, the light coloured paints of the cloud are bound with linseed oil.[15]

Interpreting the analytical results of the aqueous binders was difficult: plant gums were obviously not present, but the protein analysis revealed very small amounts of what may be strongly degraded proteins. The amount was so small that it was impossible to decide whether the identified amino acids represent the remains of a significant-but-degraded tempera binder component or are simply traces of dirt or contamination. Nevertheless, the positive protein-selective fluorescent staining confirmed the presence of proteins throughout many paint layers in the cross-sections (Neugebauer 2016: 553). Therefore, from the context of the painting, the very detailed and explicit information in the sources, as well as the technical examination and the positive protein-selective fluorescent staining, it would appear that at least some of the studied paints should, in fact, be considered tempera, but at the same time, unambiguous identification of a protein binder by chromatography was not possible. In other words, the analyses were not able to provide a definitive answer to the most important question, namely whether the analysed paints were tempera or oil paints. Taking all available information into account, it seems likely that the white and grey paints of the cloud as well as the green underpaint of the meadow were initially tempera paints, whereas the upper green glaze is presumably an oil paint or *Firnisfarbe*. However, disconcertingly, this interpretation could not be confirmed or refuted by analysis alone. It must be said that *Vita somnium breve* was only one of several case studies where a clearly expected tempera protein could not be confirmed by chromatographic analysis and the unambiguous classification of tempera and oil paints proved impossible. This was especially true for paintings where egg white protein was expected. It might be inferred that egg white is less stable and significantly more degraded than egg yolk protein in such samples, but this conclusion is highly speculative.

Conclusion

Challenges of analysing and interpreting 19th-century tempera paints

Developments in instrumental analysis and improved analytical methods nowadays allow the precise identification of individual binding media components in relatively small samples, even if their composition is very complicated and several classes of substances are present at the same time. The 'Munich tempera project' has confirmed the complexity of the composition of 19th- and early 20th-century tempera binding media. On the one hand, this analytical progress is a huge success, but on the other hand, this complexity poses many questions of interpretation that are sometimes difficult to answer unambiguously. As demonstrated by the case studies, the reliable identification of minor compounds is decisive but not sufficient for an interpretation of the initial paint system.

As pointed out above and discussed in Dietemann *et al.* (2014), it is not the quantities of individual binders that define the properties of a paint. Because paints are colloidal systems, the properties of a mixture cannot be deduced from those of the bulk individual components – instead, the main influence originates from interfaces between the phases obviously not present in the single components, as well as interactions between the individual colloids.[16] The fact that mayonnaise, basically a mixture of egg and oil, reveals a yield point and does not flow if left to stand, even though all its components are liquid, can only be explained by the stability of the oil droplet interface: the droplets do not coagulate (fuse) even though they are pushed together so strongly that they cannot flow past each other. Nevertheless, mayonnaise is not a model for paints because it lacks pigment. If pigments are present, many more interactions between paint components are possible, and very complex structures may be formed, often depending on minor amount additives. For example, less than 1% water in a dispersion of pigment in oil can form complex gel structures, known as capillary suspensions.[17] The gel structure and strength of such mixtures, as well as the yield point, which is absolutely crucial for the formation of impasto, depends largely on the wetting properties of the pigment surfaces (Bossler and Koos 2016), which are highly sensitive to trace amounts of minor components.

As a consequence, the fundamental parameters of paints do not directly depend on the bulk composition of the paint but mainly on the distribution of the phases, the microstructures formed by the interacting colloidal particles (pigments, proteins and other macromolecular molecules), and the properties of the interfaces between the phases, which again can be largely influenced by minor compounds. Therefore, identification of the main binder alone is clearly insufficient and not conclusive in determining the type of paint being examined, and the occurrence of minor additives may be crucial. Accordingly, the identification of minor compounds is very important. This is not only an analytical challenge, but also a problem of sample size, which is always difficult for artworks, particularly if the amount of the minor components is further reduced by degradation or by binders of complex composition.

The case studies presented here demonstrate that the composition of 19th- and early 20th-century tempera paints is likely to be relatively complex. A paint can easily contain many different binders from various classes of materials (oils, resins, proteins, polysaccharides, waxes) because tempera binding medium systems may consist of emulsions of several non-miscible ingredients, stabilized by additional materials, and various systems can be combined if

Table 3 List of the paintings studied and results of the binding medium analyses of the 'Munich tempera project' (see also Neugebauer 2016).

Artist	Title	Provenance	Year	Interpretation binding medium system
Franz von Lenbach	*Portrait der Angela Böcklin*	Alte Nationalgalerie Berlin, A III 336	1860-62	egg tempera with added oil, possibly oil paint with egg
Arnold Böcklin	*Villa am Meer I*	BStGS[a] 11528	1864	frankincense-sandarac suspension, coated with beeswax
Arnold Böcklin	*Villa am Meer II*	BStGS 11536	1865	egg tempera with added oil/resin mixture and oleoresinous paint with egg
Franz von Lenbach	*Salome* (Copy after Titian)	BStGS 11437	1864	egg tempera with added oil/resin mixture, possibly oleoresinous paint with egg
Franz von Lenbach	*Das Konzert* (Copy after Giorgione)	BStGS 11486	1865	egg tempera with added oil/resin mixture, oleoresinous paint with egg
Arnold Böcklin	*Triton and Nereide*	BStGS 11534	1873/74	egg tempera with added oil/resin mixture and oleoresinous paint with egg
Arnold Böcklin	*Vita somnium breve*	Kunstmuseum Basel, Inv. No. 112	1888	oil/resin varnish, possibly with egg tempera underpainting
Franz von Stuck	*Kämpfende Faune*	BStGS Inv. No. 11867	1889	possibly oil paints from tubes
Arnold Böcklin	*Venus Genitrix*	Kunsthaus Zürich, Inv. No. 1167	1891	oleoresinous paint with egg and/or egg tempera with added oil/resin mixture cherry gum (egg) emulsion, shellac isolation
Franz von Stuck	*Der Krieg*	BStGS Inv. No. 7941	1894	Syntonos tube paint (cherry gum-linseed oil emulsion with egg)
Julius Exter	*Karfreitag* (*Triptychon*)	BStGS Inv. No. 7956 (centre panel) (side panel)	1895	cherry gum-egg emulsion and oleoresinous paint (cf. Lutz 2011) ceresin-starch-egg emulsion and oleoresinous paint (cf. Lutz 2011)
Wassily Kandinsky	*Kochel – Sitzende Dame am Seeufer*	Lenbachhaus München, GMJE Ky5	1902	possibly wax emulsion?
Franz von Stuck	*Verwundete Amazone*	Van Gogh Museum Amsterdam, S442/M1993	1904	possibly egg tempera with added oil/oleoresinous paint with egg?
Fritz Overbeck	*Auf der Höhe*	Overbeck-Museum, Bremen-Vegesack, Inv. No. 1907/7(99)	1907	Wurm tempera[b] (cf. Kruppa 2011)
Paula Modersohn-Becker	*Kinderakt mit Goldfischglas*	BStGS 13468	1907	possibly Wurm tempera (cf. Kruppa 2011)
Wassily Kandinsky	*Reiter auf einer Brücke* (Fragment)	Lenbachhaus München, GMS 775	1909	possibly wax emulsion?
Franz von Stuck	*Portrait Gertrud Littmann*	BStGS 14450	1911	gum-(egg) emulsion; resin-gum-animal glue emulsion; egg tempera with oil
Franz von Stuck	*Der blasende Faun*	Museum Villa Stuck, G911-12	1914	gum-(egg) emulsion; egg tempera with oil, possibly oil paint with egg

Notes: [a]BStGS: Bayerische Staatsgemäldesammlungen; [b] See also Wibke Neugebauer, Ursula Baumer and Patrick Dietemann, 'The exception to the rule: reconstructing Richard Wurm's *Temperafarbe*', in this volume.

different colours (e.g. commercial tube paints) are mixed. Therefore, reliable identification of all minor components is important. At the same time, it should be considered that materials from intermediate varnishes and top layers can deeply penetrate the layer build-up, and discrimination between original binders and penetrated materials would be desirable. However, even if all these goals are achieved, it is not always possible to reliably identify the type of paint, i.e. to distinguish between, for example, an egg tempera with added oil and an oleoresinous paint with egg (Dietemann *et al.* 2014).

So how can analytical results of tempera paints be interpreted? There is no definitive answer to this question, yet obviously it is always important not only to look at the analytical results but also to combine this data with information from written sources and technical examination of the artworks being studied, possibly complemented by reconstructions (Lutz 2011). Nevertheless, even after the end of the 'Munich tempera project', the interpretation of some paint systems of the studied pieces remains unclear (indicated by 'possibly' and '?' in Table 3). Nonetheless, a considerable amount of information was obtained on tempera painting around 1900, and although many important questions remain and future work is needed, a deeper understanding of the properties of paints in general was achieved, with Table 3 reflecting the broad variety of materials and techniques that were applied by various artists at that time (Neugebauer 2016).

Notes

1. See also Eva Reinkowski-Häfner, 'Tempera: narratives on a technical term in art and conservation', in this volume.
2. See also Annika Hodapp, Patrick Dietemann and Norbert Willenbacher, 'Flow behaviour and microstructure of complex, multiphase fluids', in this volume.
3. Even though an exception is discussed elsewhere: see Wibke Neugebauer, Ursula Baumer and Patrick Dietemann, 'The exception to the rule: reconstructing Richard Wurm's *Temperafarbe*', in this volume.
4. See Hodapp *et al.* cited in note 2 above.
5. *Ibid*., Fig. 7.
6. Project funded by the German Research Foundation (DFG, project no. DI 1575/1-1).
7. For more details see Dietemann *et al.* 2016.
8. See Hodapp *et al.* cited in note 2 above.
9. See discussion in Dietemann *et al.* 2014: 38 and literature cited therein.
10. For a comprehensive discussion see Neugebauer 2016: 266–79, 555–73.
11. 'Cherry' gum is actually fruit tree gum, because it includes gums from various species of the *Prunus* genus: cherry, plum, peach, apricot and almond. However, in Germany *Kirschgummi* (cherry gum) is an umbrella term for all these fruit tree gums (e.g. Doerner 1938: 183).
12. This is still a problem today. The Doerner Institut was unable to buy unadulterated copaiba balsam a few years ago. All the commercially acquired materials contained large amounts of colophony-type resins, and one sample contained no copaiba at all.
13. For a detailed discussion see Neugebauer 2016: 127–37 and Neugebauer 2018.
14. Visual examination revealed partial final varnishes in some areas that might be egg white varnishes; however, samples were not taken from these areas.
15. The ratio of palmitic to stearic acid (P/S ratio) is used for the identification of oils (P/S linseed oil *c.*1.5, nut oil *c.*3, poppyseed oil *c.*5). If an oil binder is strongly degraded, the P/S ratio can decrease below P/S 1, which was the case for the green paints.
16. A detailed demonstration of this is found in Hodapp *et al.* cited in note 2 above.
17. *Ibid*., Fig. 7.

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Authors' addresses

- Patrick Dietemann, Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich, Germany (patrick.dietemann@doernerinstitut.pinakothek.de)
- Wibke Neugebauer, Munich, Germany (wibke.neugebauer@neugebauer-restaurierung.de)
- Cedric Beil, Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich, Germany
- Irene Fiedler, Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich, Germany
- Ursula Baumer, Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich, Germany (ursula.baumer@doernerinstitut.pinakothek.de)

Towards historical accuracy in the production of historical recipe reconstructions

Leslie Carlyle

ABSTRACT This paper discusses the concept of historical accuracy in the preparation of oil and oil paint reconstructions. Explored during a MOLART Fellowship and the HART Project (2002–2005), the model relies on documentary research to identify historical instructions and recipes, followed by sourcing materials appropriate to the time of the recipes. The term 'accuracy' in this context is discussed in relation to ISO Standard 5725-1 which defines 'accuracy' and 'precision'. The products of this approach are referred to as 'highly characterized reconstructions' (HCRs) whereby the raw materials and their combination are documented in detail throughout the preparation and application of the reconstructed recipes. These HCRs are then available as reference materials to compare with actual painting materials using various analytical techniques, to monitor their behaviour over time, and to be used in future research. Various applications of these reference materials are described. The interpretation of the recipes that results in variants being prepared also involves certain compromises which are discussed. The importance of careful documentation of the reconstruction materials and their processing is emphasized, and the problem of caring for and keeping in perpetuity the archive of raw materials, reconstructions and their documentation is identified.

The concept of historical accuracy

The HART Project (Carlyle 2006) represented a formal attempt to articulate the issue of 'historical accuracy' in the creation of reconstructions of paint materials and systems. The use of the terms 'historical' and 'accuracy' in combination immediately drew fire from critics who questioned the viability of such a goal. Since then, various workarounds to explain the concept without using this particular terminology have been introduced. One is to talk about reconstructions using 'historically appropriate' materials (Stols-Witlox 2014, 2017), another is to introduce the concept of 'highly characterized reconstructions' (HCRs) (Carlyle 2017). In any case the goal remains to find a way to the past and to past

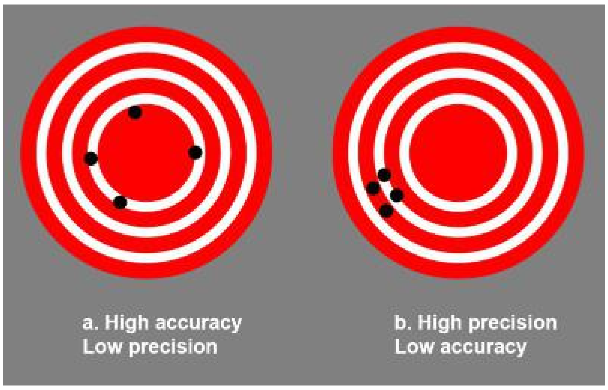

Figure 1 According to ISO 5725-1, 'accuracy' is used to describe the closeness of a measurement to 'trueness'; 'precision' is the closeness in agreement among a set of results. (Images taken from http://en.wikipedia.org/wiki/Accuracy_and_precision, BS ISO 5725-1: 'Accuracy (trueness and precision) of measurement methods and results – Part 1: General principles and definitions', p. 1, 1994.)

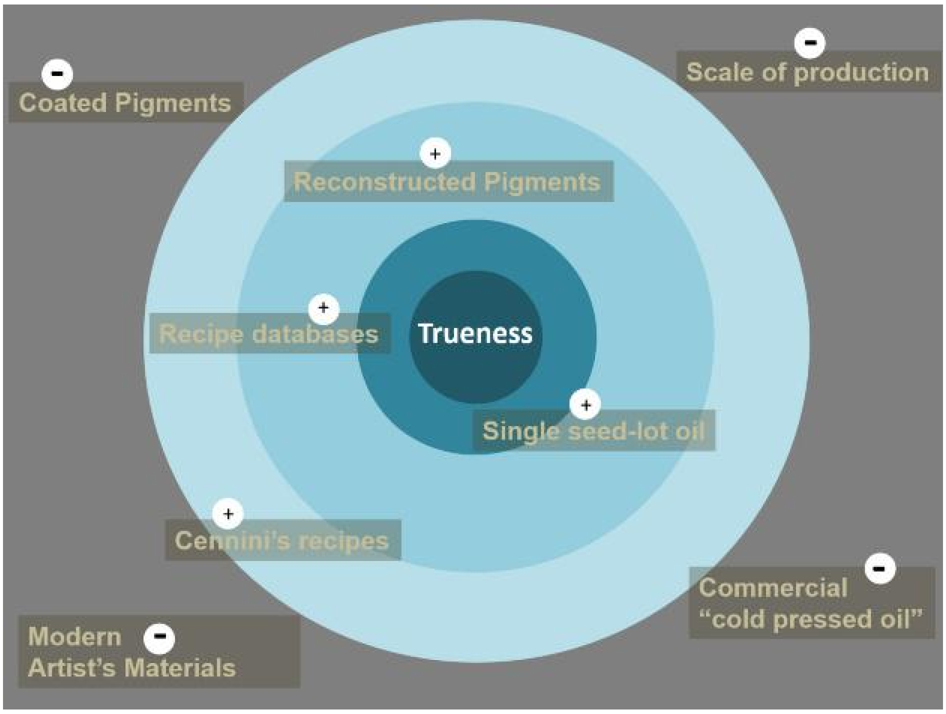

Figure 2 ISO 5725-1 definition of 'accuracy' applied to historical reconstructions, illustrating how the relative closeness to 'trueness' can be evaluated. Note the position on the bullseye of the use of a single source recipe (e.g. from Cennini) compared with recipes selected from a large collection (recipe databases), and the use of commercially prepared 'cold pressed linseed oil' relative to a linseed oil extracted from a single seed lot.

practices through documentary analysis: what do past documents actually say, what do they mean, and where does their information sit within an historical context? This detailed analysis is then used to model reconstructions which are intended to approach some semblance of what could have been used in the past.

Accuracy in any common use of the word when applied to historical interpretations is of course nonsensical: our interpretation of the past must always be through the distorting filter of the present. However, accuracy in the world of science does have meaning, and a meaning which is highly appropriate to the goals of HART reconstructions. It is there that we find ISO standard 5725-1 which explains the scientific concept of accuracy and precision. We need go no further than the internet for a clear definition (Figs 1 and 2). Accuracy in this context is a measure, more or less, plus or minus, in relation to a core goal. In ISO 5725-1 the goal is referred to as 'trueness'. What this standard allows us to do is to formulate a relationship between the goal of approaching the past and some relative indication of how far we are from it.

Using the concept of 'historical accuracy', buying a tube of contemporary oil paint off the shelf and using it to recreate 19th-century paint practices to evaluate paint behaviour, flow properties, and appearance can be evaluated and compared in relation to pressing oil from linseeds, processing the oil according to 19th-century recipes, adding pigments which are in themselves reconstructions from past recipes, and painting out the results. One represents the present (with certain distortions, such as the substitution of linseed with safflower oil and the use of industrially prepared and coated pigments), and the other attempts to model what materials were like in the past by following actual recipes and instructions as closely as possible using materials appropriate to the period being investigated.

When these two approaches are evaluated using the plus/minus terminology from science, the first – employing contemporary commercial artists' oil paint to represent a 19th-century oil paint – is demonstrably a long way from the goal, or trueness, whereas the second approach – endeavouring to discover aspects of the materials which were available in the past – sits somewhere closer. What is relevant in our investigations of past materials and practices with so-called historically accurate reconstructions is the distance between these two approaches.

The HART Project attempted to address at least some of the myriad issues involved in the effort to get closer to the centre of the ISO 5725-1 bullseye. HART reconstructions were made with very specific objectives: overall, to provide a set of grounds and paints for which every aspect of their materials and production was known. These would allow evaluation of how these materials functioned during production and provide answers to questions such as: what effect does the percentage of barium sulphate or chalk used have on lead white paint properties? This was followed by an evaluation of how they behaved during application and finally how they appeared in various standard analyses such as scanning electron microscopy (SEM) backscattered images. These reconstructions were intended as reference materials for visual, physical and chemical studies, both while they were being produced and after.

Therefore, following this logic, every aspect of the materials used needed to be known as far as possible. As previous papers have detailed, and as explained in the HART Project Report (Carlyle 2005), in order to control at least some of the variables, materials were sourced which had not undergone industrial processing (i.e. chalk that had not been pre-treated with anti-clogging agents, and barium sulphate in its raw state before whitening and grinding). Linseed oil was pressed from a single seed source using a stainless steel press to eliminate contaminants and oil seed blends resulting from commercial oil extraction and refining methods. Flake white pigment was prepared according to conditions described in the traditional stack method whereby lead metal was corroded over dilute vinegar inside a ceramic pot that was buried in horse manure.

In this way, reconstructions of oil paint grounds and oil paints could be compared within a given set to address specific questions. In the case of oil paints, what difference did it make to water-wash the oil prior to use as a paint binder? What were the consequences of water-washing the traditional stack process lead white pigment prior to use? What immediately became evident in this work was the necessity to accept compromise. Time, resources and current knowledge all influence the degree to which the pursuit of accuracy can be achieved.

The placement of the HART Project reconstructions on the ISO 5725-1 bullseye in relation to ‘trueness’ will continue to be evaluated and likely repositioned as more attempts are made to develop historical accuracy further. The seeds used to extract HART linseed oil turned out to be from a relatively recently developed cultivar, not from flax plants with a more ancient pedigree. HART flake white was produced from lead with a measurable copper content which may or may not reflect the contaminants in previous leads used to produce flake white.

Highly characterized reconstructions

However, the HART Project did succeed in its central goal of producing HCRs. Rigorous documentation of each step meant that the production method, materials used and date of production for any given sample of paint or ground or combination of both, is available. Therefore, detailed information (along with the original raw materials used) for each paint or ground sample produced can be provided. For example, on 2 April 2003, HART Sample SUW11D was made with Seynaeve (S) traditionally prepared lead white batch 2.6.[1] The Seynaeve lead white was used unwashed (UW), that is, not further processed by washing with water. It was ground dry (D) with #11 linseed oil. Number 11 linseed oil was produced for the MOLART Fellowship Project (Carlyle 2001) from ‘Electra’ linseeds purchased from a Dutch flax producer in 1999. The oil had been extracted from the seeds in 1999 using a stainless steel oil press and stored without further treatment since extraction. SUW11D contains 12.5 g lead white, and 2.3 ml linseed oil. The paint was hand-ground on a granite slab using a muller made from the same granite. Nine samples of SUW11D were painted out by brush or applied with a drawdown bar (fixed distance stainless steel applicator) onto different substrates, including polyester film, commercially prepared ‘artists' boards’ or canvas prepared with a reconstructed ground based on a 19th-century recipe.

SUW11D can be compared to its counterpart in the set, SUW11W, which was prepared the same day, but ground ‘wet’. Since early instructions called for either grinding dry pigment with oil, or adding water to the pigment first, then adding the oil during grinding, both methods were followed to explore the difference. In turn, SUW11D and SUW11W can be compared to their counterparts, SWA11D and SWA11W, whereby the flake white was pre-washed in water to remove residual lead acetate present in the flake white after production. The washed and then dried pigment is referred to as SWA (Seynaeve washed). All four paint samples were made the same day and applied to the same number and type of substrates. These HART Project flake white oil paints were part of a larger project (Project One, described in Carlyle 2005) that was designed to compare washed and unwashed flake white pigments which were then used with oil from the same seed lot that had been expressed at different times and had undergone various forms of water-washing. Washing instructions for the oil introduced other sets of variables, for example, washing with unsalted or salted water.

During paint making, observations were recorded regarding the behaviour of the paint under the muller, and the flow properties of the paints produced (e.g. their ease of application by brush or during the production of a fixed thickness drawdown on polyester film). HART Project Two explored the effect of adding either chalk or barium sulphate extenders to the Seynaeve flake white in oil. Paints with stepped proportions of either chalk or barium sulphate were prepared using modern chalk or barium sulphate as well as unprocessed chalk or barium sulphate. An unexpected result of this work was the discovery that the Vangard software associated with the SEM used was unable to accurately report on the proportions of either chalk or barium sulphate present in the dried lead white oil paint samples (Haswell and Carlyle 2006; Haswell *et al*. 2011, 2013). The previously unrecognized need to calibrate the SEM software based on known proportions of either extender was demonstrated with these samples.

Detailed documentation for the MOLART Fellowship and the HART Project has continued to prove essential to the usefulness of these reconstructions to researchers. Recently, the work of Laura Hendrik (Hendrik *et al*. 2018) relied on knowing the date of production of a sample of Seynaeve flake white to verify her findings for carbon dating based on lead white pigment.

Interpretation and compromise

One of the most challenging aspects of creating reconstructions with the goal of achieving some degree of historical accuracy is traversing the difficult terrain involved in the interpretation of original recipes, and the inherent compromises in terms of determining what constitutes an 'historically appropriate' material. Where the identity of specific materials listed in a recipe is not clear, the solution is to repeat the recipe using other possible interpretations. This was the case in one of the earliest attempts to achieve historical accuracy while making flour-paste ground recipes (Carlyle *et al*. 2008), where the identity of pipe clay was considered ambiguous. The recipe was repeated twice, once with ball clay and a second time with kaolin. Since there was also a question of whether the flour paste itself was intended to be cooked or uncooked, this also led to more reproductions of the recipe to explore this variable. In fact, as this work has developed, it has become apparent that one of the most instructive areas in creating these reconstructions is the exploration of the influence of multiple variables.

The importance of documentation

With hindsight, the value of written documentation made at the time of preparation cannot be underestimated. Having a hard copy (laboratory notebook) of weights, measures, and observations made on the day are essential, since unanticipated questions arise which can sometimes be answered by reference back to the original notes. The next step, writing up the notes for a more formal presentation (e.g. the HART Project Report) is also essential for clarifying potentially ambiguous hard copy, and for producing the many spreadsheets and descriptions that summarize the work carried out. Since the HART Project relied on teams of individuals all working simultaneously, the need to track and clarify the total documentation for the project became evident. The HART Project Report was produced in an era when online access was not as well developed as it is now. It is intended that this documentation, and the 25 PowerPoint presentations with images supporting the findings, will soon find a presence on the web for general access.[2] Given the unreliability of electronic data over decades of migration from platform to platform, it is essential that for any future reconstruction projects detailed documentation must also exist in hard copy: both the original notebooks and as printouts of the original report.

Keeping and caring for the physical archive in perpetuity

In a similar vein, it has become apparent in the years since the MOLART Fellowship and HART Project that the samples produced require careful storage to secure their continued availability as these materials only grow more valuable with time and natural ageing. Oil paints present particular difficulties in terms of long-term storage. Initially dry oil paint can, after 15–20 years, become sticky (particularly if applied to a non-porous surface such as polyester film or glass slides). Therefore, it is essential that all paint surfaces are allowed full access to air and prevented from coming into contact with any kind of covering. Similarly, oil paint responds dramatically to light such that samples yellow in the dark and bleach back during light exposure. This behaviour appears to occur indefinitely, but the degree of recovery in subsequent light exposure after being stored in the dark is not known (Carlyle *et al*. 2002; Townsend *et al*. 2011). It is intended that a set of original materials and reconstructions from the MOLART and HART projects, along with their documentation, will be housed in at least three separate institutions for accessibility and to ensure their care over time.

Conclusion

The goal of producing 'historically accurate reconstructions' in the HART Project was aspirational but how well we succeeded can only be measured through further study and research using the MOLART and HART paint and ground samples, and with continued efforts to produce historically accurate reconstructions while refining the methodology in future projects.

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Notes

1. Jef Seynaeve produced the stack process lead whites for the HART Project, and the dates for his various batches were recorded.
2. In the meantime, the full report is available by request from the author.

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Author's address

Leslie Carlyle, Associate Professor of Paintings Conservation, Department of Conservation and Restoration, Faculty of Sciences & Technology, University NOVA of Lisbon, Portugal (leslie.carlyle50@gmail.com)

The exception to the rule: reconstructing Richard Wurm's *Temperafarbe*

Wibke Neugebauer, Ursula Baumer and Patrick Dietemann

ABSTRACT It is often the exception that furthers our understanding of what defines a rule, and the *Temperafarbe* made by Munich manufacturer Richard Wurm deserves closer examination for precisely this reason. An important common feature of late 19th- and early 20th-century tempera paints used in Germany was the fact that they contained aqueous binders and were miscible with water. Wurm's *Temperafarbe*, however, was different – it was not miscible with water and did not contain aqueous binders. Despite this, the paint still shared other important features that artists associated with tempera paints, such as short drying times and a matt surface appearance. But how was this achieved without aqueous binders? This paper examines Wurm's exceptional tempera paint more closely to further our understanding of what defined tempera paints during the period in question. To this end, information from previous studies – gathered from written sources, technical examinations of paintings and analytical results – are correlated and complemented by practical reconstructions.

Historical context

Richard Wurm's Munich factory for artistic paints and canvases was founded in 1864 and continued production until at least 1925 (Berberich 2012: 2, 5). Not only did Wurm soon become one of the most renowned suppliers of artists' materials in Munich, he also shipped his products to customers throughout Germany and to other European countries. His business produced paints and supports on a semi-industrial scale.[1] The company produced its *Temperafarben* in tubes accompanied by its special own-brand vehicle (*Malmittel*) for the paints between *c.*1877 and 1917 (Berberich 2012: 23, 25).

Current state of knowledge

Although the company kept the exact formulae confidential, we now know more about the material composition of the *Temperafarbe* and its vehicle thanks to recent studies. Researchers were able to deduce essential new information by evaluating written sources, examining paintings and conducting material analyses of surviving paint tubes. Angelika Hoffmeister-zur Nedden was the first to mention a brochure listing products and prices of the Richard Wurm company (Wurm 1906/07; Hoffmeister-zur Nedden 1997: 288, 291; Kruppa 2011: 12). It is the only surviving source in which the manufacturer himself describes paint properties and painting techniques.

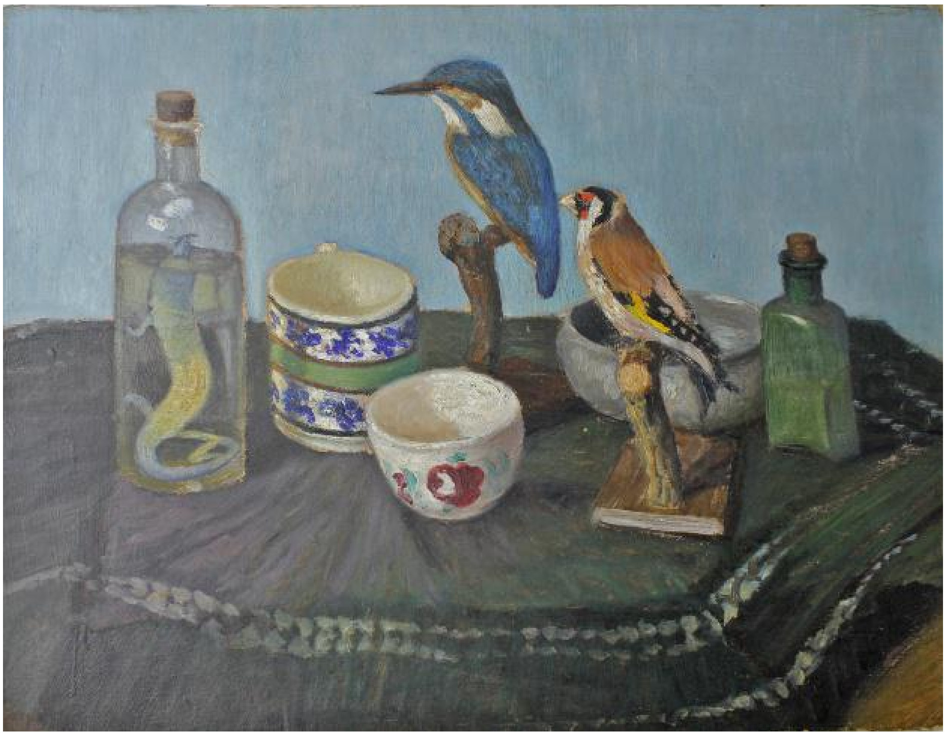

Figure 1 Otto Modersohn, *Stilleben mit ausgestopften Vögeln, Lurch in Flasche, Tasse und Schale*, 1906, paint on millboard, 35 × 46 cm, Paula-Modersohn-Becker-Stiftung, Bremen. (Photo © Ewa Kruppa.)

Christine Berberich's research focused on evaluating letters and postcards sent to Wurm by customers between 1872 and 1917 (a total of 715 documents from more than 300 authors) and extracting relevant information, such as descriptions of the handling properties of Wurm's tempera paints (Berberich 2012). Furthermore, she evaluated letters from the painter Hermann Urban (1866–1946) to his friend Wolfgang Koller (1904–1974) that implied that there once existed a factory recipe book that included the formulae for the tube paints; unfortunately, this recipe book has been lost (Berberich 2012: 72–3, 299). Nonetheless, she also discovered another recipe book that contained what probably represents a transcription of the original recipe of Wurm's *Malmittel* in the estate of the painter Aziz Raza (1938–2001) (Berberich 2012: 72–3).

Ewa Kruppa focused on the tempera painting techniques of Paula Modersohn-Becker (1876–1907) and Otto Modersohn (1865–1943), both known for their use of Wurm's tempera. She technically examined selected paintings and combined the results with source research from Otto Modersohn's unpublished diaries and selected binding media analyses of paint layers (Kruppa 2011).

Undated paint tubes of *Temperafarbe* from the estate of Edvard Munch (1863–1944) (Munch Museet, Oslo) were analysed by two working groups employing different analytical techniques: Dietemann and Baumer used gas chromatography-mass spectrometry (GC-MS) (Neugebauer 2016: 158), while La Nasa *et al.* (2015) applied GC-MS and liquid chromatography-mass spectrometry (HPLC-ESI-Q-ToF).

Evaluation of written sources

The aforementioned studies were systematically searched for any information that would be relevant for reconstructing Wurm's tempera, for example, handling properties such as consistency or miscibility, drying times, indications of the composition of the vehicle and binding medium, and descriptions of characteristic visual appearance. The written sources describe the consistency of the tube paints as pasty and viscous (Berberich 2012: 28), although not as smeary as oil paints (Kruppa 2011: 92). They could be worked in a pastose manner like oil paints and would retain their pronounced relief during drying (Berberich 2012: 29).

As the evaluation of letters and postcards revealed, the tube paints could not be diluted with water – in fact, it is even reported that they decomposed if water was added (Berberich 2012: 32). Instead, artists blended them with the vehicle or with linseed oil, lavender oil, oil of turpentine and various varnishes (Berberich 2012: 27). Among the media recommended for mixing with his tempera, Wurm's brochure explicitly mentions the 'vehicle for tempera' (*Malmittel zu Tempera*), bleached manganese linseed oil (*Manganleinöl gebleicht*), superfine mastic varnish (*Mastixfirnis superfein*), mastic varnish I (*Mastixfirnis I*), and three qualities of lavender oil (*Lavendelöl I, II, III*) (Wurm 1906/07: 12). Artists' letters reveal that the final degree of gloss varied depending on the vehicle used: when blended with linseed oil, for example, the painted surface would become glossy like the surface of oil paints, whereas using the paints directly from the tube or blended with Wurm's vehicle would enable the artist to achieve a matt effect (Berberich 2012: 27).

Accordingly, the unique feature of Wurm's tempera as described in his brochure was its versatility, which made it suitable for different painting techniques. Artists could use it to paint *alla prima* by blending the colours wet-in-wet, or apply them in layers and combine them with other paints such as oils. Furthermore, it was possible to achieve a matt, tempera-like appearance by using absorbent grounds or an oil-paint effect by employing semi-absorbent grounds (Wurm 1906/07: 8–9). Moreover, the artists' letters recount that the paints were used for both easel and wall painting (Berberich 2012: 30). According to the brochure, the drying time was short compared to contemporaneous oil paints, lying somewhere between two and four days if the painting was dried in the sun or near an oven, after which period they would become 'seemingly dry' (Wurm 1906/07: 9).

Although Wurm kept the recipe secret, the sources provide several clues as to the composition of the binding medium and vehicle. From the lost recipe book it is known that the tube paint allegedly contained an excessive amount of soft soap and potassium hydroxide (Berberich 2012: 299).[2] Another fairly detailed recipe for *Temperafarbe* survived as a transcript in a notebook dating from 1992: 'Dissolve 250 g soft soap in 100 cc alcohol*, then add 50 cc lavender oil and 50 cc alcohol* / *alcohol 94%'[3] (Berberich 2012: 72). Given the obvious lack of binding medium in this recipe, it can be assumed that this was the recipe for Wurm's vehicle rather than his tube paints.

Figure 2 Otto Modersohn, ***Stilleben mit ausgestopften Vögeln, Lurch in Flasche, Tasse und Schale***: detail showing paint with sharp and clearly defined relief, applied with a brush and subsequently modelled with a pointed object. (Photo © Ewa Kruppa.)

Figure 3 Fritz Overbeck, *Auf der Höhe*, 1907, paint on canvas, 61 × 93 cm, Overbeck-Museum, Bremen-Vegesack. (Photo © Ewa Kruppa.)

Technical examinations

It was interesting to compare the sources' description of how these paints could look with their actual visual appearance in paintings even though there may be no such thing as a 'characteristic appearance' of the paints owing to the fact that their visual and technical versatility was their main feature (as described in the brochure). Accordingly, technical examinations by Kruppa showed different examples of how these

Table 1 Material analysis of Wurm's tempera paint tubes from the estate of Edvard Munch (Munch Museet Oslo). Potassium was identified in the samples using scanning electron microscopy.

Dietemann and Baumer	Interpretation	La Nasa *et al.* 2015	Interpretation
Drying oil	Linseed or nut oil	Drying oil	Linseed oil
Fat with a high amount of palmitic acid	Japan wax	Fat with high amount of tripalmitin	Palm oil
Fat with a high amount of short chain fatty acids (lauric and myristic acid)	Coconut fat or animal fat (?), probably a component of soft soap	Not mentioned	
Potassium	Probably a component of soft soap	Not mentioned	
Glycerine	Probably a component of soft soap	Not mentioned	
Spike oil	'Lavender' oil	Not mentioned	

paints can look. On the one hand, Otto Modersohn's *Stilleben mit ausgestopften Vögeln, Lurch in Flasche, Tasse und Schale* (1906) is an example of a matt, tempera-like appearance, painted *alla prima* by blending the colours wet-in-wet (Kruppa 2011: 89–95): the paints show sharp and clearly defined relief, having been applied with a brush and in some areas subsequently modelled with a brush handle or other pointed tool (Figs 1 and 2). On the other hand, Fritz Overbeck's canvas painting *Auf der Höhe* (1907) may exemplify a painting technique that applies Wurm's tempera in layers and finishes with a varnish, resulting in a glossier appearance similar to oil painting (Kruppa 2011, appendix: 4–19) (Fig. 3).

Analysis of tube paints

Surviving paint tubes from the estate of Edvard Munch were analysed by two working groups (Dietemann and Baumer, Doerner Institut, published in Neugebauer 2016: 158 and La Nasa *et al.* 2015). Table 1 compares their findings and interpretations. Both working groups identified drying oil(s) and fats containing a high amount of palmitic acid as major components of Wurm's tempera paints. However, interpretations of the analytical data are not identical: while in our study the fat component was identified as Japan wax,[4] La Nasa *et al.* (2015: 186) concluded that the fat is palm oil.[5] Both materials consist of triglycerides with large amounts of saturated fatty acids, mainly palmitic acid. Due to their similar compositions, they are difficult to distinguish. Similarly, while we found components that suggest a soft soap ingredient (consisting of a saponified material with a high amount of short chain fatty acids, potassium and glycerine), this was not mentioned by the other group. However, both groups agreed that the tube paints did not contain any aqueous components such as proteins or polysaccharides, the likes of which would clearly be expected in tempera paints.[6] Moreover, it is both peculiar and surprising that the only binding media identified in the tube paints are drying oil and Japan wax/palm oil. Therefore, on the basis of our analyses, Wurm's tempera paint might be considered to be a perfect typical 19th-century oil paint containing some sort of fat as an additive (except for the soft soap), as used by Ernst Ludwig Kirchner (1880–1938) in the first half of the 20th century for instance (Dietemann *et al.* 2013).

Reconstruction strategies and choice of materials

It can be assumed that Wurm's tempera was not a 'typical' tempera paint[7] for the period in question because it did not contain any aqueous binder and was not miscible with water. Wurm provided artists with an extremely versatile paint system that combined the advantages of tempera and oil paints in many respects as previously mentioned. Using different vehicles and supports, artists were able to achieve a wide gamut of effects, ranging from a tempera-like, matt surface appearance to a glossy, oil paint-like effect. The paints dried quite quickly, the colours could still be blended wet-in-wet, and, as with oil paints, impasto application was also possible. The reconstructions therefore addressed the question of how these properties could be achieved with a binder consisting of drying oil, Japan wax/palm oil, soft soap and spike oil. The basic hypothesis of the reconstructions was that a high amount of a solid binder (Japan wax/palm oil) in a drying oil, combined with a fast evaporating essential oil such as spike oil, would dry faster than a pure oil binder and therefore match the descriptions in the sources.

Because the information gathered from sources, technical examinations and material analyses was quite heterogeneous, the aim of our study was more proof of principle than an attempt to create an 'historically accurate' reconstruction as described by Carlyle,[8] therefore it seemed appropriate to choose modern materials for our purpose (see 'Materials and suppliers' below). To ensure that their chemical compositions came close to the materials identified in the tubes, they were examined by GC-MS prior to the experiments.

Binding medium of the tube paints

In place of the 'drying oil' detected during analysis, a modern, fast-drying linseed oil containing a small proportion of a manganese drier was chosen, not least because Wurm's brochure also lists a manganese linseed oil for tempera painting. The first variable that had to be addressed was choosing between Japan wax and palm oil, both of which became available in Germany in the 19th century, as this was one of the major differences between the two sets of analytical results (Table 1). Even though their chemical compositions are quite similar, their physical properties at room temperature differ: Japan wax has a relatively hard, beeswax-like consistency, whereas palm oil is considerably softer, with a tallow-like consistency. This is also reflected in their melting temperatures, which vary between *c.*53–55 °C for Japan wax and *c.*27–43 °C for palm oil (Roth and Kohrmann 2000: 126, 142–3). In initial experiments, Japan wax appeared to be much better suited to our purpose: it is firmer, it provides the paints with a certain corporeality and structure while at the same time stabilizing the paint films, rendering them harder and more resistant to mechanical stress. In contrast, films containing palm oil were considerably softer, remained sticky and dried much more slowly, properties that clearly contradict the quick drying times of Wurm's tempera. For this reason, palm oil was excluded from use in further experiments.

The next question addressed was the ratios of the individual components within the binding medium. The ratios of palmitic and stearic acid (P/S ratios) in the analysed tubes were used to estimate the amount of Japan wax. Unfortunately the P/S ratio of Japan wax seems to be somewhat variable, with historical reference samples at the Doerner Institut indicating P/S ratios of *c.*10–14, but sometimes as high as 24.[9] However, recently acquired commercial Japan wax revealed dramatically lower P/S ratios of *c.*1.5–4. It is unclear whether this is a problem of adulteration, botanical source or modern material processing methods. However, because the P/S ratio of linseed oil is 1.5 and the P/S ratios of the Wurm tube paint samples were around 4.5–5 (La Nasa *et al.* 2015), it can be concluded that the binding medium must have contained a very high amount of Japan wax, approximately 30–40 wt%. For the reconstruction, a modern Japan wax with a P/S ratio of 9.5 was used.

In order to determine how varied amounts of Japan wax could potentially influence the properties of the binding medium, different mixtures of linseed oil and Japan wax were prepared containing 10, 20, 30 and 40 wt% Japan wax. The mixtures were heated until the Japan wax melted and clear solutions were achieved. After cooling down to room temperature, these mixtures turned turbid and opaque, and became quite pasty and hard. As discussed in more detail elsewhere (Dietemann *et al.* 2013: 48), waxes are generally not soluble in drying oils, which might also apply to mixtures of the saturated triglycerides Japan wax and linseed oil. Thus, when present in relatively high concentrations, phase separation occurs, causing solid Japan wax particles to form during cooling or evaporation of a shared solvent. The phase separation would explain the opacity of such mixtures at room temperature because the light is scattered at the surface of the Japan wax particles. Their occurrence is presumably also the reason for the matt appearance of the paints (Dietemann *et al.* 2013: 48–9), as reported below and in the sources.

The hard consistencies of the mixtures at room temperature also explain the presence of spike oil in the tube paints: the mixture containing 20 wt% Japan wax was already too stiff for grinding and blending colours without further addition of a solvent. Spike oil was therefore an important component required for grinding the paints and keeping them soft in the tubes.

The next variable to consider was the soft soap ratio within the binding medium. Our experiments revealed certain traits: soft soap generally facilitates the mixing of paints and vehicle and renders the paints more supple. However, it also considerably slows down the drying process of the paints and is a possible threat to alkaline-sensitive pigments due to its pH value between 9 and 10. It was concluded that the soft soap content has to be as low as possible to prevent damage to the pigments, but as high as required for it to positively impact the paint properties. Therefore, two different amounts of soft soap in the binding medium were tested in the following experiments (1 and 5 wt% of the binding medium).

It was not possible to analyse the exact composition of the 'soft soap' referred to in the sources as an important ingredient of the tube paints and the vehicle. However, 19th-century technical literature on soap fabrication reveals that historical soft soaps generally consisted of various fats or mixtures of fats, usually saponified using a potassium hydroxide solution (see for example Perutz 1866). Among others, coconut fat is mentioned for soap fabrication (Perutz 1866: 22). This fat contains a high amount of short-chain fatty acids, which is quite a good match with the analytical results. Thus an organic, unprocessed coconut fat was chosen and saponified with a potassium hydroxide solution,[10] resulting in a white soft soap with a pH value between 9 and 10.

Pigment–binder ratio

Richard Wurm published selected pigment–binder ratios for his oil and tempera paints in parts per weight (Pettenkofer 1870: 7–8; Wurm 1906/07: 8): 100 parts lead white required 10 parts tempera binder and 12 parts oil respectively, while 100 parts terra di Siena called for 200 parts tempera binder or 240 parts oil. Comparison of the datasets revealed that Wurm's tempera paints contained *c.*83% of the amount of binder used in his oil paints. For further experiments, Prussian blue was selected to test whether the soft soap within the binding medium and the vehicle would be detrimental to the alkaline-sensitive pigments. According to Wurm, 100 parts Prussian blue required 106 parts oil binder (Pettenkofer 1870: 8), therefore 83% of the oil binder would be 88 parts tempera binder for 100 parts Prussian blue. This was the ratio used for the reconstructions.

Reconstruction of paint properties

Binding media with various ratios of linseed oil, Japan wax and soft soap were prepared and then ground with the same amount of Prussian blue (see above). The Japan wax content of the binding medium varied from 5 to 29 wt%, with two different ratios of coconut soft soap (1 and 5 wt%) tested at the same time (Table 2 and Fig. 4). In each case, spike oil was necessary to render these mixtures soft enough for grinding with Prussian blue. Paints containing higher amounts of Japan wax required considerably more spike oil than those containing less Japan wax and a higher oil content. For comparison, egg yolk tempera and pure linseed oil paints were also prepared.

The first characteristic property of the paints mentioned in the sources is a drying time of between two and four days (Wurm 1906/07: 9). After four days of drying, the reconstructed paints containing higher amounts of Japan wax were considerably harder than those with less Japan wax and a higher oil content. The sources hint at a possible explanation: Wurm claimed that his paints become 'seemingly dry' through exposure to the sun or being placed near an oven. In this case, the spike oil would evaporate quite quickly, whereas the Japan wax would crystallize and potentially form a kind of gel structure enclosing the oil particles. The film would then become relatively hard and resistant to mechanical stress, i.e. 'seemingly dry', even though the oil enclosed in the paint structure might not have chemically dried at the time. Higher amounts of the solid binder Japan wax did indeed result in harder paint films in our reconstructions.

Taking a closer look at the differences between the consistencies of the fresh paints in relation to the varying amounts of Japan wax they contain, the sources describe the paints as pasty and viscous, but not as smeary as oil paint. When applying the paints containing different amounts of Japan wax, it became clear that 'smeary' might describe a longer paint with higher cohesion, as found for the paints containing pure linseed oil or only 5 wt% Japan wax. The longer,

Table 2 Mixtures of binding media used for the reconstructions.

Linseed oil (wt%)	Japan wax (wt%)	Soft soap (wt%)	Egg yolk (wt%)
100	–	–	–
90	5	5	–
80	15	5	–
70	25	5	–
90	9	1	–
80	19	1	–
70	29	1	–
–	–	–	100

Figure 4 Paint reconstructions with six different mixtures of linseed oil, Japan wax, soft soap and Prussian blue, mixed with a selection of vehicles mentioned in the sources. After nine months of ageing, paints mixed with the vehicle show the first signs of discoloration, possibly due to the reaction of Prussian blue with the soft soap.

smeary consistency of the oil paint was gradually reduced when higher amounts of Japan wax were added. Furthermore, a high amount of Japan wax seemed to increase the paint's yield point[11] because the shape of the impasto was better preserved after working it with a brush or spatula – yet another characteristic property described in the sources. The result was a paint that produced a crisp and sharply defined surface relief while the impasto of the longer paints appeared more rounded and less sharp (Fig. 5).

