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Picture-Perfect – The Perception and Applicability of Facsimiles in Museums

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Abstract
Various types of digital and physical three-dimensional facsimile technologies (e.g., high-definition digital modelling and 3D printing) have entered the art world and have become increasingly important for research and presentation purposes. Yet, studies that go beyond the technical aspects of (3D) facsimile techniques, such as their significance for the conservation/restoration field and museum display, are scarce, especially in the case of easel paintings. Furthermore, studies that analyse the perception of these methods and, consequently, their impact on the authenticity of the original painting, do not exist to our knowledge. The aim of this research is twofold: firstly, it evaluates a viewer's perception of various facsimiles; secondly, on the basis of this analysis, it aims to gain a better understanding and provide an overview of the applicability of (3D) facsimiles of artworks for presentation purposes and potential users (technical art historians, conservators, curators, material scientists and museum visitors). This research was executed by combining a literature review with quantitative and qualitative analyses of the data acquired through a) a questionnaire of 17 closed and open-ended questions and (b) an on-site session at the Mauritshuis museum (The Hague, The Netherlands). Based on analysis of the data collected through these activities, this paper attempts to provide an indication of the current attitude towards (3D) facsimile methods as well as to present some criteria of using these methods in a museum environment.

Keywords
3D reproductions, 3D printing, facsimiles, art perception, museum presentation, authenticity, paintings

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1. Introduction

Reproductions that use digital technologies, such as digital modelling and 3D printing, have become increasingly important within the art field and museum practice. These digital methods offer the possibility to recreate and alter images of artworks regardless of the artwork's physical complexity, size and shape. Furthermore, the digitization of artworks facilitates their wide accessibility without any physical limits. Although facsimile techniques are already being used in the art field (mainly by conservators, restorers and technical art historians), the new possibilities and opportunities that arise with digital technologies ignite a reconsideration of the role that artworks play in our society and the way reproductions of art might change our perception and the authentic value of the original object.

In the case of paintings, *perception* refers to the relationship between the artwork's materiality as the starting point of one's personal emotional connection with the object and the various meanings the viewer might attach to it. This works both ways: plausible changes in emotional and/or functional connections signify a change in the perception of the artwork. Describing the term *authenticity* is challenging as it is diverse, culturally determined and personal (Tissen, 2020). In the case of a Western culture (within which this research was carried out), the authenticity of art is generally associated with a materially unique artwork signed by an artist. This would mean that the reproduction of artworks causes a complex discussion. Namely, reproductions can never conform to an originality in materials and could thus be labelled as 'anti-authentic'. Yet, this notion of authenticity and the emphasis on the original artwork is rather new as it is only a development of the last two centuries. Before this time, reproductions were widely accepted and aided in the dissemination of artworks, next to having an educational purpose. Art students copied their masters to understand the tricks of the trait. Only during the preceding scientific revolution (about 1550–1700) in Western Europe did the idea about reproductions start to change. This firstly had to do with rapid developments in the natural sciences, which changed the understanding of the (material) world, as everything became measurable and based on empirical facts. Later on, new methods of reproduction (e.g., the printing press, etching and lithography) made artworks into mass-reproducible objects. Both these developments resulted in a fixation on the material uniqueness of artworks. Subsequently, the advent of increasingly better methods of reproduction initiated a new way of thinking about art and the rejection of the reproduction of artworks (Tissen, 2021a). Walter Benjamin's essay (1936) on mechanical reproduction – in his time photography, but nowadays also applicable to other reproduction methods, such as 3D printing – is still relevant today. The mechanical reproduction captures the world around us faithfully with just one

click of a button and spreads an artwork quickly and endlessly. Although this offers new possibilities (e.g., capturing the same scenes from a different angle) it causes the exclusive character of an artwork to disappear. Through mechanical reproductions such as photography and 3D printing you extract the tradition and meaning of a work of art because it is no longer unique for it can be everywhere at once. This way, art loses its authentic experience or 'aura', in Benjamin's words. Although we have become more used to seeing artworks everywhere through facsimiles, this has not led to a waning interest in the original. On the contrary, the popularity of museums, where the original is highlighted, show that this only has been increasing (Tissen, 2021b). Art's popularity and the resulting model of blockbuster exhibitions and mass events contribute to the objectification of authenticity. In a world where facsimiles, 'fake news' and high-value counterfeits are ubiquitous, museums are supposed to communicate about 'the real (object)', rejecting almost any form of physical reproduction. Therefore, it can be said that the increasing quality of facsimiles and their omnipresence results in an increasing obsession with the original artwork, thus rejecting the reproduction of art entirely, especially within a museum setting. With this definition of the aura of art and the museum, it can be expected that any facsimile will be immediately rejected and that it will only have a negative effect on the perception of the original artwork.

Following this Western idea about authenticity, reproduction methods cannot be 'authentic'. However, there is an increasing amount of studies that show a shift in the perception of authenticity (Gao and Jones, 2021; Lowe, 2020; Malik *et al.*, 2021). These studies reveal that, in a world which is becoming increasingly connected through digitalization and the rapid development of technology, authenticity should not be considered as something that is solely static, fixed and based on materials alone. Instead, authenticity is becoming increasingly more complex as the value of art also relies on intangible qualities, such as one's emotional connection to an artwork or its significance in a cultural context. For this reason, authenticity should be seen as a phenomenon that relies on art's intangible and ever-changing emotional and social values. Only a small part of the notion of authenticity depends on the artwork as a material expression of a fixed moment in time and space. Shifts due to the changing relationships of the individual (artist) in society, new scientific discoveries, changes in social networks and transitions in cultural perception and preference are much more important for the assessment of authenticity. 'Aura' is place- and time-dependent as it is inherently linked to fluctuations in the perception of a variety of values that influence the meaning of both original artworks and their reproductions (Tissen, 2021a). In this case, facsimile technologies could be authentic and of value to our understanding of the original object.

2. State of the Art – Literature Review

Due to the rapid technological advancements and the ease with which artworks can be digitized and reproduced, the urgency to research and explore the possibilities facsimile methods offer has increased significantly (Mason, 2020; Parry, 2013). This has led to a growing number of projects involving the mass digitization of art works (e.g., The Smithsonian, Uffizi gallery), and an increasing number of studies concerning the importance of facsimiles. Despite the usefulness of these projects and studies, the majority is technology driven, meaning that the practical implications of facsimiles have not yet been considered, nor has the significance of these technologies for the perception of original artworks been analysed. Moreover, the majority of research focuses on eminent 3D objects (e.g., sculptures) and rarely considers the use of 3D facsimile technologies for easel paintings.

Within the museum discourse, the role of facsimiles and their relationship to the original is rarely discussed (Dudley, 2013; Hooper-Greenhill, 2013; Macdonald *et al.*, 2015; McClellan, 2008). Approaching this topic from the perspective of conservation studies, the literature is slightly less scarce. Yet, these studies mostly focus on 'traditional' reconstructions and oftentimes do not include more recent methods nor a comparison between a diversity of facsimile methods (e.g., 3D printing and digital reproductions) (Acke *et al.*, 2020; Schweibenz, 2018; Stols-Witlox, 2020; Tissen, 2018, 2021b). Despite the attempt to grasp the usefulness of facsimiles for conservation and presentation purposes, the aim of these studies is oftentimes practice-based. This results in research which only touches upon the ethical consequences of art replication applicable for their specific case, meaning there is little attention for a profound investigation of the significance of facsimiles on our perception of original artworks (Acke *et al.*, 2020; Di Giuseppantonio Di Franco *et al.*, 2018; Lowe, 2020; Neumüller *et al.*, 2014).

Studies involving the facsimile versus authenticity debate have primarily involved theoretically analyzing the ethical significance of recent technologies and usually focus on solely one method, for example 3D printing (Lowe, 2020; Tissen, 2021b; Soulioti and Chatzidaki, 2022). Although these studies are helpful in obtaining a more contemporary idea of authenticity, they do not include quantitative and qualitative testing. Studies focusing on viewer responses of facsimiles that include and compare new technologies such as 3D printing are scarce. Existing studies do not or rarely include reconstructions focused on historical materials (Malik *et al.*, 2021). Paintings are furthermore not included within the analyses, because of their seemingly two-dimensional appearance. The few studies that do analyse the perception of original paintings versus facsimiles currently solely focus on the perception of two-dimensional (e.g., photographs) and digital reproduction methods and do not include

physical and 3D reproductions, which this study mainly focuses on (Grüner *et al.*, 2019; Leder *et al.*, 2015, Specker *et al.*, in press). Early empirical perception studies have furthermore been based on displaying facsimiles through digital methods of the 1990s, photographs or computer screens or hand-painted *reproductions* which do not reflect the possibilities and qualities these technologies have developed since (De Winter and Wagemans, in press; Hubard, 2007, Jucker *et al.*, 2014). More recent studies are helpful in grasping the possible effects of displaying paintings alongside facsimiles within museum spaces (De Winter and Wagemans, in press; Pelowski *et al.*, 2017). Although these articles stress the importance of including 3D reproductions within perception analysis, studies analysing a diversity of 3D technologies do not exist. Furthermore, with technologies such as 3D printing, it becomes possible to touch artworks. Several studies indicate that this is a valuable asset to experience an artwork (Bitgood, 1992; Locher, 2015; Pelowski *et al.*, 2017), which can also be traced back to the success of a diversity of exhibitions where touching 3D prints was central (e.g., *Touching the Prado* and *Feeling van Gogh*) For this reason, this study allows participants to interact with – and in some cases touch – the facsimiles to discover how this influences perception of the artwork and facsimile itself. Furthermore, because there is a restrained attitude towards facsimiles, it is interesting to explore to what extent this can be related to the lack of understanding of these types of methods. Several studies show the potential and the efficacy of labels and descriptions in museums to provide a more profound understanding and appreciation of the original artworks presented (Cupchik, 1994; Jucker *et al.*, 2014; Leder *et al.*, 2006; Millis, 2001; Russel, 2003). Yet, none of them consider the importance of providing information about facsimile methods and the changes this may cause for the appreciation of facsimiles in a museum environment.

In short, the existing publications fail to evaluate the perception of various art facsimile technologies and thus how these methods can be used effectively for museum presentation. This scarcity of literature motivated us to initiate field research within the Dutch art sector, where both researchers are based.

3. Research Aim

This paper aims to gain a better understanding of the perception of various physical and digital facsimiles (illusionistic reconstructions, schematic reconstructions, 3D prints, enlarged 3D prints and digital reproductions) in order to evaluate their usefulness for various disciplines within the art field, and for museum presentation and interaction. Specifically, we seek to determine in what sense the perception differs of physical facsimile methods and of the more recently developed digital reproduction methods.

This is a pilot study at the intersection of multiple broader research projects, e.g., Liselore Tissen's PhD research *Indistinguishable Likeness: 3D printing's significance for art research, conservation and presentation of paintings* (2019–2023), her projects *Gold or Blue? 3D printing for conservation and presentation* (2021–2024), *Eye-tracking Rembrandt original vs. 3D print in museums* (2022–2023) and Mané van Veldhuizen's MA thesis *A Pearl is Forever*: *Comparing Facsimile Methods on their Characteristics, Limits and Potential for Technical Art History, Conservation and the Museum* (2022). The latter involves the scope of several painting facsimiles for research and presentation purposes, while the first three research projects evaluate the significance of 3D printing for the research, conservation and presentation of paintings. Within this study, a variety of (potential) users of these technologies were interviewed: technical art historians, painting conservators, material scientists, curators and museum visitors. This allowed for evaluating the usefulness of these various techniques in the work of museum professionals, and the creation of enhanced experiences for museum visitors. Although this study focuses on practices within museums and is the first research on the perception and use of a diversity of facsimiles of easel paintings, the results could be helpful to the art field in a more general way. Furthermore, it is one of the few studies that has synthesized the opinions of people with different art backgrounds and expertise into one comparative study. It uniquely combines the perception of analogue facsimile methods that have been used for some time in the art field (such as illusionistic and schematic reconstructions) with more recent and contemporary technologies (such as 3D printing and digital visualizations). This pilot study provides the first steps for a toolkit to adequately use facsimiles for presentation purposes.

