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DETECTING LATENT BLOODSTAINS THROUGH PRIMERS DESIGNED TO BLOCK STAINS, AND PAINT PLUS PRIMER MIXED PAINTS USING BLUESTAR® FORENSIC

A THESIS

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ASHLEY NORMAN
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DETECTING LATENT BLOODSTAINS THROUGH PRIMERS DESIGNED TO BLOCK STAINS, AND PAINT PLUS PRIMER MIXED PAINTS USING BLUESTAR® FORENSIC

A THESIS APPROVED FOR THE
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BY

Dr. Dwight Adams, Chair

Mr. Craig Gravel

Dr. John Mabry

Mr. Austin Kress

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Abstract

This study was conducted to determine if a paint plus primer or a primer designed specifically to block stains would affect the efficacy of Bluestar® Forensic, a blood enhancement reagent, through varying layers of paint. Very little research has been done on Bluestar® Forensic within the forensic science community, meaning research into its limitations is still in its infancy.

This study focused on a dark colour versus a light colour, spatter versus swipe patterns, and four different brands of paint. Sixteen two-foot by two-foot pieces of sheetrock were purchased and sorted into two equal groups. Eight of them were used for swipe pattern testing and eight were used for spatter pattern testing. Within each group of eight, two pieces of sheetrock were put together to create a two-foot by four-foot panel. Each piece of sheetrock was split into one-foot by one-foot sections. Each row was assigned a different paint and or primer. Starting at the left, the first one-foot by one-foot square was split into two control squares, and then in each square from left to right thereafter, each paint was applied with one layer, then three layers, then five layers.

Ultimately, there was one two-foot by four-foot panel for light coloured paint plus primer, one two-foot by four-foot panel for dark coloured paint plus primer, one two-foot by four-foot panel for light coloured stain blocking primer, and one two-foot by four-foot panel for dark coloured stain blocking primer for each pattern tested (spatter and swipe) for a total of eight two-foot by four-foot panels.

The goal of this study was to determine the limitations of Bluestar® Forensic using commonly available paints and/or primers found in any local hardware store. This study found that visually, the dark colour was more effective in concealing bloodstains. The paint plus primers were visually less effective than the stain blocking primers when using a light colour.

The concentration of blood applied to the surface, via swipe over spatter, did make a difference in Bluestar®'s ability to detect the hidden bloodstains with the lighter colour.

Introduction

Perpetrators of violent crimes often try to cover up their crimes in various ways. Within crime scenes, bloodstains may be cleaned up with household chemicals or simple soap and water. However, those more dedicated to the coverup may try to paint over bloodstains in an attempt to eradicate evidence or hide it from view. Below is a summary of the current literature surrounding blood detection agents including brief histories, how they have evolved, and their effectiveness at detecting bloodstains through varying layers of paint and a combination of paint plus primer. These sources have been gathered with the goal of demonstrating how blood detection reagents have evolved throughout the years, including Bluestar® Forensic, and the high success rate of this blood enhancement reagent.

Bloodstain pattern analysis has been used to tell the story of crime scenes for nearly 150 years (Bevel & Gardner, 2008, p. 2). With the correct training, a crime scene investigator can reconstruct the crime scene, and even go as far as sequencing some of the events within the scene. Whether it be minute cast off and spatter or larger surface area stains like transfers or swipes, investigators need all the details of a scene in order to make an accurate reconstruction of the events of the crime. Bloodstains are sometimes covered up or cleaned after the commission of a crime to try to confuse crime scene investigators. From 1902 through 1942 extensive research was conducted into various methods for identifying bloodstains (Hesskew, 1991). Through trial and error, the chemical reagent known as Luminol was discovered (Hesskew, 1991) and used for many years as a blood detection reagent in crime scenes across the globe. Since Luminol, multiple techniques and differing chemicals have been researched and used to assist in the location and identification of different patterns and sizes of bloodstains within crime scenes.

