Study of the Use of the Colour Blue in Byzantine and Early Post-Byzantine Church Decoration in the Context of the Presumed Contemporary Interior Lighting

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ABSTRACT

This explores the effect of interior lighting on the perception of the colour blue, produced from three different pigments (lapis lazuli, azurite, and smalt) in post-Byzantine churches where the interior illumination was low and dominated by incandescent light. Moreover, the background to the church decoration at the time was painted black. Our hypothesis is that the blue obtained from lapis lazuli would have conferred no perceptual advantages over the cheaper pigments. To test the hypothesis the closest Munsell matches were selected for the colours of azurite, smalt and lapis lazuli, using CIECAM02 and for both, illuminant D65 and the candlelight illuminant (~1800K). Each Munsell match was presented on a black background. In the case of the lighter blues, such as lapis lazuli and azurite, the closest Munsell notation found using CIECAM02 did not depend on the illuminant. This supports the notion that lapis lazuli was not used in the post-Byzantine church decoration because under the contemporary incandescent illumination the same visual result could have been achieved with the cheaper pigments. This notion challenges the view of the traditional art historical scholarship on the matter, where the reason for non-use was considered to be purely economic.

1. INTRODUCTION

The aim was to consider to what extent the omission of lapis lazuli from the interior decoration of the early post-Byzantine churches could be associated with the predominance of incandescent light, compared to the Byzantine churches, where the interiors were dominated by daylight. The gradual conquest of the Balkans by the Ottoman Empire led to dramatic changes in the architecture of the Eastern Orthodox Church in the region. Outward changes in the appearance of the churches included the loss of the characteristic dome and a return to the basic basilica form. Moreover, for security reasons, the external openings – both windows and doors – became restricted in number and size. Church buildings in this particular style continued to be built during the sixteenth and seventeenth centuries (Gradeva 1994).

The stylistic changes in the early post-Byzantine architecture altered not just the appearance, but also the performance of the buildings in terms of the characteristics of their interior illumination. For example, while the domed Byzantine architecture flooded the interior with daylight, the post-Byzantine architecture was dominated by artificial illumination. Consequently, the viewing conditions of the latter interiors were determined by the light from incandescent sources; candles and oil lamps.

Comparative examination of the interior wall-painting from both eras has revealed that the range of pigments used in the post-Byzantine churches was different to that used before the Ottoman conquest. The most significant difference is in the type of blue pigment used (Manova 1985). Lapis lazuli has so far been identified only in wall-painting carried out within the Byzantine period, while azurite was used in both eras. Smalt was introduced at the end of the sixteenth century in Cyprus and in Epirus (Daniilia et al. 2008).

Traditional art historical research has so far offered only two possible explanations for the absence of lapis lazuli from post-Byzantine wall paintings: price, as lapis lazuli was as expensive if not more expensive than gold, or availability. High quality lapis lazuli was imported and therefore presumed to have been difficult to obtain. However, recent research has confirmed that lapis lazuli was readily available in the Ottoman Empire, at least to meet the needs of the Ottoman Muslim miniaturists and for the decoration of mosque and domestic interiors (Kirby, Nash and Cannon 2010). There must, therefore, have been some other reason for the limited use of this pigment.

The hypothesis in this paper is that because of the low intensity and the colour of the incandescent light, which is within the yellow part of the spectrum, and the fact that blue colours would usually have been presented within a black background, in such viewing conditions the blue obtained from lapis lazuli would have been perceptually no more effective than that obtained from the cheaper pigments. When considering the high price of the pigment it can be suggested that the omission of lapis lazuli in wall paintings from the post-Byzantine era might have been a consequence of an unfortunate combination of both economic and perceptual disadvantages in its use, compared to the considerably cheaper azurite. To test the hypothesis, using previous research on the effect of candlelight on the colour appearance in seventeenth-century church interiors, the closest Munsell matches were selected for the colours of azurite, smalt and lapis lazuli, using CIECAM02 and for both illuminant D65 and the candlelight illuminant (~1800K) (Tantcheva, Cheung and Westland 2009). Each Munsell match was presented on a black background.

2. METHOD

The original artists prepared the paint by mixing the pigment – usually a single one – with water and applying it directly to the plastered wall, so the painted colour was relatively close to that of the initial pigment (Prashkov 1985). The pigments which we examined were supplied by L. Cornelissen & Son, London and were marked as lapis lazuli (dark), smalt and azurite. A sample was prepared from each pigment by mixing it with water and applying it to a white card. Full coverage of an area of approximately one square centimetre was aimed for. Subsequently reflectance factors were measured for each sample, using a hand-held Minolta CM-2600d spectrophotometer fitted with a target mask CM-A146 (8mm measurement area). Before commencing the measurements, the spectrophotometer was calibrated using the white calibration plate CM-A145.

