CRIME SCENE DOCUMENTATION- IPHONE VERSUS THE NIKON D5600

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Abstract

A picture is worth a thousand words because of its power and influence. They are an unbiased representation of fact and why crime scenes are documented with powerful cameras like the Nikon Digital Single-Lens Reflex. Modern smartphone technology provides us with an alternative. This study compares an iPhone XS Max to a Nikon D5600 to accurately depict a crime scene. This study compares each camera's mechanisms and judges the quality of their exposures through sharpness, resolution, and acutance. Standards of measurements to eliminate prejudice include four components: an anonymous popular vote, histogram measurements, particle analysis, and distance analysis, which is evaluated through the post-processing software of Image J. These cameras have several juxtaposing features, such as the size of the iPhone's flash, and the iPhone's fixed F1.8 lens and the DSLR F5-F32 range capability. The iPhone is equally limited with 12 megapixels compared to the Nikon's 24.2. These differences mean the iPhone will lose image quality with zoom and limits its ability for post-image magnification. An anonymous vote of more than 50 individuals revealed the iPhone image was 60% more popular, and statistical analysis revealed no significant difference between the popular vote and the most accurate camera. Histogram measurements revealed the standard deviation and average red, green and blue values significantly differed under abnormal lighting conditions but were comparative under normal lighting. Particle analysis and distance analysis through Image J software revealed no statically significant results. They indicated that the iPhone was comparable to the Nikon D5600 but at a much lower pixel value. The iPhone produced some remarkable images in this study and showed an excellent ability to capture data without distortion under normal lighting. However, during low light conditions, it failed to depict a crime scene

accurately. This study's results do not indicate this model iPhone should replace the DSLR, but newer iPhone models have potential as technology evolves.

Introduction

Pictures began as a written language thousands of years ago and developed over the centuries to better visualize a story or concepts. Dating as far back as 17,000 years, some of those stories were told through prehistoric artwork discovered in the Lascaux Caves (Groeneveld, E., 2016). These various depictions give an incredible insight into their lives, what was important to them, and their culture. Humanity mastered the art of pictures through portraits, illustrations, and abstract art, telling their stories that survived hundreds of years, giving modern society a better understanding of the past. Fast forward to the 19th century, and another historical event occurred; the camera's invention in 1816 by Nicephore Niepce (Jade, 2019). The groundbreaking discovery quickly gained recognition and spread throughout the world, opening photography studios in New York City as early as 1840 (Photography's early evolution, 2020). Cameras were originally bulky, time-consuming, and impractical for mobile use until around the early 20th century where the application of crime scene documentation and photography finally meet. (Barnes, S, 2017.) Some of the first photos taken to document murder scenes provide an incredible visualization of what investigators saw. A narrative verbally told to a courtroom jury could result in 12 different visualizations of facts, whereas a picture leaves no room for imagination or misinterpretation. This is why crime scenes documented with photography is such a powerful tool if used correctly. No longer would the jury have to rely on a story told to them by lawyers. Now, the power was in their hands. Their understanding of the events improved, and their ability to render fair sentences increased. This is why a picture is worth a thousand words, and this is why crime scene documentation needs to take the next step with technology and integrate the smartphone camera technology.

One of the greatest challenges young field Agents face is their ability to expose quality crime scene and evidence comparison photographs. This isn't from a lack of training; agencies take numerous hours of photography classes, Advanced Crime Scene Photography, and specialized training. Even with these courses provided, the results still vary in quality and relevance. One of the four faults of crime scene documentation in a study of crime scene scanning was incomplete photographic documentation (Marcin, 2017). This systemic problem can be addressed and adjusted by studying this research project in the Digital Single Lens Reflex Camera versus the iPhone Camera.

There is much work to do at the crime scene. One of the more monotonous tasks is photography. Regardless of the type of scene, this process is the same- exterior, interior, and close-up photographs with and without scale. Many photographs captured at the scene could look great on the camera, but when magnified on a computer screen, the picture focus might be wrong, the perspective is incorrect, or the depth of field is not accurate. There are no second chances at capturing most of the images, especially those at the crime scene. This problem will perpetuate if photographic processing continues the same way. Agents waste time at a crime scene, spending excessive time with a DSLR camera and tripod attempting to capture less relevant photographs while using the camera's manual mode. Agents are instructed to mount the camera on a sturdy tripod for examination-quality photographs (Rolph, 2006), which takes more time, which could otherwise be limited. Some departments even limit their photographs to be exclusively captured with manual mode, leaving automatic mode unauthorized. These Departments spend thousands of dollars on a camera featuring the latest automatic technology only to limit the camera's exposure by not allowing it to use that technology and capture images on its own.

The problem is the camera. FBI Field Agents can be as young as 23 (How old, 2016). Since cell phone cameras have been around for 20 years, these field agents have more than likely used cell phone cameras their whole lives. They grow up knowing how to use them. They understand the 'selfie' and are good at quickly adapting to the latest technology released with smartphones. The foreign object is the big chunky DSLR Cameras. They are used to iPhone cameras, smartphone cameras, cameras small enough that fit in your hand. Touch operated devices that upload data immediately to a cloud. This same technology of smartphone cameras could be in the hands of field agents to document crime scenes. Further, the cloud storage could be replaced with a link to the ECMX system, where the photographs were immediately imported and integrated into a documented system. I believe this would improve our photographs and increase the ability to capture minute comparison points for evidence yielding more conclusive results. This will not only save these Agents time on the scene, but it will save departments money by switching cameras. Most departments have duty phones that are smartphones. That means everyone already has their own. No additional equipment is necessary. No special purchases, no SD cards and CDs for storage, no more dead camera batteries. This would significantly impact the forensic community and give confidence to Agents conducting this portion of documentation. The results would remove the DSLR from the Outer and Midrange photos and use their Duty iPhone to execute those photographs instead. This analysis will determine that for the intermittent photo range, the iPhone performs just as well as the DSLR and will have no problem utilized as original evidence. After an overview of the capabilities of each device, this analysis will conclude with a photographic comparison that will get down to the basics in various conditions, lighting and see if the results are valid enough to prove to the field of forensics that the iPhone camera is ready for crime scene documentation. This technology already exists, and this study will show the iPhone camera is ready to meet the challenge.

Research, Objectives, Hypotheses

To say that Cameras and technology have grown over the years would be an understatement. From the invention of cameras around 200 years ago, the industry saw the most advancements in the last 40 years. Cameras went from wet film to Digital Cameras and got smarter are faster each year. The digital camera (recording and storing digital images) was invented in 1975 by Steven Sasson that weighed 8 pounds and captured 30 images on a cassette tape (Aldred, J., 2016). A few years after the introduction of the digital camera came the Digital Single Lens Reflex cameras. These cameras were capable of capturing images exactly as they looked through the viewfinder. This is about when Kodak first created the digital camera that transformed photography entirely, putting a camera in the hands of amateurs like never before (Casey, 2018). Considering all of these advancements, the single most significant advancement in photography was the cell phone and camera's unification. No one suspected 20 years ago when Samsung put a camera on their SCH-V200 (Weitz, A., 2017) that it would grow to what it has become today. It began as a .35MP image file that could hold up to 20 photographs that had to be transferred to a computer to share once taken. Less practical, but a step towards innovation that would change the way the world operates. Before cameras were built into phones, only trained professionals knew how to operate cameras. The camera on the cell phone was easy to use, allowed for amateur skill levels to develop, and placed them in the hands of everyone with a phone. The cell phone industry grew exponentially, selling more than 122 million phones in 2007 to 571 million in 2020 (O'Dea, P., 2020). Today, statisticians estimate that about 5 billion people on earth own a cell phone (Silver, L., 2020), which means that smartphone technology is in the hands of most of the planet.

H- The iPhone camera will produce exposures of equal quality to that of a Nikon.

(Four standards of measurement to eliminate a subjective outcome of equality)

1. Popular Vote. A random population will be presented with several sets of two photographs of the same image, one captured with an iPhone and the other with a Nikon. The results will indicate which device produces the more popular image.
2. Histogram. Several images will be captured with both devices to measure the Histogram differences which will provide an overall range of color interpretation.
3. Particle Analysis. *Image J* will measure pixel value. The iPhone and Nikon will capture the same image which will be processed for equal threshold values and measured by their analyzed particles in set data points of the image.
4. Distance Analysis. *Image J* will measure distance. The same subject will be captured on an iPhone and Nikon. The image will be magnified and calibrated. Data points on the image will be measured and compared for a distortion analysis.

Crime scene documentation with photographs is commonplace today but has an interesting history. The first recorded U.S. case where a photograph was used was in 1859. The photograph was used to a title for land was a forged document. More cases saw the integration of photographs; in 1902, they were used for bullet comparisons, 1910 they were used for speed recorders, 1911 saw fingerprint comparison in photographs. (Reis, G., 2005) Crime scene documentation that included photographs saw many benefits. Not only did it help with the documentation process 'a picture is worth a thousand words', but it helps with the investigator's memory of the scene. Some crime scene investigators see hundreds of scenes before a specific case is taken to trial; those photographs from the scene help them remember the event's specifications. It also helps show the courtroom exactly what happened rather than relying on a verbal explanation that can easily be misunderstood. Further, photographs help with laboratory examinations of evidence (which will discuss later in this study). Corroboration and lead development are also major benefits of documentation with photographs.

Admissibility

The rules for courtroom admissibility are simple; the photograph must be relevant and authentic. (Nagosky, D., 2005) It is relevant because it is used to add to the likelihood that something either did or did not happen and Authentic in the fact that the image is accurate and can be confirmed by a knowledgeable person to the scene. The person who confirms the authenticity does not necessarily need to be the same person who exposed the photograph. The requirements for this individual are that they are familiar with the case, explain their familiarity (on the scene when the photograph was taken), and understand what is depicted in the image. Accuracy might be difficult for jury members to understand if they do not have a background in photography. Accuracy by courtroom definition means the photograph is in focus, the colors are correct, the depth of field is correct, the image is not distorted, and it is a fair representation of the scene. What causes a photograph relevant is answering whether it proves or disproves a fact or dispute in the case. An example of that would be a picture of the location of the murder weapon, the position of the body, or other evidence that was recovered at the scene. Lastly, a picture must be more probative than prejudicial. This means that the photograph's probative values must greatly outweigh its potential prejudicial effect on the jury. In essence, it cannot confuse or mislead the jury or be used as a tool of wasting time or buying time for the prosecution (Rule 403.). As long as those criteria are met, a photograph is technically admissible into a courtroom. Any alterations, enhancements, or deletions are grounds for inadmissibility if a proper explanation is not provided. Altered photographs can greatly impact a case and cast doubt in the jury's minds and on the crime scene investigator's testimony. Case Law states in Owens v. State, 363 Ark. 413, 421 (Court, 2018) 'we further disagree with Owens that expert testimony of no alteration was required when there was no indication that the still photographs had been enhanced from the videotape or alerted in any way.' The fact that photographs can be altered is not enough to exclude their admissibility, but rather, the burden rests on the witness to eliminate doubt from the jury. Original photographs are always kept, and no image is ever deleted that was taken on the scene, no matter if the shutter accidentally took a photograph or not. Some photographs can be post-processed, meaning enhancements are added to a copy of the photograph for a specific reason. The image is not altered but rather enhanced to light a certain area that was previously difficult to see or similar applications. The witness's burden remains to explain how the image was enhanced (post-processing) but not altered and is still considered probative and accurate.

Photographs are not scrutinized based on the device that captured the image. Some of the court cases that examined photographs and the extent of their admissibility are the following: Almond v. State, 274 Ga. 384 (Carley, 2001) stated 'we are aware of no authority… that the procedure for admitting pictures should be any different when a digital camera took them'. Owens v. State, 363 Ark. 413, 421 (Court, 2018) 'we do not agree that this court should impose a higher burden of proof for the admissibility of digital photographs merely because digital images are easier to manipulate.' Renzi v. Paredes, 452 Mass, 38, 52 (Anthony, 2008) 'photograph is generated as a digital image… the judge must determine whether the image fairly and accurately presents what its purpose to be, whether it is relevant, and whether its probative values outweigh any prejudice to the other party.' (Hodges, K., 2008) Renzi v. Paredes reestablished the judge as to the gatekeeper for admissibility. They can determine the photograph is evidence and decides for any of the above reasons not to allow the jury to view the photograph. An important part of this explanation is that any potential inadmissibility has nothing to do with the device that the photograph was taken with; however, it was improperly documented with the laws of the court; relevant and authentic. Similar studies with admissibility and iPhone video showed its ability to render original, authentic, and verifiable results based on the unique characteristics of that device's time-delayed sound (Hwang, M. 2017). This study ties in with camera application in that the iPhone has already proven itself as a true and authentic device that is reliable for accurate data. Some cameras are built to cater to a specific audience. There is not one that is limited to personal or professional. With the advancement of technology in smartphone cameras and photographs admissibility based on relevance and authenticity, I believe most crime scene documentation can be executed using the technology with the iPhone camera. I believe these cameras are the next generation of cameras and can replace expensive DSLR cameras for most Crime Scene Documentation.

Relevant Literature

The iPhone's camera breakdown reveal it has a (Raab, J., 2017) dual-lens camera system that includes a wide-angle lens and telephoto lens. Both produce a 12-megapixel image. The camera's wide-angle lens is a fixed F1.8, and the telephoto is a fixed F2.4. The Nikon D5600 has a single reflex lens, meaning the camera uses a system of mirrors and prisms to produce the same image to both the viewfinder and sensor. The lens is capable of adjusting from wide-angle at 18mm to telephoto at 55mm. It has an aperture setting that is adjustable from F5 to F 32 that gives it an incredible range for depth of field.

Design and Variables

The design and variables for this study are found in the details of each of these devices' designs. They are important to examine their configuration to understand the results of the tests better. The first of those details lies in each device's ability to capture a clear, focused image. Several key factors of Focus are important to look at with comparing the iPhone and DSLR and their capabilities, Sharpness, Resolution, and Acutance. These aspects of focus are vital to the fair and accurate portrayal of the scene. It could mean the difference between admissibility and inadmissibility in the courtroom if any of these three aspects of focus are incorrect or poorly captured. An improper photograph could be argued that the focus was incorrect, which hid evidence that could have exonerated the defendant, or that the photograph was purposely taken out of focus as a personal bias, or that the photographer was too incompetent to take a properly exposed photograph. These arguments could be made against an improperly focused photograph, which underscores the importance of this section.

Sharpness is the overall concept of being in focus. Crime scene photography is different from personal photography in that not just one item needs to be in focus. Crime scene photography focuses on the entire scene, where everything in the composition is relevant, and therefore the ability of the camera to render images in focus has to happen.

Focus

A photograph's resolution is the number of pixels, or picture element, per inch that a photograph has. The more pixels per inch, the more resolution that a photograph has. This can directly translate to the amount of detail that a photograph has. The megapixels are based on the sensor and can be determined by their size and are used to describe screen resolution. The screen resolution is an important number because that number is a fixed number per the device, meaning a phone or TV can only display a photograph with the available screen resolution it has on that device. A device with a higher pixel count would show more detail with the same photograph. This is also why photographs sometimes look different when viewing them on the camera screen and an HDTV screen. The same data is in the photograph but is not available to view on the camera. The sensor determines the pixel count. For example, multiply the number of horizontal pixels by the number of vertical pixels (3000x3000), which equals a nine-megapixel camera. (Kyrnin, M., 2016) Comparing the two devices, the iPhone has 12 megapixels, which means 12 million pixels in a photograph. (Apple, 2020) For smartphones and the amount of space and size they have available, 12 megapixels is the ideal resolution for most sensors built into their platform. In contrast, the D5600 has 24.2 megapixels partly because of the size and space available in the camera. The D5600 has a much larger sensor and can consume a much higher amount of light than the iPhone. Megapixels might not show much distinction on a camera screen or even a TV, but the information matters when the photographs are printed. The general acceptable best print range is 300 dots per inch. (Kyrnin, M., 2016) At this number, the human eye is at its limit for its ability to distinguish detail. The printed image's ability to achieve the benchmark of 300 will be determined by how large the print is. The smallest pixel count required for a 300 dots-per-inch (DPI) picture on a 4x6 photograph is 2 megapixels. On the larger scale, an 11x14 photograph with the same 300 dots-per-inch requires 13.9 megapixels. This limits the iPhone to about an 11x14 size print before noticeable distortion is generated. The D5600 can produce a much larger photograph, but for crime scene photography, there is not a specific need for photographs much larger than 11x14 for courtroom purposes. Also, larger photographs are typically viewed at a distance. Large photographs with lower DPI can serve a purpose for a jury to view at a distance, much like a billboard. DPI has nothing to do with the digital image. It is a physical property of the ability of the printer itself. More pixels also have a downside. The more pixels packed onto a sensor, the sensor itself will read less light per pixel. The more pixel information the sensor has to record, the less room there is for it to absorb light. Also, there is no resolution standard for crime scene photography. A recent High-Resolution Imaging System study of crime scenes cited that the image that the device captures should have *at least* 2048 X 2048-pixel resolution (Jackson, G. 1994), which is much lower than both devices can capture. Again, much of the photograph production has just as much to do with the outlet that the image is viewed upon as it does with the amount of data that the image holds itself (Elizabeth, 2019).

The Acutance is defined as the camera's ability to render sharp edges of a line or shape. Clear-cut, distinct edges from one object to another with no overlap is said to have good acutance. An example of this would be a photograph of a white line. A camera with good acutance would have no overlap between white and black. The line would be a stark difference and clearly visible.

The Diopter is considered part of the DSLR focus but does not come equipped with the iPhone. It can adjust the viewfinder for a specific person, so eyeglasses are not required while looking through the viewfinder. This feature is convenient for some who wear eyeglasses and would rather not wear them while looking through the viewfinder. It is unnecessary for the iPhone because the photographer is looking at the screen rather than through a hole. While the diopter could save a photographer from wearing their glasses, they run the risk of out of focus images by adjusting too far or close to an object. This tool on the DSLR is best not used for crime scene photography.

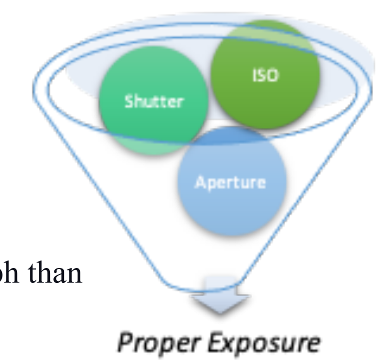
Aperture

Breaking down the concept of photography is easy to understand with the analogy of water and buckets. There is a lot we cannot control in a photograph, and for this analogy, the uncontrolled variable will be the rain. Once we introduce our bucket or 'camera,' we understand the camera's components that we *can* control. For example, how large is the bucket that we have? The size of the bucked represents the aperture setting of the camera. How much water will we allow into the bucket? This amount of water allowed in represents the ISO setting. Furthermore, how long will we leave the bucket out in the rain? This variable equates to the shutter speed of the camera. Changing any one of these variables will drastically alter the photograph's outcome, much like changing the size, duration, or amount of water allowed into the bucket would change the outcome. This concept can also help understand reciprocal exposures, which means changing a certain image element to produce the same photograph. If we change the bucket's size to a larger bucket, we also have to increase the amount of water to fill the bucket for the same overall exposure. This ability is important with photography in specific circumstances where a reciprocal exposure is required to eliminate camera shake, freeze an object in motion, or increase field depth. These topics will be further explored with the comparison breakdown in this study.