In 2000, a luminol based chemical reagent called Bluestar® Forensic was discovered by Lois Blum ("Bluestar® Chemistry", 2020). This blood detection reagent claims bloodstains may be visible to 1:10,000 dilutions (Blum et al., 2006). However, since Bluestar® Forensic is a relatively new blood detection reagent, there is limited research into the product. Many different researchers have successfully demonstrated detection of bloodstains with Bluestar® Forensic through paint, and some through primer and then paint, but there has been no research that only uses a primer that is specifically designed to block stains, and few have tried to use a paint plus primer in one, to test the efficacy of Bluestar® Forensic.

Review of Literature

History

Bloodstain pattern analysis has a nearly 150-year history that predates many modern forensic disciplines (Bevel & Gardner, 2008, p. 2). Referencing bloodstains in crimes has been written about creatively, even as far back as Shakespeare and Sir Arthur Conan Doyle (Bevel & Gardner, 2008, p. 3). However, it was not until 1970 when Herbert MacDonnell began the push for bloodstain pattern analysis to be recognised as a technically sound discipline. In 1983, the International Association of Bloodstain Pattern Analysts (IABPA) was formed. In 1990, the International Association of Identification (IAI) accepted bloodstain pattern analysis as a discipline, removing it as a subcategory of crime scene analysis, and fully recognizing the specialty as its own forensic science discipline. In 2002, the Federal Bureau of Investigation (FBI) formed the Scientific Working Group for Bloodstain Pattern Analysis (SWGSTAIN) with the purpose of exploring and defining functional guidelines for the discipline. (Bevel & Gardner, 2008, pp. 12-13). However, in 2015, the FBI decided to divest the Scientific Working Groups (SWGs). Bloodstain analysis research moved from the FBI Laboratory to the Midwest Forensic Resource Center in Ames, Iowa. The National Institute of Standards and Technology (NIST) took over the SWG from the Midwest Forensic Resource Center and created sub-organizations called Organizations of Scientific Area Committees for Forensic Science (OSAC). Within the Forensic Science Organizations there is an OSAC specifically for bloodstain pattern analysis ("OSAC Annual Report", 2016). OSAC drafts proposed standards and sends them to standard developing organisations which further develop and publish said standards. Inclusion in the OSAC Registry indicates that a standard is technically sound and that laboratories should consider adopting said standards ("About OSAC", 2022).

Bloodstain pattern analysis is based on the theory that blood is a fluid that will react to external forces in a predictable way. The cohesive forces of surface tension and viscosity, external forces (e.g., impact, accelerated motion, stream ejection), as well as gravity and air resistance will act together to produce repeatable and reproducible patterns (Bevel & Gardner, 2008, p. 1). This means that crime scene investigators can reproduce patterns in bloodstains to reconstruct crime scenes. Being able to reconstruct or sequence events in crime scenes is invaluable as a crime scene tool. The reconstruction can allow crime scene investigators to determine large amounts of information, such as a minimum number of attackers, a minimum number of blows to a victim, the potential order of the attacks within a scene and a number of other crime solving factors. Because of the increasing expertise of crime scene investigators, perpetrators of violent crimes will sometimes try to hide or clean up the bloodstains on scenes. As a result of the attempts to clean up bloodstains, several different kinds of products have been discovered that further bring to light hidden and cleaned up bloodstains. These reagents are crucial tools for visualising bloodstains that are otherwise invisible to the naked eye.

Luminol

Luminol was synthesised for the first time in 1853 and was observed to luminesce on contact with blood by Albrecht in 1928 (“Bluestar® Chemistry”, 2020). In 1942, J. McGrath recommended Luminol as a blood detection agent (Hesskew, 1991). McGrath’s research showed that the aging process of blood forms ‘hematin’. Hematin is a brown substance that is derived from the hemoglobin in the blood. The older the stain, the more hematin is found in the stain, hence the change in colour from red/fresh bloodstains to darker brown/older bloodstains. Luminol reacts with the hematin through chemical processes (Hesskew, 1991) and emits appreciable amounts of light, able to be seen with the naked eye when its electrons are in an excited state. This reaction is referred to as chemiluminescence. Luminol’s chemiluminescence