The next property that required testing was the miscibility with various vehicles mentioned in the sources. The vehicle was prepared according to the transcript of the recipe for *Malmittel* cited above. The various paint formulations were then mixed on a palette with, in turn, the vehicle, linseed oil, spike oil and water. As expected, water did not mix with any of the paints, but they did work quite well with the other diluents. Just as the sources describe, the paint becomes more matt if diluted with the vehicle or with spike oil, and glossier if blended with linseed oil (Fig. 6). This was generally found to be true of all types of binding media that were tested, but as these results clearly showed, higher proportions of Japan wax led to paint surfaces that were more matt (Fig. 6). It was found that, while the amount of soft soap contained within the binder did not affect the Prussian blue, those paints mixed with the vehicle

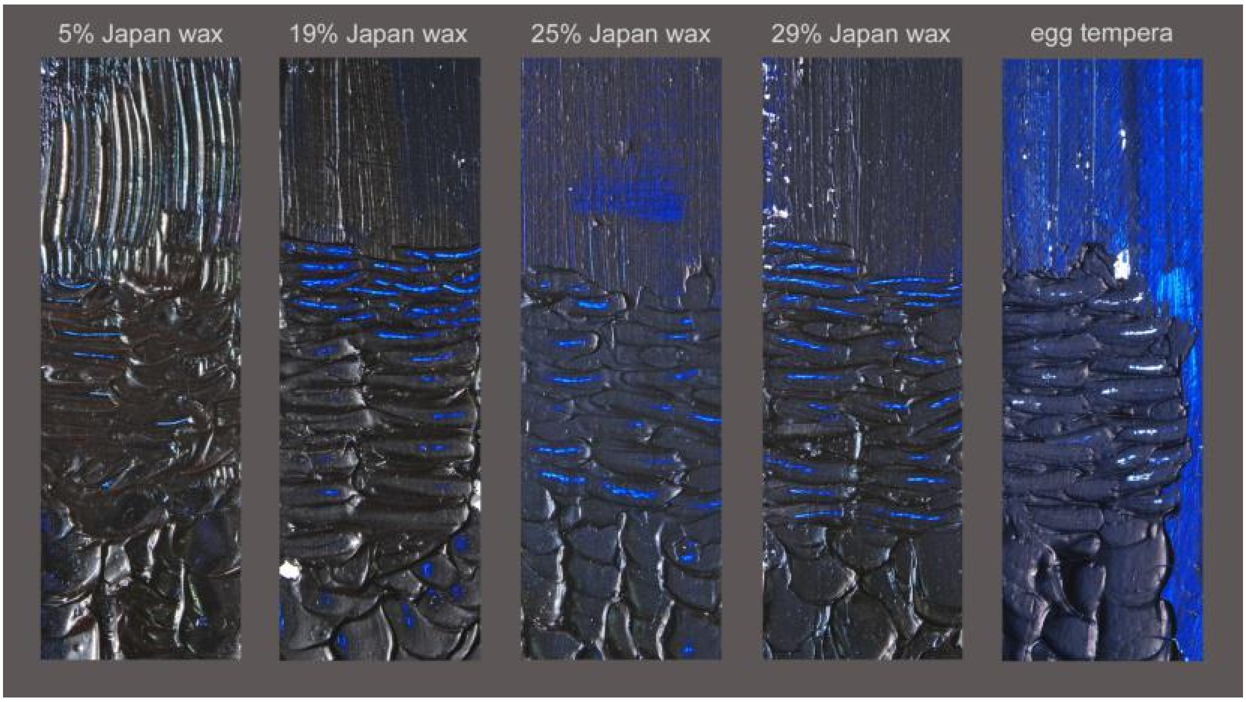

Figure 5 Paints with higher proportions of Japan wax are more matt and show a sharper and more clearly defined surface relief.

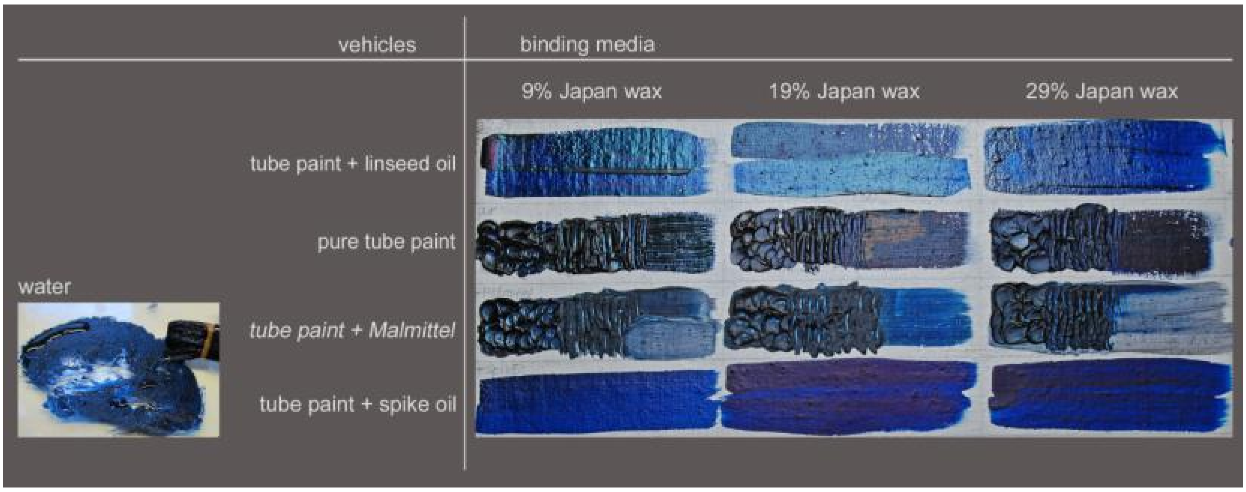

Figure 6 This image shows the influence of different vehicles on the surface gloss of paints. As described in the sources, the vehicle linseed oil generally results in glossier surfaces, while the *Malmittel* and spike oil create matt surfaces.

showed the first signs of discoloration after nine months of ageing (see Fig. 4).

Finally, the mock-ups were compared with paints from one of Otto Modersohn's paintings. The paints containing the highest amounts of Japan wax were the best visual matches (compare Figs 2 and 5). This correlates well with the analytical results that suggested a high amount of Japan wax within the original binder, and also accords with the consistencies of the different reconstructed paints as compared to the descriptions in the sources.

Conclusion

Although the reconstructions were based on heterogeneous and fragmentary information gathered from diverse sources, this study provides a likely and convincing hypothesis for the composition of Richard Wurm's *Temperafarbe*. Despite many variables and uncertainties, the reconstructions represent a proof of principle because they allow a correlation between the unusual and remarkable properties of Wurm's tempera and its composition by isolating relevant paint properties, analysing these from different viewpoints, and successfully combining information from sources, material analyses and technical examinations.

Moreover, this approach enhances our understanding of what was considered to be tempera painting during the period in question. Wurm's tempera paints were exceptional because, in contrast to the vast majority of contemporary tempera paints, they did not contain any aqueous binders and were not miscible with water. Instead, their major compounds – drying oil and Japan wax – would usually be considered typical binders of 19th-century oil paints. However, the reconstructions made clear that the major difference between a 19th-century oil paint with wax additive and Wurm's tempera is not the materials they contain, but the ratios in which these are combined within the binder. Choosing to combine a fairly high amount of solid binder (Japan wax) with spike oil affects the handling properties, drying time and visual appearance of the paint in ways that quite successfully match the artists' expectations as to how a tempera paint should look, behave and dry. Thus Wurm's tempera was designed to mimic the defining features of contemporary tempera paints while at the same time offering artists an extremely versatile product – one that enabled them to achieve both tempera and oil painting effects, depending on the vehicles, supports and painting techniques used.

Acknowledgements

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Notes

1. For further details on the history of the company and its owner, see Berberich 2012: 1–11, 16.
2. Letter from Hermann Urban to Wolfgang Koller, 30 December 1936, BSB ANA 416.B.II.1, cited in Berberich 2012: 299. Hermann Urban owned the now lost recipe book containing Richard Wurm's detailed recipe for his *Temperafarben* at the time.
3. 'Wurmtempera. Schmierseife gr 250 / Alkohol* cc 100 / lösen dann / Lavendelöl cc 50 / Alkohol* cc 50 / *Brennalkohol 94%.' Notebook of Aziz Raza preserved in the city archive of Bad Aibling, recipe book no. V, recipe no. 19060, 30 August 1992, cited in Berberich 2012: 72.
4. Despite its name, Japan wax is a vegetable fat consisting of triglycerides, and is collected from the berries of *Rhus verniciflua* or *Rhus succedanea*; Roth and Kohrmann 2000: 126.
5. Palm oil is a vegetable oil derived from the reddish pulp of the fruits of different oil palm species; Roth and Kohrmann 2000: 142–3.
6. In an earlier publication it was assumed that karaya gum was the aqueous component of Wurm's *Temperafarbe* following analysis of samples from a painting (Kruppa 2011). However, only a small trace of polysaccharides bearing some similarity to karaya was found. Nevertheless, following our analysis of the tube paints we can confirm that no aqueous compound was detected in these samples.
7. Which contained aqueous binders and were miscible with water: Neugebauer 2016: 36–40. See also Eva Reinkowski-Häfner, 'Tempera: narratives on a technical term in art and conservation', in this volume.
8. See Leslie Carlyle, 'Towards historical accuracy in the production of historic recipe reconstructions', in this volume.
9. Data not shown.
10. 50 g coconut fat was melted, 12.5 g potassium hydroxide was dissolved in 18 g distilled water, mixed with the fat and heated while stirring until saponification was completed.
11. See Annika Hodapp, Patrick Dietemann and Norbert Willenbacher, 'Flow behaviour and microstructure of complex, multiphase fluids', in this volume.

Materials and suppliers

- Japan wax: Beerenwachs (Art. No. 16112), *Rhus succedanea* fruit cera, Brennessel (Munich, Germany).
- Organic palm oil: Rotes Palmöl mild, Rapunzel (Legau, Germany). Cold-pressed and purified with water vapour (manufacturer information).

- Organic coconut fat: Rapunzel (Legau, Germany). Cold-pressed and purified with water vapour (manufacturer information).
- Linseed oil: Kremer Leinöl Firnis, Kremer Pigmente (Aichstetten, Germany), Art. No. 73100, linseed oil boiled with a manganese drier (less than 0.1%) (source: Kremer Pigmente data sheet).
- Spike oil: Kremer Pigmente (Aichstetten, Germany), Art. No. 73800.
- Prussian blue: Miloriblau (PB27), Kremer Pigmente (Aichstetten, Germany), Art. No. 45200.
- Potassium hydroxide: Kaliumhydroxid Plätzchen, Merck (Darmstadt, Germany), Art. No. 5021.

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Authors' addresses

- *Corresponding author*: Wibke Neugebauer, Munich, Germany (wibke.neugebauer@neugebauer-restaurierung.de)
- Ursula Baumer, Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich, Germany (ursula.baumer@doernerinstitut.pinakothek.de)
- Patrick Dietemann, Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich, Germany (patrick.dietemann@doernerinstitut.pinakothek.de)

Tempera painting in Veneto at the beginning of the 20th century

Teresa Perusini, Giuseppina Perusini, Francesca C. Izzo and Giovanni Soccol

ABSTRACT This paper considers a period between 1890 and 1950 in Veneto (Italy) with a particular focus on artworks by Gennaro Favai, Guido Cadorin and their teachers Mario de Maria and Cesare Laurenti. In this study, the binding media of 12 paintings were analysed and the results compared with the painters' recipes. Together with artist Giovanni Soccol, a pupil and friend of both Favai and Cadorin, we reconstructed their tempera recipes and prepared some mock-ups for binding media analyses. This is the first time that paintings by de Maria, Laurenti, Favai and Cadorin have been analysed and most of their recipes published. All four painters used similar tempera media but it is important to highlight that many of their recipes also contain, among several 'conventional' ingredients (animal glue, egg yolk, drying oils, starch, etc.), flax seed water and mucilage. Organic analysis confirmed that they all used different binding media for bright and dark colours.

Introduction

This paper considers the use of tempera in the period between 1890 and 1950 in the Italian region Veneto focusing on two major Venetian artists, Gennaro Favai (1879–1958) and Guido Cadorin (1892–1976), and their teachers, Mario de Maria (1852–1924) and Cesare Laurenti (1854–1936) respectively. Assisted by artist Giovanni Soccol (b.1938), a pupil and friend of both Favai and Cadorin, a multidisciplinary approach was used to study 12 paintings[1] by these four painters:

- A technical study was carried out on the recipes held in de Maria's archive,[2] in papers by Favai and Cadorin conserved in Soccol's personal archive and in some previously published technical notes by Laurenti (Laurenti 1990: 80–82, Torresi 2002; Rinaldi 2015; Baroni *et al.* 2016: 120–21; Rinaldi *et al.* 2017: 145–52).
- Their tempera recipes were reconstructed and mock-ups prepared for the analysis of the binding media using micro-Fourier transform infrared (μ-FTIR) spectroscopy and gas chromatography-mass spectrometry (GC-MS).
- The analytical results were then compared with the painters' recipes.

Although further research will be required, this is the first time that the binding media used by de Maria, Laurenti, Favai and Cadorin have been analysed and some of their recipes published.

Technical context in Veneto

The tempera tradition was still alive and well in scenography, decorative and landscape easel paintings (Perusini and Perusini 2016: 28) at the end of 19th century in Veneto, as in the rest of Italy. In

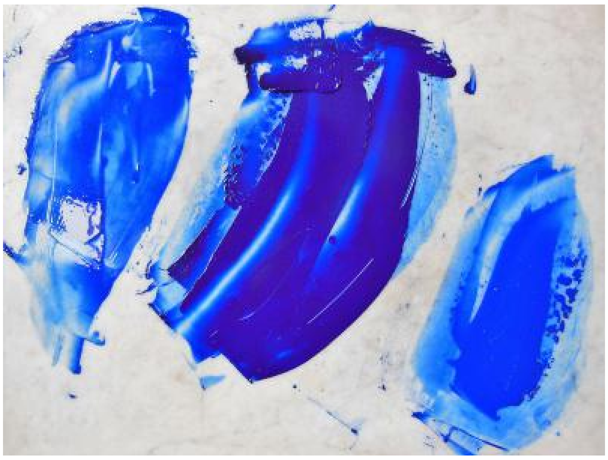

Figure 1 Giovanni Soccol's reconstruction tests of Cadorin's tempera: (*left*): pigment in linseed oil; (m*iddle*): egg emulsion plus linseed oil; (*right*): egg emulsion.

19th-century Italian treatises, such as that published in Venice by Bonaiuto del Vecchio (1842: 117), tempera is described as:

- *tempera magra* (lean tempera) when made mainly with vegetal and animal glue, and a small amount of sugar or gum such as those of Ippolito Caffi and Bernardino Bison (Perusini and Perusini 2016: 29; Casellato *et al*. 2013: 54).
- *tempera grassa* (fat tempera), as used by de Maria, Laurenti, Cadorin and Favai, when made with an emulsion of aqueous and oily media, similar to Gustav Berger's *Öltempera* (Berger 1912: 276–9) and to that described by Max Doerner as *fette Tempera* (Doerner 1921 [1971]: 202–3).

The Venetians, in common with all Italian painters, had a direct knowledge of the tempera painting technique that was still practised in Italy, but for geographical and historical reasons, artists living in Veneto at the beginning of the 20th century became more aware of German research on art technique than those living in the rest of the country.

Until 1866, Veneto was part of the Austrian Empire and many Austrian and German artists and scholars (e.g. Benno Geiger, August Wolf, Theodor Wolf Ferrari) lived in Venice. A few northeast Italian artists studying in Munich or Vienna (e.g. Bortolo Sacchi, Cesare Sofianopulo, Alberto Martini, Nino Springolo, Luigi Scopinich), were exposed to German art exhibitions (as were Laurenti and de Maria) or had formed personal relationships in German-speaking countries. For example, Mario de Maria's wife, Emile Voight, was from Bremen, and his most important gallerist, Schulte, was located in Berlin (Di Raddo 2013: 28). The famous tempera revival promoted by Giorgio de Chirico in his *Ritorno al mestiere* (Return to the craft) (De Chirico 1920 [2006], 1928) was of greater importance to the next generation of Venetian painters such as Afro Basaldella (1912–1976) (Perusini 2010; Perusini *et al*. 2013).

Despite the links with Germany, the context of the tempera debate in Veneto was quite different due to Venetian painters' direct knowledge of tempera, and the lack in Veneto, as in the rest of Italy, of the systematic and wide discussion on painting technique which in Germany involved producers, scholars and academy painters promoting exhibitions, conferences such as the *Maltechnik* exhibition in Munich in 1893 and reviews in the *Technische Mitteilungen für Malerei*. The numerous art treatises published in Italy at the beginning of 20th century reveal a general interest in the subject but lack a common forum (Torresi 2002).

Italian painters who did not produce their own colours used the new materials provided by foreign suppliers obtainable from colour retailers such as Calcaterra in Milan or Giosi in Naples (Bensi 2015; Gioli 2015; D'Ayala Valva 2015; Scotti 2015; Rinaldi 2015; Baroni *et al.* 2016; Rinaldi *et al*. 2017). Unsurprisingly, Laurenti began using Wurm Tempera from 1891 although he complained about its quality in 1894 and 1896 (Rinaldi *et al*. 2017: 1467), and de Maria employed Pereira Tempera from 1893 (Beltinger 2016: 114). We know that Alfons von Pereira also successfully presented his tempera at the Venice Academy of Fine Arts despite some criticism, for example by the painter Carlo Linzi (Bensi 2015: 29). However, both Laurenti and de Maria decided to produce their own tempera paints: Laurenti went down the industrial route using the colour factory Giorgi in Rovigo (Laurenti 1990: 22–3; Rinaldi 2017: 148) whereas de Maria's paints were handmade using recipes until now only partially known (Rinaldi *et al*. 2017: 148–9). Later, Favai and Cadorin adopted de Maria's approach. Raffaele Armando Califano Mundo praised Pereira tempera paints and appeared to have a good knowledge of European art products available in Naples, some of which he subjected to comparative

Figure 2 Gennaro Favai, *Self-Portrait in his Venetian Studio*, tempera on canvas, 115 × 93 cm, *c.*1930, private collection, Venice.

ageing analysis (Bensi 2015: 28–29). Italian painters of 19th and 20th centuries rediscovered tempera paints mainly for:

- their clarity and reduced darkening in ageing compared to oil paints: this topic was widely discussed by several Italian treatises of the 19th century (Perusini and Perusini 2016: 25–7);
- their quicker drying characteristics;
- creating layered paintings finished in oil or oil/varnish to emulate the technique of Renaissance Venetian painters (and confirmed by recent analysis);
- the expressive brushstrokes offered by this paint although 'pasty' tempera can only be achieved with an emulsion (animal glue or glue/gum temperas produce very thin paint layers such as those normally seen in scenography).

Giovanni Soccol's reconstruction tests clearly show the thickness of the tempera emulsions compared with oil media, which is much more liquid (Fig. 1).

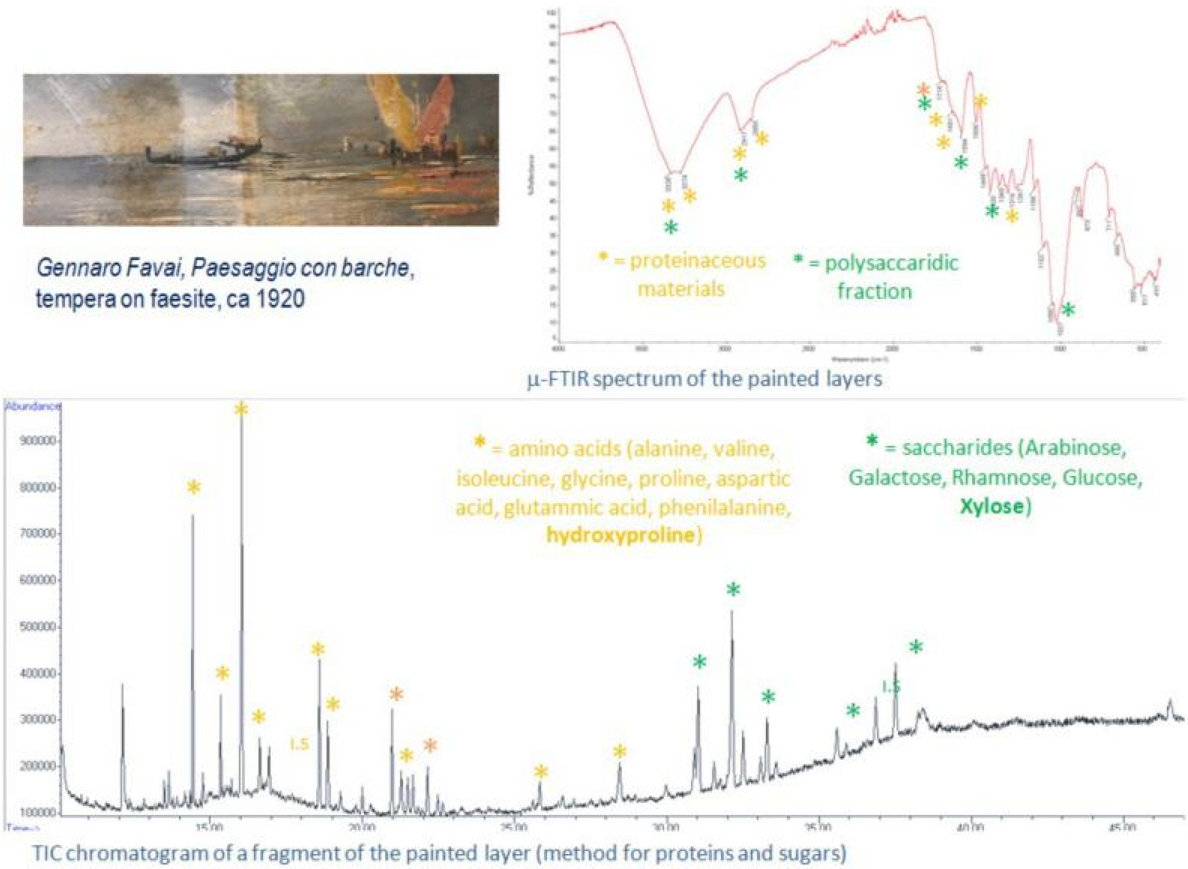

Figure 3 Micro-FTIR and GC-MS analysis of Favai's tempera.

Gennaro Favai and his master Mario de Maria

After spending a short time at the Venice Academy of Fine Arts, Favai became a pupil of Zanetti Zilla (1864–1949) and then of Mario de Maria (Prete 2011; Mazzanti 2007; Di Raddo 2013). Favai's archive has been conserved by Giovanni Soccol, who was his pupil and heir (Soccol 2011). As reported in his notes, Favai's tempera is mainly a mixture of vegetal and animal glue, cooked linseed oil, flax seed water, varnish, sometimes with the addition of Canada balm, vinegar or ammonia. According to Favai, his formula is the result of knowledge learned from Venetian painters working in decoration and scenography with the aim of obtaining the clarity of the Venetian Renaissance (Borgmeyer 1912: 230) (Fig. 2). We found several of de Maria's unpublished tempera recipes in his own archive, now preserved in Museum Correr Library in Venice.[3] The most complete recipe by the artist, 'Tempera de Maria', contains starch, cooked linseed oil, dammar or mastic varnish, flax seed water and gum arabic. According to their technical notes, some of Favai's tempera recipes are very similar to de Maria's, while others contain skin glue, not normally found in the latter's tempera. In fact, the main difference between de Maria's and Favai's recipes is that most of the former's recipes do not mention any animal glue.

Although so far we have only discussed the German connection, Favai's letters and recipes also evidence the influence of French culture on his pictorial art. In the 1930s Favai became good friends with Raoul Dufy who, in 1937 painted *La fée électricité* (approx. 600 m^2) at the Paris *Exposition Universelle* using Maroger medium (Maroger 1986). Dufy and Favai often collaborated on art experiments. Favai's library contains Severini's book on art technique, *Ragionamenti sulle arti figurative* (1936), in which Maroger medium is described in detail a few years after it was presented in Paris (1931/1933) and his papers also include a note on this medium. Soccol possesses two small paintings by Dufy executed with Favai's medium when he was his host in Venice. Favai's archive also contains some

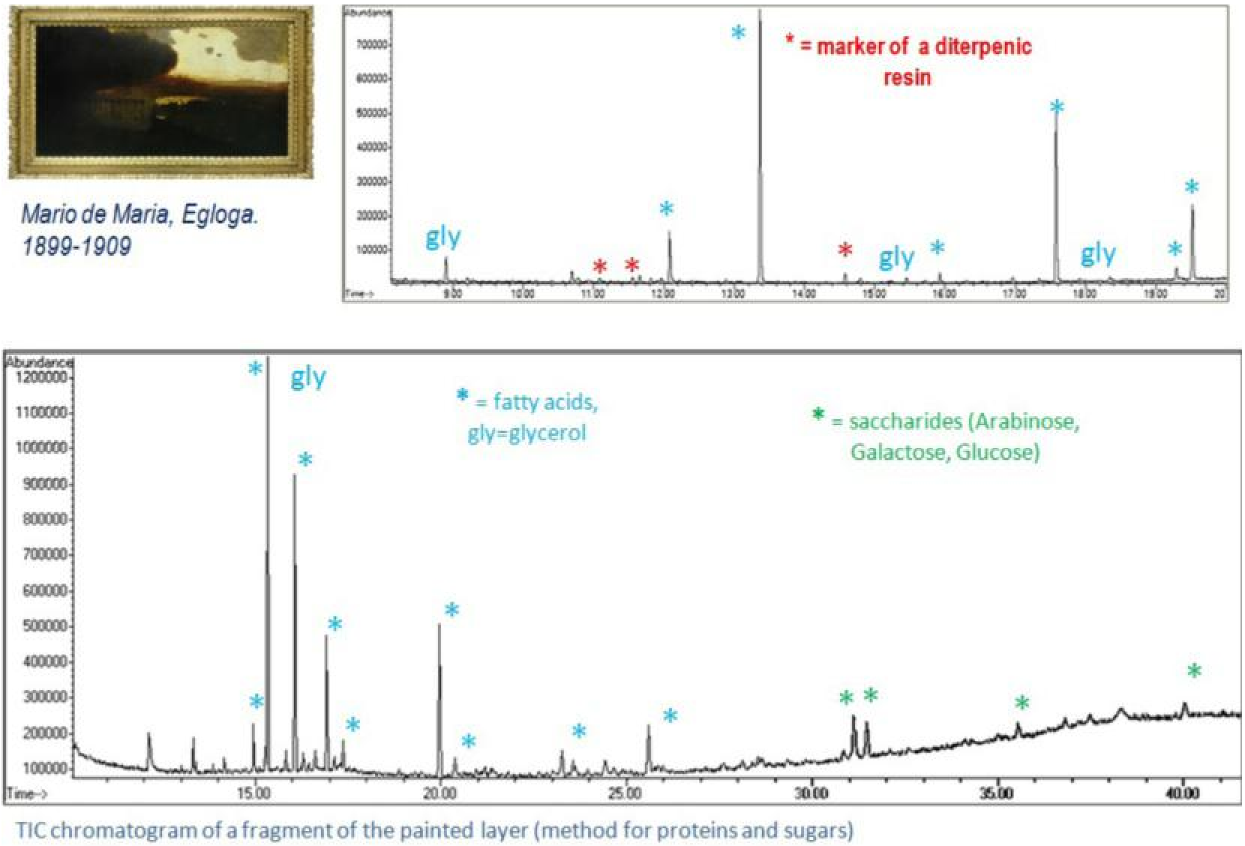

Figure 4 GC-MS analysis of de Maria's tempera.

letters on the casein tempera of the painter Renato Berti (1884–1938), a native of Veneto who was living in Paris. Although Berti appreciated the quality of his casein tempera, it dried too quickly so he asked Favai what he put in his medium to achieve a longer wettability. This question introduces a substance that we did not find in Favai's recipes but was detected in de Maria's organic analyses: glycerol.

We also compared their recipes with the organic analyses performed on their paintings and Soccol's reconstruction tests. Five paintings by Favai,[4] conserved in Soccol's atelier in Venice and dating from 1920 to 1950, were analysed using μ-FTIR and GC-MS to identify the complexity of the tempera paints and the diversity of the recipes used by Favai in his artworks. Generally, lipidic, proteinaceous and polysaccharidic materials were found mixed together. One recipe contains mainly a mixture of animal glue, gum arabic and flax seed mucilage. In another, drying oil was detected with a minor amount of proteinaceous and polysaccharidic compounds. With regard to de Maria's tempera paints, the organic results obtained by analysing two paintings by the artist showed the presence of a mixture of drying oil, diterpenic compounds (probably dammar resin) and polysaccharides (probably from flaxseed mucilage and flour). A high amount of glycerol was detected presumably added as an emulsifier and/or to increase working time, as reported in Berti's letter.

In both paintings by Favai and de Maria, linseed oil was generally detected in the dark colours, and poppy seed and/or sunflower oil in the blue and white colours. The analytical results on Favai's and de Maria's paintings highlighted the fact that researchers need to be aware of the considerable variability that may be found in the paintings of some artists: there will always be an element of freedom in painters' use of their own recipes. It is important to compare documents, artist declarations and scientific analysis (Figs 3 and 4).

Guido Cadorin and his teacher Cesare Laurenti

Guido Cadorin's first teacher was August Wolf, copyist for Adolf Friedrich Graf von Schack in Munich and father of the painter Teodoro Wolf Ferrari. For two

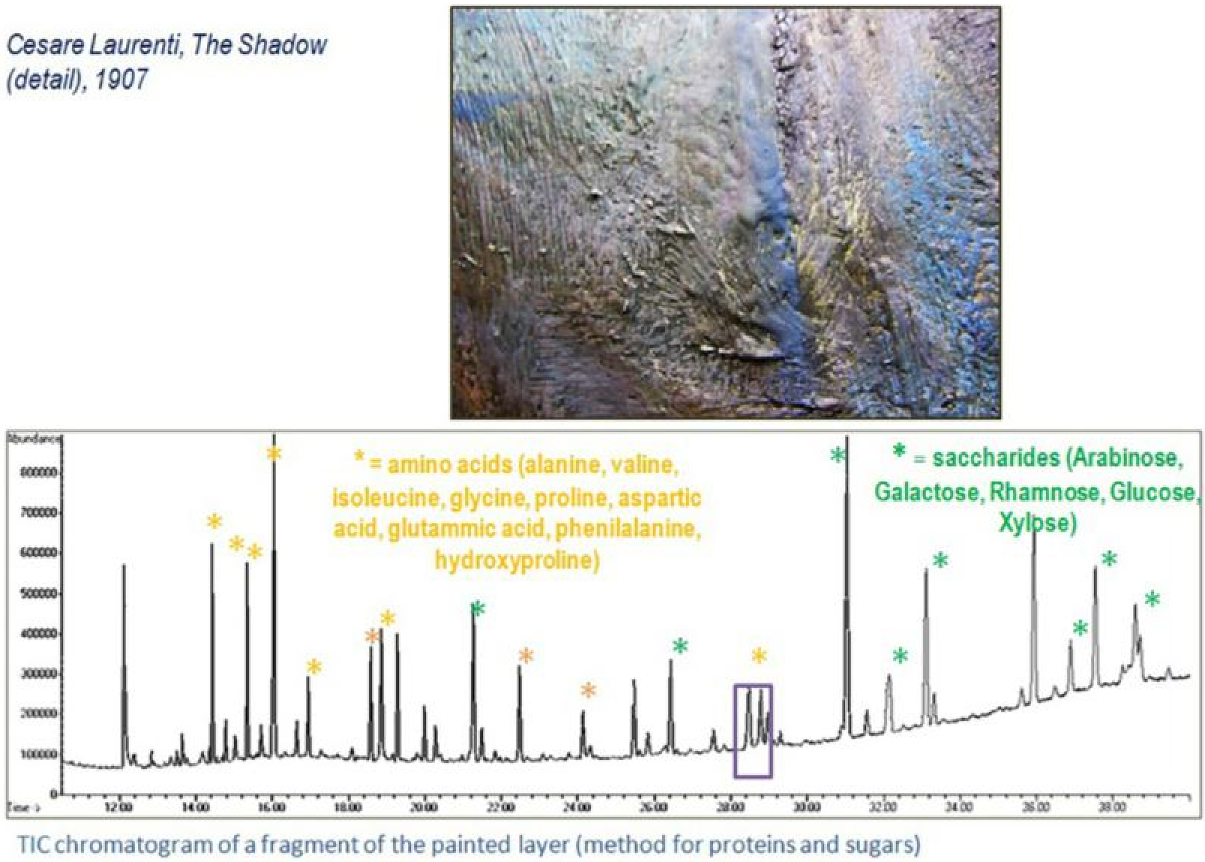

Figure 5 GC-MS analysis of Laurenti's tempera.

Figure 6 Cesare Laurenti, *The Shadow* (detail), tempera on wood, 1907, Museo Ca' Pesaro, Venice.

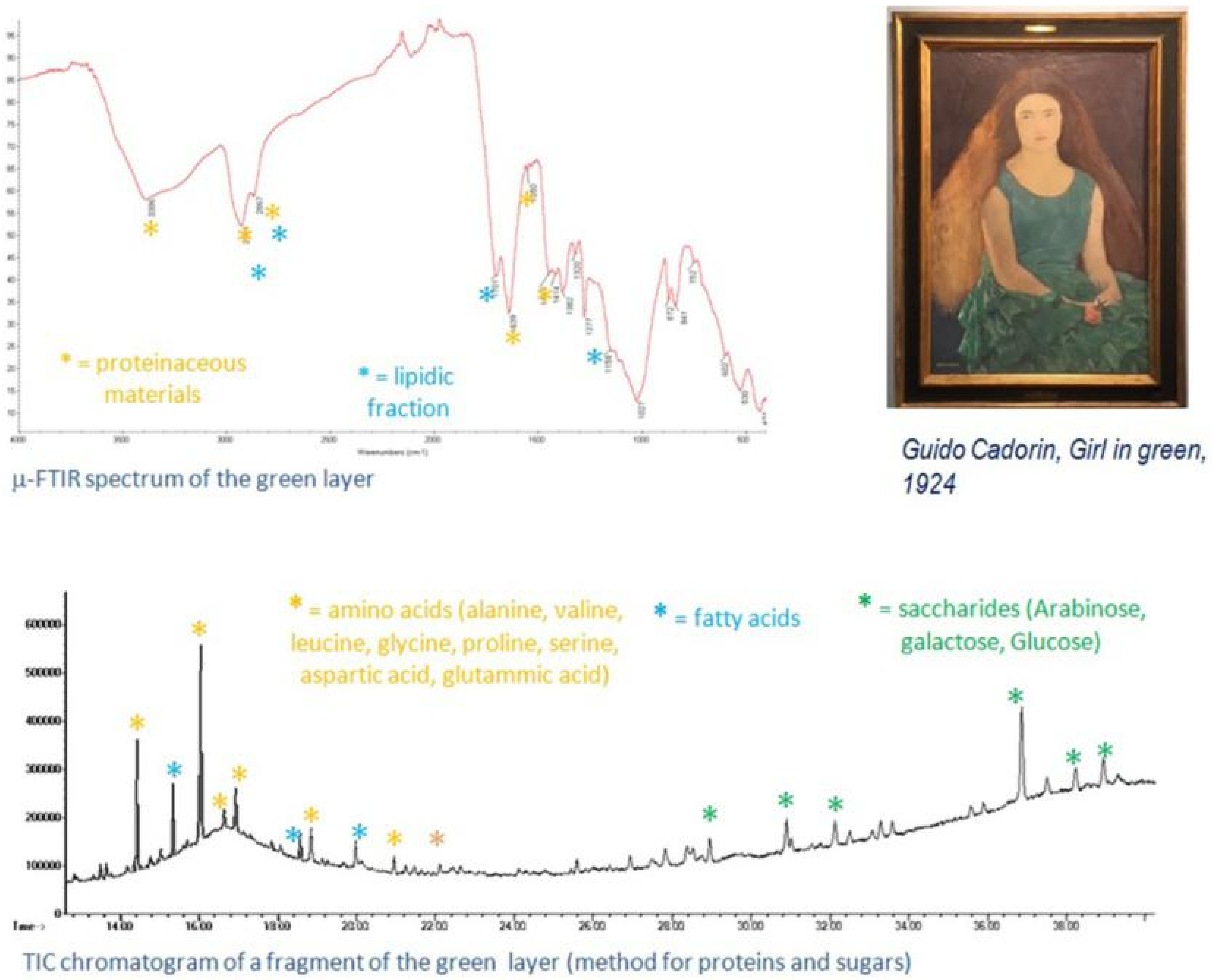

Figure 7 Micro-FTIR and GC-MS analysis of Cadorin's tempera.

years from the age of 15, Cadorin attended the school run by Laurenti from whom he learned the love of tempera (Dal Canton 2007: 32–9). In his technical notes, Laurenti suggested the use of skin glue-based tempera as a medium for clear colour and a mixture of gum arabic and flax seed mucilage for dark colours (Laurenti 1990: 81; Rinaldi *et al*. 2017) but until now his tempera medium has not been analysed. In this study, for the first time, we have scientific evidence of the recipes used by Laurenti for two important paintings in the International Gallery of Modern Art Ca'Pesaro in Venice, *New Flowering* (1897) and *The Shadow* (1907), both dating to the period in which the artist carried out most of his experiments with tempera recipes. Analyses using μ-FTIR and GC-MS performed on microsamples taken from the selected paintings confirmed Laurenti's descriptions of his recipes: in particular, animal glue was found as the binding medium for white and clear brushstrokes, while the typical polysaccharidic compounds present in the gum arabic and flaxseed mucilage were detected for dark and brown colours (Fig. 5). Furthermore, Soccol's reconstruction tests showed that the latter recipe is perfect for dark pigments especially in thin layers as can be observed in *The Shadow* (Fig. 6).

With reference to Cadorin's tempera paints, it is known that he mainly used an emulsion tempera containing egg, glue and linseed oil (Fig. 7) for easel paintings and a casein-based tempera on walls. Unlike Maimeri or Ferrario, neither Cadorin nor Favai turned from self-made paints to industrial tempera even in the 1940s and 50s when inexpensive Italian commercial tempera paints were easily available. From the 1960s Cadorin added Vinavil (a vinyl polymer produced by Montedison, Italy) to his egg

Figure 8 Guido Cadorin, *Girl in Green*, 99.5 × 68 cm, tempera on cardboard, 1924, Museo Revoltella, Trieste. (Photo: Archive of Museo Revoltella.)

tempera. We know from Giovanni Soccol that in the last years of his life Cadorin also employed industrial oil paint (mainly Talens) to finish the superficial layers of his paintings. Soccol's archive contains several tempera paint recipes by Cadorin that, together with his pupils, he prepared four to five times a year.

For this study, we were able to examine three paintings by Cadorin: *Girl in Green* in the Revoltella Museum in Trieste (1924) (Fig. 8), and *Female Nude* (*c.*1920) and *Benno Geiger Portrait* (1943) both in the Ca'Pesaro in Venice. According to the analytical results, it seems that the tempera used by the artist was mainly a mixture of drying oil (linseed oil), proteinaceous materials (egg yolk and animal glue) and a polysaccharidic fraction (probably due to the use of flour/starch and flax seed mucilage) (see Fig. 7).

Conclusion

This preliminary study on the tempera paints used by Gennaro Favai, Guido Cadorin, Mario de Maria and Cesare Laurenti has allowed us to draw the following conclusions. Their common Venetian culture can be seen in their passion for Venice's Renaissance paintings used as their artistic and technical models. The Renaissance technical model is evidenced in the use of tempera both in a layered painting method with tempera underpaint and oil or oil/varnish glaze and in the reproduction of *sfregazzo* (brushstroke) with pasty tempera emulsions used in particular for clear colours. Their Venetian tradition is also apparent from their close connection to the artisanal world which may have given rise to their practice of preparing their own media for most of their careers. All four painters were experimental and their techniques varied. In addition, a certain discrepancy can be discerned between their recipes, written sources and the results of scientific analyses, therefore it is important to verify the information from documents with analyses. The use of different media for different colours, for which written and scientific evidence is available, should be noted by conservators in the treatment of these paintings.

From a technical point of view, the fact that flax seed mucilage or flax seed water is a distinctive component in all their recipes is remarkable. However, given that the use of flax seed mucilage or water was common at that time for medical, veterinary and alimentary purposes,[5] it is perhaps not surprising to find flax seed mucilage in painting media: flax seeds were less expensive than gum arabic and flax seed mucilage can act as an emulsifier for water-in-oil emulsions, particularly if egg yolk or oil is absent. Flax seed water was also detected recently in some paintings by the American artist Henry Ossawa Tanner (1859–1937) (Kerr *et al.* 2014).

Acknowledgements

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Notes

1. Two paintings by Mario de Maria: *Eclogue* (1899–1909) from the International Gallery of Modern Art Ca' Pesaro in Venice and *Church and Executed Field in Val d'Inferno* (1907), from Museo Revoltella in Trieste; two paintings by Cesare Laurenti: *New Flowering* (1897) and *The Shadow* (1907), from Museo di Ca' Pesaro in Venice; five paintings by Gennaro Favai from *c.*1920–*c.*1950 belonging to Giovanni Soccol: *In the Arsenale*, *Venetian Houses*, *La Salute*, *Trees in Capri* and *Boats*; three paintings by Guido Cadorin: *Girl in Green* (1924), from Museo Revoltella in Trieste, *Female Nude* (1920) and *Benno Geiger Portrait* (1943) from Museo di Ca'Pesaro in Venice.
2. De Maria's archive is now preserved in the library of Museum Correr in Venice.
3. Some in his correspondence, but most in *Taccuini* (notebooks) *1905–06*, Taccuino 2 (ADM - de Maria Archive - c. 62).
4. See note 1 above
5. Flax seeds were used to cure bronchitis, for horses' intestines and to prepare less expensive olive oil by adding flax seed mucilage (see L. De Seta, *La cucina in tempo di Guerra*, Florence, Salani, 1942).

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Authors' addresses

- Teresa Perusini, Università Ca' Foscari, Venice, Italy (teresa.perusini@perusini.com)
- Giuseppina Perusini, Università di Udine, Udine, Italy
- Francesca C. Izzo, Università Ca' Foscari, Venice, Italy
- Giovanni Soccol, Accademia di Venezia, Venice, Italy

‘I explored every means of painting back then, notably every tempera’: Hermann Prell’s research on tempera

Silke Beisiegel

ABSTRACT Hermann Prell, a monumental painter in Imperial Germany, was particularly interested in the technical and artistic implementation of the concept of a *Gesamtkunstwerk* (an ideal work of art). Sadly, however, of his monumental works, only the mosaics in the Bremen Cotton Exchange have survived. Prell’s practical work was accompanied by questions of painting technique as can be seen in extensive writings documenting his painting experiments and recipes – in total about 6500 pages of written sources can be found in the Dresden archives. He also maintained close contact with other artists. This paper uses Prell’s notes on the historical and contemporary literature he consulted, along with fellow artists, as the basis for a breakdown of the recipes used and of industrially produced art materials.

Introduction

Hermann Prell (1854–1922) (Fig. 1), professor of history painting at the Royal Academy of Art (Königliche Kunstakademie) in Dresden from 1892 to 1914, enjoyed an important role as a monumental painter in Imperial Germany including major public building commissions such as the city halls in Worms and Hildesheim, the throne room in the German embassy in Rome and the staircase of the Albertinum in Dresden. Prell was particularly interested in the technical and artistic implementation of the concept of a *Gesamtkunstwerk* (an ideal work of art). Tragically, however, apart from the mosaics in the Bremen Cotton Exchange, none of his monumental works has survived. Throughout his life, Prell’s practical work was accompanied by an intense confrontation with questions of painting technique that are reflected in extensive writings documenting his painting experiments and recipes – about 6500 pages of written sources can be found in the Dresden archives alone (Wünsch 1994: 4–5, 205–6). He also maintained close contact with other artists such as Hans von Marées (1837–1887) and Carl Gussow (1843–1907). Prell’s notes on the historical and contemporary literature he consulted, along with fellow artists, provide the basis for a breakdown of the recipes used and of industrially produced art materials.

Between fresco and tempera painting

In Prell’s work, the confrontation with tempera paints played an important role both in his easel painting and the murals. He studied oil painting at the Royal Academy of Art in Dresden but from 1879 onwards, he began to focus on fresco. After winning the Biel

Figure 1 Hermann Prell in his studio, *c*.1910. (Photo: SLUB/ Deutsche Fotothek, http://www.deutschefotothek.de/documents/obj/70221650 [CC-BY-SA 4.0].)

fresco prize for the painting of the banqueting hall in the Berlin Architektenhaus, he started studying painting techniques.[1] The art historian Max Jordan (1837–1906) referred Prell to literary sources such as Pliny, Vitruvius and Theophilus Presbyter (Prell *c*.1921, V: 77).[2] In addition to his interest in the writings of Leonardo da Vinci and Vasari, Prell also made his own translation of the manual of Cennino Cennini (Prell *c*.1921, V: 77).[3] His sketchbooks contain passages from these sources which he found important, as well as recipes on the basis of which some personal encounters with artists can be reconstructed. From 1885, his notebook records such recipes along with excerpts from writings on painting technique.

'Home-made' egg-tempera formulations

During a study trip to Italy from 1879 to 1881, Prell gained inspiration and valuable knowledge on both fresco and tempera painting techniques (Wünsch 1994: 18). He was able not only to view the antique murals and Marées's designs for the Stazione Zoologica in Naples, but also to meet the master himself (Wünsch 1994: 18). Prell venerated Mareés, and through him made the acquaintance of the painter Heinrich Ludwig (1829–1897), whose Ludwig Petroleum paints influenced the development of his technique (Prell *c*.1921, VI: 91). In addition, Prell and Marées together met Arnold Böcklin (1827–1901) to discuss the ancient fresco technique (Prell *c*.1921, VI: 91–2). The two artists also introduced Prell to 'home-made' egg-tempera paints. Prell identified a direct connection between fresco painting and tempera painting: 'I have at last looked at tempera and resin painting, and I suspect that both are also linked to fresco' (Prell *c*.1921, VI: 93).[4] He went on to explain in more detail: 'I get totally absorbed in craft experiments – since the art of the oil painter is unusable in the inevitably planned procedure when working on the wall, I follow up the tempera and resin experiments with fresco studies; for the rest, the ancients have preserved the scheduled aspect of the royal technique in their panel paintings, and not to their detriment!' (Prell *c*.1921, VI: 100).[5] Prell described the concrete form taken by these experiments with tempera:

> Using his [Marées's] technique, I ground the paints in water, (according to the instructions of Cennini, whose palette was that of the entire Renaissance period, and was also his), starting them fresh each morning with egg yolk, after careful removal of the 'blood spot', using a pestle and spatula on the porphyry plate, and painted on one of the beautiful wooden boards, primed with Bolognese plaster, such as are made by the Roman Gessatori, in the way I was accustomed (Prell *c*.1921, VI: 95).[6]

In Marées's studio Prell also witnessed the multi-layered paint structure with underpainting in egg tempera and further work with varnish paints (Prell *c*.1921, VI: 108). He had observed this procedure being used in a similar manner by Arnold Böcklin when he visited him in Florence in 1881 (Prell *c*.1921, VI: 108). The recipe for Böcklin's paints using egg yolk and varnish can be found in slightly different variations in Prell's writings.[7]

Prell drew on his experience with egg tempera for the design of the banqueting hall in the Berlin

Architektenhaus in order to complete the painting on the gold ground (Prell *c.*1921, VI: 127), but his experiences in Italy also had an effect on his two paintings *Evening Stroll* and *First Spring*, completed in 1885:

> Both paintings … deviated completely from the previous impasto *alla prima* technique in their treatment, and were for the first time executed in the spirit of old Italian or old German painting with gouache on lightly absorbent, smooth plaster grounds on mahogany panels; varnished with shellac and spirits to exclude all excess oil, and completed with oil paint and amber lacquer, either opaque or as a glaze. The mysterious effect of the ancients and their gradual, mature approach, which also characterizes Böcklin's technique, was in my mind as I did it (Prell *c.*1921, IX: 159).[8]

Industrially produced tempera paints

In 1881 Prell was commissioned to carry out his first large-format tempera painting, *Victorious Art*, for the ceiling of the banqueting hall in the Berlin Architektenhaus, which he executed in 1885/86 (Wünsch 1994: 79). The picture support was 'a particularly strong sailcloth' made by the George company in Berlin, 'which has woven all my canvases ever since' (Prell *c.*1921, IX: 168).[9] His former teacher at the Academy, Carl Gussow, continued to support and help him overcome problems with the tempera on a chalk ground (Prell *c.*1921, IX: 175). His notes on the execution of the painting do not sound exactly enthusiastic: 'Ceiling picture. Wurm tempera (turpentine & vehicle) on nothing but chalk and glue. passable material' (Prell 1916: 9).[10] However, at the same time, in a letter to the manufacturer Richard Wurm, he stated: 'I am very satisfied with the paints' (Berberich 2012: 392).[11] Prell and Richard Wurm had been in contact since 1879, suggesting that the artist had already worked with the company's tempera paints (Berberich 2012: 242). In addition, Prell was a friend of the artist Max Klinger (1857–1920), who also used tempera paints made by Wurm (Prell *c.*1921, IX: 170).