The main question this research aims to answer is: what effects do facsimiles have on the perception of an original painting, and what design factors should be taken into account when using facsimiles in a museum environment? By approaching this question, this research aims to:

1. Provide an idea of how the facsimiles under study are perceived (on their own and in comparison to each other) by both professionals as well as non-professionals;
2. Investigate in which elements the strength/weakness of each method lie;
3. Demonstrate how facsimiles can impact the perception of authenticity of an original artwork;
4. Understand whether or not providing information about the reason for creating a specific type of facsimile affects the viewer's perception of the method and the original artwork; and
5. Evaluate what design factors should be considered when presenting facsimiles in a museum context.

Figure 1. Johannes Vermeer, c. 1665, *Girl with a Pearl Earring*, oil on canvas, 44×39 cm, Mauritshuis (The Hague, The Netherlands).

These research questions were answered by re-evaluating data from earlier published studies and by performing new quantitative and qualitative analyses in the form of questionnaires and interviews using a constructivist Grounded Theory approach (Charmaz, 2014). Johannes Vermeer's *Girl with a Pearl Earring* (c. 1665) serves as a case study for this research (Fig. 1). This specific artwork was chosen, because significant technical data about the painting were acquired during the elaborate research project *The Girl in the Spotlight* in 2018 (Vandivere *et al.*, 2019), which allowed for making the facsimiles under study within this research. Furthermore, it is an incredibly well-known painting with a rich history, thus providing ground for authenticity problems to arise.

4. Hypotheses

On the basis of the literature research conducted and the researcher's experiences, the following hypotheses were developed:

– Overall, material correctness of a facsimile would be perceived more important than 1:1 visual similarity, because it explains the making process of the original (to professionals) and respects its authentic experience (to museum visitors).
– Technical art historians will be the most positive towards facsimiles, as making reconstructions is an important part of their education and training.
– Museum visitors would prefer digital reproductions (1) and illusionistic reconstructions (2), because their intentions are most easy to grasp. They are visually similar to the original artwork and can be used in an interactive way (1) or respect the material authenticity of the original (2).
– 3D printing presumably has the most potential for presentation purposes, but would be simultaneously considered the most threatening to the authenticity of the original, so a 1:1 reproduction cannot yet be successfully applied in museum context.
– When compared to seeing facsimiles with no prior knowledge, participants would value facsimiles more after participation in the research, and consequently know more about the methods and their possible usefulness.
– A facsimile would become increasingly interesting when it presents information that is currently not visible on the original painting (e.g., discolorations, reconstruction of colors, reconstruction of the craquelure).
– A facsimile can replace an artwork when it is too fragile to be displayed, lost or not available to a specific museum.
– Touching 3D prints can add to the museum experience, since the making process of a painting might be better understood by experiencing topographical differences.

5. Terminology and Techniques

Some terms used (Fig. 2) – *original, facsimile, reproduction, reconstruction* – require some clarification because their definition is related to the context of this research. Providing an exact definition of these terms is hardly achievable, since various disciplines within the art field approach these definitions differently. For this reason, we have developed a definition of the terms which are useful for this research specifically. Furthermore the facsimile technologies that are discussed in this article will be overviewed (see Note 1).

Original: An original artwork is made by a particular artist in a particular time. This can be retraced and verified by conducting technical analysis as well as archival, provenance and documentary research.

Facsimile: The term facsimile originates from reprinting books. They are as true to the original source as possible as they should convey the content, appearance, and dimension as closely as possible. In this sense, a facsimile

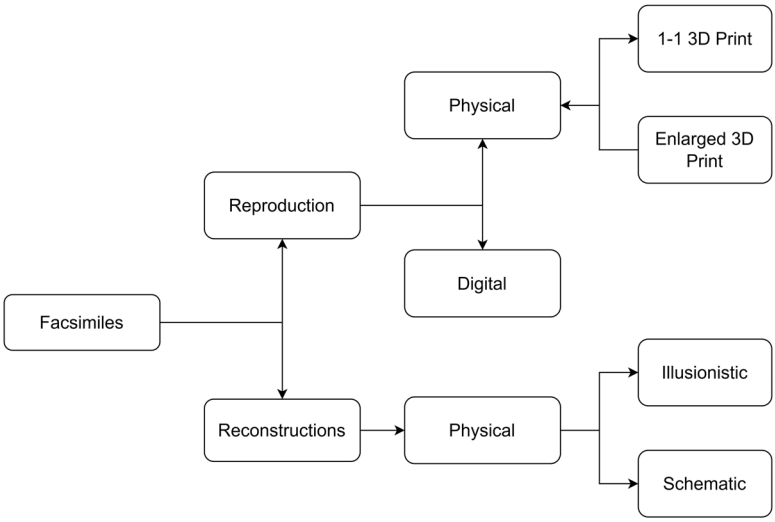

Figure 2. Schematic representation of the technologies and terms studied.

records every aspect of the original at a high quality (Tissen, 2020). An original artwork's value can thus be highlighted and transferred to a different version. For this reason, throughout this paper the word 'facsimile' will be used as the overarching term to describe reproductions and reconstructions.

Reconstruction: A reconstruction is a close copy of an original work that was made 'by hand' using techniques and materials that are *historically appropriate* (Carlyle and Witlox, 2007). This means that the working manner should reflect the processes the original artist followed as closely as possible.

Reproduction: A reproduction is a close copy made after an original. The technique and materials do not have to be historically accurate, but can for example be a modern equivalent of a historical paint or a digital representation (Tissen, 2020).

For this research Johannes Vermeer's *Girl with a Pearl Earring* (c. 1665) was reproduced using four types of facsimiles. These technologies were chosen based on the backgrounds of the researchers (technical art history and 3D printing) and their diversity in current applications, way of creation and material.

5.1. Schematic Reconstructions

A schematic reconstruction (SR) determines the most probable chemical paint composition of one layer in a painting or tells something about the material behaviour of a pigment/paint. The researcher makes different paint-outs in simple geometric forms, thereby keeping certain variables constant and varying other ones in such a way that a comparison of the paint-outs reveals

information about the paint composition and the way in which the appearance (in colour, glossiness, topography and other aspects) may have changed over time or will change in the future. Schematic reconstructions have no pictorial reference to a painting, but mimic specific layers in it (van Veldhuizen, 2022). In this example, a 'brush stroke' of blue paint of a specific thickness was applied to opacity charts (half white/half black sheet). By making small changes to the paint recipe, a researcher can assess how this might affect the colour and/or transparency of the paint (Figs 3, 4).

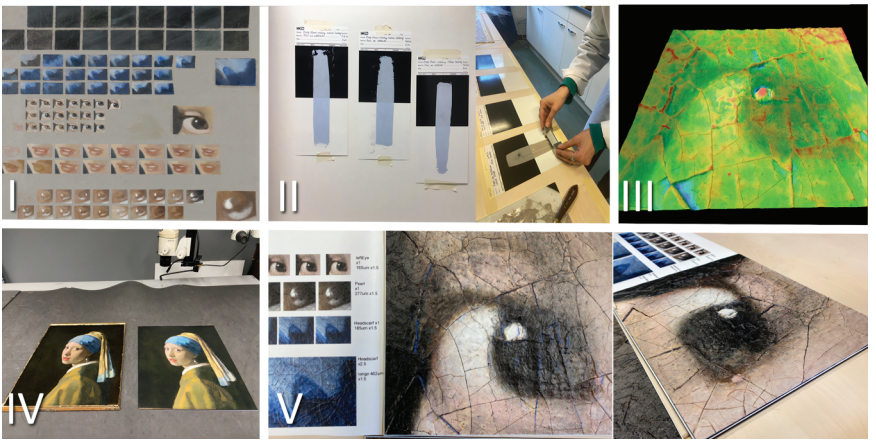

Figure 3. (I) Illusionistic reconstruction; (II) schematic reconstruction; (III) digital reproduction; (IV) 1:1 3D print; (V) enlarged 3D print.

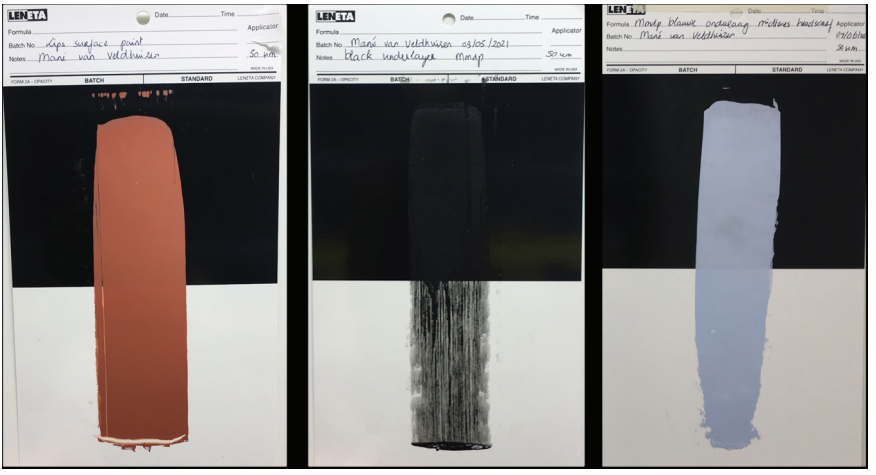

Figure 4. Schematic reconstructions of *Girl with a Pearl Earring*. Left: surface paint of lips. Middle: black underlayer. Right: blue underlayer mid-tones headscarf, oil on opacity charts, 10 × 15 cm, Mané van Veldhuizen, 2021.

5.2. Illusionistic Reconstructions

Illusionistic reconstructions (IR) try to imitate pictorial effects of a painting by replicating the original working methods and using materials that are historically appropriate (Carlyle and Witlox, 2007). Like schematic reconstructions, illusionistic reconstructions tell something about a paint system. However, their objective is to focus on the working process of the artist by combining paint layers instead of investigating one paint layer (van Veldhuizen, 2022). In this example five details of *Girl with a Pearl Earring* were painted multiple times to experience the effects of differences in layer build-up (Figs 3I and 5).

5.3. Digital Reproduction

Digital reproductions (DR) are digitized versions of original artworks. They can be viewed and shared online, but can also be manipulated. For instance, it becomes possible to digitally remove, add or change layers of information (for example changing the way a painting is lit). This happens by integrating information from computer models, reproductions and other types of (material) research. As a result, different layers of a painting can be explored freely, remotely and endlessly. In this particular case, *Girl with a Pearl Earring* was

Figure 5. Illusionistic reconstruction of *Girl with a Pearl Earring*, Mané van Veldhuizen, 50×50 cm, oil on canvas, 2021.

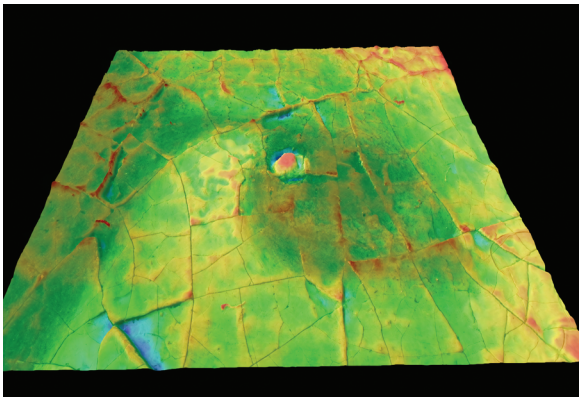

Figure 6. Digital reproduction of *Girl with a Pearl Earring*.

digitized by photographing the painting using a Hirox 3D digital microscope (Hirox Europe, Limonest, France), which magnified the surface up to 140 times. This produced digital images, from which height maps can be generated and overlaid with additional information (e.g., gloss variances) to show the topography of the painting. We provided the participants access to this model through this webpage: https://www.micro-pano.com/pearl/ (Figs 3III and 6)

5.4. 3D Printed Reproduction

A 3D printed reproduction (3DP) replicates a painting's colour, gloss and texture using a technology called *elevated printing*, which uses material jetting. First, a painting is scanned with a specialized stereo camera setup, then a computer translates this scan into 3D printable information (Tissen *et al.*, 2020). A specialized 3D printer, in this case an Arizona flatbed printer developed by Canon (Canon Production Printing BV, Venlo, The Netherlands), prints thin layers of white plastic to reproduce the different heights and depths of the painting's surface with a resolution of 450 dpi. The final layers are printed in colour using an inkjet printing system using CMYK and white. The painting's glossiness can be reproduced using up to six layers of transparent inks. The result is a life-sized (1:1) 3D print of the painting. The 3DP is the only life-size reproduction used within this research (Figs 3IV and 7).

