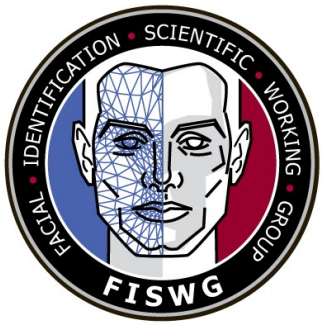

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Image Factors to Consider in Facial Image Comparison

Purpose

The purpose of this document is to describe imaging factors that can affect the photography/videography of a physical subject's face and which should be evaluated when conducting morphological facial analysis.

1. Scope

1.1 The scope of this document covers the factors that can impact facial images for consideration by facial image reviewers and examiners. This document provides standard terminology to identify imaging factors and guidance on how to describe their effect on the face or facial features. It is not an exhaustive list of possible factors. This document does not consider video processing in its entirety, analog imagery capture, three-dimensional capture, post image processing, including in camera filters and curves, deliberate image modification, printing, or visual display issues.

2. Referenced Documents

2.1 ASTM Standards[1]

E2916 Terminology for Digital and Multimedia Evidence Examination

2.2 Other Biometric Standards:

ANSI-NIST ITL 1-2011 Update:2015, Data Format for the Interchange of Fingerprint, Facial & Other Biometric Information[2]

[1] For referenced ASTM standards, visit https://www.nist.gov/osac/astm-launch-code, or the ASTM website, https://www.astm.org/, or contact ASTM Customer Service at service@asstm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

[2] Available from National Institute of Standards and Technology (NIST) website https://www.nist.gov/programs-projects/ansinist-itl-standard or https://www.nist.gov.

FISWG Facial Image Comparison Feature List for Morphological Analysis[3]

FISWG Facial Comparison Overview and Methodology Guidelines

ISO/IEC SC37 19794-5 Biometric data interchange formats[4]

3. Introduction

3.1 Morphological analysis is the best practice for facial comparison (FISWG Facial Comparison Overview and Methodology Guidelines. However, it is highly sensitive to image quality. Loss of image quality through e.g., blurring, compression artifacts, or reduction in spatial resolution can reduce or eliminate the visibility of facial features and characteristics. As a result, the ability to compare two or more images will be reduced and greater uncertainty will be introduced.

3.2 The facial image capture factors presented in this document are intended to serve as part of the FISWG morphological comparison guidelines. Any reference in this document to the word “image” refers to a digital still image.

3.3 This document includes imaging factors that may be visible or affect the images being analyzed and compared, specifically when using the FISWG document “Facial Image Comparison Feature List for Morphological Analysis”.

3.4 These image capture factors may lead to an image being assessed as ‘limited value’ or ‘unsuitable’ for facial comparison.

3.5 This document is not intended to cover all possible imaging effects on the images used in facial comparison; however, other FISWG documents focus on various factors that are outside the scope of this document. This document is not intended to imply that each factor must be identified during analysis and comparison. Additionally, the implementation of this guideline will vary depending on the agency.

3.6 This document uses histograms to objectively show the effects of various image factors on image tonal range and distribution, with a corresponding impact on exposure and contrast.

4. Image Factors

[3] Available from Facial Identification Scientific Working Group (FISWG), https://fiswg.org/documents.html.

[4] Available from International Organization for Standardization https://www.iso.org/committee/313770/x/catalogue/ or https://www.iso.org.

4.1 The following image factors are to be considered in the analysis and comparison of facial images. It is important to understand some factors are not mutually exclusive. Also, some image factors are very common and easily observed while others are not. It also may not be possible to determine the specific cause of an image factor where there are multiple contributing causes, but recognizing the presence and potential impact of such a factor is imperative.

4.2 A wide range of factors may affect the quality of facial images. These include, but are not limited to, the following list (Table 1).

Table 1

Image Factors
Artifacts
Distortion
Lighting
Near Infrared
Noise
Obstructions
Pose
Sharpness
Resolution

5. Artifacts

5.1 The term **Artifacts** refers to a wide range of image anomalies influenced by the camera's optical qualities and the digitizing process. These can include spatial sampling, compression, electrical interference, sharpening, and high intensity light issues. These anomalies may obscure or introduce false facial details and make the image appear as though it has been altered. Distortions are also classified as artifacts but are considered separately in this document.

5.1.1 **Blooming** refers to bright spots/areas, smears and streaks that occur across multiple pixels in an image. Blooming is caused by the over-saturation of parts of the sensor in response to a bright (intense) light source. This causes the surrounding pixels, sometimes in lines, to lighten and even overexpose that part of the image. It can commonly cause Chromatic Aberrations and Lens Flare (see below) at the same time.

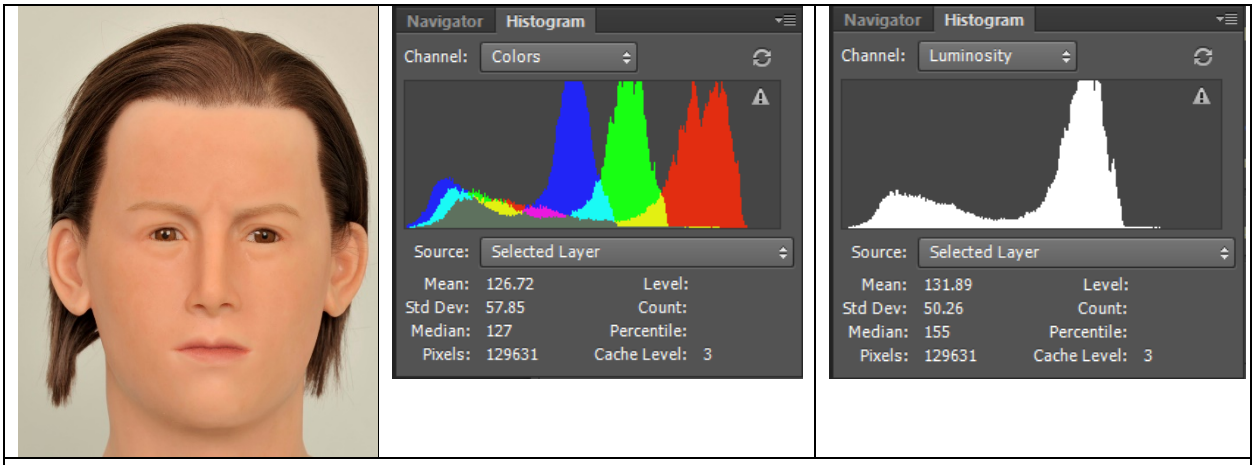
- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 9 Image Sensors Page 169.
- Sencar H.T., Memon, N., Digital Image Forensics, Springer, 2013, 3.3.6 Saturation, Page 39.
- https://www.cambridgeincolour.com/tutorials/lens-corrections.htm

- https://info.adimec.com/blogposts/ccd-versus-cmos-blooming-and-smear-performance
- https://micro.magnet.fsu.edu/primer/digitalimaging/concepts/ccdsatandblooming.html

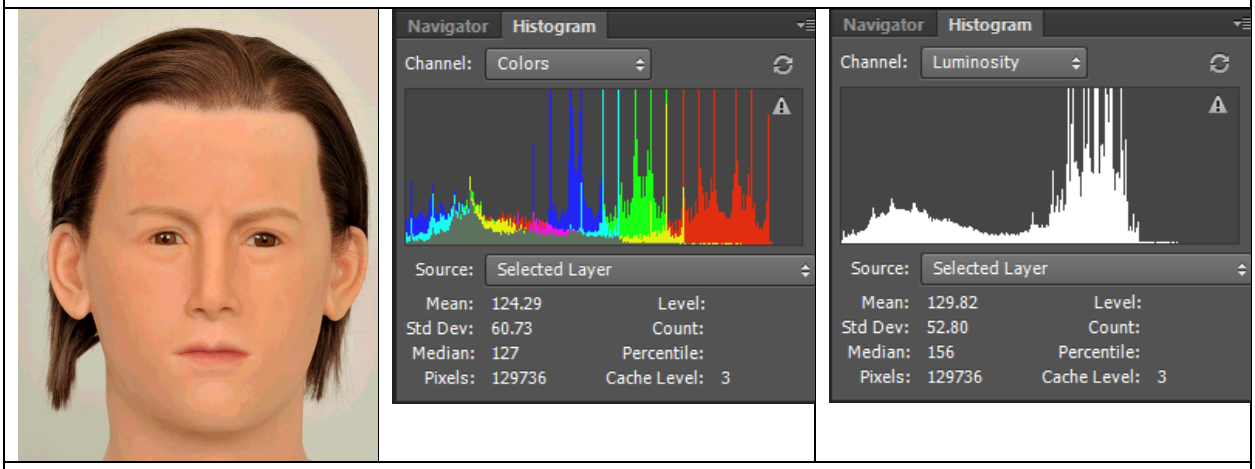
This image (above) demonstrates the effect of blooming. The close crop highlights the overexposure and washing out of visible detail adjacent to the eye region visible in the histogram as a clipping of highlights.

5.1.2 **Banding (posterization)** is a loss of image data and can be observed as a pronounced transition in tone and color (chroma). It is typically caused by low bit-depth, compression, and printing processes. It affects the whole image and is more observable in areas of low contrast.

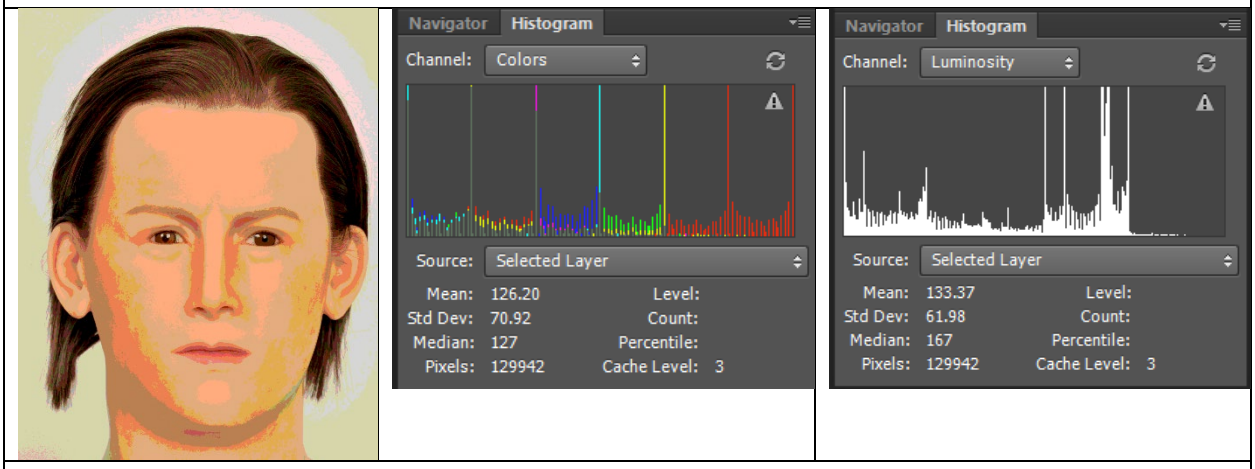
- McHugh, S, T,. Understanding Photography Volume 1 (Version 1.3), 2017, Cambridge in Color, Pages 25- 27 Understanding Bit Depth
- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 21 Tone reproduction Pages 388-391.
- https://www.cambridgeincolour.com/tutorials/posterization.htm
- https://www.imatest.com/solutions/artifacts/#compression



Reference image (above) showing a fine gradient representation of tones and hues within the image.



Posterization is visible with distinct gradient transitions occurring between tones. The histogram (above) demonstrates the grouping of hues synonymous with a lower bit depth.



Posterization shows as bands of color present on the face. The histogram is divided into distinct peaks of color due to the reduction in bit depth in comparison to the reference image (above).

5.1.3 **Ringing (haloing)** can be observed as a lighter area immediately adjacent to darker regions in high contrast areas (areas of an image that have a large intensity gradient). As the lighter region becomes light the adjacent darker region can also become darker, and can lead to the clipping (loss) of bright and dark detail. It may also appear as a color distortion. Compression, and filtering techniques such as sharpening, can cause this effect. For faces it is typically seen around hair, ears and irises, resulting in the distortion of adjacent tones in comparison to those of the rest of the face. Ringing may conceal fine detail.

- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 19 Introduction to image quality and system performance, Pages 350-351.
- Schewe, J., Fraser, B., Real World Image Sharpening With Adobe Photoshop, Camera Raw, and Lightroom, Chapter One. What is Sharpening, Locations 299-399 of 4934.
- https://www.cambridgeincolour.com/tutorials/image-sharpening.htm
- https://www.imatest.com/solutions/artifacts/#compression
- https://www.photozone.de/jpeg2000-vs-jpeg-vs-tiff