There are three topics of consideration that go hand in hand when comparing these two devices' ability to capture distances: focal length, depth of field, and aperture. These topics are explained together because each affects the other, and both devices starkly juxtapose by design.

The focal length is one of the larger differences between these two devices. It is defined as the distance measured between the camera's lens and sensor or how zoomed in the camera is on a specific subject. From looking at the iPhone, there is not an obvious 'lens' like there is on the D5600. This means that the focal length is likely to be much shorter than that of the D5600. However, what does that mean for the photograph?

The focal length perspective of a camera is quantified numerically and depends on the device. The Nikon registers at anything below 35mm for a wide-angle lens, 35mm is considered a normal range, and anything above 35mm is considered a telephoto lens. Some device's measurement is a 50mm benchmark, so it all depends on the device. Each of these types of camera lenses comes with a unique ability. Wide-angle lenses give photographs a wider field of view, meaning that more is objects and information seen in the photograph than you would normally see with your naked eye. This lens elongates foreground to background distances, making them appear longer than they actually are, and it increases the depth of field, meaning that more is in focus from near and far away. When near and far objects look the same through the viewfinder as they view them directly, the lens is considered 'normal.' Different makes and models of cameras might enumerate this 'normal' look with a different number. However, the Nikon D5600 categorizes it as 35mm. This photograph's setting or look is the standard, most accurate representation of a place or item looked like to the viewer. Telephoto lenses have a dramatic effect on a photograph. They magnify a specific area,



limit the field of view, capture less information in the photograph, make the foreground and background have a compressed look meaning the distances look crunched and not as far apart as they actually are, and narrow the depth of field range.

While the Nikon D5600 focal length can range from 18-55mm, the iPhone has a set focal length at 28mm for the wide-angle lens and 52mm for its telephoto lens. This gives the D5600 a great advantage for range but considering that a crime scene photograph needs to be as fair and accurate as possible, meaning it looks the same in the photograph as it does to the naked eye, the only setting that most photographs will be taken on with the D5600 will be at 35mm even though it has much greater ability.

Depth of Field

Depth of field is defined as how much is in focus in a photograph. A short depth of field means that the background is completely out of focus, but a large depth of field means that background and foreground objects are all in clear focus. Several factors go into the depth of field: the distance from the subject to the camera, aperture, and focal length. The photographer may or may not have control of the distance to the subject, so the ability to change the settings of aperture and focal length is important—the smaller the aperture, the greater the depth of field. Depth of field has a calculation that determines the aperture (focal length/aperture =diameter of the diaphragm). This is what causes wide-angle lenses to have a greater depth of field than a telephoto lens. For example, a wide-angle lens at 24mm with an aperture of F-8 equals a 3mm diameter of the diaphragm. Small diameter, more depth of field. Transversely, the same F-8 at a 100mm lens has a diaphragm of 12.5mm. This has a much larger diaphragm than the wide-angle lens, but both have the same aperture. More items will be in focus with the same aperture at a wider-angle lens.

A typical photograph at a crime scene could use a 35mm focal length and F8 aperture. This gives a diameter of the diaphragm opening of 6.25mm. These settings are adjustable for a greater depth of field as needed. The iPhone, on the other hand, has fewer options for manipulation. The settings to see the photograph data are also complicated to find without conducting a multi-step process that is unrealistic for the number of photographs taken at a crime scene. A third-party application that makes these settings readily visible is called 'Merapho.' This application gives instant information on the ISO, Aperture, Shutter Speed, Focal Length, Lens, and Software readings for each photograph. Using this application reveals that a typical photograph taken outside with sunlight uses an ISO of 25, an aperture of F1.8, a Shutter speed of 1/121, a Focal Length of 26mm, a Lens of iPhone XS Mad back dual camera, and a Software of 14.0.1. Using this information, 26mm/ F1.8 shows a diaphragm diameter of 14.4mm, which is incorrect as that is a huge opening. The actual focal length on a smartphone with a 26mm lens is closer to 4.25mm. (Bedeviled, Sem, 2020) Smartphones do not use the same system for measurement as DSLR cameras but instead use several magnification lenses inside the lens to achieve the same outcome of a 35mm focal length. (Apple, 2020) The wide apertured camera setting for smartphones does not produce a short depth of field because of the size ratios and design. The aperture is the amount of light that is allowed through the lens onto the film sensor or the bucket's size. This setting is measured in fractions and begins with the largest opening 1/1 or 1, which is a fully open aperture; however, the largest opening is usually around 1.4. The full fraction is not normally written, and the denominator is the only quantified number. The aperture or f-stop then cuts the light in half with each stop, allowing half of the amount of light in than the previous stop, and usually follows a sequence of 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32, 45. Aperture controls the depth of field or how much is in the focus of a photograph. A small aperture means more information in the photograph will be in focus.

Part of the reason that a smartphone camera needs such a wide camera lens that allows plenty of like onto the sensor is the sensor's size. The sensor on a smartphone camera is much smaller than that on a DSLR and thus needs as much light as possible for proper exposure.

Unlike the aperture of the D5600, the aperture of the iPhone cannot be changed. However, effects are built into the software of the iPhone that allows for a type of simulation of the larger and smaller aperture setting either during or after the photograph is taken. This is found in the 'portrait' mode of the camera and allows the users to choose from a range of F1.4 to F16. For this study and crime scene photography, limiting the DOF is the opposite of a fair and accurate representation of a scene.

ISO

The International Organization for Standards (ISO) is the ‘film speed’ or the film’s sensitivity to light or its ability to capture light, or the amount of water allowed into the bucket. The film is more sensitive to light the higher the ISO. Cameras have an image sensor where the light converges, and the camera converts that light into electrical signals. The ISO raises and lowers those signals. Raising the ISO raises the electrical signals, which lowers the amount of light needed for proper exposure. This allows for reciprocal exposures where a ‘stop motion’ photograph is required, or a faster shutter speeded is necessary to eliminate camera shake (DSLR Camera Basics, 2020).

ISO ranges are necessary for a variety of photographs. Low-light photographs required a longer shutter speed to allow a longer duration of light on the sensor. Slower shutter speeds are more likely to have blurred with camera shake but raising the ISO’s light sensitivity allows for that low light photograph to be taken at a faster shutter speed, known as a reciprocal exposure. ISO is also helpful to capture the background of low light photography without a flash or in situations where the range of a flash is too short.

Higher ISOs have multiple benefits for enhancement but come with limitations. The higher the ISO, the more 'noise' that is introduced to the photograph. The term 'noise' is referring to the grainy look that is produced. Raising the ISO raises the electrical signal but also raises the noise in the photograph.

The D5600 ISO range is from 100-25,600 (DSLR Camera Basics, 2020), wherein the iPhone ISO range is from 24 to 2304. (With, S., 2018) This looks like an incredible difference in that the iPhone is limited past 2304 ISO. Depending on the lighting, ISO noise can be seen as early as a 1600 setting. Most crime scene photographs are routinely taken between 100 and 400 ISO, so while the range of the D5600 is quite higher than the iPhone, it should not make a difference for the type of photographs used for comparison in this study. Manipulation of the ISO is accomplished by changing the settings on the camera. The iPhone does not come equipped with the same settings; however, 3rd party applications allow for the auto setting override of the iPhone and allows the freedom of ISO choice to the user. One of these applications is called 'ProCam.' Once downloaded, this application allows for many user preference settings that are normally automatic functions of the iPhone. The ISO setting on this application allows for a setting range from 24-2304. This is a free application and easy to use and install.

Shutter Speed

Another critical component of proper exposure is Shutter Speed. This aspect of crime scene photography is important for instances where a 'freeze motion' photograph is required, or a faster shutter speed is necessary to eliminate camera shake or even a slower shutter to eliminate rain and snow. The Shutter design for both devices is quite different; the Nikon has a typical shutter that opens and closes, allowing light to reach the sensor. However, the iPhone has an electric sensor wherein the sensor itself is turned on and off, eliminating the traditional shutter. Both cameras have a wide range of speeds. The Nikon ranges from 30 seconds to 1/4000, and the iPhone has 1/3s to 1/8000s. Part of the reason the iPhone can capture light at such an incredible speed is the electric sensor's design. A traditional shutter has to open and close, which takes time, but an electronic efficiently turns on and off.

The image captured on the sensor is converted into a JPEG image, meaning that the file has already been converted and ready to view and print. This type of file is easy to use and is compatible with most software systems. A JPEG comes with disadvantages in that since it is already processed, some of the information is lost. The computer algorithm for the design, which incorporates white balance, tone, color saturation, and the image's space, discards some colors to compress the file. The file also comes with 8-bits, meaning that it has a limitation of 16.8 million colors. In comparison, RAW photographs are images that contain all the original data and require a post-processing technique. A digital imaging study concluded RAW photographs could provide images with greater bit depth (Reis, G., 2005). They are the 'digital negative' of the photograph and can yield a more dynamic color range with its 12-bit, 68.7 billion color platform. Most laboratories request a RAW image of the photograph for their comparisons and come equipped to handle the increased data size and compatibility issues. There are third party platforms that alter the images captured on an iPhone to a RAW format because the iPhone does not automatically take images in RAW. For this analysis, both devices will capture JPEG images for comparison (Mansurov, 2020).

All of the above aspects of the iPhone and Nikon were researched to determine how the iPhone compares to the Nikon with the technical value, features, and software they are equipped with. The Nikon appears to have several advantages over the iPhone on paper, but the following 4-step analysis will determine how they perform and either prove or disprove the hypothesis.

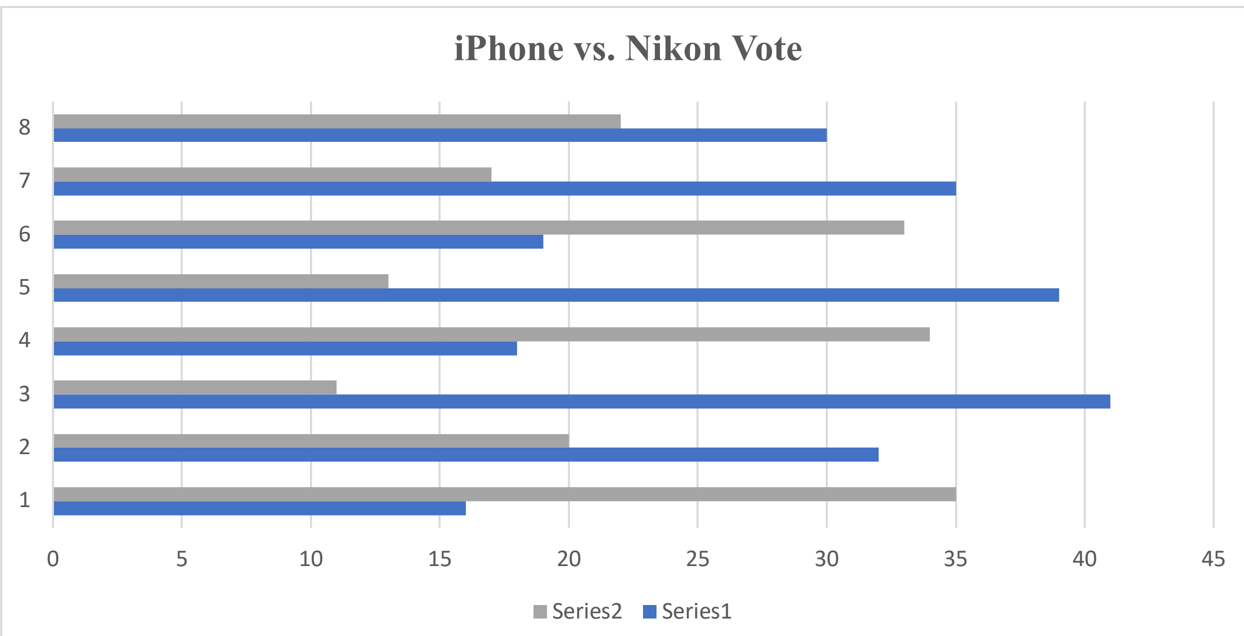
Data Analysis and Interpretation

#1 Popular Vote

A random population will be presented with several sets of two photographs of the same image, one captured with an iPhone and the other with a Nikon. The results will indicate which device produces the more popular image.

A Qualtrics survey was conducted wherein 51 random individuals voted for the image they preferred. The images ranged in categories and were used to illustrate different compositions. The individuals were not provided any information on the image and were only told to vote for their preferred image. The results on this chart quantify Series 1 as iPhone and Series 2 as Nikon.

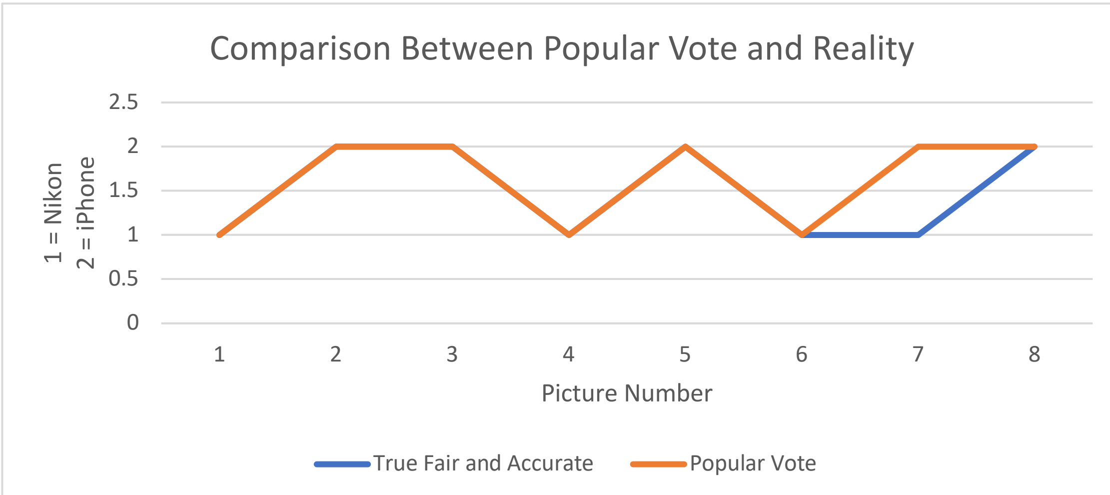
The results show the iPhone won the popular vote 5 out of 8 times or quantified as the random population voted for the iPhone image 60% of the time. It is also significant to note the percentage difference between the two votes when measuring actual votes. When the Nikon image won the popular vote, it did so by an average of 93% increase in votes. The iPhone won each image by an average of 134% vote per image increase. This means that even when the Nikon image won, the popular opinion was much closer than when the iPhone won.



These 8 images are also subjected to a ‘fair and accurate’ test. The photographer of these images used the results produced by each device to judge which most fairly and accurately represented all of the information on the scene, including lighting, shadows, and detail. The device that achieved the most fair and accurate for each set are as follows-

1. Nikon
2. iPhone
3. iPhone
4. Nikon
5. iPhone
6. Nikon
7. Nikon
8. iPhone

The results show that the popular opinion mirrored the fair and accurate test in 7 out of 8 images. Image #7 is a nighttime photograph. The iPhone likely won the popular vote due to the increased light in the image. The iPhone automatically calibrated the exposure for the darkness and extended the length of time that the shutter was open to compensate; however, the actual scene was much darker and better captured with the Nikon.
Original Survey Images provided on page #85



t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.625	1.5
Variance	0.267857	0.285714
Observations	8	8
Pooled Variance	0.276786	
Hypothesized Mean Difference	0	
df	14	
t Stat	0.475191	
P(T<=t) two-tail	0.641979	
t Critical two-tail	2.144787	

This t-Test is a statistical analysis that measures the difference between the two groups of votes. This two-tailed analysis measures both the positive and negative values to determine if the results' probability is random. The results show a P-value greater than .5, which indicates no statistically significant difference between the popular vote and what is true, fair, and accurate. Thus, it fails to reject the null hypothesis.

#2 Histogram

Several images will be captured with both devices to measure the Histogram differences which will provide an overall range of color interpretation.

Ambient Light Evaluation

1

Nikon- F5.6, 1/125, ISO 400

iPhone- F1.8, 1/121, ISO 40

	Nikon Mean	Standard Deviation	*iPhone* Mean	Standard Deviation
Green	111.4	54.2	67.90/	48.91
Blue	109	57.4	66.9/	48.3
Red	97.8	52.8	66.4/	42.7

Green	43.5	5.3
Blue	42.1	9.1
Red	31.4	10.1

Web- This photograph simulates an up-close situation where the focal point is on something close but has a distracting background. It was captured in the morning with a crisp dew on the ground. The Nikon image has a large aperture setting that makes the background appear more blurred. Both images have about the same shutter speed, but the iPhone has a much lower ISO. The higher ISO makes the Nikon more sensitive to light, thus making this photograph appear brighter. Zooming in on the images, there is more detail in the iPhone image, most likely due to the lower ISO. Overall, the iPhone image has a more dramatic feel, but both are a fair and accurate representation. The Histogram shows a much higher range for all three-color values between the two photographs and is most likely due to the Nikon image's higher ISO.

2

Nikon- F4.5, 1/60, ISO 1400

iPhone- F1.8, 1/60, ISO 160

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	90.64	57.88	87.05/	58.02
Blue	87.18	56.38	75.74/	49.19
Red	96.40	58.61	94.41/	60.98

Green	3	.14
Blue	11.44	7.19
Red	1.99	2.36

Shadows- This photograph simulates complicated lighting where flash is not available. It was captured on a cloudy morning and highlighted the difference in coloring between the Nikon and iPhone. The Nikon image has a duller feel, whereas the iPhone colors are more dramatic. Both are clear, sharp images, and the iPhone has a slightly higher degree of detail in the background. Both images have a large aperture, but the Nikon chose a very high ISO at 1400. This was most likely raised to bring some of the hallway shadows to light, and it did a better job than the iPhone at detailing the darker areas. Both are clear, sharp images, but the coloring is very different. The histogram shows the greens and reds of this image are quite similar, whereas the blue is drastically higher on the Nikon.

3

Nikon- F4, 1/60, ISO 560 *iPhone- F1.8, 1/60, ISO 160*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	95.7	58.9	109.4/	63.3
Blue	101.9	60.6	104.5/	58.8
Red	93.6	57.1	111.8/	65.9
Green	13.7	4.4		
Blue	2.6	1.8		
Red	18.2	8.8		

iPhone- F1.8, 1/122, ISO 25 (shadow) *iPhone- F1.8, 1/235, ISO 25 (sunlight)*

Tire- This photograph represents a difficult lighting situation. It was a cloudy morning, and neither camera was allowed to flash. The vehicle's color is called 'sting grey,' and the wheels, tires, and pavement are all black. Again, both cameras have a large aperture, their shutter speed is the same, but the Nikon's ISO is slightly raised. The color difference here is interesting. The iPhone appears much brighter, but the Nikon's color results are closer to the actual appearance of the tires that morning. Both are fair and accurate, but the iPhone's colors are more dramatic, where the Nikon is duller. This difference is important because this vehicle could be misidentified due to incorrect lighting with the photograph. Two subsequent photographs were taken of the same tire later in the day using the iPhone in the morning sun and shade (shadow and sunlight). The ISO is lowered, and the shutter is increased and gives a fairer representation of the true colors. The two photographs' difference is fair and accurate for how this tire looks both in the sun and shade. This shows that the iPhone does not have a problem capturing the colors when the ambient light is normal sun but struggles in other conditions. The Histogram shows the red and green colors are much higher on the iPhone and gives it that amber tone.

