Lacuna Restoration: How to Choose a Neutral Colour?

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ABSTRACT: Painting restoration which involves filling in material loss (called lacuna) is a complex process. Several standard techniques exist to tackle lacuna restoration, and this article focuses on those techniques that employ a "neutral" colour to mask the defect. Restoration experts often disagree on the choice of such a colour and in fact, the concept of a neutral colour is controversial. We posit that a neutral colour is one that attracts relatively little visual attention for a specific lacuna. We conducted an eye tracking experiment to compare two common neutral colour selection methods, specifically the most common local colour and the mean local colour. Results obtained demonstrate that the most common local colour triggers less visual attention in general. Notwithstanding, we have observed instances in which the most common colour triggers a significant amount of attention when subjects spent time resolving their confusion about whether or not a lacuna was part of the painting.

1 INTRODUCTION: The conservation and restoration of artworks are complex processes which require consideration of the artist, the medium, the historical context and the art materials used, to name a few. In particular, the restoration of paint and support material loss in paintings (known as lacunae) may present an especially difficult problem, if the damage is extensive enough to destroy "the potential integrity of the work"[1].

The literature on principled methods of restoring lacunae is sparse at best. For general restoration theory, the work of Cesari Brandi remains the gold standard. From his ideas, several best practice approaches to lacunae have emerged. For small lacunae it is common to fill the missing areas such that the intervention is unnoticeable when viewed at a distance, but recognizable at close range [2]. One well-known technique to achieve this is the *trateggio* technique, where small dots or narrow stripes are painted into the lacunae, using colours which blend with the original. However, for large lacunae, where the "potential unity" [3] of the work has been compromised, the *acqua sporca* technique is often used. This method consists of covering the affected area with as "neutral" a colour as possible and it is this technique that we explore in this article. For a more comprehensive exploration of different lacuna restoration techniques we refer the interested reader to [4].

It is debatable whether any colour can really be neutral since any colour would influence our perception. Therefore, for the purposes of this article, "neutral" is a relative term used to indicate colours that trigger less visual attention with respect to other colours. A neutral colour should shift attention to other areas of the image, or at least should not attract attention to itself. However, determining such a colour is not trivial. Experts on restoration of this kind often disagree on the best neutral colour for a particular restoration case.

We posit that the problem of choosing a neutral colour can be defined as selecting the colour which triggers the least visual attention, taking into account the colour-composition of the painting and the location of the lacuna in that painting. To this aim we conducted a psychophysical experiment, using an eye tracker, to compare two candidate neutral colour selection methods in order to determine which would guide less attention. Our results showed that using the most common colour around the lacuna is generally a less noticeable neutral colour than the average colour around the lacuna.

2 DATASET: A lacuna may be defined variously as a gap, hole, blank spot, hiatus, vacancy, cavity or void in music, text, imagery and architectural structures, to name a few media. In the artistic domain, a lacuna may be considered to be present when there is an aggressive interruption of the figurative pattern that is consequently perceived as a part of the foreground of the image, and damages the comprehension and the meaning of the artwork [3]. This

definition leaves a lot of room for interpretation. For instance, a lacuna can be large or small, regular or irregular in shape, in the centre of the image or in its extremity. For example, a little loss which covers the eye and the nose of a figure in the foreground is more disturbing than a bigger loss situated in the background.

Due to difficulties in procuring digital samples of lacuna appropriate for an eye-tracking experiment, we chose to artificially create lacunae in images of paintings of an appropriate size and composition. In creating these artificial lacunae, we were careful to create pairs of lacunae with similar shapes.

As stated previously, we investigated two methods of obtaining a neutral colour:

- Local mean colour (LMeC): The mean colour in the surrounding local region of the lacuna was chosen as the neutral colour with which to fill the lacuna. This measure is commonly used by lacuna restorers.