5.5. Enlarged 3D Printed Reproduction

An enlarged 3D printed reproduction (E3DP) is made with the same technology as the 1:1 life-sized 3D printed reproduction mentioned before, but the printed image is enlarged compared to the original. In this example, the eye of *Girl with a Pearl Earring* has been enlarged 10 times. This means that

Figure 7. (A) Johannes Vermeer, *Girl with a Pearl Earring*, 1665, oil on canvas, 39×44,5 cm, Mauritshuis, The Hague. (B) 3D print of *Girl with a Pearl Earring*, 2018, polymer, 37,5×45,8 cm, Mauritshuis, The Hague.

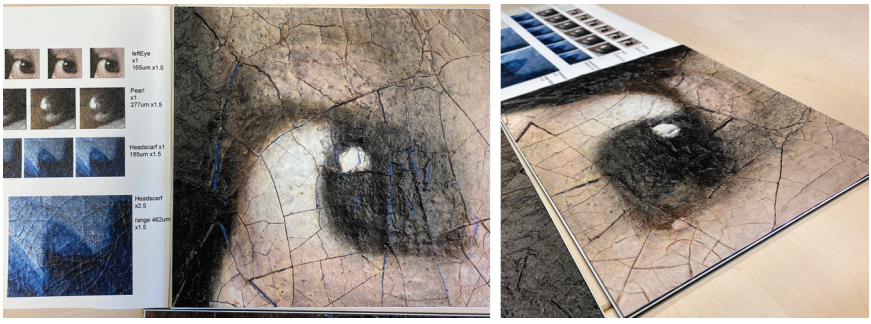

Figure 8. Enlarged 3D print of the proper right eye of *Girl with a Pearl Earring*, 2021, polymer, 24.5×21.7 cm, private property.

topographical features like brushstrokes, particles and cracks in the paint are more clearly visible. Printing parts of the painting in this way makes it possible to get a better tactile feel and understanding of the painting's texture in comparison to a 3D print. (Figs 3V and 8)

6. Method

The data were collected through video, voice recordings of the conversations during the on-site session and by documenting the opinions of the participants by using an Excel spreadsheet. The data were analysed both quantitatively using mean, mode and median as well as qualitatively using the constructivist

Grounded Theory approach (Charmaz, 2009, 2014). This contributes to grasping the complexities of the ethical discussions included within this type of research. Previous research done in social sciences and the arts using Grauser and Glaser's Grounded Theory has shown to be effective for perception research and will therefore be implemented as an addition to the quantitative data (Charmaz, 2017). The Grounded Theory is a complex but commonly used method and promotes a circular approach toward the collection of data. Within this theory, data are gathered until theoretical saturation is reached. In the case of perception research, the data come from a variety of sources such as interviews, focus groups, group discussions and participant observations, making this approach very useful for this study. Furthermore, in contrast to other methods, the presence of the researcher and their interference/interaction with the participants under study can be included. Lastly, by coding and categorizing the results according to a few selected parameters (e.g., discipline, background, preferences), the hypotheses can be tested and reflected upon in an organized manner (Charmaz, 2009). The reformulation of the results can lead to more efficient and precise approaches to the issue under study. Most importantly, particular subjective points of view are not encouraged within the Grounded Theory approach (Charmaz, 2014). In contrast, the focus lies on the unveiling of underlying social phenomena in a more general way, which was considered crucial for the analysis of the qualitative data gathered during the sessions.

The analysis started with individual questionnaires, which involved closed questions but also writing down thoughts and feelings that arise from the analytic process by two researchers separately. Furthermore, the audio recordings and videos served as an extra backup for the data written on site as one of the researchers took notes during the sessions. Subsequently, these data were analysed by coding based on the relevancy of concepts, similarity between them and the frequency with which they were mentioned. As different groups approached the same questions in their own way, the analysis was made in the context of the individual backgrounds of the participants and the group they belonged to. These data were analysed by coding based on the relevancy of concepts and similarity between them. With data coding during a qualitative evaluation, dealing with inter-rater reliability had a high priority for this research and literature shows that this is highly recommended to avoid the influence on the quality of data evaluation due to researchers' own experience. This way, possible biases of the researcher can be avoided. Therefore, both researchers analysed the data separately and individually. They both expressed and redefined the most important concepts implicit in each group. Finally, the researcher's individual results were compared in order to pinpoint the most prominent concepts and re-occurring themes. These concepts were counted and ranked to the number of times they were mentioned and were compared to

the other mentioned concepts. In the end, these data were analysed through a constructivist Grounded Theory approach. Lastly, the inter-rater reliability was calculated using Cohen's kappa, resulting in $\kappa = 0.84$ with a 92.31% agreement (Landis and Koch, 1977).

6.1. Target Groups

A total of 30 people were invited to participate in this research, of which 27 took part in the questionnaire. The participants were approached by the researchers personally and through the help of the staff of the Mauritshuis. At the end, all participants were rewarded a free ticket to the museum. Based on their profession, the participants were divided into five groups. Due to the pandemic, three participants could not make it to the session on site. For this reason, some groups are not as well represented as initially planned. The whole group on site ($n = 27$) consisted of nine males and 18 females and the median of the age was 39.37 years (oldest 78, youngest 23). In the end, this research consisted of:

Museum visitors	11
Painting conservators	5
Technical art historians	4
Material scientists	4
Museum curators	3
Total	27

We chose these groups to get a real-world selection of people that are involved with viewing a painting in different contexts. As Brieber *et al.* (2015a, b) and Grüner *et al.* (2019) show, individual preferences and knowledge in art play a significant role in art experience, because each group will have their own baseline of expectations which differs between groups. Furthermore, De Winter and Wagemans (in press) show that a diversity in experience and expertise leads to varying experiences especially considering the aesthetic experiences of the materials of both the original and the facsimile. For this reason, five groups were made for this study: technical art historians, conservators, material scientists, museum curators and museum visitors. It was decided that the group of museum visitors should be a larger group in comparison to the other individual groups of participants, since they were the only ones without professional experience in a museum environment. The professionals had either an art history or science background or were educated in both. Some of the professionals had previous knowledge about *Girl with a Pearl Earring*. Almost all participants had seen the painting in real life before and all of them were at least familiar with the image and the artwork. During

the research and within the questionnaire, we defined these groups as follows:

Technical art historian (TAH): A technical art historian primarily focuses on the artwork as a physical object. Using scientific equipment, they study the materials, techniques and production methods that went into making an art object. They also have experience making illusionistic and schematic reconstructions. These activities allow them to gain a better understanding of the artist's creative process.

Conservator (CONS): A conservator primarily focuses on taking care of artworks. They aim to extend the lifespan of an artwork by investigating its material history and technique, and intervening when necessary. As part of this intervention, the work of art is stabilized (conservation), and might receive an aesthetic treatment (restoration).

Material scientist (MAT): A material scientist primarily focuses on investigating the chemical compounds of art at a molecular level, and their effects on the material appearance of the artwork over time. This helps to explain why certain materials might have decayed over time, and how these changes can be mitigated in the future.

Museum curator (CUR): A museum curator primarily focuses on the artwork as a visual and aesthetic object in a social context. Some of their tasks within a museum might include: researching specific artists or artworks, looking into their history and provenance, and developing exhibitions to present them to the public.

Museum visitor (VIS): A museum visitor primarily focuses on enjoying the experience of seeing artworks in a curated gallery space. Different people will have more or less prior knowledge about the artworks, and might learn or appreciate different things about them.

6.2. Research Procedure

The research consisted of two elements: a questionnaire to be filled in at home, and subsequently an on-site session at the museum (Fig. 9). As one of the aims of this research was to test whether or not providing information about facsimiles would affect the perception of the artwork and the facsimile, participants were provided with different amounts of information per round of questions. In practice, this meant that some of the questions in the questionnaire and the questions asked on site were repeated. Furthermore, the on-site session was divided into two parts. The visitors were only allowed to see the original artwork during the second part. The on-site sessions took place before opening hours so the participants would not be interrupted or distracted by fellow visitors not partaking in this research.

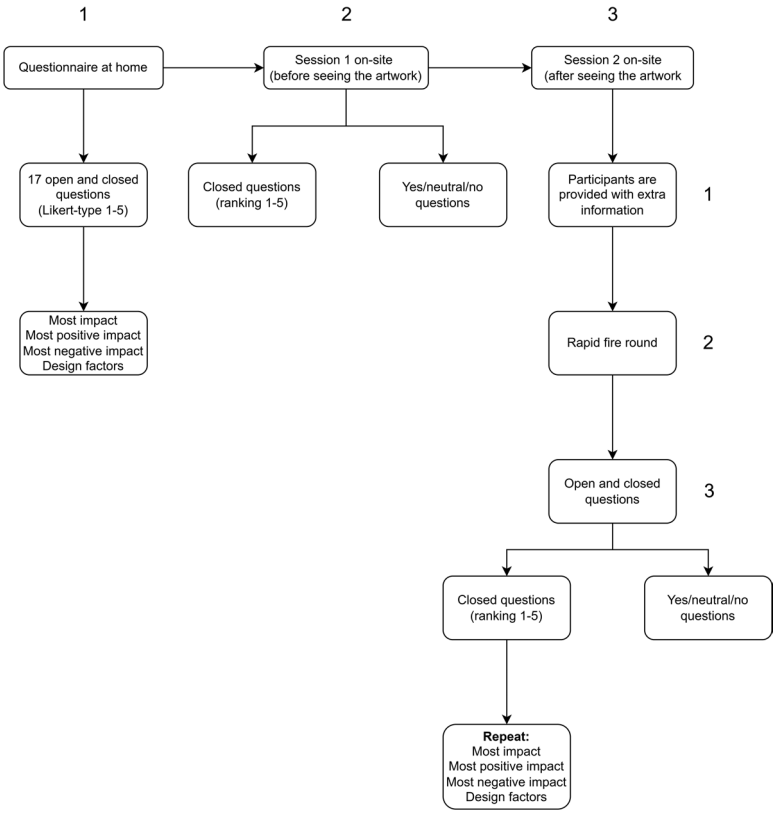

Figure 9. Schematic overview of the research procedure.

6.2.1. Pre-Visit at Home Questionnaire

The pre-visit questionnaire was sent to the participants before their on-site session at the Mauritshuis. This questionnaire was made in Google Docs and consisted of 17 closed and open-ended questions in total, which could be answered online. During the closed questions, the participants were asked to give ratings based on a five-point Likert-type scale from 1 (not at all) to 5 (very). Only basic information was provided, such as an explanation of the terminology used throughout the questionnaire, how the specific groups under study are defined and some guidance as to what purpose the facsimile methods could have (Appendix A1). The questionnaire took about 15 minutes to complete.