4

Nikon- F7.1, 1/200, ISO 400 *iPhone- F2.4, 1/74, ISO 16*

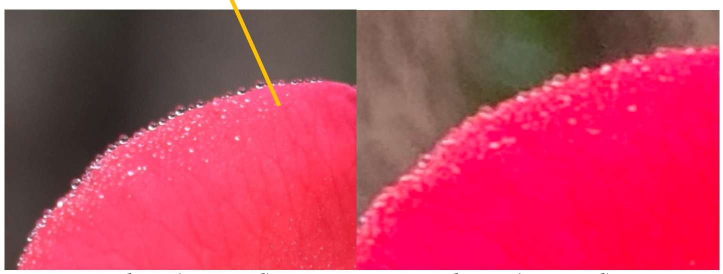
	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	108.1	46.7	109.9/	47.6
Blue	83.4	55.5	79.9/	57
Red	121.1	45.1	126.7/	46.5

Green	1.8	.9
Blue	3.5	1.5
Red	5.6	1.4

Fountain- This photograph was taken to represent a type of 'freeze motion' situation. This probably is not the fairest way to conduct this test because both were taken with an automatic setting. The Nikon and iPhone are capable of a much higher shutter speed, but neither knew that was the intention. None the less, the Nikon and iPhone are colors are pretty close, only slightly duller image with the Nikon. The Nikon ISO is raised much higher than the iPhone, and its shutter speed is also a couple of stops higher. The result is about the same image, though. Zooming in, there is a difference with the water blurred more in the iPhone photograph, but both photographs are clear, sharp, and a fair and accurate representation. The histograms show the color variation is minimal.

5

Nikon- F1.7, 1/200, ISO 400 *iPhone- F1.8, 1/121, ISO 25*

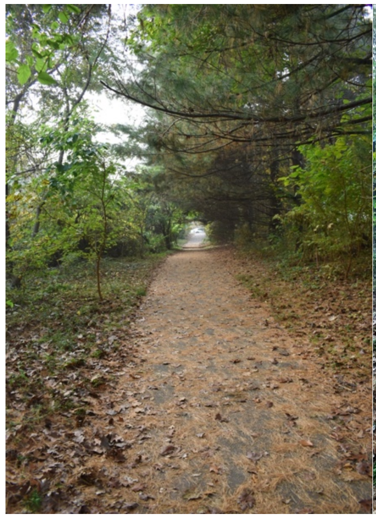
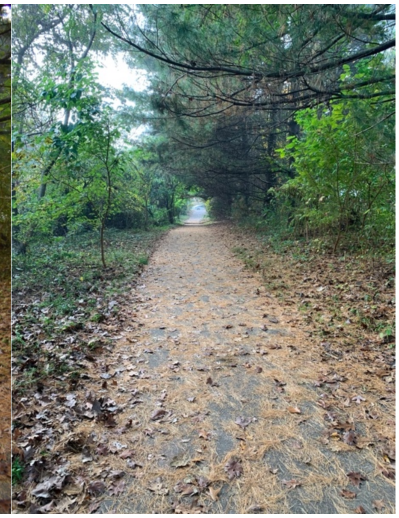


Nikon (Zoomed) *iPhone (Zoomed)*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	104.8	30.2	121.7/	39
Blue	87.2	33.5	101.6/	36.7
Red	112.7	48.3	137/	47.1
Green	16.9	8.8		
Blue	14.4	3.2		
Red	24.3	1.2		

Flower- This photograph is an excellent representation of an outdoor closeup with ambient light. A flower normally has bright colors, but ambient lighting tends to dull those colors. The Nikon image shows a more muted color scheme, whereas the iPhone image is much brighter, almost glowing. Both the aperture and shutter speed are relatively the same, but the Nikon's ISO is a couple of stops higher. The iPhone does a better job keeping the background visible, although both backgrounds are out of focus. Zooming in on these images shows a big difference. The Nikon captured individual, clear, distinct water droplets on the petals of the flower. The iPhone image is blurred and makes it look more like a rough surface than water droplets. The iPhone could probably do a better job at capturing the zoomed-in areas if that was the photographer's intention, but the Nikon image gives you both without having to choose. The histogram shows all three colors are much higher on the iPhone.

6

Nikon- F5.6, 1/125, ISO 500 *iPhone- F1.8, 1/121, ISO 80*


Nikon- F4.5, 1/80, ISO 400 *iPhone- F2.4, 1/122, ISO 100*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	102.4	45.2	122.7/	48.6
Blue	75.5	48.1	109.8/	49.3
Red	110.6	48.1	117.6/	54.4
Green	20.3	3.4		
Blue	34.3	1.2		
Red	7	6.3		

Landscape- The intention here was to test what both cameras would do with this lighting and distance. The results- dramatic and surprising. This photograph was taken in the morning, hazy sky and seconds apart. The only setting difference on both cameras was the zoom. The Nikon zoomed out has a slightly elevated aperture, shutter speed, and ISO. Once zoomed in, the colors change to a dull feel. This is likely based on the white balance from the first one reading more light and greener trees, which made it produce a more vibrant look. The iPhone, on the other hand, did almost the opposite. The zoomed-out photograph had a much duller look than zoomed in. Its shutter and ISO setting were almost the same, minus a smaller aperture. All four of these images are clear and in focus, and it could be fair to say that lighting appears different to the human eye, depending on the viewer's location on this path. Which is fair and accurate? The Nikon did a better job at capturing true color once it zoomed in, and the iPhone performed better at the normal distance. The histogram shows much higher color saturation with the iPhone.

7

Nikon- F5.6, 1/125, ISO 400 *iPhone- F2.4, 1/1212, ISO 50*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	141.6	42.8	144/	43.6
Blue	105.1	41	111.7/	37.6
Red	133.9	42.2	136.5/	41

Green	2.4	.8
Blue	6.6	3.4
Red	2.6	1.2

Grass- This photograph simulates a normal outside, grassy landscape. Both photographs show impressive results and probably the most comparable to each other out of the entire test. The iPhone has a higher shutter but lower ISO. Zooming in on both of these photographs actually gives a better result to the iPhone as more detail is shown in the fence line. This is likely due to the Nikon's large aperture that it chose, but none the less, both photographs are fair and accurate. The histogram shows a relatively similar color pattern with only slightly blues. These two photographs look almost the same at face value.

8

Nikon- F4, 1/60, ISO 640 *iPhone- F1.8, 1/60, ISO 100*

	Nikon Mean	Standard Deviation	*iPhone* Mean	Standard Deviation
Green	112.3	48.6	97/	43.5
Blue	85	53.4	69.1/	50.1
Red	142.8	52	119.5/	50
Green	15.3	5.1		
Blue	15.9	3.3		
Red	23.3	2		

Water- This comparison captures water. Neither was affixed with a polarized lens, and neither was allowed flash. The image was captured mid-morning without direct sunlight. The iPhone again has a richer color group with almost an enhanced color grouping, whereas the Nikon is rather dull. The main difference between the two settings was an elevated ISO for the Nikon. Both images are in focus, sharp quality, and a fair and accurate representation of how the scene looked. Looking at these images side by side on a large screen, the iPhone photograph is in better focus with sharper edges in the water lines and leaves. The average colors are much higher on the Nikon; however, less noticeable when viewed side by side.

9

Nikon- F8, 1/250, ISO 360

iPhone- F2.4, 1/361, ISO 16

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	112.3	48.6	97/	43.5
Blue	85	53.4	69.1/	50.1
Red	142.8	52	119.5/	50

Green	15.3	5.1
Blue	15.9	3.3
Red	23.3	2

Landscape (Lake)- This image was captured because of the unique colors; fog, rich greens, water, sky. These colors are drastically different and create a difficult reading for the camera. The Nikon used an F8, which gives it a midrange depth of field and probably loses focus at distant objects. The iPhone used its telephoto lens at 2.4 and showed some greater detail along the lake's far side. Again, the Nikon image is duller than the iPhone. There are also parts of the Nikon image where detail is completely lacking in the water and sky. The richer color scheme of the iPhone gives color to the sky and water and even enhances some of the foliage's colors. Both are clear and in focus and represent a fair and accurate representation of the scene. The slight variance in the sky color is not great enough to affect either of these photographs' overall outcome.

10

Nikon- F7.1, 1/200, ISO 400

iPhone- F1.8, 1/122, ISO 32

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	94.8	55.5	100.6/	51.3
Blue	35.8	65.3	51.2/	56.1
Red	117	55.8	124.2/	52.8
Green	5.8	4.2		
Blue	15.4	9.2		
Red	7.2	3		

Tree- This image was taken to compare how the cameras capture color when lighting is not mid-day sunlight. This tree is a vibrant yellow but has a muted feel under this lighting condition. The Nikon has a mid-range aperture and higher ISO than the iPhone. The results are a slightly muted look compared to the image the iPhone captured. There is greater detail in the overall image captured by the iPhone (brown body of tree). Both are clear, in-focus images and would be a fair and accurate representation. The standard deviance is greater than expected, with the blue tone much higher in the iPhone photograph.

11

Nikon- F7.1, 1/200, ISO 400

iPhone- F1.8, 1/160, ISO 25

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	125.2	67.2	121.6/	57.7
Blue	100.2	79.1	105.4/	69.6
Red	133.3	66	122.7/	52.6

Green	3.6	9.5
Blue	5.2	9.5
Red	10.6	13.4

Half sky- This image compared how each camera would perform under a half sky lighting condition. Again, the Nikon has a mid-range aperture and higher ISO, but the color difference between the two is very subtle. The major difference is the sky. The Nikon image is almost as if the sky data was not readable, whereas the iPhone has a blue tint. This difference shows the iPhone can capture color when the lighting is complicated for this type of situation. The sky was not bright blue, but it was also not completely white, as seen in the Nikon image. The histogram shows similar color patterns with a slight elevation in reds in the Nikon image.

12 

Nikon- F5, 1/100, ISO 400   iPhone- F1.8, 1/93, ISO 100

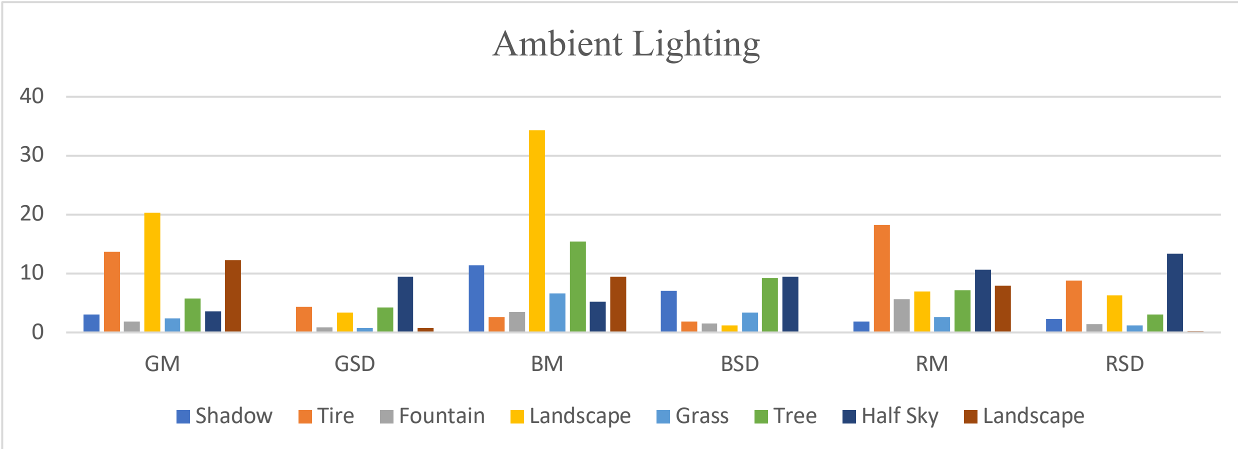
	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	104	43	116.3/	42.2
Blue	88.9	39.5	98.3/	39.5
Red	106.6	44.3	114.5/	44.5

Green	12.3	.8
Blue	9.4	.0
Red	7.9	.2

Landscape (Trail)- This comparison was another example of complicated colors under ambient lighting. The Nikon has a relatively large aperture and higher ISO, but again, has a more muted color palate than the iPhone. The Nikon image was taken a step further off of the path, which makes the path appear curved, but both are fair and accurate from their respective position. The iPhone colors are slightly richer but do not alter the overall quality or reality of what this scene actually looked like from a human eye perspective. The histogram shows an incredible low difference between the two photograph's standard deviation.

Ambient Lighting

		GM	GSD	BM	BSD	RM	RSD
1	Web	43.5	5.3	42.1	9.1	31.4	10.4
2	Shadows	3	.14	11.4	7.1	1.9	2.3
3	Tire	13.7	4.4	2.6	1.8	18.2	8.8
4	Fountain	1.8	.9	3.5	1.5	5.6	1.4
5	Flower	16.9	8.8	14.4	3.2	24.3	1.2
6	Landscape	20.3	3.4	34.3	1.2	7	6.3
7	Grass	2.4	.8	6.6	3.4	2.6	1.2
8	Water	15.3	5.1	15.9	3.3	23.2	2
9	Landscape	15.3	5.1	15.9	3.3	23.3	2
10	Tree	5.8	4.2	15.4	9.2	7.2	3
11	Half Sky	3.6	9.5	5.2	9.5	10.6	13.4
12	Landscape	12.3	.8	9.4	0	7.9	.2



Direct Sunlight Evaluation

13

Nikon- F11, 1/500, ISO 200 *iPhone F1.8, 1/6061, ISO 25*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	155.5	84	118.8/	71.5
Blue	155.5	89.5	123.8/	79.8
Red	142.8	52	128.7/	69.1
Green	36.7	12.5		
Blue	31.7	9.7		
Red	14.1	17.1		

Clothing (contrast)- These images were captured in direct sunlight, without clouds or shadows. The shirt is bright white with stark contrast on the sleeves. Both cameras could have probably captured this image with no problem in a shaded area, but the direct sunlight complicated the settings. The Nikon image has a relatively fast shutter speed and lower ISO. It used an F11, which is an excellent choice for limited diffraction. The iPhone raised its shutter speed to 1/6061 and kept a low ISO of 25. The results are a darker image, missing details from the sleeves, and an overall duller color from the iPhone. While both are clear and in focus, the

Nikon is a fairer and more accurate representation of the scene's brightness. High differences in the histograms and shows the Nikon was able to capture more color.

14


Nikon- F13, 1/640, ISO 200 *iPhone F1.8, 1/9524, ISO 24*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	199.8	42.9	145.1/	45.4
Blue	208.5	47.4	160/	49.6
Red	201	41.8	142.5/	44.4

Green	54.7	2.5
Blue	48.5	2.2
Red	58.5	2.6

Clothing (white)- This comparison took away the contrast from the previous photograph set and used a plain white shirt. The iPhone again raised the shutter dramatically and kept a low ISO. The result was an underexposed image from the iPhone. The Nikon camera was able to capture the direct sunlight's feeling along with the true color of the white shirt. The histogram shows incredibly high readings for the Nikon image, but the standard deviation difference is minimal.

15


Nikon- F6.3, 1/160, ISO 400 *iPhone- F1.8, 1/149, ISO 25*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	152.3	33.8	144.5/	37.6
Blue	155.4	33.1	143.7/	36.2

Red	153.2	33.9	146.5	37.7

Green	7.8	3.8
Blue	15.9	11.7
Red	6.7	3.8

Clothing (black)- This shirt is dark black (the darkest black shirt I own). The shirt was exposed to direct sunlight and appeared to be a light grey rather than black. Both cameras read how dark the shirt was and lowered the shutter speed accordingly. The iPhone image is slightly darker, but not by much. The takeaway from this image is how drastically a color can appear different depending on direct or indirect lighting. Both images are fair and accurate for their brightness, color, and overall image quality. These images are both fairly washed out, and their histograms show they are similar in color quality.

16

Nikon- F8, 1/250, ISO 220 *iPhone- F1.8, 1/749, ISO 25*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	106.4	68.8	82.1/	57.1
Blue	117.6	66.4	89.3/	53.9
Red	140.6	78.7	112.6/	70.4

Green	24.3	11.7
Blue	28.3	12.5
Red	28	8.3

Clothing (plaid)- This shirt has a complicated plaid pattern and was placed in direct sunlight. There is a big difference in all three of the camera settings for each camera. The plaid color is normally a dark pattern under normal light but appears washed out in direct sunlight. The iPhone does a nice job picking up the deep red coloring but makes it look more vibrant than it actually does to the human eye in this setting. Both cameras performed nicely with clear, sharp images, but the iPhone produced more dramatic coloring, whereas the Nikon exposed coloring fairer and more accurate lighting conditions. The histogram reflects the higher washed-out coloring on the Nikon image; however, the standard deviation remains close.

17

Nikon- F9, 1/320, ISO 200 *iPhone- F1.8, 1/2033, ISO 25*

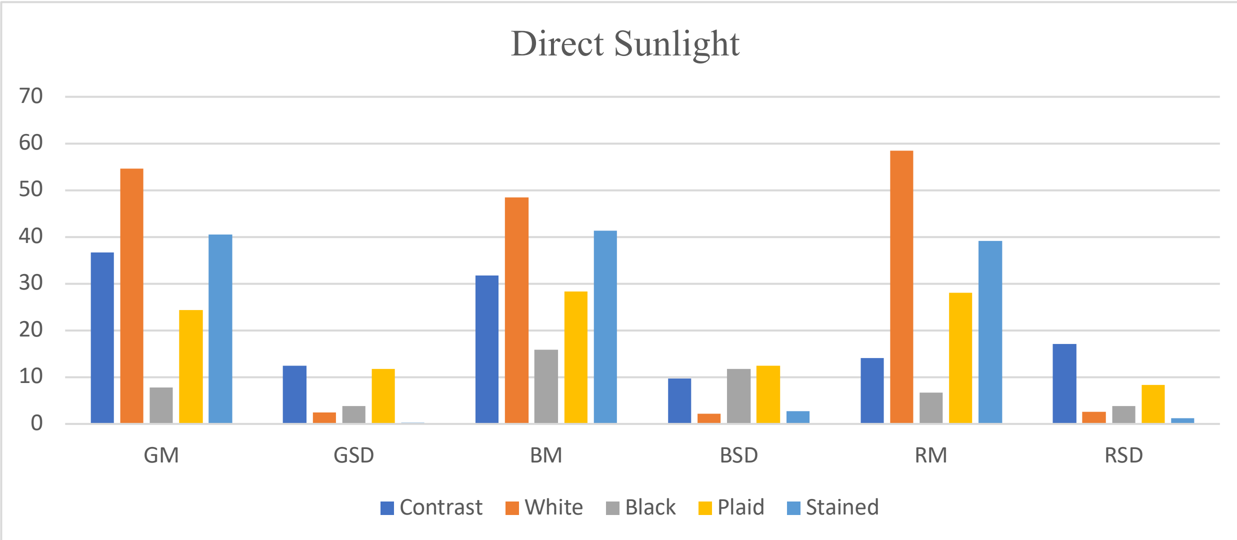
	Nikon		iPhone	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	167.8	53.8	127.3/	54
Blue	156.8	49	115.5/	46.3
Red	176.6	55.6	137.5/	56.8

Green	40.5	.2
Blue	41.3	2.7
Red	39.1	1.2

Clothing (Stained)- This comparison featured clothing that was stained with various substances. The clothing was placed in direct sunlight to compare how each camera reacted. All three settings are starkly different; the iPhone went with a very high shutter speed, much as it did for the all-white shirt, which is interesting because the basic colors here are closer to the plaid shirt. The Nikon image appears to be washed out from the lighting, which is a fair representation of how this clothing appeared. The iPhone, while it produced a darker image, produced more detail in that image. Since the Nikon camera washed out many areas of the clothing and sidewalk, the detail was lost. The iPhone has a fast shutter speed with a low ISO, producing a darker image and more detail. This difference is important to note, which difference is more important? Capturing the lighting 'as is' or capturing the detail of that image regardless of light? The histogram shows the higher intensity of coloring in the Nikon image, but the iPhone standard deviation is similar to a high degree.