is a blue-green colour and can only be observed in near or total darkness (Bily & Maldonado, 2006). This is limiting factor of Luminol; the need for total darkness to visualise the chemiluminescence. Other limiting factors include freshness: Luminol must be repeatedly or constantly sprayed to ensure a strong chemical reaction that can be observed. Over wetting of dried blood can result in fading of the chemiluminescence or can create streaking on vertical surfaces and pooling on horizontal surfaces. Luminol also must be freshly mixed as close to the time of the application as possible. Appropriate personal protective equipment must be worn prior to mixing and using Luminol, due to its potential as a carcinogen (Dilbeck, 2006). Despite its limiting factors, Luminol has been successfully used on various surfaces, and visualised through various different mediums. In 2006, Bily and Maldonado successfully observed Luminol reacting to bloodstains through eight layers of paint. In 2010, Howard and Nessan also found that Luminol successfully showed latent blood stains through four layers of a paint and primer combination. Even as late as 2017, Nagesh and Ghosh determined that Luminol was able to detect bloodstains on concrete blocks, wooden planks and metal sheets. All of the bloodstains were able to be observed through a paint and primer combination.

Fluorescein

Due to Luminol's need for total darkness, and its carcinogenic properties, various other products have been proposed and researched. Another such product is Fluorescein. Fluorescein did not originate in the forensic science field. As of 1994, fluorescein already had a twenty-year history in the medical field of ophthalmology and was Food and Drug Administration (FDA) approved for clinical application in retinal and choroidal angiography. It has been used as such in the clinical setting since the 1940s (Reichel, 1994). When Fluorescein did enter the forensic science field, it too had limitations. It requires two separate spray applications and like Luminol, it requires a light mist in order to keep the reagent from running. Fluorescein also requires a

commercial thickener for most applications. One of the thickener sprays often used is sodium hydroxide, which is extremely caustic. Because of the caustic nature of the sodium hydroxide, personal protective equipment should be worn when working with Fluorescein.

Fluorescein fluoresces a yellow-orange colour and does not require complete darkness to work, unlike Luminol. However, because of its fluorescence, it requires an alternate light source to visualise the stains, which makes the use of light filtering goggles necessary (Cheeseman & DiMeo, 1995). Fluorescence occurs when light of a certain colour and frequency strikes an object and returns light of a different colour and frequency. Because the returned light is so much weaker, the goggles are used to filter out the visible light, and allow the fluorescence to be visible (Penven, 2013). The fluorescence does last approximately five to seven minutes, longer than Luminol's thirty seconds, making it easier to photodocument the results (Tomboc, 2011).

Fluorescein has been shown to fluoresce under four layers of paint and a layer of primer (Howard & Nessan, 2010). According to Cheeseman in 2015, Fluorescein is at least twice as sensitive as Luminol and as much as five times more sensitive than Luminol in some respects. As such, Fluorescein seems to have many apparent benefits over Luminol but also has its own unique limitations in the requirement of the alternate light source and goggles.

Bluestar® Forensic

In 2000, Jean-Marc Lefebvre-Despeaux, president of Bluestar® and chairman of ROC Imports, asked Loic Blum to find a new formula that would be luminol based, but eliminate the inconveniences of Luminol. Blum created a new formula called Bluestar® Forensic ("Bluestar® Chemistry", 2020). Bluestar® Forensics' original purpose was to aid hunters by helping locate wounded animals in various conditions. The Bluestar® Forensic produced for hunters has a pH of 12.6 which makes it unsuitable for DNA processing of blood. An import-export supplier of products for shooting, hunting, safety and performance, ROC Import Group then created a

special version of Bluestar® Forensic for police work by developing a formula that has a pH of 11.5. Now, because of the adjusted pH, Bluestar® Forensic is suitable for DNA STR typing (Dilbeck, 2006). Bluestar® Forensic produces a more intense and longer-lasting luminescence than Luminol and does not need total darkness to be visible to the naked eye (Blum et al., 2006). It can be sprayed several times on the same area, making observations and photography easier. It is more stable, meaning it can be used several days after preparation ("Bluestar® Forensic Performances-Sensitivity", 2020). Bluestar® Forensic does not require mixing to be done in a laboratory and can instead be mixed as needed in the field. It also does not require the use of personal protective equipment, alternative light sources, or light filtering goggles (Bluestar® Forensic "Training", 2006). It has been shown repeatedly to be more successful than luminol or fluorescein at detecting bloodstains in optimal conditions.