The spectral data were converted to CIECAM02 coordinates using the CIE 10º observer and, for both, illuminant D65 and an illuminant defined by a blackbody radiator at 1800K (Wyszecki and Stiles, 2000). Calculations were based upon CIECAM02 equations and the parameters are listed in Table 1. The dim surround condition was employed; the Y of achromatic background Y_b and the luminance L_A were assumed to be 50% and 10 $cd\cdot m^{-2}$ respectively.

Table 1: Parameters for CIECAM02 calculation.

F	c	Nc
0.9	0.59	1.1

The closest Munsell sample was obtained according to the minimal Euclidean distance between a point representing the blue colour of the pigment and a set of points representing 1269 Munsell reflectance spectra (Parkkinen, Hallikainen and Jaaskelainen 1989). The calculation was carried out using two illuminants (Table 2).

Table 2 : Definition of the six experimental conditions.

Condition	Colour difference	Illuminant
A	XYZ	CIE D65
B	XYZ	Blackbody 1800K
C	CIEDE2000	CIE D65
D	CIEDE2000	Blackbody 1800K
E	CIECAM02	CIE D65
F	CIECAM02	Blackbody 1800K

3. RESULTS AND DISCUSSION

Table 3 shows the closest Munsell notation found for the four pigments for each of the six conditions listed in Table 2.

Table 3: Munsell notations for the blue colours of the different pigments and the black colour of the background, using each of the two viewing conditions.

	XYZ		CIEDE2000		CIECAM02	
	A (D65)	B (1800K)	C (D65)	D (1800K)	E (D65)	F (1800K)
lapis lazuli	5 PB 6/8	5 PB 6/8	5 PB 6/10	5 PB 6/10	7.5 PB 5/12	7.5 PB 5/10
azurite	7.5 PB 4/12	5 PB 4/8	2.5 PB 4/8	5 PB 4/8	7.5 PB 4/10	5 PB 4/8
smalt	7.5 PB 4/12	7.5 PB 4/12	2.5 PB 5/8	7.5 PB 4/10	7.5 PB 4/12	7.5 PB 4/12
black	10 Y 2.5/1	10 P 3/1	5 G 3/1	5 G 3/1	5 GY 3/1	5 GY 3/1

The information in Table 3 is not easily analysed visually, especially when the Munsell notations for the blue colours need to be interpreted in the context of the black as a background colour. Hence, the information has been presented visually using sRGB representations (Figure 1) of the Munsell chips referred to in Table 3.

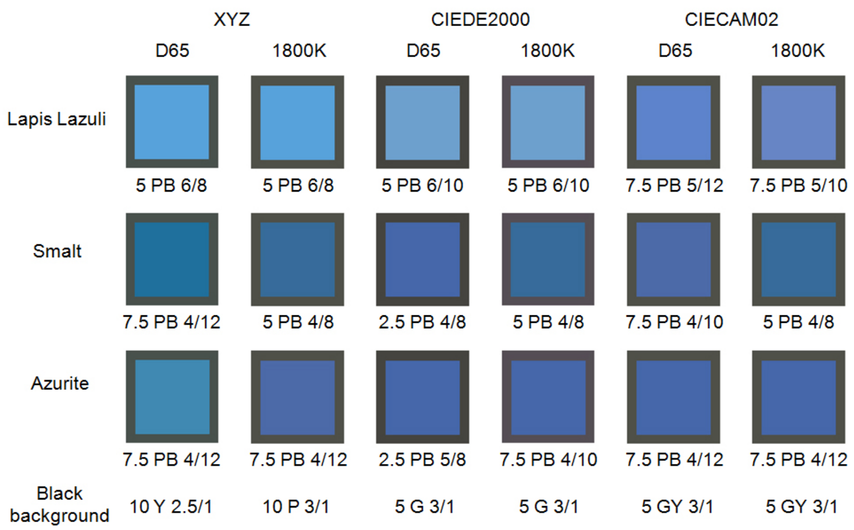

Figure 1: sRGB representations of the colours selected.

4. CONCLUSIONS

Our aim was to establish to what extent the use of lapis lazuli was perceptually effective under flame illumination (the type of illuminant under which the frescoes used in the post-Byzantine era were intended to be viewed) compared to smalt and azurite, the other two blue pigments used at the time. Visualisations of the closest Munsell notation for each of the blue pigments was shown within a black border, as post-Byzantine frescoes normally used black as a background colour. We computed three colour differences (XYZ, CIEDE2000, and CIECAM02) to find the closest Munsell notation, using either D65 or candlelight as the illuminant. It can be concluded that in the case of the lighter blues, such as lapis lazuli and azurite, using CIECAM02, the closest Munsell notation did not depend on the illuminant. CIECAM02 is the most sophisticated colour-appearance model of those used in this study, and therefore this provide some evidence that the perceptual performance of the expensive lapis lazuli and azurite is rather similar. This supports the notion that lapis lazuli was not used in the post-Byzantine church decoration because under the contemporary incandescent illumination the same visual result could have been achieved with the cheaper pigments. This notion challenges the view of the traditional art historical scholarship on the matter, where the reason for non-use was considered to be purely economic.

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