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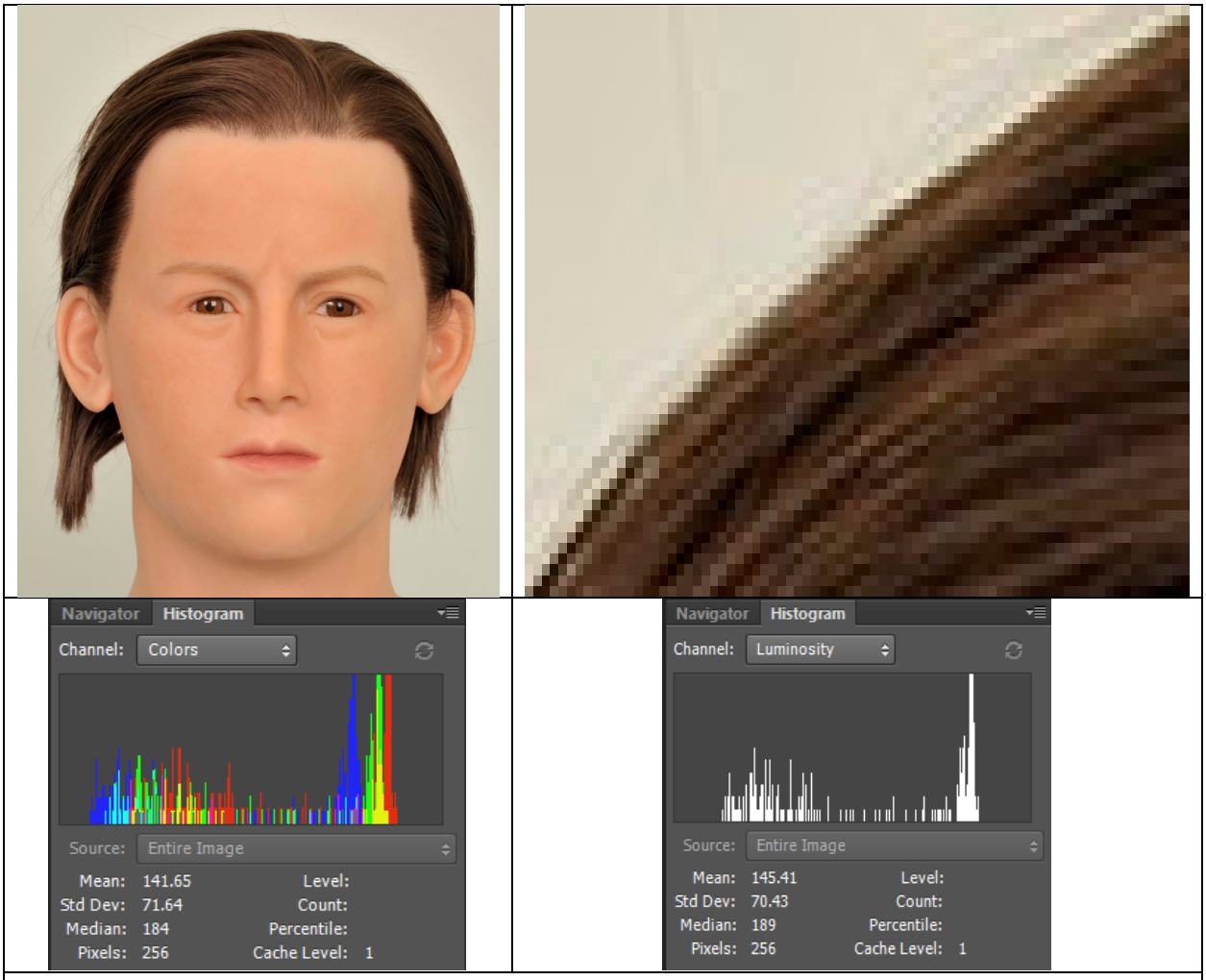
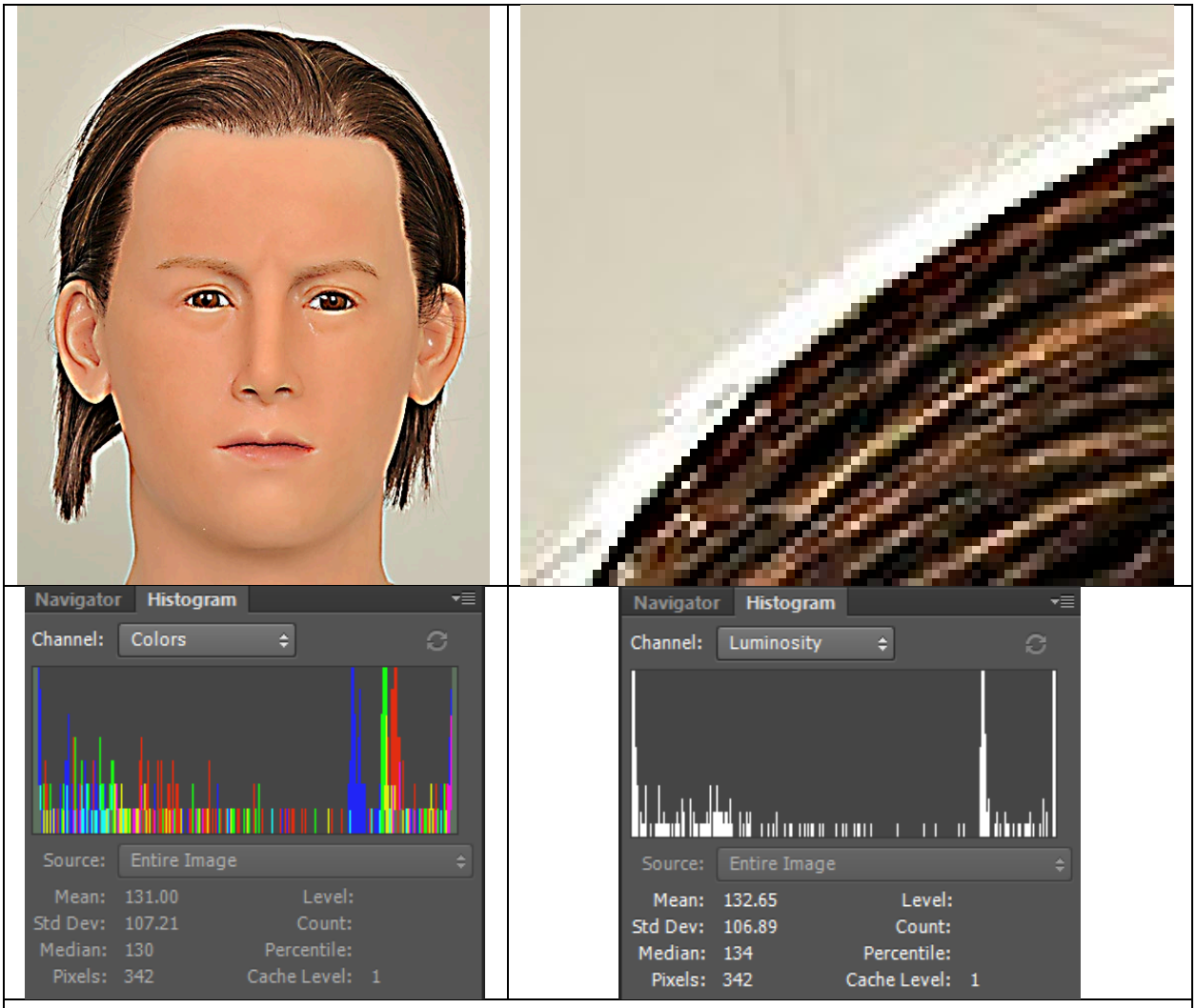
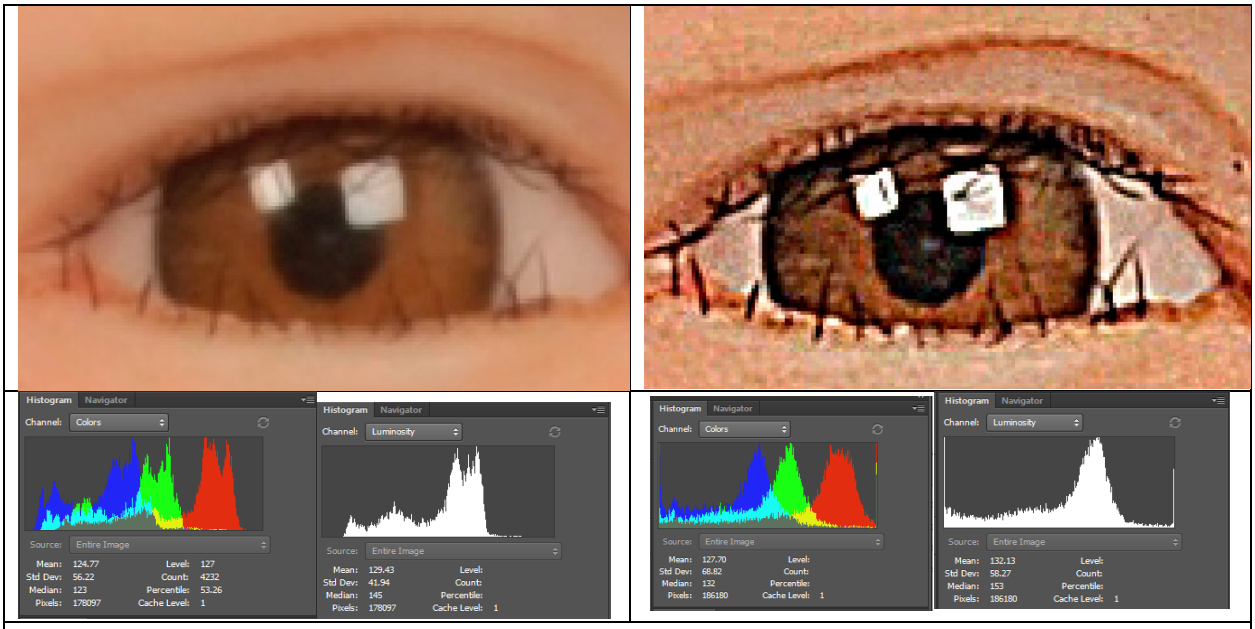


Reference image (above). A histogram of a close crop or the hair region shows the tonal range and even distribution of hues.



This compressed image (above) demonstrates the halo effect, highlighted in the close crop as a whitish region adjacent to the hairline. The histogram is segregated into distinct hues. The contrast has intensified indicated by the increase in the breadth of the histogram.



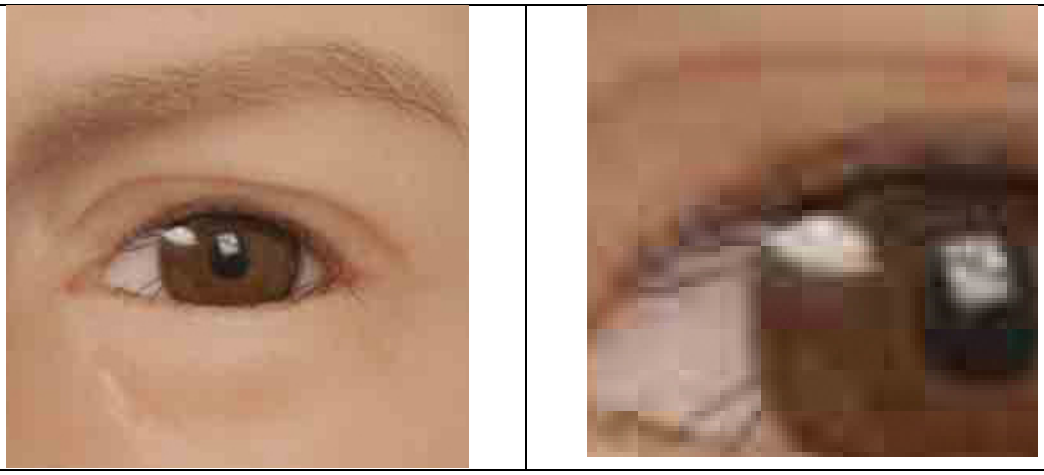
This image (above) represents a side-by-side comparison of close crops of the unaltered reference image and a highly compressed (jpeg compression) version of the reference. A visible halo is present around the iris of the compressed image. This has caused an increase in contrast and resulted in the clipping of light and dark pixels as demonstrated in the histograms.

5.1.4 **Blocking - JPEG Compression/Macro-Blocking**

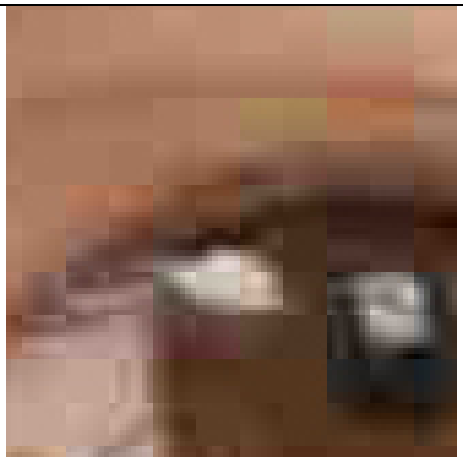
5.1.4.1 Compression effects can be observed in lower resolution images or more highly compressed images. A common example is Joint Photographic Expert Group (JPEG) images that typically display eight by eight (64 pixels) pixel blocks. This compression technique can cause blocking artifacts making round objects like pupils and iris' appear squarer and results in the introduction of color as well as tonal loss and alteration. Compression results in a loss of fine detail and the introduction of false detail.

- Robinson, E, M,. Crime Scene Photography, Second Edition, Academic Press 2010, Chapter 10, Digital Imaging Technologies, Pages 520-523.
- Unterweger, A., Compression artifacts in modern video coding and state-of-the-art means of compensation, 2013. https://wavelab.at/papers/Unterweger13a.pdf
- Jakulin, A., *Baseline JPEG and JPEG2000 Artifacts Illustrated*, https://stat.columbia.edu/~jakulin/jpeg/artifacts.htm, 2004.
- Multimedia Communications Laboratory, University of Texas at Dallas, *JPEG Post-Processing*, https://tinyurl.com/bgf98j3o, 2002.

Reference image (above) and close crop of the eye region with good resolution of fine detail including individual hairs.



JPEG Lowest Quality first generation. There is visible blocking despite the ability to resolve individual hairs. (above images)

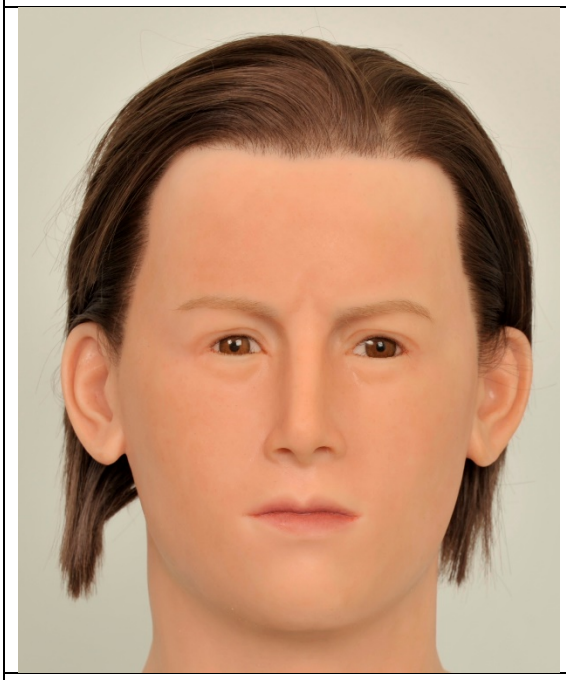
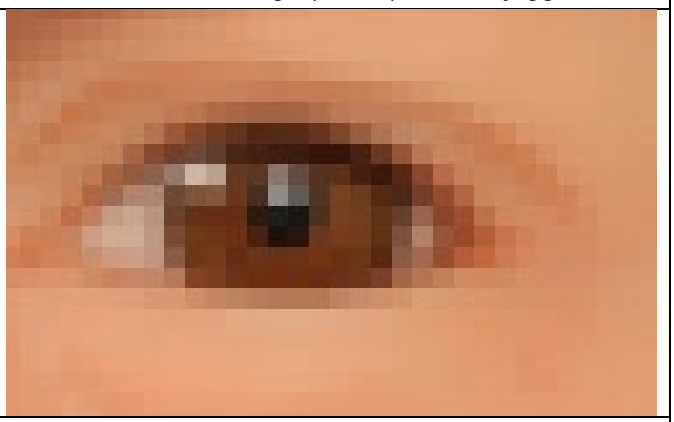


JPEG Lowest Quality tenth generation. The pupil and iris outline has become square and blocky in comparison to the reference image. There are noticeable 'blocks' of color across the image (above) and the ability to define single hairs is reduced. The overall tone has altered as a result of compression.

5.1.5 **Sampling artifacts:**

5.1.5.1 **Aliasing (Jaggies / Zigzag)** can be observed as a blocky (jagged/staircase/zigzag) appearance of fine detail and patterns of visible striping in tone and color. This occurs in regular patterns with fine detail near the resolution limit of the digital sensor.