Prell continued to experiment with various recipes in addition to following the recommendations of fellow artists. In 1904 he tested, and rejected, the technique employed by his colleague at the Dresden Academy, Osmar Schindler (1867–1927), who painted with 'Pereira tempera & resin … on smooth linen, [with] chalk ground' (Prell 1916: 80).[12] After his own trial of the technique, Prell noted: '*nichts werth*!' ('useless!') (Prell 1916: 80).

In 1907 his work on the large-format painting *Saxonia and the Three Estates* led him to undertake new experiments:

> As always with large formats, I tried tempera underpainting to the form. All sorts of new materials were tried out – matt 'Mussini' paint, 'Renaissance' from Fleischer etc.– until the oil tempera from Wurm on a half-chalk ground which I'd tried earlier turned out best once more. Wurm's soapy Wassermalmittel or with manganese oil and turpentine are best used as an impasto underpaint – always starting with the light colours, as the material easily darkens; by way of compensation it keeps its hue and strength unchanged when varnished (Prell *c.*1921, XX: 2).[13]

Among the vehicles he also mentioned the varnish from Vibert and the *Harzmittel* (resin vehicle) (Prell *c.*1921, XX: 2) from Walter Firle, which he praised in conversation with Richard Wurm (Berberich 2012: 246). Prell assessed his experience with the materials by stating that: 'The paint always remains in place, it glazes, it covers, it never seeps into the layer beneath – in short, it is totally similar to the material of the Old Masters; for matt painting not to be recommended though' (Prell *c.*1921, XX: 2).[14] But in parallel, he took an active interest in the casein technique on canvas for monumental commissions (Prell *c.*1921, XIV).

Industrially produced casein paints

In 1895, for the council chamber in Danzig (now Gdansk) city hall, Prell painted the two pictures *The Polish Attack on Wisłoujście Fortress in 1577* and *Reception of a Legation from Gdansk in Venice by Doge Marino Grimani in 1601* (Wünsch 1994: 88–9). As the location did not allow a fresco execution, the artist used casein paints on canvas. In the course of carrying out this commission, Prell began to develop his casein-on-canvas technique (Prell *c.*1921, XIV) probably as a result of his contact with the Düsseldorf

Figure 2 The staircase in the Albertinum in Dresden, *c.*1904 (reproduced from Galland 1916, fig. 40).

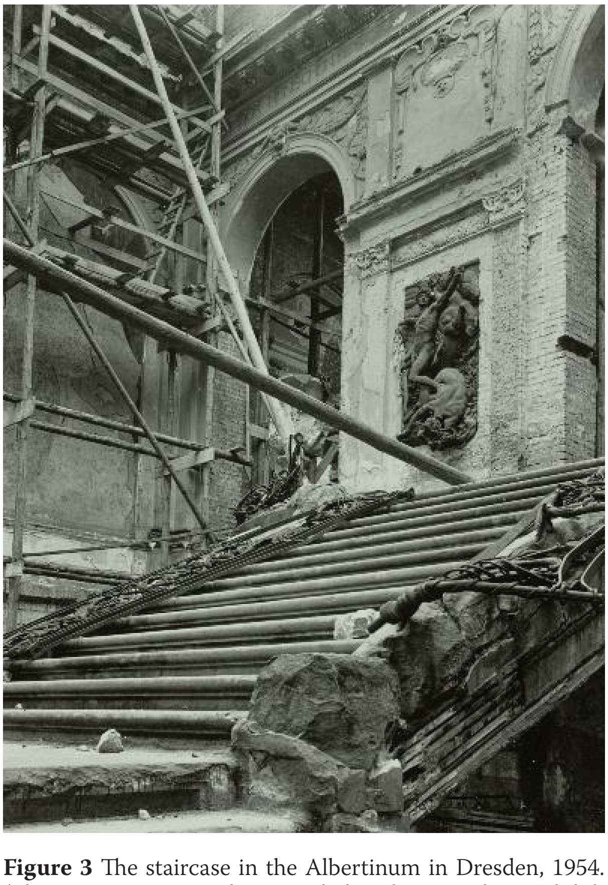

Figure 3 The staircase in the Albertinum in Dresden, 1954. (Photo: SLUB/Deutsche Fotothek, photographer Adolph Canzler, http://www.deutschefotothek.de/documents/obj/7106026 [CC-BY-SA 4.0].)

artists Fritz Gerhardt (1828–1921), Peter Janssen (1844–1908), Friedrich Geselschap (1835–1898) and Eduard von Gebhardt (1838–1925). In the summer of 1885, Prell visited Düsseldorf on behalf of the Prussian education minister Gustav von Gossler in order to conduct experiments in the application of Gerhardt's casein paints to murals (Prell *c.*1921, IX: 179).[15] Prell's notes for 1888 contain entries relating to these paints (Prell 1916: 20). In November 1889 he met Eduard von Gebhardt in Düsseldorf for an intensive discussion on painting technique (Prell *c.*1921, XII: 11).

The canvas, again from the George company, was sized twice with casein with an addition of '*salicyl*'.[16] It was primed twice: once with a chalk slurry in casein and once with a chalk slurry with zinc white in casein (Prell 1916: 46). The picture support was sprayed from behind with water and painted *alla prima* with Gerhardt's casein paints produced by the Schoenfeld company (Prell 1916: 46). In 1915 Prell noted next to this recipe: '*Das bleibend richtige Verfahren*' ('The lastingly correct technique') (Prell 1916: 46). The reasons for moistening the reverse of the canvas were explained by Prell as deriving from his passion for the fresco technique: 'I treat mural pictures – like the present one in Danzig – just like frescoes to the extent that I keep the canvas I am working on damp on the reverse' (Prell *c.*1921, XIV: 3).[17] His studio assistant, Karl Kehrer, helped to moisten the canvases. Prell was familiar with painting on wet canvases from the literature on technique, namely in Armenini (Prell *c.*1921, IX: 188) and Vasari, who doubtless also influenced Arnold Böcklin to do the same (Neugebauer 2016: 76). Prell may therefore have also been inspired by his contact with Böcklin to use this method. For Prell the advantage lay in the damp ground, which he had already learned to appreciate when painting frescoes as 'one's painting becomes more fluid, and is above all bound once more through the softening of the ground' (Prell *c.*1921, XIV: 3).[18]

From Prell's notes dating from around 1895, we can reconstruct experiments with a few industrially produced paints, probably partly in combination with his casein technique: 'Herz & Co casein very unsatisfactory, too watery … Syntonos too much glycerine, not very luminous, shines easily. Neisch is developing, & will produce the only good casein & tempera paints' (Prell 1916: 47).[19] Prell changed the source of the painting material he used for his monumental works from Gerhardt's casein paints to those made by Neisch & Co., probably around 1896–1898:

> Gerhard in Düsseldorf … blended them with powdered marble; the name 'Kasein-Marmorfarben' [casein marble paints] certainly had a monumental charm – but otherwise no use. I have found and tried out many new things with the busy old practitioner, … only in the end to turn away from him after all, and to use the purer material from Neisch& Co. in Dresden (Prell *c.*1921, XIV: 3).[20]

Example of the use of casein paint: the staircase in the Albertinum in Dresden

Prell documented his work on the staircase in the Albertinum in Dresden between 1899 and 1904 in considerable detail (Fig. 2). The mural was destroyed in 1945 (Fig. 3) but the painting technique and numerous painterly studies for the development of the composition allow retrospective statements to be made concerning the work process (see Figs 4, 6–8). The project involved several artists and craftsmen who helped Prell to realize his idea of a *Gesamtkunstwerk*. This paper only discusses Prell's application of casein paint, although numerous other materials and techniques were used in the design, such as fresco, *scagliola*, mosaic, stucco relief, marble sculpture and painted plaster casts.

Figure 4 *Pine-trees*, 1898, oil on canvas board, 47 × 33 cm, Albertinum/Galerie Neue Meister, Staatliche Kunstsammlungen Dresden. (Photo: Silke Beisiegel.)

The *Tartarus*: casein paint applied to the wall

Prell generally preferred the fresco technique for murals, but he departed from it if the building situation demanded it. He repaired a crack in the masonry on the west wall of the staircase by installing a wire plaster wall in front of the crack which was then painted with casein paint (Prell *c.*1921, XVI: 55). Due to his lack of experience with this procedure there were problems in the execution. After he had 'coated [the wall] with casein and paint and impregnated it several times with Neisch casein' (Prell 1916: 76),[21] he applied the underpainting. But he noted in frustration: 'The plaster of the wire plaster wall comes

Figure 5 *Fall of the Titans*, *c.*1904, casein paint on canvas (reproduced from Galland 1916, fig. 42].

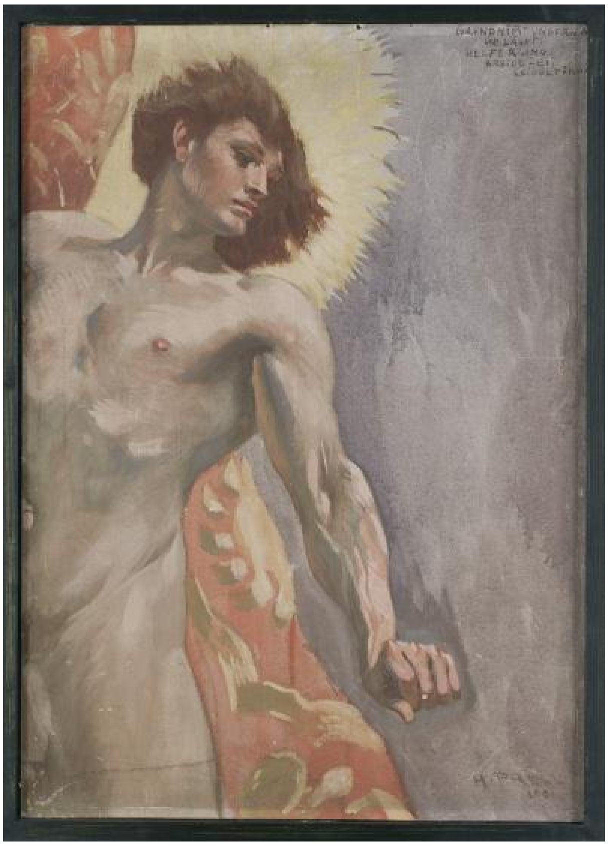

Figure 6 *Head of Apollo*, 1901, tempera on canvas on cardboard, 88.5 × 64.5 cm, Städtische Galerie Dresden – Kunstsammlung Museen der Stadt Dresden. (Photo: Franz Zadnicek.)

away in small flakes when it is painted; very bad!' (Prell 1916: 76).[22] The drenching of the surface in casein or a mixture of wax and petrol was unsuccessful. Recognizing that Gerhardt's impregnation lacquer made the painting appear darker he only used it elsewhere (Prell 1916: 76). The tempera from Neisch & Co. was used for the top paint layer (Prell 1916: 76).[23] Finally he was satisfied at least with the aesthetic aspects of the execution, noting that 'it looks just like fresco, but it is not so firm as all the rest, and care will be needed when it comes to be cleaned' (Prell *c.*1921, XVI: 55).[24]

Fall of the Titans: casein paint on canvas

The staircase ceiling had originally been divided into three areas by stucco ornaments. Prell however intended to create just one picture, and had a wire-mesh plaster ceiling installed below the existing ceiling (Prell *c.*1921, XVI: 1). The painting (80 m^2) was executed in tempera paints on canvas and later adhered to the ceiling (Wünsch 1994: 24) (Fig. 5).

Before carrying out the work, Prell tested a number of technical variants: 'Experiment with Neisch tempera, on the Neisch Helferling ground, and egg, zinc white, chalk slurry and boiled linseed oil. The ground is firm; when moistened from behind it softens, however; it is easy to moisten from in front. The paint is easy to treat; it remains almost entirely unchanged' (Prell 1916: 71).[25] The tempera study *Head of Apollo* (Fig. 6) for this painting, dating from 1901, has survived, with an inscription recording a similar recipe: 'Ground does not take easily/ and runs/ Helferling/ chalk-egg/ boiled linseed oil.'[26]

Two further studies are inscribed with technical details that show how the artist approached the materials. *Titan and Horse* (Fig. 7) was painted in casein paints from Neisch on a Helferling ground

Figure 7 *Titan and Horse*, *c.*1901, tempera on canvas, 71 × 100 cm, Städtische Galerie Dresden – Kunstsammlung Museen der Stadt Dresden. (Photo: Franz Zadnicek.)

with casein zinc white and judged by Prell to be very good: 'Ground: casein-zinc-white [Helferling] Neisch/ casein paints Neisch/ very good, even on dry [canvas]/ only slight brightening/ very firm.'[27] He painted *Titan's Head* (Fig. 8) in tempera paints made by Neisch on a moist Helferling ground: 'Neisch tempera/ Helferling ground/ wets from behind.'[28]

The execution on 'casein canvas' (Prell 1916: 71) seems to have corresponded with his 'casein technique on canvas' for the Danzig paintings described above: 'The large cartoon for the ceiling picture transferred to the canvas by two pupils, [Richard] Schlösser and [Paul] Harnisch and the underdrawing executed' (Prell *c.*1921, XVI: 28).[29] In the process, he carried out the 'underpainting on the dry [canvas] with umbra, terra di siena, ultramarine – as needed. Finally underpainting in local colours without looking at the effect until no bare canvas was anywhere to be seen and the picture was there in its entirety' (Prell XIV, 310).[30]And then Prell began to paint:

> I had it moistened from behind piece by piece with a spray and a large sponge, until it was totally wet. The wet area looks considerably darker. I mixed the main hues, as with fresco, in glass jars until they were stiff, in order to constantly keep the

Figure 8 *Titan's Head*, 1903, tempera on canvas, 43.6 × 30.8 cm, Städtische Galerie Dresden – Kunstsammlung Museen der Stadt Dresden. (Photo: Franz Zadnicek.)

scale. But otherwise impasto and *alla prima* just like with oil painting, and finish the section completely by evening' (Prell *c*.1921, XIV: 311).[31]

Once again the artist draws a parallel with the fresco technique. The moistening of the canvas is evidenced by the water stains on the studies *Head of Apollo* and *Titan and Horse* (Figs 6 and 7). This may explain the note: 'There are always concerns about wetting a second time: it causes edges and dries darker. This is why the final finish and harmonization takes place on a dry ground, impasto and glaze' (Prell *c*.1921, XIV: 311).[32] How, in these circumstances, a piece-by-piece wetting and painting of the canvas, as in a day's work in fresco painting, was possible without producing such water stains, may perhaps be explained by the following: 'One must note that drips flowing down over the canvas leave ugly streaks of water behind; the assistant doing the wetting must watch out and catch them – however they can also be removed later by washing on the reverse to create fluid transitions' (Prell *c*.1921, XIV: 311).[33] Alternatively the artist may have used the term 'harmonization' as described to overpaint any edges that might have appeared. According to his own statement, Prell painted with 'Neisch's casein, which is better and has richer colour than Gerhard's' (Prell 1916: 72).[34] Finally, the painting was adhered using 'Gerhard paste' to 'the mortar ceiling which had received a number of coats of oil paint' (Prell *c*.1921, XVI: 46) (Fig. 5).[35]

Conclusion

Thanks to his widespread networking with other artists and art historians, Hermann Prell left extensive notes and documents that represent an outstanding source on painting technique around 1900. The artist used tempera paints both for easel paintings and murals in a more nuanced way than can be described here. Furthermore, it has only been possible to give isolated examples of the recipe collection that Prell prepared for his fellow artists. His experiments in painting technique were influenced by the exchange with artists such as Hans von Marées and Fritz Gerhardt. He summarized his position thus:

> At that time I explored every means of painting, notably every tempera, knowledge of which the aspiring age was developing in every direction right down to the old sources and the latest refinements, and even today I look through, with interest, the experiments and notes that later ages will laboriously re-acquire (Prell *c*.1921, XIV: 2–3).[36]

For selected monumental works, the painter achieved his artistic aims with his casein technique on canvas, which he consciously related to the fresco technique he preferred. The difficulty of assessing his knowledge and its practical application is exacerbated by the almost total loss of those works that were inseparable from their architectural setting.

Acknowledgements

I extend my thanks to Michael Scuffil for the translation of this paper and to Maria Körber and Stephanie Exner.

Notes

1. In 1878 Baron Biel von Kalkhorst had announced a prize for murals that were to be executed in fresco (Wünsch 1994: 17).
2. Prell's use of the mentioned literature will be discussed further in my dissertation, following details from Zindel 2010. Plinius Gaius Secundus, *Naturalis historiae, libri XXXVI I*, *c*.77 AD, 1st edn Venice 1469; Marcus Vitruvius Pollio, *De architectura, libri decem*, *c*.40–27 BC, 1st edn Rome 1486; Theophilus Rugerus Prebyter, *Schedula diversarum artium*, *c*. 11th century, 1st edn Braunschweig 1774.
3. Cennino Cennini, *Il libro dell'arte o trattato della pittura*, *c*.1390, 1st edn Rome 1821; Leonardo da Vinci, *Trattato della pittura*, *c*.1480, 1st edn Paris 1651; Giorgio Vasari, *Le vite dei più eccellenti architetti, pittori, et scultori italiani, da Cimambue, insino à tempi nostri, descritte in lingua toscana da Giorgio Vasari pittore aretino. Con una sua utile e necessaria introduzzione a le arti loro*, Florence 1550.
4. '*Endlich habe ich mich hier mit Tempera- und Harzmalerei befaßt, und vermute daß Beide auch wieder mit dem Fresko in Verbindung stehen.*'
5. '*Ich gehe ganz auf in handwerklichen Proben – da die Kunst des Oelmalers bei dem unerläßlichen planmäßigem Vorgehen an der Wand unverwendbar ist lass ich den Tempera- und Harzexperimenten Freskostudien folgen; im Uebrigen haben die Alten das Planmäßige der königlichen Technik auch in den Tafelbildern innegehalten, nicht zu ihrem Schaden!*'

6. '*Ich rieb in seiner* [Marées] *Art die Farben in Wasser an, (entsprechend auch der Vorschrift des Cennini, dessen Palette die der ganzen Renaissancezeit geblieben ist, und auch die Seine war) setzte sie jeden Morgen frisch mit Eidotter, nach sorgfältiger Beseitigung des ‚Hahnentritts', auf der Porphyrplatte mit Stiesel und Spachtel an, und malte auf einer der schönen Holztafeln, mit Bologneser Gips grundiert, wie sie die römischen Gessatori herstellen, so wie ich es gewohnt war.*'
7. For example: '*Eigelb von vornherein bis zu 15 Tropfen Firniss bei, beides gut gemischt. Die Farben wurden damit angerieben; sein Verdünnungsmittel, in das er beim Malen die Pinsel eintauchte, war nur Wasser*' ('Egg yolk right from the start with up to 15 drops of varnish, the two well mixed. The paints were ground with this; his thinning agent, in which he dipped the brushes when painting, was only water'), Prell *c*.1921, IX: 160.
8. '*Beide Bilder … wichen in der Behandlung vollkommen von der bisherigen pastosen Primatechnik ab, und sind zum erstenmal im Sinne etwa altitalienischer oder altdeutscher Malerei mit Gouache auf leichtsaugende, glatte Gipsgründe auf Mahagonitafeln gemalt; mit Schellack und Spiritus gefirnisst, um alles überschüssige Oel auszuschliessen, und mit Oelfarbe und Bernsteinlack deckend oder lasierend vollendet. Die geheimnisvolle Wirkung der Alten und ihr schrittweises, reifes Vorgehen das auch Böcklin's Technik charakterisiert, lag mir dabei im Sinn*.' The locations of the paintings remain unknown.
9. '*ein besonders starkes Segeltuch*' der Firma George in Berlin, '*die mir von damals ab mein Leben lang alle meine Leinwände gewebt hat.*'
10. '*Deckenbild. Wurm Tempera (Terpentin &* [Mal] *Mittel) auf blos Kreide & Leim. leidliches Material.*' The Richard Wurm company in Munich had been producing *Wurmsche Temperafarben* (Wurm Tempera Paints) and painting vehicles for tempera paints since 1877 (Reinkowski-Häfner 2014: 376; Pohlmann *et al*. 2016: 164–5).
11. '*Ich bin mit den Farben sehr zufrieden.*'
12. '*Pereiratempera & Harz … auf glattes Leinen,* [mit] *Kreidegrund.*' Pereira's tempera was produced by the Stuttgart-based company J.G. Müller & Co. between 1891 and 1908. Perhaps the 'resin' mentioned here also refers to 'tempera resin vehicles' (gum arabic) produced by the company (Reinkowski-Häfner 2014: 366; Beltinger 2016).
13. '*Wie immer bei grossen Formaten suchte ich Temperauntermalung zur Vollendung der Form. Allerhand neue Mittel wurden versucht – matte „Mussini" farbe, „Renaissance" von Fleischer etc. - bis die früher erprobte Oeltempera von Wurm auf Halbkreidegrund sich wieder bewährte. Mit Wurm's seifigen Wassermalmittel, oder mit Manganöl und Terpentin wird am besten pastos untermalt – immer aus dem Hellen heraus, da das Material leicht dunkelt; dafür behält es gefirnisst unverändert Ton und Kraft.*' Dr. Fr. Schoenfeld & Co., based in Düsseldorf, produced *Professor Philipp Fleischer's Meisterfarben der Renaissance* in two varieties with five different vehicles (Reinkowski-Häfner 2014: 371; Pohlmann *et al*. 2016: 160–61).
14. '*Die Farbe sitzt immer, sie lasiert, deckt, schlägt nie ein – kurz völlig dem Material der alten Meister ähnlich; für Mattmalerei aber nicht zu empfehlen.*'
15. Fritz Gerhardt's *Kaseinfarben* were distributed in Düsseldorf from 1888 by the Schoenfeld paint company (Reinkowski-Häfner 2014: 363; Pohlmann *et al*. 2016: 160–61).
16. This presumably means salicylic acid, which is used as a conservation agent for its antimicrobial properties.
17. '*Ich behandle Wandbilder – wie die vorliegenden in Danzig – dann ganz wie Fresken insofern ich das zu bemalende Stück von rückwärts nass halte.*'
18. '*die Malerei wird flüssiger, und wird vor allem durch den erweichten Grund nochmals gebunden.*'
19. '*Herz & Co Casein ganz ungünstig, zu wässrig... Syntonos zuviel Glycerin, leuchtet wenig, glänzt leicht. Neisch entwickelt sich, & giebt später die einzig guten Casein & Temperafarben.*' Casein and casein paints featured among the products of the Berlin-based company Herz & Co. (Reinkowski-Häfner 2014: 365; Pohlmann *et al*. 2016: 152–3). Syntonos paints were made from 1893 by L. Auerbach & Comp. in Fürth (Reinkowski-Häfner 2014: 373; Pohlmann *et al*. 2016: 164–5) and Neisch & Co. in Dresden produced various tempera paints for artists (Reinkowski-Häfner 2014: 366; Pohlmann *et al*. 2016: 154–5).
20. '*Gerhard in Düsseldorf… versetzte sie mit Marmormehl; der Name „Kasein-Marmorfarben" hatte schon an sich monumentalen Reiz – sonst aber keinen Nutzen. Ich habe mit dem regsamen alten Praktiker …, vielerlei Neues versucht und gefunden, um zuletzt dennoch von ihm abzukommen, und das reinere Material von Neisch& Co. in Dresden zu verwenden.*'
21. '*Casein & Farbe gestrichen & mehrmals mit Neischcasein getränkt.*'
22. '*Der Gips der Rabitzwand blättert beim Malen in kleinen Punkten ab; sehr schlecht!*'
23. Neisch & Co. in Dresden produced tempera for decoration, egg tempera, liquid tempera and tempera paints for studies, artists' tempera paints with egg, oil or casein, and the Saxonia oil tempera (Reinkowski-Häfner 2014: 366; Pohlmann *et al.* 2016: 154–5).
24. '*es sieht ebenso wie Fresko aus, aber es ist nicht so fest wie alles übrige, und muß beim Reinigen später geschont werden.*'

25. *'Versuch mit Neischtempera, auf den Helferlinggrund von Neisch, und Ei, Zinkweiss Schlemmkreide & Leinölfirniss. Der Grund steht; beim hinten Netzen wird er gleichwohl weicher; vorn gut zu netzen. Farbe behandelt sich gut; bleibt fast ganz unverändert.'*
26. 'GRUND NIM[M]T UNGERN A[N]/ UND LÄUFT/ HELFERLING/ KREIDE-EI/ LEINÖLFIRNI[S].'
27. 'GRUND. CASEIN-ZINKWEISS [HELFERLING] NEISCH/ CASEINFARBEN NEISCH/ SEHR GUT, AUCH AUFS TROCKNE/ HELLT WENIG NACH/ SEHR FEST.'
28. 'NEISCH TEMPERA/ HELFERLINGGRUND/ NÄSST V. RÜCKSEITE.'
29. *'der große Carton zum Deckenbild von 2 Schülern, Schlösser und Harnisch auf die Leinwand übertragen und untertuscht.'*
30. *'Antuschen aufs Trockne mit Umbra, Terra di Siena, Ultramarin – wie man braucht. Endlich Antuschen in farbigen Localmassen, ohne auf Wirkung zu sehen, bis nirgends mehr reine Leinwand steht und das Bild im Ganzen dasteht.'*
31. *'Ich liess sie stückweise, von rückwärts, mit der Spritze und grossem Schwamm benetzen, bis zu völliger Nässe. Das nasse Stück sieht erheblich dunkler aus. Die Haupttöne, wie beim Fresco, in Glasnäpfen steif gemischt, um immer die Scala zu behalten. Im übrigen aber pastos und prima, genau wie beim Oelmalen, das Stück bis zum Abend völlig vollenden.'*
32. *'Zum 2ten mal benetzen hat immer Bedenken: es macht Ränder und trocknet dunkler. Deshalb folgt das letzte Uebergehen und Zusammenstimmen auf trockenem Grund, pastos und lasirend.'*
33. *'Zu beachten ist, dass auf der Leinwand herablaufende Tropfen hässliche dunklere Wasserstreifen hinterlassen; der benetzende Diener muss aufmerksam sein und sie abfangen – indessen lassen sie sich später auch durch verlaufendes Waschen auf der Rückseite noch beseitigen.'*
34. *'Neisch's Casein, das besser ist & farbreicher als Gerhards.'*
35. *'die mehrfach mit Oelfarbe gestrichene Mörteldecke mit dem Gerhardkleister.'*
36. *'Ich verfolgte damals alle malerischen Mittel, namentlich jede Tempera, deren Kenntnis die emporstrebende Zeit nach allen Seiten hin entwickelte, bis in ihre alten Quellen und ihre neuesten Finessen, und sehe noch heute mit Interesse Versuche und Aufzeichnungen durch, die spätere Zeiten mit Mühe wiedererwerben werden.'*

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Author's address

Silke Beisiegel, Staatliche Kunstsammlungen Dresden, Gemäldegalerie Alte Meister/Galerie Neue Meister, Dresden, Germany (silke.beisiegel@skd.museum)

‘If there is no struggle there is no victory’: Christiana Herringham and the British tempera revival

Michaela Jones

ABSTRACT Christiana Herringham was a leading figure in the tempera revival that took place in Britain at the turn of the 20th century. She corrected John Ruskin’s erroneous belief that early Italian paintings were produced mainly in oil and opened his eyes to the medium. In 1899, she published the second English translation of Cennino Cennini’s *Il libro dell’arte*, complete with notes concerning her own artistic experiments. She used Cennini’s treatise to produce paintings in tempera, and in 1901 she co-founded the Society of Painters in Tempera. Despite Herringham’s significance, she has largely been overlooked in the history of the movement and her works have received little examination from scholars. This paper addresses this gap in the historiography by using Herringham’s works as a case study to examine the British tempera revival in its historical and cultural context. It discusses the impact of Herringham’s translation, her role within the movement, and examines the results of analysis recently undertaken on two of her paintings. These investigations reveal that while Herringham was faithful to Cennini’s advice and employed traditional techniques, she also embraced more modern methods.

Introduction

Christiana Herringham (1852–1929) played a leading role in the British tempera revival at the turn of the 20th century. In 1899, she published the second English translation of Cennino Cennini’s *Il libro dell’arte*, and in 1901, co-founded the Society of Painters in Tempera. According to Roger Fry, it was Herringham who opened John Ruskin’s eyes to the medium. When Ruskin encountered Herringham copying paintings in the National Gallery in London he questioned her choice of medium. She responded by pointing out that many of the early paintings Ruskin so admired were in fact painted in tempera rather than oil (Fry 1905: 175). In addition to her extensive knowledge of the medium, Herringham was a skilled tempera artist and many of her works are now in the collections at Royal Holloway, University of London.

Yet, despite these achievements, Herringham has remained something of a shadowy figure in the history of the movement. This is perhaps partly because the majority of her works in tempera were copies rather than originals, as well as the fact that her career came to an end in 1911 when she was committed to a mental asylum. This paper attempts to return Herringham to the art-historical narrative by discussing her translation of Cennini’s treatise and its impact on the revival. Additionally, Herringham’s copies are examined in detail to gain a greater understanding of her motivations, and to establish how far her technique corresponded to the ancient methods which she so admired.

Herringham's translation of *Il libro dell'arte*

Herringham was the eldest of nine children. Her father, Thomas Wilde Powell, was a stockbroker as well as a patron of the Arts and Crafts movement and his interests undoubtedly had a significant impact on Herringham's artistic outlook. In the 1870s, she studied at the Female School of Art in London and was an early student of the Slade School of Fine Art. Her own writings suggest that she also began experimenting with tempera in the 1870s, possibly when she was a student (Herringham 1903: 3), yet the earliest record of Herringham exhibiting in tempera is in the 'Woman's Work' section of the *Victorian Era* exhibition, held at Earl's Court in 1897. In the 1880s, her artistic career was put on hold following her marriage and the birth of her two sons. It seems that after the death of her eldest son in 1893, she threw herself into her work as a distraction from her grief.

Herringham first began working in tempera after becoming frustrated that she was unable to replicate the 'lustre', 'purity' and 'bloom of colour' of early Renaissance paintings when making copies in watercolour (Herringham 1903: 3). She began her experiments after coming across the first English translation of Cennini by Mary Philadelphia Merrifield, which was published in 1844. However, she found that Merrifield's translation was often incorrect, which she speculated was due to the latter's lack of practical knowledge on the subject (Cennini 1899: v). By contrast, Herringham claimed that she had used the treatise to teach herself how to paint in tempera. Moreover, she had read everything she could find that touched on the subject, and therefore felt she was in a good position to create a greatly improved new translation (Cennini 1899: vi). Herringham used Merrifield's translation as a starting point, amending the mistakes and writing her corrections directly onto her copy of the Merrifield text,[1] probably to allow her own translation to imitate Merrifield's style, which she believed was 'pleasant'. It meant that in her own translation she intentionally kept as close as she could to the words to which she had grown accustomed before knowing the Italian (Cennini 1899: v). She additionally employed several other different editions to create her translation: the 1859 Italian edition by Gaetano and Carlo Milanese, which included several passages that had not been published in previous editions, and the 1871 German translation by Albert Ilg to aid with translating more challenging passages. She also owned the 1858 French translation by Victor Mottez.

Herringham's translation was incredibly successful: it was published in New York as well as London and was reprinted several times until it was superseded by the publication of Daniel V. Thompson's edition in 1933. The artist Walter Sickert was one of Herringham's greatest admirers, stating that she was a woman of such 'genius' that he considered her to be practically a man (Sickert 1912 [2003]: 324). Upon reading her translation he declared that she was 'the greatest living critic', believing that the book was 'The most important piece of art-criticism that has appeared in Europe in modern times.' He claimed that it was its 'endearing modesty, the conscious force, the sense of humour implied in things unsaid, in conclusions undrawn' that made Herringham's translation 'the most powerful and most respectable … the most virile and gracious piece of literature I have met on the subject of painting' (Sickert 1910 [2003]: 200).

The significance of Herringham's publication was not only the translation itself, but also the inclusion of her notes concerning her own attempts in tempera. In recording her experiments, Herringham was able to provide feedback on the practicality and applicability of Cennini's advice. Her publication went a step further than earlier translations as it offered contemporary artists useful and helpful information as to how they could realistically apply the methods of the past to their own artistic practice. According to Jill Dunkerton, the publication of Merrifield's translation had little immediate impact on painters and theorists in Britain, and that even the Pre-Raphaelite Brotherhood did not fully consider the possibilities of tempera and fresco (Dunkerton 1980: 18). Yet Herringham's translation was instrumental in stimulating the British tempera revival at the turn of the century and found a ready audience of artists who were increasingly concerned about the longevity of oil and the quality of commercially produced materials. Herringham, in common with a growing number of artists, emphasized the importance of knowing the exact content of their materials, to both ensure their purity and guarantee that their work would last for centuries 'as pure and fresh and luminous as the day it was first laid on' (Herringham 1905: 6).

The Society of Painters in Tempera

Many of the artists involved in the British tempera revival, including Joseph Southall, Walter Crane and Maxwell Armfield, were influenced by the writings of figures such as John Ruskin and William Morris. Ruskin was also a significant influence on Herringham's work and she owned several of his books. Ruskin believed that while technology and machines may allow workers to achieve preciseness and perfection, as a consequence, 'soul and sight [are] worn away, and the whole human being [is] lost at last' (Ruskin 1853: 161). Like Ruskin and Morris, these artists strongly believed in the moral dimension of art and were concerned that industrialization had led to the decline of both craftsmanship and society. Tempera artists criticized oil painting's 'convenience', with Herringham claiming that it 'too readily lends itself to false finish and smugness' (Herringham 1905: 8). According to the writer and critic Alice Meynell, Marianne Stokes came to believe that oil painting was 'too tolerant of handling and re-handling', and that the adoption of oil painting had 'separated the art of Europe from simplicity' (Meynell 1901: 243). Tempera, by contrast, claimed Stokes, was 'a medium which lends itself most to spirituality, sincerity, and purity of colour' (Vallance 1901: 164). These artists considered it essential to be involved in every step of the artistic process – from preparing the panel to gilding the frame – to ensure the quality of their work. Southall sometimes even dug up his own pigments to ensure their purity, and kept chickens to guarantee a steady supply of eggs (Breeze 1984: 66). These artists believed that tempera's challenges ensured its superiority. As Herringham commented, 'But without difficulty there would not be achievement; if there is no struggle there is no victory; and the triumph of a technique lies in the elaboration of its possibilities and the conquest of its difficulties' (Herringham 1905: 8).

While some artists, including Southall and Stokes, were working in tempera in the 1880s and 90s, the publication of Herringham's translation in 1899 introduced the medium to a widening audience who were seeking to expand beyond the boundaries of oil and watercolour. Herringham's translation and writings on tempera were read and used as a practical guide by numerous artists, including Walter Crane and G.F. Watts.[2] Furthermore, while Stokes had already begun to exhibit paintings in tempera by the early 1890s, including *The Princess and the Enchanted Prince*[3] in 1892, it was not until she read Herringham's translation that she was able to break away from oil (Evans 2009: 79). Fry credited the publication of Herringham's edition with the 'diffusion of practical knowledge' of tempera painting, and indeed, D.S. MacColl later recounted that it was due to Herringham's influence that Fry experimented with the medium (Fry 1905: 175; MacColl 1934: 232). In 1901, several of these like-minded artists came together and held an exhibition of their work at Leighton House in London. Shortly after the exhibition's opening, Herringham co-founded the Society of Painters in Tempera. The organization was designed as a space where artists could share their knowledge and exchange ideas, and hold official exhibitions of their work in London, including at the Carfax Gallery in 1905 and the Baillie Gallery in 1909.

The works included in these exhibitions reveal how many of these artists, including Southall, Arthur Gaskin and John Dickson Batten, sought, like the Pre-Raphaelites before them, to depict a sentimental view of the medieval past. Several of their paintings were inspired by folktales and literature. Herringham, meanwhile, attempted to represent the past through her copies of early Renaissance paintings. At the 1901 exhibition, Herringham exhibited two detail copies taken from *Madonna and Child with Six Saints*, also known as the *Sant'Ambrogio Altarpiece*, by Sandro Botticelli (*c.*1470, Florence, Galleria degli Uffizi). She chose to focus on the two female saints on the edges of the painting: *Head of the Magdalene* and *Head of Saint Catherine* (Figs 1 and 2). In the original altarpiece, the Magdalene is holding a jar of ointment, which she used to anoint the feet of Jesus, while Saint Catherine's hand is on a wheel, a symbol of her martyrdom. However, by focusing solely on the faces of these saints, Herringham has omitted these symbols. She chose to isolate these figures from their wider context, and in doing so, transformed a large altarpiece into individual religious icons. As argued by Hannah Spooner, the painting has been reconstructed into 'saintly character studies … We are invited to contemplate at close range the physical appearance of the pure in heart' (Spooner 2003: 52). With these and her other copies, Herringham created new translations of old paintings. They demonstrate how, as her friend William Rothenstein explained: 'She was no mechanical copyist, but an interpreter' (Rothenstein

Figure 1 Christiana Herringham, *Head of the Magdalene* (after Botticelli), exh. 1897, tempera on panel. (Photo: Royal Holloway, University of London.)

Figure 2 Christiana Herringham, *Head of Saint Catherine* (after Botticelli), exh. 1897, tempera on panel. (Photo: Royal Holloway, University of London.)

1935). Herringham's copies enabled her to further her own understanding of tempera, demonstrate the beauty of the medium, and reinterpret old paintings for a modern audience.

Herringham's artistic practice

Two of Herringham's copies from the collections at Royal Holloway have recently undergone conservation and analysis to obtain a greater insight into how she interpreted Cennini's treatise and approached her own work.[4] It revealed that Herringham employed a combination of both traditional and more modern techniques in her work. The first painting to be analysed was her copy of Gherardo di Giovanni's *The Combat of Love and Chastity*, which she exhibited at both the 1901 and 1905 tempera exhibitions (Fig. 3). The original dates from the late 15th century and was acquired by the National Gallery in London in 1885, where Herringham would have made her copy. Her work was in a poor condition: there were several areas of paint loss and flaking, which were especially obvious on the dress and face of Chastity. These flakes were being held in place by the thick varnish which lay on top of the painting. There were also numerous other small areas of old paint losses that had been retouched; these lay underneath the varnish layer and did not exhibit a notably different fluorescence to the original paint. However, the quality of the retouched areas was questionable, and therefore it is unclear whether it was Herringham who made these alterations.

The other painting analysed was Herringham's copy of Cosmè Tura's *Madonna and Child* (Fig. 4). The original dates from the mid-15th century and is also known as *The Madonna of the Zodiac*, as the Virgin is surrounded by the symbols of the zodiac, alluding

Figure 3 Christiana Herringham, *The Combat of Love and Chastity* (after Gherardo di Giovanni), exh. 1901, tempera on panel: before conservation. (Photo: Royal Holloway, University of London.)

Figure 4 Christiana Herringham, *Madonna and Child* (after Cosmè Tura), *c.*1896–1908, tempera on panel: before conservation. (Photo: Royal Holloway, University of London.)

to her epithet as the Queen of Heaven. Herringham most probably painted this copy after 1896, when the original was acquired from a private collection by the Italian government for the Accademia in Venice. She displayed this work at an exhibition held at the Whitechapel Gallery in London in the spring of 1908, therefore dating her copy to these intervening years. The panel for this copy was formed of two pieces of wood. When the painting was removed from its frame for conservation it was discovered that the two pieces had completely separated and were only being held together by the frame. Yet, despite the splitting of the panel, overall this work was in a reasonable condition. Unlike *The Combat of Love and Chastity*, it was not varnished, but rather covered with a wax coating, evidence of Herringham's experiments with a variety of techniques.

Herringham probably prepared the panels for her paintings herself, as she noted that egg tempera 'will not adhere to any ground which has oil in it, so the ordinary colourmen's canvasses and panels are useless' (Herringham 1903: 6). In the preparatory layers of the panels of both analysed works, she faithfully copied Quattrocento methods. In the case of her copy of Tura's *Madonna and Child*, a woven material was applied to the wood, followed by gesso. Analysis suggests that Herringham applied *gesso grosso* and *gesso sottile* in sequential layers, as described by Cennini. Fourier transform infrared (FTIR) spectroscopy identified the primary component of the ground as gypsum, with traces of an unidentified protein which, if Herringham was following the teachings of Cennini, is probably animal size. These results coincide with her notes on her experiments, which she both included in her translation of Cennini and in a pamphlet, published in 1903, entitled *How to Paint Tempera Pictures*. In these texts, she describes priming her panels with plaster of Paris mixed with size, which she made by boiling parchment shavings (Cennini 1899: 234; Herringham 1903: 3).

Gas chromatography-mass spectrometry (GC-MS) analysis has established that the primary binding medium in both paintings was egg, therefore definitively confirming Herringham's use of tempera.

Analysis of the paintings' pigments revealed that she used traditional pigments, such as lead white, yellow ochre and red-brown paints composed primarily of natural earth pigments. However, it also confirmed that she employed colours that were not available until the 19th century, such as zinc white and viridian. These findings are perhaps not surprising as the notes to her translation state that it would be 'antiquarianism' to only use materials that were available in the 15th century. She acknowledged that traditional colours were not always preferable, and advised that artists 'should reject for some purposes pigments which [Cennini] employed, having now better ones' (Cennini 1899: 244). Herringham's open-mindedness and her willingness to experiment with materials demonstrates that she was an artist who was keen to look towards the future as well as the past.

The results also demonstrate that Herringham took the idea of craftsmanship seriously; she prepared her own panels and probably mixed at least some of her own paints. This is a reflection on how the revival of tempera emerged from the Arts and Crafts movement, with this generation of artists hoping once again to bring fine arts and craftsmanship together. The exhibitions held by the Society of Painters in Tempera included not only tempera paintings, but also modern illuminations, book bindings, gilded boxes and mirrors. Furthermore, the artists and craft workers involved with the Society often collaborated on the paintings' frames. This emphasis on craftsmanship and collaboration is evidenced in Herringham's copy of *Madonna and Child*.

Herringham presented her work in an almost exact replica of the original, intricately carved frame, which she probably designed herself. It is possible that the gilding for the frame was completed by Mary Batten. In 1905, Herringham exhibited a copy of Botticelli's *Calumny*[5] in a frame that she designed herself and which was gilded by Batten. Southall regularly designed and carved his frames, and employed his wife, Anna Elizabeth ('Bessie'), to carry out the gilding. He also occasionally collaborated with other craft workers. The exhibition held by the Society of Painters in Tempera in 1905 included his painting *The Rose Bowl* (1905, private collection) in a frame gilded by May Morris and Winifred Boielle (Society of Painters in Tempera 1905: 13). Herringham advised that artists should avoid modern gilders, who aim for 'machine-like perfection'. Instead, she recommended that 'it is better deliberately to aim at a certain ruggedness and want of finish' (Cennini 1899: 240). By designing and gilding their own frames these artists were ensuring the quality and integrity of their work.

Conclusion

In designing and gilding their own frames, as well as preparing their own panels and mixing their own paints, the artists of the British tempera revival brought together the ideas of art and craftsmanship. Herringham and other artists involved with the revival were motivated by the belief that art, as Southall stated, 'is a language of the soul' (Homan 2000: 73). They believed that art has a higher, almost spiritual purpose, and therefore artists should pursue suitably pure methods and mediums in order to create truly 'pure' art.

Herringham's translation served as an inspiration to this new generation of tempera artists, keen to ensure both the quality and the longevity of their work. Her translation and accompanying notes provided contemporary artists with practical advice on how to apply historical art methods to modern art. Fry's assertion that Herringham was responsible for the spread of practical knowledge of tempera was demonstrated by the small, yet significant, group of artists, craftsmen and women, who used her translation as a manual for their own work, and further evidenced by the fact that her translation continues to be cited in the work of academics up to the present day. While her copies in tempera had less of a lasting impact on the movement, they provide a significant insight into the working practices of tempera artists at the turn of the 20th century. They demonstrate how Herringham was flexible, open-minded and experimental in her technique. She was an artist willing to both employ the expertise of the past, as well as look towards to the future.

Notes

1. Over 300 books from Herringham's private collection survive in the collections at Royal Holloway, University of London.
2. Crane named Herringham's translation one of his favourite books of the year in 1900 (*The Academy*,

8 December 1900, p. 578) and Watts kept a copy of her 1903 pamphlet in his studio (Dudkiewicz and Willoughby 2010: 107).
3. Current whereabouts unknown.
4. Conservation undertaken by Harriet Pearson and analysis by Hannah Tempest.
5. Current whereabouts unknown.

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Author's address

Michaela Jones, Royal Holloway, University of London, Egham, UK (michaela.jones.2010@live.rhul.ac.uk)

Joseph Southall and the tempera revival

George Breeze

ABSTRACT Joseph Southall was an artist who held a very rounded view as to what an artist should be. This paper concentrates on his painting in egg tempera, following his trials and tribulations and eventual success in learning and using the medium. It discusses why he admired the medium and his desire to promote it. Finally, in considering his importance, it is suggested that he became the leading tempera painter in Britain, but was perhaps most admired in Paris.

Introduction

Joseph Southall (1861–1944) was a totally committed Quaker whose political views were what he called socialism in the tradition of William Morris. Quakers hold pacificism as a core part of their Christian belief, but Southall was an absolute pacifist who did not tolerate war under any circumstances. During the First World War he was fully committed to opposing it through pamphlets, cartoons and speeches, with little time left for painting. Rather than discussing these key facets of his life and his major interest in, and keen promotion of, *buon fresco* painting (Fig. 1), this paper concentrates on that key characteristic

Figure 1 Joseph Southall, *Corporation Street, Birmingham, in March 1914*, 1916, *buon fresco*, 279 × 163 cm, on the wall of the main staircase of Birmingham Museum & Art Gallery.

Figure 2 Joseph Southall, *Self-portrait*, 1884, watercolour in an ivory locket, always carried by the artist's wife, Birmingham Museum & Art Gallery.

Figure 3 Joseph Southall, *The Coral Necklace*, 1894–95, egg tempera on wood panel, 29.5 × 22.1 cm (private collection).

of his life: his devotion to the art of painting in egg tempera. All things considered, it could be said that Southall brought together the gathered stillness of a Quaker Meeting, the peace sought by pacificism and the jewelled calm of tempera painting.