6.2.2. On Site: Before Seeing the Painting

After filling in the questionnaire, all of the participants were invited to the Mauritshuis. Participants within a test group all belonged to the same target

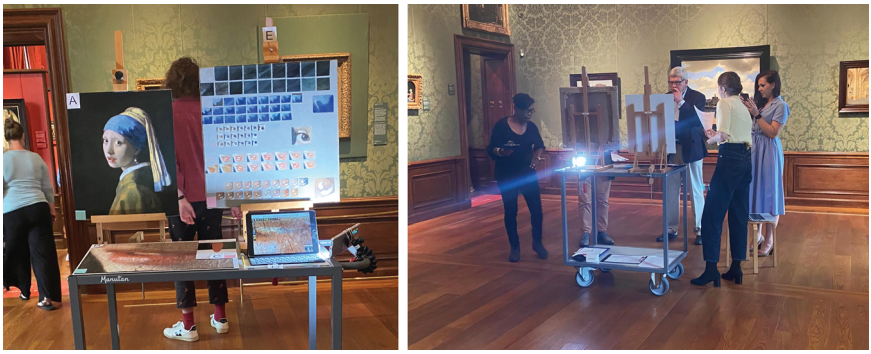

Figure 10. (Left) Setup with the reproductions displayed on a cart. (Right) Session with the participants and the researchers pointing at the illusionistic reconstruction.

group to prevent mutual influence between different target groups and amongst the participants of each group. The groups were kept small (a maximum of four participants per session) to avoid influence and to provide the participants with sufficient time to share their thoughts. During the first round, the participants were not facing the painting and were only allowed to look at the presented facsimiles displayed on a movable cart (Fig. 10). The participants were allowed to touch the 3D-prints and the digital reproduction presented on an iPad. Furthermore, no additional information on the use or significance of the facsimiles and technologies was provided. During this session, the participants each received a clipboard with six questions in which they were asked to rank the technologies from 1 to 5 (5 being the most, 1 being the least). After writing down their answers to the questions, for which they received 5–7 minutes, they were provided with three dilemmas and had to decide between two options provided (e.g., *What is more important, chemical or visual similarity?*). Lastly, they were asked what their feelings towards facsimiles were. They could answer by saying positive, neutral or negative (Appendix A2).

6.2.3. On Site: After Seeing the Painting

This was the first moment that participants were allowed and specifically asked to look at the actual artwork (*Girl with a Pearl Earring*) and compare it with the presented facsimiles. They received five minutes to walk around freely. Furthermore, additional information was provided about the purpose of each of the technologies, how they were made and what they might explain or highlight about the painting. The researchers additionally presented examples to show how the facsimiles are used in the context of art research nowadays and can potentially be used in the future. During this part of the on-site session,

the participants were first asked to partake in a 'rapid-fire round', consisting of four questions. In this round, the participants were asked to choose one of the samples of the illusionistic reconstruction they thought most accurately represented the painting. Afterwards it was tested whether they preferred material or visual accuracy by telling them that their chosen sample was painted with modern materials (whether or not this truly was the case) and asking them if they would rather pick a detail that was painted with historically correct materials (Note 2). After this round, four of the questions asked in the questionnaire were repeated to get a better understanding of how being in a museum and receiving additional information had changed their feeling towards the facsimiles *(Which technique has the most impact on your perception of art? Which technique has the most negative impact on your perception of art? Which technique has the most positive impact on your perception of art? Which factors are important for correctly representing the original painting?)* They were again asked to rate the facsimiles on the forms on their clipboards. They were also provided with three questions to which they could answer positive/neutral/negative. Furthermore, they were asked which facsimile they would prefer to see displayed with the original, to which they could mention more than one technique. For this reason, in the results, *n* does not correspond to the total of participants, but to the number of votes. The session ended by providing some space for the participants to express their thoughts and to discuss more about the authenticity of the artwork. The entire on-site session took 30 minutes per group of four.

7. Results

In this section, the results of the analysis will be shared. Firstly, a short insight into the way the different groups of participants observed the same questions will be provided. Secondly, it will be discussed how facsimiles were perceived in a museum environment as a part of exhibition design. The third section (7.4.3.) will go into more detail on the perception of each facsimile method under study. Lastly, in section 7.4.4. it will be discussed what design factors should be considered when creating a facsimile. The quantitative data are presented with the number of participants (*n*) and the percentage of participant responses greater than or equal to four (≥4). Additionally, the open-ended questions that were part of the questionnaire and on-site discussions generated valuable qualitative data to support the quantitative results and the decisions made by the individuals taking part in this research. This combination of data analysis has made it possible to generate a way of measuring both the ideas and opinions of the entire group as well as grasping the individual view of the focus groups under study [see Appendix A3 for the tables with data of the individual groups, median (*M*) values and the standard deviation (SD)].

7.1. Understanding the Concepts and Questions

When analysing the answers to the questions asked in the questionnaire, it became clear that some of the questions (e.g., question 2.4: *What, in your opinion, are the design factors to be considered in order to develop enhanced experiences and interactions with the above mentioned methods?(for example: the facsimiles should be self-explanatory and easy to use, its colors are of great importance, there should be an option to rescale elements)*) were relatively hard to understand for those not familiar with using facsimiles or those not working in the conservation or technical art history field (46.4%) (Fig. 11). Given the results and some comments provided through e-mail or conversations during the session on site, the questions were considered (too) difficult for the museum visitor. This was especially the case for the at -home questionnaire, where little information was provided and questions could not be easily asked. This seemed to be less of a problem for those working with the technologies or those working directly with artworks, as they were all able to formulate answers to the questions asked.

7.2. General Findings About Facsimiles in Museum Exhibitions

Both the questionnaire and the on-site session before seeing the artwork showed that none of the participants was negative towards the use of facsimiles. Slightly more than half of the participants ($n = 27$; 54%) were positive, whereas the others were neutral ($n = 27$; 46%). Especially the group of visitors inclined towards a neutral perspective ($n = 11$; 73%) before seeing the painting. The participants voiced that when presenting facsimiles in a museum

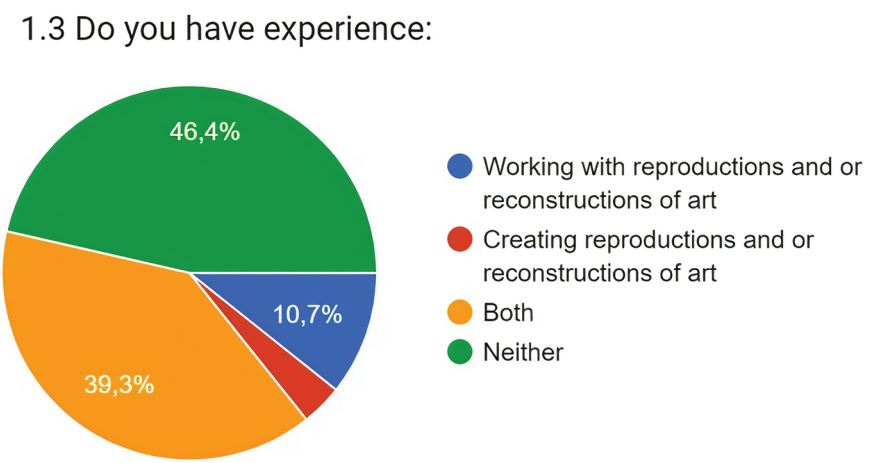

Figure 11. Overview of the experience of the participants based on questionnaire question 1.3.

setting, they should never replace the original artwork or take up the space of any other 'authentic' artwork. However, it was frequently mentioned in both the questionnaire as well as the on-site sessions that facsimiles are useful in an exhibition if they add something to the understanding of an original. For example, the participants often mentioned that replicas could be useful to show several stages of a painting through time and learn more about its history or to aid/educate children or visually impaired people. This confirms the hypothesis that a facsimile becomes increasingly interesting if it presents new information about the artwork. After seeing the potential of each technique, the participants were also more likely to go to exhibitions with facsimiles ($n = 27$, 73%). They were also more positive towards the use of facsimiles in a museum setting compared to the start of the research ($t_{26} = 3.02$, $p < 0.01$). One requirement all participants agreed upon was that when a facsimile is used in an exhibition, it should be communicated that it is not an authentic artwork. Furthermore, the majority of participants considered it valuable to know *why* a facsimile is presented ($n = 27$, 89% voted 'positive'). The research also showed that a clear explanation adds to the value and appreciation of a replication.

7.3. Perception of a Variety of Facsimiles

Within this section, a division is made between technologies made based on original materials (Reconstructions) and digitally generated facsimiles (Reproductions).

7.3.1. Reconstructions

7.3.1.1. *Schematic Reconstructions*

At home. The at home questionnaire showed that of all techniques, schematic reconstructions were expected to have the least negative influence ($n = 27$, 7%) (Fig. 12). It is worth noting that the technical art historians believed that SRs would also have the most positive effect on their perception, closely followed by digital reproductions ($n = 27$, 75%). Yet, whereas the latter were simultaneously considered to have the most negative influence ($n = 4$, 0%), schematic reconstructions were not seen as negative at all. This could be caused by the fact that technical art historians are concerned with the material history of an artwork and its changes over time (such as discoloration), and know from experience that this type of reconstruction can give insight into such matters. Although other target groups generally agreed that SRs would not influence perception negatively (CONS $n = 5$, 0%; MAT $n = 4$, 50%; CUR $n = 3$, 33%), they, however, did not necessarily perceive them to be positive, except for the conservators (CONS $n = 5$, 60%; MAT $n = 4$, 25%; CUR $n = 3$, 0%). This

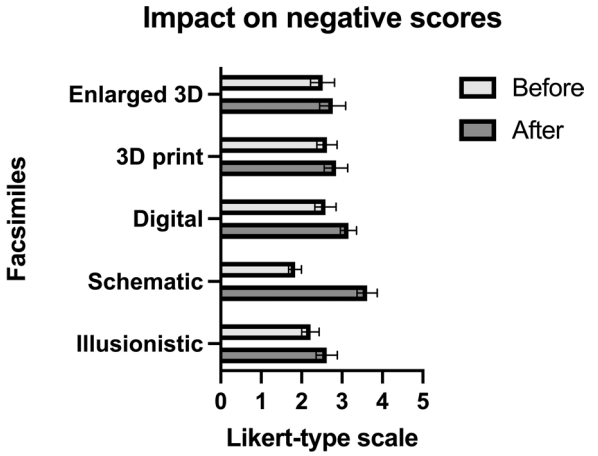

Figure 12. Overview of the most negative impact on the perception of the original (median and standard error of the mean).

could be related to the limited information the participants were given beforehand, causing SRs to be a vague concept, therefore making it hard to comment on their possible effects. Additionally, the majority of the participants expected SRs to be most valuable for technical art history and least valuable to curators and museum visitors, thus labelling SRs as a research tool rather than a tool useful for museum presentation ($n = 27$, 100%).

On site. The on-site questionnaires did change the participants' perspectives. After seeing the artwork, the negative evaluations numerically increased for all the facsimiles, especially for the SRs ($t_{26} = 4.45$, $p < 0.001$). Most positive scores went down, again mainly for the SRs ($t_{26} = 6.42$, $p < 0.001$). The participants were least interested in going to a museum if this technique was presented next to the original ($n = 36$, 0%) compared to all of the other facsimiles. This confirms the idea that SRs can be considered most effective for research purposes and are not suitable for museum presentation. The conversations revealed that their purpose is often too complicated to understand for visitors if one has not used SRs in practice ($n = 27$, 38%; VIS $n = 11$, 72%).