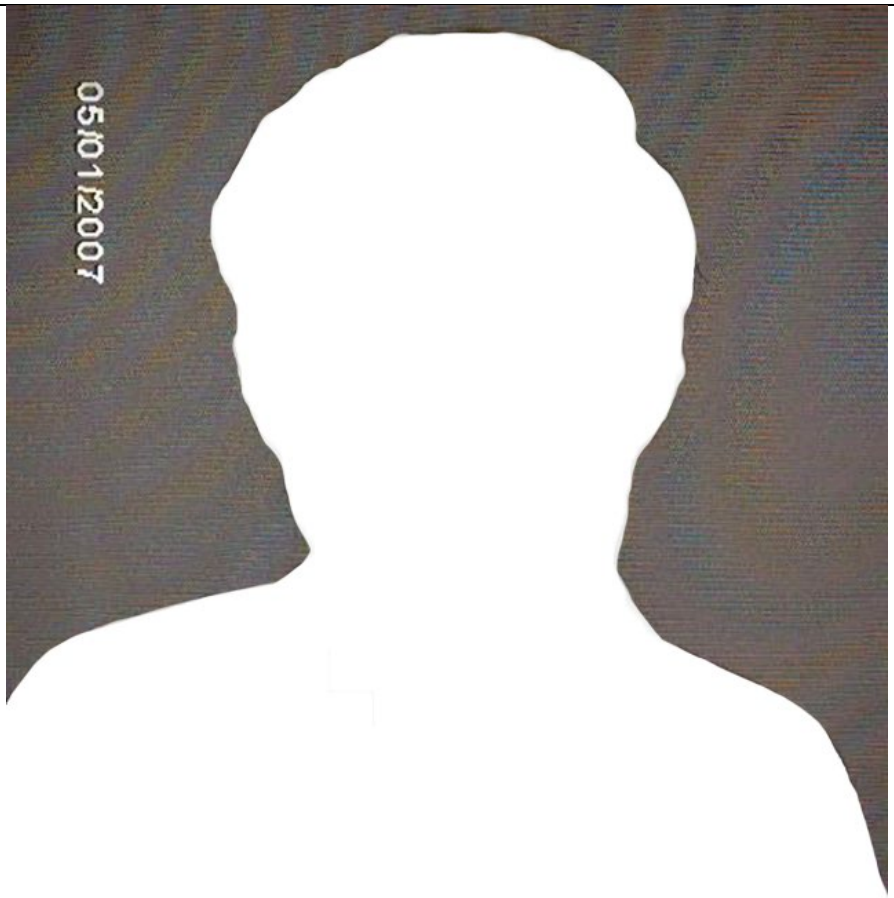
- Langford M. Bilissi, E., Langford's Advanced Photography 8th Edition, Focal Press, 2011, Chapter 6 Image Sensors, pages 160-161.
- Gonzalez, R, C. Woods, R, E,. Digital Image Processing, Third Edition, Pearson/Prentice Hall, 2008, Chapter 4, Filtering in the Frequency Domain, pages 228-233.
- Johnson, JR, CS, Science for the Curious Photographer, CRC Press, 2010, Chapter 16 Image Capture and Processing, Pages 122-123
- Johnson, JR, CS, Science for the Curious Photographer, CRC Press, 2010, Chapter 17 What is perceived Image Quality?, Pages 131-132
- https://www.cambridgeincolour.com/tutorials/image-interpolation.htm
- https://www.cambridgeincolour.com/tutorials/camera-sensors.htm
- Guttosch, R. J. (2002). Investigation of Color Aliasing of High Spatial Frequencies and Edges for Bayer-Pattern Sensors and Foveon X3® Direct Image Sensors. Foveon Inc. https://tinyurl.com/2p8cdd4f

<table>
<tr><th colspan="2">Jaggies</th></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td></td><td>Close crop of an enlarged zoom of the eye region of the reference image (above) to show jaggies.</td></tr>
<tr><td></td><td>  </td></tr>
<tr><td></td><td>A close crop of the eye region of a lower resolution copy of the reference image (above) that demonstrates jaggies.</td></tr>
</table>

5.1.5.2 **Moiré** pattern, caused by aliasing, occurs when the sensor resolution is insufficient to resolve the detail of objects with repetitive patterns. Moiré patterns generally will not affect the face (unless capturing an image from a screen or printed document) but are typically seen on clothing and in the background of images and presents as repeating patterns, color artifacts or an unrealistic maze-like pattern of pixels.

- Langford M. Bilissi, E., Langford's Advanced Photography 8th Edition, Focal Press, 2011, Chapter 6 Image Sensors, pages 160-161.

- Gonzalez, R, C. Woods, R, E,. Digital Image Processing, Third Edition, Pearson/Prentice Hall, 2008, Chapter 4, Filtering in the Frequency Domain, pages 233-235
- Damjanovski, V, CCTV From Light to Pixels, Third Edition, Butterworth-Heinemann, 2014, Chapter 5 CCTV Cameras, page 179
- https://photographylife.com/what-is-moire/
- https://www.imatest.com/solutions/moire/
- https://www.cambridgeincolour.com/tutorials/camera-sensors.htm
- Owyoung, T., Understanding Moiré patterns in Digital Photography, https://www.ishootshows.com/understanding-moire-patterns-in-digital-photography/, 2017.



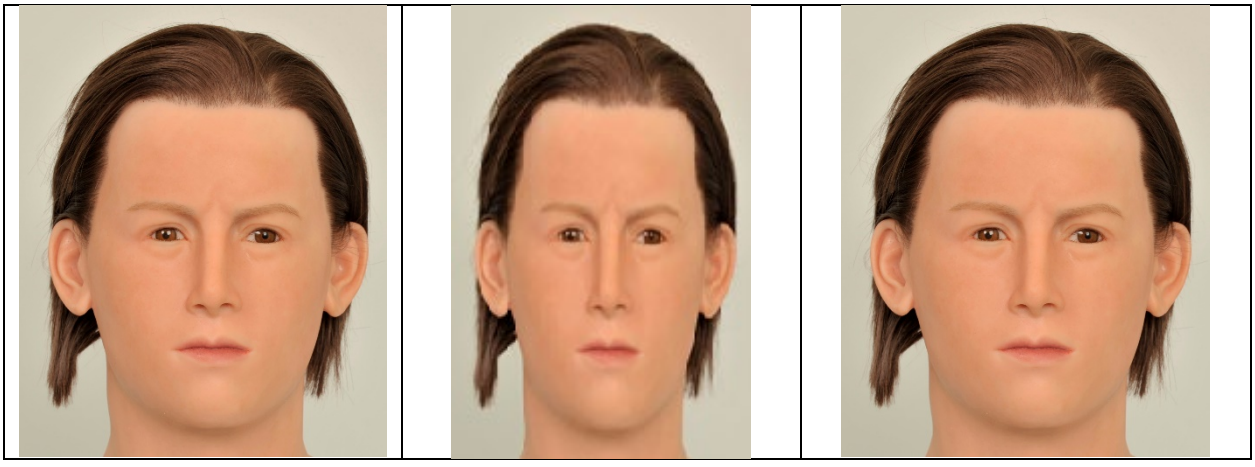
This image (above) shows the appearance of tonal and color lines/regions as a result of the sensors inability to resolve the fine details in the background.

6. Distortion/Aberrations

6.1 Distortion refers to effects that can change the appearance of shapes and objects, the face, or facial features in an image. Optical distortion refers to variations created by the optical system properties and settings that distort the shape of the captured scene. Distortion may also lead to the diffraction of light into different component colors as the spectrum becomes partly separated. Some distortions are commonly known as aberrations.

6.1.1 **Aspect Ratio Changes** can be observed as altered image proportions. This can be caused by differences in capture devices, display devices or their settings, or in post capture processing by changes in image or pixel width to height ratio. Facial shape can appear either thinner (horizontal reduction or vertical expansion) or wider (vertical reduction or horizontal expansion) than the actual face.

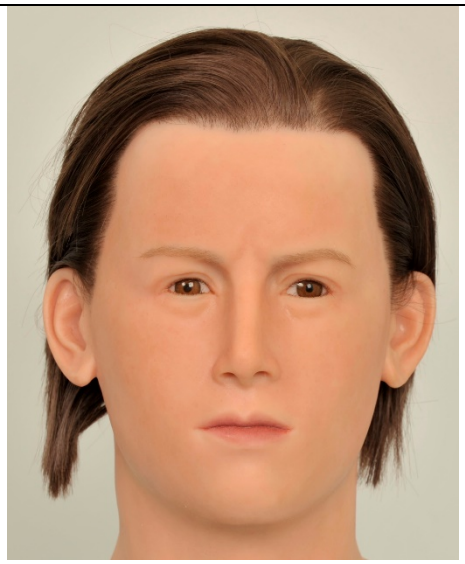
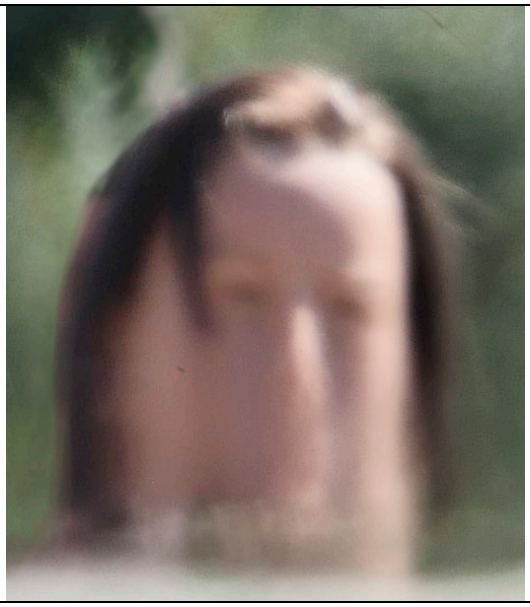
- https://aso.gov.au/about/aspect-ratio/
- Damjanovski, V, CCTV From light to pixels, Third Edition, Butterworth-Heinemann, 2014, Chapter 3, Optics in CCTV, page 90
- https://digital-photography-school.com/aspect-ratio-what-it-is-and-why-it-matters/
- https://www.bhphotovideo.com/explora/photography/tips-and-solutions/how-aspect-ratios-affect-look-your-pictures



This series (above) demonstrates aspect ratio changes and the affect that it has on the overall appearance of the face as well as the individual features within the face. The top left image is the reference image.

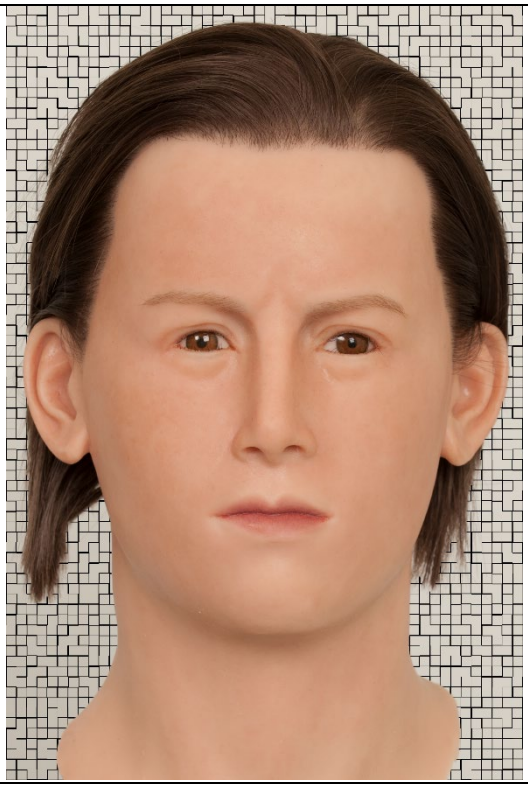
6.1.2 **Atmospheric Distortion** can be observed as the uneven magnification or illumination of elements within an image that may obscure details. Thermal activity creates variances in air density which in turn causes the refraction of light. As air at different temperatures moves across, usually vertically, the field of view it creates waves of distortion i.e., mirage effect. This is typically only seen under telephoto capture conditions close to the ground and objects. It results in blurring and obstruction of facial detail, as well as a loss of contrast.

- Siljander, R,P,. Juusola, L,W, Clandestine Photography, Basic to Advanced Daytime and Nighttime Manual Surveillance Photography Techniques, Charles C. Thomas Publishing, 2012, Pages 525-531.
- https://www.the-digital-picture.com/Photography-Tips/heat-waves-and-photography.aspx
- https://fstoppers.com/education/warning-long-lens-shooters-heat-wave-distortion-40508

	
The reference image (above) captured in an indoor environment.	An example (above) of atmospheric distortion with visible distortion of the lower portion of the face.

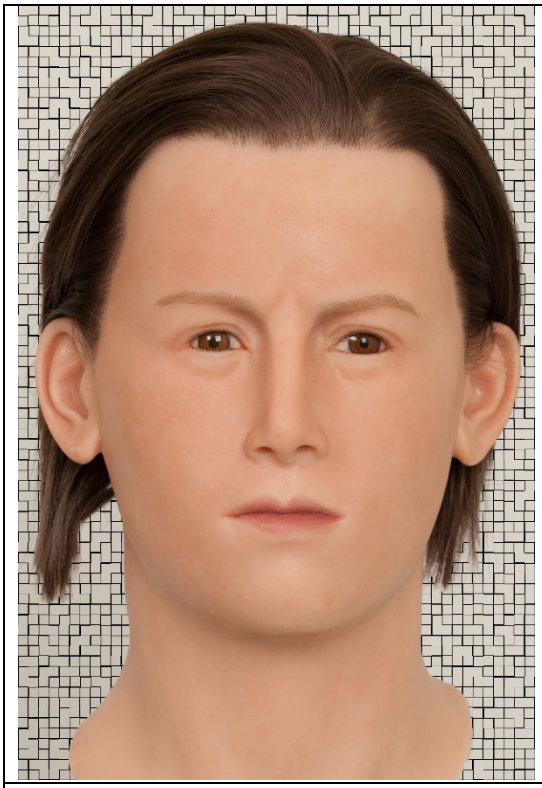
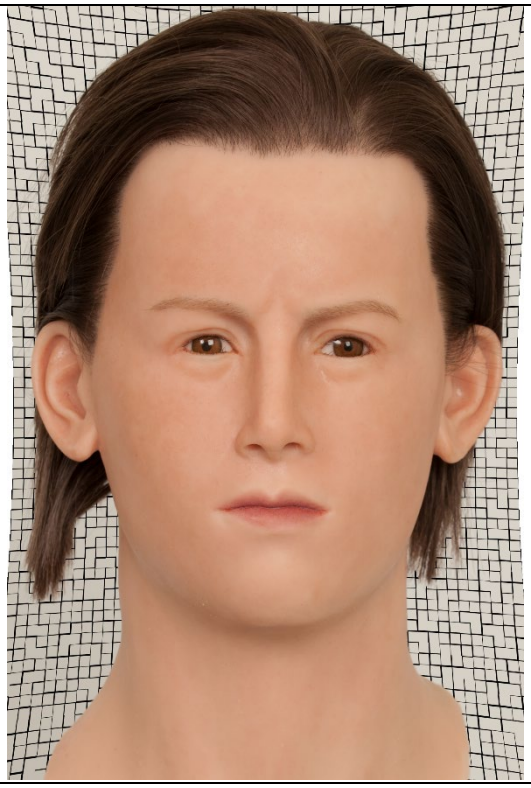
6.1.3 **Barrel Distortion (aberration)** can be observed as straight lines appearing to bend away from the center of the image, with the center of the image enlarged. This is caused by the optical system of image capture devices such as wide-angle lenses. This is especially noticeable when 'fisheye' lenses are used. Barrel distortion of the face is not easily distinguished from perspective distortion. It tends to make the facial features at the center of the image appear larger and changes the relationship of facial features on the face to each other.

- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 10 Camera lenses, Pages 178-180.
- Blitzer, H,. Stein-Ferguson, K,. Huang, J, Understanding Forensic Digital Imaging, Elsevier 2008, Pages 55-57.
- Savazzi, E,. Digital Photography for Science, 2011, Chapter 2, Pages 146-149; Chapter 6, 304-307.
- https://www.cambridgeincolour.com/tutorials/lens-corrections.htm
- https://www.dxomark.com/glossary/distortion/
- https://www.imatest.com/support/image-quality/distortion/

	
Reference image (above) with patterned background displaying no distortion.	Image (above) displays barrel distortion that shows enlargement of the center of the face. The background shows the expansion of the central part of the image and a convergence of the pattern at the periphery.

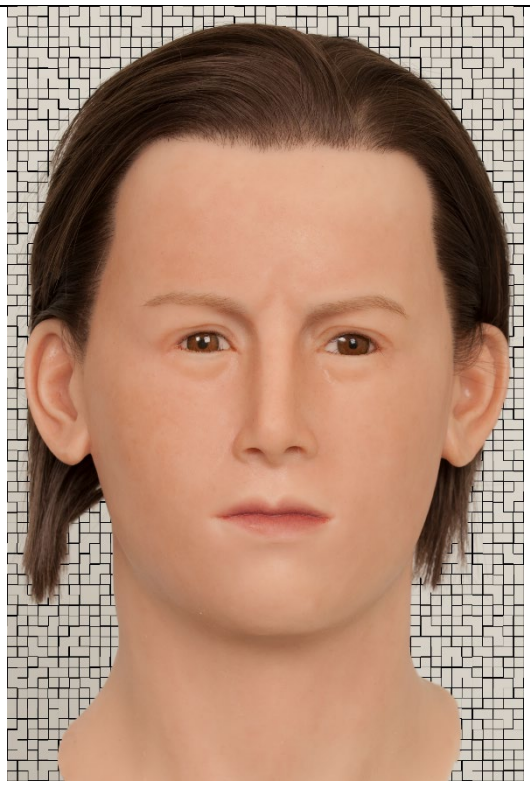
6.1.4 **Pin-Cushioning Distortion (aberration)** can be observed as straight lines appearing to bend towards the center of the image, with the center of the image more compressed. This is caused by the optical system of image capture devices such as telephoto lenses. Pin-cushioning is the opposite of barrel distortion.

- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 10 Camera lenses Pages 178-180.
- Savazzi, E,. Digital Photography for Science, 2011 Chapter 2, Pages 146-149.
- https://www.cambridgeincolour.com/tutorials/lens-corrections.htm
- https://www.dxomark.com/glossary/distortion/

	
Reference image (above)with patterned background displaying no distortion.	This image (above) demonstrates the compression occurring at the center if the image associated with the pin cushion effect. Note the reduction in size of the central features of the face and convergence of the background pattern centrally.

6.1.5 **Complex (mustache) Distortion** can be observed as a combination of both barrel and pin cushioning, and can result in uneven magnification of the image.

- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 10 Camera lenses Pages 178-180.

	
Reference image (above) with patterned background displaying no distortion.	A combination of barrel and pin cushion distortion was applied to this image (above). The pattern in the background is an indicator that distortion is present.

6.1.6 **Perspective Distortion** can be observed as magnification of the subjects' features that are closer to the camera making them appear larger than those further away (e.g., larger nose and smaller (or non-visible) ears in a front facing facial image). This is due to the short physical distance between the subject and the camera sensor. It can have a noticeable distortion effect when the camera is closer than 2 meters to the subject, which becomes more apparent at less than 1 meter. It can alter the appearance of the shape of facial features, making them relatively wider/larger at close distances and narrower/smaller at a longer distance. It also affects their relative positions to the features on the rest of the head as well as altering vertical and horizontal parallel lines behind the subject to make them appear as if they converge or separate.

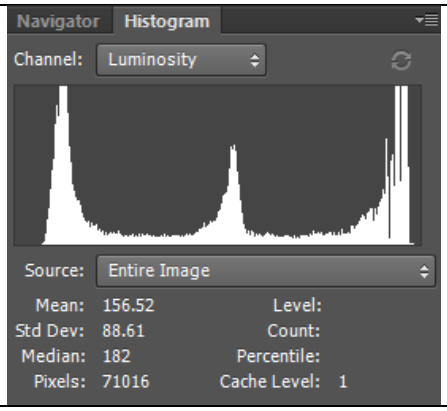
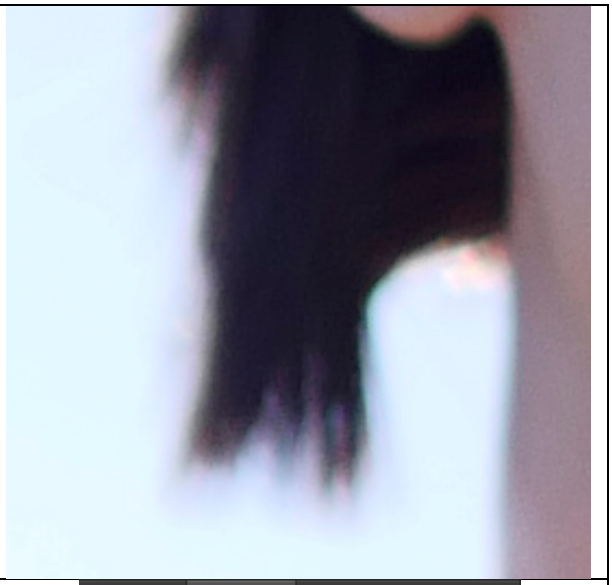
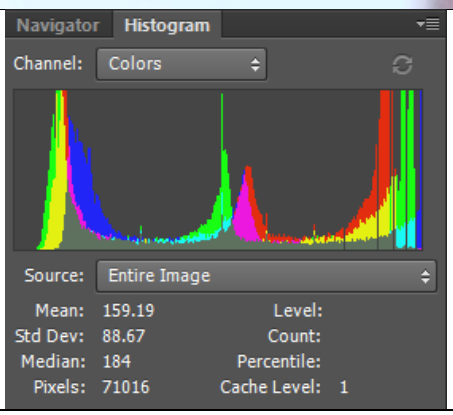
- https://www.cambridgeincolour.com/tutorials/lens-corrections.htm
- Edmond, G., Biber, K., Kemp, R., Porter, G., Law's looking glass: expert identification evidence derived from photographic and video images, Current Issues in Criminal Justice, 20, 337-377, 2009.

		
Baseline (above)	Close – not central features are larger than outer features (above)	Very close – shows significant distortion of facial proportions and loss of visibility of parts of the ears. (above)

6.1.7 **Chromatic Aberration (CA)** can be observed as color fringing that creates color and tonal changes in the high contrast areas of an image. Purple/magenta fringing is the most common but cyan/magenta and blue/yellow also occur. It is caused by imperfections and distortions creating an uneven diffraction of light through the lens. Polarizer filters may also introduce colors and rainbow effects.

- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 10 Camera lenses Pages 175-178.
- Langford M. Bilissi, E., Langford's Advanced Photography 8th Edition, Focal Press, 2011, Chapter 6 Image Sensors, pages 152-153.
- McHugh, S, T,. Understanding Photography Volume 1 (Version 1.3), 2016, Cambridge in Color, Polarizing Filters Pages 110-117.
- Sencar H.T., Memon, N., Digital Image Forensics, Springer, 2013, 3.3.6 Saturation, Page 53-54.
- Savazzi, E,. Digital Photography for Science, 2011, Chapter 2, Pages 141-145.
- https://www.cambridgeincolour.com/tutorials/lens-corrections.htm
- https://www.image-engineering.de/library/technotes/750-longitudinal-and-lateral-chromatic-aberration
- https://www.imatest.com/solutions/chromatic-aberration/
- https://photographylife.com/what-is-chromatic-aberration/

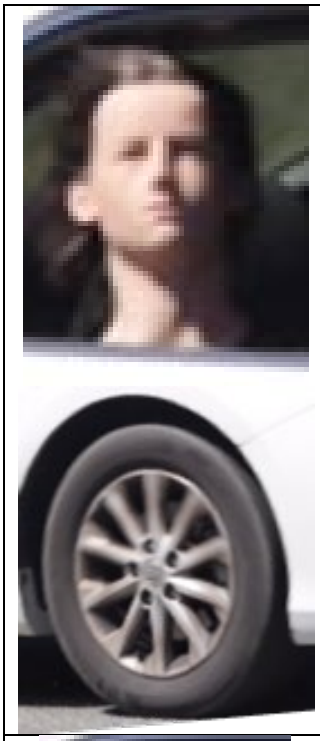
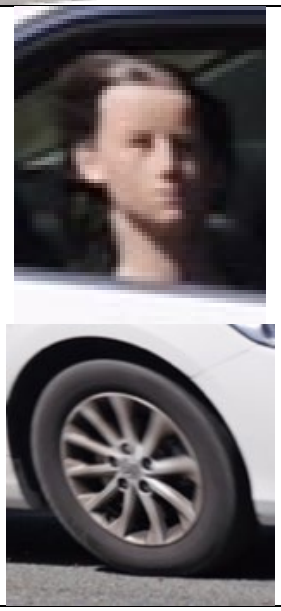
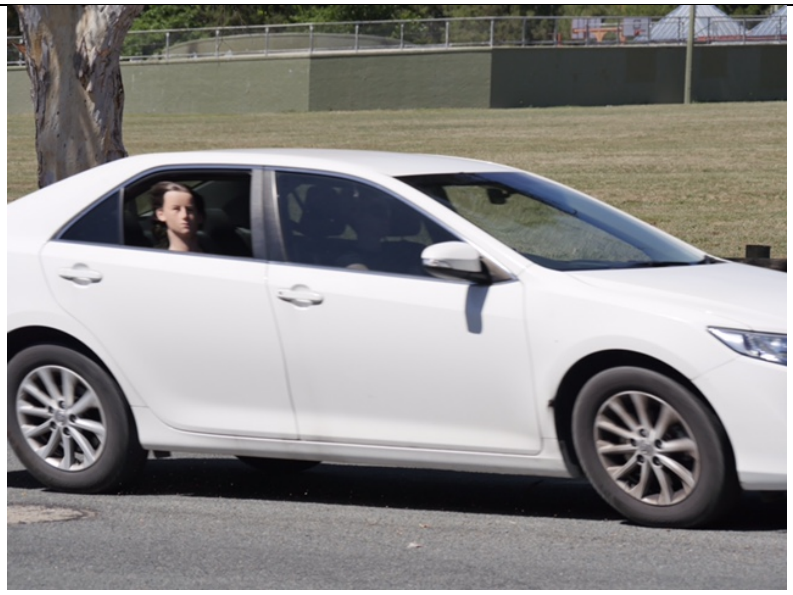
	
Purple/Magenta fringing at high contrast areas (above)	Extract of hair against background (above)

 	 
Magenta and Green Fringing (above)	Extract to highlight effect around hair edges (above)

A related effect when using a polarizer filter which appears as chromatic distortion of the image (above) (as a “rainbow” of colors) effect due to polarity of glass and film of a car window that is not visible without a polarizer.

6.1.8 **Rolling Shutter Effect** – can be observed as skewing or stretching of fast-moving objects in an image where the sensor captures images line by line. The effect also occurs when the capture device is moving quickly in relation to the subject. The result is an alteration in the appearance and shape of facial features, making them wider or longer, depending on the direction of motion.

- https://www.diyphotography.net/everything-you-wanted-to-know-about-rolling-shutter/
- https://petapixel.com/2017/06/30/rolling-shutter-effect-works/
- Sencar H.T., Memon, N., Digital Image Forensics, Springer, 2013, 3.3.8 Rolling Shutter, Pages 39-40.

	
	
First set of images (above) are undistorted baseline.	Second set of images (above) display distortion of shapes as upper parts are captured before the lower.

6.1.9 **Horizontal video misalignment / combing (interlacing)** is observed where subjects and objects in the image are positioned differently between alternating horizontal lines of a video image. This is due to the motion of the camera or subjects. Horizontal misalignment may make images appear blurred, limiting the identification of facial features. Horizontal misalignment impacts the accurate reproduction of facial features depending on capture resolution.

- Winkler, S., Van Den Branden, Lambrecht, C., Kunt, M., "Vision Models and Applications to Image and Video Processing," Chapter 10, Vision and Video Models and Applications, Springer, 2001.
- Damjanovski, V., CCTV, From Light to Pixels, Third Edition, Chapter 2, Light and television, Eye Persistence., Butterworth-Heinemann, 2014.

	
	
Baseline facial image (above) taken with phase alternating line (PAL) camera but no motion	Facial image (above) taken with PAL camera moving horizontally (introducing motion blur), with extract of right eye region to show interlacing / combing.

6.1.10 **Mirroring** can be observed as an image flipped horizontally. This can be the result of some camera configurations (like in 'selfies') or where the image captured is a reflection such as in a mirror or window. Reversed asymmetry, text, symbols, and facial mark positions are some indicators of a mirrored image.

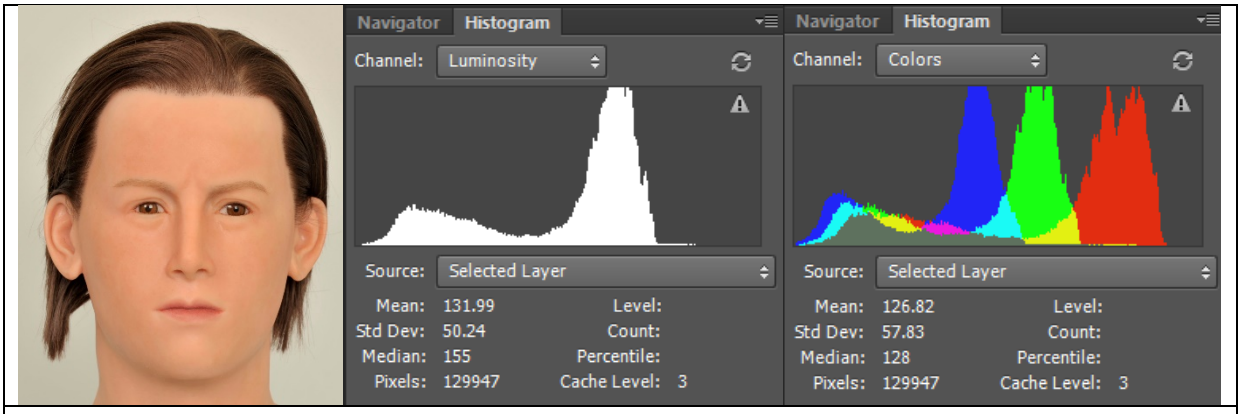
	
Reference image (above).	Reference image (above) has been flipped horizontally.

7. Lighting

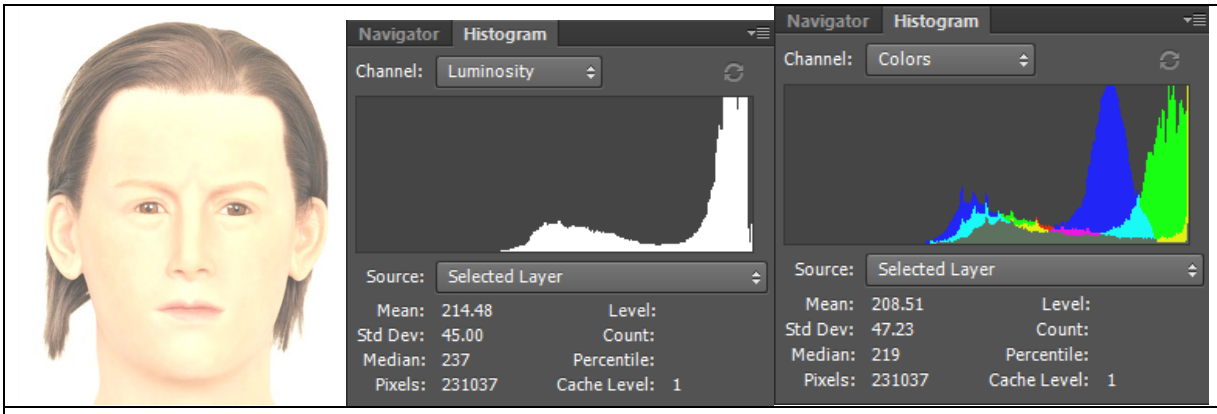
7.1 Lighting refers to the illumination of the subject and impacts the visibility, exposure, contrast, and colors of objects or subjects in images. For facial examinations any descriptions of lighting effects should focus on those lighting issues that negatively impact on the ability to distinguish facial features.

7.2 **Under or Over Exposure** can be observed as overly dark (shadows) or bright (highlights) areas that can affect the visibility of facial details. This may be the result of the camera settings or the available light at the time of capture. Use of image histograms can reveal under and over exposure distribution issues across the facial image.

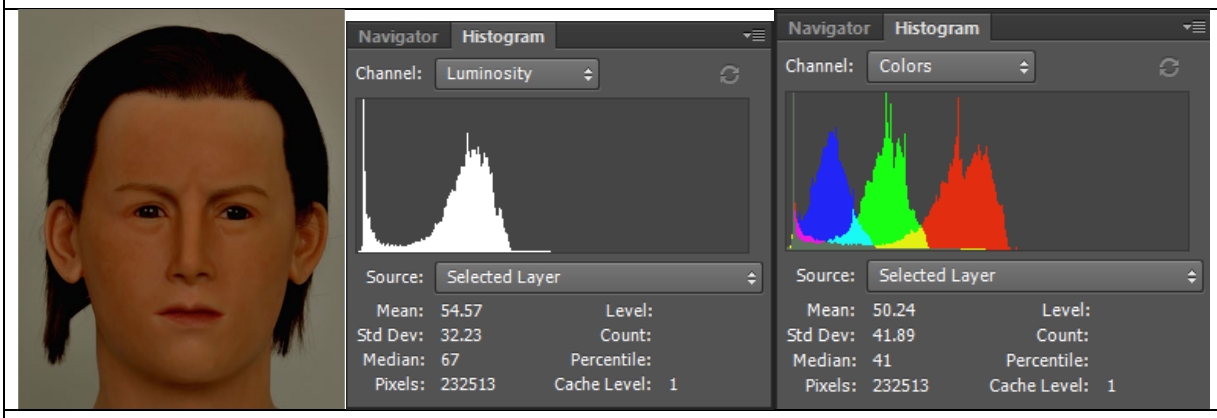
- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 12 Exposure and image control, Pages 227-241.
- McHugh, S, T,. Understanding Photography Volume 1 (Version 1.03), 2017, Cambridge in Colour, Image Histograms Pages 32-37.
- McHugh, S, T,. Understanding Photography Volume 1 (Version 1.03), 2017, Cambridge in Colour, Intro to Portrait Lighting Pages 144-151.