- Local most common colour (LMoC): As a second neutral color we selected the most common or least informative colour, which is a common cue in visual saliency [5] [6]. This theory states that feature saliency is inversely related to feature occurrence, i.e. rare features are more informative and therefore more salient than features that occur more frequently. Hence, we have selected as a neutral color, the colour which appears most often in the lacuna's surrounding. This color will be less salient, and therefore, it is expected to be less disturbing (see Figure 1).

Fig. 1: Lacuna filled by LMeC and LMoC respectively.

We chose the local region to be a border around the lacuna of two pixels in width.

We started with 9 digital images of paintings and created 2 pairs of lacunae for each image in Photoshop. Each pair appeared in the image separately, resulting in 18 images. We chose 2 pairs to introduce variation in the positioning of the lacuna in each image. For each pair of lacuna, the LMeC was used to fill one, while the LMoC was used to fill the other. Another stimulus was created with the methods reversed. Therefore from each of the original 9 images 4 stimuli were obtained: 2 images containing a different pair of lacuna, with each of these two images having lacuna filled in two different ways. Figure 2 shows a set of 4 stimuli created from one of the 9 original images.

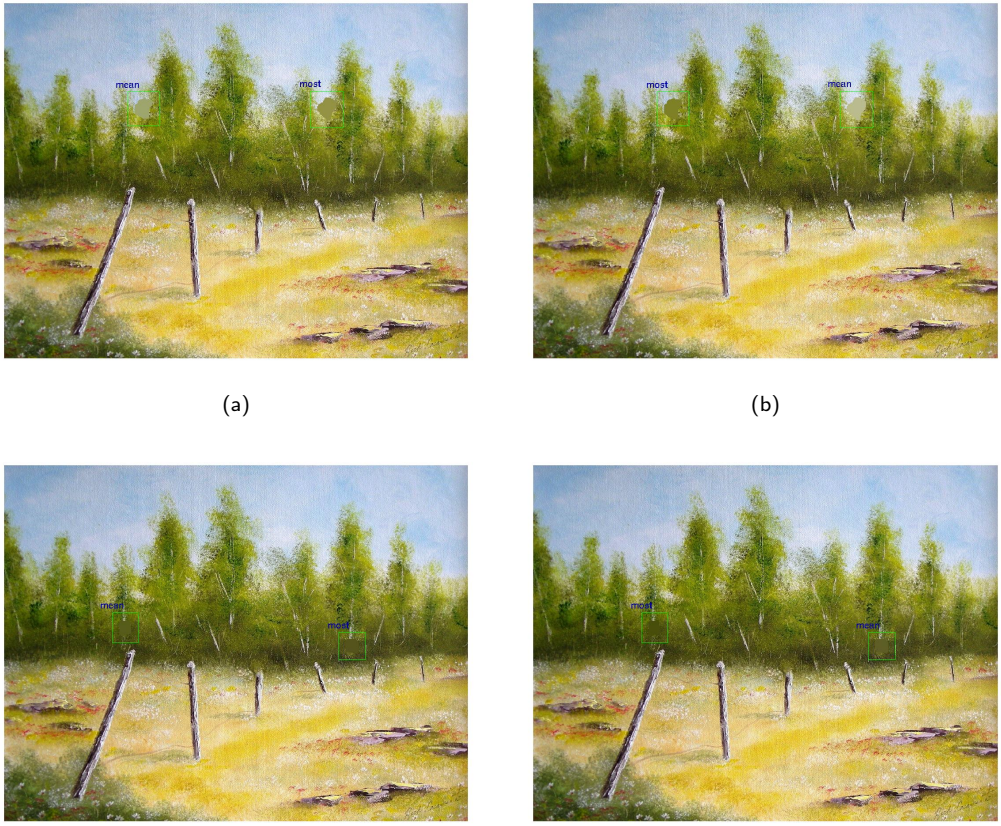
3 EXPERIMENTAL SETUP: Eye tracking is the process of "measuring the movement of the eyes, usually in response to a visual, auditory, cognitive, or vestibular stimulus"[1]. This technology is widely used in visual attention experiments as it gives a precise account of the areas of an image that attract and hold attention. As such, it is highly suitable technology for determining which lacuna attracted attention, at what time it attracted attention and for how long. The experiment is described in detail below.