7.3.1.2. *Illusionistic Reconstructions*

At home. Overall, IRs were considered to neither negatively nor positively affect the perception of the original (positive $n = 27$, 63%; negative $n = 27$, 19%). Yet, IRs were not considered to be the most negative technique, but were still seen as a potential threat to the perception of the artwork according to the visitors ($n = 11$, 19%). One interesting result was the fact that conservators ($n = 4$, 100%) as well as curators ($n = 3$, 100%) rated IRs most positively. In contrast, technical art historians believed them to be neither positive, nor

negative, something that was voiced by the other target groups too ($n = 4$, 25%) ($n = 4$, 25%) This result was surprising as it was expected that technical art historians – having experience creating IRs – would rate them more positively. Within their practices reconstructions can provide them with tacit knowledge (practical knowledge that cannot be written down). Still, technical art historians did believe IRs to be useful to their practice ($n = 4$, 55%). All groups, and especially technical art historians, did expect illusionistic reconstructions to be rather valuable to museum visitors ($n = 27$, 36%)

On site. The session on site revealed that IRs yielded low negative scores and rather positive scores after viewing the original, although the changes relative to before the original were not significant ($p > 0.30$). Furthermore, it was the second most positive. Interestingly, whereas the questionnaire showed that this method was considered somewhat useful in a museum setting and for presentation purposes, in the museum it appeared that IRs gained more importance ($t_{26} = 3.03$, $p < 0.01$). However, based on the observations, these opinions originated from the museum professionals and not necessarily the visitors themselves, who, instead, perceived illusionistic reconstructions more negatively than before ($t_{26} = 3.56$, $p < 0.01$). Furthermore, in general, this technology was seen as most historically correct ($n = 27$, 78%) as well as the most scientifically correct ($n = 27$, 89%). Only the visitors and material scientists considered the enlarged 3D print to be the most scientifically correct, followed by the life-size (1:1) 3D print. This might strengthen the assumption that the visitor and material-scientist groups did not have sufficient knowledge about what material correctness means through lack of experience with this concept.

Conclusion. The analysis of these techniques contrasts our hypothesis that material correctness of a facsimile is of importance in a museum context. Instead, material accuracy is generally seen as a complicated concept within a museum setting, and should not be the point of focus when using facsimiles for exhibition purposes. Participants believed that visual similarity to the original is more valuable than material accuracy. Techniques focusing on correctness in materials are instead more suitable for research; however, it is expected that if schematic reconstructions change a viewer's interpretation of the original (e.g., they show that the *Girl's* background was originally dark green instead of dark black) and this is visually communicated within an exhibition, people might show interest in materiality. Testing this viewpoint was however beyond the scope of this research. Additionally, it is noteworthy that the illusionistic reconstruction made for this study was probably less accessible to a general public, because only parts of the *Girl* were reconstructed instead of the entire painting. Therefore the details were presented out of context, which could make comparing them difficult. More positive tendencies might be

observed if the complete painting was reconstructed step by step, since this might be more narratively interesting. Based on the latter, our hypothesis that technical art historians would be the most positive towards the use of reproductions can be confirmed. Yet, our idea that visitors would prefer the illusionistic reproduction because it is more true to the original has been contested. However, it became clear that thanks to the additional information provided during the second part of the on-site session, the interest in this type of reconstruction increased slightly.

7.3.2. Reproductions

7.3.2.1. *Digital Reproductions*

At home. The questionnaire showed that, initially, DRs were considered to be the least useful for visitors ($n = 27$, 26%) and the most useful for technical art historians ($n = 27$, 81%). This is interesting since digital reproductions are increasingly being used in a museum environment (Cameron, 2003, 2013). The perception of digital reproductions is quite neutral. Although the SD shows that opinions varied within the groups, in the end, none of the groups found this technology to have a considerable positive ($n = 27$, $M = 3.48$, SD = 1.89, 50%) or negative influence ($n = 27$, $M = 2.59$, SD = 1.37, 32%).

On site. During the on-site session it was shown that the positive scores tended to decrease and the negative scores tended to increase but only the latter tendency approached significance ($t_{26} = 1.82$, $p = 0.08$), yet both results cannot be considered statistically significant. However, surprisingly, many participants remarked that they were likely to go to a museum if this method was presented near the painting ($n = 39$, 23%). A small group (four people) even voiced that this would be especially interesting in the case of artworks that are more expressively painted, and thus have more texture, impasto and different material features. Although the opinions varied, in general, digital reproductions were considered the least scientifically correct ($n = 27$, 22%), but as previously discussed for IRs and SRs, this does not necessarily affect the perception of the artwork in a negative way. DRs were also considered as visually *incorrect* ($n = 27$, 25%). This is surprising, since the digital reproduction used was based on microscopic images, thus very precisely visualizing the painting's surface at a high definition.

7.3.3. 3D Printed Reproductions

7.3.3.1. *3D Print*

At home. Life-sized (1:1) 3D prints (3DP)were generally not seen as influential to the perception of the original artwork (positive: $n = 27$, 46%; negative: $n =$

27, 43%). Interestingly, the museum professionals deemed 1:1 3D printing to be of most value within a museum setting and therefore rated them to be most suitable for visitors ($n = 27$, 43%) and curators ($n = 27$, 32%). However, these target groups themselves do not agree (CUR $n = 3$, 0% and VIS $n = 11$, 18%). Instead, curators and visitors believed the prints to be very useful to conservation professionals and material scientists. Thus, no target group deemed the reproductions to be of interest to themselves. It is possible that authenticity plays a role here: participants may perceive a 1:1 copy as a 'threat' to the authenticity of the original, but may be willing to see its potential for others. It is furthermore interesting to note that the participants expressed the importance of recognizability and as indispensable when presenting a replication in a museum. Yet, paradoxically, a technique that meets these requirements most accurately – 1:1 3D print – seems to be rejected.

On site. During the first session, although the opinions varied, in general 1:1 3D prints were considered to have the most positive impact on the perception of the artwork ($n = 27$, $M = 3.46$, SD = 1.68, 62%). The high SD is mainly influenced by the curators, who rated the 3D print very highly (see Appendix A3). This could be explained in two ways. Firstly, the absence of the original in this round possibly made that the 1:1 print became a stand-alone object, rather than something that had to be compared against the original. Therefore, the original's authenticity may not have been compromised and participants might have been willing to see the 1:1 print as enhancing, instead of a threat. Secondly, the specific 1:1 print was not presented in a frame and did not have the necessary resolution to copy the original with microscopic accuracy. It could therefore have been clearly recognisable as a plastic reproduction. Since the *Girl* is such a well-known painting, people might have presumed that it is of good quality, even without seeing the original. In this way, by seeing the plastic 'lifeless' print, the appreciation for the high-quality original could have increased.

However, somewhat surprisingly, after having explained the facsimiles on view and letting the participants compare the 1:1 3D print with the original artwork, the value and usefulness of this technology within a museum setting drastically changed. 1:1 3D prints were now considered the least interesting ($n = 27$, 8%, $t_{26} = 3.17$, $p < 0.01$) and effective in explaining something about the original artwork ($n = 27$, 8%, $t_{26} = 5.48$, $p < 0.0001$). Furthermore, the question was proposed as to whether or not the participants would still visit a museum if the original artwork was replaced by a 1:1 3D print (e.g., if the artwork is on loan). Within this scenario all participants unanimously said that this would not withhold them from going to the museum, but that they would not specifically go to the museum to see the facsimile. In the end, the 1:1 print was thus seen as least successful for museum presentation of all facsimile methods for all target groups.

7.3.3.2. *Enlarged 3D Print*

At home. If we look at the enlarged 3D print (E3DP), based on the questionnaire the participants thought this technology would have the biggest positive impact on their perception of the original ($n = 27$, 82%). Furthermore, whereas none of the target groups considered the 1:1 3D print to be useful to themselves, the E3DP was seen as the facsimile that most positively influences the perception of the original by museum professionals ($n = 16$, 82%). Conservation professionals mentioned that the enlarged version is interesting for their practice; possibly because these prints can show aspects of the original that can only be seen with high magnification and cannot be seen with the naked eye, like impasto, crack patterns and dust. Additionally, they are the only facsimile method that makes it possible to physically *feel* the texture of a painting.

On-site. On site, the majority of the participants ($n = 27$, 70%) was convinced that an E3DP was the most interesting, especially in a museum setting, although the *t*-test did not show a significant difference between before and after ($t_{26} = 2.00$, $p = 0.056$). Most participants said they thought an E3DP was the most useful in communicating detailed information about the artwork ($n = 36$, 69%) and more than half of all participants added they would like to see this technology presented in the museum ($n = 27$, 59%). The majority of all groups ($n = 36$, 64%) consider the E3DP to be a valuable asset to be presented next to the painting as a means of deepening the understanding of the artwork. However, it must be mentioned that enlarged 3D prints can also have a *negative* influence on the perception of the artwork. Technical art historians mentioned that in a museum the enlarged features could expose the original in a sense that it confronts the viewer with the 'undesirable' aspects of the artwork's degradation. The damages stand out and the difference in material build-up does not do justice to the material complexity of the original painting. Visitors seemed unbothered by these aspects and might even value seeing degradation patterns.

Conclusion. It can be said that the participants preferred using physical facsimiles over digital reproductions for museum presentation (Fig. 13), which disproves our hypothesis that the digital reproduction would be a valuable asset within a museum environment. This however could be attributed to the particular type of digital reproduction that was used for this research as it was based on the data gathered with a highly accurate microscope generating height maps useful for research. There are other types of digital reproductions being used within the field of art, such as IPARC's (2020) curtain viewers, *The Bosch Project* (2016) or Factum Foundation's (2022) multi-layered viewers in which the composition of an artwork and its different layers can be demonstrated. Still, it must be emphasized that such models are hard to understand for participants who do not have any experience working with them. This

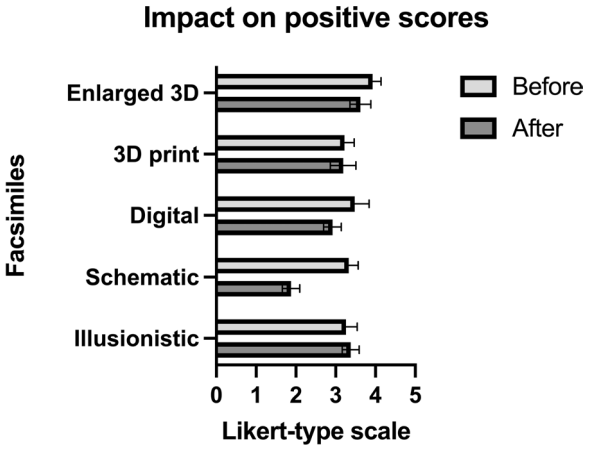

Figure 13. Overview of the most positive impact on the perception of the original (median and standard error of the mean).

might explain the sometimes contradictory results we encountered during the analysis of the data. Another reason for the lack of interest in digital reproductions could be attributed to the fact that people go to the museum to see and experience physical objects, something which is hardly possible at home. Nonetheless, it can be concluded that when deciding to use digital reproductions in museum presentations, they should be simple and self-explanatory. Additionally, the technology in itself might not be considered as interesting as 3D printing for example. This might be the reason why enlarged 3D prints were considered more valuable for presentation purposes.

In general, 1:1 3D printing was considered the least useful for all purposes in a museum environment whereas enlarged 3D prints were seen as positive. The negative perception of the 1:1 3D print arose when participants compared it to the original in Session 2. They may have felt that due to the visual similarity the print could disguise itself as the original, thereby threatening its authenticity. The fact that the 1:1 print did not give any new information about the original might have reinforced this idea. Another possibility for the negative perception of the print is that, reversely, participants clearly saw the differences between print and original. In this case, they may also have felt that the print threatened the authenticity of the original: it could be seen as a plastic copy, lacking authentic materials and making process.

If the 1:1 3D print had presented something new (e.g., a visual approximation of the colours in 1665), it might have influenced the perception of the target groups more positively (Fig. 14). Furthermore, the technique might become more interesting when a more textured painting is replicated, where touching the artwork could be a valuable asset. The result that enlarged 3D

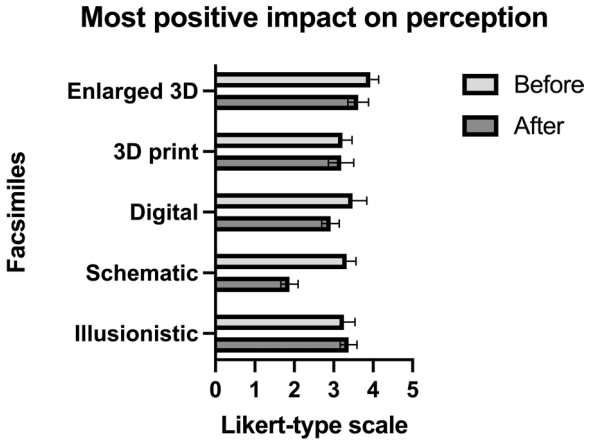

Figure 14. Overview of the most impact on the perception of the original (Median and SEM).

prints are accepted in a museum environment could be based on the fact that they are clearly recognisable as reproductions and therefore are unlikely to be seen as forgeries and cause authenticity problems.