Reference image (above) – The broad histogram indicates higher contrast whilst the position of this histogram relates to a higher proportion of midtones.



Overexposed image (above)– This narrow histogram indicates that this image has a lower contrast than the native image. The position of the histogram toward the right correlates to a large proportion of highlights with visibly overexposed areas and clipping.



Underexposed image (above) – This narrow histogram reflects the low contrast in this image. The position of the histogram indicates a high proportion of shadows that are visibly apparent within the image.

7.3 **Lighting direction** may alter the appearance of the head in addition to the individual features within the face. The direction of the illumination source can impact both the sense of depth as well as the apparent size and shape of the individual facial features. It can also obscure some portions of the face.

- McHugh, S, T,. Understanding Photography Volume 1 (Version 1.03), 2017, Cambridge in Colour, Intro to Portrait Lighting Pages 144-151.

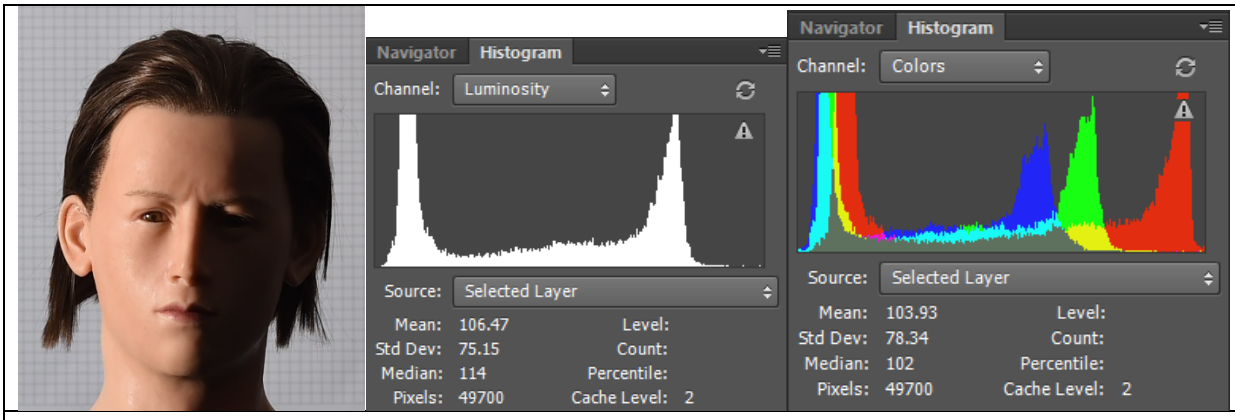


Image (above) shows direct lighting to the right side of the subject's face. The broad histogram indicates high contrast with peaks in the shadows. Highlights show a large proportion of light and dark pixels. Features on the left side of the subject's face are in shadow and almost invisible without some form of image enhancement.

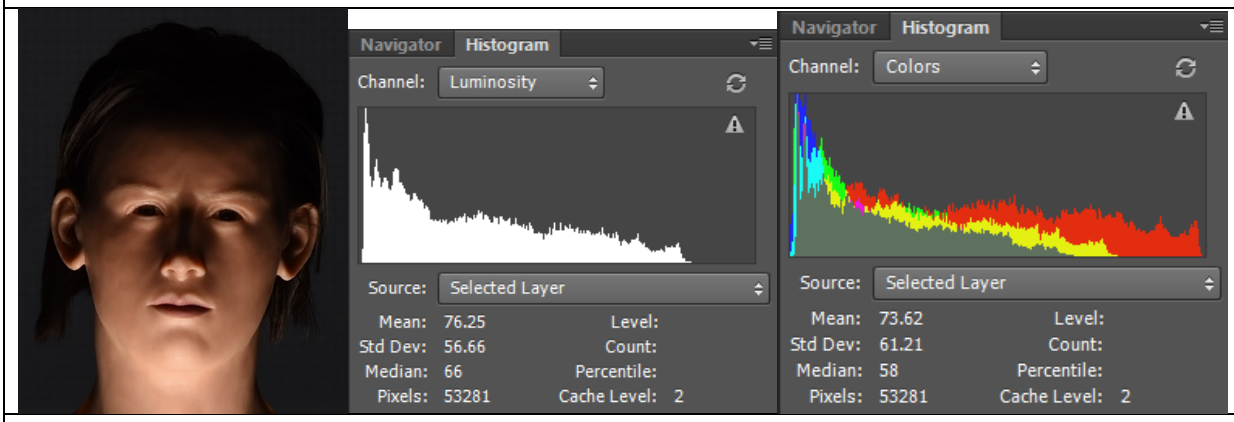


Image (above) shows illumination from below the subject. This is representative of a low-key histogram where most of the tones are in shadow. Contrast is high with the lower part of the face illuminated and the body of the nose and the top and sides of the forehead in shadow.

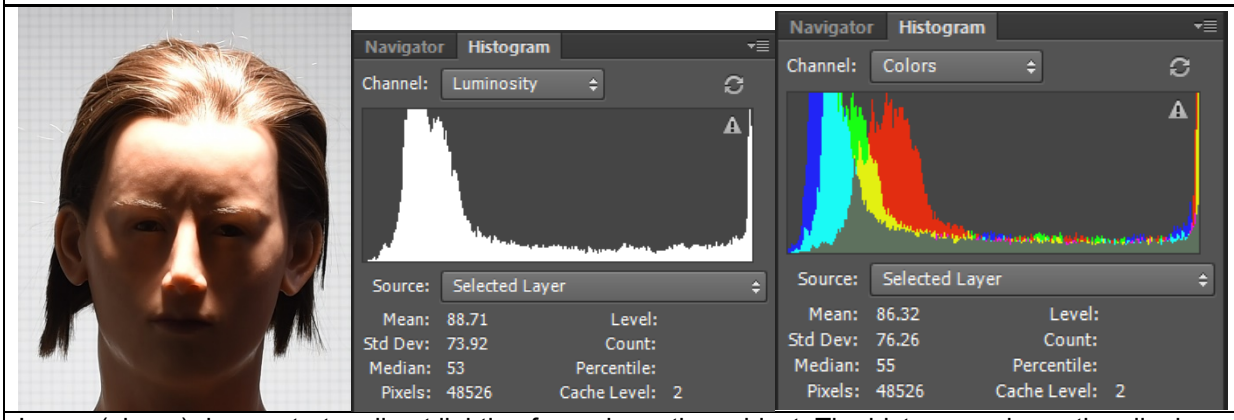


Image (above) demonstrates direct lighting from above the subject. The histogram shows the clipping of highlights and correlates to the loss of detail evident in the overexposed areas of the forehead and the nose. There are a high proportion of darker pixels visible as shadows in the image.

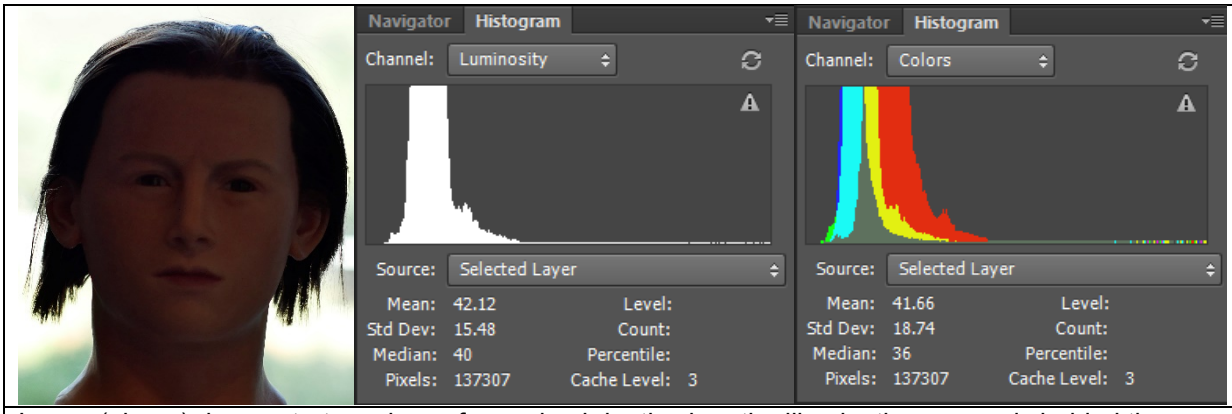


Image (above) demonstrates a loss of perceived depth when the illumination source is behind the subject. The narrow histogram represents low contrast, and the peak indicates a large proportion of darker pixels as is reflected in the image.

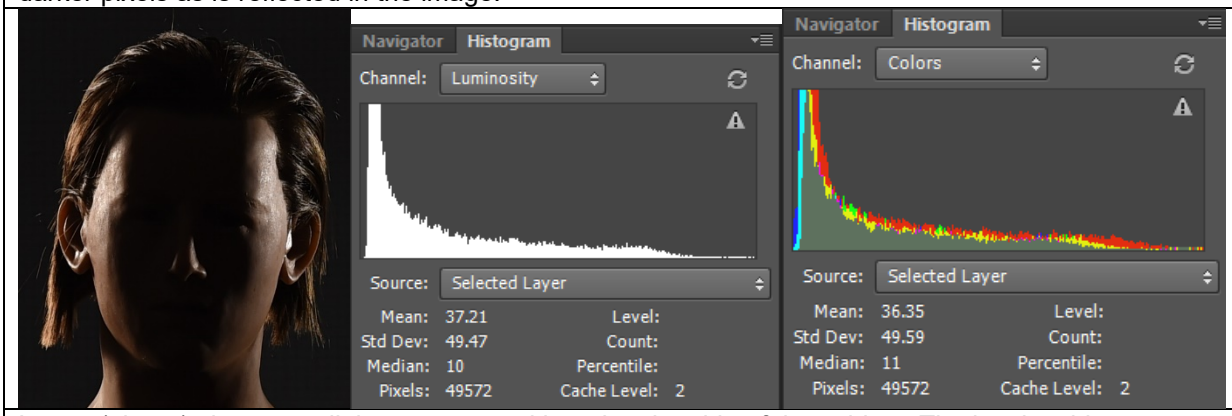
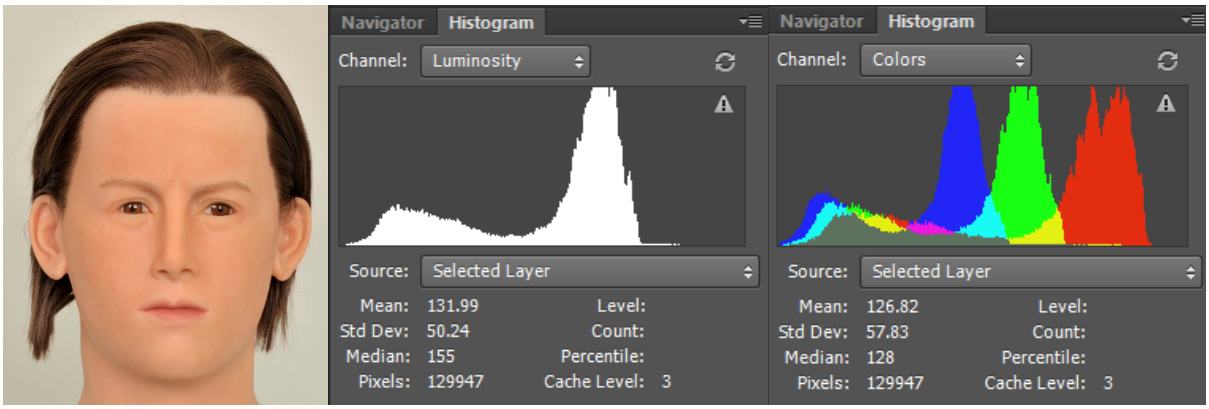


Image (above) shows two light sources positioned at the side of the subject. The low-key histogram shows that the majority of the tones are shadows. The sides of the face are illuminated however the central facial features are obscured by shadow.

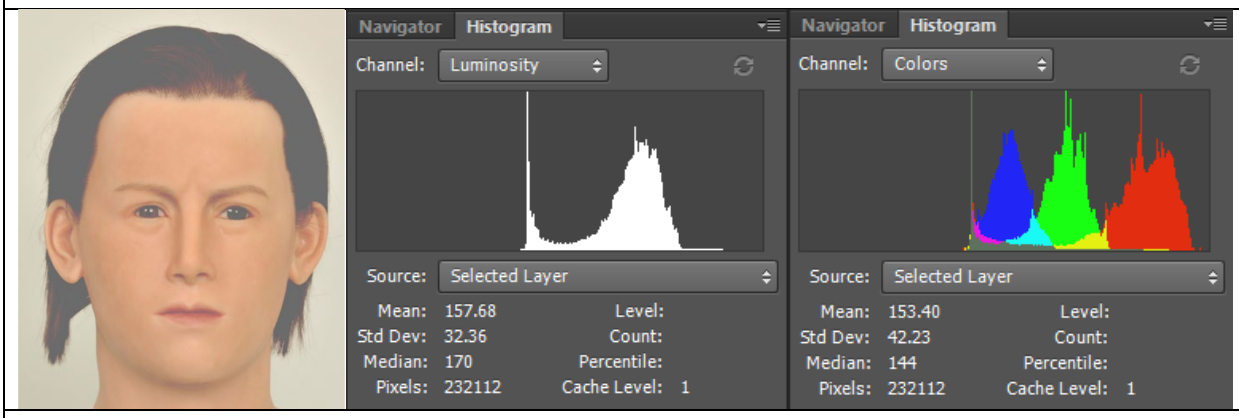
7.4 **Poor Contrast / Dynamic Range** can be observed as the limited distribution or separation of light and dark, which affects the resolution of facial details. This may be due to such factors as exposure, stray light in the lens, dynamic range of the sensor, artifacts, etc. Images with low bit depth and those subjected to lossy compression may also show reduced contrast. It is usually described in terms of the tonal ranges, as they appear to the human eye, and can be visualized in the image histogram.

- https://www.imatest.com/solutions/dynamic-range/
- https://www.imatest.com/solutions/artifacts/#compression
- https://www.cambridgeincolour.com/tutorials/histograms1.htm
- https://www.cambridgeincolour.com/tutorials/histograms2.htm
- McHugh, S, T,. Understanding Photography Volume 1 (Version 1.03), 2017, Cambridge in Colour, Image Histograms Pages 32-37.

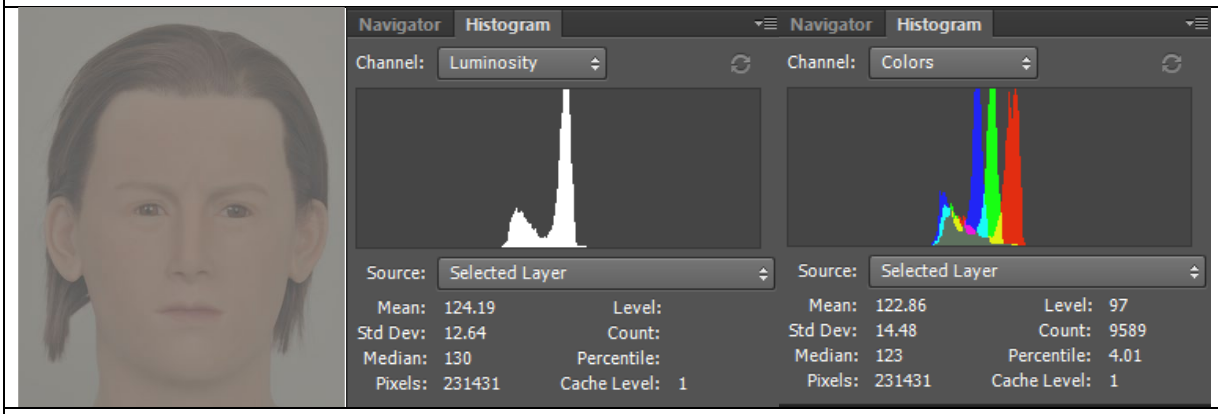
- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 12 Exposure and image control, Pages 227-241.