3.1 Subjects: Four men and four women (ages ranking from 24 to 29) participated in our experiment. They had normal or corrected-to-normal acuity and normal color vision as confirmed by testing on the HRR pseudoisochromatic plates (4^{th} edition). Subjects were unaware of the purpose of the experiment.

3.2 Apparatus: Stimuli were presented on a 19" monitor operating at 1280x1024 pixels and 24-bit color resolution. The eye-tracker used in the experiment was the SMI RED-4.2-922-156, with a temporal binocular resolution of 60Hz.

3.3 Procedure: The subjects were placed in front of the monitor at 70cm. They were informed that a set of pictures will appear in front of them for 4 seconds. They were in-

[1] iView X System Manual, version 2.2, Sensomotoric Instruments, Inc. March 2009



(a) (b)

(c) (d)

Fig. 2: Examples of a set of 4 stimuli

structed to analyse each scene but were not informed about the presence of lacuna. Therefore, it was a free-viewing experiment. The 36 stimuli were displayed in a randomised order, and it was ensured that two stimuli from the same source image were never displayed a short time apart from each other.

4 RESULTS: As expected, the LMoC attracted less attention than the LMeC. To evaluate our results we made a tally of the number of instances in which a lacuna filled with the LMoC was noticed before the lacuna filled with the LMeC and vice versa. We found that, 61% of the time, the LMeC was noticed first.

In addition, we measured the fixation times on each lacuna. A fixation is considered to be the relatively static state of the eyes "during which gaze is held upon a specific location" [7]. A boxplot of the fixation times for lacuna filled with the LMeC colours versus those filled with LMoC colours is shown in Figure 3. The figure shows that the median value for the LMeC fixation times is 996ms while it is 587ms for the LMoC fixation times. Therefore the data indicates that the LMeC colours trigger 66% more fixation time than the

LMoC colours.