7.4. Design Factors for the Use of Facsimiles in a Museum Setting

When asking the participants to choose between aesthetic and chemical similarity, all of them except from the technical art historians, believed the aesthetic similarity to be of more importance for exhibition purposes ($n = 27$, 74%). However, upon proposing the option to choose between historical and visual similarity (the way the artwork looks now), it appears historical similarity is preferred ($n = 27$, 59%). Regarding the question if touching facsimiles is important for the experience of the artwork and the museum, the opinions varied (17 positive, eight neutral, two negative).The visitors were moderately interested in this feature, as the majority was either negative ($n = 11$, 45%) or neutral ($n = 11$, 18%) The latter disproves the hypothesis that touching an artwork would be a significant addition to the museum experience. This result might be due to the case study as it does not contain a large topographic variety on its surface. In the case of paintings with more impasto (e.g., Vincent van Gogh's *Sunflowers*), touching the artwork might be more interesting as was also mentioned by the participants.

In terms of the characteristics of the facsimile, the participants believed accurate composition to be of most importance, followed by colour. Additionally, surface topography and historical accuracy were deemed less important. During the research, the interest in topography and its importance slightly increased. This was probably influenced by seeing the enlarged 3D

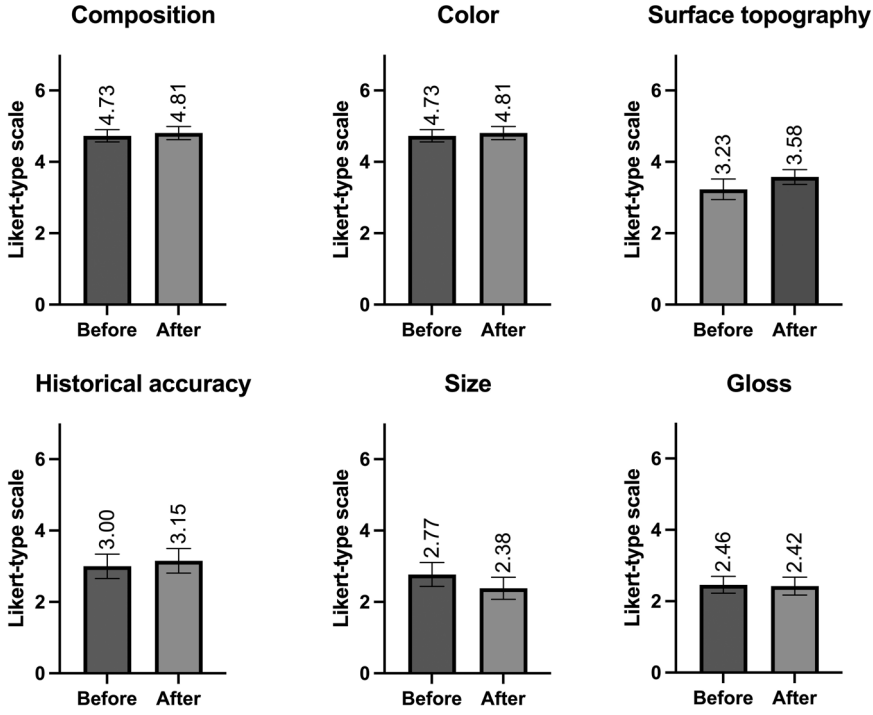

Figure 15. Overview of the importance of various design factors for the design of facsimiles (error bars and medians included).

print next to the artwork (Fig. 15). Gloss and size were not seen as necessary. However, the participants did not see facsimiles with large gloss variations in this research. Therefore, participants might not have understood the potential effects and impact of the absence of glossiness, hence deeming it to be of lesser interest. However, *t*-testing showed that the differences between the two sessions are not statistically significant ($p > 0.1$) indicating that the opinions hardly changed after the on-site session.

The following requirements are noted for the design of facsimiles. Firstly, replications have to be respectful to the original and its authenticity. Secondly it should always be made clear why a method is used and what can be learned from it. Thirdly, the facsimile should be easy to use and understand for a variety of groups. As mentioned before, physical facsimiles are considered to be more suitable within museum exhibitions than digital ones (Fig. 16)

8.1. Conclusion and Future Research

This research aimed to provide more insight into the effect of facsimiles on the perception of original paintings and the design factors to be considered

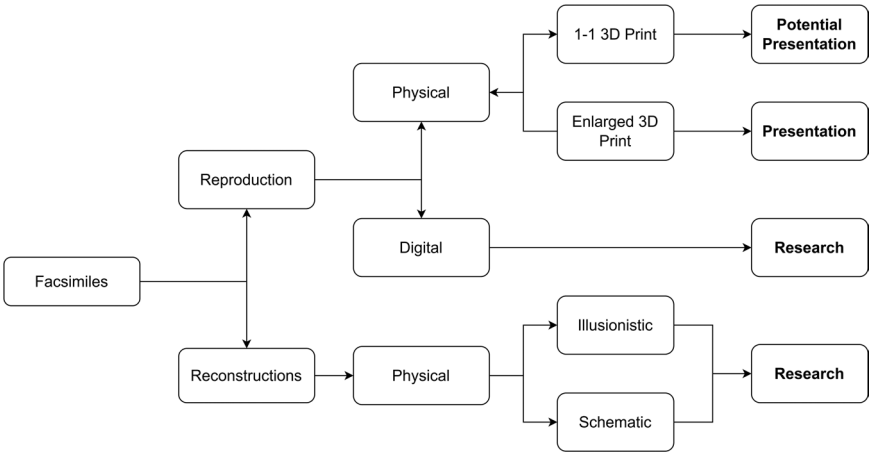

Figure 16. Schematic overview (Fig. 2) and the purpose for which these methods can be used most successfully based on this research.

when presenting these facsimiles in a museum environment. The questionnaire and on-site sessions revealed that although the participants – consisting of museum professionals and museum visitors – have very diverse ways of approaching the questions asked, the majority generally considered facsimiles to be effective or have potential for museum presentation.

The results show that, apart from schematic reconstructions – which are solely considered suitable for research purposes – facsimiles are accepted in museums and sometimes are even perceived as a positive addition to the experience of the original. Furthermore, this research has shown that providing information about facsimiles and presenting them next to the artwork caused a significant change within the understanding and appreciation of the facsimiles. Whereas schematic reconstructions lost their appreciation in comparison to the original, technologies such as enlarged 3D printing gained significance.

When it comes to the design of these facsimiles for use within a museum environment, a facsimile should be easy to understand and should always add something to the experience of the original artwork, for example by enlarging the painting's physical features or by explaining something about its history. For museum presentation, facsimiles should be aesthetically and compositionally similar to the original. Material correctness, gloss, size and topography are of less interest. It also became clear that facsimiles can replace an original when it is absent, but in this case people would not specifically go to the museum to see the facsimile. Participants voiced that replicas should never be presented instead of another original painting if the latter is available. When designing facsimiles for museum exhibitions, it is

most important that they are visually similar to how an original looks today or used to look. In order to safeguard the authenticity of the artwork, it is important to always clearly mention when a facsimile is being used and why it is displayed.

Material accuracy in general is seen as a complicated concept for museums, and should not be the primary focus. It became evident that physical facsimiles are preferred over digital reproductions. In this way, enlarged 3D printing was determined to be the most effective method within this specific study. In contrast, material and historical similarity were considered to be important for research purposes specifically and not for presentations in museums. In the case of research, physical reconstruction technologies such as schematic and illusionistic reconstruction methods could be considered more useful.

8.2. Limitations and Future Research

As this study was a pilot project and rather explorative, not everything could be considered and included. An important limitation is the fact that we did not differentiate the results as a function of participant characteristics such as demography, gender or ethnic background. Research considering these characteristics could provide a more refined insight into the interpretation of facsimiles and the authentic value of original artworks. Research considering these elements could be interesting and could provide a broader analysis on the interpretation of facsimiles and the authentic value of original artworks. Furthermore, the focus groups were very small and thus might not truly provide a complete representation. Additionally, focusing on five groups at the same time was difficult. Some concepts were incomprehensible to groups that did not have previous experience with facsimiles (material scientists and visitors). In this regard, we would recommend using this research as a starting point for a study with a larger group of participants or by individually studying each focus group but with more participants. This way, all participants start at the same level of understanding, resulting in clearer and better results. Additionally, this study was executed in a museum environment and focused on museum presentation to a large extent. It could initiate research with a focus on the use of these facsimile techniques for research related purposes. Additionally, presenting the same questions within a different environment (e.g., a conservation lab or a classroom) could lead to different results. Furthermore, this study used only one painting as its case study. Using a series of paintings by the same artist or by comparing paintings with different painting styles or material issues could potentially alter the perception of each individual facsimile technique. It is, for example, not clear how a 1:1 illusionistic reconstruction would be perceived in an exhibition, nor do we know what would happen when we present a facsimile that shows how a painting used

to look (rather than, or alongside, its current appearance). Could this evoke an interest in materials and technique of the original? A useful way to gather more quantifiable data into this matter would be to use eye-tracking research, as a diversity of papers show (De Winter and Wagemans, in press; de Winter *et al.*, 2022) that this could be an effective way to determine what visitors pay attention to when looking at the original versus the facsimile, or when presenting a 1:1 facsimile versus a (colour) reconstructed version of the artwork. During *Gold or Blue? 3D printing for conservation and presentation* (2021–2024) this will be implemented as an additional research method. The context in which a 3D print is exhibited needs additional research too. Do we need to frame it? Can we hang it close to the original? Or should we rather present it outside of a museum hall, in a 'safe' space? Lastly, this research did not focus on facsimiles as tools of education, but it is expected that they are of value in this area. Is this the case and what are their possibilities when presented outside of the museum as a surrogate of the original? As many aspects were left unresearched, we are planning on continuing this research and expanding this pilot study further in 2023.

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Notes

1. For more specific information about the use of schematic and illusionistic reconstructions, and an analysis of these methods for technical art historical purposes, see van Veldhuizen (2022).For more specific information about the use of 3D printing for conservation purposes, see Tissen (2018).
2. Material accuracy: similarity to the materials of the original; visual accuracy: similarity to what the original visually looks like today.