The reference image (above) demonstrates good tonal range as represented by a broad distribution in the luminosity histogram.



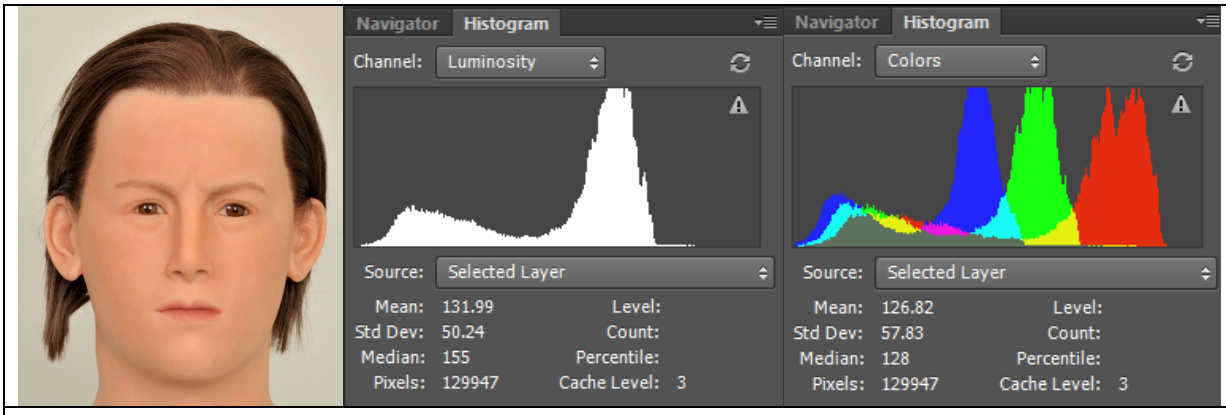
This image (above) shows a narrower tonal range situated predominantly in the midtones. The facial details are more difficult to discern due to a reduction in contrast.



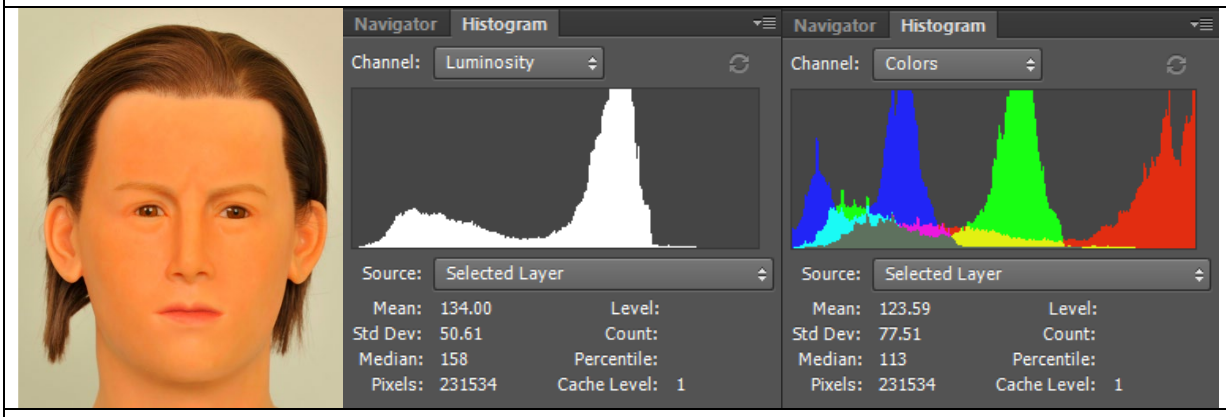
This image (above) has a very narrow tonal range as evidenced by the lack of contrast in the image. The facial features lack depth and the image appears ‘flat’.

7.5 **Color Misrepresentation** can be observed as a change in the actual color of subjects or objects depicted in an image. Large variations (color cast) in white balance and light temperature and color, wavelengths, camera settings including white balance, in-camera color processing, image format, and lens quality are just some possible causes. Filters, including polarizers, as well as protective glass coatings can also saturate and cause color tints. It is for this reason that contrast and tone are more reliable than color for facial comparisons.

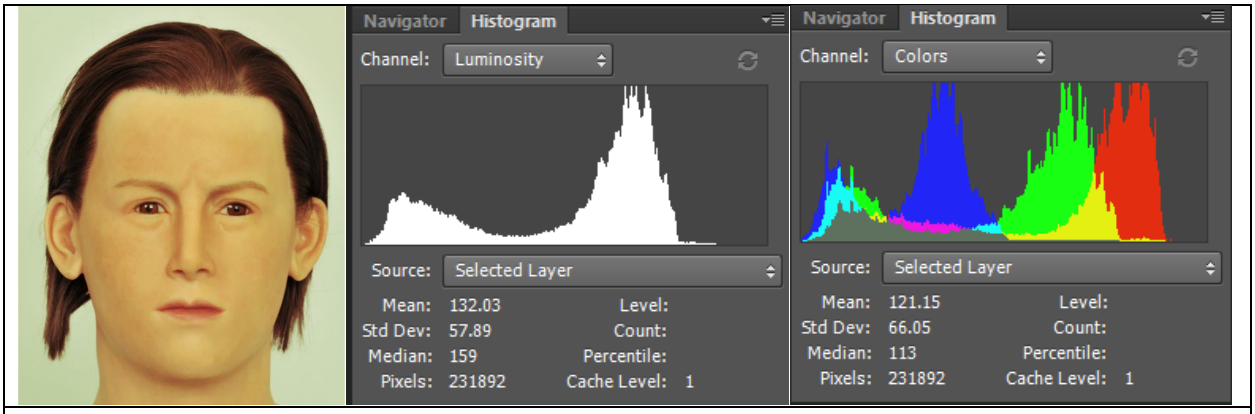
- https://www.dxomark.com/glossary/vignetting/
- https://www.imatest.com/solutions/color/
- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 5 Introduction to colour science, Pages 94-97.
- McHugh, S, T,. Understanding Photography Volume 1 (Version 1.0), 2016, Cambridge in Colour, Polarizing Filters Pages 110-117.



Reference image (above) which is a true to life representation of the subject's true color as it appears to the human observer.



The color histogram shows a shift in the intensity of the reds with clipping occurring as they reach a maximum of 255. This shift is visible in the image (above) which appears saturated in comparison with the reference image.



A shift to the left has occurred with a reduction in the intensity of the blues and greens which leaves the image (above) with a yellowish/greenish hue.

8. Near Infrared (IR)

8.1 Images from night vision enabled devices are mostly observed as shades of gray. Sometimes the intensities are represented as “pseudo colors” to improve detail discernment, for example those ranging from blue to red instead of dark to light shades of gray. For faces the intensity of the captured light can be quite different from the human perception of the visible light, with skin tones and hair color appearing different from the tones and colors perceived in only visible light. IR illumination on human flesh can make textures appear smoother and make surface marks and skin tone lighten or even disappear, whilst veins may become darker and more visible. Clothing can also appear very different in terms of shades and colors from the visible spectrum, and some pigments may not be visible at all. Eyes can appear light, reflective, or go dark depending on the wavelength of the IR light and the strength of the light. All these changes are due to the camera’s sensitivity to wavelengths outside the range of those visible to the human eye.

8.2 For facial comparisons you may see images captured within the visible and non-visible light spectrum (e.g., night vision goggles). A mixture of visible and infrared imagery is characterized by color shifts and false colors (meaning one color becomes another e.g., red becomes white).

- Kruegle, H., CCTV Surveillance: Video Practices and Technology, 356-357, Butterworth-Heinemann, 1995.
- Ghiass, R.S., Arandjelovic, O., Bendada, A., & Maldague, X.P. *Infrared face recognition: A comprehensive review of methodologies and databases*. https://arxiv.org/abs/1401.8261, 2014.
- Rand, K., *Infrared Light - Seeing What You Can't See*, https://www.physicscentral.com/explore/action/infraredlight.cfm, 2013.

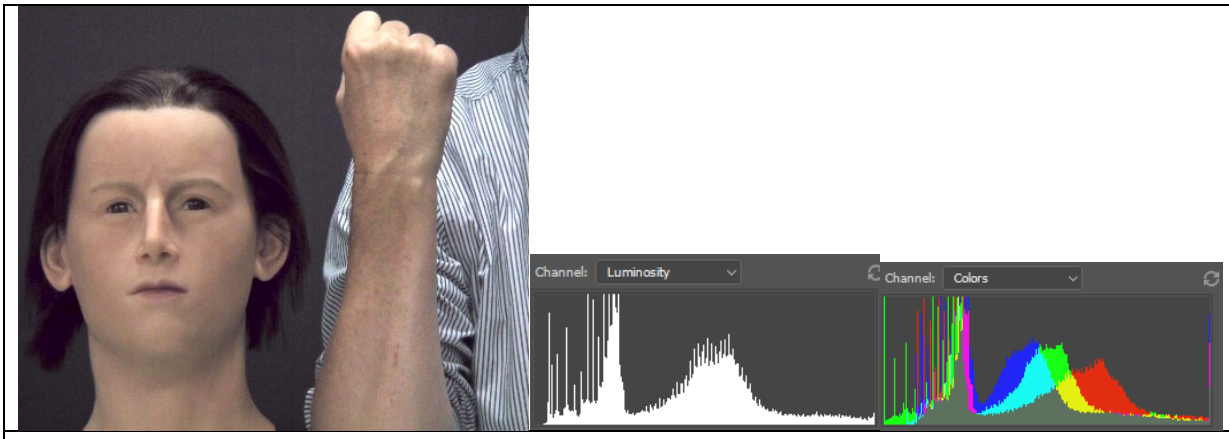


Image (above) captured using an IR capable video surveillance camera under lights with IR off.

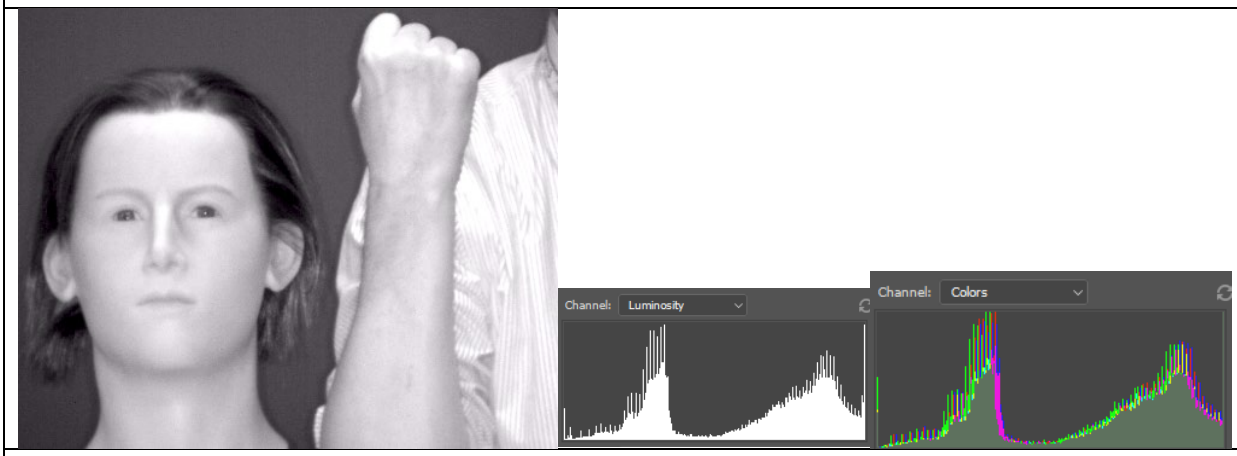


Image (above) captured using an IR capable video surveillance camera under lights with IR on. Note: on the arm (not the mannequin head) in gray scale view skin tone becomes lighter, marks become less visible, and veins become more visible.

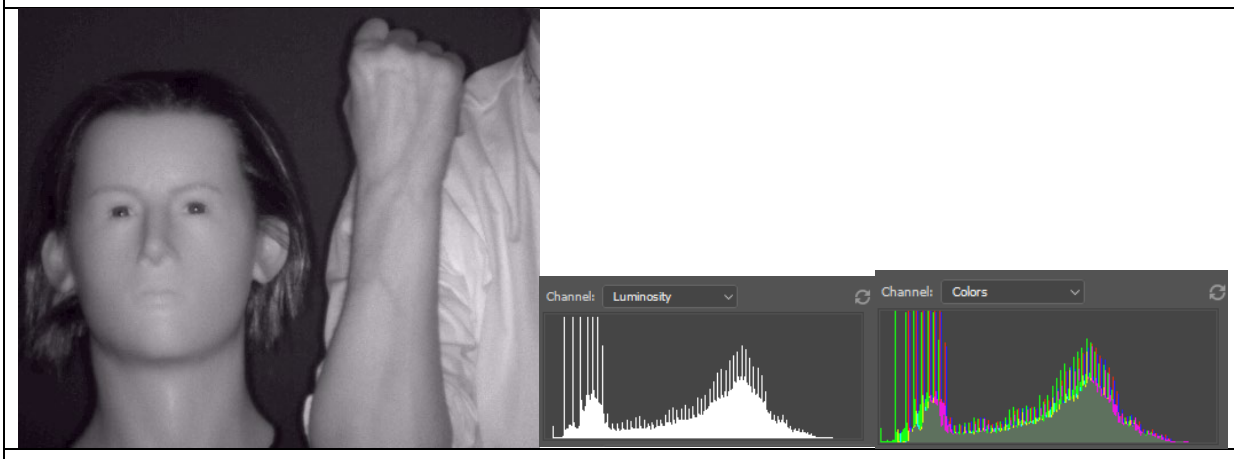


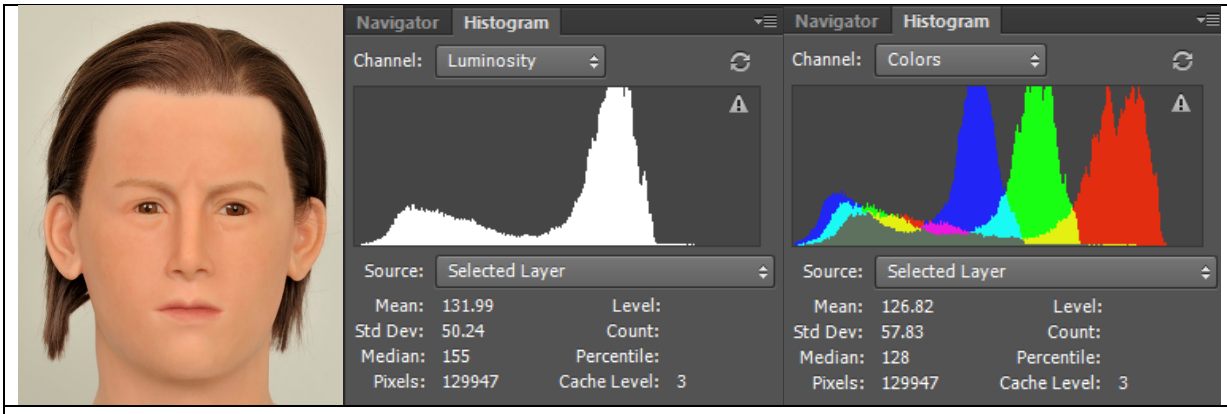
Image (above) captured using an IR capable video surveillance camera in dark with IR on. On the arm in gray scale view skin tone is leaves no marks and skin appears smoother, veins become clearly visible, and shirt stripes are no longer visible.