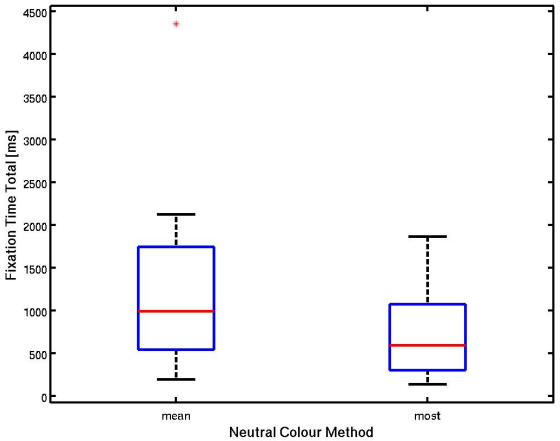


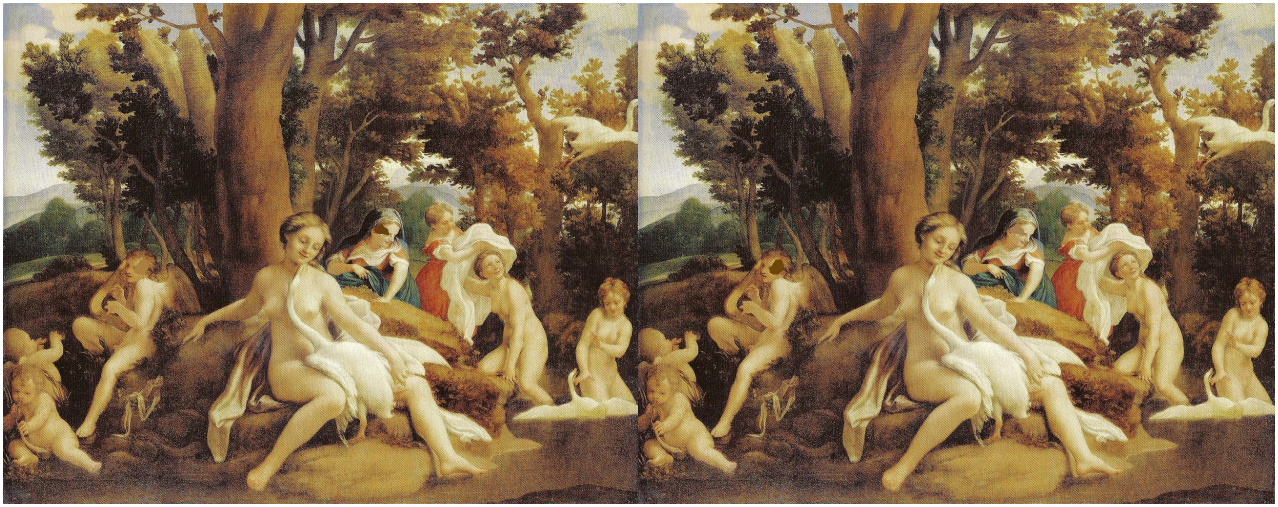
Fig. 3: Box plot comparison of fixation times for the LMeC and LMoC methods respectively. The upper and lower boundaries of the standard boxplots are at the 25th and 75th percentiles. The horizontal red line across the box marks the median of the distribution, and the vertical lines below and above the box extend to the minimum and maximum, respectively.

5 DISCUSSION: Some observations from our experiment point to the difficulty of creating suitable stimuli for such a complex issue. For example, we observed that several lacuna were not noticed at all, indicating that these lacuna were too small for the experiment. In addition, it was extremely important to postion competing lacunas so that one lacuna was not in a more prominent location. As shown in Figure 4, placing one lacuna too close to the centre of the image resulted in that lacuna being noticed first, no matter what neutral colour was used. We also encountered instances in which a lacuna that we expected to attract little attention, instead attracted quite a lot. This begs the question of whether the lacuna attracted attention because it disrupted the harmony of the image or rather, it attracted attention because it was neither clearly a lacuna, nor clearly part of the image, so that the subjects spent time resolving their confusion. Figure 5 shows an example of one of these stimuli. For this reason the fixation time data may not be a reliable measure of how disturbing a lacuna is. In addition, these instances show that choosing a neutral colour is not simply a question of finding the least salient colour because as it turns out, a lacuna may be disturbing precisely because it is not obviously a lacuna.

Fig. 5: Example of confusion-triggered attention: Some subjects spent an inordinate amount of time examining the lacuna on the right.

CONCLUSION: We determined that, 61% of the time, lacunas filled with the mean colour in the local region around the lacuna were noticed sooner than lacunas filled with the most common colour in that region. However, in some cases the reverse is true. As discussed, this may be due to the confusion of the subject. With such a complex stimulus as a painting, it is difficult to isolate and control for different sources of attention. To further this work, a similar experimental framework could be used, while working with a more extensive dataset and more subjects. Any future experiments should investigate the balance between choosing a colour that is too subtle and one that is not subte enough.

The problem of neutral colour selection has many links with saliency and visual attention which remain unexplored. In particular, applying computational models for saliency to this problem, with appropriate task-specific constraints, could be a promising avenue. In addition, we have only investigated the use of two colour seletion methods, and there should be more candidate methods to evaluate. Also,



(a) (b)

Fig. 4: Example of position-triggered attention: More attention was paid to the more central lacuna in both cases, indicating that its central position outwayed its neutral colour as a trigger for attention.

our analytical framework could be applied to more complicated restoration techniques, by considering the texture of the painting, the surface of the lacuna and the effect of applying trateggio or other techniques. Lastly, restoration of lacunae in other media such as ceramics may be explored.

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