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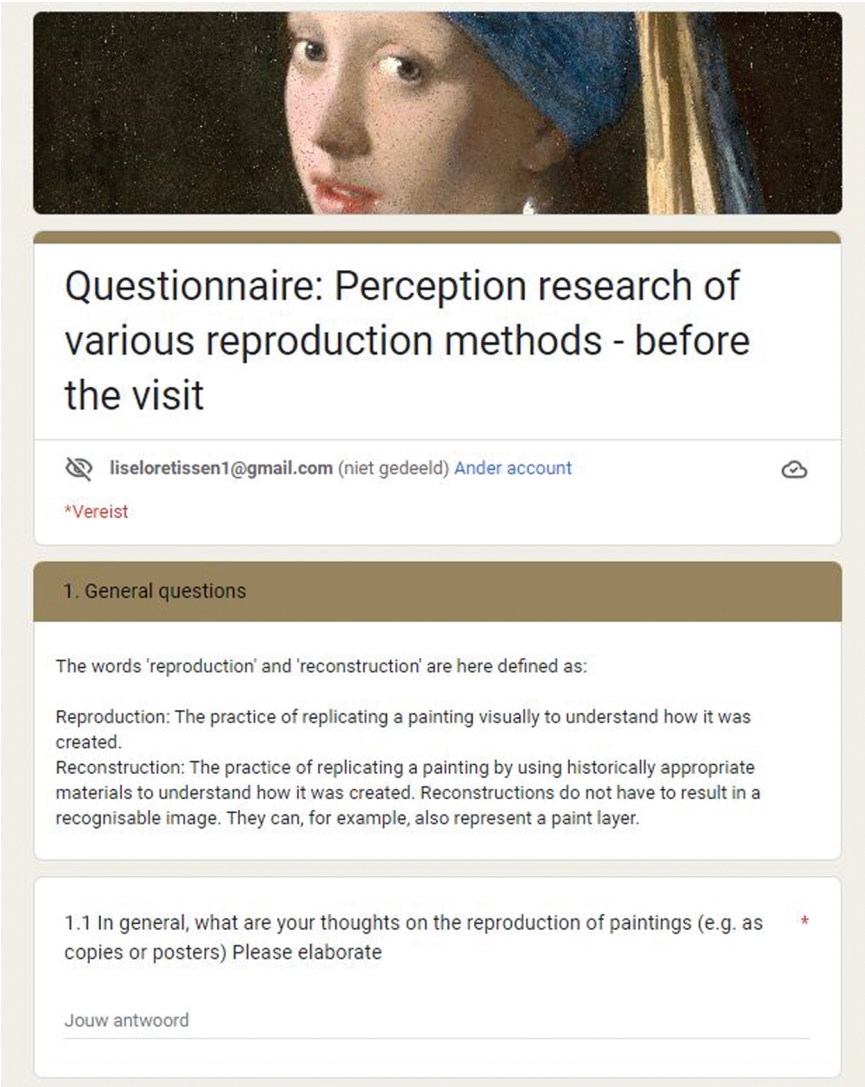
Appendices

Appendix A1. Online Questionnaire



Questionnaire: Before the Visit

In this questionnaire, we will ask you 17 closed and open-ended questions about the ways different types of facsimiles can be used to learn about and visualise artworks. If you experience any difficulties with the questionnaire or

if you do not understand the questions, please send an email to l.n.m.tissen@tudelft.nl.

The words 'reproduction' and 'reconstruction' are here defined as:

Reproduction: The practice of replicating a painting visually to understand how it was created.

Reconstruction: The practice of replicating a painting by using historically appropriate materials to understand how it was created. Reconstructions do not have to result in a recognisable image. They can, for example, also represent a paint layer.

1. General Questions

1.1. In general, what are your thoughts on the reproduction of paintings (e.g. as copies or posters). Please elaborate

1.2. What are your thoughts on the use of reproductions and or reconstructions of paintings for a certain purpose (e.g. education, restoration, research, presentation) Please elaborate

1.3. Do you have experience:
- Working with reproductions and or reconstructions of art - Creating reproductions and or reconstructions of art
- Both
- Neither

2. Facsimile Techniques

The following questions will focus on the usefulness and importance of five different technologies used for the reproduction of paintings. Each technology is explained below in an image and short text. We refer to the 'real painting' (hanging in the Mauritshuis) as the 'original artwork'. Please answer the following questions on a scale of 1 to 5 (1 = Lowest rating; 5 = Highest rating).

Illusionistic Reconstruction

An illusionistic reconstruction replicates the pictorial effects created by the artist: it tries as much as possible to look like the original artwork. For example: Charlotte Caspers painted an illusionistic reconstruction of *Girl with a Pearl Earring* for the Dutch TV programme *Het Geheim van de Meester*. She tried to copy Vermeer's working methods and materials as closely as possible.

Illusionistic reconstruction

You can view a 4-minute clip showing the reconstruction at: https://www.avrotros.nl/hetgeheimvandemeester/uitzendingen/detail/het-geheim-van-de-meester-extra- vermeer-meisje-met-de-parel/

Schematic Reconstruction

A schematic reconstruction can investigate the materials that the artist used. In this example, a 'stripe' of blue paint of a specific thickness was applied to opacity charts (half white/half black sheet). By making small changes to the paint recipe, a researcher can assess how this might affect the colour and/or transparency of the paint.

Schematic reconstruction

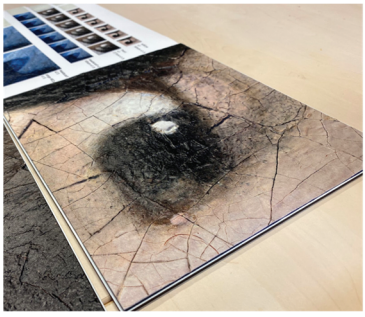
3D Printed Reproduction

A 3D printed reproduction replicates a painting's colour, gloss and texture using a technology called stereolithography. First, a painting is scanned with a specialised stereo camera setup, then a computer translates this scan into 3D printable information. A specialised 3D printer prints extremely thin layers of white plastic to reproduce the different heights and depths of the painting's surface. The final layers are printed in colour using an inkjet printing system. The painting's glossiness can be reproduced using up to six layers of transparent inks. The result is a life-sized (1:1) 3D print of the painting.

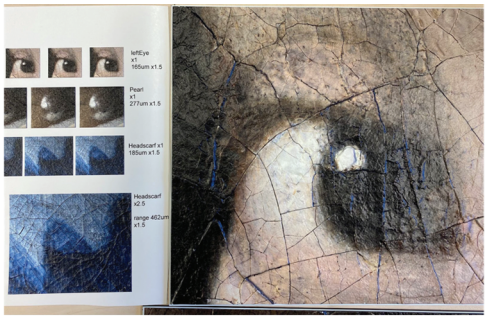
Left: Original painting, Right: 2.5D printed reproduction

Enlarged 3D Rrinted Reproduction

An enlarged 3D printed reproduction is made with the same technology as the 1:1 life-sized 3D printed reproduction, but the printed image is larger than the original. In this example, the eye of *Girl with a Pearl Earring* has been enlarged 100 times (10× in X and 10× in Y). This means that features like brushstrokes, particles and cracks in the paint become more visible. You might be able to touch the 3D print to get a tactile feel of the painting's texture.



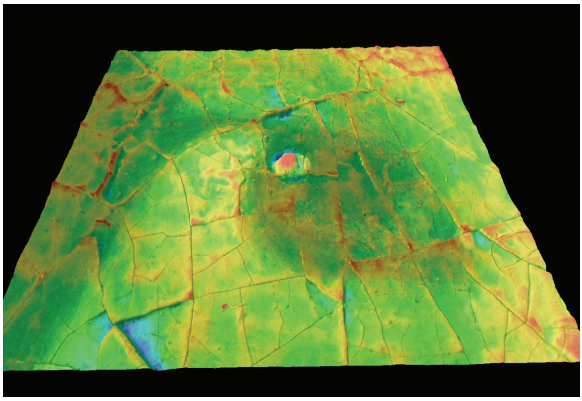
Enlarged 2.5D print photographed at an angle



Left: 2.5D print at original size (1:1) - Right: enlarged 2.5D print (10:1)

Digital Reproduction

Digital reproductions are digitised versions of original artworks. They can be viewed and shared online, but can also be manipulated. Digital reproductions make it possible, for example, to digitally remove, add or change layers of information (for example changing the way a painting is lit). This happens by integrating information from computer models, facsimiles and other types of research. As a result, materials and different layers of a painting can be explored freely. For example: the painting *Girl with a Pearl Earring* was photographed using a HIROX 3D digital microscope, which magnified the surface up to 140 times. This produced digital images, where height maps can be overlaid to show the topography of the painting.



Height map of eye *Girl with a Peal Earring*

2.1. To what degree do you think the following methods will impact your perception of the original artwork?

	1 - Not at all	2 - Barely	3 - Neutral	4 - Somewhat	5 - Very
Illusionistic reconstruction					
Schematic reconstruction					
3D printed reproduction					
Enlarged 3D printed reproduction					
Digital reproduction					

2.2. To what degree do you think that each method could influence the perception of the original artwork in a positive way?

	1 - Not at all	2 - Barely	3 - Neutral	4 - Somewhat	5 - Very
Illusionistic reconstruction					
Schematic reconstruction					
3D printed reproduction					
Enlarged 3D printed reproduction					
Digital reproduction					

2.3. To what degree do you think that each method could influence the perception of the original artwork in a negative way?

	1 - Not at all	2 - Barely	3 - Neutral	4 - Somewhat	5 - Very
Illusionistic reconstruction					
Schematic reconstruction					
3D printed reproduction					
Enlarged 3D printed reproduction					
Digital reproduction					

2.4. What, in your opinion, are the design factors to be considered in order to develop enhanced experiences and interactions with the abovementioned methods? (For example: the facsimile should be self-explanatory and easy to use, its colours are of great importance, there should be an option to rescale elements.)

3. The Use of Facsimile Techniques

In this section we will ask you to evaluate how useful facsimiles might be for certain groups of people, each with a different 'focus' when they look at an artwork:

Technical art historian: A technical art historian primarily focusses on the artwork as a physical object. Using scientific equipment, they study the materials, techniques and production methods that went into its making. They also have experience making illusionistic and schematic reconstructions using materials as similar as possible to the ones the original artist would have used.

Conservator: A conservator primarily focuses on taking care of artworks. They aim to extend the life of an artwork by investigating its material history and technique, and intervening when necessary. As part of this intervention,

the work of art is stabilised (conservation), and might receive an aesthetic treatment (restoration).

Conservation scientist: A conservation scientist primarily focuses on investigating the chemical compounds of art at a molecular level, and their effects on the material appearance of the artwork over time. This helps to explain why certain materials might have changed or decayed over time, and how these changes might be mitigated in the future.

Museum curator: A museum curator primarily focuses on the artwork as a visual and aesthetic object in a social context. Some of their tasks within a museum might include: researching specific artists or artworks, looking into their history and provenance, and developing exhibitions to present them to the public.

Museum visitor: A museum visitor primarily focuses on enjoying the experience of seeing artworks in a curated gallery space. Different people will have more or less prior knowledge about the artworks, and might learn or appreciate different things about them.

Please answer the following questions on a scale of 1 to 5 (1 = Lowest rating; 5 = Highest rating).

3.1. Imagine that a reproduction and reconstruction of *Girl with a Pearl Earring* were made available to museum professionals. How interesting would this be for the (hypothetical) people described above:

	1	2	3	4	5	Don't know
Technical art historian Conservator						
Conservation scientist						
Museum curator						
Museum visitor						

3.2. How relevant do you consider an illusionistic reconstruction to be for these people?

	1	2	3	4	5	Don't know
Technical art historian Conservator						
Conservation scientist						
Museum curator						
Museum visitor						

3.3. How relevant do you consider a schematic reconstruction to be for these people?

	1	2	3	4	5	Don't know
Technical art historian						
Conservator						
Conservation scientist						
Museum curator						
Museum visitor						

3.4. How relevant do you consider a 3D printed reproduction to be for these people?

	1	2	3	4	5	Don't know
Technical art historian						
Conservator						
Conservation scientist						
Museum curator						
Museum visitor						

3.5. How relevant do you consider an enlarged 3D printed reproduction to be for these people?

	1	2	3	4	5	Don't know
Technical art historian						
Conservator						
Conservation scientist						
Museum curator						
Museum visitor						

3.6. How relevant do you consider a digital reproduction (e.g. HIROX) of the painting to be for these people?

	1	2	3	4	5	Don't know
Technical art historian						
Conservator						
Conservation scientist						
Museum curator						
Museum visitor						

3.7 What do you think is important when using reproductions and reconstructions for technical art historical research:

	1 - No importance	2- Low importance	3- Neutral	4- Moderate importance	5- High importance
It has the same 'artistic expression' as the original painting.					
The materials used are as 'historically accurate' as possible (similar to those used in original painting).					
It resembles the painting, as it would have been when it left the artist's workshop (in this case, Vermeer's workshop c. 1665).					
It resembles the painting, as it appears now.					
The original image is recognisable.					
The original image is three-dimensional.					

3.8. What do you think is important when using reproductions and reconstructions for material research of artworks:

	1 - No importance	2- Low importance	3- Neutral	4- Moderate importance	5- High importance
It has the same 'artistic expression' as the original painting.					
The materials used are as 'historically accurate' as possible (similar to those used in original painting).					
It resembles the painting, as it would have been when it left the artist's workshop (in this case, Vermeer's workshop c. 1665).					