Early years

Southall was born in 1861 in Nottingham, but moved with his mother to Birmingham on the death of his father the following year, spending the rest of his life in what was, and is still, regarded as England's second city. The painter and writer on art, Sir William Rothenstein, observed that Southall's loyalty to Birmingham was rare, as few artists have resisted the lure of London. However, like Norwich, Birmingham had a rooted local school of painting (Rothenstein 1934).[1]

Trained as an architect, Southall maintained his interest in architecture throughout his life. This is evident both in his paintings and their frames, which he frequently designed and sometimes carved himself. His fiancée and future wife, Anna Elizabeth Baker (known as Bessie) would often gild his frames and prepare the supports for his paintings with their gesso ground. We know this because she kept a record of the time taken and materials used so she could invoice Joseph for these expenses. They had been in love from an early age, and she remained a key figure throughout his life. But, being first cousins, they decided not to get married until 1903 when she became 44 and had passed what was then considered child-bearing age.

To Southall, being an architect did not mean sitting at a desk drawing up plans and elevations, but someone who was a craftsman and could paint frescoes, as well as panels and canvases, and carve. Thus on his 21st birthday, in August 1882, he abandoned his narrow architectural apprenticeship to branch out into what he regarded as the wider world of the architect (Fig. 2).

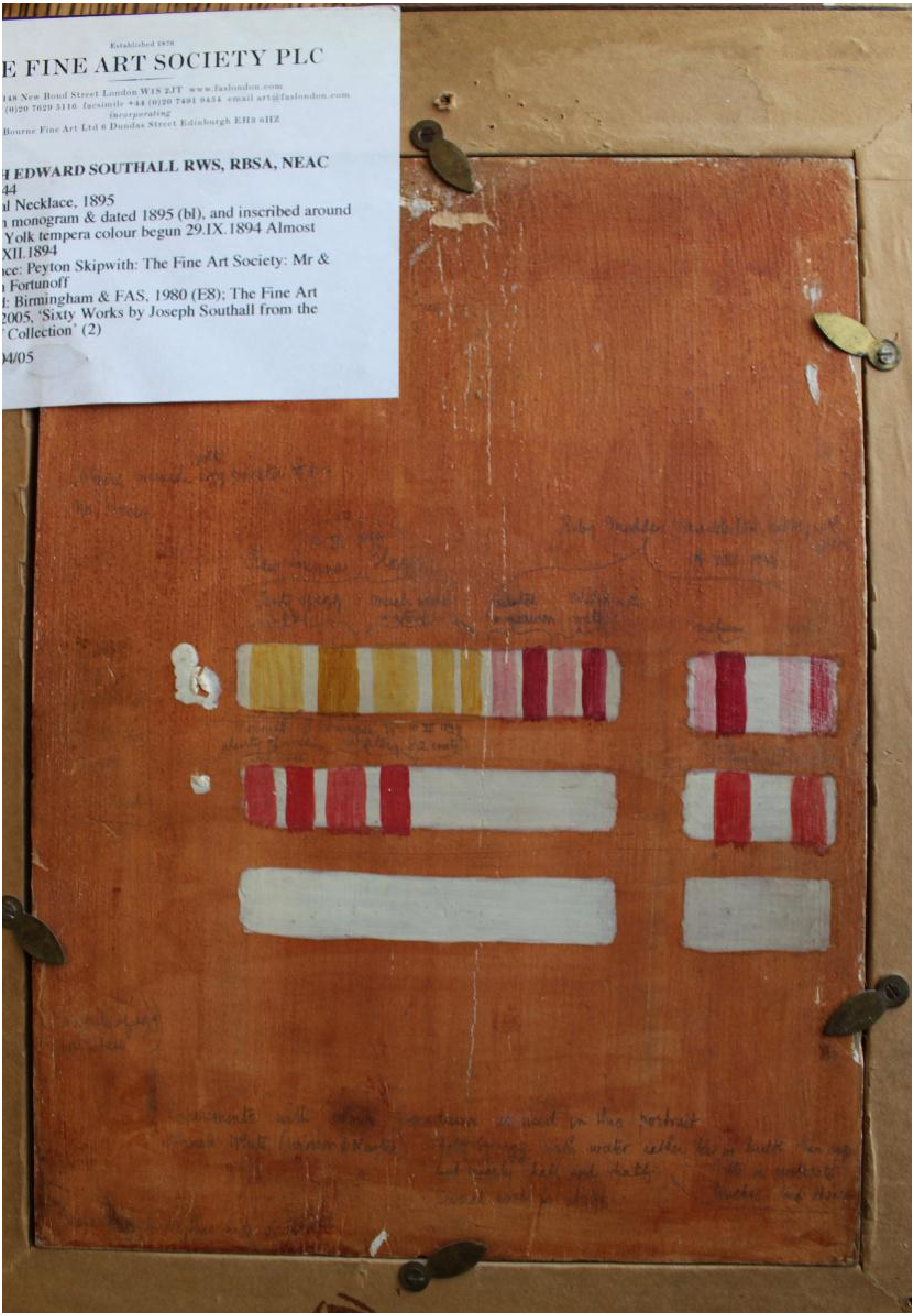

Figure 4 Joseph Southall, *The Coral Necklace*: reverse.

Table 1 Deciphered handwriting on the reverse of *The Coral Necklace*.

Text at upper left: *colours mixed egg (yolk) & water 1/3 and ½ / No Honey*

Upper horizontal band of samples

over all the yellows
10.XII.1894
Raw Sienna Glazes

over the left two samples	over the next three samples
[P..nty?] of egg ½ & ½	*much more water*

over all the reds
Ruby Madder [..?adderton] paste; with yolk(?) / 14.XII.1894

over the two left samples	over the next two samples	in next band to the right	
diluted with medium	*diluted with water*	left two samples	right two
		medium	*water*

Middle horizontal band of samples

over the left block		over the right block
vermil[ion] & *Chinese w*[hite] *10.XII.1894*		*pr[.?.] 18.XII.94*
below that		*medium*
two left bands	next two bands	
plenty of medium	*watery & 2 coats*	
one coat		

Text to the left of these two bands is indecipherable

(Lower horizontal band is blank)

Text to the lower left back of the panel: [..?..] *white of egg / in [..?..]*

Text above the bottom of the panel: *Experiments with colour & medium as used in this portrait / Chinese White (Winsor & Newton) Yolk of egg with water rather less in bulk than egg / but* nearly *half and half. / Several coats* [used] *in strips.*
At right: *Ditto in impasto / touches laid [..?..]*

Text at the very bottom of the panel: *Gesso [..?..] under this side of panel*

Interest in tempera

In early 1883 Southall made an eight-week visit to Pisa, Florence, Siena, Orvieto, Rome, Bologna, Padua, Venice and Milan and, as a result, he decided to study the particular art of painting in tempera. As a schoolboy he had been taught watercolour painting by Edwin Moore, brother of the artists Albert and Henry Moore. The Benozzo Gozzoli frescoes in the Campo Santo at Pisa greatly impressed him: 'entering into my deepest depths', and 'formulated a vision of the Earthly Paradise never to be effaced'.[2] He had become a keen admirer of what he called the Italian Primitives, those painting in tempera before the advent of oil painting. Specifically, it was the sight of Carpaccio's paintings in San Giorgio degli Schiavoni in Venice that sparked this interest, combined with the statement in John Ruskin's *St. Mark's Rest*, published six years earlier, that they were painted in tempera: 'And … I am disposed to think

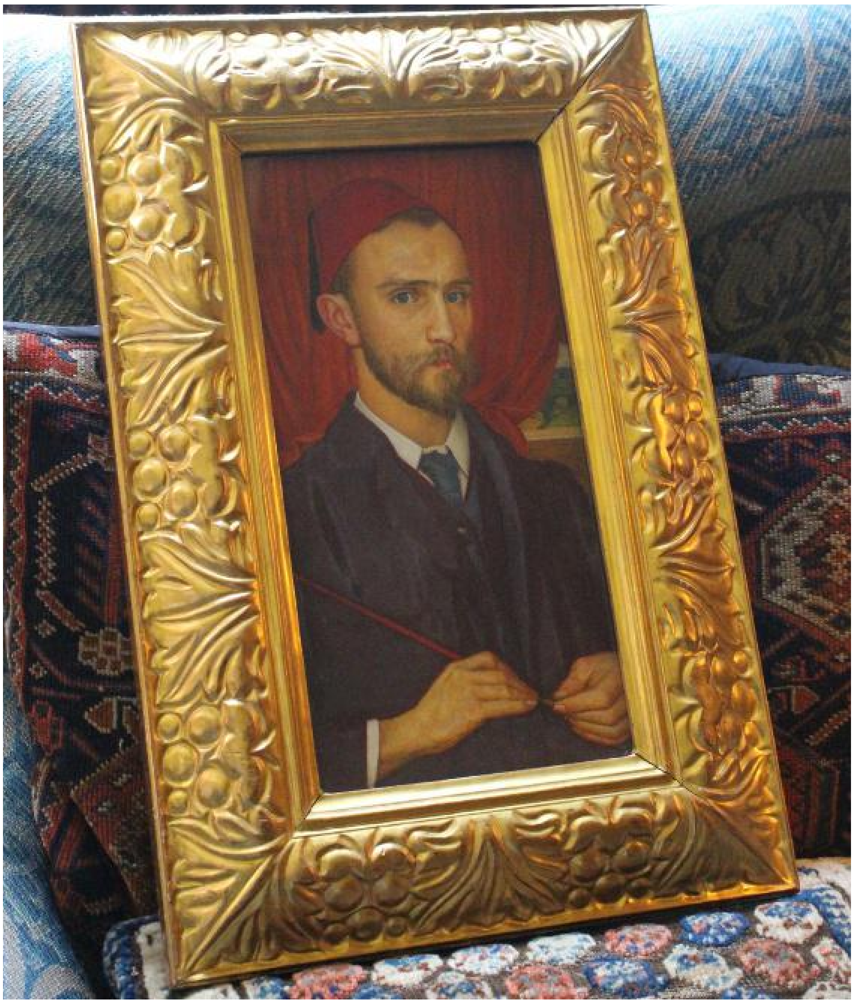

Figure 5 Joseph Southall, *Man with a Sable Brush*, 1896, egg tempera on wood panel, 42 × 20 cm (sight size) (private collection).

that ultimately tempera will be found the proper material for the greater number of most delightful subjects' (Cook and Wedderburn 1877 [1906]: 364).[3]

Trials and tribulations

Apart from observation, Southall's only guide was Charles Eastlake's *Materials for a History of Oil-Painting*, first published in 1847. Eastlake's most sustained study of the tempera medium takes up some 11 pages but there are other references throughout this wide-ranging study. Most are comparisons with oil or advice, such as the addition of honey to egg yolk to slow down the process of the paint drying.

In 1884 Southall met the artist William Blake Richmond when, as president of the Birmingham School of Art, he gave out prizes to students. Southall was among those to receive special mention, but it was not until 1891 that sustained help was offered by Richmond at his London home, where Southall learnt about 'glazing and super posing of colours'.[4] In the intervening years, between 1884 and 1891, Southall made a second visit to Italy in 1885 and to Venice in 1890, being particularly enchanted by Veronese, Titian and Tintoretto, all of whom painted in oil. This may have had a bearing on his decision to abandon tempera due to the difficulties of the medium and turn to oil painting at this time. However, he did not find oils much easier. Sometime after reading Eastlake's book, Southall came across Mrs Merrifield's 1844 translation of Cennino Cennini's *Il libro dell'arte* and it was this, combined with his visits to Italy and the National Gallery in London, that enabled him to develop his tempera method (Merrifield 1844).

In early 1893 Southall went to see Edward Burne-Jones, a fellow Birmingham artist, in the first of a series of visits up to the latter's death in June 1898.

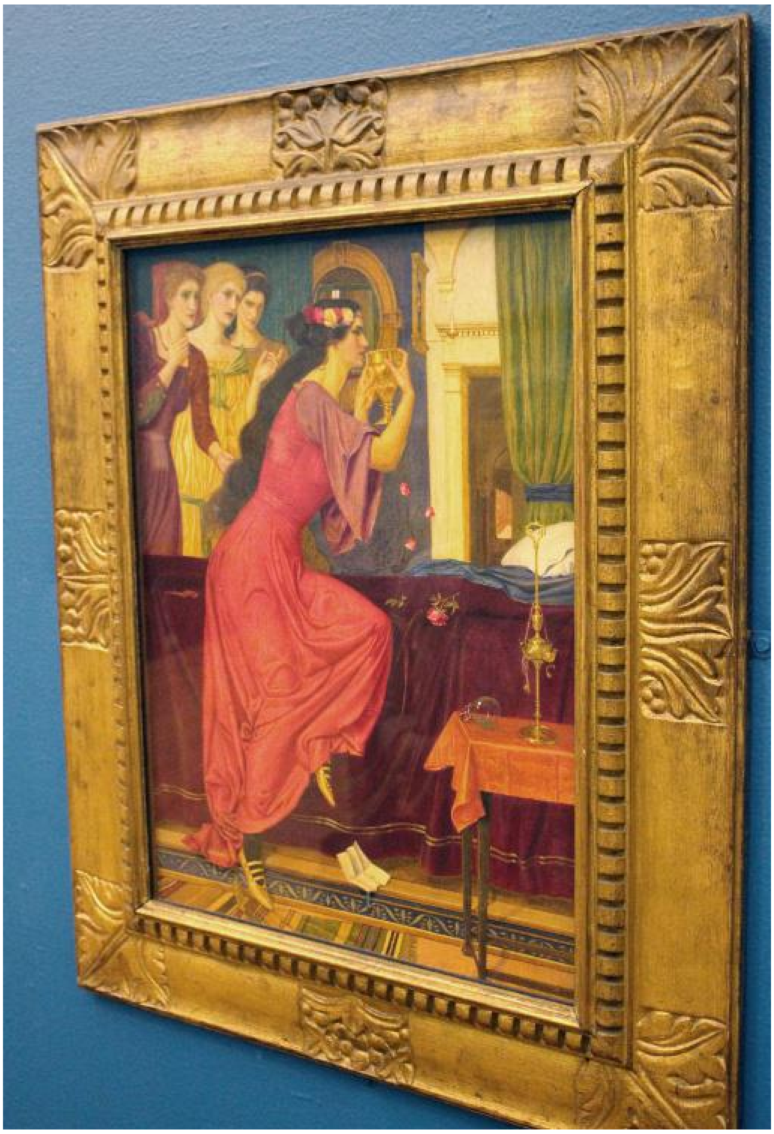

Figure 6 Joseph Southall, *Gismonda* or *Sigismonda Drinking the Poison*, 1896–97, egg tempera on linen, 58.5 × 43 cm, Birmingham Museum & Art Gallery.

Burne-Jones particularly encouraged Southall's use of colour, and his settling of the composition and detail before embarking on the actual painting. According to Southall, he himself had never used tempera, but that both he and Holman Hunt 'expressed their pleasure at the revival of it and their belief in its value'.[5] However, Burne-Jones had a recipe for it, which suggests that he could talk intelligently to Southall about the medium. As far as I am aware the recipe is not to be found in any biography but it does appear in a typescript originally written by Burne-Jones' assistant T.M. Rooke (Rooke 1890–99). It is described as part of a visit by a Miss Boddington to Burne-Jones' studio in July 1897.[6]

Success

Having abandoned the tempera medium since 1889, Southall took it up again with three works. The first, *The Coral Necklace,* a portrait of his future wife painted in egg tempera on wood panel (Fig. 3), is inscribed around the edge 'Yolk Tempera colour begun 29.IX.1894. Almost finished XII.1894'. The text on the back has not previously been made available, although a small photograph has been published (Fig. 4).[7] I have deciphered Southall's handwriting on the back of the panel in Table 1.

The second work was a self-portrait, *Man with a Sable Brush*, in egg tempera on wood panel (Fig. 5).

Figure 7 Joseph Southall, *The Agate*, 1911, egg tempera on linen, 100.3 × 50.3 cm, National Portrait Gallery, London. (Photo: courtesy of Liss Llewellyn Fine Art.)

Begun in autumn 1896, in his notebook the artist recorded that it was 'a trial trip in the egg medium [which I now] seemed to master … and greatly like its rich qualities so that from that time I adopted it as my own' (Southall 1898).[8] The third work, *Gismonda*, in egg tempera on linen (Fig. 6), was begun in December 1896, although preparatory drawings had been made that September. It was finally finished in Burne-Jones' studio in 1898. The latter praised the work, stating that 'in colour and tone [Southall] had nothing to learn!' (Southall 1898).[9]

At last Southall seemed have mastered the tempera medium – at the age of 35 in 1896 he had begun to fear that he might be a failure. But three years later, on a visit to the National Gallery and sitting in front of works by the Tuscan School and Taddeo Gaddi (the father of Cennini's painting master Agnolo Gaddi), he noted in a sketchbook:

> I sit here lost in delight and amazement: What colour! What dignity of life! What ornament! What design! Wonderful here in bustling London. How much more so in the great Churches and palaces of celestial Italy. How much of all this can we ever recover I wonder.[10]

Technique, pigments and medium

By the summer of 1904 Southall's tempera technique had distilled as follows:

1. Design the picture carefully on a small scale first in black and white then in colour, making the spacing of it what he called 'beautiful'.
2. Draw details from nature.
3. Make full size cartoon.
4. Prepare ground of gesso.
5. Trace outline onto ground.
6. Mix colours with yolk of egg and water.
7. Lay warm underpainting in flat tints.
8. Lay flat tints of local colours.
9. Shade with pure colours.
10. All to be painted with sable brushes in a fluid manner, no impasto (Southall 1904).[11]

In 1924 Southall wrote out his recipe.[12] It would be appropriate here to mention briefly his colour boxes: he always prepared his own paints as in his own words you 'never *know* colours till you meet them *alone* – in powder. Mix them & find out [their] peculiarities [and] characteristics' (Southall 1908). His main colour box contained 82 pigment jars.[13] The use of such a wide range of pigments is one reason why Southall's tempera paintings look different from the more restricted palette of Cennini's day. In 1910 he acquired a travelling colour box but he also kept much larger jars and tins of pigments that he himself had ground, particularly earth colours, which have excellent permanence. But as a reporter who visited his studio in 1939 related, Southall nonetheless had charts of colour samples pinned up to test their propensity to fade, some staying up for as long as quarter of a century (*Birmingham Mail* 11 November 1939). Finally it should be noted that in order to have a fresh supply of eggs he kept his own chickens.[14] During the Second World War and food rationing he was reproached for using his eggs for painting rather than eating. Maxwell Armfield relates that he had to turn down a few commissions in 1941 for lack of eggs.[15]

Spreading the word

Having resolved most of the problems connected with tempera to his satisfaction, Southall wished to spread the word as widely as possible. He was one of the founders of the Birmingham-based Craftsman's Club, a particularly lively body of artists who met to discuss common issues. Founded in 1902 it was wound up in 1939. Southall lectured on 'pigments and mediums', *inter alia*, in 1908 and 'the juxtaposition and superposition of colour' in 1923.[16] In 1919 the major publisher Bodley Head urged him to write a book on tempera but apart from the odd jottings, it never materialised.

In the 1890s Southall had helped to form the Birmingham Group of Artist-Craftsmen which included the leading Birmingham artists Arthur Gaskin, Charles March Gere, Margaret Gere and Henry Payne. He taught many of them the tempera medium, and stated that their work was 'mainly influenced by the Primitives and by the English Pre-Raphaelites' and could be described as decorative and romantic but also included modern subjects and portraits. Southall painted portraits,[17] landscapes, beach scenes, sailing ships (which so impressed Picasso), and a few religious subjects, alongside his mythological and romantic scenes.[18]

But the most important society for expanding knowledge of tempera was undoubtedly the Society of Painters in Tempera. Lectures given to the Society were published in four volumes between 1907 and 1954. In Southall's preamble to the paper that he presented in May 1901 at Leighton House in London, which was later published in the first volume,[19] he starts by saying he does not pose as an authority on the subject, but that the real purpose of his paper 'is to start a discussion in which all may learn and all may teach'. The reason for choosing grounds for tempera as his first paper was because he considered it 'wise in painting as in building to begin at the foundations, making them secure if possible before laying anything upon them'.

Maxwell Armfield, who had dedicated his 1930 book *A Manual of Tempera-Painting* to 'JES [Southall] and all Pioneers', considered that the Society of Painters in Tempera had more or less done its work in promoting the tempera medium by 1940, four years before Southall's death (Armfield 1945). It is interesting to note, however, that Viola and Rosamund Borradaile's *How to Paint in Egg Tempera*, published in 1937, was the first instance of extracting from the *Libro dell'arte* as a whole Cennini's teaching *solely* with regard to tempera. The two Borradaile sisters were key upholders of the Society's reduced work after the Second World War.[20]

Greatest success

Southall promoted his own work as well as that of other tempera practitioners through exhibitions across England and internationally. His greatest triumph came in 1910 at the Galeries Georges Petit, a distinguished Parisian gallery that exhibited major French artists of the day. Southall sold a considerable number of works at the gallery's exhibition, but what he found particularly pleasing was the large number of artists who came to study his paintings (Galeries Georges Petit 1910). Writing in Boston's *Christian Science Monitor* in the same year, Maxwell Armfield observed that 'he [Southall] has not only been received but accorded an oration by artistic Paris such as few English painters have received' (Armfield 1910). The French recognized his technical mastery and significance.

Doubtless buoyed by the Parisian reception in 1910, Southall painted a double portrait in tempera of himself and his wife in the following year. Called *The Agate* (Fig. 7) and painted in egg tempera on linen, it was recently bought from Paul Liss by the National Portrait Gallery in London. It shows the artist's wife passing agates to him, standing on the beach at Southwold, where these stones are easily found. Agates were used by Bessie to polish the frames she had gilded for her husband, so this evidences their close bond.

But, if Southall had confidence in his art form, others were less certain. The Royal Academy of Art in London did not know where to hang tempera in relation to other media, and in its famous Summer Exhibitions, works in tempera were usually placed with watercolours. It was only following the success of the major exhibition of Italian painting at the Royal Academy in spring 1930, in which many examples of early tempera painting were shown, that the institution finally relented and gave tempera paintings their own distinctive space (Royal Academy 1930). This was also the same year that the Society of Painters in Tempera, essentially a scientific rather than an exhibiting body, held a major retrospective designed to capitalize on these events (Whitechapel Art Gallery 1930).

Conclusion

Reviews of the 1930 Society of Painters in Tempera exhibition state that Southall probably knew more about the tempera medium than anyone alive and he had almost certainly worked longer in the medium than any other artist. I believe he had a key role in the revival of tempera painting in the UK and certainly interested fellow artists in that major artistic capital, Paris, where he was elected an Associé of the Société Nationale des Beaux Arts in 1925.[21]

Notes

1. Sir William Rothenstein made this statement in several forewords to exhibition catalogues of Southall's works. The foreword to the *Exhibition of the Works of Joseph Southall* (Rothenstein 1934) is just one example.

2. The quotation is from notes for an autobiography that Southall drafted in 1929 in one of his notebooks (private collection).
3. Quoted by Southall at the beginning of his paper 'Grounds suitable for painting in tempera' (Southall *et al*. 1901–1907: 1–8).
4. A statement by Southall contained in one of his pocket notebooks (private collection).
5. Southall's description of Burne-Jones' method in a pocket notebook quotes him as saying 'he *never* uses tempera' (private collection).
6. Rooke quotes Burne-Jones as saying: 'Do you know how to paint in tempera? This is what you do. You take the yolk of an egg – if it is fresh, so much the better for many reasons, and you put it in a wineglass, taking care that there shall be none of the white with it. Then you mix with it about a spoonful of claret, and if you keep that mixture covered up it will last good for three days. Then you get all sorts of pretty colours from the colourman's, in powder fastened up in bottles and you put out which of these you'd like to paint with and mix them up with the liquid and use it always as a medium, putting the least drop of water to it if it gets too thick, but not much, as it doesn't bind. And then you'll be happy, for you can paint in beautiful colours unsullied with nasty oil and varnish stuff, and you can take the finest brush, as fine as a needle if you like, and draw a beautiful line with it in colour, which you can't in oil. And then when it is dry your work will look like a lovely fair pastel thing.'
7. A small photograph of the back was published in 'London Letter' by Peyton Skipwith in the *Journal of Decorative and Propaganda Arts* 12, Spring 1989, p. 96; see also Breeze *et al*. 2005: 65.
8. Statement written by Southall on 7 September 1898.
9. Statement written on 7 September 1898, but Southall is describing his visit to Burne-Jones on 13 April 1898: 'I went to lunch with E.B.J. and he discussed the picture which needed certain alterations principally to the faces which were not beautiful enough though he said of the picture as a whole that "he" *loved* that picture. In colour and tone he said I had nothing to learn!'
10. Remark recorded by Southall on 26 January 1899 in one of his sketchbooks (private collection).
11. Drawn directly from Southall's note on his method dated 31 August 1904.
12. Southall's recipe was to take the yolk of egg well beaten up and strained through muslin and add 1½ drops of Formalin 40% as a preservative. 'Next take a medicine glass and mix equal bulks of yolk and boiled cold water. With this medium the various powder colours are mixed with a bone palette knife on a ground glass slab, not to a stiff paste but just liquid enough to drop slowly from the end of the palette knife into the small deep round wells (about 20 in number) in the china palette in which they are to be kept for use while the egg remains good'. Quote from Southall's note 'On Painting a picture in Tempera 28 [November] [19]24', in *Notes for my book on Painting*, MS (private collection). See also Jill Dunkerton's technical note in Breeze 1980: 18–24.
13. For a description of the contents by the paintings conservator Jill Dunkerton see Breeze 1980: 110–11.
14. When answering questions after presenting his paper 'What is the difference between tempera and oil paint[ing]s?' [*sic*] to the conference on 15 March 2018, Patrick Dietemann stated that it did not matter so much what sort of chicken lay the eggs as what they were fed. I can only say that I think the Southall's eggs would have been organic.
15. Letter from Maxwell Armfield to Joseph Southall, 31 March 1941 (private collection).
16. See the Minute Books of the Craftsman's Club, Birmingham, 1902–39 (University of Central England, Birmingham Institute of Art and Design Archives). I am grateful to Abbie Sprague for drawing my attention to the Minute Books and these references.
17. Statement from one of Southall's notebooks (private collection).
18. The reference to Picasso admiring Southall's work (on a visit to Violet Gordon-Woodhouse in 1928) arises from remarks made by Osbert Sitwell in his autobiography, *Noble Essences* (London, Macmillan, 1950, p. 261). The artist is not named but as the distinguished arts and crafts historian Charlotte Gere first noted, no one else answers to the descriptions of artist and paintings other than Southall (see Charlotte Gere's 'Introduction' to *The Earthly Paradise*, London, The Fine Art Society, 1969, p. 2).
19. It seems this only exists in a manuscript copy made in October 1901 by Bessie, Southall's future wife (private collection). The paper, apart from the preamble, was the first article printed in the first volume of the *Papers of the Society of Painters in Tempera* (Southall *et al.* 1901). The following two quotations in this paragraph are from this MS.
20. In 1978 Rosamund Borradaile informed me that the Society's archive contained 16 files, some with up to 100 letters. I have not been able to locate these files and would be grateful if any readers who have information with regard to their whereabouts would kindly contact me.
21. Southall was also invited to become a member of the Union Internationale des Beaux-Arts et des Lettres at its Paris Congress in 1910.

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Author's address

George Breeze, Cheltenham, UK (gr.breeze@gmail.com)

The spiritual from the material: exploring the tempera recipes of African-American artist Henry Ossawa Tanner in his later visionary paintings

Brian Baade, Amber Kerr, Kristin deGhetaldi and Chris Petersen

ABSTRACT The mid-to-late career paintings by African-American artist Henry Ossawa Tanner were often executed using experimental paint recipes and complex layering systems. These included unconventional emulsion paints formulated by the artist. Tanner recorded his experimental recipes in journals and on handwritten notes, which he inscribed onto the reverse of stretchers or on paper scraps tucked behind canvases. These recipes are complex mixtures of drying oils, natural resins, parchment glue, flaxseed extraction, and lanolin. Access to Tanner's journals and notes in the Archives of American Art and to the largest public collection of his artworks in the Smithsonian American Art Museum in Washington, DC, enabled the study and reconstruction of Tanner's temperas from his original recipes. Reconstructions also revealed that Tanner integrated these materials within the paint stratigraphy to manipulate the superimposed tempera layers in order to achieve particular optical effects. Preliminary findings published in the 2012 exhibition catalog *Henry Ossawa Tanner: Modern Spirit*, combined with expanded research, has broadened our understanding of Tanner's paintings. This paper continues the exploration of Tanner's recipes and application/layering strategies and documents additional analysis of his paintings and the reconstructions.

Introduction

Henry Ossawa Tanner (1859–1937) was one of the leading American artists at the turn of the 20th century, and the first African-American painter to receive international recognition for his artistry. His early successes included imagery that contained a respectful depiction of African Americans as exemplified in his iconic early works such as *The Banjo Lesson* (1893) and *The Thankful Poor* (1894). Despite the importance of this period, Tanner most identified with his mid-to-late career religious paintings.

Tanner was raised in a distinguished family, the son of Benjamin Tucker Tanner, a bishop in the African Methodist Episcopal Church (AME). His mother, Sarah Elizabeth Miller Tanner, was born into slavery in Virginia but escaped North with her family via the Underground Railroad (Bruce 2002: 30). Although Henry Tanner was the best-known member of the family, achieving both national and international acclaim as a painter, his siblings had successful careers in medicine, social activism, as well as ecclesiastic positions within the AME (Bruce 2002: 30).

Tanner's formative years spanned the period from the Civil War through Reconstruction in American History. We are unsure why he was drawn to pursue painting as a career although he certainly would have known of the African-American artists painter Edward Bannister (1826–1901), sculptor Edmonia Lewis (1845–1911), and illustrator/artist Robert Douglass (1809–1887) (Bruce 2002: 35). We really only have anecdotal stories from family and friends of his childhood interests, and speculation as to his father's influence through his educational, political, and civil connections. We do know that Tanner was persistent in his efforts to become an artist. After a number of disappointing starts, his talents were finally recognized by Henry Price, a Philadelphia artist who briefly took Tanner on as his apprentice (Bruce 2002: 46). In 1880, Tanner enrolled as the first full-time African-American student at the Pennsylvania Academy of Fine Arts (PAFA). These studies resulted in a number of important lifelong relationships, most notably with his teacher and mentor, Thomas Eakins (1844–1960) (Mathews 1969: 24).

After struggling to establish himself in America, Tanner was given the opportunity to study in Europe. In 1891 fellow PAFA alumnus Robert Henri encouraged him to attend the Académie Julian, a private art school for painting and sculpture founded in Paris, France, by the painter and teacher Rodolphe Julian (Bruce 2002: 60–61) where he studied under Jean Joseph Benjamin Constant and Jean-Paul Laurens. Tanner began to establish a professional reputation, settling for a time at the Étaples art colony in Normandy (Mathews 1969: 53–61). Throughout the 1890s, Tanner became an integral part of a group of Americans in Paris and in 1895 he joined the American Art Association of Paris. Its president, American merchant heir Rodman Wanamaker (1863–1928), became Tanner's most generous patron and sponsored a pivotal trip to the Holy Land that would alter Tanner's professional vision and inspire him to paint religious subjects (Marley 2012: 10–27). Tanner's travels to Palestine, Egypt, the Holy Land and later to Algeria and Morocco had a huge impact on the artist, and the light, landscape, and architecture would feature in his paintings for the rest of his life.

As Tanner's reputation grew the Academy in Paris accepted his works in a number of its Salon exhibitions. His first significant recognition was *The Resurrection of Lazarus* (1896), which received a third-class medal in the 1897 Paris Salon and was purchased by the French government for the Musée du Luxembourg. Tanner's success in France translated to the United States, where his works were shown in major cities from New York to San Francisco and displayed in international art expositions (Marley 2012: 30). However, he still faced social prejudices in America, which ultimately led to his choice to remain in France until he died in his sleep in 1937.

The development of Tanner's painting styles leading to the introduction of his tempera recipes

Tanner's earliest paintings reflect his largely self-taught style and are quite orthodox in their execution, warm tonal palette, and rather simple paint application. His acceptance into PAFA under Thomas Eakins provided him with a more traditional education in both indirect and direct painting techniques. This period was also one of self-discovery as he sought to identify with the subject matter in his painting, choosing genre scenes of African-American life in the United States as his primary focus, with religious themed works beginning to emerge.

Tanner's work in the Académie Julian period also tends to be directly painted. Even as late as 1910, he was painting substantially using a direct method, mixing colors on the surface with small additions added after the lower layer dried. Yet, as he matured, Tanner progressed toward indirect techniques, as evidenced by his extensive use of glazing and the complex layering structures revealed in his later paintings.

As he approached his mid-career, Tanner's subject matter switched to predominantly religious themes. Although initially, his palette remained warm in tone, it would soon take a dramatic shift to the cooler blue-green palette that would dominate his mid-to-late career color schemes and become his hallmark. During this transition period, his surfaces

Figure 1 Henry Ossawa Tanner, *The Good Shepherd (Atlas Mountains, Morocco)*, *c.*1930: recto and detail. American Art Museum.

began to take on greater textural quality, with a sculptural appearance and build-up of layers that show methodical construction. Many of the works from this era exhibit a layered yet broken wet-on-dry technique achieved by roughly dragging a layer of wet paint over dry layers with little evidence of direct mixing on the surface. This timeframe coincides with the start of Tanner's experimentation with quick drying emulsions.

Based on his journals, inscriptions, and material evidence, the artist began the use of interlayered oil and emulsion paints as early as the late 1910s. These 'emulsion' or mixed binder paints behave and may appear very different from single-phase binders, such as oils or watercolors. Many 19th- and 20th-century artists experimented with emulsion binders in their pursuit of 'lost secrets of the old masters' while others exploited them for their novel effects (Mayer and Myers 2002).

Cross-sections of Tanner's mid and later career paintings reveal very complex stratigraphy, sometimes containing as many as 22 layers of pigmented and unpigmented media. Another distinguishing quality is the absence of artifacts or evidence of the tool used to apply his paint, despite the frequent existence of raised impasto. Tanner's representation of the rocky surface on *The Good Shepherd (Atlas Mountains, Morocco)* from around 1930 was achieved through the application of many discrete and separate layers and daubs of paint, often separated by transparent and translucent interlayers

Figure 2 Henry Ossawa Tanner, *The Fisherman's Return*, n.d., oil on canvas: recto and IRR detail of the verso crossbar. Smithsonian American Art Museum, Washington, DC, 1983.95.212.

(Fig. 1). The final effect is rather like that of peering into an agate with alternating bands of opacity and transparency. The total effect is representational yet abstract, visionary and spiritual at the same time. There are many works like this in Tanner's oeuvre, but we were only able to study a few.

Tanner recorded his layering of oil and tempera directly on the back of some of his paintings, two of which are in Smithsonian American Art Museum's (SAAM) collection. The following was written in pencil on the crossbar of *The Fisherman's Return*: 'Picture painted in 1917 in oil/ retouched in tempera with (illegible. Possibly soap) 1919 then glazed in oil/ painted with tempera 5 days afterward July 1919' (Fig. 2).

On a note dated 'Jan 26th 1920' and tucked into the stretcher of *Head of a Jew in Palestine*, Tanner conveys that it was originally painted in oil paint and allowed to dry for two or three years, after which the surface was rubbed with an emulsion before the background was painted in tempera. Tanner's correspondence with a patron discussed his experimentation: 'I have been working upon a tempera mixture for the last 5 or 6 years and have finally a wonderful binder. I am now using it exclusively and I am sure you will find no loss of quality in my paintings' (Mathews 1969: 219).

While his early tempera recipes are unknown, Tanner's journals from 1932 and 1935–36 record four different recipes as well as annotations and frequent revisions. These vary in proportions, but ingredients such as parchment glue, mastic varnish, oil, syrup obtained from soaking flaxseeds in water, and small amounts of lanolin and alcohol, remain constant. His use of an emulsion containing parchment glue and oil was not unique. In lectures given at England's Society of Mural and Decorators and Painters in Tempera in 1922, the painter and teacher Ernest Percyval Tudor-Hart (1873–1954) recommended a parchment glue and linseed-oil emulsion.[1] Both Tanner and Tudor-Hart studied at the Académie Julian in the 1890s, where they had likely met. Correspondence from one of Tanner's patrons reveals his experimental use of tempera and a reference to the Old Masters: 'when did you begin your new method of painting by mixing oil & egg colours – or rather by using the two on the same canvas? It seems it was the Van Eycks' method & "Beaux Arts" says that is was lost until discovered again by a chemist in 1931.'[2] Unfortunately, we do not have Tanner's reply.

Technical studies of Tanner's working methods

This paper is informed by three studies of the painting materials and techniques of Henry Ossawa Tanner. These started as a collaborative project initiated by PAFA and facilitated by SAAM, whose extensive collection of Tanner's work continues to provide the groundwork for this research. We hoped to address a number of subjects associated with Tanner's paintings including documenting changes in the artist's working methods over time, determining whether specific materials, paint applications, or layering strategies are attributable to his paintings, and investigating the effect his experimental materials and methods may have on the preservation of his artworks (Baade *et al.* 2012: 157).

Nine Tanner works from SAAM were studied and analyzed. We also reconstructed Tanner's paint formulations based on his notes and journal entries. Our methods were optimized to separate and analyze the disparate components within his complex layering systems,[3] and used comparative analysis of his paint and reconstructed recipes to substantiate and identify layering systems documented by the artist during his creation of specific works (Kerr and deGhetaldi 2014). Finally, new methods were tested for treating and preserving Tanner's complex paintings (Angelova 2015). Analytical techniques included cross-sectional analysis, X-radiography, infrared reflectography (IRR), examination in ultraviolet (UV) light, scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS), X-ray fluorescence (XRF), Fourier transform infrared (FTIR) spectroscopy, gas chromatography-mass spectrometry (GC-MS), pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS), X-ray diffraction (XRD), reflectance transformation imaging (RTI), and time-of-flight secondary ion mass spectrometry (ToF-SIMS).

Technical analysis of materials and reconstructions

Samples collected from Tanner's paintings revealed extensive and complex layering systems. Cross-sections from *The Fisherman's Return* show 19 layers, which vary in transparency, color, and thickness.

When viewed in UV light, another sample exhibits seven transparent interlayers and overall autofluorescence (Fig. 3).

Cross-sections from this painting were analyzed using ToF-SIMS imaging at the University of Delaware (Kerr and deGhetaldi 2014), which allowed us to localize Tanner's use of materials. The lower layers contain both oil and glue while the middle layers are predominantly bound in oil. Finally the uppermost paint layers display a strong signal for protein, which corresponds to Tanner's use of a tempera mixture containing glue. This layering directly corresponds to the inscription noted on the reverse of the stretcher bar (Fig. 4).

A major aspect of our Tanner studies included reconstructing the artist's paint recipes. The reconstructed paints were then analyzed and the results compared to those from samples taken from his own works. The primary source for the reconstruction recipes were Tanner's journals housed in the Archives of American Art. There are four distinct recipes for the artist's emulsion or tempera paints, all recorded in the 1930s, although analysis confirmed the presence of these emulsions as early as the 1910s. One of the four recipes is reprinted in Figure 5.

One curious ingredient is what Tanner refers to as water or syrup from linseeds. Jean-François-Léonor Mérimée recommended a similar ingredient for creating flexible grounds on textiles (Mérimée and Taylor 1839: 221). Additionally, it was also used by at least two other artists: Cesare Laurenti and Abraham Hermanjat (Baroni *et al.* 2016: 120, 137 n.2; Langer 2012). Tanner's recipes do not indicate the proportions of water to flax seeds needed to achieve the syrup, so several experiments with varying proportions were carried out before settling on one that contained 227 g flax seeds to 700 mL water. After soaking the seeds overnight the syrup was extruded from the swollen seeds by pressing them through cheesecloth.

It was challenging to identify the flax seed syrup using GC-MS, as it is difficult to differentiate between various polysaccharide markers. To refine the analysis, individual polysaccharide standards were created from the reconstructed syrup and their retention times recorded so that a reference library could be established for comparison between the original samples and the reconstruction samples.

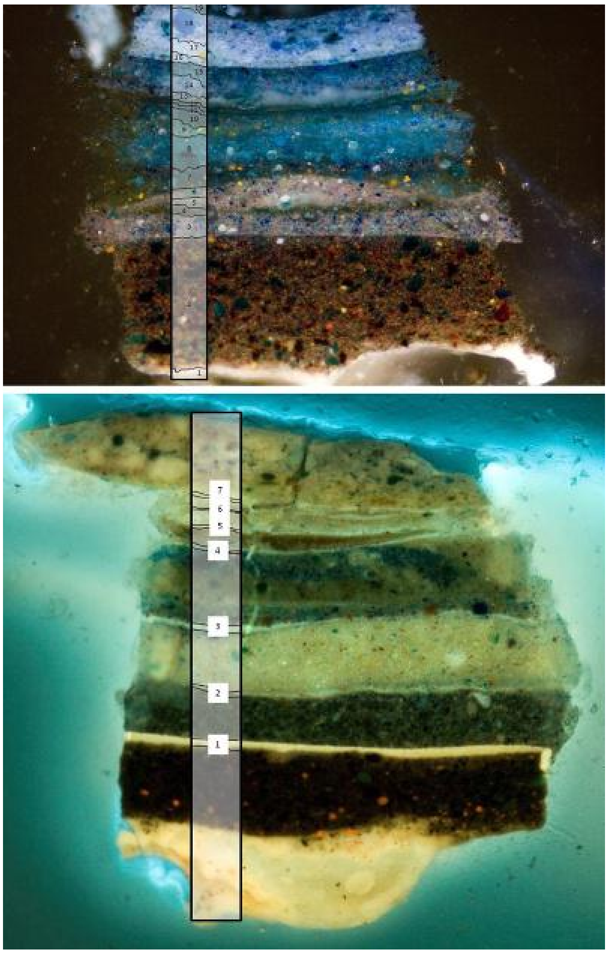


Figure 3 Henry Ossawa Tanner, *The Fisherman's Return*. Top: cross-section in visible light showing 19 media layers (×100). Bottom: UV image of another cross-section showing seven autofluorescent interlayers (×100).

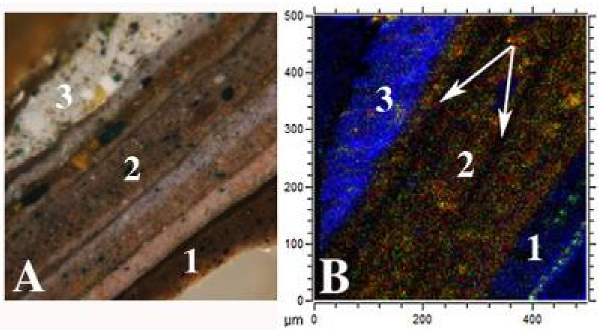
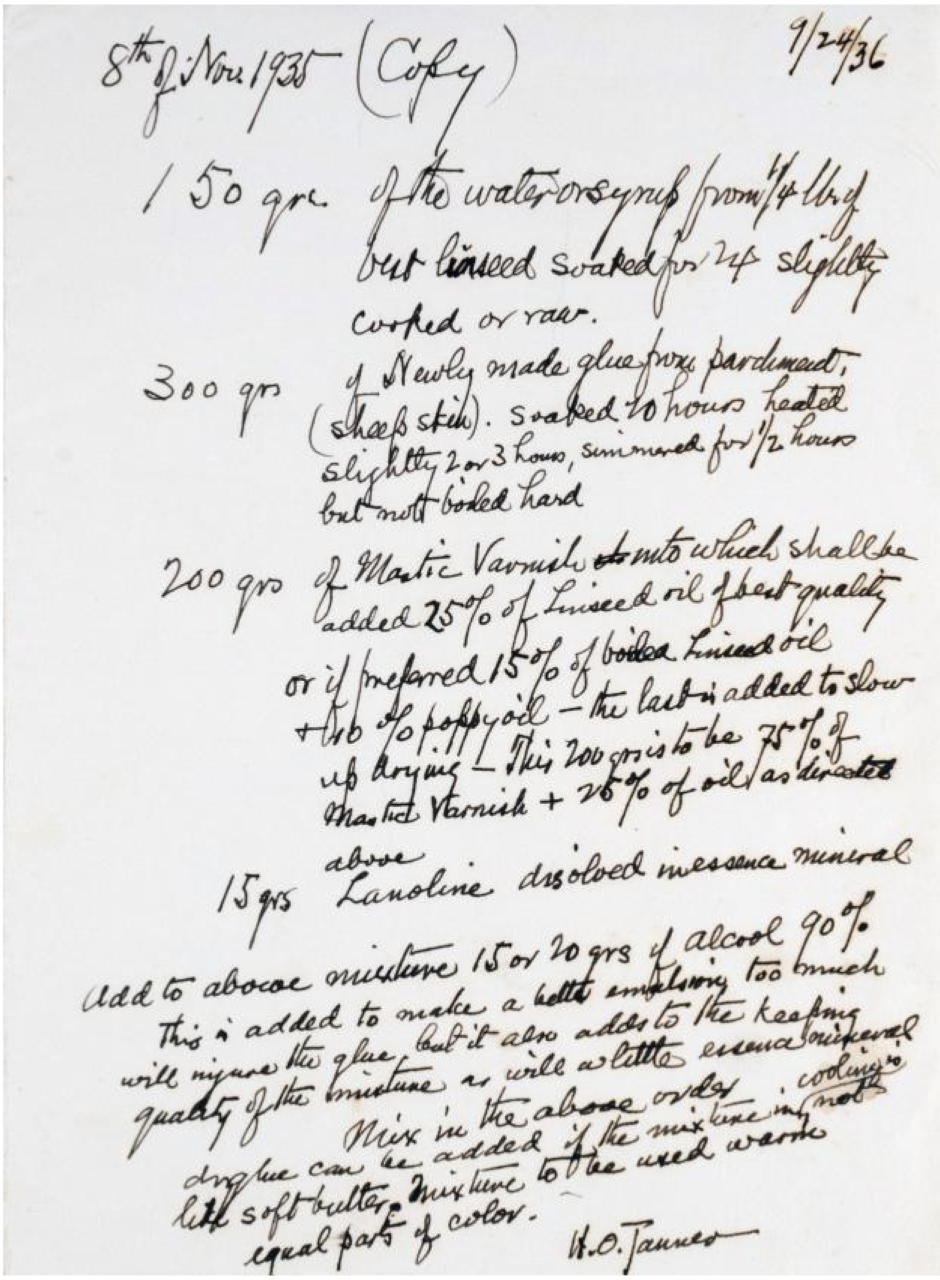


Figure 4 Henry Ossawa Tanner, *The Fisherman's Return*, 1917/reworked 1919, mixed media on canvas, Smithsonian American Art Museum, Washington DC. A: Detail of a paint cross-section in visible light (×100). B: The corresponding image collected using ToF-SIMS shows the distribution of protein (CN-ion; blue) in regions 1 and 3, which was also confirmed with the identification of several amino acids. Region 2 is rich in palmitic and stearic fatty acids ($C_{16}H_{31}O_2$-; red/$C_{1b}H_{35}O_2$; green). The ToF-SIMS data are supported by written notations found on the reverse of the painting: 'Retouched in tempera in soap in 1917/then glazed with oil/ Painted with tempera 5 days afterward July 1919.' The arrows indicate thin layers that could not be characterized.



8th of Nov. 1935 (Copy) 9/24/36

1 50 grs of the water or syrup from 1/4 lb of [illegible] linseed soaked for 24 slightly cooked or raw.

300 grs of Newly made glue from parchment, (sheep skin). soaked 10 hours heated slightly 2 or 3 hours, simmered for 1/2 hours but not boiled hard

200 grs of Mastic Varnish into which shall be added 25% of Linseed oil of best quality or if preferred 15% of boiled Linseed oil + 10 % of poppy oil – the last is added to slow up drying – This 200 grs is to be 75% of Mastic Varnish + 25% of oil as directed above

15 grs Lanoline dissolved in essence mineral

Add to above mixture 15 or 20 grs of alcool 90%. This is added to make a better emulsion too much will injure the glue but it also adds to the keeping quality of the mixture as will a little essence mineral

Mix in the above order, cooling is not [illegible] dry glue can be added if the mixture is [illegible] little soft butter. Mixture to be used warm equal parts of color.