Direct Sunlight

13	Contrast	36.7	12.5	31.7	9.7	14.1	17.1
14	White	54.7	2.5	48.5	2.2	58.5	2.6
15	Black	7.8	3.8	15.9	11.7	6.7	3.8
16	Plaid	24.3	11.7	28.3	12.5	28	8.3
17	Stained	40.5	.2	41.3	2.7	39.1	1.2



Normal Daylight Photography Evaluation

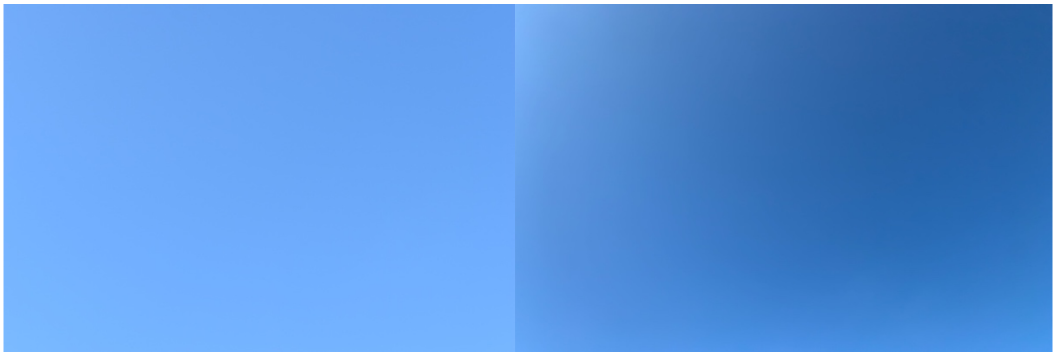
18


Nikon- F5.8, 1/80, ISO 400 *iPhone- F2.4, 1/122, ISO 80*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	118.8	57.4	143.1/	52.6
Blue	108.9	65.1	128.6/	58.9
Red	119	58.4	143.7/	55.1
Green	24.3	4.8		
Blue	19.7	6.2		
Red	24	3.3		

Exterior Overalls (with reflection)- This photograph was a test for exterior overalls with reflective surfaces. The building was shaded, and both cameras performed well. The iPhone used its smaller aperture of F2.4 and made the composition slightly brighter than the Nikon. Both are clear and in focus, and only very little noticeable difference between the two. The histograms show much more intensity in the iPhone image, likely from the smaller aperture used.

19



Nikon- F9, 1/320, ISO 200 *iPhone- F1.8, 1/1812, ISO 25*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	170.2	6.5	120.8/	10.9
Blue	249.5	5.6	191.2/	13.8
Red	111	5.5	77.5/	8.7
Green	49.4	4.4		
Blue	58.3	8.2		
Red	33.5	3.2		

Blue Sky- This photograph test of the plain blue sky was conducted to understand how each device would interpret this situation. The Nikon was unable to focus on the sky and instead focused on the tree line, then remained at that focal length to capture this image. The iPhone had no problem focusing and taking a photograph right away. The difference is clear; the iPhone is putting more contrast into the sky that was not there, whereas the Nikon does a nice job capturing the plain blue color. The color is much higher on the histogram, but the standard deviation is surprisingly similar.

20

Nikon- F9, 1/320, ISO 200 *iPhone- F2.4, 1/269, ISO 16*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**

Green	91.5	62.8	90.2	49
Blue	21	45.3	25.5/	33.3
Red	122.2	75.4	133.8/	69.8

Green	1.3	13.8
Blue	4.5	12
Red	11.6	5.6

Yellows- This mid-day photograph was taken to capture the different results of a bright yellow object. While both are clear and in focus, the iPhone has a higher red tone, as seen on the elevated histogram report. This type of photograph is important to note when this color variation is of value. The iPhone's interpretation of this color on a bright day is incorrect and most likely due to its low ISO.

21 

Nikon- F7.1, 1/200, ISO 400 *iPhone- F1.8, 1/173, ISO 25*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	83.7	66.4	106.5/	53.1
Blue	53.3	56.9	66/	45.5
Red	70.9	65.4	83.5/	52.7

Green	22.8	13.3
Blue	12.7	11.4
Red	12.6	12.7

Half Sun/ Shade- This photograph indicates a genuine possibility on a crime scene where important information is half-way in the sun or shade. Both cameras captured a clear and in-focus image, but the iPhone provided a higher amount of information in the shadow than the Nikon. The Nikon image is fair and accurate to how the ground appeared but loses important details in the grass. The standard deviation on the Nikon is much higher, showing a greater range of contrast. The iPhone captured the shadow but made it appear less dark as it actually did on the scene.

22

Nikon- F10, 1/400, ISO 200

iPhone- F2.4, 1/1142, ISO 16

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	137.6	65.2	123/	54.6
Blue	174.9	98.1	170.8/	91.8
Red	103.8	48.3	95.7/	44.3

Green	14.6	19.6
Blue	4.1	6.3
Red	8.1	4

Large Scale Item- This image captures the essence of an overall photograph on a crime scene, something that is required at all scenes. The mid-day sunlight shows little difference between the two results. Both are clear, in-focus photographs and detail the entire large object without a distorted look. The color patterns are slightly elevated on the Nikon, but the standard deviation is similar. Both are fair and accurate representations of the scene.

23

Nikon- F7.1, 1/200, ISO 400

iPhone- F1.8, 1/275, ISO 25

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	154.9	24.6	152.3/	37.8
Blue	153	27.4	148.2/	38.6
Red	156.9	23.1	153.3/	35.7

Green	2.6	13.2
Blue	4.8	11.2
Red	3.6	12.6

Footwear Impression- This is a typical photograph taken on a crime scene, a footwear impression. The impression was mostly in the shade but partly lit by sunlight. The histogram shows the color pattern in these two photographs is very much alike, but the iPhone seems to give a lot more detail with the lower ISO used to capture the image. There is more contrast in the iPhone photograph, which is the best use compared to an original item. Both are clear, in-focus images and are a fair and accurate representation of the image.

24

Nikon- F6.3, 1/160, ISO 400 *iPhone- 1.8, 1/121, ISO 32*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	113.9	68	94.8/	60
Blue	114.2	82.9	101.4/	80.3
Red	112.7	54.1	87.5/	46.3

Green	19.1	8
Blue	12.8	2.6
Red	25.2	7.8

Exterior Building- This comparison is likely to be seen in crime scene overall type photographs. The camera is tilted up, on a reflected surface, in mid-day sunlight. Both are clear and in focus, but the Nikon gives the edges and bottom of the building a bowed look. This result is surprising from the Nikon and is not accurate to the scene. This result is typically something seen in a telephoto lens, not the regular lens that was used on the Nikon. The iPhone image captures straight lines that were true to the lines of the building. Other than the bowing, the image color pattern is slightly deeper with the iPhone. The color intensity is higher in the Nikon, likely due to the higher ISO.

25

Nikon- F8, 1/250, ISO 360

iPhone- F1.8, 1/500, ISO 25

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	124.7	60.5	107.6/	52.2
Blue	119.3	65.5	89.9/	51.9
Red	120.2	65.4	112.7/	60.5

Green	17.1	8.3
Blue	29.4	13.6
Red	7.5	4.9

Unique Lighting- This photograph was taken with this unique lighting where sunlight is reflected off the building mirrors. The light from the building caused the ISO to raise on the Nikon image, giving it a brighter feel. The iPhone remained at a low ISO and is a fuller, richer color pattern. Both photographs are clear and in focus and performed well with this test. The Nikon color histogram is a much higher intensity, whereas the lower color pattern on the iPhone brings more detail to the ground. Both are fair and accurate representations of the scene.

26


Nikon- F4, 1/60, ISO 400


iPhone- F1.8, 1/121, ISO 100

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	133.8	63.3	127.5/	62.1
Blue	128.4	68.7	116.6/	63.1
Red	138.4	59.6	132.3/	60.6

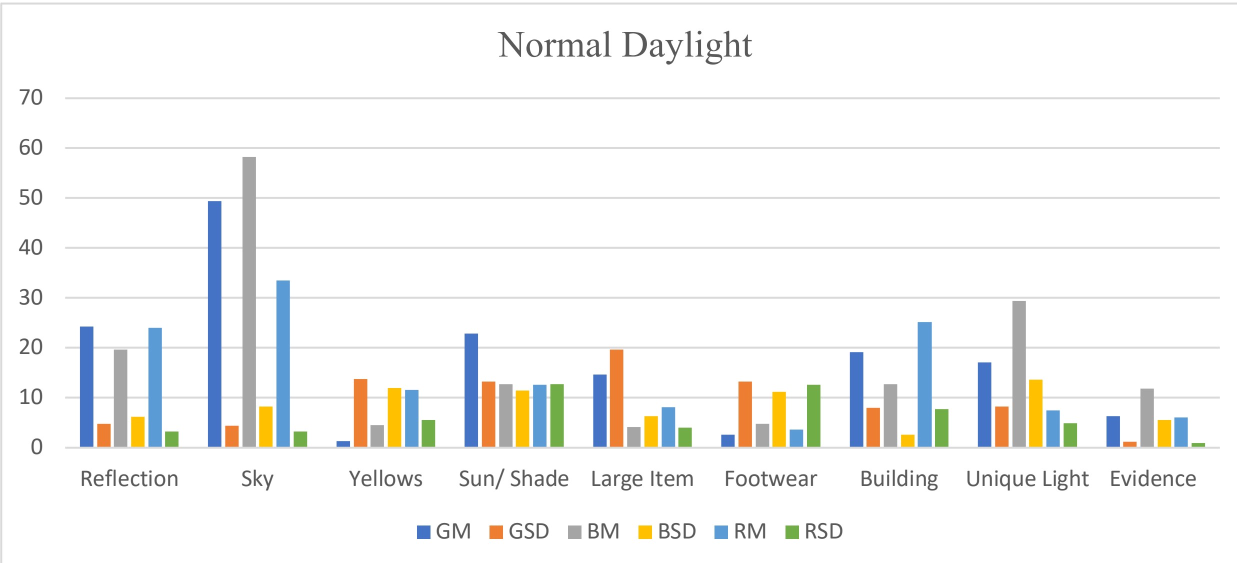
Green	6.3	1.2
Blue	11.8	5.6
Red	6.1	1

Evidence Photograph- This photograph is the best representation of a 'normal' setting—mid-day sunlight but not directly on the object. There is nothing complicated about the color pattern, and the result was two almost identical photographs. The Nikon image is only slightly more intense with the higher ISO, but both of these images exposed well and are a fair and accurate representation of the scene.

Normal Daylight

18	Reflection	24.3	4.8	19.7	6.2	24	3.3
19	Sky	49.4	4.4	58.3	8.2	33.5	3.2
20	Yellows	1.3	13.8	4.5	12	11.6	5.6
21	Sun/ Shade	22.8	13.3	12.7	11.4	12.6	12.7
22	Large Item	14.6	19.6	4.1	6.3	8.1	4
23	Footwear	2.6	13.2	4.8	11.2	3.6	12.6
24	Building	19.1	8	12.8	2.6	25.2	7.8

25	Unique Light	17.1	8.3	29.4	13.6	7.5	4.9
26	Evidence	6.3	1.2	11.8	5.6	6.1	1



Indoor Flash/ Without Flash Evaluation

27

Nikon- F4.2, 1/60, ISO 2500

iPhone- F1.8, 1/60, ISO 320

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	93.7	63	99.9/	73.3
Blue	92.1	59.4	96/	61.1
Red	96.4	64.8	106.6/	76.7

Green	6.2	10.3
Blue	3.9	1.6
Red	10.2	11.9

Clothing (Indoor Lighting)- This comparison was conducted with limited variables. Normal, indoor light and exposing an image of lights and blacks. Both devices performed well with negligible difference. The color pattern and deviance spread are small, and both resulted in a clear, fair, accurate exposure of this item.

28

Nikon- F4.2, 1/60, ISO 8000 *iPhone, F1.8, 1//30, ISO 640*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	75.6	57.6	65.6/	41.1
Blue	71.3	64.7	75.6/	49.4
Red	113.5	62	99.3/	51.8

Green	10	16.5
Blue	4.3	15.3
Red	14.2	10.2

Unique Indoor Lighting- The two images capture the lighted shoe's timing at different points, which resulted in the blue and pink colors. This most likely threw off the color pattern results, and deviance spread but should not take away from both camera's ability to capture this image well. The iPhone did a good job picking up background information behind the shoe but lowered the shutter speed to 1/30, which likely caused some camera shake motion if the image was zoomed.

29 

Nikon- F3.5, 1/60, ISO 2800 *iPhone- F1.8, 1/4, ISO 80*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	117.5	60.8	100.2/	53.2
Blue	116.1	71.8	98.3/	57.7
Red	125.9	45.6	106.9	46.6

Green	17.3	7.6
Blue	17.8	14.1
Red	19	1

Evidence Item- This comparison also has limited variables, but the low lighting caused the flash to be used for both photographs. The iPhone lowered the shutter speed to 1/4, which likely caused a camera shake, but the Nikon photograph shows the edges are bowed, which is not a fair and accurate representation. The Nikon flash is much brighter and more accurately reflected the color pattern, and it did so without sacrificing the shutter speed below 1/60. Both devices exposed a clear photograph, but both have issues. The bowing Nikon photograph also has hot spots where the flash was too intense on the blue paint, which causes lost data. The iPhone also has lost data with color variables due to a weak flash. A simple fix for both problems would be a flashlight pointed at the ceiling that illuminates the room.

30

Nikon- F3.5, 1/60, ISO 2800 *iPhone- F1.8, 1/24, ISO 40*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	140.7	53.3	99.4/	50.6.5
Blue	134.9	55.2	93.2/	51.3
Red	143.8	50.7	111.2/	52.4
Green	41.2	2.7		
Blue	41.7	3.9		
Red	32.6	1.7		

Interior bathroom- This comparison highlights a bathroom photograph with bright whites and flash. The Nikon flash is much stronger and gave its photograph a greater depth of color, as seen on the histogram, but the standard deviation is minimal. The iPhone photograph could be post processed and brightened, but the coloring has a yellow tint, which is off-center for true and accurate. Both are clear and in focus, but the Nikon flash is so strong that it created hard shadows and hot spots compared to the iPhone photograph, where there are no hard shadows but not enough light.

31

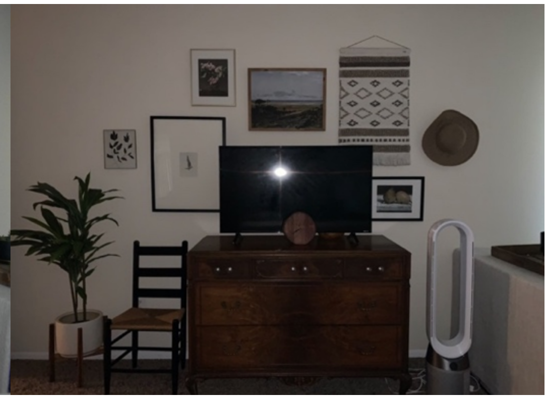
Nikon- F3.5, 1/60, ISO 6400 *iPhone- F1.8, 1/4, ISO 80*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	132.4	70.1	62.9/	49.2
Blue	126.8	71.5	55/	46.3
Red	137.1	69.2	69.1/	51.5
Green	69.5	20.9		
Blue	71.8	25.2		
Red	68	17.7		

Interior (colors)- This composition is likely seen at crime scenes and again shows the iPhone flash's weakness. Not only is the iPhone photograph extremely underexposed, but the shutter speed was lowered to 1/4, which means the image is blurred when magnified. The iPhone photograph makes it seem as there is litter color variation in the image and the Nikon image shows how much information the iPhone did not capture. The Nikon's intense flash created some hard shadows on the left side, which could be fixed with a different flash angle or bounce card.