In 2010, Howard and Nessan tested Luminol, Fluorescein and Bluestar® on sheetrock using white paint and maroon paint. They discovered that Luminol was able to react with bloodstains covered with four layers of white paint but was only able to react through two layers of maroon paint. Fluorescein also reacted through all four layers of white paint, but also only two layers of maroon paint. Bluestar® Forensic reacted through four layers of white paint and three layers of maroon paint. Howard and Nessan's results showed Bluestar® Forensic to have the best results of all three of the blood reagents tested.

In 2017, Pettolina, Rainey and Sanchez tested Bluestar® Forensic on drywall using three unique paints. Paint one was a dark purple colour, 100% acrylic latex enamel paint plus primer. Paint two was a blue-green colour, 100% acrylic paint with an eggshell base, primer and stain blocking power. Paint three was eggshell in colour, 100% acrylic enamel paint with an eggshell base. Their results showed that through all four layers of paints one and three, Bluestar® Forensic was able to luminesce upon contact with the bloodstains. With paint two, it was only

able to detect bloodstains through the second layer. It should be noted that while they used a paint and primer and stain blocker, it was an all-in-one product, making it impossible to determine which part of the combination negated the effect of Bluestar® Forensic.

Most recently, in 2020, Dombaxe, Vecellio, Kasamba and Walker, tested three different commercially available paint plus primers in flat white, antique white and a warm caramel colour. They found that through nine layers of paint plus primer Bluestar® Forensic was successful 100% of the time with the flat white, and 95% of the time with the antique white and the warm caramel. This study, while testing paint plus primers, did not test stain blocking primers.

Research Questions

Bloodstains are one of the best sources of evidence in a crime scene. The reproducibility of the patterns made by blood allows crime scene investigators to use that evidence to reconstruct and even sequence the pattern of events in a scene. When the bloodstains are covered with paint in the hopes of eliminating them from a crime scene investigator's view, other chemical processes are needed to make them visible. Over the years, many different reagents have been used for this purpose. The newest and seemingly most sensitive is Bluestar® Forensic.

The limited published research has shown Bluestar® Forensic effective at detecting bloodstains through as many as nine layers of paint plus primer; however, there is inconclusive research that has been done on the use of stand-alone primers, and none on primers that have been made to specifically block stains. With the commonality of paints and primers being available in one unit, and the emergence of specific stain blocking primers, further research into the blood detection reagent is needed.

The questions this experiment seeks to answer are: does the colour of the paint (a light colour versus a dark colour) have any effect on the efficacy of Bluestar® Forensic? How does

using a paint plus primer compare to the results of previous studies? Does a stain blocking primer cover bloodstains more effectively than a paint plus primer? Does the amount of blood under the paint (spatter versus swipe) affect the efficacy of Bluestar® Forensic?

It is predicted that the dark colour will negatively affect the efficacy of Bluestar® Forensic and that a stain blocking primer will cover bloodstains more effectively than a paint plus primer. It is also predicted that the amount of blood will have an impact on the efficacy of the reagent, and that the results of previous studies will be reproduced.

Methodology

Sixteen pieces of two-foot by two-foot sheetrock were purchased and one-foot by one-foot squares were measured out and marked with Frog Tape to separate each piece of sheetrock into four quadrants. Two two-foot by two-foot pieces were placed together to create a two-foot by four-foot panel. This process was repeated to create a total of eight panels. The first column in each panel was designated as the control squares. The control squares were split into two additional sections, each measuring one-foot by half a foot. One of the sections was a control for the blood and the other section was a control for the stain blocking primer or the paint plus primer. This ensured that the blood correctly reacted with Bluestar® Forensic and that the stain blocking primer and paint plus primer did not introduce errors when the test was conducted. The panels were then further split into two groups. Four of the panels were allocated to receive high impact blood spatter and four of the panels were allocated to receive swipe patterns.