9. Noise

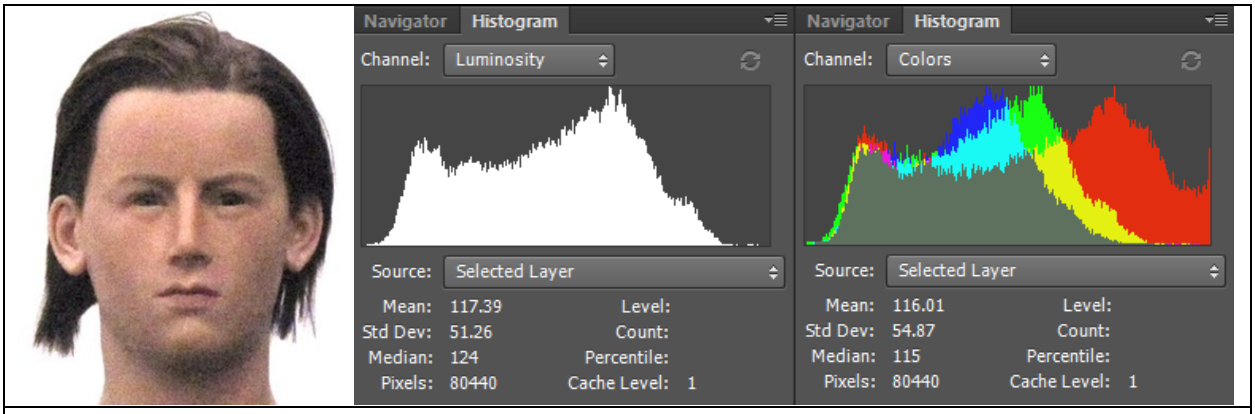
9.1 Noise can be observed as fixed, random and semi-random spots, shapes or patterns.

9.2 Noise can occur as a result of random variations in luminous flux (photonic noise), random signals generated by the sensor in response to temperature (thermal noise) or charge transfer issues (transfer process noise). The image is not representative of the original signal from a subject and can be heavily affected by lighting conditions, the camera type and settings. Noise can introduce apparent marks on the face where they do not exist or obscure marks that do exist. The effect on facial features will be relative to the size of the subjects face within the frame.

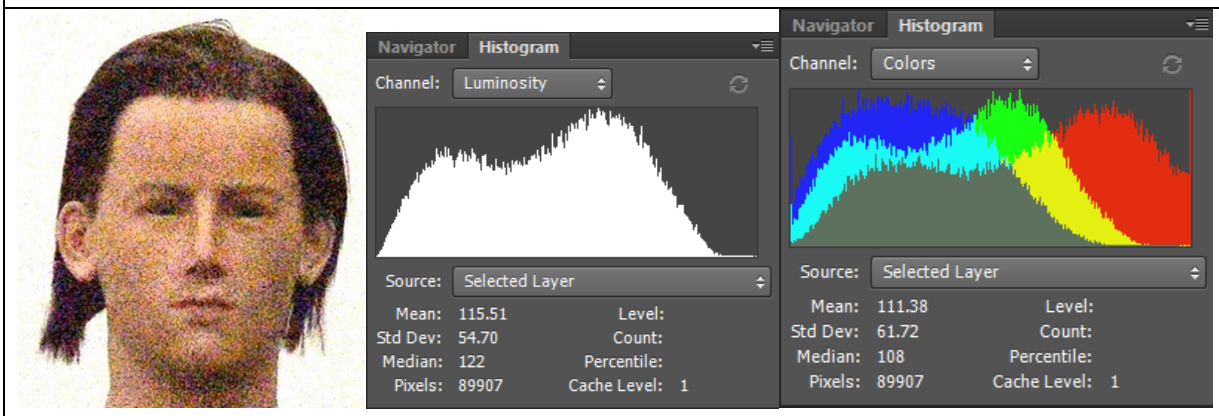
- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 24 Noise, sharpness, resolution and information, Pages 433-451.
- Blitzer, H,. Stein-Ferguson, K,. Huang, J, Understanding Forensic Digital Imaging, Elsevier 2008
- McHugh, S, T,. Understanding Photography Volume 1 (Version 1.03), 2017, Cambridge in Colour, Image Noise Pages 38-43
- Langford M. Bilissi, E., Langford's Advanced Photography 8th Edition, Focal Press, 2011, Chapter 6 Image Sensors, pages 162-167.
- https://www.imatest.com/docs/noise/
- https://www.imatest.com/solutions/noise/
- https://www.dxomark.com/glossary/noise/
- https://www.cambridgeincolour.com/tutorials/image-noise.htm
- https://www.cambridgeincolour.com/tutorials/image-noise-2.htm



Reference image (above) with little visible noise.



The histograms relating to this image show an increase in the pixel count in comparison to the reference image demonstrating the introduction of false data.

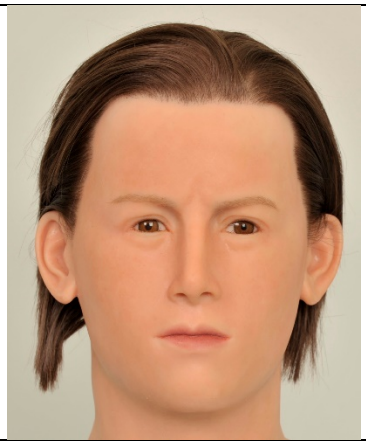


This image (above) presents with a high amount of visible noise. The tonal range and pixel count has increased in comparison to the reference image with the introduction of false data.

10. Obstructions

10.1 Obstructions can be observed as a total or partial physical obscuration of facial features. Obstructions can be solid or semi-transparent and include but are not limited to, hats, dirty optics, sensor faults, smoke, glasses, masks, hair, hands, makeup, and other people.

- Savazzi, E,. Digital Photography for Science, 2011, Chapter 2, Page 149.
- https://photographylife.com/dead-vs-stuck-vs-hot-pixels
- https://www.imatest.com/docs/iqfactors/#blemish

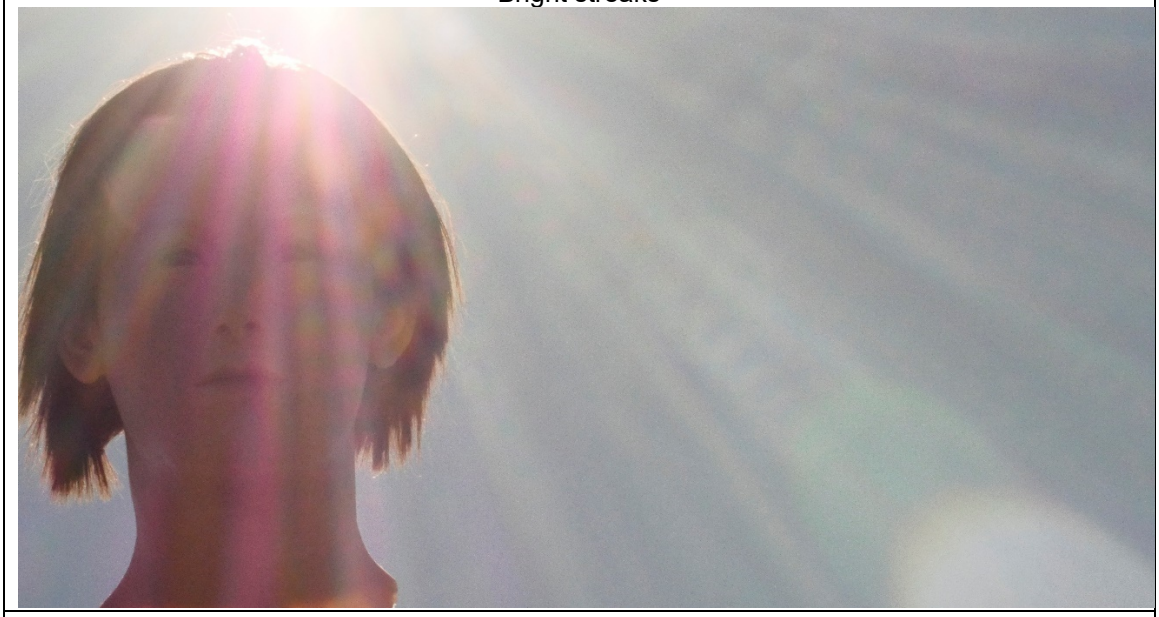
	
By glasses	Reflections
	
Obstruction by hat	Reference Image

10.2 **Lens Flare (Veiling Glare / Ghosting / Sensor Flare)** can be observed as haze, bright streaks, orbs or polygonal bright regions within an image as a result of a bright light source. It refers to the “stray” light in the optical system caused by internal reflection and scattering from imperfections in the lens (including sensor micro lenses), dust/dirt, filters, the sensor and the diaphragm.

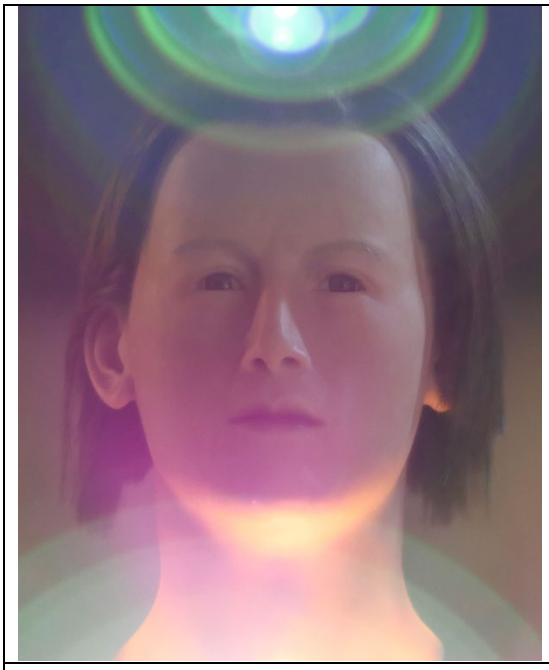
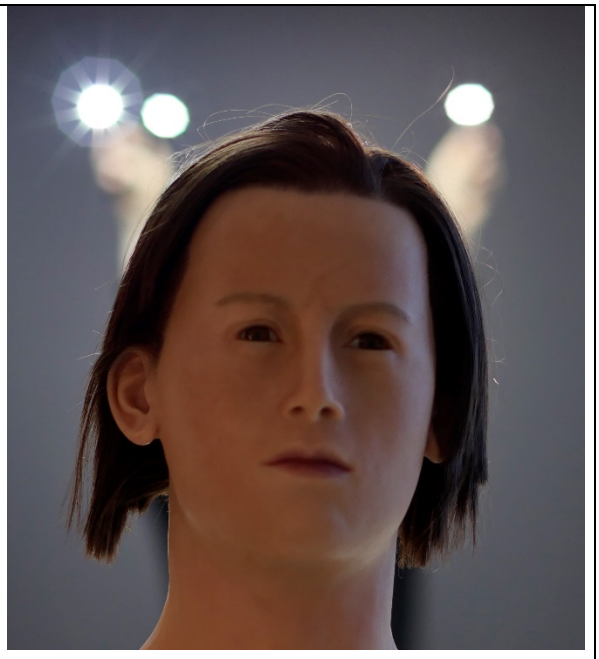
10.3 The result of lens flare can be observed as artifacts within the image obscuring detail or a haze that reduces the contrast and color saturation.

- https://www.imatest.com/docs/veilingglare/
- Lens Characteristics: Flare, Ghosting and Aberration, Digital Camera Online Lessons, https://av.jpn.support.panasonic.com/support/global/cs/dsc/knowhow/knowhow15.html, Panasonic, 2014.
- https://photographylife.com/what-is-ghosting-and-flare/
- Reddy, D,. Verarghavan, A, Computer Vision, A Reference Guide, 2016, Lens Flare and Lens Glare, Pages 445-447.
- Savazzi, E,. Digital Photography for Science, 2011, Chapter 2, Page 150-151.

Bright streaks

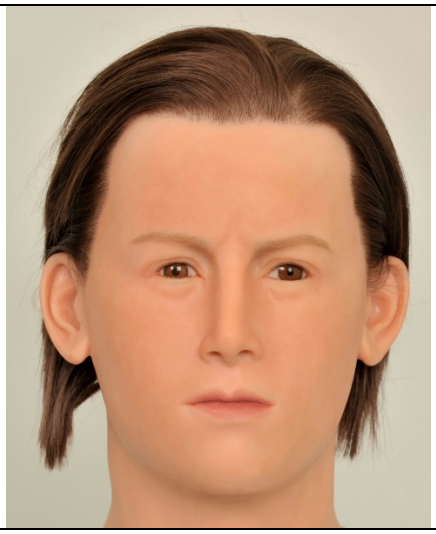
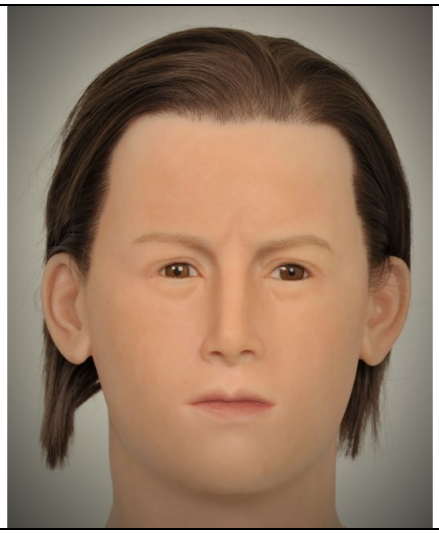


This image (above) demonstrates lens flare with visible bright streaks of light and an example of ghosting in the lower right of the image where the light repeatedly reflects off the surface of the lens.

	
This image (above) demonstrates visible chromatic aberration due to lens flare that has occurred adjacent to the bright light sources.	This image (above) demonstrates ghosting with the reflections occurring in front and behind the lens aperture resulting in polygonal shapes that are representative of the shape of aperture.

10.4 **Vignetting (light fall off)** can be observed as a reduction in brightness and contrast towards the edges of an image. Vignetting can be caused by objects physically blocking light for example lens hoods, or by elements of the lens and camera. Vignetting rarely affects facial images unless the subject is positioned in the periphery of the frame, however, it can reduce the dynamic range in the affected areas limiting the ability to resolve detail. Vignetting is also an indicator that the lens is not set at its sharpest optimal aperture.

- https://www.cambridgeincolour.com/tutorials/lens-corrections.htm
- https://www.imatest.com/solutions/uniformity/
- https://www.dxomark.com/glossary/vignetting/

	
Reference image (above) which shows an even distribution of light at the periphery of the image.	This image (above) demonstrates the light fall off at the edges associated with vignetting.

11. Pose

11.1 Pose is the “orientation of the face with respect to the camera, consisting of pitch, roll, and yaw” (ASTM E2916). An optimal frontal pose may be considered as 0° in all directions. ISO/IEC SC37 19794-5 defines how to refer to changes in pitch, roll, and yaw as positive (+) or negative (-) angles. Variations to the optimal pose can be due to the position of a subject who can move freely during the capture process, or misalignment of the camera. As images are a two-dimensional representation of the three-dimensional world, the pose of a subject has a major influence on the image in terms of the appearance and relative position of facial features. Changes in roll do not change the appearance of features of the face. Changes in pitch and yaw can affect the apparent relationship of facial features to each other as well the appearance of their size and shape.

- ISO/IEC SC37 19794-5 Biometric data interchange formats
- ASTM E2916 Terminology for Digital and Multimedia Evidence Examination
- ANSI-NIST ITL 1-2011 Update:2015, Data Format for the Interchange of Fingerprint, Facial & Other Biometric Information

This series (above) is an example of how the shape and relative positions of the facial features change through a range from a yaw of zero degrees (frontal) to a negative yaw of 90 degrees (profile, looking to the subject's left).

This series (above) represents a gradual change in pitch in both the negative (looking up) and the positive (looking down).