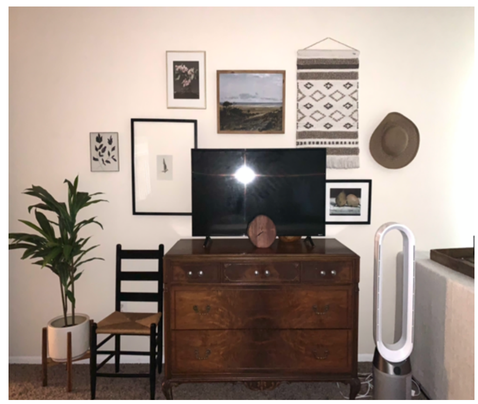
32

Nikon- F3.5, 1/60, ISO 6400



iPhone- F1.8, 1/4, ISO 40

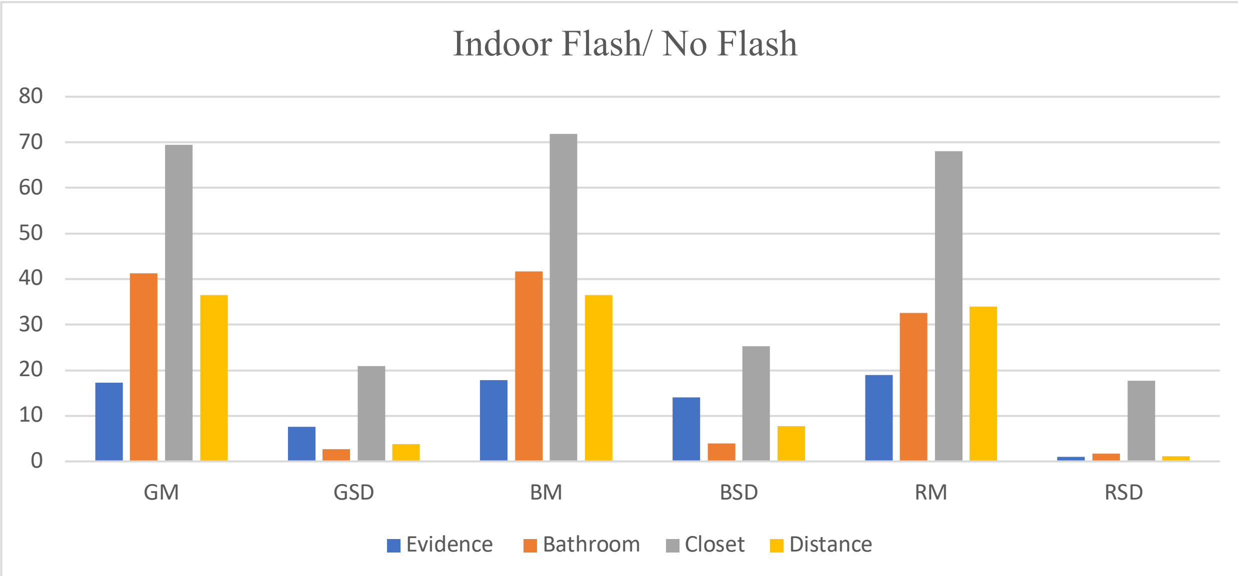
Nikon	**Mean**	**Standard Deviation**
Green	112.6	49.6
Blue	107.7	52.7
Red	117.3	44.5
iPhone	**Mean**	**Standard Deviation**
Green	76.1/	45.8
Blue	71.2/	45
Red	83.4/	45.7
Green	36.5	3.8
Blue	36.5	7.7
Red	33.9	1.2



Interior (distance flash)- This comparison captures what the flash looks like about a 15' distance indoors. The brighter Nikon flash captured more intense colors but made the photograph look rounded on the edges, whereas the iPhone is truer and more accurate for the scene's structure. Both photographs created a hotspot. The ***third*** photograph is the iPhone exposure post-processed with the exposure brightness raised to 100%. This shows additional information in the exposure, but the color variation is incorrect due to the flash difference.

Indoor Flash/ No Flash

27	Clothing	6.2	10.3	3.9	1.6	10.2	11.9
28	Light	10	16.5	4.3	15.3	14.2	10.2
29	Evidence	17.3	7.6	17.8	14.1	19	1
30	Bathroom	41.2	2.7	41.7	3.9	32.6	1.7
31	Closet	69.5	20.9	71.8	25.2	68	17.7
32	Distance	36.5	3.8	36.5	7.7	33.9	1.2



Zoom Evaluation

33

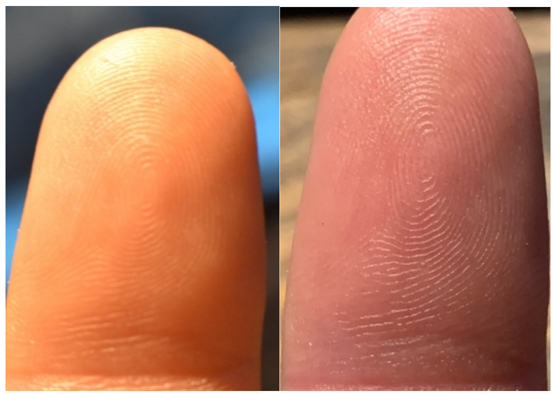
Nikon - Focal Length 82mm *iPhone- Focal Length 121mm*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	113	50.9	133.3/	50.3
Blue	97	48.1	94.3/	46.7
Red	128.8	55.2	128.7/	52.9

Green	20.3	.6
Blue	2.7	1.4
Red	.1	2.3

Zoom (Coin)- Both cameras were zoomed to their maximum length. The iPhone has a much greater focal length, and the image is much sharper and more in focus than the Nikon. The Nikon image (the same goes for all zoomed Nikon images in this section) was not this magnified originally and had to be magnified further in post-processing to replicate the size the iPhone was able to produce. The color pattern of the histogram is extremely close. Overall, this is a great photograph produced by the iPhone.

34



Nikon- Focal Length 82mm *iPhone- Focal Length 121mm*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	125.8	53.8	112.7/	37.9
Blue	85	53.4	96.5/	33.2
Red	191.1	73.9	171.8/	48

Green	13.1	15.9
Blue	11.5	20.2
Red	19.3	25.9

Fingerprint- This comparison is not a fair and accurate comparison on the histogram chart and will not be included in the graphed analysis but was left in this study to show the iPhone's ability to capture ridge detail of a fingerprint. The two photographs have different lighting, which was not the camera's fault, which gives different readings on the histogram chart. Both photographs are clear and accurate, and the iPhone could capture more detail of this fingerprint with the extended focal length.

35

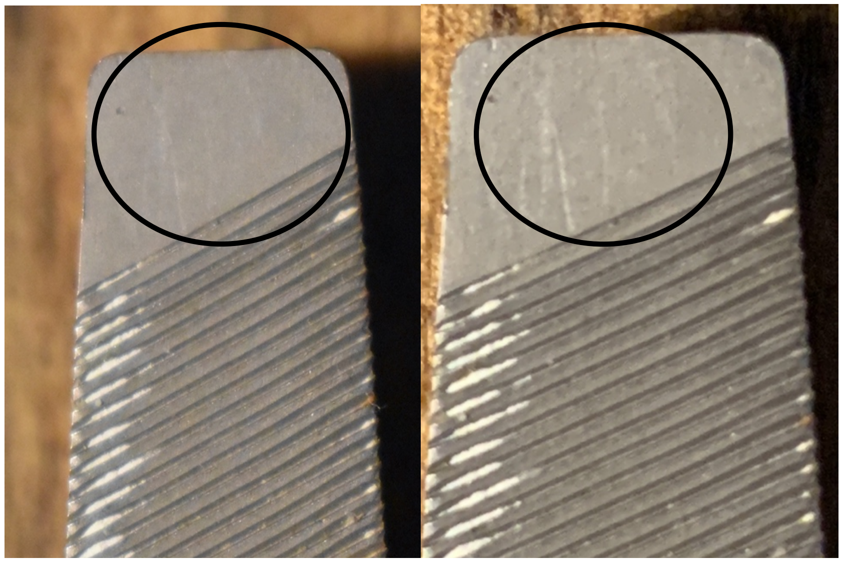
Nikon- Focal Length 82mm *iPhone- Focal Length 189mm*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	88.5	42.9	116.1/	52.6
Blue	64.6	32.4	99.9/	45.2
Red	146.3	43.5	166/	44.8
Green	27.6	9.7		
Blue	35.3	12.8		
Red	19.7	1.3		

Resolution

Currency- The iPhone appears to have captured more light in this comparison and also more detail. The difference in Resolution is outstanding. The iPhone focal length is much greater than the Nikon and gives it the ability to resolve those line pairs more accurately. Both are clear images, but since the iPhone is further zoomed, its image is sharper.

36



Nikon- Focal Length 82m *iPhone- Focal Length 179mm*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	119.2	43.8	128.6/	48.2
Blue	102	42.7	114.2/	44.8
Red	136.6	49.6	139.6/	49.7

Green	9.4	4.4
Blue	12.2	2.1
Red	3	.1

Knife Blade- Again, with the iPhone's ability to zoom at a higher focal length, it produces much more detail than the Nikon. The histogram charts are similar, but the details inside the circles drawn onto the exposures are limited on the Nikon exposure compared to the iPhone. Both photographs represent a fair and accurate representation, but the detail in the iPhone photograph far outweighs the Nikon for examination purposes.

37

Nikon- Focal Length 82mm

iPhone- Focal Length 121mm

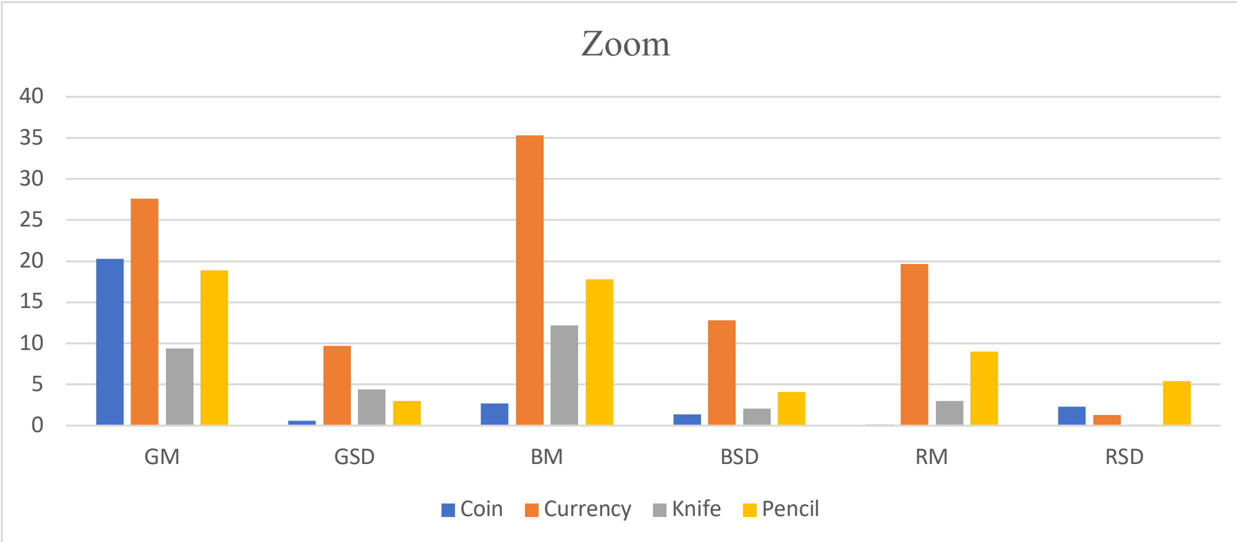
	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	88.2	58.2	107.1/	61.2
Blue	63.4	44.7	81.2/	48.8
Red	121.3	76.6	130.3/	71.2

Green	18.9	3
Blue	17.8	4.1
Red	9	5.4

Pencil- The histogram shows interesting results with the variance between colors. The iPhone picked up more greens and blues for this image, whereas it usually struggles with those colors. The Nikon image appears to have more of a red tone and is blurred and not a good representation for comparison. The iPhone photograph is much better for evidence comparison.

Zoom

33	Coin	20.3	.6	2.7	1.4	.1	2.3
34	Fingerprint	13.1	15.9	11.5	20.2	19.3	25.9
35	Currency	27.6	9.7	35.3	12.8	19.7	1.3
36	Knife	9.4	4.4	12.2	2.1	3	.1
37	Pencil	18.9	3	17.8	4.1	9	5.4



Night Photography Evaluation

38

Nikon- F18, 1/13, ISO 12,800

iPhone- F1.8, 1/4, ISO 3200

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	17	21.2	25/	28
Blue	23.1	25.2	19.1/	23.5
Red	18.1	26.1	31.4/	34.6

Green	8	6.8

Blue	4	1.7
Red	13.3	8.5

Landscape- This photograph compares how each camera captures night light without flash. The iPhone struggled with its ability to capture this image. It lowered the shutter to 1/4, which means there will be an image blur. It raised the ISO to 3200, which gave it a noisy, grainy tone. The Nikon also lowered the shutter below 1/60 and raised the ISO much higher than the iPhone but could capture more color without a grainy image. The iPhone image captured more light throughout the buildings but sacrificed the information for a blurred, unfocused image.

39

Nikon- F4.5, 1/60, ISO 9000 *iPhone- F1.8, 1/5, ISO 800*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	35.7	32	55.4/	38.8
Blue	9.8	21.4	29.6/	27.7
Red	54.2	37.4	73.5/	44.2

Green	19.7	6.8
Blue	19.8	6.3
Red	19.3	6.8

Night (Yellow Lamp)- The iPhone did a nice job at capturing information in the foreground and tree line. Along with this information is the higher histogram numbers from the iPhone. Neither device used a flash, but the Nikon camera did not go below a 1/60 shutter, meaning its image is likely more in focus at magnification. The display of these two images is important if the question is how much illumination was on the scene. The iPhone makes the area appear brighter, whereas the Nikon image makes the scene look less illuminated.

40

Nikon- F5, 1/40, ISO 12,800 *iPhone- F1.8, 1/15, ISO 1,250*

Lens Flare

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	44.3	29.7	62.3/	34.2
Blue	34.4	31.5	51.8/	33.7
Red	54.6	31.6	64.7	36.5

Green	18	4.5
Blue	17.4	2.2
Red	10.1	4.9

Night (white lamp)- Both cameras lowered the shutter to less than 1/60. The ISO for the Nikon is maxed, but it can capture the image without noise. The iPhone again makes the entire scene appear more illuminated than the Nikon, which could be an important detail in crime scene photography. The histogram chart is relatively similar, and the standard deviation is minor.

41

Nikon- F3.5, 1/6, ISO 12,800 *iPhone- F1.8, 1/4, ISO 3200*

Nikon		*iPhone*	
Mean	**Standard Deviation**	**Mean**	**Standard Deviation**

Green	54.7	42.2	52.6/	40
Blue	31	42.1	38.4/	35.8
Red	72.8	59.9	61.3/	47

Green	15.3	5.1
Blue	15.9	3.3
Red	23.3	2

Night (tree line)- This photograph was unique in that it was exposed in complete dark minus the minute illumination from the streetlamp. The trees and sky appeared black on the scene, and neither camera was allowed to use flash. The test was to understand how each camera would capture these colors. Both cameras have a deficient shutter speed and high ISO. The iPhone image has more noise and less color. The Nikon's higher ISO allowed it to have a slower shutter and capture more color.

42

Nikon- F3.5, 1/60, ISO 11,400 *iPhone- F1.8, 1/15, ISO 1,250*

	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	28.7	29	48.6/	42.3
Blue	23.3	25.5	42.7/	35
Red	38.9	36.7	53.2/	45.9

Green	15.3	5.1
Blue	15.9	3.3
Red	23.3	2

Street- This comparison did not allow either camera to use flash, which allowed a comparison of how each would capture these different lights. The Nikon was able to capture all of the information at 1/60 but has several areas where information is missing. The iPhone lowered the shutter to 1/15 and showed a blurred vehicle in the corner. The longer exposure for the iPhone makes the scene appear brighter than it actually was.

43 

Nikon- F3.5, 1/13, ISO 12,800 *iPhone- F1.8, 1/4, ISO 800*

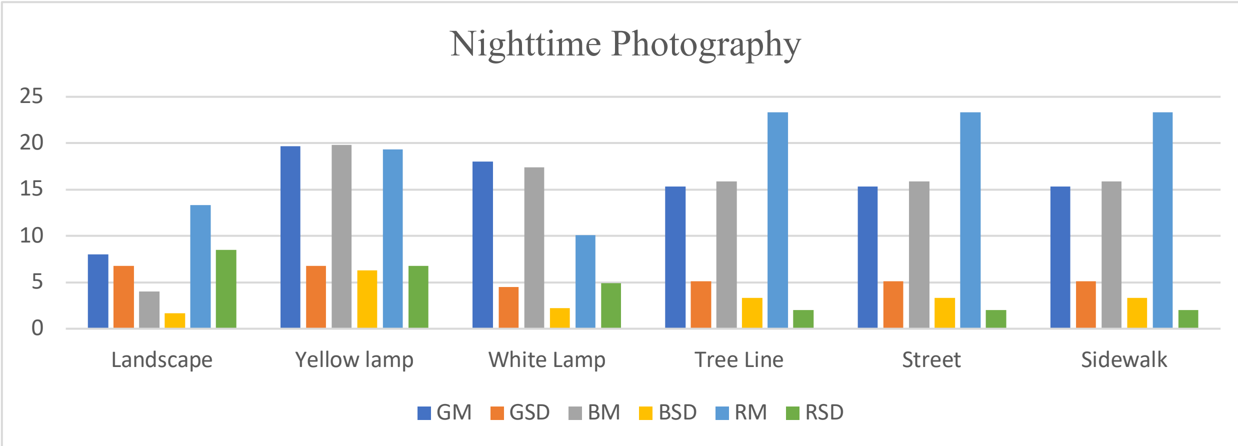
	Nikon		*iPhone*	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Green	65.4	33.6	52.2/	31.1
Blue	8.1	11.5	34.6/	23.4
Red	104.5	47.4	76.3/	42.8

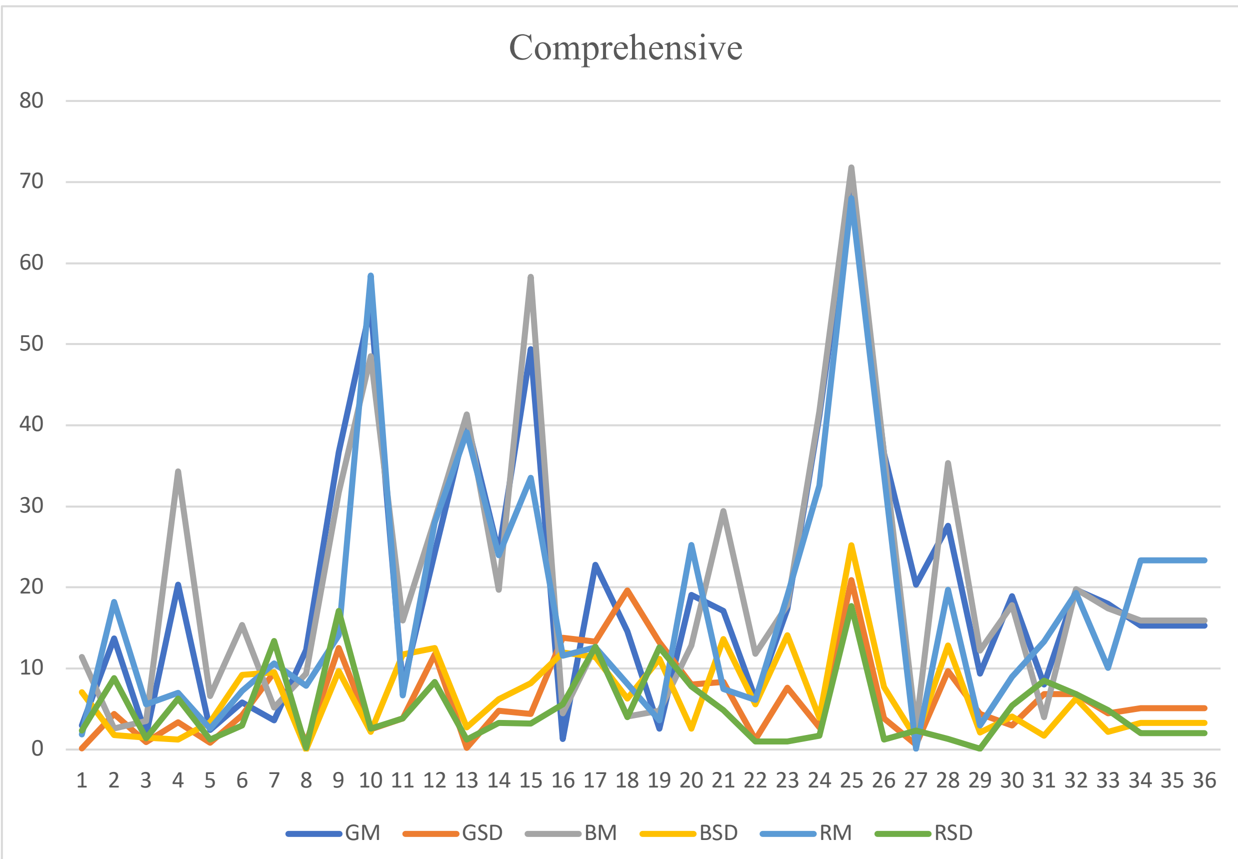
Green	15.3	5.1
Blue	15.9	3.3
Red	23.3	2

Sidewalk (yellow lamp)- This comparison highlights how each camera interprets this yellow lamplight. The Nikon is a fair and accurate representation of the ambient light color, whereas the iPhone makes the scene appear to have a red tone. Both are clear and in focus, but the iPhone did not capture the correct color.