H.O. Tanner

Figure 5 A tempera recipe in an entry in Tanner's journal dated November 8, 1935 (Archives of American Art, Henry Ossawa Tanner papers, 1860s–1978, bulk 1890-1937, Series 3: Writings and Notes, 1897-circa 1950s [Box 1-2, OV 5; 9 folders], Box 2, Folder 2, 9/24/36, p. 27).

The polysaccharide compounds were identified in the reconstructed reference sample and five identical markers were then discovered in the sample taken from *The Fisherman's Return* (Fig. 6).

Similar challenges were encountered for the parchment glue ingredient although the recipes do state that it needs to be thick and gelatinous. After experimentation, a strong collagen glue was made from heating 4 oz of well-soaked parchment scraps in 16 oz water in a partially covered vessel until the water was reduced by half. The solution was then filtered to extract the glue. While there is a significant amount of animal glue present in Tanner's recipes, it was difficult to extract the proteins from his paint samples and it took multiple efforts before the characteristic amino acids were detected, including the presence of hydroxproline, a strong indicator for animal glue (Fig. 7).

The mastic varnish ingredient also required experimentation, as Tanner recorded the weight of

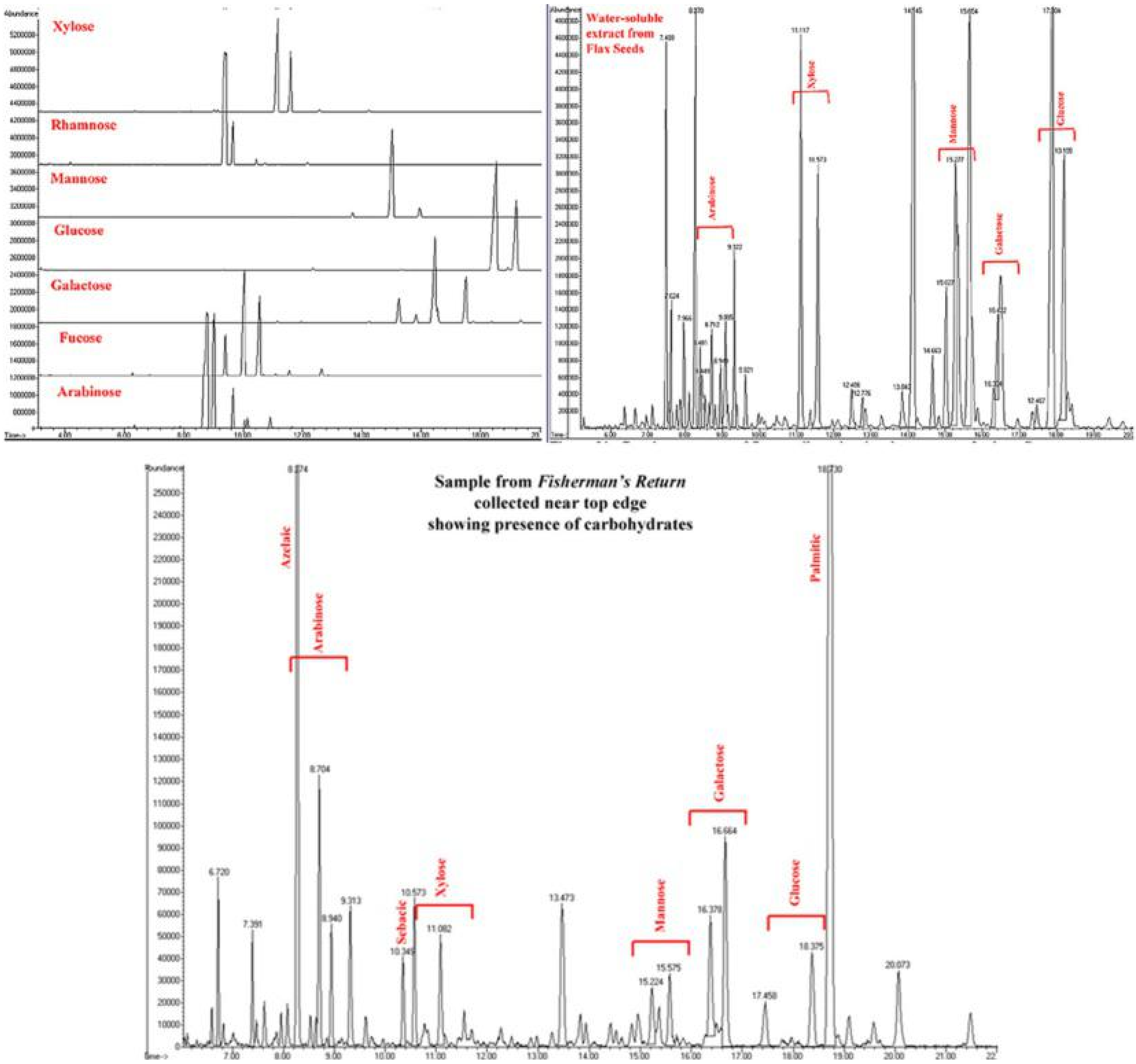


Figure 6 GC-MS analysis of unaged, water-soluble components of flax seeds corresponding to the carbohydrate markers found in samples of Tanner's paint.

the varnish and the proportions of oil to combine without indicating the ratio of mastic resin to solvent. We decided on a one part resin (by weight) to three parts turpentine (by volume), as this was a common concentration recommended for varnishing in early 20th-century art manuals.[4] Additionally, experiments with more concentrated varnish yielded a medium that was immiscible in water. For the reconstruction, 150 g of 1:3 mastic varnish, and 50 g cold-pressed linseed oil were used for what Tanner refers to as the varnish ingredient. GC-MS analysis was able to identify drying oils in the samples taken from Tanner's painting, but the resin markers were slightly more difficult to discern.

Tanner's recipe includes a small amount of lanolin. In this recipe, 7.5 g lanolin was diluted in 2.5 mL petroleum benzene and added to the previous ingredients. This remains a difficult ingredient to identify, as analysis was unable to detect lanolin in either the samples taken from his painting or those of the reconstructions. Tanner's final ingredient was the addition of ethanol to complete the emulsion. The various ingredients remain in separate layers until the addition of alcohol and shaking. When cool, the resultant medium is an opaque soft gel, resembling cold cream. It does soften and flow slightly if water is added and mixed with a palette knife. Tanner mentions that an equal amount of pigment should be

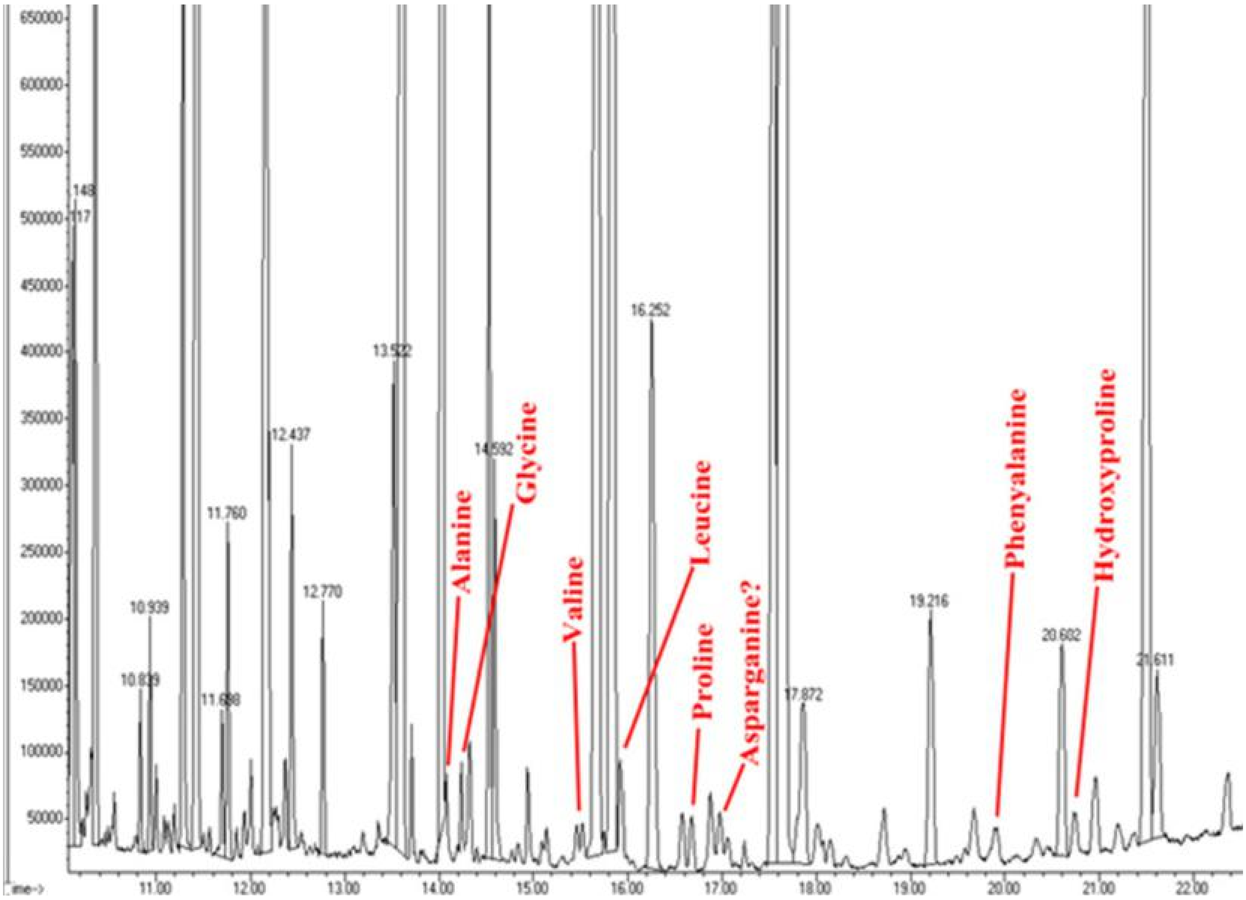


Figure 7 Gas chromatogram of a paint sample from *The Fisherman's Return* showing the presence of characteristic amino acids.

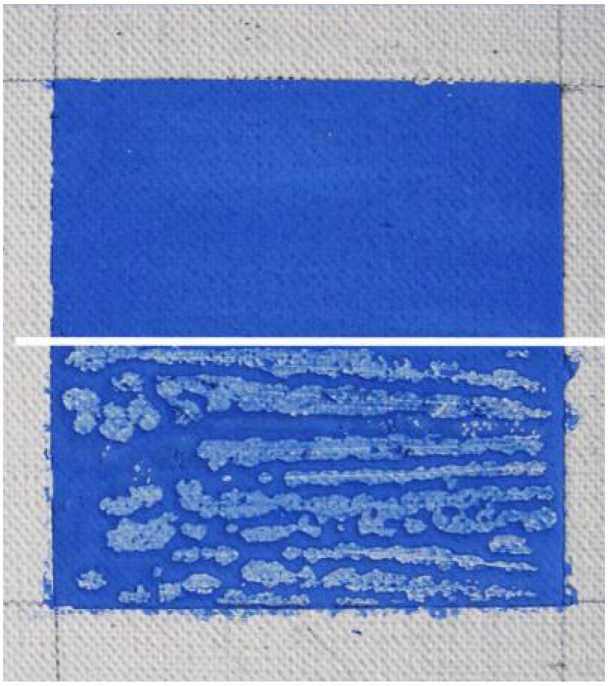


Figure 8 The top section of the oil ground was first coated with animal glue to allow a smooth, even surface to be achieved with the tempera paint.

added to the binder. The two easily combined with a palette knife, but it must be mulled for several minutes to transform it into a smooth, workable paint. The resulting paint dries very matt in just a few minutes, as is typical for oil-in-water emulsions. If thinned with water, Tanner's paint emulsion is capable of making fine lines, especially on lean absorbent grounds, such as traditional gesso. His medium does lack the ability to create the crisp fine and articulated lines possible with true egg yolk tempera, but is effective at creating broader strokes that can be applied rapidly. A slight dilution with water created a paint that could be applied in relief and yet would subtly level to remove evidence of the brush or knife. The paint could also be applied in a broken manner to replicate Tanner's dry, dragged paint layers when applying them over textured underlayers, and reconstructions easily matched the surface of many of his paintings from the 1910s.

Additional tests were made on various grounds, including chalk-glue, semi-lean oil, and oil grounds.

Tanner mentions the application of a glue varnish or rubbing the emulsion mixture over oil paint layers. When tested on a lean ground, the reconstructed paint was easy to apply thickly as well as in thin washes. It could also be easily applied over fatty oil grounds, oil glazes, and varnishes if they were first coated with animal glue. Our reconstructed paint beaded up if applied directly on fatty oil underlayers without a glue interlayer (Fig. 8) but it seems likely, however, that he exploited this beading for some effects (see Fig. 1).

Another paint recipe contains additional instructions: if the tempera is to be applied over works that have already been varnished, the paint should be modified to include additional oil, resin, and glue. Reconstructions of this formulation created a paint that could be applied over oil glazes and a thick coating of mastic varnish without beading.[5]

The presence of very thick, transparent, glassy, almost ceramic-like glaze layers is common on Tanner's later works. Many are a rich warm green, but there are also examples of cerulean blue hued glazes. Often these glazes exhibit sharp fractures and cracks indicating their glassy, brittle nature. We discovered that the artist applied his test glazes on the reverse of his *Sketch for The Annunciation* which included an annotation in what appears to be his handwriting with the word 'cracks' noted and an arrow pointing to the cracked glaze (Fig. 9).

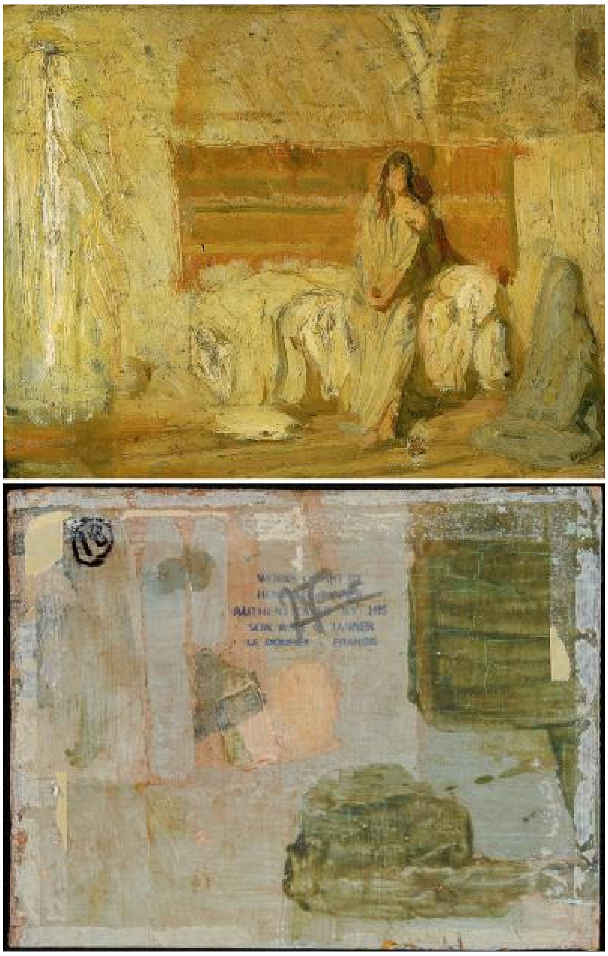


Figure 9 Henry Ossawa Tanner, *Study for The Annunciation*, *c.*1898, oil on board, Smithsonian American Art Museum, Washington, DC.

A fractured glaze layer is found on many of Tanner's other works. We created a physically similar glaze by mulling one part viridian pigment into four or five parts of the emulsion. This glaze levels out upon application with a palette knife, thus diminishing the evidence of the application tool. It dried to a satin yet transparent finish, unlike the opaque matt finish of his leaner paint mixtures. Tanner's green glazes are much warmer despite having the same pigmentation. This is likely the result of the subsequent yellowing of the high proportion of animal glue and organic binder in these glazes, and probably plays a role in their inherent brittleness.

The unique qualities of Tanner's experimental tempera paints, combined with his complex layering systems, have had a profound effect on the preservation of his artworks. A number of his mid-to-late career works are sensitive to conservation treatments and can react severely to poor environmental conditions (Baade *et al.* 2012: 164–5). This condition is to be expected based on his idiosyncratic use of materials and the multitude of layering strategies he employed to achieve his enigmatic surfaces and visionary imagery.

Conclusion

Tanner was an African-American artist of international stature who reframed genre scenes of African-American life, Orientalist imagery, and religious painting through his own innovative painting practices and techniques. Documented evidence from his journals, correspondences, archival notes and annotations left by the artist with his paintings, analysis of his works, and reconstructions of his recipes all indicate that he manipulated an emulsion medium containing animal glue, linseed syrup, resins, drying oils, and lanolin in his later works.

Tanner's painting process required an unconventional number of layers, and resulted in a complex stratigraphy when viewed in cross-section. His experimental use of materials and eccentric techniques are essential components of his artistic vision, but they may also be contributing to their deterioration.

Acknowledgements

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Notes

1. The recipes suggested by Tudor-Hart are recorded in Hiller 1970: 49–54.
2. Archives of American Art, Tanner Archives, Series 2, Box 1, Folder 21, July 21, 1934, pp. 186–9.
3. C. Walker, 'Improved cleaning techniques through medium analysis of paintings by Henry O. Tanner', Smithsonian American Art Museum, Smithsonian Institute Fellowship Research Project, *c.*2012, p. 3.
4. A survey of late 19th- and early 20th-century painting manuals by Brian Baade.
5. Archives of American Art, Henry Ossawa Tanner papers, 1860s–1978, bulk 1890–1937, Series 3: Writings and Notes, 1897–circa 1950s (Box 1–2, OV 5; 9 folders), Box 2, Folder 2, 6/23/32, p. 30.

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Authors' addresses

- Brian Baade, Assistant Professor, Painting Conservator, and Researcher of Historical Painting Materials and Techniques, University of Delaware, Newark DE, USA (apigmentboy@yahoo.com)
- Amber Kerr, Paintings Conservator, Acting Chief of Conservation, Smithsonian American Art Museum, Lunder Conservation Center, Washington DC, USA
- Kristin deGhetaldi, Painting Conservator, Instructor Winterthur/University of Delaware Program in Art Conservation, University of Delaware, Newark, DE, USA
- Chris Petersen, Conservation Scientist, Affiliated Associate Professor, University of Delaware, Newark DE, USA

‘Then egg, then watercolour or tempera paints, then alcohol resin’: Paul Klee’s tempera painting techniques

Patrizia Zeppetella, Stefan Zumbühl and Nathalie Bäschlin

ABSTRACT Various projects concerning research in art technology and conservation have been undertaken in the Zentrum Paul Klee and the Museum of Fine Arts in Bern during the last two decades. In conjunction with these projects Klee’s own terminology for painting techniques repeatedly became a key issue. Paul Klee used the term ‘tempera’ for the first time in 1905 in the handwritten catalogue of his oeuvre. It is a rich source of information on painting techniques and indispensable for understanding his highly diverse art. These documents can only reveal specific information if the artist’s terminology can be properly comprehended. In order to understand Klee’s tempera in greater depth the artist’s materials were analysed to precisely define the individual layers of paint as well as the material structure of a selection of his paintings. This paper seeks to clarify Paul Klee’s terminology for painting techniques to allow us to better understand the wealth of context information on his artworks in the future.

Introduction

Paul Klee’s artistic work is captivating not only by virtue of its artistic originality, but also as a result of its texture, which is not left to chance. His work was always characterized by the search for adequate stylistic means. Accordingly, experimenting with materials played an important role, and consequently left its mark on his style. For the comprehension of his work, his extensive writings provide a rich source – over decades he noted his recipes and described his techniques in different notebooks. The main source is Klee’s handwritten catalogue of his works (Fig. 1) which he started editing in 1911 to include a retrospective catalogue of his earlier works. The catalogue consists of four booklets and a number of individual sheets stored in loose-leaf binders. He numbered the works consecutively by year, but also made notes on the title and technique, picture support, as well as indicating sales, prices and donations. It is in these notes where the term ‘tempera’ is first found. He often used the term tempera to differentiate ‘tempera’ from ’oil’, but it should be noted that in the majority of cases he did not indicate the technique he used, and the distribution build-up of tempera over time is not homogeneous. Furthermore, he referred to the term ‘tempera’ in different contexts, often in combination with other techniques such as watercolour, gouache and oil. To verify the written information, we decided

Figure 1 Handwritten catalogue of the works of Paul Klee, stored in the Zentrum Paul Klee, Bern.

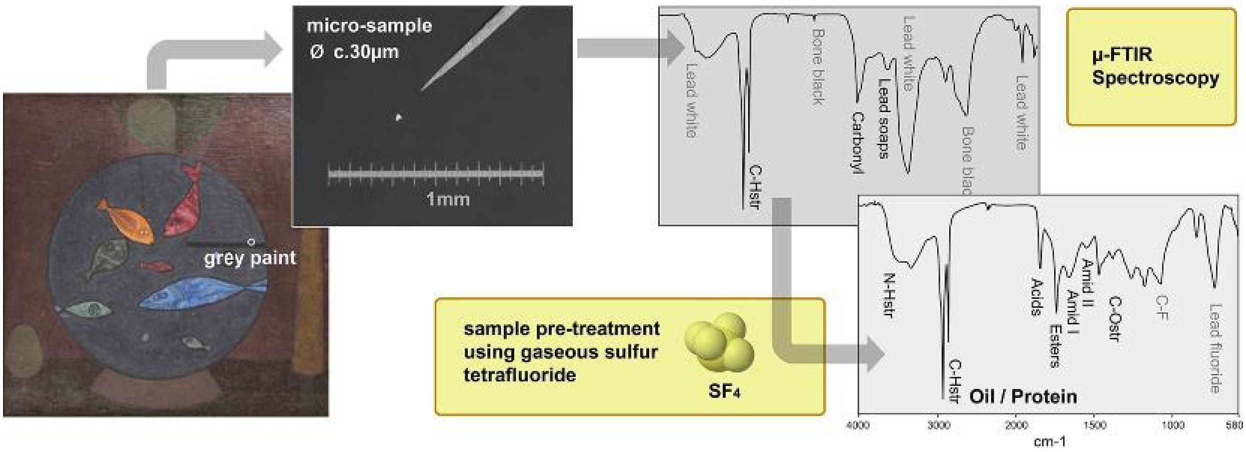

Figure 2 Scheme of the analysis of paint microsamples using infrared spectroscopy.

to investigate the corresponding paintings to find common features.

For the analytical investigation, Fourier transform infrared (FTIR) spectroscopy was used. The advantage of this technique is the need for only very tiny microsamples (*c*.20 µm). However, there are clear limitations to the technique when analysing binding media in aged paint samples, due to spectral interferences generated by this heterogeneous mix of compounds. Therefore, a sample preparation and derivatization technique using gaseous sulphur tetrafluoride (SF_4) was employed to discriminate binder signals and eliminate overlapping infrared (IR) bands from inorganic components and metal soaps (Fig. 2). This makes it possible to characterize the composition of tempera binders at the micron scale and in paint cross-sections using infrared spectroscopic imaging (FTIR-FPA) (Zumbühl *et al.* 2014). A total of 45 microsamples from 15 paintings from different time periods was investigated with this technique. The object of the investigation was to determine the place of tempera painting in his work. How did he use the term? Did his concept of tempera change in the course of his work? How did he prepare his paint? Did he use industrial products or make his own binder mixtures? And finally, how did his paint formulation and his painting technique affect the visual characteristics of the resulting picture?

Figure 3 Two examples of reverse-glass paint: *The Merman as Fetishist*, 1907,16 and *Nude on a Swing*, 1906, 15 (recto and verso).

Tempera in Klee's early works

In an artist's early phase, not only does the question of the source of inspiration often arise, but also that of the development of artistic work processes. In Klee's case too, these questions cannot be approached in isolation from the biographical background. In 1898, after graduating from high school, Paul Klee went to Munich to study art. The city was already a well-known centre for painting technique and many artists congregated there to trace the technical aspects of Old Master painting. However, it is not known whether Klee was also guided by these aspects. In any case he made an effort to get accepted by the Academy, albeit unsuccessfully, whereupon he attended various private painting schools in the city, as a result getting to know Heinrich Knirr, who reinforced Klee in his individuality. Klee was then admitted to the class of Franz Stuck but after six months he realized that Stuck was not the right teacher for his needs. From then on, Klee directed his own artistic education. It is not known from Klee's writings whether, like many of his fellow artists in Munich, he grappled intensively with tempera painting, or whether this period can be seen as having provided the initial spark for his later oeuvre. What is certain, however, is that demands regarding the texture and the technical properties of his paints would accompany him throughout his life. In 1902 Klee returned to Switzerland by a circuitous route, where until 1906 he lived and worked in his parents' house. He devoted himself to self-study and attempted to liberate himself from norms in respect of formal expression as well of technical aspects of painting.

During this time, he began producing reverse-glass paintings, a painting technique using glass as the supporting material (Fig. 3) (Bigler-Görtler 2003). One specific focus was dealing with the 'white' line. This group of works is a logical development of his skills as a draughtsman and graphic designer. It is noteworthy that the term *Tempera* first crops up in Klee's notes in the context of this very specific group of works, in other words detached from various painting-technical tendencies of the Munich tempera movement. In his diary Klee sums up the technical structure as follows: cover the glass plate evenly with 'tempera white', possibly by spraying a thinner (Klee 1988). In this case he used a glue/paste paint based on a protein glue thickened with starch, containing a low amount of oil and resin. After drying, scratch the drawing with the needle and fix it. And finally, back the drawing with black or coloured areas. This early work is of interest when attempting to understand his approach to applying materials. In 1900 Klee wrote to his wife Lily: 'Unfortunately, my attempt at oil painting failed. I finally made the experience. Now, however, tempera seems to be better suited to me' (Klee 1979). His letters and diaries make it clear that he introduced the term during a period of upheaval. The move away from oil to tempera paint poses the question: was the tempera technique an approach to a new colour implementation? Independently of the technical developments in Munich, the use of tempera by Klee was not following a fad – rather it corresponded to an inner necessity by reason of his way of working. After this initiation, tempera appears again and again in combination with other water-based techniques, usually applied in layers and partially separated with intermediate layers, utilising a wide variety of paint formulations over time.

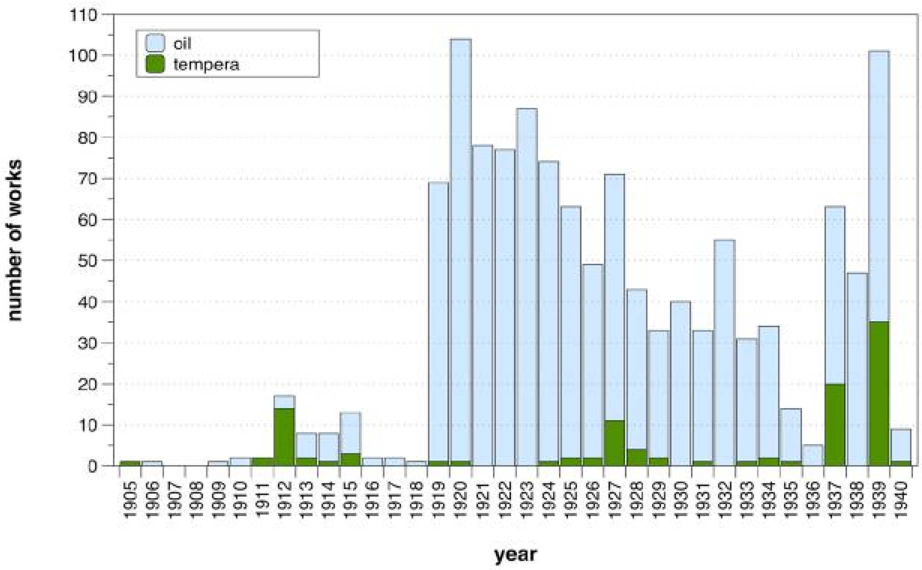

Figure 4 Graph showing the incidence of the term 'tempera' mentioned in the catalogue.

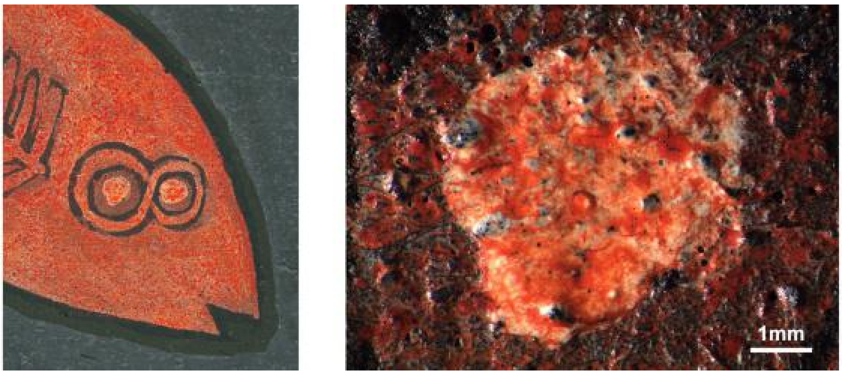

Figure 5 Paul Klee, *Fishes in a Circle*, 1926, 140: details.

Characteristics of the 1920s work group

The overview of Klee's handwritten catalogue (Fig. 4) shows that in addition to the early period (1911–1915) a second group of works should be noted, where Klee often declared the use of tempera. These pictures, dating from 1924–1929, were mostly painted while Klee was teaching at the Bauhaus in Dessau. Generally, these groups of works are based on multilayered systems containing different binders. Each of these paint layers is made with a mix of several organic binder materials. The paintings often show a classic structure building up from lean to fat. His technique can be followed using the painting *Fishes in a Circle* (Fig. 5) as a case study: the picture support, which consists of relatively thick cardboard covered with a cotton fabric, is coated over its entire surface with a protein-bound black ground layer with a matt appearance. The matt and opaque colour should be considered a lean tempera, consisting of protein and drying oil. Locally, the colour areas are structured in different ways, a stylistic element of Klee's painting technique. To reach these paint characteristics heavy body paint is necessary, which was achieved by the protein content in the paint. In the next step, the fishes were underlaid with a white well-saturated paint containing a higher proportion of oil, and finally covered with a translucent, glossy oil-rich glaze-like paint layer with a certain amount of protein. It appears that in principle, the paints consist of the same starting materials, but that Klee guided the applicability and the optical characteristics deliberately by varying the relative proportions. In this perception the tempera system is first processed with water and dries matt and opaque. The greater the oil content, the more difficult it becomes

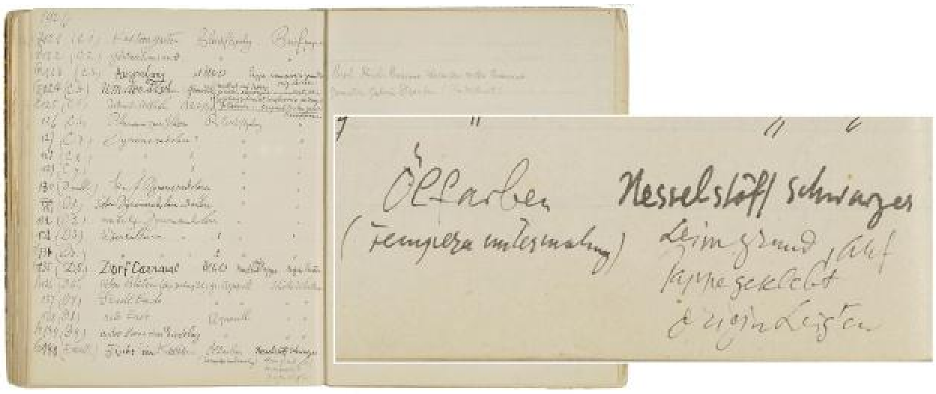

Figure 6 Pages from the catalogue with a notation to *Fishes in a Circle,* 1926, 140.

to mix with water and the more pronounced the oil character of the paint becomes. The changing effect of matt and gloss, opaque and translucent, despite similar binder systems, is fascinating. With these variation possibilities, he could do justice to his different surfaces. He made even more use of this technique in his late work, using heavy body paint as a stylistic element. He referred to this paint as 'paste tempera', a starch-based medium, often containing protein as a second main component, and traces of oil. It serves as the base for the overlying oil-rich glazes containing resins. The white substrate increases this shiny effect and the colour intensity. This effect was enhanced further with the specific use of colorants. For instance, in the glazes he used colour-intense synthetic organic pigments locally, whereas in the matt paint he preferred the use of earth pigments.

Importance of the written sources

It has been shown that the notes and lists represent important primary sources for the technical assessment of Klee's works but there is still scope for interpretation. From the first to the last booklet, he entered the work numbers with the meticulousness of an accountant, leaving no gaps (Fig. 6). It is tempting to believe that he made each entry at the time the corresponding work was produced. However, it is known that he entered the works in whole groups at a time, as the appearance of the handwriting and the colour of the ink also indicate. The different use of the technical information corresponds more to a thematic and technical aide-memoire for the artist. Over time, the notes and the itemization sometimes differ from information obtained from his letters. Therefore, the abundance of records must be scrutinized and evaluated critically. This applies in particular to the terminological interpretation, as can be seen strikingly by the example of the term tempera, which cannot be clearly or uniformly understood either in respect of the texture or of any painting-technical system. For this reason, not only do the sources facilitate understanding of the actual works, but analytical data can also provide a better assessment of the significance of the information contained in the written documents. Thus, the question arises: what links the works for which Klee used the term 'tempera'? The previous hypothesis – that in Klee's self-conception the term is obviously a synonym for a bodied water-based paint (Bäschlin *et al.* 2000a, b) – can be supported by his term 'paste paint' or 'paste tempera' since this method is not an emulsion but an almost oil-free system. The main property of these paints is water solubility. He frequently combined the two aqueous techniques tempera and the gum-based aquarell to obtain different opacity. But in conclusion, the paint designations 'tempera' and 'oil paint' primarily define the way the paints were applied. The designation tempera does not therefore refer mainly to a particular material (in the historical sense) (Reinkowski-Häfner 2016) or a paint (Pohlmann *et al.* 2016), nor to a characteristic painting technique (Beltinger 2016; Zumbühl and Beltinger 2016), as was normal practice in the Munich tempera discussion of the early 20th century. For Paul Klee, tempera meant, rather, an important quantity in the work process which, from a technical point of view and from the artist's own basic approach makes sense. The same is true of the term 'oil', which is how he described the technique of *Fishes in a Circle*: 'oil paints with tempera overpainting', although the 'oil paint' contains a proportion of protein and thus

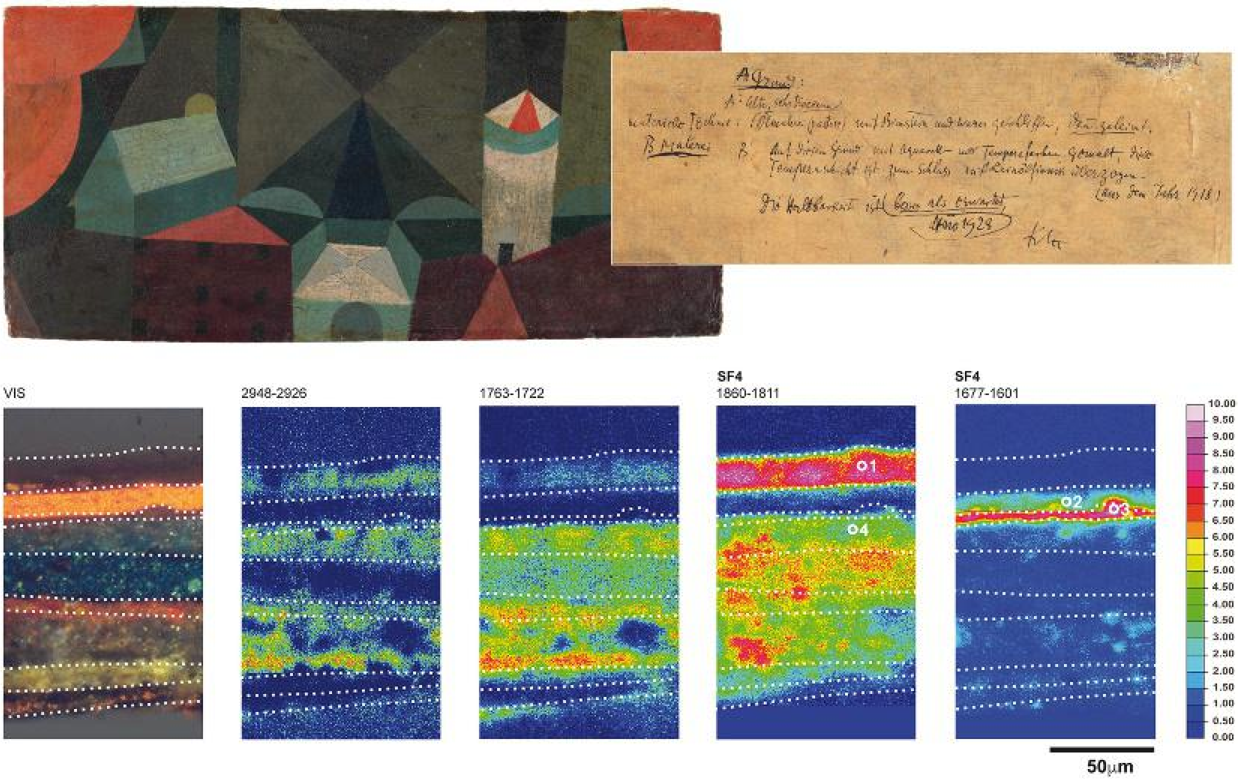

Figure 7 *Above*: Paul Klee, ***Architecture on the Stage***, 1918, recto and verso. The reverse of the painting contains a description of the paint layer. *Below*: FTIR-FPA images (binder components) of a paint cross-section.

cannot be distinguished from a fatty tempera. This shows clearly that the terms 'tempera' and 'oil paint' can be understood as technical colour characteristics.

The conservation-technical context

With this basic understanding of how to read the written sources, these documents represent important working foundations for the conservational approach to Paul Klee's works, even though conclusions regarding texture can only be drawn to a certain extent on this basis. However, as we have come to know, Paul Klee was a very experimental artist and often mixed several components in his paints, the resulting paint frequently being heterogeneous in composition. In some cases, this has led to his works becoming very fragile. Klee was certainly aware, though, of the problems involved in his tempera painting, and as a result, became interested very early on in the durability of his techniques, using different systems to test the materials' behaviour. In combination with the documentation, these also represent important sources of information on Klee's painting technique. The painting *Architecture on a Scene* is a good example of such a work that he did not include as completed in the catalogue (Fig. 7). On the reverse he describes in 1918 the layer structure of the painting:

> A: old, very dry oil painting (impasto) smoothed with pumice stone and water, then glued. / B: Painted on this ground in watercolour and tempera, this tempera layer is coated finally with boiled linseed oil varnish.

This painting was investigated with chemical imaging using FTIR-FPA on a cross-section. The analysis indicates that the description 'dry oil painting' is related to fatty paint systems which, as described above, contain small amounts of protein. The oil paint was provided with a glue layer, overpainted with a tempera paint made with oil, protein and a carbohydrate component, and finally covered with an oil varnish containing a triterpene resin. Evidently Klee regarded this layer structure as an experiment, without being able to judge its long-term stability. From his notes it seems quite evident that he was uncertain about this experimental technique but 10 years later he assessed the state of preservation and added: 'The durability is anno 1928 better than expected!' All this information illustrates the complexity of an oeuvre as extensive as that of Paul Klee. In particular, it confirms that the intelligibility of technological notes depends on our ability to comprehend the artist's specific standpoints and attitudes.

Conclusion

Like his fellow artists of the age, Paul Klee was concerned to find his own way of expression and was searching for his very own stylistic means. Impelled by his inner need to combine the content of his works with their material texture, the effort and desire to ensure the durability of his works is evident in the pleasure in experimentation and the recording of the successful artefacts in his handwritten catalogue. His extensive writings provide a rich source of information on his use of tempera: over decades he noted his recipes and described his techniques in different notebooks and his handwritten catalogue of his works. But it should be noted that he mainly used this declaration to differentiate 'tempera' from 'oil', and the distribution build-up of tempera over time is not homogeneous. He also used the term in different contexts, often in combination with other techniques. This investigation shows that the terms 'tempera' and 'oil paint' have to be understood as technical colour characteristics, rather than a specific material or technique. Depending on his creative phase and artistic content, he used tempera either layered or as a single paint layer on a variety of picture supports. The material-technical investigations have demonstrated the complexity and the nuances of Paul Klee's application techniques, allowing the richness of expression to be experienced down to the smallest detail.

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Authors' addresses

- Patrizia Zeppetella, Zentrum Paul Klee, Bern, Switzerland (pzeppetella@bluemail.ch)
- Stefan Zumbühl, University of Applied Sciences, Bern, Switzerland (stefan.zumbuehl@hkb.bfh.ch)
- Nathalie Bäschlin, Museum of Fine Arts Bern, Bern University of the Arts, Bern, Switzerland (Nathalie. Baeschlin@kunstmuseumbern.ch)

Tempera and pastels: the colour effects created in Paul Klee's later work

Nathalie Bäschlin and Stefan Zumbühl

ABSTRACT Paul Klee specifically negated the boundaries of artistic and technical genres, and explored possible combinations for connecting them. These are visually perceivable and often create surprising effects through the materials used. This article demonstrates the common features of Klee's tempera and pastel painting in his later work, and discusses them in the context of contemporary and historical painting discourse. As clarified by new analyses, Klee's concept of tempera encompassed, at least in his later work, for the most part a classic, exceptionally lean emulsion system. The multilayered structure and the translucent glazes were the related technical characteristics. He also reduced the binder content of the paints to a minimum, using gloss and/or impasto accents only in a specifically targeted manner. Another group of works, the pastels, are characteristically high in colour saturation of the underbound pigment conglomerates and their mechanical cross-hatching on structured, coloured or aged grounds. Klee used weakly bound sticks and pastes made of a proteinic binder and a small amount of oil. He also worked on the coloured surfaces with brushes, although it is not clear-cut as to whether he used this in order to fix his artwork or implemented it as a form of painting. The tempera as well as the pastel painting can be viewed as 'individual consistent implementation of painting without binding media' as propagated by the chemist Wilhelm Ostwald.

Tempera and pastel: Paul Klee's notations

In his handwritten catalogue of works, Paul Klee (1879–1940) kept a very detailed account of a large number of things.[1] His description of the materials used and his notes on the technical implementation provide a very rich source, which in regard to terminology and completeness, as well as the chronology and his own later editing, not only contains a wealth of information but also raises many new questions. Klee's remarks on pastel and tempera in the catalogue of works make it clear that he was interested in the techniques early on, but that he actually used them intensively only in the 1930s (Fig. 1).

The tempera annotations dating from the 1920s reflect upon the multilayered systems using several organic binder materials and built up from lean to fat. Later Klee added a new variation, the so-called 'paste tempera' (*Kleistertempera*), a heavy body paint that he employed as an intermediate layer within his complex multilayered systems.[2] Looking more closely at the pastel annotations it is evident that with this technique he was focusing on the combination of drawing and watercolour, as well as on the use of different supports with a variety of colours and textures and different absorption properties. The first pastel entry in 1907 is listed as a 'watercolour charcoal drawing, pastel, brown ink / on Ingres' and another interesting

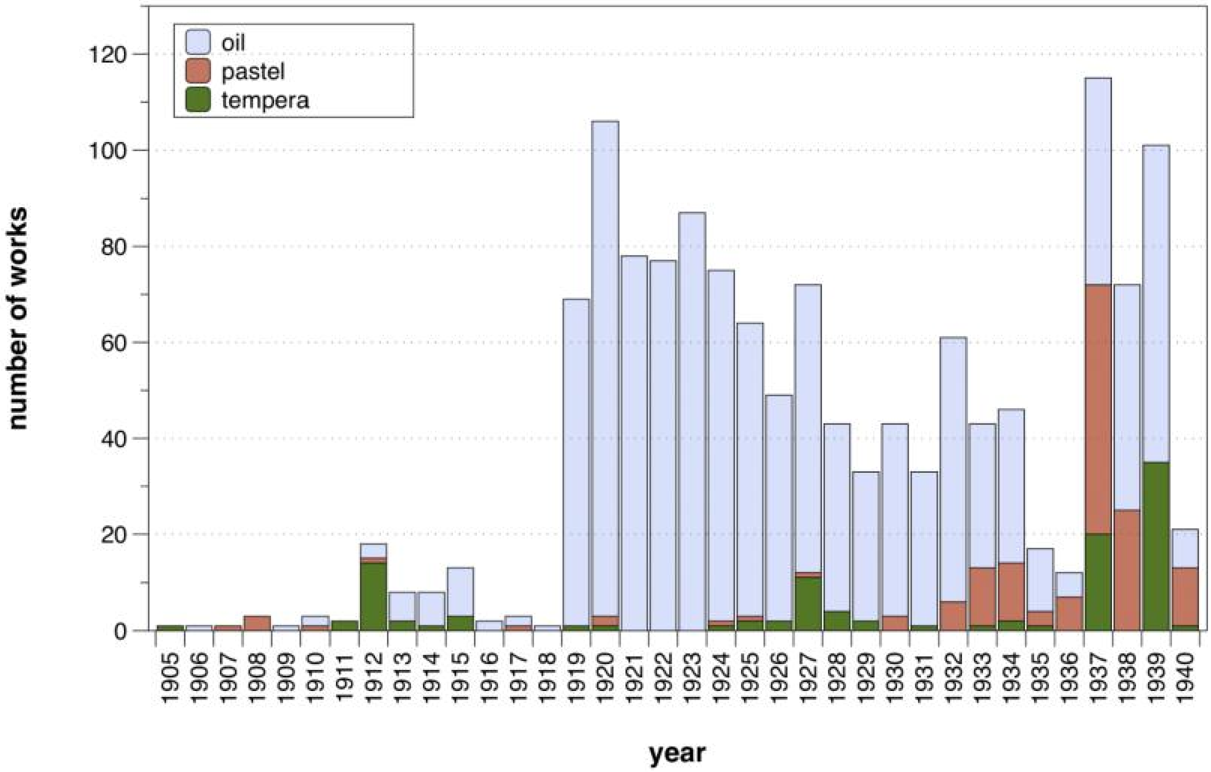

Figure 1 Graph showing Paul Klee's annotations of oil, pastel and tempera in the handwritten catalogue of his works. Tempera appears in the catalogue from 1905 but he had mentioned the technique earlier in his diaries. Around 1912 and in the late 1920s, tempera crops up comparatively often in the catalogue while the pastel technique was recorded only occasionally from 1907. Numerous entries were made in the early 1930s. Both tempera and pastel are noted mainly in the years 1937–1940.

example dated 1908 is 'pencil toned with pastel, poor paper' referring to the poor quality paper Klee mounted on cardboard.[3] From 1917 on, some notes include pastel on wet supports, glue fixatives and varnishes.[4]

In 1920 Klee used the term 'pastel colours' for the first time instead of just 'pastel'.[5] These exemplary notes demonstrate the artist's interest in modifying, combining and constantly reinventing the techniques following his artistic interests. In 1936, for health reasons, Klee spent about 10 weeks in the Valais mountains, Montana, with his wife Lily. At that time, his illness had been noted although not yet diagnosed as scleroderma. He produced very little work that year: according to Lily, 'Klee did not work at all, even though he brought his beautiful pastel-sticks to Montana.' However, the statistics clearly show that the disease could not have been the sole motivation for his use of the pastel technique: the increase in pastels compared to oil and tempera had started earlier. Klee's health stabilized in 1937, the year in which he recorded by far the most pastels in the catalogue. He had a secure income during this period, which to a large extent allowed him a free choice of technique.

Tempera and pastel in Klee's later work

The painting *Flora on the Rocks* (Fig. 2), dating from 1940, was the final painting for which Klee used the term 'tempera' in the handwritten catalogue and the last easel painting listed in that year. At first glance, the details (Figs 3 and 4) reveal a variety of surface effects related to the material and application. The texture of the fabric is materially present as a loosely woven and fibrous structure. The multifaceted intense colour effect is, in its turn, overlayered by structures resulting from the fibrous fabric, the porous matt surfaces and the brushwork.