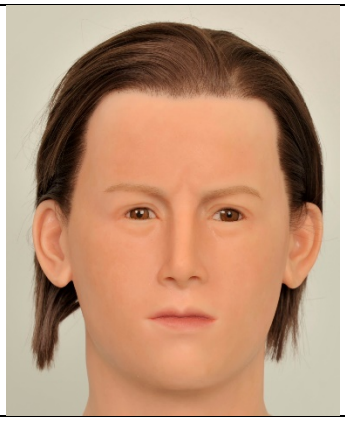
12. Sharpness

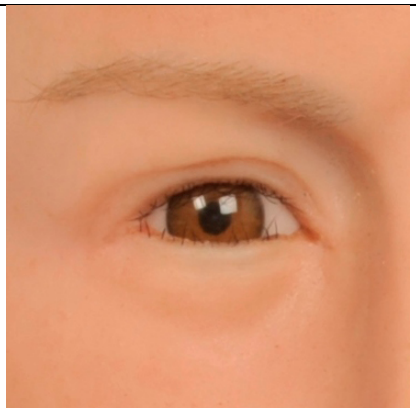
12.1 Sharpness can be observed as the overall clarity and detail of the facial features. Poor sharpness in an image can be due to many factors including lens quality/construction, sensor/processing performance, incorrect focal point, limited depth of field, lens/aperture settings, different types of filters, and camera/subject motion.

12.2 Poor sharpness can be determined through analysis of the edges and contrast between adjacent pixels of the image. Sharpness impacts the accurate reproduction of facial features irrespective of capture resolution although resolution has a real impact on sharpness of facial features. Poor sharpness may make images appear blurred limiting the identification of facial features.

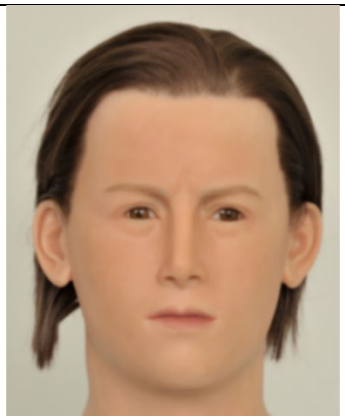
- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 10 Camera lenses, Pages 178-179.
- https://www.cambridgeincolour.com/tutorials/lens-quality-mtf-resolution.htm
- https://av.jpn.support.panasonic.com/support/global/cs/dsc/knowhow/knowhow14.html and https://av.jpn.support.panasonic.com/support/global/cs/dsc/knowhow/knowhow15.html
- Bailey, M., Sharp Shooter, Proven Techniques for Sharper Photos, Craft & Vision 2013.
- Blitzer, H,. Stein-Ferguson, K,. Huang, J, Understanding Forensic Digital Imaging, Elsevier 2008, Pages 55-57.
- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 10 Camera lenses Pages 177-178.

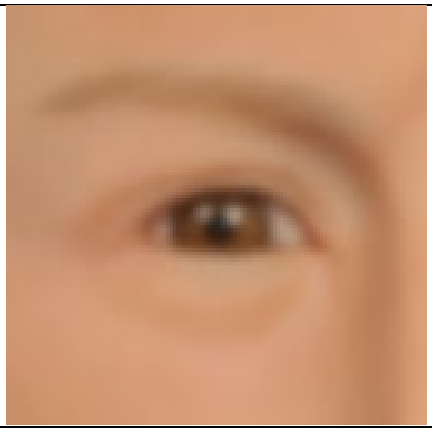
- https://www.imatest.com/docs/sharpness/
- https://www.dxomark.com/glossary/mtf-2/
- https://www.cambridgeincolour.com/tutorials/image-interpolation.htm



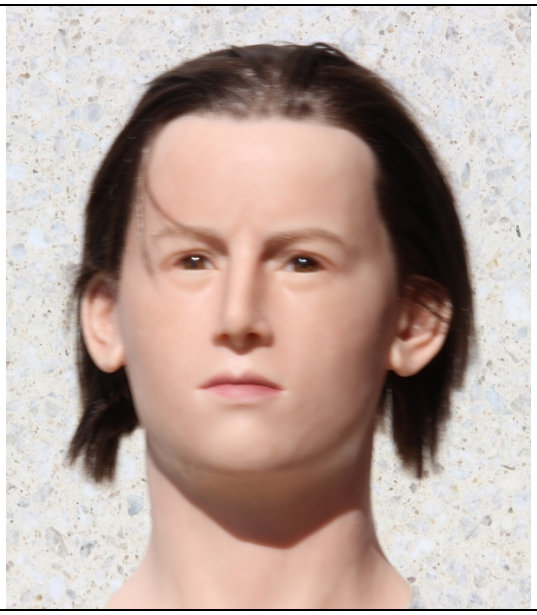


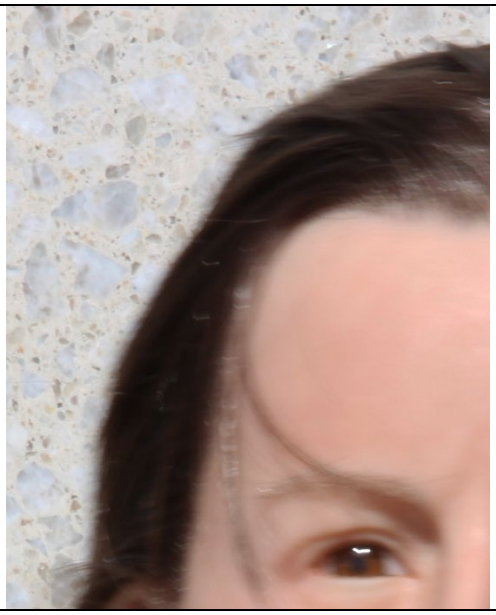
Reference image (above) and a close crop of the eye region showing visibility of fine detail including individual hairs.





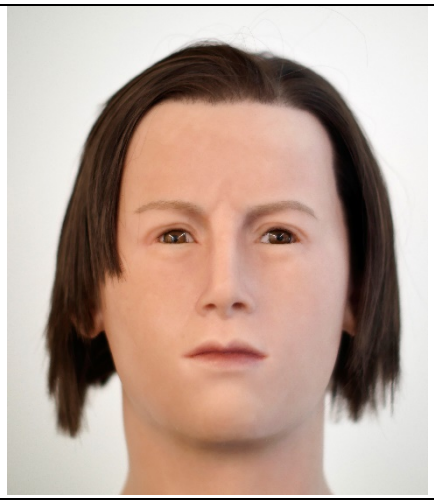
This image (above) lacks sharpness and the close up shows a reduction in contrast and clarity in comparison to the reference image. While the features are visible the fine detail is unresolvable.

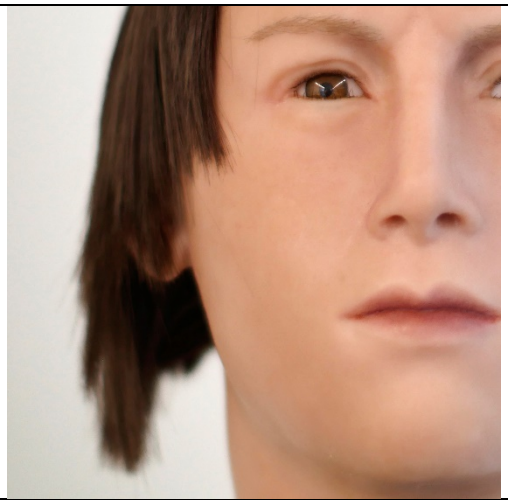




This image (above) demonstrates how motion blur affects sharpness. The close crop shows the movement of the subject discernible by the sharp background, causing blurring of the facial features.

This reference image (above) has a depth of field that allows for all of the features of the subject to remain in focus. The crop shows that features in the foreground such as the nose are in focus as well as the fine hairs behind the subject.





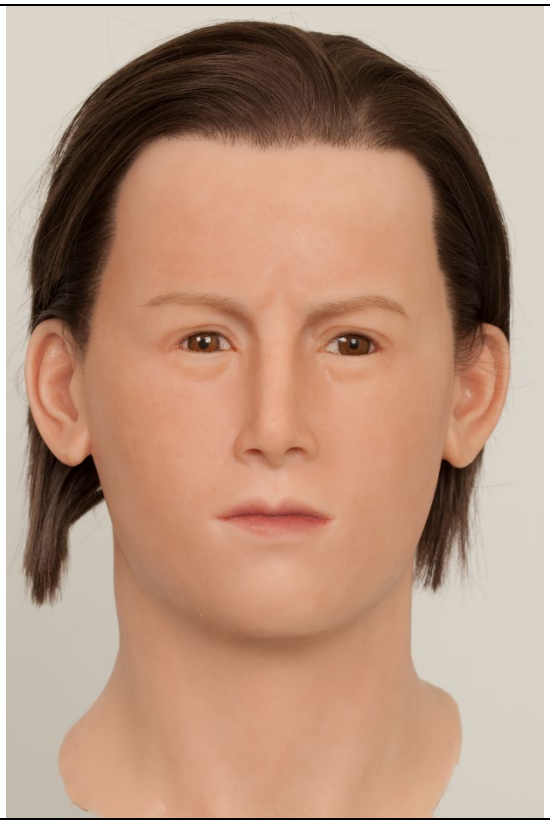
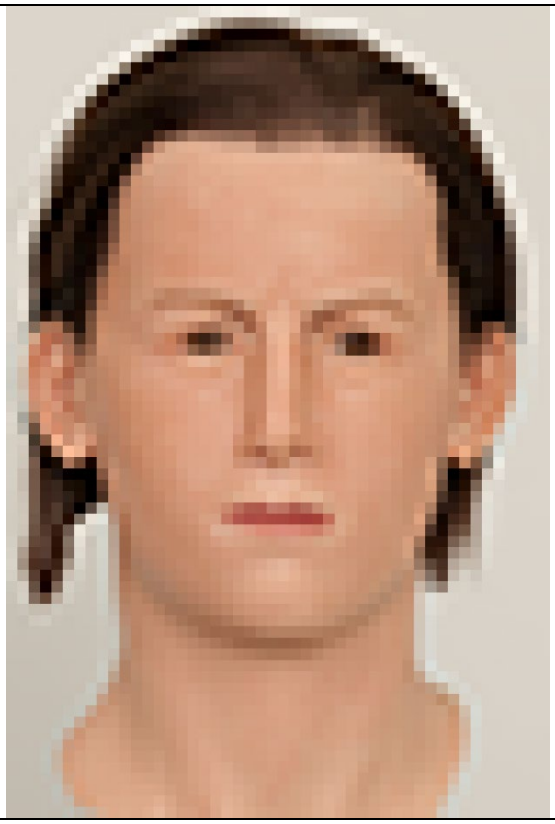
This image (above) has a shallow depth of field. While fine detail is resolvable in features in the foreground, the background has a lack of sharpness and appears blurry.

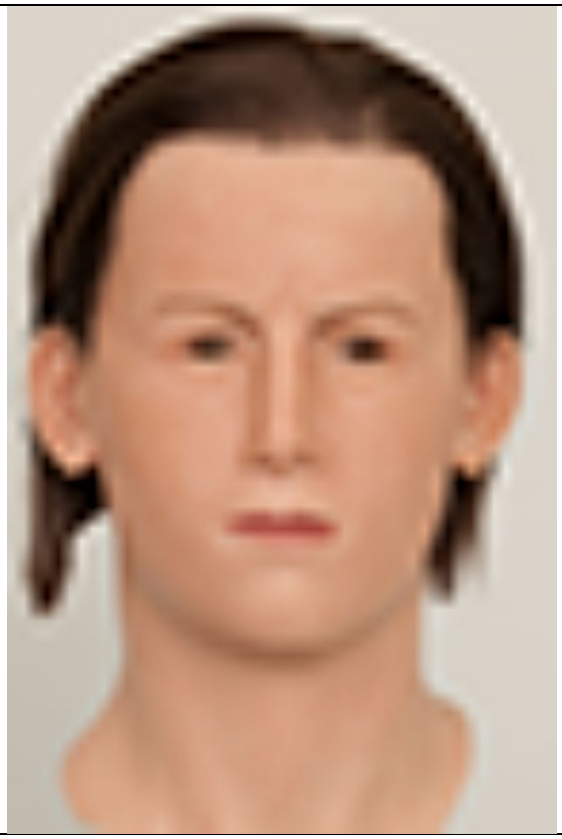
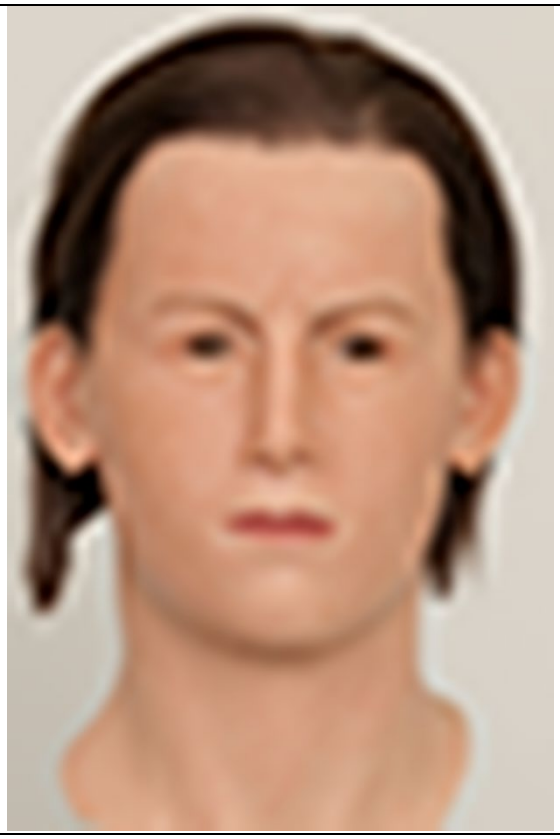
13. Resolution (Spatial)

13.1 **Resolution** can be observed as the finest level of distinguishable facial detail (spatial resolution) recorded in an image. A facial image may have a high pixel count but poorly resolved facial features. This can be due to low resolution, resampling from low resolution (interpolation), diffraction effects due to the lens and aperture used, exposure, or artifacts. Measuring the interpupillary distance (IPD) can assist in assessing the maximum effective spatial resolution of a facial image. This is commonly called pixelization and usually has issues of sampling artifacts, such as jaggies. Many cameras with digital zoom and image programs will use different techniques of interpolation to allow images to be viewed larger, with different results for each technique applied (see examples below), but adding pixels does not improve true resolution and images usually appear to be less sharp or blurred.

- Blitzer, H,. Stein-Ferguson, K,. Huang, J, Understanding Forensic Digital Imaging, Elsevier 2008, Pages 54-57.
- Langford M. Bilissi, E., Langford's Advanced Photography 8th Edition, Focal Press, 2011, Chapter 9 Choosing Lenses, pages 68-69.
- Allen, E., Trinataphillidou, S., The Manual of Photography, Tenth Edition, Focal Press, 2011, Chapter 24 Noise, sharpness, resolution and information, Pages 443-451.
- Savazzi, E,. Digital Photography for Science, 2011, Chapter 2, Pages 95-105.
- https://www.cambridgeincolour.com/tutorials/diffraction-photography.htm
- https://www.cambridgeincolour.com/tutorials/image-interpolation.htm
- https://www.dxomark.com/glossary/mtf-2/

- https://www.imatest.com/solutions/iso-12233/

	
(1565x1921 pixels) Reference image (above)	(74x48 pixels) Enlargement – Nearest neighbor

	
(72x48 pixels) Enlargement – Bilinear (near)	(72x48 pixels) Enlargement – Bicubic smoothing
This image set demonstrates three methods of enlargement. The reference was saved down to 72 x 48 pixels and then enlarged using nearest neighbor, bilinear and bicubic interpolation methods.	

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https://the-digital-picture.com

Museum mannequin head on loan from the Defence Science Technology Group (DTSG), Department of Defence, Australia.

Photography undertaken by the Facial Identification Team, Forensics, Specialist Operations, Australian Federal Police.

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