Nighttime Photography

38	Landscape	8	6.8	4	1.7	13.3	8.5
39	Yellow lamp	19.7	6.8	19.8	6.3	19.3	6.8
40	White Lamp	18	4.5	17.4	2.2	10.1	4.9
41	Tree Line	15.3	5.1	15.9	3.3	23.3	2
42	Street	15.3	5.1	15.9	3.3	23.3	2
43	Sidewalk	15.3	5.1	15.9	3.3	23.3	2

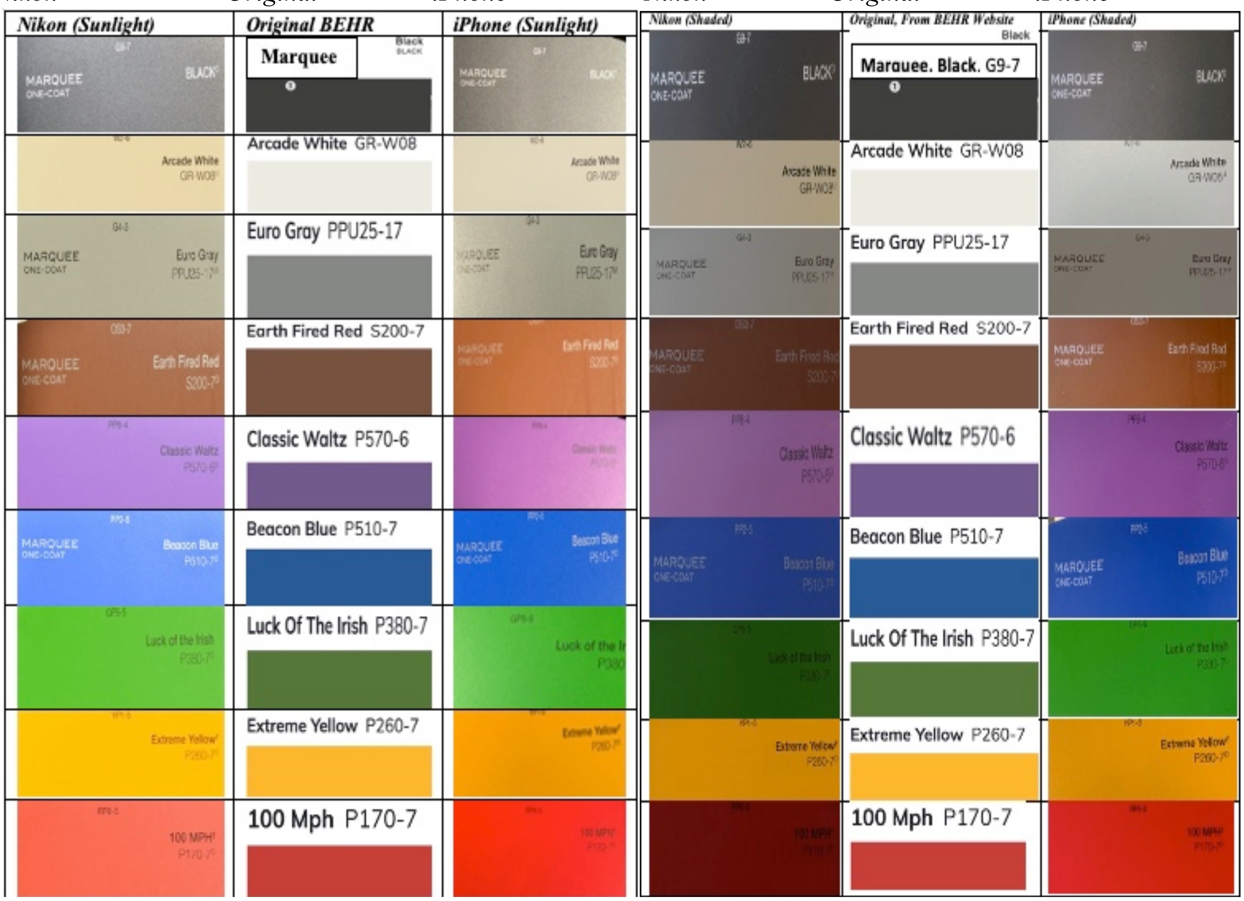




The comprehensive analysis graphs all images with several outstanding notations. Breaking down this analysis to the respective six subsections, normal daylight photography showed the least difference in red, green, and blue value variation.

Direct Sunlight vs. Shaded Compositions using BEHR Color Patterns

Nikon *Original* *iPhone* *Nikon* *Original* *iPhone*



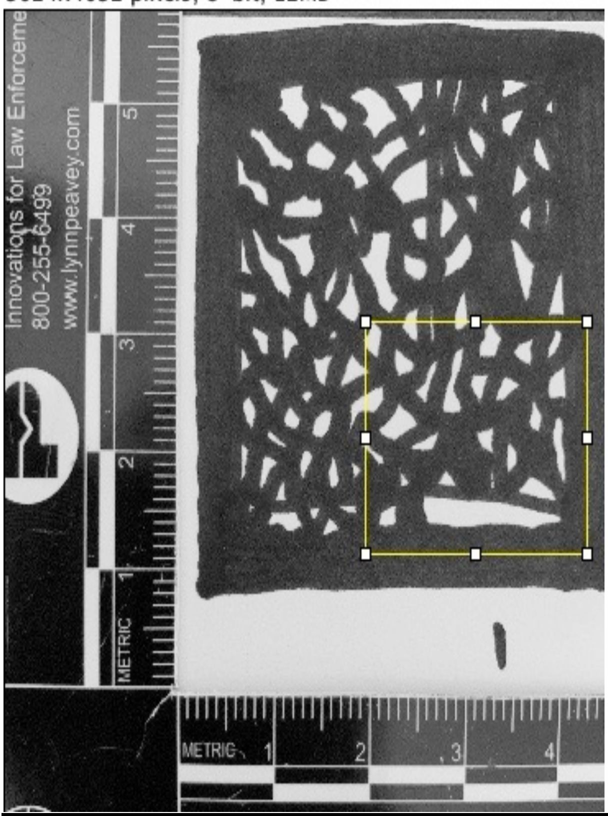
This illustration demonstrates color value interpretation and different lighting. While this data was not used in the analysis, the information is important to visualize. The middle column of each row is a screenshot of the original color from the *BEHR* website. Each camera captured the same *BEHR* color card obtained from Lowes®, as seen in the color title. This ensures the most accurate results were obtained for comparison (original color and website color). The results are mostly expected, with much of the color from direct sunlight washed out. The shaded portions show the iPhone came closer to capturing the original color. This examination proves that color is only true in certain lighting, and the same color can look different depending on the lighting.

#3 Particle Analysis

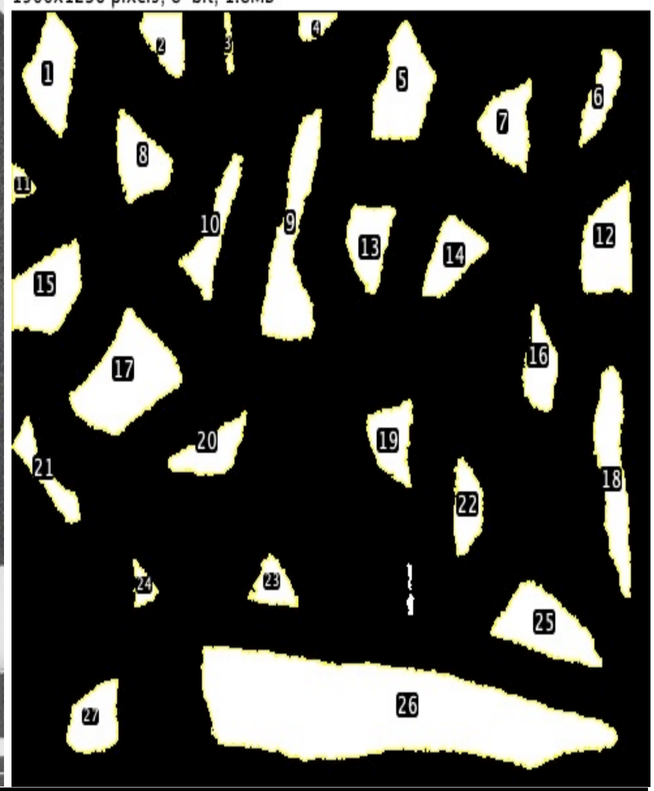
Image J will be used to measure pixel value. The same subject will be captured on an iPhone and Nikon. The images will be processed and measured by their analyzed particles.