The question arises as to what was executed in oil and what in tempera. Interestingly, material

Figure 2 Paul Klee, *Flora on the Rocks*, 1940, 343 (F3), 90 × 70 cm, 'Tempera and oil paints, jute on stretcher', original frame, Museum of Fine Arts Bern. (Image: Nathalie Bäschlin.)

analysis[6] does not reveal any significant differences between the binder systems: the primary binder contains oil and protein in varying proportions. The ground, the green paint layer and the white layer contain a lot of protein, while the glaze-like layers contain more oil. The white layer and the green layer also contain some starch. The proportion of saturated hydrocarbons, that varies regardless of the oil content, is probably due to a local wax coating, a technique often used by Klee in his later work.

The technique of *Legend of the Nile* (Fig. 5), dated 1937, is indicated as 'pastel colours on white cotton on jute'. Typical for Klee is the unusual picture-support combination: he stuck a piece of white cotton on a larger, stretched piece of jute. It is interesting that different application techniques can be identified (Fig. 6). The dark blue areas suggest a dense, repetitive stroke with pastel sticks. The pale pastel colours, blended with white, and the ochre lines also have areas in which the material was somewhat fluid and was worked with the brush. The texture of the picture support and the fibrous quality of the fabric were additionally emphasized and exaggerated by the strong strokes with the pastel sticks. They are overlayered with powdery, colour-intense pigment conglomerates. Klee applied the pale ochre border as an opaque layer with a palette knife.

The material analyses are also very revealing and indeed surprising: in the main, even the pastels comprise a lean system of oil with some protein content. The proportion of oil varies greatly: saturated hydrocarbons are sometimes included, not necessarily correlating with the oil content. A wax additive or subsequent coating of wax cannot be ruled out. What is also of note is the firm proof of a small proportion of shellac.

Brief historical review

A few individual sources make clear that a comparison of tempera and pastel in terms of their colour

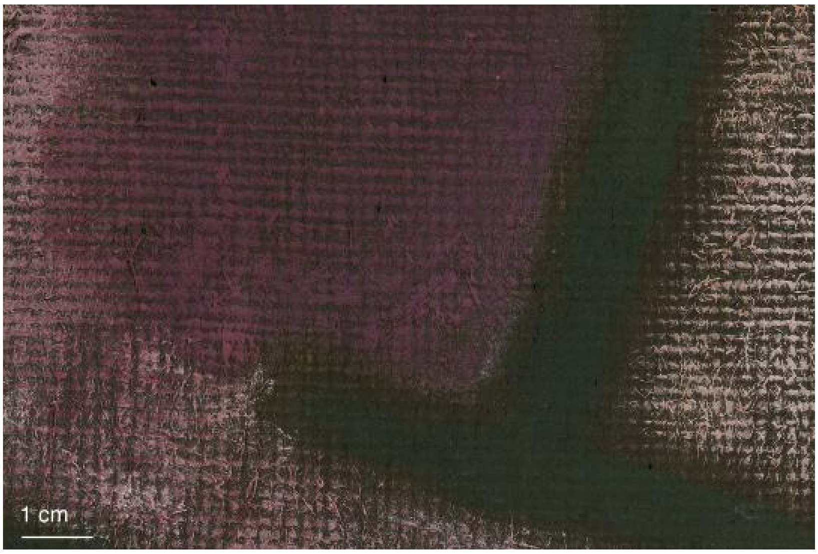

Figure 3 Paul Klee, *Flora on the Rocks*, detail. Klee primed the jute fabric with a dark layer of paint. The fabric texture is additionally exaggerated by the dry application of the white layer which lies only on the tops of the fibres. This creates a grid reminiscent of cloth prints. The high colour saturation produces a matt but intense colour effect. (Image: Nathalie Bäschlin.)

Figure 4 Paul Klee, *Flora on the Rocks*, detail. There are pale opaque colour areas whose surface is structured not by the underlying fabric but by the manner in which the paint was applied with the brush. The intense colour effect in these areas is the result of the layer system, which consists of an underlying white layer and a thin, intense colour glaze that allows the pale background to shine through. (Image: Nathalie Bäschlin.)

effect is by no means new: in 1681, under '*Pastelli*', Filippo Baldinucci in the *Vocabolario toscano dell'arte* describes the production of pastel sticks with pigments, fillers, gums and sugar. Within this context the final remark is interesting: '*lavoro che molto s'assomiglia al colorito a tempera e a fresco*' ('work very similar to the colouring of tempera and *a fresco*'). The colour effect of pastel, according to Baldinucci, is comparable to tempera and fresco (Baldinucci 1681: 119).

The comparison with tempera and the fresco technique shows that the matt colour effect and the bright colours were associated with the method. Baldinucci explains the term 'tempera' primarily as comprising a mixture of purely aqueous constituents or ox gall or egg white (Baldinucci 1681: 162).

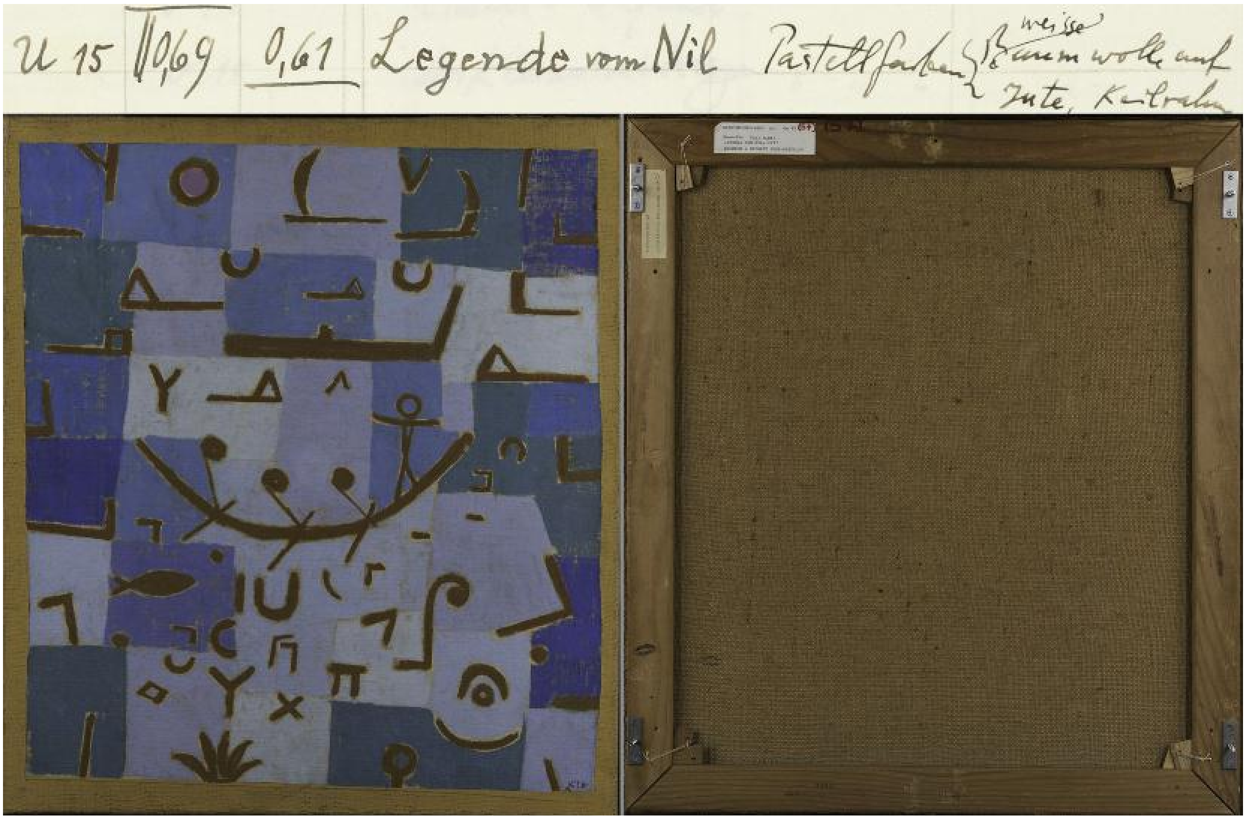

Figure 5 Paul Klee, *Legend of the Nile*, 1937, 215 (U1 5) 69 × 61 cm, 'Pastel colours on white cotton on jute, stretcher', Margrit und Hermann Rupf-Foundation, Museum of Fine Arts Bern. (Image: Nathalie Bäschlin.)

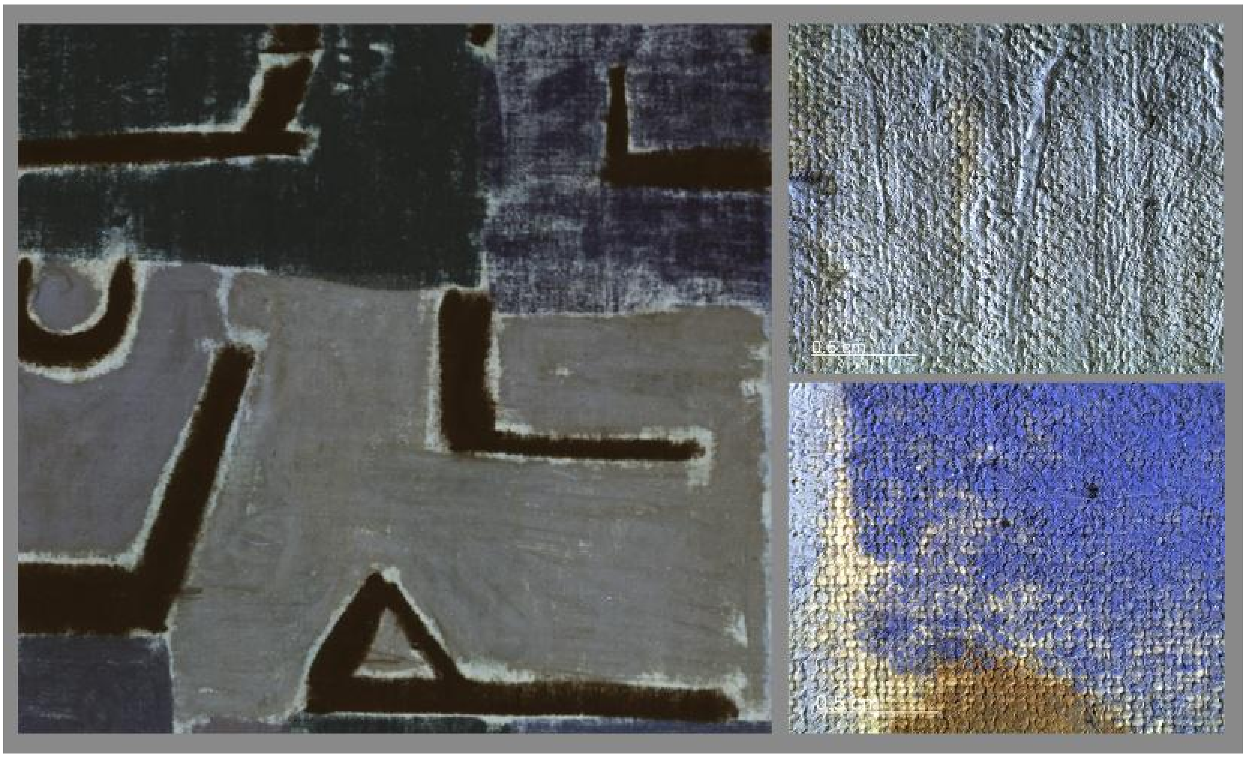

Figure 6 Paul Klee, *Legend of the Nile*, detail in UV fluorescence contrasts the pale pastel colours worked with the brush, also seen in the detail in visible light (top right). The blue pastel paint however, shows a striking density of pastel pen strokes. (Image: Nathalie Bäschlin.)

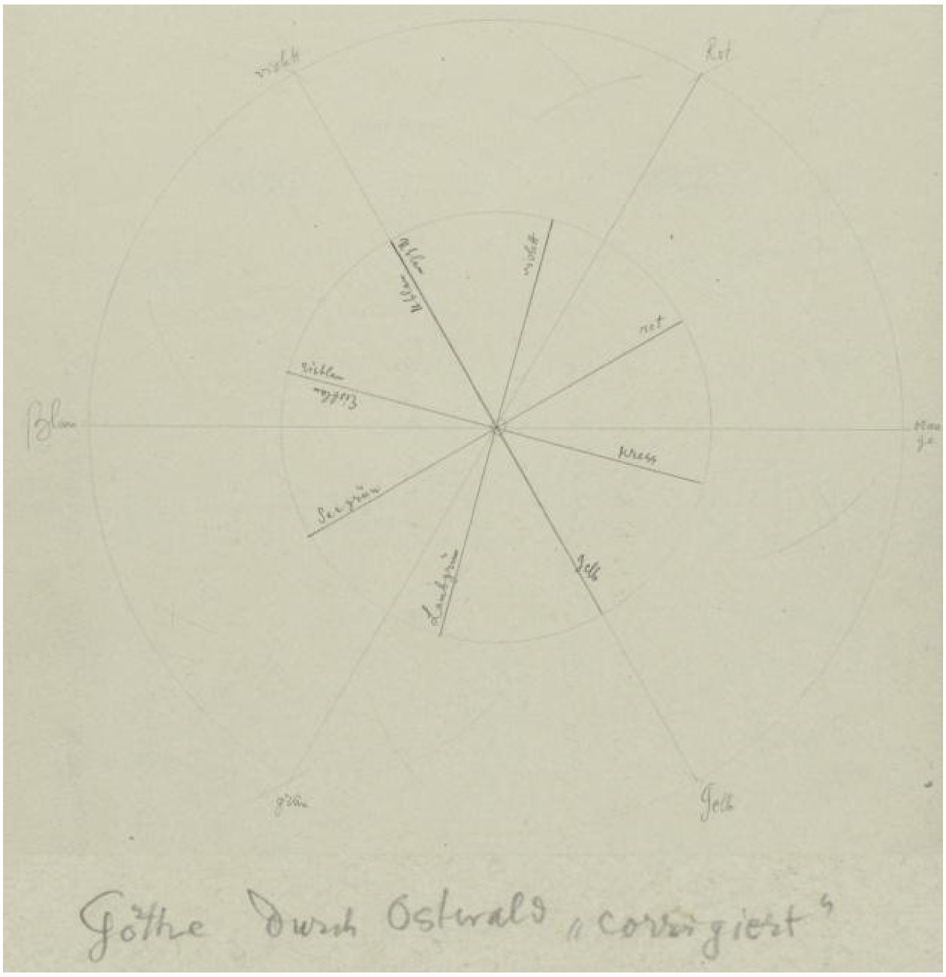

Figure 7 Paul Klee, *Goethe as 'corrected' by Ostwald*, detail. Pedagogic legacy: I.2 Principal order, inv. no. BG I.2/165, pencil on paper (flyer, 1st page), 33 × 21 cm, Zentrum Paul Klee, Bern. (Image: Zentrum Paul Klee.)

Regardless, it is clear that Baldinucci's comparison of the two techniques was not referring to a fat, oily tempera, but addressing the specific effect resulting from light scattering on the surface of aqueous paint layers paint and fresco painting.

Traité de la peinture au pastel by Paul-Romain Chaperon, dating from 1788, was based on a desire to establish pastel painting alongside 'brush painting'. The ease of use and the speed of working without paint thinners, brushes and foul odours are highlighted as advantageous. For these reasons, pastel became an established technique used both for leisure painting and by artists who wanted to quickly capture movement, light and rhythm. *Traité de la peinture au pastel* characterizes pastel painting as 'facile' and 'amiable' (Chaperon 1788: 13); other properties seen as positive are its 'amiable lightness' in the sense of airy, soft and light. Its only shortcoming is its uncertain durability. Efforts to identify a suitable fixative that would not destroy the powdery surface are reminiscent of the experiments, debates and secret formulas surrounding the rediscovery of tempera painting.

Edgar Degas's systematic experiments on a wide range of artistic techniques are well documented. Investigations by Fletcher and Desantis (1989) and Townsend (1998) of Degas's pastel technique attest to the use, alongside numerous fixatives, of resinous, proteinaceous mediums and gums. Pertinent to the current discussion, it is significant that at a very early stage Edgar Degas as well as Edvard Munch combined pastel with brush painting: sources report that Degas wetted pastel sketches with steam and further processed the moistened pastel grains with brushes. Studies demonstrate a layering technique that brought together pastel stick painting, pastel brush painting, tempera and gouache (Fletcher and Desantis 1989; Townsend 1998; Singer *et al*. 2010).

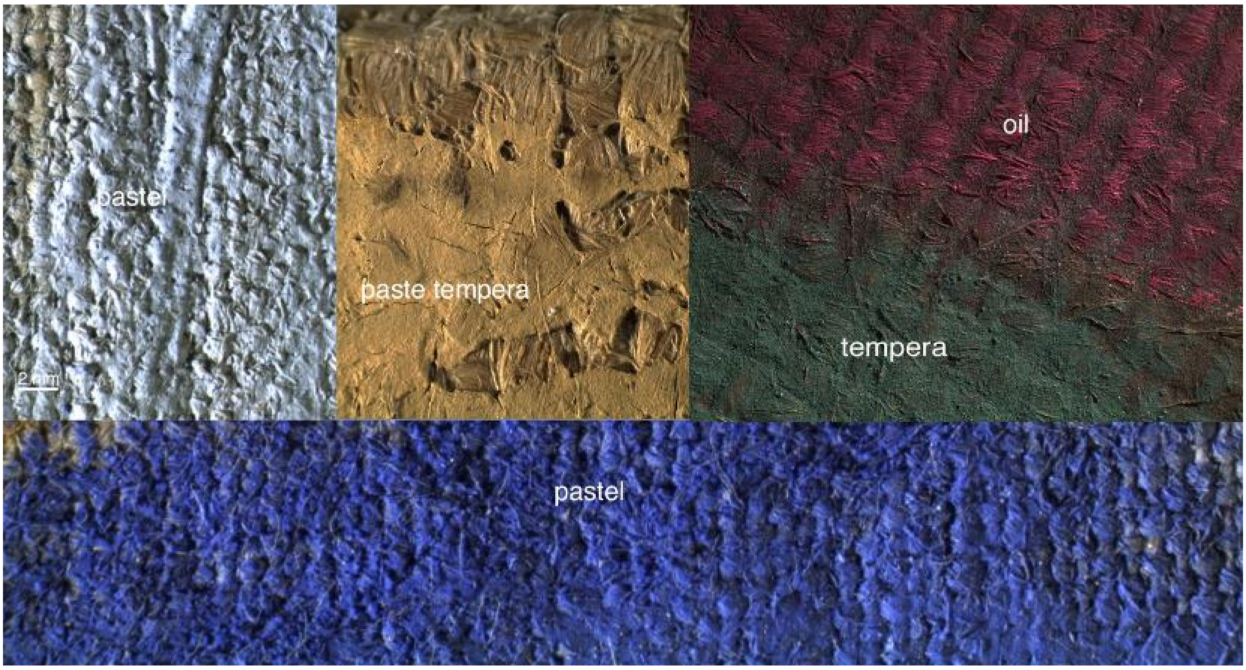

Figure 8 It seems likely that pastel and tempera painting enabled Paul Klee to delve deeper into variations in the colour effect and the possible correlations between the colour effect and the structures of the picture support. (Images: Nathalie Bäschlin.)

Paul Klee and Wilhelm Ostwald

The earliest written evidence of Klee's use of pastel crayons dates back to 1904. He first mentioned them in a letter dated 28 June to his wife Lily, inspired by his admiration for the recently published *Letters to a Painter*, in book form, by Wilhelm Ostwald:

> Upon my recommendation, the father [of Lotmar] obtained a painting book by the famous chemist and physicist Ostwald; it is an excellent scientific reference for everything that is technical; I am currently reading it with great pleasure. Also, it contains wonderful recipes, such as how to prepare one's own pastel sticks. The form of the work is very appealing, divided into letters, giving it a literary flavour. The style is magnificent. The man has to be an experienced artist himself (Klee 1979: 430).[7]

Wilhelm Ostwald, a scientist, saw himself as a modern specialist in painting technique and photography, basing his formulas on the results of scientific experiments. His instructions in painting technique were modern considering the time. Ostwald brought a new, fresh view of a scientist who ignored the traditional genre boundaries. He met the artist on equal footing and was able to convey, in a way that was easy to understand, the scientific foundations that seemed to be useful for artistic experiments. Klee was fascinated by the experimental approach and the close connection of photography, drawing and painting. His layered style of painting on a light ground, his 'pointillizing', and the reduction in binder content – all typical features of his painting – were recommended by Ostwald. The two men's understanding of tempera and the attention they gave to pastel painting can also be considered as linking elements (Ostwald 1904: 65–75, 121, 134–6, 144). But Klee's pastel painting differs from tempera painting in the method of application and the lower oil content. The binder systems used, however, are identical: Ostwald favoured binders that were used with water, referring to all of them as tempera, a description that can also be applied to Klee's later work.

The blue and purple fields and the ochre symbols in the *Legend of the Nile* display a striking density of pastel strokes: 'care must be taken that each stroke or spot is a strong colour mass, not a superficial breath' (Ostwald 1912: 7). Ostwald recommended the technique for all possible supports. He considered structured wall plaster, or paper and fabric with a pronounced texture particularly suitable because the pigments adhered well to them. The pastels were be made with chalk, pigments and glue water (gums). He found the tension created by the interplay of opaque colour areas and those that allowed the ground to shine through attractive. As a fixative Ostwald recommended subsequent impregnation or spraying with an aqueous glue and also mentions shellac. He later extended his convincing plea for pastel as a widely applicable artistic technique to architectural design. He published a book entitled *Monumentales und dekoratives Pastell* (*Monumental and Decorative Pastel*) in 1912 in which he explained the colour application, pigments, fixing and in addition, paraffin coating.

In the 1910s, Klee experimented with pastel wet-in-wet and with pastel on wet paper. He also mentions varnishing and glue as a fixative. Interestingly, the material analyses refer to wax and shellac as fixatives. In his early writings Ostwald first recommended shellac and later wax. In the 1930s the combination of aqueous techniques with pastel colours led to the mention of 'pastel colours' and 'pastel colours bound with paste', including a combination of pen and brush painting on various textured supports, as seen in the *Legend of the Nile*. The new pastel painting technique also resulted in a shift in connotation and evaluation. In 1894, Professor Karl Raupp – from today's point of view a rather old-fashioned representative of the Academy of Fine Arts in Munich – described pastel painting as a method that was suitable 'for grateful reproduction of graceful feminine virtue, and of the naive world of a child' (Raupp 1894: 81).

In 1904, Ostwald proposed a quite different argument: he considered it an advantage that the 'natural hardening of the pastel in the fixing process counteracts the danger of soft work' (Ostwald 1904: 30ff.), suggesting that it was no longer the soft transitions of the technique, but only their effect on colour that made it valuable. Although Klee had been deeply interested in the 'early' Ostwald, he vehemently rejected the 'late' Ostwald. He sharply criticized Ostwald's research into increasing the efficiency of colour mixing on the basis of a standardized colour scale. In 1920 he even penned a devastating article on Ostwald's colour theory in a special edition of the journal *Das Werk: Mitteilungen des Deutschen Werkbundes* (Klee 1920), and he created the ironic sketch *Goethe as 'corrected' by Ostwald* (Fig. 7).

The fervent rejection of Ostwald's theory of colour should also be considered in the context of the controversy at the Bauhaus. László Moholy-Nagy and Walter Gropius were fascinated by Ostwald, who regarded art as applied science, a view with which they strongly disagreed (Pohlmann 2010: 366–85).

'The precise plays a leading role'

It may not seem immediately obvious that Ostwald's innovations in painting technology should have accompanied Klee's painting technique as far as the 1930s but current art-historical research into Klee has found support for this thesis. It would appear that Klee did not develop any surprising or independent new theoretical ideas but continued to use selected theoretical approaches independently and for a very long time. Books that Klee consulted early on – such as Goethe's theory of colours, teachings on morphology or mysticism – are said to have interested him well into the 1930s. Eggelhöfer grants Klee no theoretical independence: in her opinion he had sought a synthesis of science and intuition (Eggelhöfer 2012: 36ff., 87ff., 104–8). Wedekind emphasizes that although Klee had the ability to develop artistic theories, he was not interested in them (Wedekind 2014: 92ff.).

Ostwald's motivation to popularize the pastel technique among artists lay in his conviction that it was particularly durable from a chemical point of view (Ostwald 1912: 23ff.). In 1909, the chemist Alexander Eibner (professor and head of the Experimental Institute for Painting Technique at the Technical University in Munich) referred to the pastel technique in *Malmaterialienkunde als Grundlage der Maltechnik: für Kunststudierende, Künstler, Lackierer, Fabrikanten und Händler* (*Painting Materials as a Basis of Painting Technique*) in the introduction of binding and covering agents and commented in detail on Ostwald's pastel technique. He claimed that Ostwald's prognosis was only valid if the pastels are protected from mechanical influences and high-quality, lightfast colours are used. Eibner gave an extremely critical assessment of the possibilities of technical application, stating that pastel painting is very limited and completely unsuitable for glaze painting, for example. Ostwald's plausible conclusion that less binder leads to less yellowing, however, was confirmed by Eibner (1909: 12). Klee's preference for underbound paints has been established several times in the context of art-technology research. Measurements on samples from the paint layers of the *Legend of the Nile* and *Flora on the Rock* revealed a very small amount of binder in the powder pigment conglomerates.

In 1914, the Dresden artist Wolfgangmüller published an article in the *Technische Mitteilungen für Malerei* entitled '*Warum neue Maltechniken?*' ('Why new painting techniques'), that argued for a move away from oil painting towards modern aqueous techniques, pastel and paraffin painting. Essentially his reasoning was based on the lament upon the yellowing and browning of oil previously cited by Ostwald, an opinion that won widespread approval in artistic circles at the time (Wolfgangmüller 1914). Eibner considered Wolfgangmüller's argument non-scientific and called for a more precise, chemically scientific presentation. He also demanded research into the causes and dissemination of material knowledge, which could help artists to make better, more informed use of oil which, in his view, was still a highly valuable painting medium. The arguments exemplify the historically anchored, recurrent discussion on the disintegration of the craft tradition. From our perspective it is particularly interesting that the motivation behind the re-evaluation of watery, matt and low-binder painting, as propagated by Wolfgangmüller, shows a shift in the content of the technical discourse. In addition to the newer, more strongly represented scientific support and the discussion on the painting media of the Old Masters, which was taken up by the majority of conservative artists of the 19th century, the reassessment of the effect of colour and the increase in its durability by turning away from traditional oil painting comes to the fore. The perception of, or the striving for, permanent painting in the environment of the innovative painting technicians around Ostwald thus concentrated primarily on a lasting, intense colour effect.

Which of Klee's approaches to painting techniques (Fig. 8) were reflected in his teaching? Petra Petitpierre's notes from Klee's painting class are very important in this respect: they confirm his openness in the choice of materials and technology while at the same time reminding us of the greatest possible precision. Petitpierre quotes Klee as follows: 'The question arises: What does technology contribute to the spiritual sense? Then there is the other specific question in the chemical aspect and that of shelf life … But precision still plays a leading role' (Petitpierre 1957: 16).

According to Petitpierre's notes, Klee seems to have treated the terms equally, depending on the situation. The simultaneous demand for high colour saturation, its resistance in the chemical sense and the acceptance of increased fragility with regard to mechanical resilience are not mutually exclusive. The inclusion of poor quality materials, as explicitly mentioned by Klee in his handwritten catalogue of works, and the question of durability are equally important. Weighing up and connecting these opposing poles ensures the highest possible precision.

Notes

1. See P. Zeppetella, S. Zumbühl and N. Bäschlin, '"Then egg, then watercolour or tempera paints, then alcohol resin": Paul Klee's tempera painting techniques', in this volume.
2. *Ibid*.
3. *Portrait of a Pregnant Woman*, 1907, 25, 25.5 × 34.2 cm and *Head of a Girl, Profile*, 1908, 45, 24 × 32 cm.
4. For *Carpet* 1917, 70, Klee mentioned 'pastel wet in wet/ thin japanese paper' and for *With the Water Carrier*, 1920, 10, 'pastel on wet paper, varnished, wrapping paper'.
5. *A Boy in Young Forest*, 1920, 16, 'pastel colours on wet paper, then fixed with glue'; *Colour Table (in Grey Major)*, 1930, 83, 'pastel colours bound with starch'; *Late Glowing*, 1934, 29, 'pastel colours on wet damask'; *Solo Scene*, 1934, 30, 'pastel colours on wet cotton'.
6. The analytical methods applied are described in P. Zeppetella, S. Zumbühl and N. Bäschlin 2019 (see note 1 above).
7. Paul Klee refers to Chapter III, 'Selbstherstellung der Pastellstifte' (Ostwald 1904: 23–36). The assumption that Ostwald was an 'experienced' artist must have led to disappointment later. Ostwald's artistic work was not recognized generally or by representatives of the avant-garde artists in particular. László Moholy-Nagy, who appreciated Ostwald's theory of colour and his understanding of art as applied science, is said to have made very negative comments about Ostwald's artistic works: 'He wants to revolutionize art, and he paints flowers himself' (Pohlmann 2010: 504)

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Authors' addresses

- Nathalie Bäschlin, Museum of Fine Arts Bern, Bern University of the Arts, Bern, Switzerland (Nathalie.Baeschlin@kunstmuseumbern.ch)
- Stefan Zumbühl, Bern University of Applied Sciences, Bern, Switzerland (stefan.zumbuehl@bfh.ch)

Edward Steichen's last temperas

Abbie N. Sprague

ABSTRACT In 1923, Edward Steichen and his gardener ransacked the studio in Voulangis. Lighting a match, the paintings crackled in the flames. Only a handful escaped. This end to Steichen's painting career became a legend. In 1910, Agnes and Eugene Meyer commissioned murals for their New York townhouse. *In Exaltation of Flowers* (1910–1914) was inspired by Steichen's love of gardening and his circle of artists in Voulangis. Turning his back on the tonalist style, Steichen chose a modernist composition with large flat planes. These are his earliest temperas. Recent archival and technical research has shed light on Steichen's working methods. By examining Steichen's last temperas, this paper explores the intersection of medium and style in the relatively unknown output of an overlooked precursor to the American tempera revival.

Introduction

In the early winter of 1923, Edward Steichen (1879–1973) and his gardener ransacked the house and studio in Voulangis for any remaining paintings (Niven 1997: 497). In the garden, they built a bonfire and watched the paintings melt and crackle in the flames as they danced wildly around it. Two decades of canvases were fed to the fire. Steichen later estimated that this kindling could have been sold for over 50,000 dollars:[1] the initial shock brought tears to Steichen's eyes, but then he began to sing an old wartime song 'Where will we all be one hundred years from now?' (Sandburg 1929: 44). This dramatic and fiery end to Steichen's painting career quickly became an art history legend.

Early experiments

Éduard Jean Steichen was born in Bivange, Luxembourg, but at the age of two his family immigrated to the United States and soon settled in Milwaukee, Wisconsin (Niven 1997: 66).[2] As a teenager he was apprenticed to a lithographer and in his free time, he taught himself how to draw and paint (Niven 1997: 28). He was 16 when he bought his first camera. On his way to Paris in 1900, Steichen stopped in New York City where he sought out Alfred Stieglitz (1864–1946), whose journal *Camera Notes* was a young Midwesterner's window into the world of art photography.[3] The two men immediately connected over their aspirations for elevating the status of photography. Stieglitz recognized that the work of this young painter-photographer might further the cause. Over the years, they collaborated on publications and influential exhibitions, bringing modern art to America.[4]

At the beginning of his career, Steichen exclusively used oils for his canvases – he did not experiment with tempera until his early 30s. In his formative years he embraced the trends of the *fin de siècle*. This was Steichen's symbolist period when his canvases were 'wrapped in a tonalist palette of muted greens and blues' (Torosian and Greenberg 2011: 5). In his photographs, he experimented with techniques, blurring the lines between painting and photography, and between fine art and technology.

Voulangis: a place of inspiration

In the spring of 1908, Steichen and his family rented a house and garden 20 miles east of Paris in a town called Voulangis. It was an escape to the country, but only a short train ride away from the bustling epicenter of the modern art world. Admiring the work of Maurice Maeterlinck (1862–1949), he affectionately christened the house Villa L'Oiseau Bleu.[5]

Over the next 20 years, Voulangis became a place of happy family memories, a place for learning and exploration in his garden, and a sanctuary from the realities of war (Torosian and Greenberg 2011: 12).[6] Visitors to Voulangis recalled a rambling spacious house, guests arriving and departing, a walled garden edged on one side with tall trees, and a sunlit studio for Steichen's ongoing work. Spontaneous and animated conversations at dinner with friends and muses often turned into impromptu musical performances (Hardesty 2013: 20). Its close proximity to Paris made it an easy retreat for his fellow artists: Constantin Brancusi (1876–1957), Auguste Rodin (1840–1917), Arthur Beecher Carles (1882–1952) and John Marin (1870–1953) were among his frequent visitors (Niven 1997: 288).[7]

Over the years, Steichen returned to Voulangis for inspiration and refuge. In the winter months, he and his family would travel back to New York City and sell enough art to allow them to remain in France for the rest of the year. Perched high upon a wooden column carved from a tree fallen on the property, Brancusi's *Maiastra* (1911) guarded the house and garden in their absence.[8]

Throughout his early career, Steichen experimented with a variety of media, switching fluidly between painting and photography. In his 30s, his search for a new distinctive style drove Steichen back to the fundamentals of materials and techniques, and with it his discovery of tempera. In 1910, his newlywed friends Agnes and Eugene Meyer (later owners of *The Washington Post*) commissioned seven large-scale murals for their New York City townhouse. *In Exaltation of Flowers* (1910–14) was inspired by Steichen's love of gardening and the circle of artists and intellectuals who visited him at Voulangis.

He executed the figures and flowers in tempera and oil and set them against a gilded background. The faint tile-like pattern of the large metallic planes catches the light and reveals Steichen's method of applying standardized sheets of gilding to his canvases. His friends, including Agnes, became his models and muses, while the flowers depicted – the petunias, delphiniums, lilies, and irises – came from his garden and were imbued with symbolism and inside jokes among the close-knit group. Turning his back on the tonalist style of his earlier paintings, those muted hazy tones of blues and greens, Steichen chose a modernist composition with large flat planes of color and distinct outlines, a style that lent itself to tempera, as exemplified in one of the central panels *Petunia, Caladium, Budleya* (Fig. 1). The seven panels for *In Exaltation of Flowers* are his earliest surviving tempera paintings.

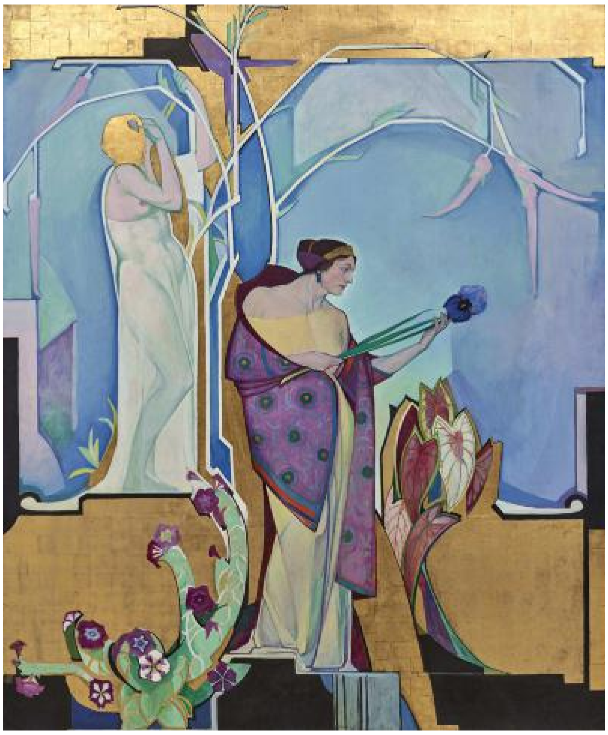

Figure 1 Edward Steichen, *In Exaltation of Flowers: Petunia, Caladium, Budleya* (1910–14), Art Bridges.

Due to financial problems, the murals were never hung in the Meyers' New York townhouse. For years they languished in the damp basement of their country house in Mount Kisco, New York and then in storage at the Museum of Modern Art, New York. The murals were de-acquisitioned and recently acquired by Art Bridges, a foundation established in 2017 by Alice Walton. Extensively researched by Sue Canterbury and painstakingly conserved by Laura Hartman and her team in the summer of 2017, the murals were exhibited at the Dallas Museum of Art from September 2017 to May 2018.[9]

Figure 2 Edward Steichen, *Le Tournesol (The Sunflower)* (1920–22), Gift of the Collectors Committee, National Gallery of Art, Washington 1999.43.1.

Figure 3 Edward Steichen, *Study for 'Le Tournesol (The Sunflower)'* (*c.*1920), Gift of Joanna T. Steichen, National Gallery of Art, Washington 2007.123.1.

Voulangis: the refuge

After serving in the United States Army during the First World War, Steichen returned to Voulangis (Niven 1997: 490). Like many of his generation, he was disillusioned and disheartened by the atrocities he had witnessed. The garden became his refuge for 'deep, earnest soul-searching' (Steichen 1963: 4). His brother-in-law Carl Sandburg (1878–1967) wrote to a friend that 'Steichen is painting flowers near Paris, and says if he keeps on, some day he may do something worth looking at' (Mitgang 1968: 192).[10]

This return to Voulangis marked a unique period in Steichen's career. He was not publishing or selling his work. He was not exhibiting. Steichen was free to explore, research, and create for himself. Nestled on the outskirts of Paris, he could carry out his ongoing experiments in form, color and value in three media: his paintings, his photographs, and his plants. His photography and painting took a new direction. Combining his passion for color, and his newfound study of spirals as found in nature, Steichen created the iconic tempera painting *Le Tournesol* between 1920 and 1922 (Fig. 2).[11] Soon after its completion, he gifted the work to a fellow painter and decorative arts designer Francis Jourdain (1876–1958), thereby saving it from that fateful bonfire.

Le Tournesol: rediscovered

Le Tournesol remained with the Jourdain family, quietly tucked away for over half a century. In 1985, it was sold to the New York art dealer Robert Miller, who hung it in his home for over a decade before selling it to the National Gallery of Art (NGA), Washington DC in 1999. The painting has become a treasured piece of the collection and rarely travels. Hanging in the museum, next to other key paintings of American modernism, *Le Tournesol* has been rediscovered.

In 2007, a bequest of 22 works of art to the NGA from Steichen's widow Joanna more than tripled the number of known tempera paintings by Steichen. The donation included two studies for *Le Tournesol* and 16 paintings for Steichen's Oochens series. Over the course of 10 years, Jay Krueger at the NGA conducted conservation work on the sunflower paintings. In *Le Tournesol*, Krueger observed that Steichen used thin direct applications of oil and tempera on a pre-primed linen canvas.[12] The S*tudy for Le Tournesol* (*c.*1920) was treated in 2008 (Fig. 3).[13] Due to condition issues related to a fire,[14] the

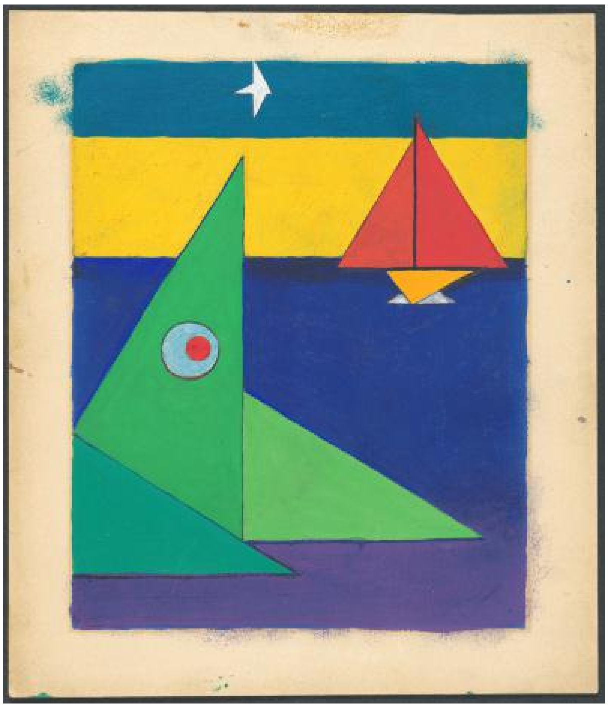

Figure 4 Edward Steichen, *The Colossal Deep Sea Ludicrocerous* (*c.*1922), Gift of Joanna T. Steichen, National Gallery of Art, Washington 2011.85.8.

Figure 5 Edward Steichen, *The-Pup-Who-Sacrificed-a-Piece-of-His-Head-So-He'd-Have-a-Tail-to-Wag* (*c.*1922), Gift of Joanna T. Steichen, National Gallery of Art, Washington 2011.85.2.

sunflower study was examined and then stabilized. As Krueger reported:

> Analysis of the paint indicated that both oil and tempera are present. Samples of the red paint and an underlying blue paint were found to be in oil, while a combination of egg and oil are contained in samples taken from the green paint from the leaves.[15]

The Oochens is a group of illustrations Steichen created around 1922. Inspired by Jay Hambidge's (1867–1924) *The Diagonal*, Steichen experimented with cutting a rectangle into three triangles and creating what he called 'curious shapes'.[16] These soon developed into the Oochens – a fanciful world inhabited by these triangular creatures. Two examples are *The Colossal Deep Sea Ludicrocerous* (*c.*1922) and *The Pup-Who-Sacrificed-a-Piece-of-His-Head-So-He'd-Have-a-Tail-to-Wag* (*c.*1922) (Figs 4 and 5). Not sure whether or not these characters were for kids, or for as he called them, 'grown up kids', Steichen never published them and they remained with his widow until her death (Niven 1997: 493). Steichen took the seemingly fictitious name Oochen from the Luxembourgish word for Aachen, an Old

Figure 6 Edward Steichen, *Rabbit (Le Tournesol)* (*c.*1920), Gift of Joanna T. Steichen, National Gallery of Art, Washington 2011.85.16.

German term for river or stream. In a rare comment on his use of a particular medium, Steichen later reminisced: 'In the small tempera paintings I made of the Oochens, I experienced a sense of freedom I had never experienced before.'[17] Steichen's newfound freedom extended to *Le Tournesol*, in which he adopted a new color palette of vibrant greens, cobalt, cerulean blue, and vermilion. The Oochens and the sunflower paintings are set among a backdrop of diagonal lines and triangles, forms that dominated Steichen's imagination and his recent study of geometry. Medium followed form and he chose tempera for these works.

Another work in this bequest was a painting called *Rabbit (Le Tournesol)* (*c.*1920) a work that can be described as somewhere between the bold and vibrant *Le Tournesol* and the whimsy of the Oochens (Fig. 6). Linda Owens from the Baltimore Museum of Art and Kathryn Morales from the NGA collaborated on the conservation of several of these Steichen temperas. Samples taken from *Rabbit* and several from the Oochens showed the presence of plant gum binder with no traces of protein.[18] For logistical reasons, paint samples were not taken from every painting in the series, but given the uniformity of appearance and the very matte surface, Owens and Morales are confident that they do not contain any egg protein either.

These results, of course, came as a surprise, as Steichen specifically referred to these works as temperas. The Oochens are, however, instead in a matte, opaque, water-based paint. This calls into question the use of the term 'tempera', which is an ambiguous term. In the United States, and particularly in the case of the British tempera revival, the term was used dogmatically to refer to egg yolk as a binder. However, in Europe the term is used in a broader sense to include any medium freely diluted with water.

Steichen: the tempera painter

Although Steichen is heralded as an American artist, he was born in Luxembourg, self-taught in Wisconsin, and entrenched in the modern art world of Paris during the first two decades of the 20th century. Therefore, his use of the term 'tempera' might be more European: after all, it is most likely that he was introduced to the medium in Paris. Like Henry Ossawa Tanner (1859–1937), Steichen, in his use of tempera, was an outlier and precursor to the American tempera revival, a movement that did not start gaining traction until the 1930s.

To label Steichen a tempera painter is complicated. Throughout his career, he switched effortlessly between media, between painting and photography, and between oil, watercolor, and tempera. Understanding Steichen's use of tempera is not as simple as finding a technical manual on his methods and processes. He did not discuss his techniques and materials on purpose: 'Let it not be the medium we question, but the man' (Steichen 1901: 5).[19] Because Steichen left no written account, to fully understand what he meant by tempera and the combinations of egg and oil he used in his paintings can only be accomplished by further scientific studies of his work.

The bonfire: new evidence

The apocryphal fiery end to Steichen's painting career has endured several retellings over the years, many of these embellished versions retold by Steichen himself. In 1928, only a few years after the actual event, Steichen described what happened to his brother-in-law. A year later, Sandburg related the story in his 1929 biography on Steichen:

> Steichen is now about ready to quit painting, to swear off brushing oils and pigments on canvas. One morning his gardener places before him on the breakfast table a painting, a copy of a Steichen picture. "Where did that come from?" Steichen asks François, a Breton peasant in wooden shoes, an ox of a man raised on potatoes and cabbage. "I did it," replies François. "You painted that picture?" "Yes." "Why," shouts Steichen, "it is better than mine!'" (Sandburg 1929: 42–3).

Sandburg continued: 'Steichen buys the painting from François. He keeps it. Years pass and many throwouts go to the trash cans. But the François painting is kept as a treasure, a mascot, a signpost, a guidon, a talisman.' As Steichen said, 'It was the one thing needed to finally convince me that so far as I was concerned painting was the bunk' (Sandburg 1929: 42–3).

To blame François for the end of Steichen's painting career would be overly dramatic. Steichen's move to photography was a gradual evolution. In his 80s, Steichen reminisced about this period of his career:

> Painting meant putting everything I felt or knew into a picture that would be sold in a gold frame and end up as wallpaper. The statement I had made so spontaneously to Steiglitz in 1900, "I will always stick to photography!" rang in my ears. It was true. Photography would be my medium. I wanted to reach into the world to participate and communicate, and I felt I would be able to do this best through photography (Niven 1997: 502).

Every once in a while, during the process of researching a topic, you serendipitously come across a little nugget – something you never expected to find. I assumed that Sandburg's story was just another embellished account of the bonfire story but while in New York researching Steichen's papers in the Museum of Modern Art archives, I came across two paintings: a still life and a copy of *Le Tournesol* (Fig. 7). Inscribed on the back of the still life, an oil on cardboard, in Steichen's unmistakable handwriting, are the words 'painting by François my gardener at Voulangis'.

The back of the sunflower painting, however, has no such inscription. But the hesitant execution and haphazard technique (major flaking is visible in the upper right and lower left-hand corners) makes a compelling case that this sunflower was the work that Steichen described as 'its simple, crude way, had something that my painting didn't'.[20] This was the work that convinced Steichen to turn his back on a painting career. Scientific analysis would be needed to determine what medium was used for the sunflower painting. Nonetheless, it is exciting to come across this kind of physical evidence to verify a myth and to shore-up an art history legend.

Figure 7 Copy of Steichen painting by François (*c*.1920) Edward Steichen Archives, The Museum of Modern Art, New York, NY, USA (Digital Image © The Museum of Modern Art/Licensed by SCALA/Art Resource, NY.)

Conclusion

Steichen's use of tempera coincides with his adoption of a new distinct style: he moved away from the ethereal haze of tonalism towards the bold lines of modernism. Tempera was first applied in the ambitious mural commission for the Meyers, and later in the making of *Le Tournesol.* Like many artists, Steichen was reluctant to discuss his materials and techniques. However, recent technical research by teams in Washington and Dallas has shed light on his working materials sometimes with surprising results. The use of egg yolk in his tempera emulsions is less prevalent than once assumed. By examining Steichen's last surviving temperas, this paper has explored that intersection of medium and style in the relatively unknown output of an overlooked precursor to the American tempera revival.