	1 - No importance	2- Low importance	3- Neutral	4- Moderate importance	5- High importance
It resembles the painting, as it appears now.					
The original image is recognisable.					
The original image is three-dimensional.					

3.9. What do you think is important when using reproductions and reconstructions as part of the conservation of artworks:

	1 - No importance	2- Low importance	3- Neutral	4- Moderate importance	5- High importance
It has the same 'artistic expression' as the original painting.					
The materials used are as "historically accurate" as possible (similar to those used in original painting).					
It resembles the painting, as it would have when it left the artist's workshop (in this case, Vermeer's workshop c. 1665).					
It resembles the painting, as it appears now.					
The original image is recognisable.					
The original image is three-dimensional.					

3.10. What do you think is important when presenting reproductions and reconstructions in a museum setting:

	1 - No importance	2- Low importance	3- Neutral	4- Moderate importance	5- High importance
It has the same 'artistic expression' as the original painting.					
The materials used are as 'historically accurate' as possible (similar to those used in original painting).					
It resembles the painting, as it would have when it left the artist's workshop (in this case, Vermeer's workshop c. 1665).					
It resembles the painting, as it appears now.					
The original image is recognisable.					
The original image is three-dimensional.					

Thank you for participating!

Appendix A2. Questions On Site

Session 1: Before Seeing the Painting

[Facsimiles laid out on the table]
Schematic reconstruction
Illusionistic reconstruction
Digital reproduction
3D print
Enlarged 3D print

Accuracy

1. Of all facsimiles, how scientifically correct do you consider them to be? (scale of 1–5, 1 being the *least* accurate, 5 being the *mos*t accurate)

2. Of all facsimiles, how historically correct (similar to how the artwork might have looked when it was made) do you consider them to be? (scale of 1–5, 1 being the *least* accurate, 5 being the *mos*t accurate)
3. Of all facsimiles, how visually correct (visually similar to the original artwork) do you consider them to be? (scale of 1–5)
4. Before/after seeing the facsimiles, do you think the following factors play a role in correctly representing the original painting (order them in a list 1–6, 6 being the most important, 1 being the least important)
   Compositional similarity
   Colour
   Gloss
   Surface topography
   Material accuracy
   Size
5. What (additional) factors do you consider essential for the correct representation of the original painting?
6. Please choose which elements you think are most important in regards to the accuracy of a facsimile:
   Chemical similarity vs aesthetic/visual similarity (e.g. similarity of the brushstrokes)
   Historical similarity (e.g. a 3D print of what the painting once looked like) vs similarity to the way the artwork looks today
   Historical correctness vs scientific correctness

Authenticity

7. Overall, what is your feeling towards the reproduction of artworks? positive - neutral - negative Why?
8. Of all facsimiles, which one positively impacts your perception of the original the most? Please number the technologies according to your order of importance (1 being the most important, 5 being the least important)
9. Of all facsimiles, which one negatively impacts your perception of the original the most? Please number the technologies according to your order of importance (1 being the most important, 5 being the least important)
10. Which features of the facsimile attribute to the negative impacts of the facsimile technology to your perception of the original artwork?

Design

11. When presenting a facsimile in a museum, do you think it is important that the wall text or audio-guide clearly states that it is a facsimile?
12. When presenting a facsimile in a museum, do you think it is important to explain *why* the facsimile is being presented?

13. Do you think that the possibility to touch a facsimile of a painting is important for your experience of the artwork and the museum?

Session 2: After Seeing the Painting

1. (Illusionistic reconstructions only.) Which detail most accurately represents the lips/background of the original painting?
2. Do you still think this detail most accurately represents the painting? Or would you now pick another detail?
3. After seeing the facsimiles and the artwork in the museum, did your idea of the use of facsimiles in museums change?
   yes - same - no. positive - negative. Why?
4. Are you likely to go to a museum if reconstruction X is presented instead of the original artwork (e.g if the artwork is on loan or too fragile to be on display)?
   yes - neutral - no. Why/how?
5. Are you more likely to go to a museum if reconstruction X is presented next to the original artwork?
   yes - neutral - no. Why/how?
6. Do you think it is important to use facsimiles in museum exhibitions?
   yes - neutral - no. Why/how?
7. When presenting a facsimile in a museum, do you think it is important that it is explained why the facsimile is presented or would you rather explore the significance of the facsimile on your own?
   Explained. On my own / without explanation
8. Which facsimile technology do you consider the most interesting? Why?
9. Which technology do you consider the most useful in communicating information about the artwork?
10. Before/after seeing the facsimiles, do you think the following factors play a role in correctly representing the original painting (order them in a list 1–6, 6 being the most important, 1 being the least important)
    - Compositional similarity
    - Colour
    - Gloss
    - Surface topography
    - Material accuracy
    - Size

Appendix A3. Before/After Results per Group

Overall (*N* = 27)

Question	*M*	SD	% ≥ 4	Least	*M*	SD	% ≥ 4	Most
BEFORE								
Positive impact	3.0	1.28	29%	3D print	4.1	1.11	82%	Enlarged 3D print
Negative impact	2.2	0.83	7%	Schematic	2.6	1.31	43%	3D print
Most impact on the perception of the original	2.92	1.06	29%	3D print	4.04	1.19	82%	Enlarged 3D print
Importance of design factors	5.04	1.28	82%	Compositional similarity	2.46	1.21	15%	Gloss
AFTER								
Positive impact	1.88	1.14	12%	Schematic	3.46	1.68	62%	3D print
Negative impact	2.62	1.39	31%	Illusionistic	3.65	1.30	65%	Schematic
Most impact on the perception of the original	2.00	1.24	8%	3D print	3.96	1.02	70%	Enlarged 3D print
Importance of design factors	5.00	1.40	85%	Compositional similarity	2.38	1.61	23%	Size

Visitors (N = 11)

Question	*M*	SD	% ≥ 4	Least	*M*	SD	% ≥ 4	Most
BEFORE								
Positive impact	2.33	1.41	33%	Illusionistic	3.56	1.51	78%	Enlarged 3D print
Negative impact	1.67	0.71	0%	Schematic	2.78	1.48	56%	3D print
Most impact on the perception of the original	2.78	1.48	44%	Schematic	4.22	1.30	89%	Enlarged 3D print
Importance of design factors	2.1	0.88	0%	Gloss	4.70	1.42	80%	Compositional similarity
AFTER								
Positive impact	1.90	1.00	0%	Schematic	3.80	1.54	30%	Enlarged 3D print
Negative impact	1.64	1.00	20%	3D print	4.10	1.00	80%	Schematic

Most impact on the perception of the original	1.89	1.29	20%	Schematic	3.67	1.00	60%	Enlarged 3D print
Importance of design factors	2.22	1.69	20%	Size	4.89	1.59	80%	Compositional similarity

Professionals (N = 16)

Question	*M*	SD	% ≥ 4	Least	*M*	SD	% ≥ 4	Most
BEFORE								
Positive impact	3.12	1.22	29%	3D print	4.06	0.83	82%	Enlarged 3D print
Negative impact	1.94	0.89	6%	Schematic	2.88	1.65	43%	Enlarged 3D print
Most impact on the perception of the original	2.71	1.05	18%	3D print	4.1	1.00	59%	Digital reproduction
Importance of design factors	2.69	1.35	29%	Gloss	5.25	1.18	82%	Compositional similarity
AFTER								
Positive impact	1.88	1.26	6%	Schematic	3.69	1.20	53%	Illusionistic
Negative impact	2.32	1.20	18%	Illusionistic	3.31	1.40	53%	Schematic
Most impact on the perception of the original	1.43	0.73	0%	3D print	4.19	0.83	76%	Illusionistic
Importance of design factors	1.13	1.20	12%	Gloss	5.13	0.72	100%	Colour

TAH (N = 4)

Question	*M*	SD	% ≥ 4	Least	*M*	SD	% ≥ 4	Most
BEFORE								
Positive impact	3.22	0.50	25%	3D print	3.93	0.96	50%	Enlarged 3D print
Negative impact	1.81	0.58	0%	Schematic	2.63	1.5	50%	Enlarged 3D print
Most impact on the perception of the original	2.97	0.96	0%	3D print	4.11	2.06	50%	Enlarged 3D print
Importance of design factors	2.00	0.82	0%	Size	5.25	1.50	75%	Compositional similarity

AFTER								
Positive impact	1.00	0.00	0%	Schematic	4.25	0.96	75%	Illusionistic & 3D print
Negative impact	1.75	0.96	0%	Illusionistic	4.75	0.5	100%	Enlarged 3D print
Most impact on the perception of the original	1.5	1.00	0%	3D print	4.5	0.58	100%	Illusionistic
Importance of design factors	2.25	1.26	25%	Gloss	5.25	1.5	75%	Composition

CONS (N = 5)

Question	*M*	**SD**	**% ≥ 4**	**Least**	*M*	**SD**	**% ≥ 4**	**Most**
BEFORE								
Positive impact	2.50	1.05	17%	3D print	3.83	0.98	83%	Enlarged 3D print
Negative impact	2.33	0.52	0%	Schematic	3.83	1.60	67%	Enlarged 3D print
Most impact on the perception of the original	2.67	1.03	17%	3D print	4.33/4.33	0.52/ 0.82	100%	Enlarged 3D print/ illusionistic
Importance of design factors	2.60	1.50	40%	Gloss	5.40	0.55	100%	Compositional
AFTER								
Positive impact	1.60	1.34	20%	3D print	4.44	0.89	80%	Illusionistic
Negative impact	1.80	1.79	20%	Enlarged 3D print	4.20	1.20	80%	Digital
Most impact on the perception of the original	1.20	0.45	0%	3D print	4.80	0.45	100%	Illusionistic
Importance of design factors	1.80	1.10	0%	Gloss	5.2	0.45	100%	Colour

MAT (*N* = 4)

Question	*M*	SD	% ≥ 4	Least	*M*	SD	% ≥ 4	Most
BEFORE								
Positive impact	2.5	1.29	25%	Illusionistic	4.5	0.58	100%	Enlarged 3D print
Negative impact	2.75	1.50	50%	Illusionistic	4.5	0.57	100%	Enlarged 3D print

Most impact on the perception of the original	2.25	1.29	25%	Schematic	3.00	1.83/1.15	50%	Enlarged 3D print/digital
Importance of design factors	1.50	0.58	0%	Historical accuracy	4.25	1.50	75%	Composition
AFTER								
Positive impact	1.75	0.96	0%	Schematic	4.25	1.5	75%	Enlarged 3D print
Negative impact	2.25	1.29	25%	Illusionistic	3.75	1.5	50%	Enlarged 3D print
Most impact on the perception of the original	1.75	0.96	0%	3D print	4.25	0.96	75%	Enlarged 3D print
Importance of design factors	1.25	0.5	0%	Size	5.25	0.96	100%	Colour

CUR ($N = 3$)

Question	*M*	SD	% ≥ 4	Least	*M*	SD	% ≥ 4	Most
BEFORE								
Positive impact	2.67	2.08/ 1.54/ 1.53	25%	Schematic/ 3D print/ Digital	4.33	0.58	100%	Enlarged 3D print
Negative impact	1.00	0.00	0%	Schematic/ enlarged 3D print	2.00	1.73	33%	3Dprint/ digital
Most impact on the perception of the original	2.33	0.58	0%	3D print	4.33	0.58	100%	Illusionistic
Importance of design factors	1.33	0.58	0%	Gloss	4.67	1.5	100%	Colour/size
AFTER								
Positive impact	1.00	0.00	0%	Schematic	4.67	1.15	100%	3D print
Negative impact	2.00	1.73	33%	3D print	4.67	0.58	100%	Schematic

Most impact on the perception of the original	1.33	0.58	0%	3D print	4.67	0.58	100%	Enlarged 3D print
Importance of design factors	1.33	0.58	0%	Historical accuracy	5.33	1.5/0.58	100%	Composition/ colour