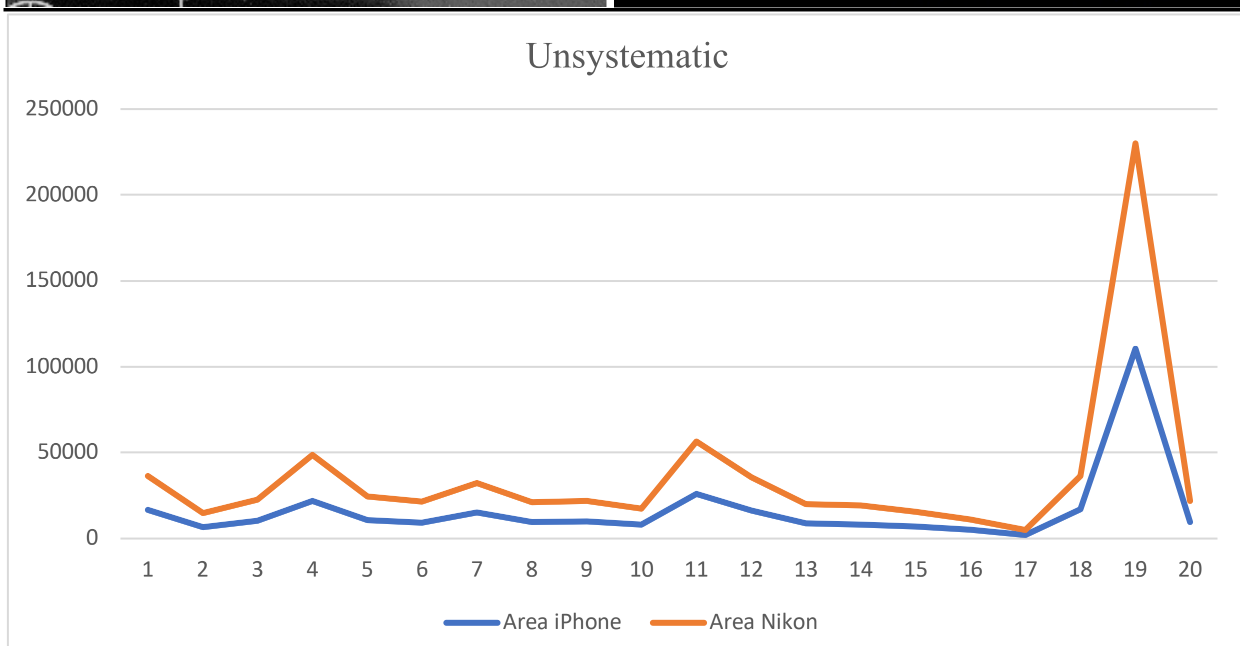
1. Unsystematic

3024x4032 pixels; 8-bit; 12MB

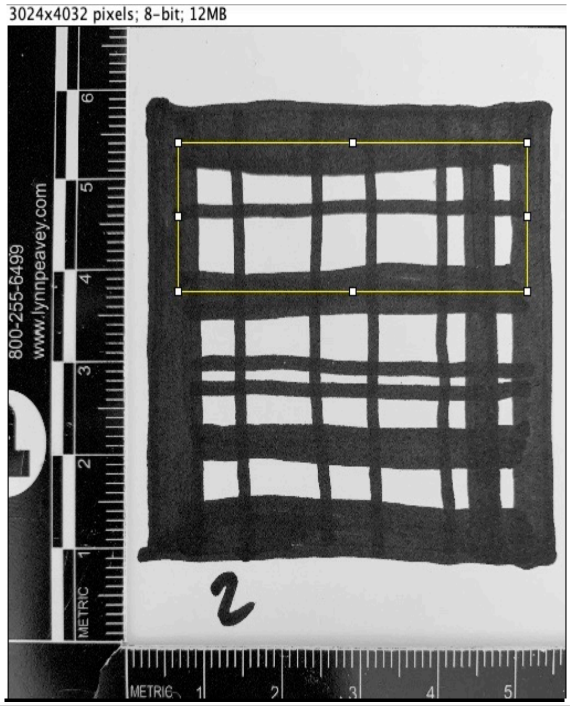


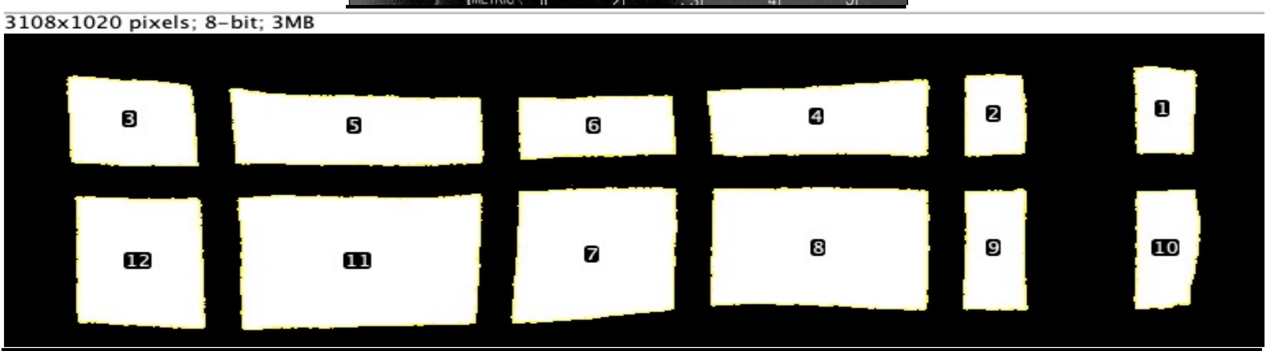
1500x1236 pixels; 8-bit; 1.8MB

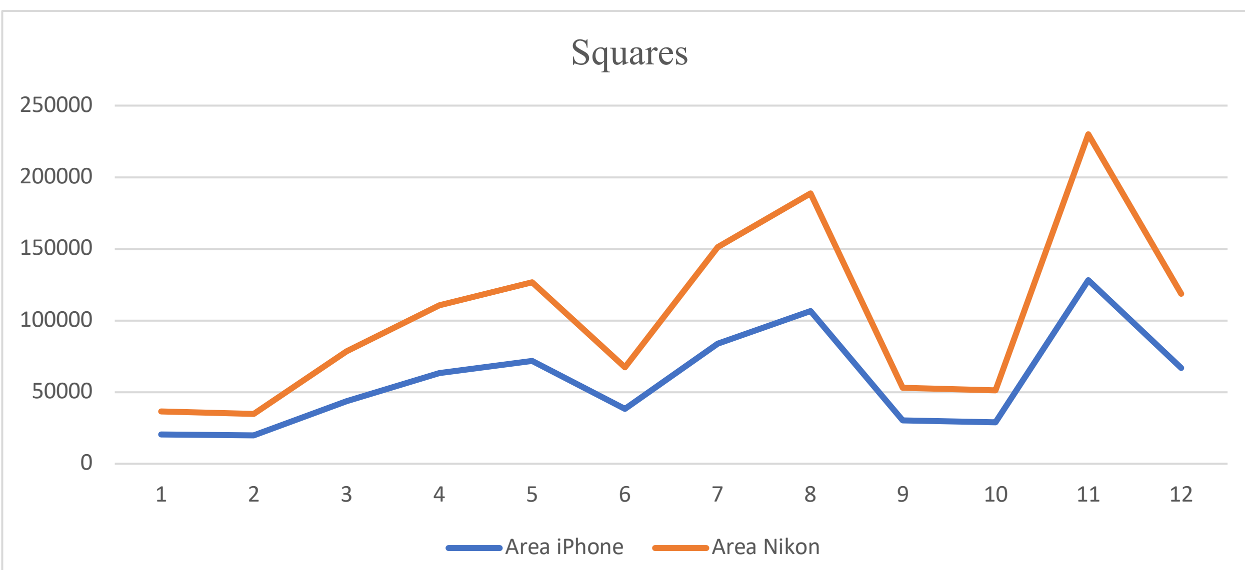




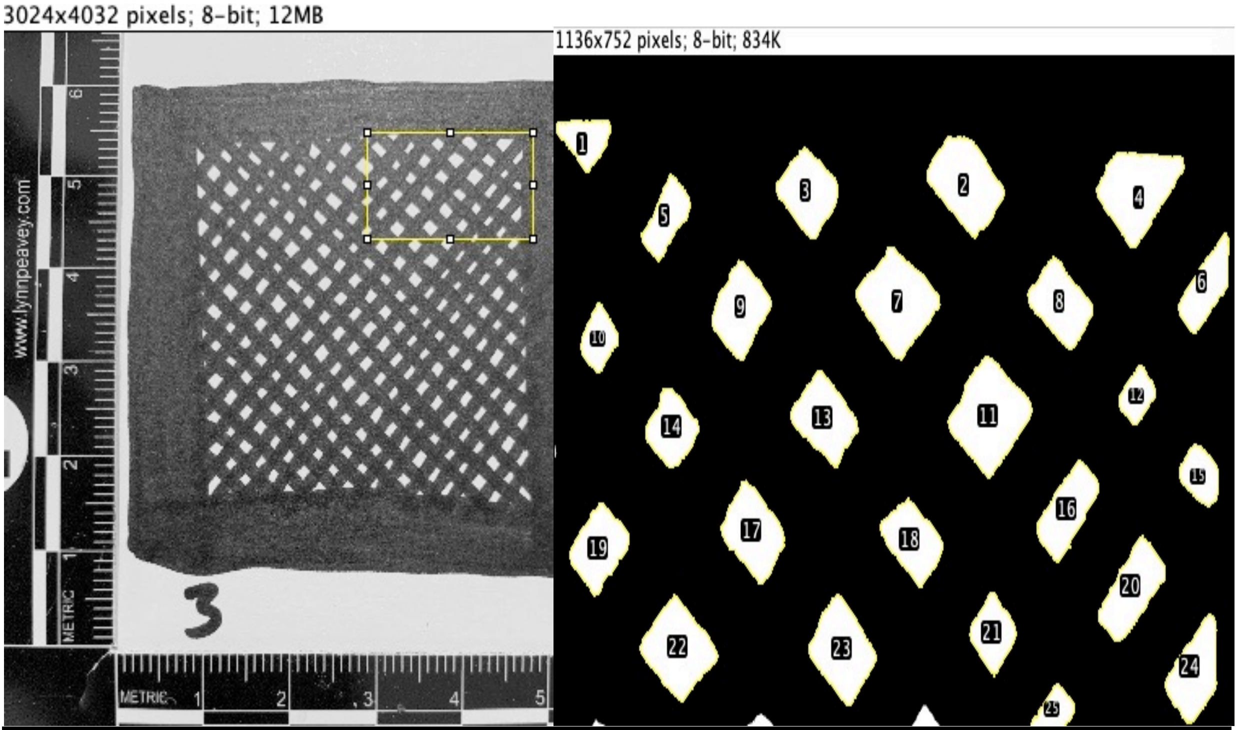
2. Squares

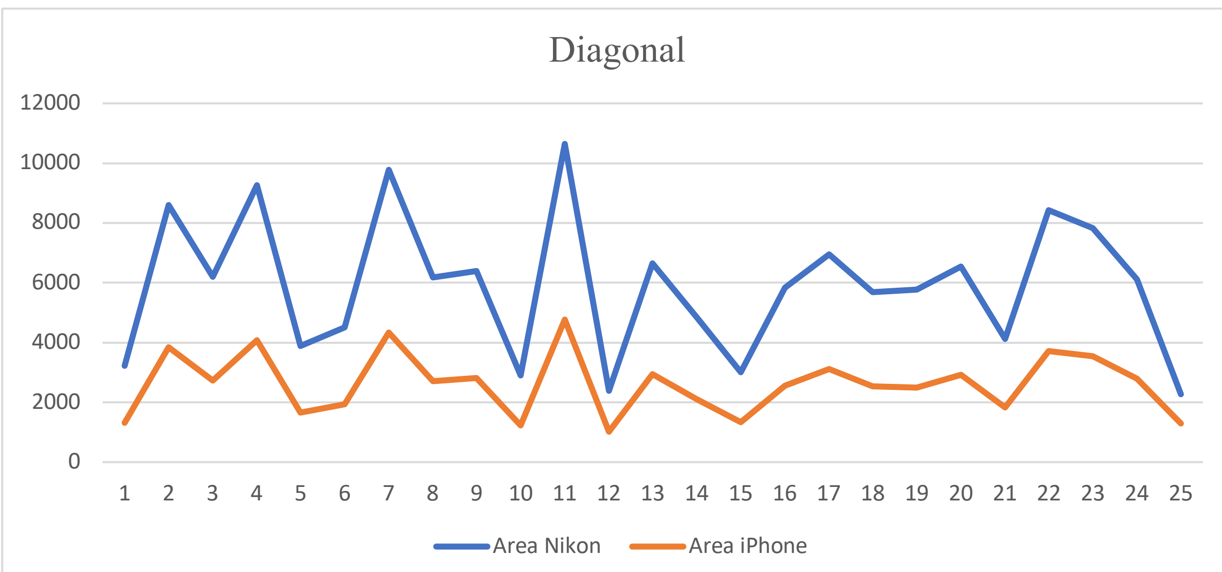

3024x4032 pixels; 8-bit; 12MB
800-255-6499
www.lynnpeavey.com
METRIC


3108x1020 pixels; 8-bit; 3MB
3
5
6
4
2
1
12
11
7
8
9
10

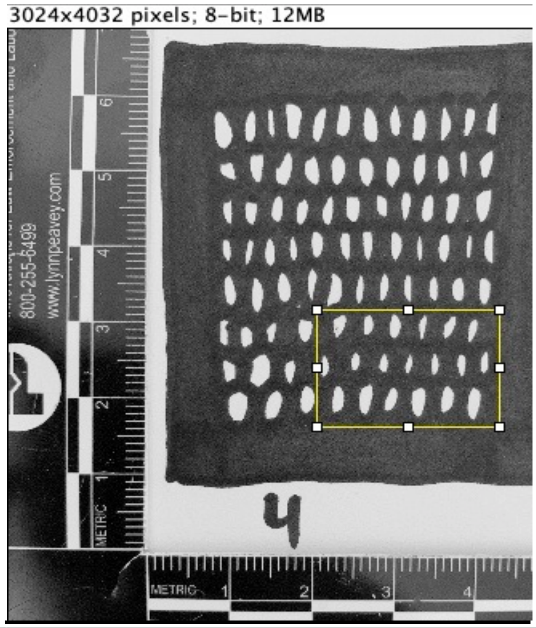

Squares
250000
200000
150000
100000
50000
0
1
2
3
4
5
6
7
8
9
10
11
12
Area iPhone
Area Nikon

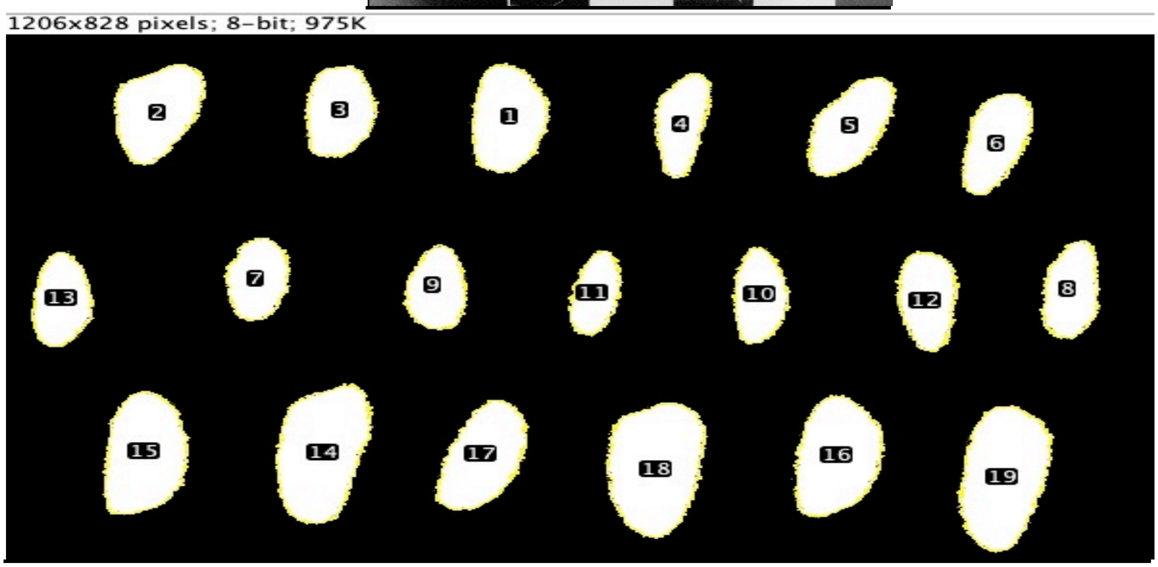
3. Diagonal

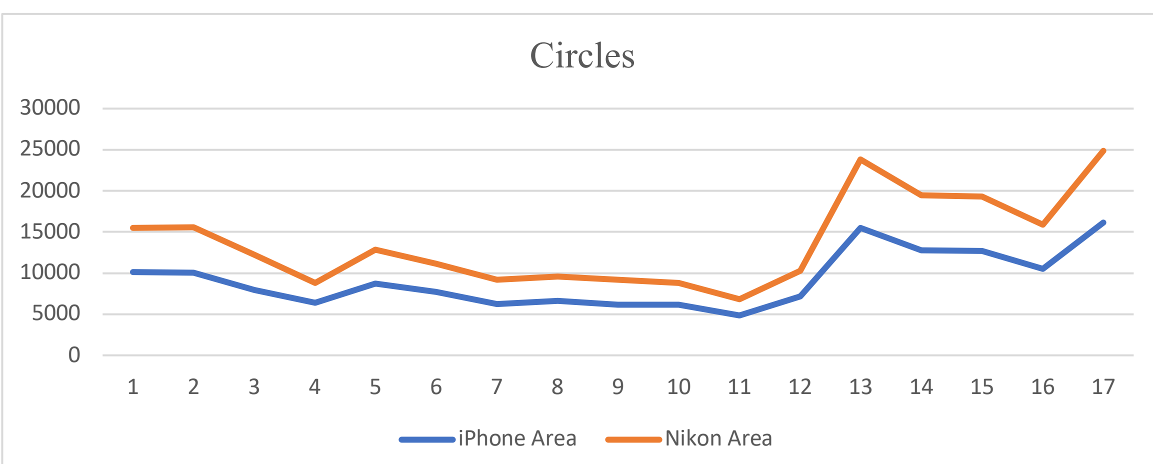

3024x4032 pixels; 8-bit; 12MB
1136x752 pixels; 8-bit; 834K
www.lynnpeavey.com
METRIC
3
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25


Diagonal
12000
10000
8000
6000
4000
2000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Area Nikon
Area iPhone

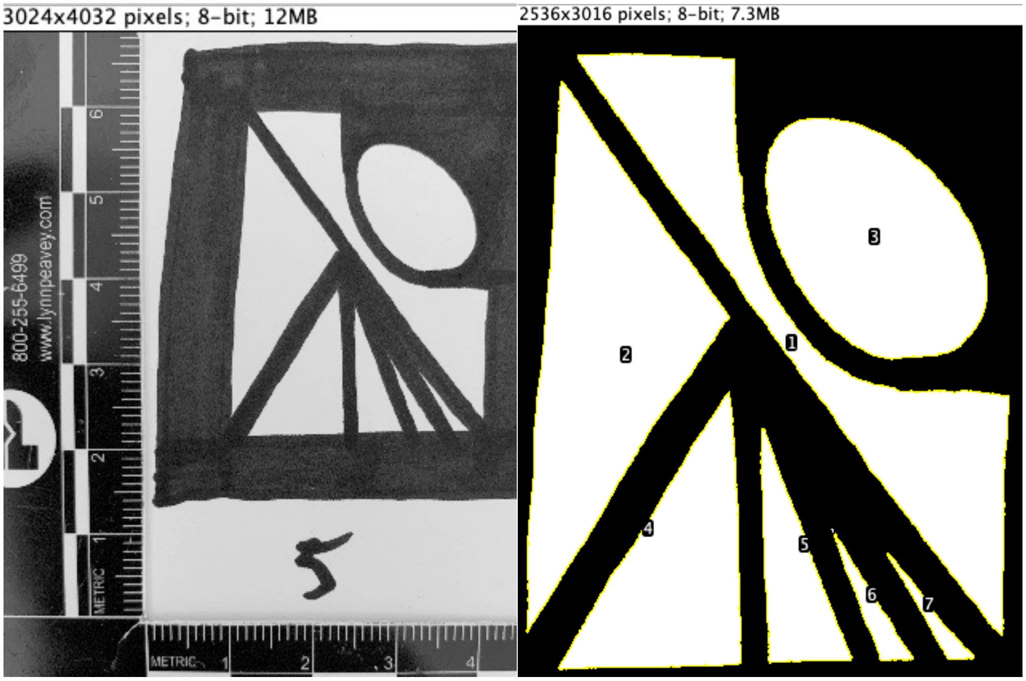
4. Circles

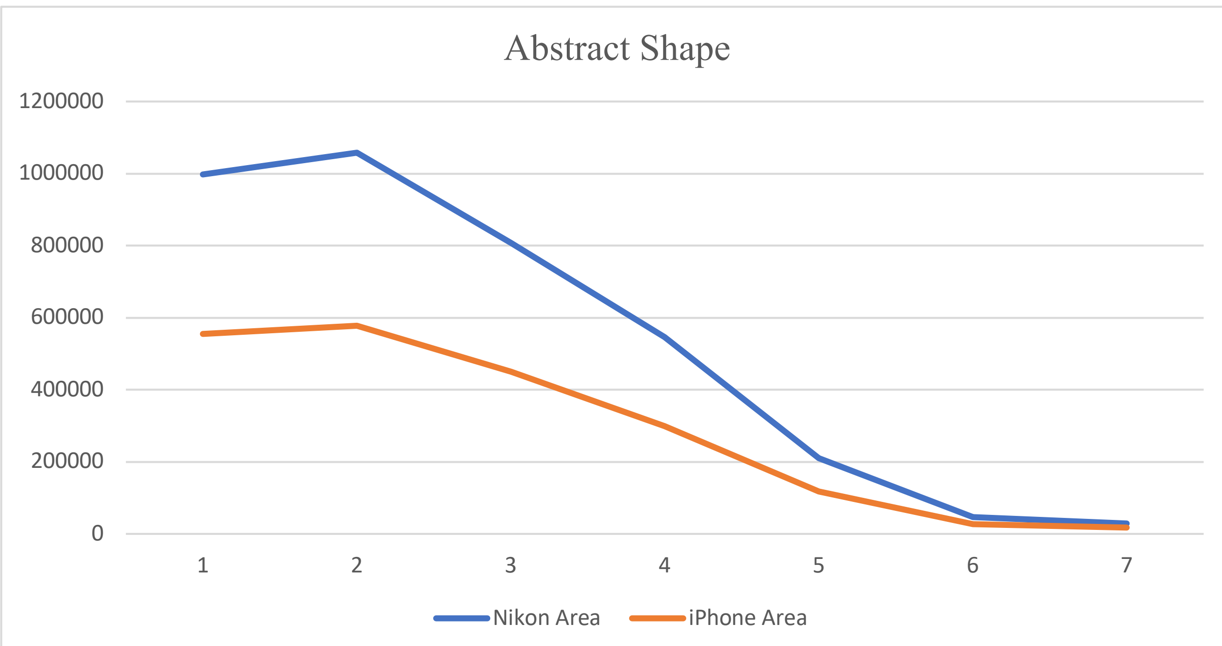

3024x4032 pixels; 8-bit; 12MB
800-255-6499
www.lynnpeavey.com
METRIC
4


1206x828 pixels; 8-bit; 975K
2
3
1
4
5
6
13
7
9
11
10
12
8
15
14
17
18
16
19


Circles
30000
25000
20000
15000
10000
5000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
iPhone Area
Nikon Area

5. Abstract Shape

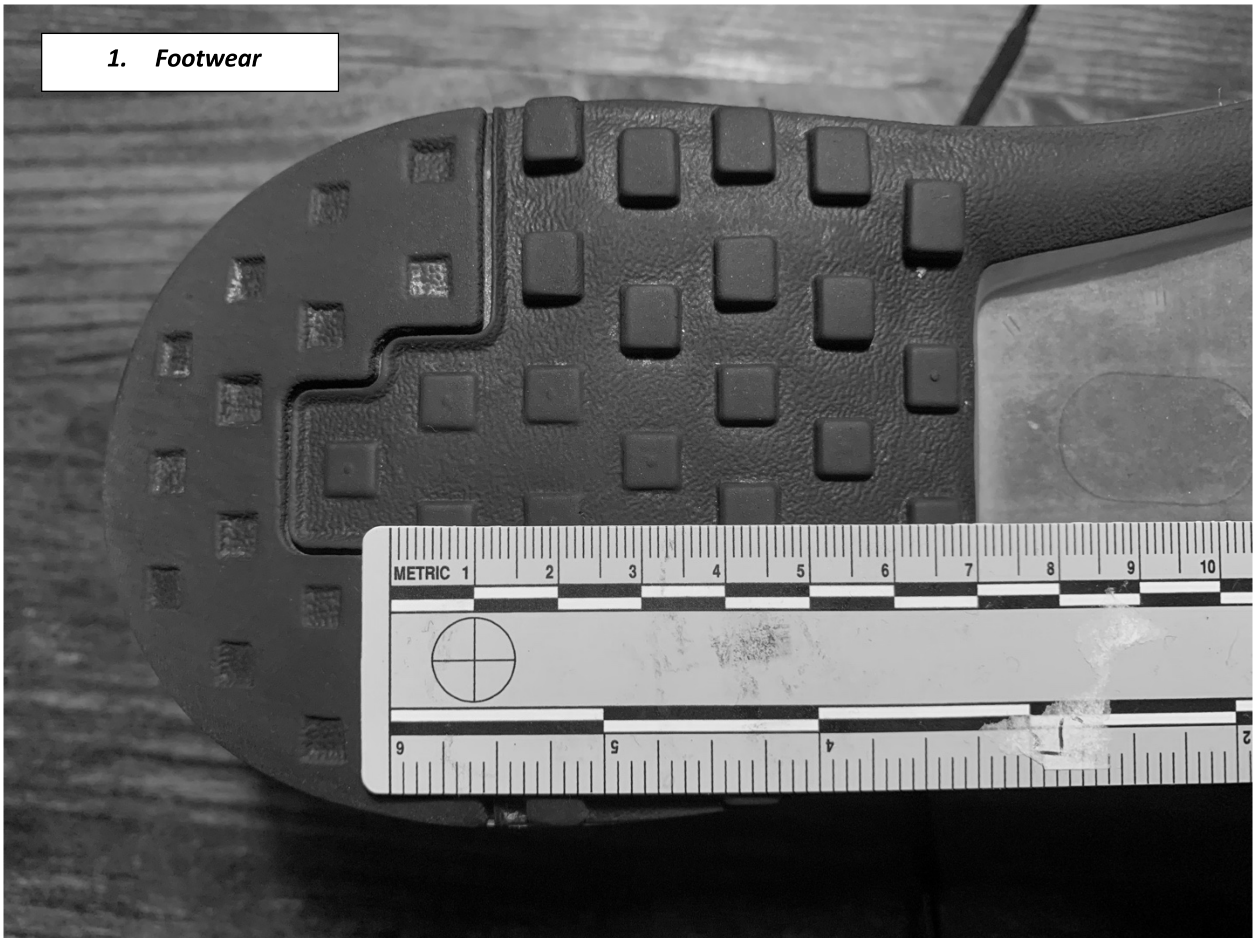




This test measured the mass value of shapes that each device captured. There are no anomalies in each of these measurements. The iPhone mirrored the value of the mass on a smaller scale for each of the shapes. The difference was greater with more surface area due to the iPhone's limited pixel per inch ability.

#4 Distance Analysis

Image J will be used to measure distance. The same subject will be captured on an iPhone and Nikon. The image will be magnified and calibrated. Data points on the image will be measured and compared for distortion analysis.