At the same time Steichen was painting *Le Tournseol*, he was pushing his photography in new directions. Within a few months of completing *Le Tournesol*, he accepted a lucrative job offer as Condé Nast's chief photographer. Over the course of his career, Steichen went on to reinvent fashion photography, win prizes for his delphiniums, be awarded an Oscar for his war documentary *The Fighting Lady*, and become the Director of the Department of Photography at the Museum of Modern Art. After receiving the Condé Nast offer, Steichen returned to Voulangis in the early winter of 1923. Set on dedicating his career to photography, his life as a painter was finished. With the help of his gardener François, Steichen committed his remaining paintings to the pyre. *Le Tournesol* was his last tempera painting.

Notes

1. More than $700,000 in today's currency.
2. In 1900, when Steichen became an American citizen, he signed his official papers as Edward J. Steichen.
3. Stieglitz established *Camera Notes* which was published from July 1897 until December 1903.
4. Their collaborations included producing the influential *Camera Work* (1903–1917) and exhibiting modernist painters, sculptors and photographers at Stieglitz's gallery 291.
5. Maeterlinck's most famous play, *L'Oiseau bleau* (1908), explores two children's quest for happiness.
6. Steichen retained the lease until 1927.
7. Carles and Marin moved into an inn in Voulangis so they could paint with Steichen during an extended stay.
8. The sculpture was inherited by Steichen's daughter Kate and sold to the Tate, London in 1973.
9. A publication of their research is forthcoming.
10. Letter from Sandburg to Alice Corbin Henderson, September 12, 1920.
11. The painting was exhibited in 1922 Salon d'Automne, Paris, 1922, no. 2163, as *Tournesol*.
12. J. Krueger, *Examination and Minor Treatment Report Edward Steichen 'Le Tournesol' (The Sunflower)*, September 28, 1999.
13. J. Krueger, *Treatment Report Edward Steichen 'Study for Le Tournesol' (The Sunflower)*, July 17, 2008.
14. Not the Voulangis bonfire, but a later studio fire.
15. J. Krueger, *Treatment Report Edward Steichen 'Study for Le Tournesol' (The Sunflower)*, July 17, 2008.
16. Steichen 1963, page preceding plate 63.
17. *Ibid*.
18. *Facture: Conservation, Science, Art History* vol. 4, 2019 (forthcoming publication from the National Gallery of Art, Washington DC).
19. Steichen was suggesting that the artist's sensibility as represented in the work was more important, not the medium, however inventive or atypical the medium.
20. *Wisdom Series*, interview of Edward Steichen by Wayne Miller, copyright National Broadcasting Company, 1954.

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Author's address

Abbie N. Sprague, Independent Art Historian, California, USA (asprague@rocketmail.com)

POSTERS

Studies on the consolidation treatment of a collection of 19th-century *Tüchlein* from the Palau Ducal of Gandia, Valencia, Spain

Esther Aznar Franco, Susana Martín Rey and María Castell Agustí

Introduction

During the 19th and 20th centuries, paintings made with the *Tüchlein* technique were one of the most prolific genres of artistic creation in Western Europe, especially in the Netherlands. This genre enjoyed great success thanks to rapid creation, lightness, versatility and low cost. In the Coronas Hall of the Palau Ducal de Gandia (Valencia, Spain) can be found a set of eight works by the painter Martín Coronas (1862–1928), executed between 1893 and 1920 during the Neo-Gothic refurbishment of the building shown in Figure 1, in which the painter attempted to emulate tapestries using the old *Tüchlein* technique. Four different types of canvas weaves derived from taffeta were used for the large format works, thereby simulating the ribbed effect of the tapestry by varying the densities and number of weft and warp threads.

Objectives

The main objective of this study was to find possible solutions for the consolidation treatment of fabrics painted with the *Tüchlein* technique, focusing attention on those made in canvas fabrics with fluted textures that have characteristics similar to those shown in Figure 2. Specifically, the intention was to establish the composition of the materials both of the support and the paint film of the *Tüchlein* collection in the Palau Ducal de Gandia in order to determine which adhesives would be appropriate for the consolidation of other artworks with similar materials and characteristics. The study aimed to utilise the data, such as the interaction between the

Figure 1 Salón de Coronas. Palau Ducal de Gandia, Valencia, Spain.

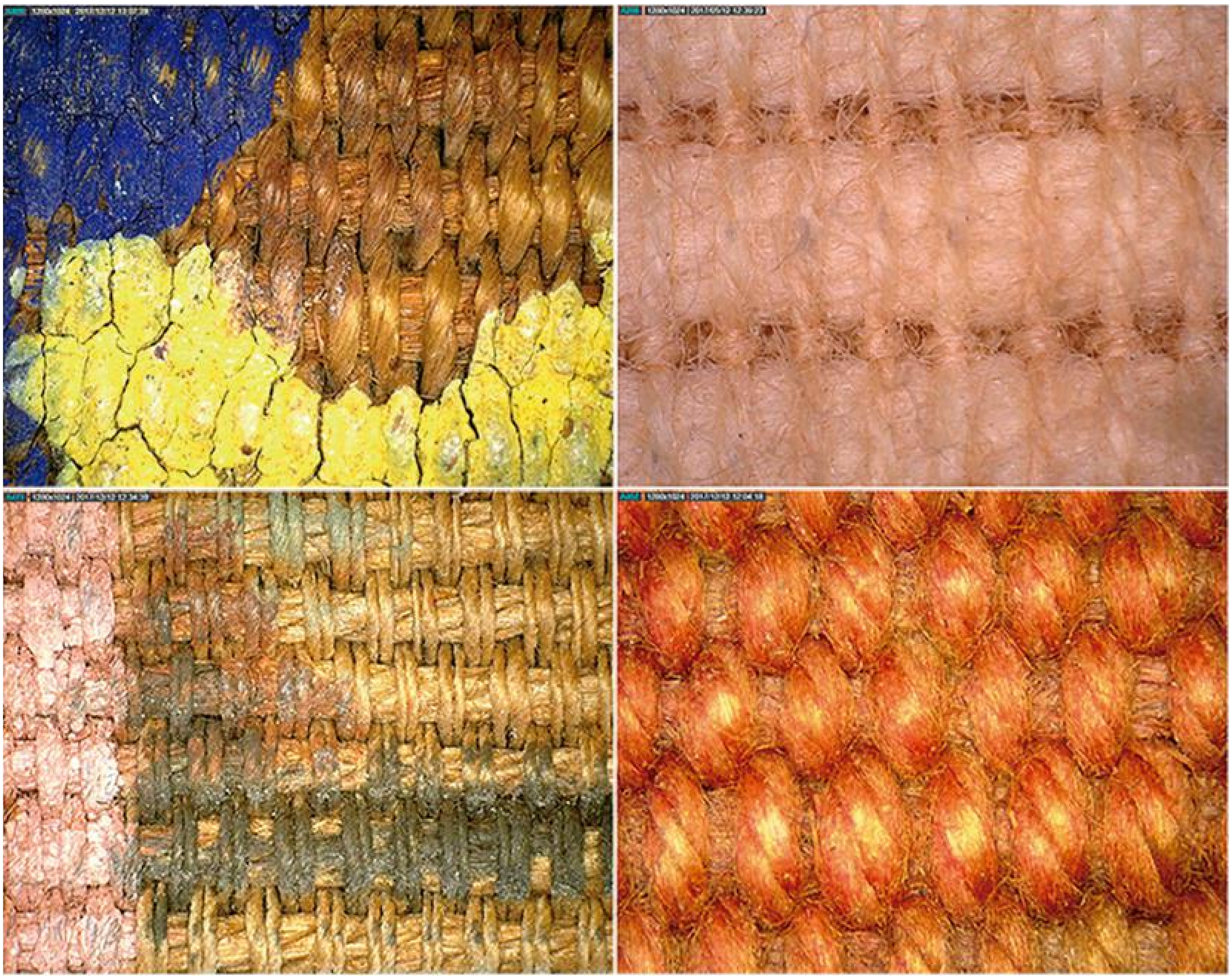

Figure 2 The four canvas weave types of the supports and different levels of thickness of the pictorial film.

support (made with cellulose materials) and pictorial film, determine the degradation of the collection and propose solutions to increase its stability.

Methodology

The first part of the study consisted of a literature search to place the works within their historical and artistic context (Solá and Cervós 2004). To understand the deterioration phenomena of the paintings, a database was compiled based on technical examination of the paintings including environmental measurements, and investigation of the assembly system and exhibition use of the room. The paintings were examined using a stereomicroscope and photographic records were made using a digital camera and a DINOLITE AM4815 microscopic camera. A morphological study of cross-sections of samples from textile fibres and paint layers was carried out using an optical microscope to identify pigments, binders and types of fibres.

The textile fibres were studied with a Leika Stereo Zoom S8APO and a Leika DM750 microscope with transmitted polarized and semi-polarized light. An in-depth study of the structure of these samples was performed based on comparative bibliographic sources by experts in the field of textiles in order to obtain meaningful data concerning canvas damage. The depolymerization of the textile fibres was studied using visual microscopic examination that involved a comparison of the fibres with recently obtained fibre examples.

Results

The data relating to the painting surface indicate that these works were produced specifically for this site during the Neo-Gothic refurbishment by the last owners of the building (the Jesuits). The painter was one of the fathers of the congregation, and the theme was the life of San Francisco de Borja, 4th Duke of Gandia, who also belonged to the order. The analyses determined that two types of fibres, cotton and jute, had been used. There are different levels of thickness in the paint layers – and in some areas no paint at all was applied by the artist, leaving the canvas visible resulting in diverse types of damage which demand different methods to rectify.

Based on the results of literature research, a first selection of materials was made to accord with the matt nature of the works: Klucel-G cellulose ether dissolved in ethanol, mucilages derived from algae such as Funori and Junfunori and the thermoplastic polymers Aquazol 200 and 500 (Down 2015). These products are used widely in conservation for consolidation treatments of matt paints: they have the penetrability necessary given the texture of the support, they adapt to the thickness variability of the pictorial film and allow these materials to accept additions of substances for the control of pH. Moreover, the results indicate that cellulase enzyme (De Lera *et al*. 2009) and nanofibres of cellulose (Kolman *et al*. 2018) can also be used for consolidation treatments of pictorial films with varying thicknesses. These act on the main support material (cellulose) and recent studies on their consolidating effect make their assessment timely.

Conclusion

Two main agents of deterioration have had an impact on the conservation of this collection: first, ageing of the pictorial materials and the progressive and gradual process of depolymerization of the textile fibres currently exposed to natural light; secondly, the inadequate assembly system consisting of wooden slats nailed directly onto the fabrics in its upper part has caused the degradation of the areas surrounding the nails, resulting in deformation and erosion of the support in the lower part. Future research is planned with the aim of stabilizing the substances that make up the works, including a review of the exhibition conditions and testing of the materials to be used for future conservation.

Acknowledgements

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Author's addresses

- Esther Aznar Franco, Conservation Institute of Cultural Heritage, Polytechnic University of Valencia, Spain (esazfra@doctor.upv.es)
- Susana Martín Rey, Conservation Institute of Cultural Heritage, Polytechnic University of Valencia, Spain
- María Castell Agustí, Conservation Institute of Cultural Heritage, Polytechnic University of Valencia, Spain

Tempera techniques used by Czech landscape painters at the end of the 19th century

Hana Bilavčíková, Václava Antušková, Radka Šefců, Václav Pitthard and Lenka Zamrazilová

Background and aim of the study

Historical sources suggest that at the end of the 19th century Bohemian painters experimented with painting techniques.[1] Our research focused primarily on the relatively unknown Syntonos tempera technique used by the students of Julius Mařák's *plein air* landscape painting studio at the Academy of Fine Arts in Prague (Domorázek 1901: 5–8; Jiránek 1959: 135–7).

As part of our research, we selected a number of works by the most important painters from the above-mentioned school including Antonín Slavíček (1870–1910), Otakar Lebeda (1877–1901) and Antonín Hudeček (1872–1941). All these artists made significant use of this tempera technique (Čapek Chod 1898), in order to assess the differences in paint composition such as the binding media and pigments used, number of paint layers and system of layering. In cooperation with the National Gallery Prague and private collectors, a broad selection of paintings was chosen for both chemical analysis of paint media and conservation research.

Methods

Painting technique (Table1) was investigated using optical non-invasive methods such as ultraviolet fluorescence (UVF), infrared reflectography (IRR) and X-radiography (RTG). In cooperation with the Chemical-Technological Laboratory of the National Gallery Prague and the Department of Chemistry at the Academy of Fine Arts Prague, numerous pigments were evaluated using non-invasive X-ray fluorescence (XRF) analysis, μ-Raman spectroscopy (μ-RS) and scanning electron microscopy with energy dispersive X-ray microanalysis (SEM-EDS). The composition of organic materials (Table 2) in the paint layers was studied using gas chromatography-mass spectrometry (GC-MS) in cooperation with the Conservation Science Department, Kunsthistorisches Museum Vienna, Austria.

Results and discussion

All the examined works were painted on paper board supports possibly containing a glue isolation layer. IRR analysis revealed underdrawing using common pencil graphite. *Pentimenti* and other

Table 1 Overview of the applied analytical techniques.

Author, owner, inv. no.	Title	Dating	Height × width (cm)	VIS	UVF	IRR	IRFC	RTG	XRF	OM	RS	EDS	GC-MS
Julius Mařák													
NGP, O 15128	*Rest under the Trees*	*c.*1895	48.5 × 62.5	+	+	+	+	+		+	+	+	
Antonín Hudeček													
NGP, O 3698	*The Bathing*	1897	50 × 66	+	+	+	+	+	+	+	+	+	+
Otakar Lebeda													
NGP, O 17164	*Carlsbad*	1898	67 × 50	+	+	+	+	+	+	+	+	+	
NGP, O 3770	*The Lilac*	1899	65.5 × 78.5	+	+	+	+	+	+	+	+	+	+
NGP, O 12922	*The Way to Bechyně Castle*	1899	66 × 50	+	+	+	+	+	+	+	+	+	
Antonín Slavíček													
Private collection	*Still Life*	1895?	66 × 50	+	+	+		+		+			+
NGP, O 10310	*Autumn in Veltrusy*	1896	65.8 × 49.7	+	+	+	+	+	+	+	+	+	
NGP, O 8304	*In Veltrusy park*	1896	65.9 × 49.8	+	+	+	+	+	+	+	+	+	
Private collection	*Study of the Deciduous Trees*	1896	66 × 50	+	+	+		+		+			+
NGP, O 13020	*Forest Road I.*	1898	54.8 × 70.7	+	+	+	+	+	+	+	+	+	+
NGP, O 3329	*A Day in June*	1898–1899	71 × 105.7	+	+	+	+	+	+	+	+	+	+
NGP, DO 6620	*A Red Roofs*	1900	89.3 × 117.8	+	+	+	+	+	+	+	+	+	
NGP, O 5279	*After Rain*	1901	65.7 × 78.7	+	+	+	+	+	+	+	+	+	+
NGP, O 7849	*The Path in the Fields*	1902	65.7 × 76	+	+	+	+	+	+	+	+	+	+
NGP, O 3061	*The View from Letná*	1908	188 × 390	+	+	+	+						+

VIS: photography in visible light; UVF: ultraviolet fluorescence; IRR: infrared reflectography; IRFC: infrared false colour; RTG: X-radiography; XRF: X-ray fluorescence spectroscopy; OM: optical microscopy; RS: Raman spectroscopy; EDS: energy dispersive spectroscopy; GC-MS: gas chromatography-mass spectrometry; NGP: National Gallery Prague

Table 2 The composition of the samples derived from GC-MS analyses.

Author, owner, inv. no.	Title	Sample location	Lipids	Resins	Proteins	Polysaccharides
Antonín Hudeček						
NGP, O 3698	*The Bathing*	Green paint layer	Oil/fat/tallow	Burgundy pitch	Animal glue	Traces of starch
Otakar Lebeda						
NGP, O 3770	*The Lilac*	Blue paint layer	Oil/fat/tallow	Burgundy pitch	Animal glue	0
Antonín Slavíček						
Private collection	*Still Life*	Grey-brown paint layer	Linseed oil Castor oil Beeswax	0	Traces of protein	Plant gum Starch
NGP, O 8304	*In Veltrusy Park*	Ochre paint layer	Linseed oil Castor oil Rapeseed oil	Pine resin	Traces of protein	Gum arabic Honey/sugar
Private collection	*Study of the Deciduous Trees*	Green paint layer from leaves	Egg yolk Beeswax	Pine resin	0	Plant gum Starch
NGP, O 13020	*Forest Road I.*	Green-purple paint layer	Linseed oil Castor oil Egg yolk	Pine resin/ Venice turpentine	Animal glue	0
NGP, O 3329	*A Day in June*	Yellow-green paint layer	Egg yolk Oil	Pine resin	Animal glue	0
NGP, DO 6620	*A Red Roofs*	White paint layer	Oil/fat/tallow	Burgundy pitch	Animal glue	0
NGP, O 5279	*After Rain*	Purple paint layer	Egg yolk Oil	Pine resin	0	Gum arabic Honey/sugar
NGP, O 7849	*The Path in the Fields*	Green paint layer	Oil Egg	Burgundy pitch	Animal glue	0
NGP, O 3061	*The View from Letná*	Green paint layer	Egg yolk Oil	0	Egg white	0

sketches not visible in daylight were found in the paintings by Antonín Slavíček (*Study of Deciduous Trees* 1896 and *Forest Road I.* 1898), Otakar Lebeda (*The Road to Bechyně Castle* 1899 and *Carlsbad* 1898) and Julius Mařák (*Rest under the Trees c.*1895). Macrophotographs showed bubbles in the paint layers, probably caused by vigorous mixing of the colours on the palette. Thicker paint layers contain significantly smaller bubbles, also visible in macrophotographs. Bubbles in the paintings by Antonín Slavíček (*Day in June* 1898–1899, *After Rain* 1901, *A Red Roofs* 1900 and *Path in the Fields* 1902) are all similar in character. The examination also revealed that the character of paint layers and craquelures are the same in the paintings by Antonín Slavíček (*In Veltrusy Park* 1896 and *Autumn in Veltrusy* 1896) and in some places on the paintings by Otakar Lebeda (*Carlsbad* 1898 and *Road to Bechyně Castle* 1899).

The analytical results confirm that the painters employed a wide range of mixtures of both pigments and binders. Mařák's followers typically used red *imprimatura* and dark green underpainting. Antimony-based yellow pigments (Naples yellow) were discovered on several of Antonín Slavíček´s paintings using XRF, SEM-EDS and RS. Raman spectroscopy also detected an unusual structure of these pigments. This structural variability is a result of the manufacturing process (different production conditions, varying input of raw materials). In addition, an amount of barite white, used in impasto paint layers, was identified in most of the paintings.

The results of GC-MS analysis of the binding media (Table 2) suggest that various types of tempera were used in the examined works. Egg was found as a major binding medium in the paintings by Antonín Slavíček (*A Day in June* 1898–1899, *After the Rain* 1901, *Path in the Fields* 1902 and *View from Letná* 1908). Other binding media were identified as proteins (animal glue), polysaccharides (plant gum, starch), lipids (beeswax, tallow, linseed oil, rapeseed oil and castor oil) and softwood resins in various combination.

In two of Antonín Slavíček's paintings (*In Veltrusy Park* 1896 and *Still Life* 1893–1895?), gum arabic was detected as a major binding medium, a typical feature of the Syntonos colours. This finding can be compared with the description of the Syntonos colours in Wilhelm Beckmann's patent (Beckmann 1893), which listed the components as including gum arabic, linseed oil, green soup, glycerine, tallow and wax. Linseed oil with castor oil and rapeseed oil were also found in Slavíček's paintings, further attesting to his use of the Syntonos technique. In addition, the analyses showed traces of pine resin, honey or sugar and wax. Traces of protein in the paintings were identified as animal glue but these probably originate from the isolation layer of the paper support.

Conclusion

The results of our study confirm that painters from Julius Mařák's studio used mainly the egg tempera technique or a combination of tempera and oil techniques. In the case of two paintings (mentioned above) the components corresponded with the composition of Syntonos tempera paints.

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Note

1. Letter from Antonín Slavíček to Professor Goll, 23 September 1905, Archive of the National Gallery Prague.

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Authors' addresses

- Hana Bilavčíková, National Gallery Prague, Czech Republic/Academy of Fine Arts in Prague, Czech Republic (hana.bilavcikova@ngprague.cz)
- Václava Antušková, National Gallery Prague, Czech Republic
- Radka Šefců, National Gallery Prague, Czech Republic
- Václav Pitthard, Kunsthistorisches Museum Wien, Vienna, Austria
- Lenka Zamrazilová, Academy of Fine Arts in Prague, Czech Republic

Hiding in plain sight? Tempera-based British paintings at Tate, London

Joyce H. Townsend

The need for a survey

There have been no detailed technical studies of the occurrence of tempera-based paints in the Tate collection[1] with the exception of the 'fresco' paintings of William Blake (1757–1827), as the artist himself described them. Ormsby *et al.* (2003) found thick layers of a mixture of gum arabic, gum tragacanth and unrefined sugar or honey, with interlayers and a final varnish of animal glue in all his temperas. His chosen medium led to cracking even when he increased the sugar content, and poor condition when such works were lined and varnished as if they were oil paintings: paint losses down to the canvas, impregnation by lining adhesive leading to discoloration, and darkening of the medium have resulted. Indeed, none of the large works Blake made with these materials survive today in any collection.

Other examples of tempera-based paint may be 'hiding in plain sight' within the collection, discoverable only when they respond in an unexpected way to conservation treatments appropriate for pure oil paint: an awareness of tempera paints can rationalise the thinking around challenging conservation treatments. In contrast, some more recent suspected works in tempera appear to be in excellent condition – often with an absence of ageing cracks and less necessity for treatment than their counterparts made using oil-based paint. I have therefore begun to review analytical studies (all undertaken or organised over three decades at Tate) for tempera candidates painted *c.*1780s–1940s. This summary presents interim conclusions.[2]

Interim conclusions

If the widest definition of tempera paints as 'mixed media, often water-dilutable' is used, then 18th-century artists who employed them include Joshua Reynolds (1723–1792) on occasion, and some of the 'process painters' active at the close of the 18th and the first decades of the 19th century such as Benjamin West (1738–1820), Robert Smirke (1753–1845), John Opie (1761–1807) and the lesser-known Henry Thomson (1773–1843), who sometimes worked on a water-based tempera ground with a variety of mixed media paints applied as glazes over a monochrome or *grisaille* underpainting. At least one example by each is identifiable.

Documentary sources can suggest mid- and later 19th-century candidate artists but not usually candidate paintings: George Frederic Watts (1817–1904) and William Holman Hunt (1827–1910) both recorded their use of tempera grounds, while John Roddam Spencer Stanhope (1829–1908) used tempera paints in later life, but these have not been found in Tate works that have undergone technical

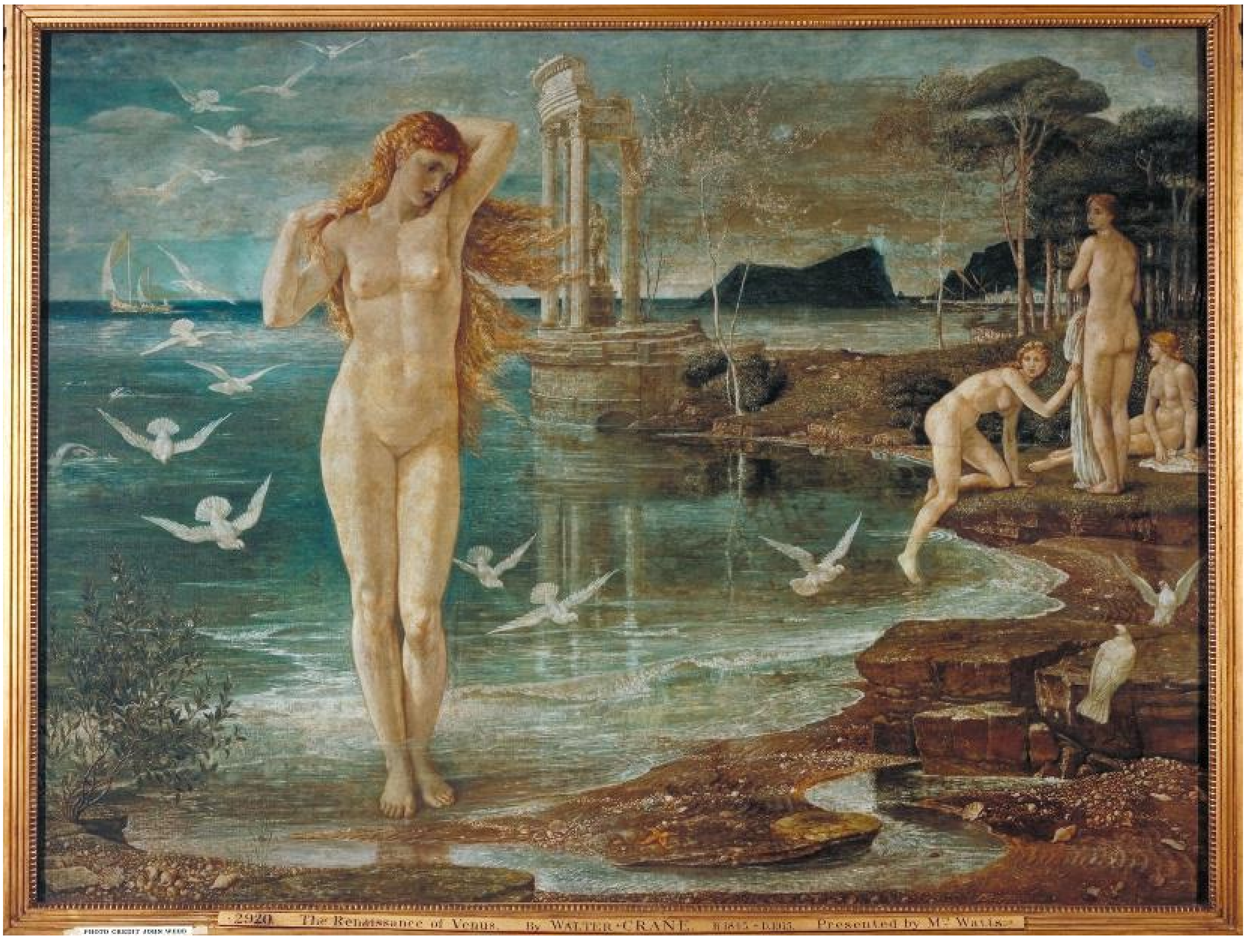

Figure 1 Walter Crane, *The Renaissance of Venus*, 1877, tempera on canvas, 138.4 × 184.1 cm, N02920. (Photo © Tate, London 2019.)

examination except for one painting by Watts. Walter Crane (1845–1915) employed both tempera and oleoresinous paints in *The Renaissance of Venus* 1877 (Fig. 1), whose priming consists of lead white and chalk in drying oil. Both the sky and landscape paints are proteinaceous, medium-rich and glaze-like. Ultraviolet light suggests that the paint medium is more likely to be egg or casein than animal glue. The flesh, water and sky were finished with oleoresinous glazes, and there is a brushed proteinaceous varnish, probably original. Where thickly applied, this is very yellowed, and where thin it is now as yellow as the discoloured glazes and hence distinguishable from them only in UV. Analysis indicates protein and its mattness due to fine crazing suggests egg white: reconstructed and both naturally aged and light-aged 19th-century varnishes show such crazing to be unique to egg white among proteinaceous materials usable as varnish.[3] This varnish compromises the appearance and has so far proved too challenging to remove in addition to being difficult to sample and analyse.

Fewer examples of tempera-based paint used by British artists in the earlier 20th century have been identified than expected. Some are either associated with artists who worked on murals or graphic art as well as paintings, suggesting a crossover of materials, or by known founders or members of the tempera revival in Britain. The former category includes MacDonald Gill (1884–1947) who advocated the use of pure egg tempera rather than casein, and whose *Punch and Judy* 1911 (Tate N04570) was analysed[4] during recent major conservation treatment.[5] Its priming is casein with a trace of animal glue or fat, but the paint is oil-based, in contrast to his stated preferences. The latter category is illustrated by Joseph Southall (1861–1944), whose paintings in (visually convincing) pure egg tempera are in such excellent condition that they have never required treatment. Crane in fact belongs to both categories. Charles Sims (1873–1928) used[6] the greatest variety of tempera formulations found thus far, in addition to pure oil paint occasionally, often with a tempera

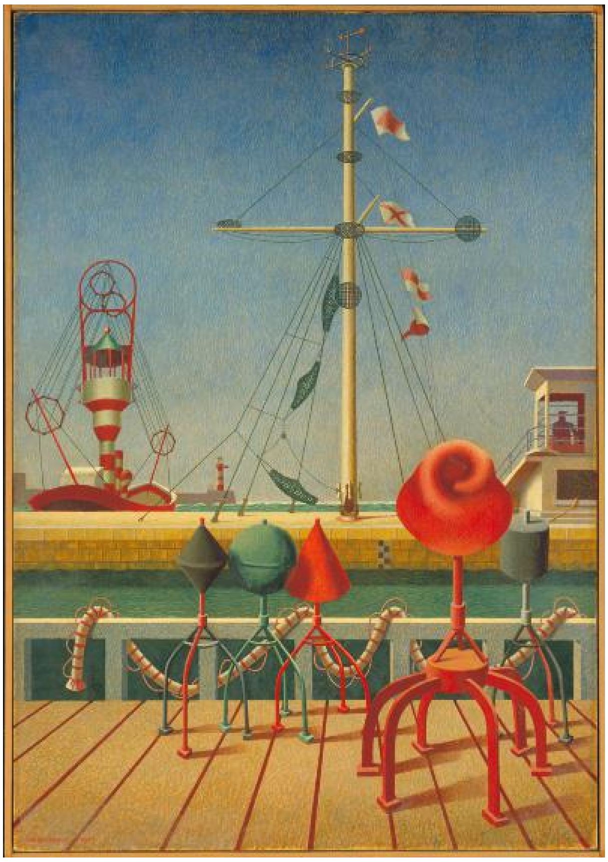

Figure 2 Edward Wadsworth, *Signals*, 1942, tempera on canvas, 101.6 × 71.1 cm, N06029. (Photo © Tate, London 2019.)

ground. His works are in good condition, the mixed media recognizable under UV examination.

Edward Wadsworth (1889–1949) stated a preference for pure egg tempera over commercial tempera (Black 2003: 43–5, 55), and indeed used it[7] in *Bronze Ballet* 1940 (Tate N05380), but at other times he described the use of an egg-oil tempera. The analysis of proteins in his paints is made more difficult by the presence of glue-paste linings. His paintings in the early 1940s show unusual and recurring deterioration problems: *Signals* of 1942 (Fig. 2) has a very low-quality wood support, a ground of animal glue with a small amount of non-drying oil or animal fat, and thin paint containing either egg white or casein or both in the green areas, and whole egg with heat-bodied linseed oil in glossier greens.[8] The surface has repeatedly developed efflorescence consisting of palmitic acid[9] on all colours, more obvious in green areas and less so where protected from light by the frame. From 1976 until its treatment in 2013–14[10] it was regarded as undisplayable. It has long been suspected by Tate conservators that he might have had to substitute for rationed eggs during World War 2, even as an official war artist.

Notes

1. Information on the paintings and artists mentioned here, and illustrations, can be found at www.tate.org.uk.
2. J.H. Townsend, 'Tempera paints used by British artists *c*.1770s–1940s', to be submitted to *Tate Papers* No. 29, spring 2019.
3. Conservation archive Q04044.2, 19th-century varnish formulations made by Deborah Dyer *c*.1990.
4. By Dr Brian Singer, University of Northumbria, using pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) with thermal methylation.
5. By Adèle Wright 2014–16 at Tate, funded by the Clothworkers' Foundation, UK.
6. Jane F. Colbourne, *A Critical Survey of the Materials and Techniques of Charles Henry Sims RA (1873–1928) with special reference to Egg Tempera Media and Works of Art on Paper*, unpublished doctoral thesis, Northumbria University, Newcastle, 2012. The research, supervised by the present author, was based on the extensive archive of the artist's unfinished work at the University of Northumbria using Tate paintings for many of the case studies of finished works.
7. Analysed by Dr Brian Singer, University of Northumbria, using high-performance liquid chromatography (HPLC).
8. By Dr Bronwyn Ormsby at Tate using Fourier transform infrared spectroscopy (FTIR), and Dr Brian Singer at the University of Northumbria using GC-MS.
9. Analysed by Dr Bronwyn Ormsby, Tate, using FTIR.
10. By Pia Gottschaller at Tate.

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Author's address

Joyce H. Townsend, Tate Britain, London, UK (joyce.townsend@tate.org.uk)

Love and the Maiden by John Roddam Spencer Stanhope: assumptions and the importance of analysis

Elise Effmann Clifford

Introduction

Love and the Maiden by the second-generation Pre-Raphaelite artist John Roddam Spencer Stanhope (1829–1908) is considered by scholars to be an important example of late 19th-century tempera painting (Fig. 1) (Sprague 1999: 47–8; Prettejohn 2017: 161–3). However, when the painting was first published with its media listed in 1989, it was believed to be in oil (Christian and Stevens 1989: 80). The tempera ascription was likely attached when the painting was sold from a private collection by Christie's in 1997.[1] Since its acquisition by the Fine Arts Museums of San Francisco in 2002, *Love and the Maiden* has always been displayed as a painting in tempera on canvas.

Stanhope and the tempera revival

The tempera designation appears to have been based on circumstantial evidence rather than scientific analysis. Stanhope was the Pre-Raphaelite with the deepest engagement with Italy, visiting regularly from his youth and moving permanently to the hills outside of Florence in 1880. By the 1870s, the artist had become deeply influenced by Italian art, particularly by the works of Sandro Botticelli. At the turn of the 20th century, Stanhope was seen as the 'pioneer' of the burgeoning tempera revival (Vallance 1901: 156). In the supplement to her 1899 translation of *Il libro dell'arte* by Cennino Cennini, the tempera revivalist Christiana Herringham commented that Stanhope was one of the first painters to 'return to this method, and has painted principally in it for many years' (Herringham 1899: 189). Stanhope himself wrote about his experience in painting with 'the yolk of egg' in an essay for the Society of Tempera painters in 1903 in which he described how he learned the technique from a 'Signor Rocci' while visiting the art galleries in Florence some 30 years earlier (Stanhope 1928: 28). In addition, both *Eve Tempted* (1877) and *The Waters of Lethe* (1880) by Stanhope in the Manchester Art Gallery, UK, are listed by the museum as painted in tempera. Stanhope actually stated that *The Waters of Lethe* was painted in 'the yolk of egg' when he wrote to the gallery after its acquisition.[2] This written evidence of Stanhope's engagement with tempera, compounded with his deep connection to Italy and clear attraction to Botticelli, has led to assumptions that his later works are painted primarily in tempera.

Figure 1 John Roddam Spencer Stanhope, *Love and the Maiden*, 1877, oil and gold leaf on canvas, 141 × 205.7 cm. Fine Arts Museums of San Francisco, Museum purchase, European Art Trust Fund, Grover A. Magnin Bequest Fund and Dorothy Spreckels Munn Bequest Fund, 2002.176. (Photograph © Fine Arts Museums of San Francisco.)

Media analysis disproves narratives on Stanhope's oeuvre

The Fine Arts Museums of San Francisco's 2018 exhibition *Truth and Beauty: The Pre-Raphaelites and the Old Masters* generated the opportunity to undertake a technical study of *Love and the Maiden* along with an earlier work by Stanhope, *Robins of Modern Times* (*c.*1860) (Effmann Clifford 2018). The paintings – the earlier with its roots in Netherlandish technique and *Love and the Maiden* based in Italian – clearly illustrate two of the primary stylistic influences on Pre-Raphaelite art. Media analysis of samples taken from *Love and the Maiden* was a critical component of the study, particularly because it was believed to be a masterpiece of 19th-century tempera painting. The analysed samples revealed that there is, in fact, no egg or protein of any kind detectable in the painting, and it appears to be painted simply in a lean oil paint.[3] The light tonality and dry surface of *Love and the Maiden*, combined with circumstantial historical evidence, led to assumptions being made about its medium. Although a simplified narrative of Stanhope's artistic development – one in which he broke from painting in oil in favour of tempera as his work became more influenced by Italian art – is tempting, the artist in fact achieved his desired effects, at least in part, with the continued use of oil during the later years of his career. What is clear is that the evolution of Stanhope's technique is more complicated than has sometimes been portrayed in scholarship, and that assumptions about his media should be avoided.

Acknowledgements

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Notes

1. The painting was sold for the first time in 110 years in the Victorian Pictures sale at Christie's London, 6 June 1997, lot 43.
2. The curatorial file at the Manchester Art Gallery contains a transcription of a letter from Stanhope to C.J. Pooley, dated 11 July 1890, held in the John Rylands Library ENG MSS 1226 (R109028) Letter no. 51. *The Waters of Lethe* has a much flatter surface than *Love and the Maiden* and is prone to flaking and lifting paint. In condition and appearance it is quite different from *Eve Tempted*, which is very similar to *Love and the Maiden* and may also be painted in oil.
3. Samples were analysed with Fourier transform infrared (FTIR) spectroscopy followed by gas chromatography-mass spectrometry (GC-MS) by Catherine Matsen and Chris Petersen at the Winterthur Museum, Delaware, and further analysed with peptide mass fingerprinting (PMF) and matrix-assisted laser desorption/ionisation time-of-flight mass spectrometric (MALDI) analysis by Dan Kirby Analytical Services.

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Author's address

Elise Effmann Clifford, Fine Arts Museums of San Francisco, San Francisco, California, USA (eeffmann@famsf.org)

Frances Hodgkins: tempera painting and experimentation in St Ives, Cornwall

Sarah Hillary and Martin Middleditch

Introduction

Frances Hodgkins (1869–1947) is an artist known principally for her paintings in watercolour, oil and gouache, but what is less known is her work in tempera, which was executed at a formative period in her development as an artist while living in the artists' colony of St Ives in Cornwall, UK, from 1914 to 1918. She was born in New Zealand but spent most of her working life in Britain. Hodgkins received recognition for her work late in life, was a member of the avant-garde group the Seven and Five Society from the age of 60 and in 1940 was chosen to represent Britain in the Venice Biennale. She worked in a modernist style of simplified forms and colour relationships but she was known particularly for her calligraphic brushwork and unique colour sense.

A change of paint medium

At the outbreak of World War I Hodgkins was in France, an established watercolourist and teacher, and had intended to remain there. Forced to leave due to the deteriorating political situation, she moved to the fishing village and artists' colony of St Ives where she could live cheaply. However, after France, the approach taken by the artists in St Ives seemed rather conservative and in a letter to her mother of 17 February 1915 she wrote: 'I find I am too modern for people down here' (Gill 1993: 303). She focused mostly on figure painting partly due to war restrictions on outdoor sketching from July 1915, but the change of scene also gave her the opportunity to experiment with paint media.

Despite her success in watercolour, Hodgkins struggled to be taken seriously as an artist in what was considered a medium for amateurs. It was in St Ives that she renewed her resolve to paint in oil, which she had begun with lessons in Paris in 1908, but in addition she painted a suite of works in a tempera medium. An example is *Refugee Children* (*c.*1916) (Fig. 1), which is one of a number of works depicting the plight of the Belgian refugees who had fled to England after the German invasion. The paint is applied in washes over a textured gesso ground on muslin and plywood (Fig. 2). Samples of the paint media have been identified as oil (walnut or linseed/poppy mixture), animal glue and a small amount of egg (Hillary and Strehle 2005: 20).[1]

War restrictions also made it difficult to obtain art materials and Hodgkins had limited means, so being able to easily source the materials used to make up the tempera and gesso was an advantage. It also allowed her to continue painting in a similar fashion to her works on paper, but on a more robust textured support. The tempera paint is thinly applied with a delicate matt surface, and although the gesso supports are stronger than paper, they are also very vulnerable to cracking and soiling. Radical conservation treatments have been carried out on at least one of these works which has saturated the surface and permanently changed the appearance, so knowledge of the paint medium is important to ensure their preservation.[2]

Oil and tempera?

In a letter to her mother on 10 February 1916 Hodgkins stated that: 'All of my work is in oils for the moment', and there is no mention of tempera in her letters at this time, so it is possible that she did not differentiate between the two (Gill 1993: 314). In order to investigate whether her use of tempera was more widespread than previously thought, a painting on canvas from the same year, *Unshatterable (Belgian Refugees)*, and variously described as 'oils and tempera' as well as 'oil', was examined (Hall 2007).[3] The paint is applied on a commercially prepared stretched canvas in the loose vigorous manner of her watercolour technique. There are also unpainted areas where the ground is visible, as well as scumbling and rubbing back. A glossy varnish which was applied in the 1980s means that it no longer has the original surface appearance.

Closer examination of *Unshatterable (Belgian Refugees)* identified several layers of paint and small areas of cracking, unlike the tempera painting, *Refugee Children*. The results of protein analysis with liquid chromatography-tandem mass spectrometry (LC-MS/MS) were negative, and the only proteins identified in samples were contaminants from human skin, sheep or wool proteins, so it appears that Hodgkins was painting in both tempera and oil paint at this time.[4]

Figure 1 Frances Hodgkins, *Refugee Children*, *c.*1916, 60.9 × 72.7 cm, Auckland Art Gallery Toi o Tāmaki, on loan from the Thanksgiving Foundation, acc. no. L1998/20.

Figure 2 Frances Hodgkins, *Refugee Children*: raking light detail.

Mixed media and new techniques

A few years later Hodgkins produced the highly textured oil painting *The Edwardians* (*c.*1918).[5] Having become more familiar with the oil medium by this stage, she continued to develop her approach and in the mid-1920s this included applying colours in casein (Silvester 2015) and albumen over the oil surface with varying degrees of success.[6] In later years, Hodgkins became best known for her work in oil as well as gouache. In both cases she modified the paint with fillers and dry pigments which altered the consistency and colour to produce the thickly painted works that characterize her distinctive mature approach (Hillary and Townsend 2005; Larsen 2009).

Notes

1. Report by J. Jonsson, B. Ormbsy and T. Learner, *Analysis of Frances Hodgkins' Paints*, Tate Britain, 2004; report by B.W. Singer, *Investigation of Paint Samples from L1998-20 Refugee Children*, Northumbria University, 2005.
2. For example, the tempera on gesso painting *Mr and Mrs Moffat Lindner and Hope* (1916, 120 × 102.2

cm) was removed from the plywood and transferred to hardboard using wax-resin as the adhesive in 1976. Collection of the Dunedin Public Art Gallery, purchased 1955 with funds from the Dunedin Public Art Gallery Society, acc. no. 7-1955.

3. *Unshatterable (Belgian Refugees)*, *c*.1916, 87.5 × 95.0 cm, Collection of Christchurch Art Gallery Te Puna o Waiwhetu; purchased with the assistance of the National Art Collections Fund, London, 1980, acc. no. 80/80.
4. Report by M. Middleditch, *LC-MS/MS Analysis of Material from the Frances Hodgkins Painting: "Unshatterable (Belgian Refugees)*, University of Auckland, 2018.
5. *The Edwardians* , *c*.1918, 101.6 × 101.6 cm, Auckland Art Gallery Toi o Tāmaki, gift of Lucy Carrington Wertheim, 1969, acc. no. 1969/13.
6. Report by M. Middleditch, *LC-MS/MS Analysis of Material from a Frances Hodgkins Painting*, University of Auckland, 2017.

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Authors' addresses

- Sarah L Hillary, Auckland Art Gallery Toi o Tāmaki, New Zealand (sarah.hillary@aucklandartgallery.com)
- Martin Middleditch, University of Auckland, New Zealand

Everything old is new again: investigating a modern tempera fake of a medieval panel painting

Glennis Elizabeth Rayermann, Anna Stein and Gregory Dale Smith

Introduction

Acquired by its donors as a Trecento Italian school of Duccio panel painting, the Indianapolis Museum of Art at Newfield's (IMA) *Madonna and Child* (#51.98) (Fig. 1) is currently attributed to Icilio Federico Joni (1866–1946), an Italian artist, restorer, and forger. The IMA's *Madonna and Child* is a modern fake, executed to convincingly imitate the tempera paintings of Italian masters. Joni created new pieces made to look old in response to the vogue for medieval Italian paintings and the corresponding lack of interest in modern Italian works. He apparently delighted in fooling experts with his fraudulent panels (Mazzoni 2011). Joni taught his counterfeiting techniques to other artists and detailed some of his methods in his memoirs (Mazzoni 2011; Joni 2004).

As an artist, Joni presents an interesting example of the renewed interest in tempera painting in the 20th century. While many of his contemporaries looked to the past to aid the expression of their modern artistic vision, Joni looked to the present to help him best emulate the artistic vision of the past. When operating as a forger, he leveraged the knowledge of medieval era techniques he gained while apprenticing in a gilding workshop, studying at Siena's Istituto di Belle Arti, and restoring medieval artworks. Utilizing this strong technical background, he constantly experimented with materials and techniques in the service of making credible fakes (Mazzoni 2011; Joni 2004). Joni had no qualms about dipping into the modern artist's toolbox in order to produce works with the appearance of centuries old masterpieces. The technical analysis of the IMA's *Madonna and Child* presents a case study to understand how a modern imitation of a medieval tempera painting was created.

Anachronistic pigments and unusual underpainting

X-ray fluorescence (XRF) and scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM-EDS) detected several elements such as titanium that are indicative of modern, synthetic pigments used throughout the painting. These anachronistic pigments were confirmed via Raman and Fourier transform infrared (FTIR) spectroscopies, demonstrating that the artist's palette included viridian, cobalt violet light, synthetic ultramarine, and anatase titanium white. The widespread presence of synthetic white anatase – unavailable prior to 1918 (Laver 1997) – provides a *terminus post quem* while

Figure 1 Icilio Federico Joni (attrib.), *Madonna and Child*, tempera and gold leaf on wood panel, 89.9 × 54.0 × 7.0 cm, Indianapolis Museum of Art (IMA) at Newfields, Indianapolis, Indiana, USA, #51.98. Gift of Mr. and Mrs. Joseph E. Cain.

the painting's purchase by its donors in 1947 provides a *terminus ante quem*. X-radiography reveals a flesh underpainting technique observed in known Joni fakes: rather than the 'lead white highlights on the cheeks, bridge of nose and upper lip' of genuine medieval paintings, 'Joni used much more solid underpainting on which the flesh tones would be laid – convincing proof of a recent attempt at fifteenth-century painting' (Mazzoni and Olivetti 1993).

Binding media

FTIR spectroscopy of a paint sample showed lipid and protein stretches consistent with aged egg yolk. However, fatty acid methyl ester (FAMES) analysis using pyrolysis-gas chromatography-mass spectrometry (PY-GC-MS) on tetramethylammonium hydroxide-derivatized samples yields values for palmitic/stearic ratios (~2.32) below and azelaic/palmitic ratios (~0.38) above literature values for pure egg tempera (Colombini *et al.* 2010). Chemical staining with fluorescein isothiocyanate, a protein-sensitive dye, on a cross-section of the Christ Child's red robe indicates the presence of protein throughout the paint and ground layers, as expected for a medieval panel painting. On the same cross-section, rhodamine B, a lipid-sensitive dye, suggests that the underlying pink paint layer is enriched in lipid content relative to the red glaze layer. These results are consonant with Joni's *ex novo* painting techniques, including stretching egg tempera with vinegar (Mazzoni 2011) and using linseed oil, copal resin, and turpentine to fix the painting (Joni 2004: 302).