Five identical Data Points in the iPhone and Nikon footwear photograph were calibrated and measured at 6, 12 and 18 inches.

t-Test: Two-Sample Assuming Equal Variances All Data

	Variable 1	*Variable 2*
Mean	1.2816	1.28593333
Variance	0.68089126	0.77561292
Observations	15	15
Pooled Variance	0.72825209	
Hypothesized Mean Difference	0	
df	28	
t Stat	-0.0139063	
P(T<=t) two-tail	0.98900334	

t Critical two-tail	2.04840714	

t-Test: Two-Sample Assuming Equal Variances 6"

	Variable 1	*Variable 2*
Mean	1.2312	1.287
Variance	0.7223167	0.9280315
Observations	5	5
Pooled Variance	0.8251741	
Hypothesized Mean Difference	0	
df	8	
t Stat	-0.0971251	
P(T<=t) two-tail	0.92501625	
t Critical two-tail	2.30600414	

t-Test: Two-Sample Assuming Equal Variances 12"

	Variable 1	*Variable 2*
Mean	1.2808	1.2854
Variance	0.7916092	0.9103673
Observations	5	5
Pooled Variance	0.85098825	
Hypothesized Mean Difference	0	
df	8	
t Stat	-0.0078844	
P(T<=t) two-tail	0.99390233	
t Critical two-tail	2.30600414	

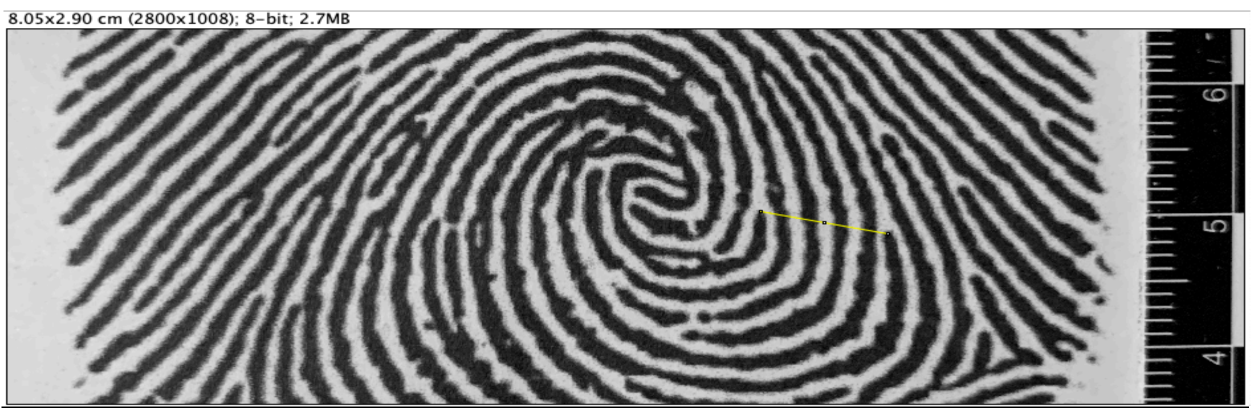
t-Test: Two-Sample Assuming Equal Variances 18"

	Variable 1	*Variable 2*
Mean	1.3328	1.2854
Variance	0.8627407	0.8762443
Observations	5	5
Pooled Variance	0.8694925	
Hypothesized Mean Difference	0	
df	8	
t Stat	0.08037397	
P(T<=t) two-tail	0.93791412	

t Critical two-tail	2.30600414

2. Fingerprint #1

Google image - https://www.ci.mequon.wi.us/police/page/public-fingerprinting



Sample measurement

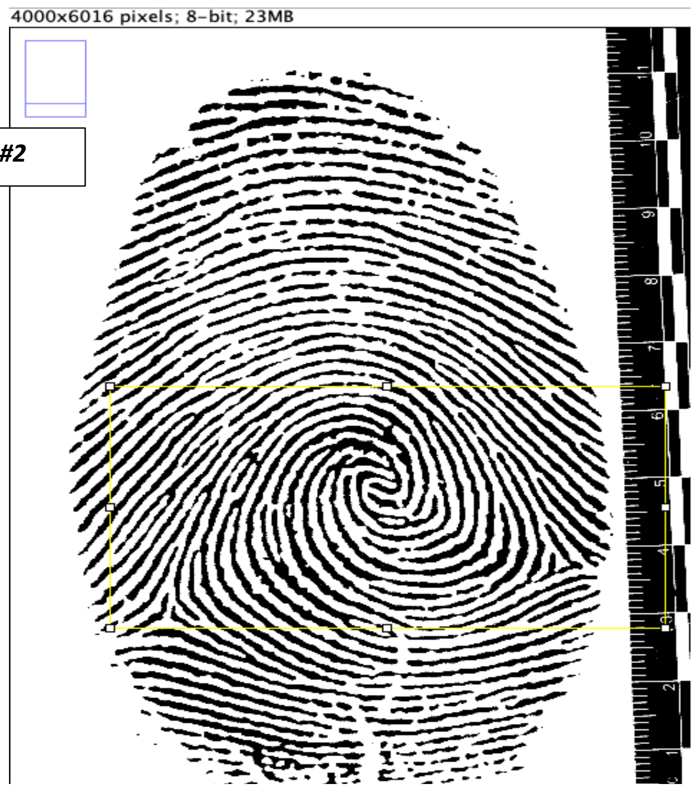
10 data points were measured and compared for the analysis

t-Test: Two-Sample Assuming Equal Variances

	iPhone L	*Nikon L*
Mean	0.9287	0.9188

Variance	0.75427734	0.73977329
Observations	10	10
Pooled Variance	0.74702532	
Hypothesized Mean Difference	0	
df	18	
t Stat	0.02561253	
P(T<=t) two-tail	0.97984821	
t Critical two-tail	2.10092204	

3. Fingerprint #2



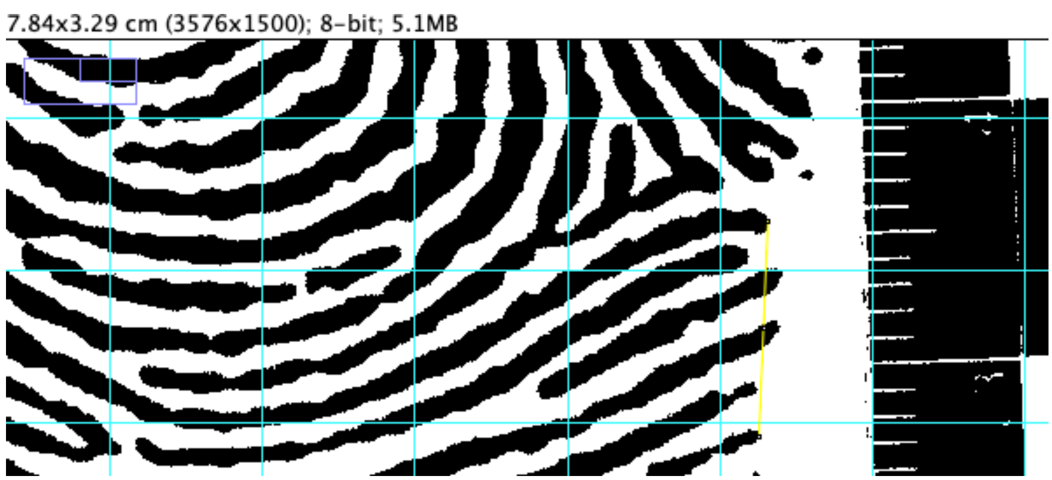
10 data points were measured and compared for the analysis

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.9439	0.9531
Variance	0.59829032	0.61761143
Observations	10	10
Pooled Variance	0.60795088	
Hypothesized Mean Difference	0	
df	18	
t Stat	-0.0263839	
P(T<=t) two-tail	0.97924147	

t Critical two-tail	2.10092204

4. Fingerprint #3



Sample measurement

12 data points were measured and compared for the analysis

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.64008333	0.63933333
Variance	0.16438427	0.1627037

Observations	12	12
Pooled Variance	0.16354398	
Hypothesized Mean Difference	0	
df	22	
t Stat	0.00454276	
P(T<=t) two-tail	0.99641636	
t Critical two-tail	2.07387307	

Combined

iPhone		*Nikon*	
Mean	0.97087234	Mean	0.971915
Standard Error	0.11029396	Standard Error	0.113197
Median	0.739	Median	0.686
Mode	0.667	Mode	#N/A
Standard Deviation	0.75613728	Standard Deviation	0.77604
Sample Variance	0.57174359	Sample Variance	0.602239
Kurtosis	0.94940578	Kurtosis	1.050691
Skewness	1.37442574	Skewness	1.420121
Range	2.856	Range	2.921
Minimum	0.171	Minimum	0.171
Maximum	3.027	Maximum	3.092
Sum	45.631	Sum	45.68
Count	47	Count	47
Confidence Level(95.0%)	0.22201022	Confidence Level(95.0%)	0.227854

This test magnified the above images to measure small data points for comparison. This application was to determine if the iPhone is suitable for evidence quality comparison images or if an iPhone image could be used for fingerprint analysis. The difference between the data distances shows no significant difference between the two devices.

This t-Test is a statistical analysis that measures the difference between the two groups of measured distances. This two-tailed analysis measures both the positive and negative values to determine if the results' probability is random. The results show a P-value greater than .5, which indicates no statistically significant difference between the two distances. Thus, it fails to reject the null hypothesis.

Overall Results

The iPhone performed as expected with the hypothesis in several categories but failed to meet the Nikon standard in others. The popular vote showed that 60% of the time, a random population enjoyed looking at an iPhone image more than a Nikon. The popular vote also scored extremely high with the fair and accurate model. The Histogram results break down the red, green, and blue values in each of the images. The analysis measured the difference between the two images by the mean and standard deviation. The ambient light was one of the best categories with the least difference between the two images, with one blue outliner in the landscape image. Differences between the two started to show in the Direct Sunlight category, specifically the white shirt. This was a difficult category for both devices, and the difference in the value of red, green, and blue was much higher than Ambient Light. The Normal Day category also correlated well with the one outliner of the sky image where there was no subject for the camera to focus. Indoor Flash was difficult for the iPhone due to its much smaller flash. All of the iPhone images here failed to capture enough light and opened the shutter too long, which allowed the camera to shake. The Zoom category scored well. The iPhone has a greater zoom that captures more detail than the Nikon. Several Nikon images were slightly blurred once zoomed, which could have also thrown off the histogram results. The final category of Nighttime photography again shows poor results from the iPhone. The Nikon captured the data ‘as is,’ whereas the iPhone tried to compensate for the lighting, which produced images that were not true to the color or lighting. The Comprehensive graph shows the Standard Deviation was low across the board, indicating all of these data points were very close to the mean. The Particle Analysis study took the image, adjusted the threshold, calibrated, and measured the particles. The Nikon image produces more pixels per inch, as previously discussed, so the data per measurement will be considerably higher than the iPhone. This study aimed to see how the iPhone's pixel value increased and decreased when compared to the same shape captured by a Nikon. Each of the images measured was graphed and show the iPhone generally mirrored the Nikon and increased with more volume and decreased with less. It also showed the higher the volume, the further apart the values become. The Distance Analysis proved to be a great evaluation of the two devices for quality comparison against distortion. The footwear was photographed at several heights, and data points were measured on each of the images. The data resulted in no significant difference between the measurements. This shows that an iPhone image can be used to measure distances in evidence for quality comparison accurately. The fingerprint images were also measured at 10-12 data points, 3 different times, and again showed no significant difference. This proves that an iPhone image can be used to capture a fingerprint for examination.

Result Discrepancies

The noted discrepancies in the first study were the limited photographs used. The population sample was high, but more images or different images could have changed the popular opinion. The Histogram excluded images with different focal lengths to separate outliners. The lighting made a difference in color. Any image that did not come with normal lighting that did not depend on the camera to manipulate its settings increased the color value difference—the particle analysis measured area based on the threshold. There could be a difference of interpretation in value input by the *Image J* software, but not enough to make a significant difference. The Distance Analysis was subject to human error. The data points were placed on the image by hand before they were measured, much like they are in the lab. The image was zoomed in for accurate placement, but the possibility of extreme minimal differences exists.

Study Limitations

This study was limited to a basic comparison of the two devices' ability to capture subject data. Each of these categories could be explored extensively in separate studies on their own. This study also limited the type of smartphone camera to the iPhone; however, many smartphones have excellent cameras that could also be analyzed. When this study was conducted, circumstances beyond control limited laboratory examination; therefore, this entire study was completed with an iPhone, Nikon, and computer, having no additional lab equipment. This study was also completed without camera manipulation, additional flash, or lenses.

Concepts for Future Directions

Future directions begin with new technology. This study compared the images of an iPhone XS Max, which was released two years ago. The iPhone has released two new devices since then, with the latest being the iPhone 12. This device comes equipped with a much better three-lens camera system that includes a wide-angle, ultra-wide, and telephoto lens. The analysis and comparison of the iPhone's new camera have an enhanced nighttime photography system that could improve the results produced in this study. This study should look into the effect an external flash or lens would have on the iPhone photograph. Several companies make attachments for the iPhone to improve the image quality in poor lighting, which could change this study's results. This study should also continue with what switching to an iPhone could mean for crime scene documentation, the systems the iPhone is compatible with, and how it could revolutionize the industry.

Conclusion

The camera tells the 'thousand words' and is the most critical component of crime scene documentation. The days of relying on witness testimony are diminishing. 'Cognitive research demonstrates that visual perception is largely "constructive," with the brain "filling in" gaps in a scene or a face' (Albright, 2017). Reliable, quality photographs have a stronger value. Crime scenes need quality photographs, and this study showed the iPhone is ready to meet the challenges in several areas.

Overall, the iPhone performed extremely well in normal lighting. Its exposure reliability was consistent, and the software increased its ability to interpret abnormal lighting even though the flash was not enough to make a substantial difference. This study used several tests to compare what the iPhone would do with various lighting and measure the results against a Nikon. Both devices were analyzed on Automatic mode, and any additional photography manipulation was not used. The Nikon has an extensive manual mode where different lighting can easily be compensated, whereas the iPhone is extremely limited. The iPhone also saturates colors for a more vibrant feel, as seen on the histograms, and sacrifices blurred images through extensive shutter times when light is limited. There are specific areas where the iPhone is excellent, such as normal daytime photography, where additional lighting is not required. Anything beyond that and the iPhone image's color value juxtaposes the Nikon.

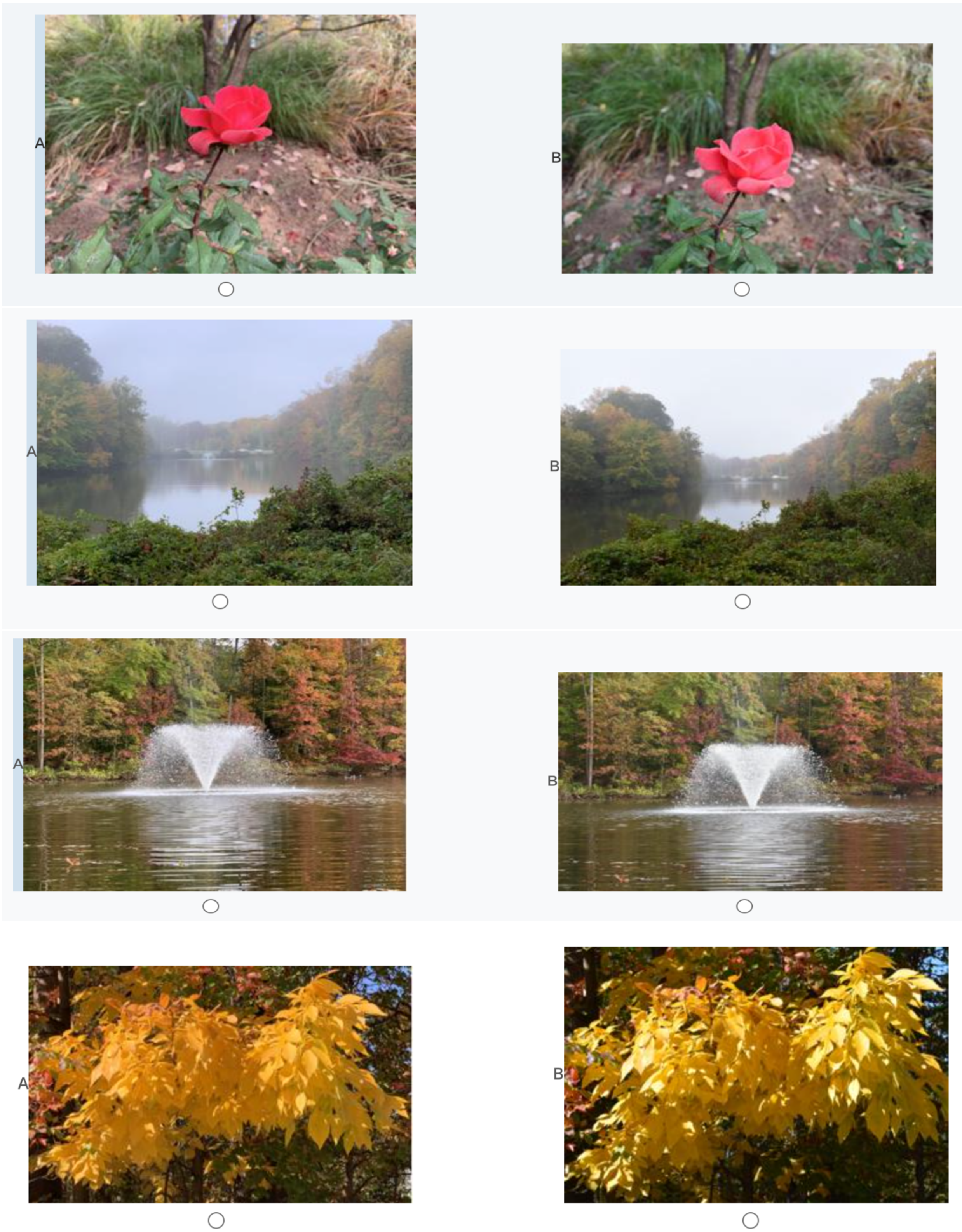
'While the development of applications on smartphones… is phenomenal in a wide range of fields, the world of forensic science, more specifically concerning crime scene investigation, seems only to be timidly interested in these new technologies (Baechler, 2017).' It is studies like this and continued studies that will help integrate this technology in the field. The results of this study showed the iPhone is capable of capturing quality images under normal lighting. It handled the lighting challenges well but was limited by the lens's size and the amount of light the flash was able to produce. The distance analysis also proved that the iPhone could take critical comparison photographs with limited distortion.

The iPhone also has one other critical component; most Law Enforcement offices already have them. Not only is the iPhone base price much lower than the Nikon, but it also does not need additional parts for full functionality like the Nikon (flash, micro-lens). iPhone owners are used to keeping the battery charged. There is no need for additional training since it is the same camera they take personal photographs with, and the process is easier for a jury to understand. Smartphone images are what people of the jury are used to seeing.

The possibilities of integrating this technology are endless. The entire photographic system could be cloud-based, saving time and money at police departments. This study proved there are many applications where the iPhone is equally capable as the Nikon. While the iPhone is not ready for every possible lighting situation, technology's future is ever developing. One day, this technology could see the full integration of smartphones and crime scenes where the iPhone documents the crime scenes.

Popular Vote Images

https://qfreeaccountssjc1.az1.qualtrics.com/jfe/form/SV_8IeUbpU6Bl68qbz



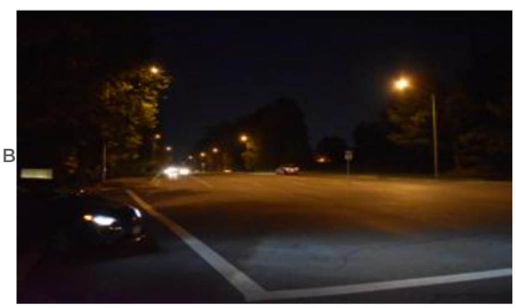
A


B


A


B


A


B


A


B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