Artificial ageing

The craquelure has two size scales (Fig. 2a): a larger scale with deep cracks that penetrate into the gesso layer (Fig. 2b) and a smaller scale with shallow cracks limited to the paint layers (Fig. 2c). These two distinct networks are consistent with methods Joni used later in his career to generate craquelure: first inducing cracks in the gesso before creating craquelure on the painting's surface (Mazzoni 2011). Modern paint has been applied across some of the larger cracks (Fig 2a), likely during the 1969 conservation treatment. Some areas of the painting appear pockmarked due to the presence of dark colored divots (Fig. 2a, c). Similar surface features have been observed in known Joni fakes (Frinta 1978) – possibly air bubbles, generated during heat cycles of accelerated ageing, which burst at the painting's surface (Rinuy 1997). SEM-EDS on a cross-section of one of the deep cracks suggests umber (Fe_2O_3 + MnO_2) is in contact with the gesso layer within the crack (Fig. 2d, e). Joni used 'umber powder to remove the white [of the gesso] in case it appears in some small breakdown' (Mazzoni 2011). Both SEM-EDS and Raman spectroscopy indicate that the crack also contains an animal-derived (phosphorus-containing) black pigment to visually enhance the craquelure (Fig. 2f). Therefore, the dark color is not due to accumulated dust, dirt, or fireplace soot as might be expected in a naturally aged painting.

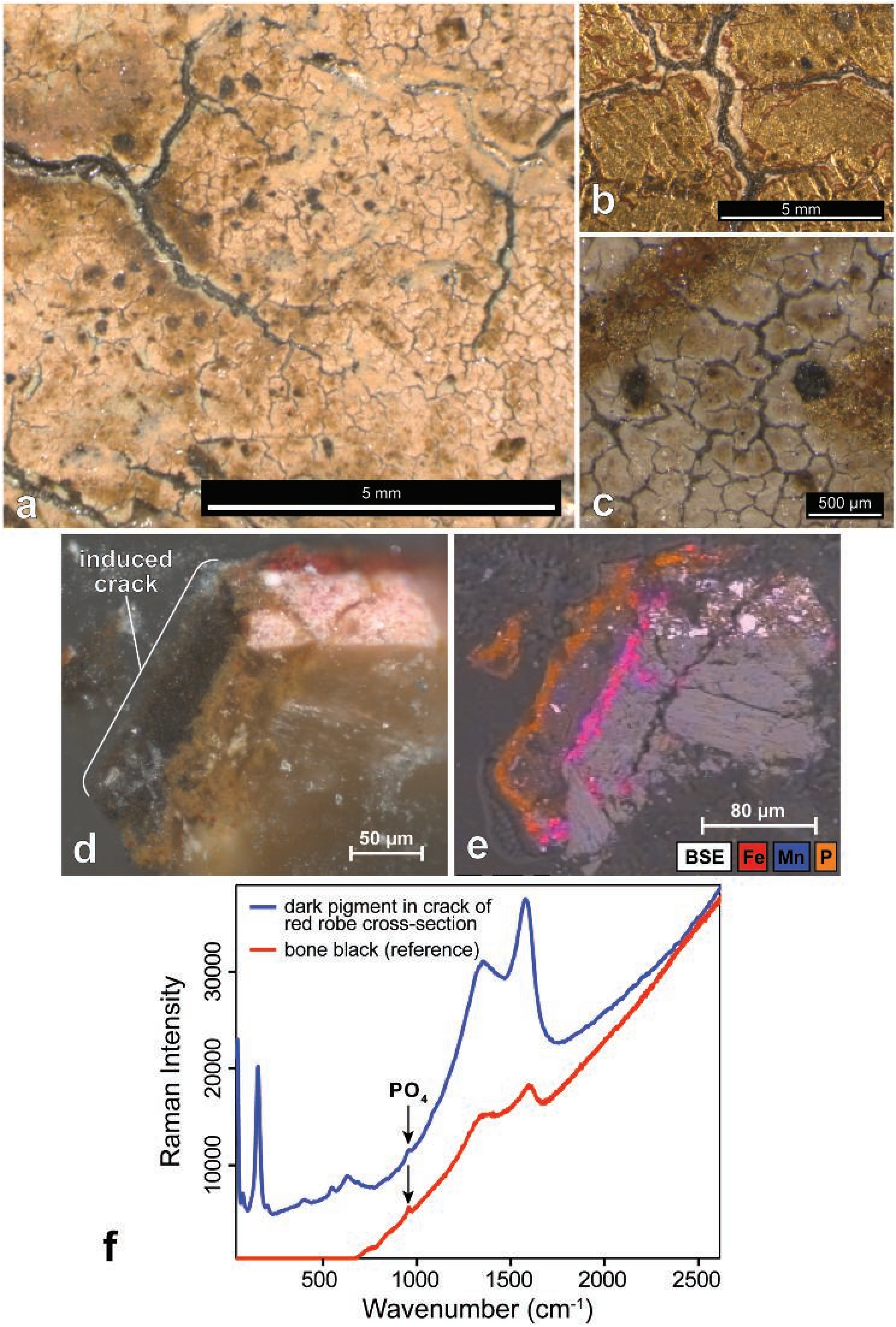

Figure 2 (a) Detail of the Christ Child's proper left toe with two size scales of crack networks; (b) detail of the incised halo around the Virgin's head showing large, deep cracks that penetrate the gesso; (c) detail of the Virgin's scarf showing smaller scale craquelure; (d) optical micrograph of a cross-section from the Christ Child's red robe; (e) SEM-EDS maps of iron (Fe), manganese (Mn), and phosphorus (P) in the cross-section shown in (d); (f) Raman spectra of the outer edge of the induced crack in the cross-section shown in (d) (blue line) and a bone black reference (red line).

Acknowledgements

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Authors' addresses

- Glennis Elizabeth Rayermann, University of Washington, Seattle, WA, USA
- Anna Stein, Indianapolis Museum of Art at Newfields, Indianapolis IN, USA
- *Corresponding author:* Gregory Dale Smith, Indianapolis Museum of Art at Newfields, Indianapolis IN, USA (gdsmith@discovernewfields.org)

Formation of efflorescence and soaps in a group of 31-year-old tempera paints: a baseline for comparison

Stephanie Barnes and Jia-sun Tsang

Introduction

The artist Jacob Lawrence (1917–2000) used a variety of commercially produced 'tempera' paints as well as homemade egg tempera over the course of his career[1] (Steele 2000; Schilling *et al.* 2000). In our recent technical study of a 1962 Lawrence tempera painting, white efflorescence on the paint surface was consistent with palmitic or stearic acid and delaminating paint was found to contain zinc stearate and proteinaceous material (Museum Conservation Institute 2016). Similarly, a study of a 1965 Lawrence tempera painting by Fourier transform infrared (FTIR) spectroscopy in 2008 identified egg tempera paint with zinc carboxylate soaps near areas of paint loss (Museum Conservation Institute 2008). These findings led to a close re-examination of a set of 31-year-old, self-made egg tempera paint samples from our studio that have developed either significant crystalline surface efflorescence or pustules within the paint layer. The paint samples were prepared from egg yolk mixed with a small amount of distilled water and dry pigments according to instructions from the University of Delaware Conservation Program. They were painted onto glass slides and stored in the dark in an opaque plastic container. The surface of the egg tempera paint was apparently in good condition until 2014 (27 years later) after which white efflorescence and protrusions began to grow rapidly (Fig. 1).

Results

Analysis of the 31-year-old egg tempera samples (Table 1) shows that:

- Pigments that did not contain metal ions to which free fatty acids could readily bind (ivory black, raw umber, Prussian blue) had a crystalline fatty acid efflorescence on the surface.
- Pigments containing metal ions to which free fatty acids could bind, such as zinc white and malachite, tended to form fatty acid soaps that appeared alongside pigments within powdery pustules or agglomerations in the paint film, rather than as a surface efflorescence.
- Analyses of ultramarine and smalt were less conclusive, although fatty acid efflorescence was present.[2] Further analysis by other techniques such as gas chromatography-mass spectrometry (GC-MS) is required.

Table 1 Summary of FTIR and XRD analyses of efflorescence and protrusions on egg tempera paints.

Pigment	Sample description	μ-FTIR	XRD
Ivory black	White crystalline efflorescence	Palmitic acid[a,b]	Palmitic acid
Raw umber	White crystalline efflorescence	Palmitic acid[a,b]	Palmitic acid
Prussian blue	White crystalline efflorescence	Palmitic acid[a,b]	Palmitic acid
Ultramarine	White crystalline efflorescence	Palmitic acid/stearic acid (?)[c]	Analysis inconclusive
Smalt	White translucent crust	Fatty acids[c]	Analysis inconclusive
Cadmium red	Semi-crystalline white efflorescence	Palmitic acid/stearic acid (?)[c]	Not analysed
Malachite	Bright green crystalline lump	Copper palmitate[b]	Copper oleate Copper palmitate
Malachite	Light green powdery pustule	Malachite Palmitic acid[a,b] Copper palmitate[b]	Malachite Copper oleate Copper palmitate
Lead white	White powdery pustule	Basic lead carbonate Lead soaps (trace)	Hydrocerussite
Zinc white	White powdery pustule	Zinc oxide Zinc oleate Zinc palmitate (?)[b,c]	Zincite Zinc oleate

[a] Palmitic acid could be identified specifically by FTIR based on small peaks in the 1380–1150 cm^{-1} region, which differ from those of stearic acid (Robinet and Corbeil 2002).
[b] Small amounts of the stearic acid/stearate soap are also likely to be present, however, the fatty acid profile of hens' eggs contains significantly more palmitic than stearic acid (Phenix 1997; Casoli *et al.* 2013).
[c] Further analysis such as GC-MS would facilitate a more conclusive identification of the type of fatty acids present.

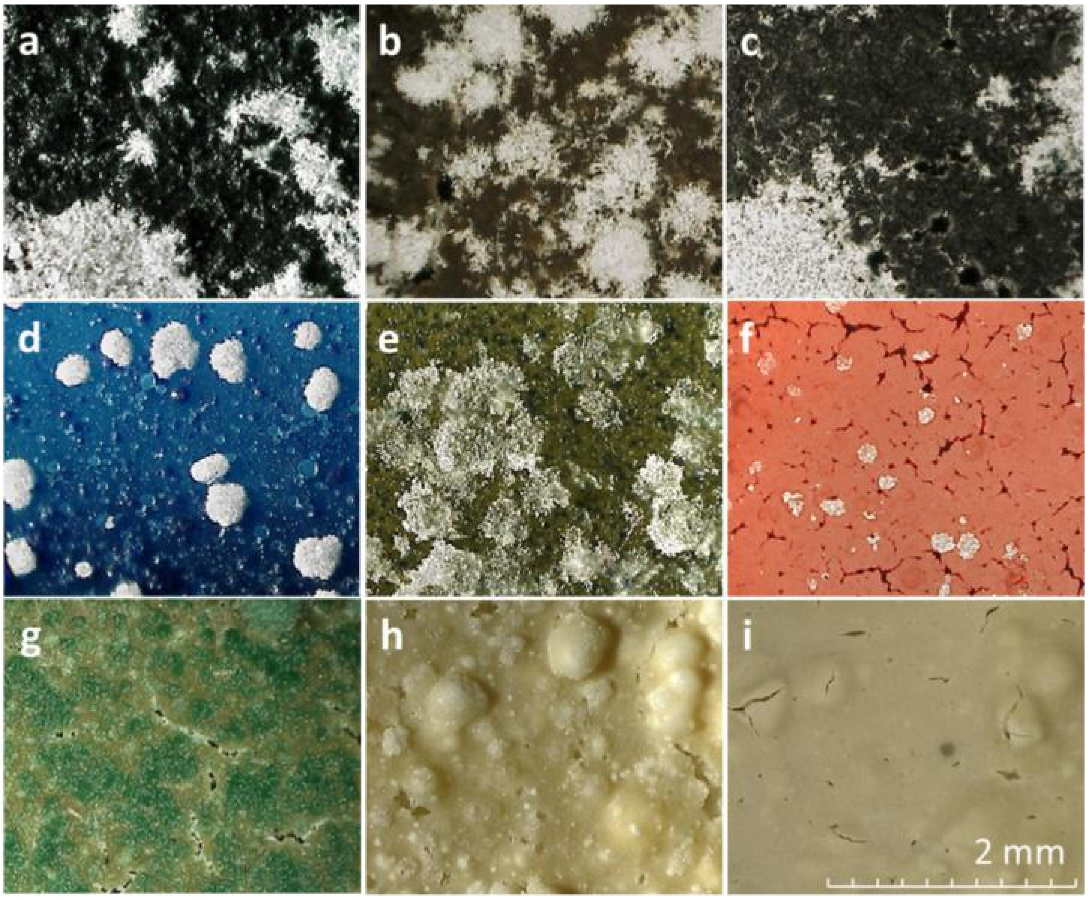

Figure 1 HIROX microscopy images of efflorescence and protrusions on egg tempera paint samples: (a) ivory black, (b) raw umber, (c) Prussian blue, (d) ultramarine blue, (e) smalt, (f) cadmium red, (g) malachite, (h) lead white and (i) zinc white. Images were captured on a HIROX digital microscope with an MXG-2500 lens using the 200× objective. Slight raking light was used.

- Cadmium red paint was the best preserved showing only a small amount of white efflorescence with no large pustules or protrusions within the paint layers.
- The zinc oxide test sample is currently being used to perfect microsampling techniques for direct analysis in real time mass spectrometry (DART-MS) and preliminary results of mass spectrometry will be correlated with the FTIR findings listed in Table 1.

Conclusion

Judging from the abundant presence of efflorescence and metal soaps on test samples, it is probably an error that occurred in the mixing ratio of egg yolk to pigments. The excess egg yolk liberated plenty of free fatty acid although it took time for it to migrate to the paint surface as white crystalline efflorescence or react with metals ions to form white pustules of metal soaps – similar to chemical changes observed in oil paint. This unintentional growth of surface defects took place in darkness with minimum airflow in a container stored in a stable museum environment. It is likely the formation of metal soaps occurred earlier, however they had not migrated to the surface and they are not visible with the naked eye. Analysis of these aged, laboratory-grade egg tempera samples might provide some insights into the egg tempera paint defects in the 20th century (Beltinger and Nadolny 2016; Boyle *et al.* 2002). In-house instrumental analysis currently used to investigate the zinc soaps from oil paint – attenuated total reflectance-Fourier transform infrared (ATR-FTIR) spectroscopy, micro-FTIR reflectance mapping, GC-MS, scanning electron microscopy with energy dispersive X-ray (SEM-EDS) analysis, cathodoluminescence scanning electron microscopy (CL-SEM) and X-ray diffraction (XRD) – will also be applied to these test tempera samples. Hopefully, this will lead to a deeper understanding of the chemical migration, the chemical changes in relation to the mixing ratio of egg yolk to pigments, the ageing effects on the production of free fatty acid, and the environmental conditions that could promote the growth of efflorescence and metal soaps. The zinc oxide test samples are currently being used to perfect the DART-MS microsampling techniques. Results will be forthcoming.

Notes

1. Lawrence's works are commonly identified as tempera or gouache; however, the artist was known to have used a wide variety of commercial water-based paints over the course of his career, including 'show-card colours', 'poster paints', Rowney Egg Tempera, Bocour Casein Colours, Shiva casein tempera, along with homemade egg-tempera paint (Steele 2000). Analyses have detected a wide variety of binders in his works – including egg, egg and oil, gum, glue, gum and glue, casein, and casein and glue – often within several different media identified within the same artwork. Free fatty acid efflorescence has also been found on some Lawrence works (Schilling *et al.* 2000).
2. Potassium soaps have previously been identified in oil paint films containing degraded smalt (Spring *et al.* 2005).

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Authors' addresses

- Stephanie Barnes, Paintings Conservator, Toronto, Canada
- Jia-sun Tsang, Senior Paintings Conservator, Smithsonian's Museum Conservation Institute, Suitland MD, USA (tsangj@si.edu)

WORKSHOP SUMMARIES

Tempera: painting with egg and oil (part 1). Recipes, handling properties and painterly qualities (part 2)

Lisa Afken and Reni Mothes

The day started with a theoretical introduction to the chemical and physical properties of tempera paints by Patrick Dietemann after which the group was divided into two workshops. In Part 1, led by Lisa Afken, participants prepared and applied their own paints made with whole egg, white and yolk. They then produced oil paints with different oils and in combination with egg. Five different pigments were available from which to choose. This group concentrated on comparing the specific handling properties of several tempera binding media and the influence of pigmentation on, for example, surface structure, viscosity, gloss, saturation and drying time. Working independently, participants tested the different paints on a test panel and made notes for a final comparison. They discovered that the results always depended on the interactions between each single material (binder, pigment, solvent) and the way in which they treated the paint (tools, order of addition etc.).

Figure 1 Tools and materials, including egg, oil and pigments, used during the workshop.

Using one constant artistic theme (drapery), participants in Part 2, led by Reni Mothes, compared the handling properties of variant egg tempera recipes as well as in combination with oil paints. They experienced the difficulty of working with paints which, during the drying process, created either reversible or irreversible films.

After lunch the groups switched, allowing participants to experience both parts of the workshop. The day finished with both groups taking part in a final discussion.

Workshop leaders

- Lisa Afken, Head of the Studio Workshop for Painting and Material Technique, Academy of Fine Arts, Mainz, Germany, and Freelance Painting Conservator
- Reni Mothes, Lecturer in Fine Art Painting Materials and Technology, Academy of Fine Arts, Leipzig, Germany

Making paints with egg, oil and pigments: possibilities, physicochemical properties and distribution of the phases

Patrick Dietemann, Ursula Baumer, Wibke Neugebauer and Ulrike Fischer

This workshop examined different mixtures of egg yolk and linseed oil with pigments. Five experiments were performed to answer questions such as: What are the properties of these systems? How do the paints flow? How does the composition of the mixture influence the flow behaviour of the paints? What do the paints look like? Mixtures of egg yolk and linseed oil with and without pigments were prepared in different ways, and their properties were correlated with the distribution of the phases in the samples. The first two experiments were intended to study presumed oil-in-water (O/W) and water-in-oil (W/O) emulsion systems by gradually adding oil to egg or egg to oil, respectively. The next three experiments included pigments, chalk:zinc white (3:1) and ultramarine. The pigments were either ground with egg yolk followed by an addition of oil or ground with oil then egg yolk was added. For the fifth experiment, part of the pigment previously ground with egg yolk was allowed to dry during the lunch period. The resulting egg-coated pigment was subsequently ground with oil in the afternoon.

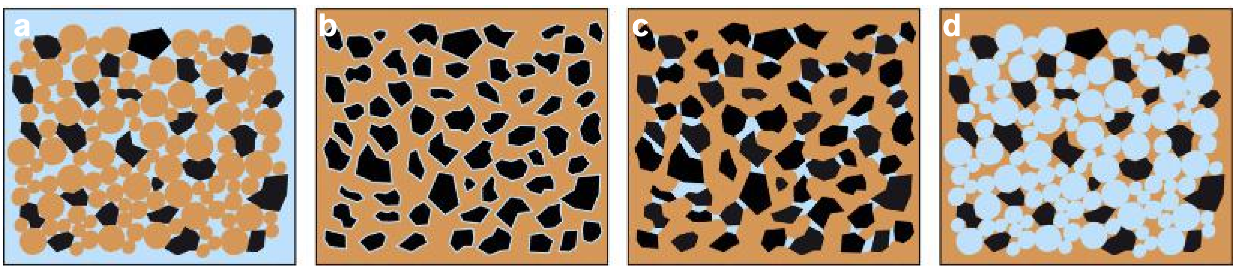

Figure 1 Systems formed by pigments with egg and oil: (a) O/W emulsion, (b) egg-coated pigment in oil (aqueous phase is solid/dry), (c) capillary suspension and (d) W/O emulsion. Blue: aqueous phase/protein, brown: oil phase.

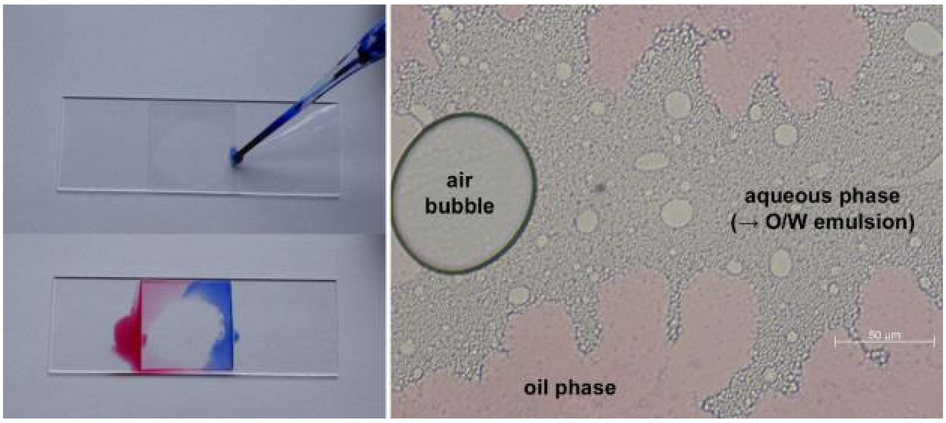

Figure 2 *Left*: application of stained water (blue) and oil of turpentine (red) to a sample. *Right*: microscopic image of a sample in contact with red oil of turpentine. The sample is pushed away by the turpentine, thus the continuous phase is aqueous (i.e. it is an O/W emulsion).

Pigments dispersed in a liquid form a suspension. Egg yolk with oil may form an emulsion, and with pigment it forms a ternary particle-liquid-liquid system. Many different systems can be produced (see Fig. 1), some of which may be inhomogeneous mixtures that are not necessarily stable for long periods.

Samples of the mixtures were studied in three ways to test what kind of system was formed depending on the composition and paint preparation:

1. Aliquots of the paints were painted out on primed cardboards to test their flow behaviour. Were they runny, stiff or easy to apply? Did they allow impasto to form or would they run?
2. To determine the continuous phase of the system, a tiny piece of sample was placed between a glass slide and a cover slip and drops of stained water (blue) or stained oil of turpentine (red) added. Both liquids were sucked into the void between the slide and cover slip and the behaviour of the sample with both liquids was observed under the microscope (see Fig. 2).
3. To observe the distribution of materials also in pigmented samples, both the proteins (egg) and oil were stained with selective fluorescent stains prior to the preparation of the paint. This allowed the distribution of the phases in the sample to be studied without adding a stain to the prepared paint.

The experiments demonstrated that the expected emulsions were not always formed and that many different systems with surprisingly varying flow properties could be produced from the same materials.

Workshop leaders

- Patrick Dietemann, Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich, Germany
- Ursula Baumer, Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich, Germany
- Wibke Neugebauer, Doerner Institut, Munich, Germany
- Ulrike Fischer, Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich, Germany

Tempera versus oil paint

Ulrich Zwerenz and Johanna Thierse

Participants in this workshop divided into two groups with each group spending half of the day preparing tempera paints and the other half preparing oil paints. Paint with different tempera binding media (egg yolk, whole egg + oil / + resin etc.) were prepared to explore the different handling properties imparted by the binder and the influence of diluting with water or glycerine. The drying properties of these paints on different substrates (grounds) were evaluated. While one group concentrated on tempera paint, the other prepared oil paints by hand to study the difference between linseed oil and poppy oil, the effect of additives on the oil paint, and the properties of oil paints when applied to different substrates (grounds).

Workshop leaders

- Ulrich Zwerenz, Artist, Munich, Germany
- Johanna Thierse, Freelance Paintings Conservator and Teacher for Historical Painting Techniques, Berlin, Germany

Figure 1 Ingredients used for the workshop. (Photo © Renate Poggendorf.)

Figure 2 Mock-ups of paints based on different binders made during the workshop. (Photo © Renate Poggendorf.)

Combining fresco and tempera

Stefanie Correll, Stephan George, Klaus Häfner, Jessica Kallage-Götze and Eva Reinkowski-Häfner

This workshop offered an opportunity to practise the combination of fresco and tempera or other organic binding media. All 15 participants, with varying experience of fresco painting, were given the opportunity to test the behaviour of organic binding media on freshly applied plasters and discuss the observations with other members of the group. Work plates for the application of fresco and other necessary working materials – such as lime plaster, aggregate (sand), several binding media and pigments – were prepared and made available.

Participants represented a range of occupations including restorers, chemists and artists. Some of the tests, using untypical materials such as water glass, a potassium silicate (K_2SiO_3) in combination with egg, linseed oil and glue, resulted in new technical insights. An excursion to St Ludwig church in Munich with its important Nazarene wall paintings by Peter von Cornelius completed the workshop. Some participants left with their mock-ups so it will be interesting to receive reports as to how the material reacted after carbonation of the lime plaster.

Workshop leaders

- Stefanie Correll, Restorer of Mural Paintings, Bavarian Administration of State-owned Palaces, Gardens and Lakes, Munich, German
- Stephan George, Advisor for Stucco Works, Academy of Arts, Munich, Germany
- Klaus Häfner, Restorer of Mural Paintings, Bavarian Administration of State-owned Palaces, Gardens and Lakes, Munich, Germany
- Jessica Kallage-Götze, Artist, Munich, Germany
- Eva Reinkowski- Häfner, Universität Bamberg, IADK, Bamberg, Germany

Figure 1 Workshop members presenting and discussing the results of their working tests.

Figure 2 Photograph of a mock-up.

Syntonos paint: an early commercial tempera paint. Its properties and applications

Catharina Blänsdorf

Figure 1 Preparing the Syntonos binding media according to the historical recipe. (Photo © TU München, Lehrstuhl für Restaurierung.)

Syntonos paint (*Syntonosfarben*) was the commercial name of tempera paint tubes developed by the German painter Wilhelm Beckmann. Syntonos paints were intended to look and be processed like oil paints but also to be dilutable with water and dry quickly. In addition, they were praised for their longevity – the paint in the tube did not dry and the applied films did not change or develop cracks. The main compounds were gum arabic and linseed oil with additions of glycerol, wax, beef tallow and green soap. Following Beckmann's patent, which was granted in Germany in 1893 and soon followed by patents in other countries, artists started to use these paints. The Munich painter Franz von Stuck (1863–1928), for example, employed them to execute his monumental painting *The War* (*Der Krieg*) as early as 1894.

The day began with a guided tour by Margot Th. Brandlhuber (head of collections/curator at Villa Stuck) through the magnificent house designed by Stuck as his residence and studio. As well as showing the rooms and providing a history of the building and details of the artist's life and the collection she drew the group's attention to several paintings for which Syntonos paints may have been used.

The second part of the day dedicated to practical work took place at the Technical University

Figure 2 Presentation of the painting *The War* in the Neue Pinakothek by Wibke Neugebauer. (Photo © Neue Pinakothek München.)

of Munich's Lehrstuhl für Restaurierung, Kunsttechnologie und Konservierungswissenschaft (Chair of Conservation-Restoration, Art Technology and Conservation Science) under the supervision of Catharina Blänsdorf assisted by Manuela Hoermann. After a short theoretical introduction, participants were allowed to gain experience using homemade Syntonos paints. Working in groups, they reconstructed the binding medium following the patent recipe, using step-by-step experiments to understand the effect of the individual components on the properties of the binding medium, and then preparing paint by adding pigments to the binder. Using the prepared paint, they then applied paint layers in different ways in order to experience its properties. Problems of ageing of Syntonos paints were discussed – shortly after it was finished, *The War* exhibited serious signs of ageing, especially darkening. Applications of Syntonos paints on canvas prepared by Wibke Neugebauer developed a distinctive craquelure after only a few years. Participants were allowed to keep samples of paint on test panels and in tubes for further observation.

The day continued with a guided tour of the Neue Pinakothek during which Wibke Neugebauer presented art-technological investigations on two paintings by Franz von Stuck: *The War* and *The Sin* (*Die Sünde*, 1893). Analyses of *The War*, which is not normally on display and was made available specifically for the workshop, have confirmed that it was painted with Syntonos paint; the use of this paint for *The Sin* is still under consideration.

The workshop concluded with lively discussions on the visual appearance, characteristics and ageing phenomena of the paint layers as well as on a comparison of the paintings with the handling properties experienced earlier during the practical experiments.

Workshop leader

Catharina Blänsdorf, Conservator, Technische Universität München, Lehrstuhl für Restaurierung, Kunsttechnologie und Konservierungswissenschaft, Munich, Germany

Case studies of tempera painting in Munich *c.*1900

Luise Sand

This workshop focused on two paintings – *Villa by the Sea I* (*Villa am Meer I*), 1864, by Arnold Böcklin and *Good Friday* (*Karfreitag*), 1895, by Julius Exter – in the Bayerische Staatsgemäldesammlungen that were examined by the Doerner Institut as part of an extensive tempera research project.[1] Tempera paints as aqueous suspensions as well as wax were employed for both paintings.

Figure 1 The pactical part of the workshop took place at the Pinakothek der Moderne.

Arnold Böcklin attempted to emulate the technique of Pompeian wall painting in *Villa by the Sea I* using an aqueous suspension of finely ground resins in combination with transparent layers of beeswax.[2] During a guided tour of the Sammlung Schack, workshop participants were able to view the painting close-up and compare the visual appearance of this technique with the second version of the motif, *Villa by the Sea II* (*Villa am Meer II*), 1865, hanging opposite, which was executed in egg tempera and oil paints.[3]

Notes by Rudolf Schick, Böcklin's student in the late 1860s, provide an important source for the materials and technique used for *Villa by the Sea I*.[4] Schick describes how Böcklin prepared frankincense and sandarac resins as a water-dilutable binder and coated the surface with molten wax.[5] Reconstructions carried out in the workshop following Schick's description, and taking into account recent technological examinations and analyses of binding media, produced paints that can be applied similarly to watercolours: they dried quickly and could not be modelled wet-in-wet. The paint layers are very hard with a porous surface. The beeswax coating saturated the colours and smoothed the surface, resembling characteristics of a mural painting technique.

Another example of the combination of tempera paints and wax is the monumental triptych *Good*

Figure 2 Workshop participants producing and appying paints with frankincense and sandarac.

Friday by the Munich Symbolist Julius Exter of the Neue Pinakothek.[6] During examination the triptych revealed a differentiated painting technique of complex tempera systems in combination with resin-oil paints.[7] The examination results of the side paintings, executed predominantly in tempera, showed an unusual binding medium made from rye starch paste, egg and ceresin (earthwax). The workshop concentrated on the making and characteristics of paints with these binder components. The procedure of adding ceresin as a solid before pasting the rye flour in water and boiling the components together under constant stirring results in a binder with favourable properties. The paints produced were easy to spread and dried very matt.

Notes

1. See http://www.doernerinstitut.de/de/projekte/tempera/tempera_1.html (accessed 16 December 2018).
2. For information on the technological examination and analyses of binding media see: W. Neugebauer, *Von Böcklin bis Kandinsky. Kunsttechnologische Forschungen zur Temperamalerei in München zwischen 1850 und 1914*, Berlin 2016, Available at: https://www.hfbk-dresden.de/studium/studiengaenge/fakultaet-2/restaurierung/wissenschaftliche-arbeiten-und-publikationen/dissertationen/neugebauer/ (accessed 11 November 2018); W. Neugebauer, 'Layered and *alla prima*: some examples of tempera painting techniques, 1850–1914', in K. Beltinger and J. Nadolny (eds), *Painting in Tempera, c.1900*, London 2016, pp. 166–82; P. Dietemann, W. Neugebauer, U. Baumer, I. Fiedler, C. Beil, A. Obermeier, S. Schäfer and S. Zumbühl, 'Analysis of complex tempera binding media combining chromatographic techniques, fluorescent staining for proteins and FTIR-FPA imaging', in K. Beltinger and J. Nadolny (eds), *Painting in Tempera, c.1900*, London 2016, pp. 183–203.
3. Guided tour: Herbert W. Rott (introduction to the collection's history), Wibke Neugebauer (*Villa by the Sea I* and *Villa by the Sea II*).
4. R. Schick, *Tagebuch-Aufzeichnungen aus den Jahren 1866, 1868, 1869 über Arnold Böcklin*, Hugo von Tschudi (ed.), Berlin 1901.
5. Schick 1901 (cited in note 4), p. 75.
6. Currently in the depot.
7. For information on the technological examination and analyses of binding media see: L. Lutz, *Julius Exters Triptychon Karfreitag (1895) – Untersuchungen zur Maltechnik*, diploma thesis, Department of Restaurierung, Kunsttechnologie und Konservierungswissenschaft, Technische Universität München, Munich 2011; L. Lutz, 'Julius Exters Triptychon Karfreitag (1895) – Untersuchungen zur Maltechnik', in *Beiträge zur Erhaltung von Kunst und Kulturgut* 1, 2014, pp. 42–55.

Workshop leader

Luise Sand, Freelance Conservator, Munich, Germany

Exploring the working methods of Henry Ossawa Tanner and other selected early 20th-century emulsion recipes

Brian Baade

This workshop focused on reconstructing emulsion paint recipes used by Henry Ossawa Tanner and experimenting and applying the resultant paint. These were then compared to paints obtained by reconstruction of a contemporary early emulsion recipe described by Jacques Maroger. Photocopies of Tanner's paint recipes housed in the Archives of American Art, Smithsonian Institute were distributed to the participants. The chosen Tanner recipe included flax seed syrup, parchment glue, linseed oil, mastic varnish, lanolin, and ethanol. One half of the class worked to prepare these ingredients in the proper proportions while the other half recreated the Maroger recipe, which included melting dammar resin into linseed oil and then whipping an aqueous solution of gum arabic into the resin-oil solution. All participants mulled a group of pigments, including viridian, cerulean blue, bone black, alizarin crimson, and zinc white, used by Tanner into the two emulsion binders.

Each of these paints was applied to a series of pre-prepared substrates and grounds using both a brush and palette knife to experience their tactile and rheological qualities. The grounds included an oil/glue/chalk emulsion ground on canvas, an animal glue/chalk/zinc white ground on panel, and an animal glue/chalk ground on panel. One half of the canvas sample was coated with mastic varnish while animal glue was applied to the lower half to create four distinct absorbencies and surfaces.

The reconstructions of Tanner's paints were very laborious. The resultant paint was readily miscible with water, dried quickly, and created a matt effect. The paint moved easily across the substrates. Participants also reconstructed Tanner's green glazes by mulling one part of viridian pigment by volume into five parts of the emulsion to create a transparent glaze with a satin sheen. The paints could be applied easily to the uncoated ground but were slightly repelled by areas of the ground that had been varnished with mastic. However, the paint did adhere to the section where the mastic varnish was coated with animal glue. The results correspond to Tanner's notes on the working properties of his paint.

The reconstruction of the Maroger emulsion paint was only soluble in organic solvents and was immiscible in water. The paint was very sticky, viscous, and easily leveled. It was very glossy and the

Figure 1 Some of the raw ingredients and prepared starting materials used in the workshop. (Photo © Chieh Li.)

colors were much more saturated than those produced by the reconstructed Tanner paints.

The workshop concluded with a discussion of the results and each participant left with a full description of the recipes and techniques, and their paint-outs of the reconstructions.

Workshop leader

Brian Baade, Assistant Professor, Painting Conservator, and Researcher of Historical Painting Materials and Techniques,University of Delaware, Newark DE, USA

Ernst Berger #temperaemulsions: tempera networks in Munich *c*.1900

Kathrin Kinseher

The use of tempera emulsions was discussed and intensely studied in Munich at the turn of the 20th century. As a leading author and teacher on painting techniques, Ernst Berger exerted a great influence on this discussion.[1] During this workshop modern oil tempera emulsions first published by Berger in 1897[2] were compared with recipes by the Munich pharmacist Ernst Friedlein[3] and those from an unpublished notebook of the same period from the estate of Wassily Kandinsky.[4] The workshop aimed to revive the experimental studies in tempera paints as they were carried out at the artist's studio in Munich-Schwabing around 1900. The participants prepared selected recipes based on egg yolk, gum arabic and casein as emulsifying agents. For example: 1 part gum arabic + 2 parts linseed oil or boiled linseed oil + 2 parts (or more) water[5] (Fig. 1) and a casein-oil tempera published by Friedlein in 1906: 100 g casein solution + 50 g poppy seed oil + 50 g water.[6]

Figure 1 Participants during preparation of a selected Berger recipe involving the mixing of gum arabic, linseed oil and water. (Image: Othmar Walchhofer.)

In total, six recipes were prepared and applied using the following method: each in pure binder, then in mixtures with cobalt blue pigment (Cobalt Blue Pale, PB 28.77346, Kremer Pigmente 457141) and transparent iron oxide pigment (Translucent Orange Red, PR 101.77491, Kremer Pigmente 52350), in full tone and diluted with water. These brush-outs were contrasted to pure yolk and oil paint applications previously applied in the first line of the sample board ahead of the workshop (Fig. 2). Participants were able to experience the process from preparing a peculiar recipe to handmade paint and from paint substance to colour tone and surface texture.

The workshop benefited from the advice of the artist Othmar Walchhofer and was complemented by an afternoon programme at the Lenbachhaus where head of conservation Iris Winkelmeyer presented insights into the restoration work of Franz von Stuck's painting *Salome*.[7]

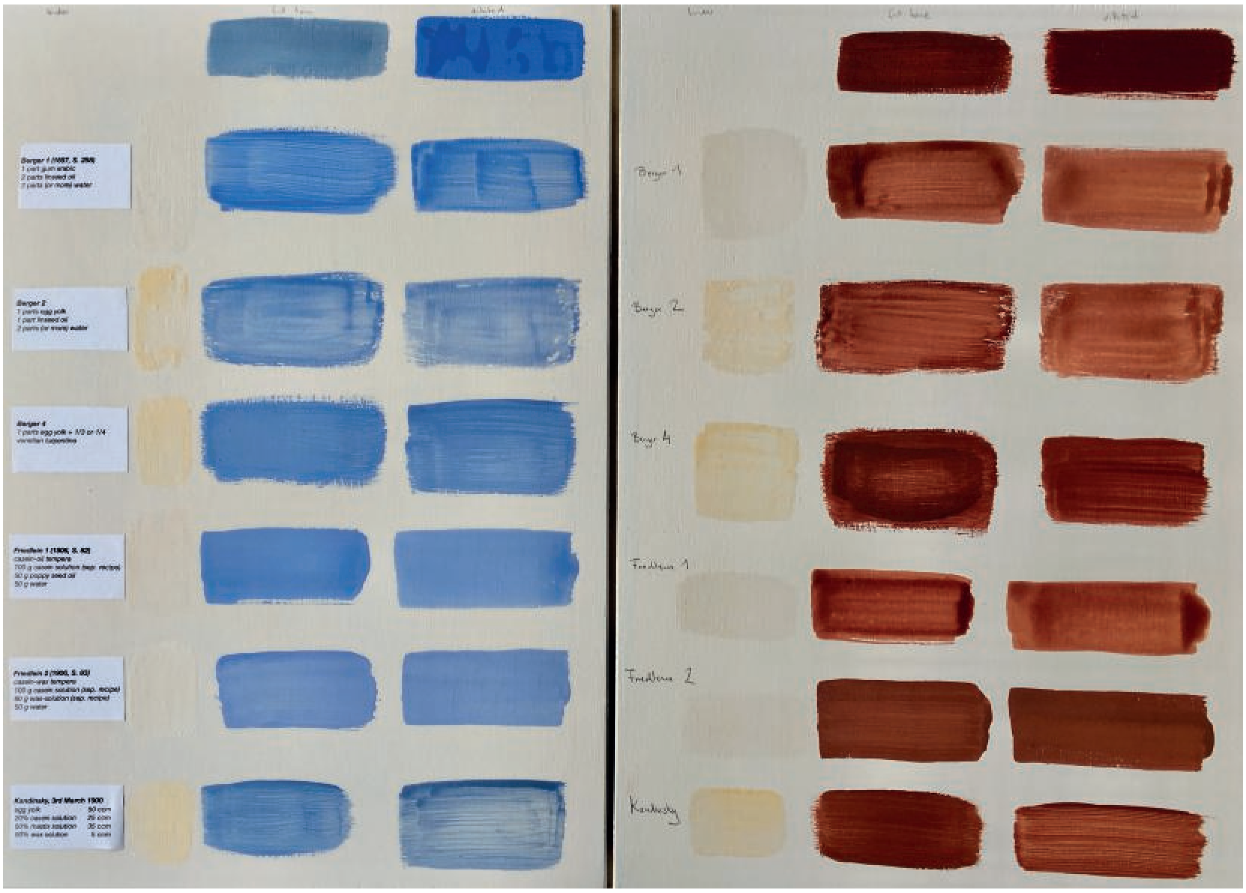

Figure 2 Sample boards made by participant Franziska Motz. (Photo: Kathrin Kinseher.)

Notes

1. See Kathrin Kinseher, 'Colour and form in highest perfection: teaching tempera in the early 20th century', in this volume.
2. E. Berger, *Quellen und Technik der Fresko-, Oel- und Tempera-Malerei des Mittelalters*, Beiträge zur Entwickelungs-Geschichte der Maltechnik, Munich 1897.
3. E. Friedlein, *Tempera und Tempera-Technik*, Munich 1906.
4. Centre Pompidou Paris, Fonds Kandinsky 188-e.
5. Berger 1897 (cited in note 2), p. 258.
6. Friedlein 1906 (cited in note 3), p. 82.
7. I. Winkelmeyer, 'Never use water! Stuck und die Temperarenaissance in München um 1900', in M. Mühling (ed.), *Franz von Stuck, Salome*, Munich 2014, pp. 45–77.

Workshop leader

Kathrin Kinseher, Akademie der Bildenden Künste München, Munich, Germany

Max Doerner's tempera painting techniques

Elisabeth Fugmann, Iris Masson and Valerie Müller

The Materials of the Artist and their Use in Painting by Max Doerner is considered one of the most influential books on painting techniques since its first edition in 1921. It is based on Doerner's lectures at the Academy of Fine Arts Munich, which he started in 1912/13. In chapter 4 he describes in detail how to prepare tempera paints as well as four different tempera painting techniques.

According to Doerner, 'the special character of tempera rests on the fact that it is an emulsion,' a 'watery, turbid, milk-like mixture of oily and watery constituents.'[1] He differentiates 'natural emulsions,' containing egg and casein, from 'artificial emulsions,' containing gum, animal glue or saponified oil or wax. In his opinion, mixing the substances well together is the best way to prepare the tempera binding media. Various recipes are described, including the amount of binding media required for 12 pigments, but Doerner also points out that every painter has to acquire his own experience in preparing proper tempera paints.

Figure 2 The participants produced and applied different tempera binding media.

Figure 1 Using Max Doerner´s 'mixed technique'.

Guided by Doerner's original recipes, participants produced and applied up to six different tempera binding media: egg, casein, gum, animal glue, starch and wax tempera. It was possible to compare the characteristics of 'natural' and 'artificial' emulsions and to experience the challenges of producing tempera paints. It became obvious that recipes such as wax and starch tempera require more skill to produce than the classic egg tempera.

Doerner describes four different tempera painting techniques: the unvarnished and varnished tempera, tempera as underpainting for oil and the so-called *Mischtechnik* (mixed technique). His 'mixed technique', i.e. painting with tempera into wet resin-oil colour, was a special focus in this workshop. Using the study of a Madonna by Max Doerner (which included notes documenting the painting materials) as a base, the participants implemented the 'mixed technique' to create their own copies. In order to experience all paint layers independently from drying times, each participant obtained a previously prepared underpainting consisting of underdrawing, *imprimatura* (resin-oil colour) and white underpainting (egg-yolk tempera). They were able to experiment using both their own underpainting and a previously prepared one to carry out the next step: application of the colour with thin, flat transparent resin-oil colour glazes. Detailed lines were painted with tempera into those wet glazes, as described by Doerner. Participants compared their own experiments with historical paint samples from the archive of the Doerner Institut, prepared by Max Doerner and his students.

The workshop concluded with a short visit to the Pinakothek der Moderne, led by Maria Körber and Iris Masson, to examine two paintings by Otto Dix, who first applied Doerner's 'mixed technique' in 1926.

Note

1. M. Doerner, *The Materials of the Artist and their Use in Painting: with Notes on the Techniques of the Old Masters*, E. Neuhaus (tr.), London rev. edn 1969, p. 211.

Workshop leaders

- Elisabeth Fugmann, Conservation Fellow, Doerner Institut, Munich, Germany
- Iris Masson, Conservation Fellow, Doerner Institut, Munich, Germany
- Valerie Müller, Conservation Fellow, Doerner Institut, Munich, Germany

Kurt Wehlte's tempera recipes on different ground layers

Ivo Mohrmann and Monika Kammer

After graduating from the Art Academy in Dresden in 1925, the artist and art technologist Kurt Wehlte focused on the production and quality assurance of artists' colours.[1] In 1931, in cooperation with the paint manufacturer Hermann Ehlert (Herrmann Neisch & Co.) in Dresden, his second textbook on egg tempera was published.[2] Wehlte recognised the advantage of tempera in the variety of applications and expressions by commenting that 'Tempera is a more subtle material than oil paint.'[3]

This workshop was based on the recipes in his later book, which was translated into English by Otto Dix's son Ursus in 1975.[4] *The Materials and Techniques of Painting* by Kurt Wehlte was first published in 1967 and contains a collection of his practical experiences and lectures on painting techniques held at the art academies in Dresden, Berlin and Stuttgart between 1925 and 1963. As a teacher of painting techniques at these institutions, he shared his knowledge with many artists of his time including among others Otto Dix, Max Slevogt and Max Feldbauer. As an artist, Kurt Wehlte addressed his recipe instructions to artists. He cites the advantages and disadvantages of the materials and their processing from his personal experiences, rendering his instructions especially valuable.

The workshop began with an introduction to the theme by a talk on Wehlte's painting technique workshop at the Vereinigte Staatsschulen für angewandte Kunst Berlin (1933–1945). Participants then produced five exemplary tempera recipes by Wehlte (Fig. 1):

- Gum tempera: 4 parts gum arabic (40% in water) + 1 part linseed oil varnish[5]
- Glue tempera: 3 parts hide glue (6% + 0.6% alum) + 1 part linseed oil varnish[6]
- Casein tempera: 40 g casein (powder) in 125 ml water + 16 g borax in 125 ml water + 25 ml linseed oil varnish + 25 ml Venice turpentine[7]

Figure 1 Production of a glue tempera: linseed oil is added to a glue colour drop by drop. (Photo © Monika Kammer, HfBK Dresden.)

Figure 2 Working situation at the Art Academy in Munich. (Photo © Ute Roeseler.)

- Soap emulsion: 10 g ammonium carbonate (salt of hartshorn) in 60 ml water + 25 g beeswax (bleached) in 25 g turpentine oil = 1 part + 1 part casein emulsion[8]
- Oil tempera (modified industrial oil colour): 1 part resin-oil colour (Schmincke *Mussini*) + 1 part glue tempera [9]

The tempera colours were applied on a cardboard prepared with absorbent and semi-absorbent grounds.[10] The practical part of the workshop focused on the interaction between the ground layer and tempera paints (Fig. 2). Differences of application, structure of brushstrokes and transparency provided an idea of the whole spectrum of possibilities offered by these painting materials. Most of the working steps and quantities given in Wehlte's recipes were precise, easy to produce and successful in application, revealing their textbook characteristics.

Notes

1. M. Körber, 'Studien zur Maltechnik der Neuen Sachlichkeit in Dresden', in B. Dalbajewa (ed.), *Neue Sachlichkeit in Dresden, Staatliche Kunstsammlungen Dresden – Galerie Neue Meister*, Dresden 2012, S. 150.
2. K. Wehlte, *Ei-Tempera und ihre Anwendungsarten*, Dresden 1931.
3. Wehlte 1931 (cited in note 2), S. 45.
4. K. Wehlte, *The Materials and Techniques of Painting*, U. Dix (tr.), New York 1975.
5. K. Wehlte, *Werkstoffe und Techniken der Malerei*, Ravensburg 1967, p. 607.
6. *Ibid*., p. 608.
7. *Ibid*., pp. 608, 456.
8. *Ibid*., pp. 609, 237.
9. *Ibid*., p. 609.
10. (A) Cardboard only with glue size, (B) chalk-zinc white ground, (C) chalk-zinc white ground with addition of alum (10%), (D) emulsion ground.

Workshop leaders

- Ivo Mohrmann, Head of the Department of Art Technology, Photography and Radiological Investigations, Degree Programme in Art Technology and the Conservation and Restoration of Works of Art, Dresden Academy of Fine Arts, Dresden, Germany
- Monika Kammer, Scientific Assistant, Degree Programme in Art Technology and the Conservation and Restoration of Works of Art, Dresden Academy of Fine Arts, Dresden, Germany