To replicate high impact blood spatter, a micropipette was used to place 1,000 µl of liquid cow blood onto a platform at the end of two hinged pieces of wood, also known as a mousetrap. The mousetrap was placed approximately 24 inches away from the square being spattered. The mousetrap was then allowed to fall closed using only gravity. To keep cross contamination to a minimum, a barrier was applied to the squares not being spattered, leaving only the relevant square uncovered. Between each application of blood and subsequent spattering, a new micropipette tip was applied to the micropipette, and the mousetrap was thoroughly cleaned. The used tips were discarded.

After the blood was applied to the panels, labels were made for each square. Each label consisted of a colour and three characters. The high impact spattered squares were given the colour yellow. They were then documented using the letter ‘E’ or ‘G’ to represent the eggshell colour or dark grey colour of the paint and/or primers. The letters ‘S’, ‘V’, ‘K’, or ‘Z’ were

added to represent the brand of paint and/or primers. Then either a ‘C’ for the paint and/or primer control, a ‘0’ for the blood control, or a ‘1’, ‘3’, or ‘5’ was used to correspond to the number of layers of paints and/or primers that were applied. Figures 1-4 show the spattered panels prior to paint application.

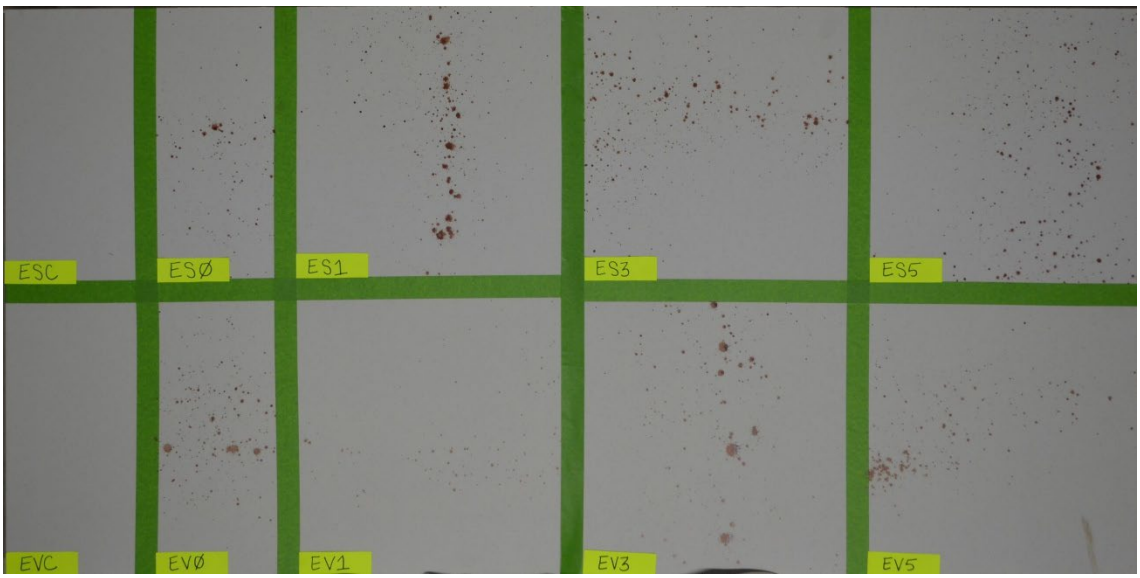

Figure 1. Spatter, Eggshell Colour, Sherwin Williams & Valspar Paint and Primer

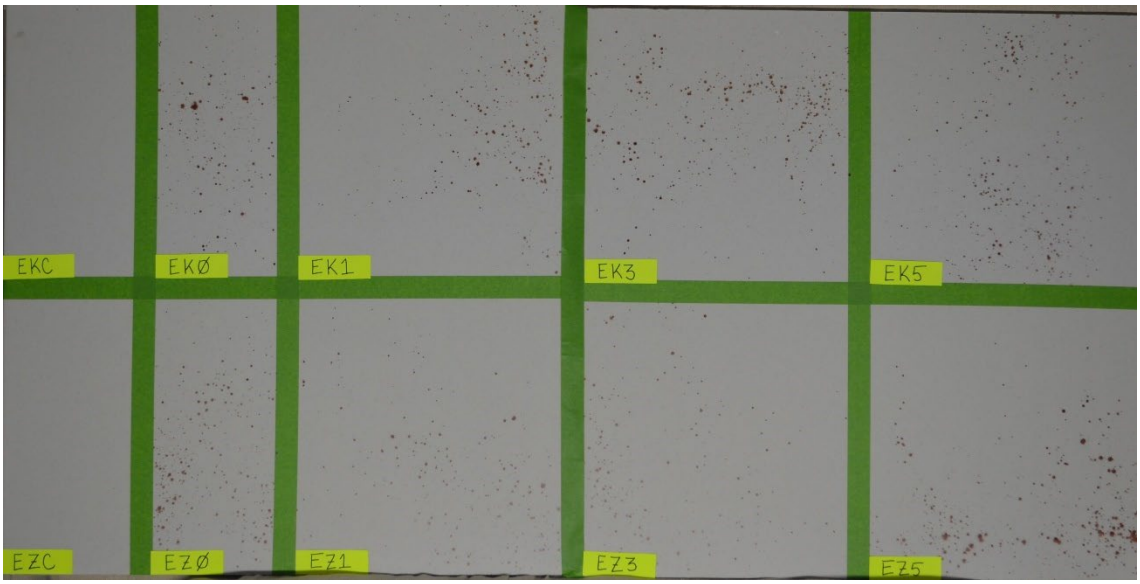

Figure 2. Spatter, Eggshell Colour, Kilz & Zinsser Primer

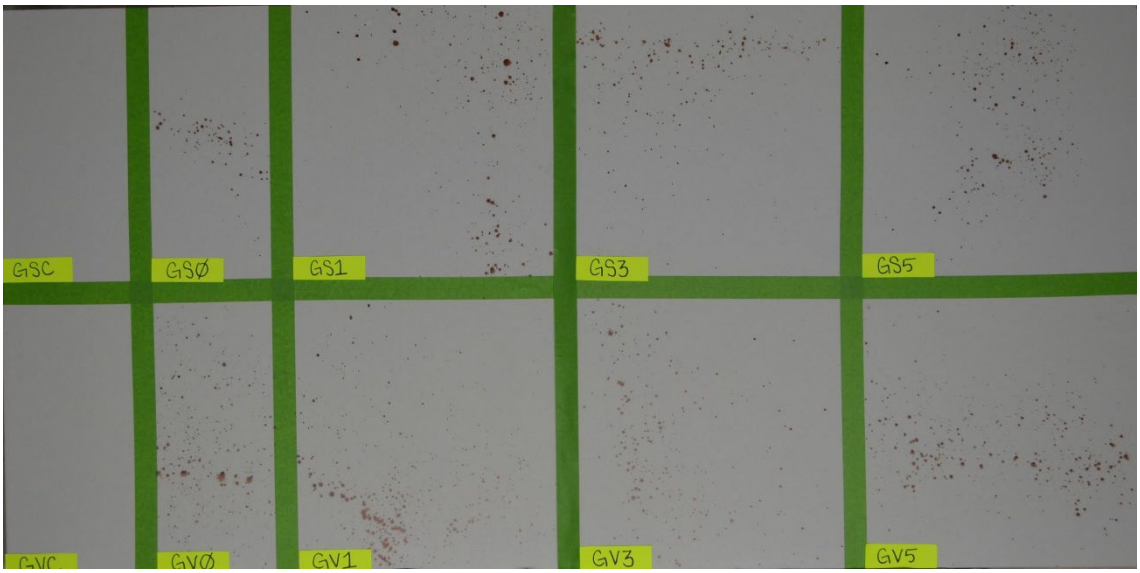

Figure 3. Spatter, Grey Colour, Sherwin Williams & Valspar Paint and Primer

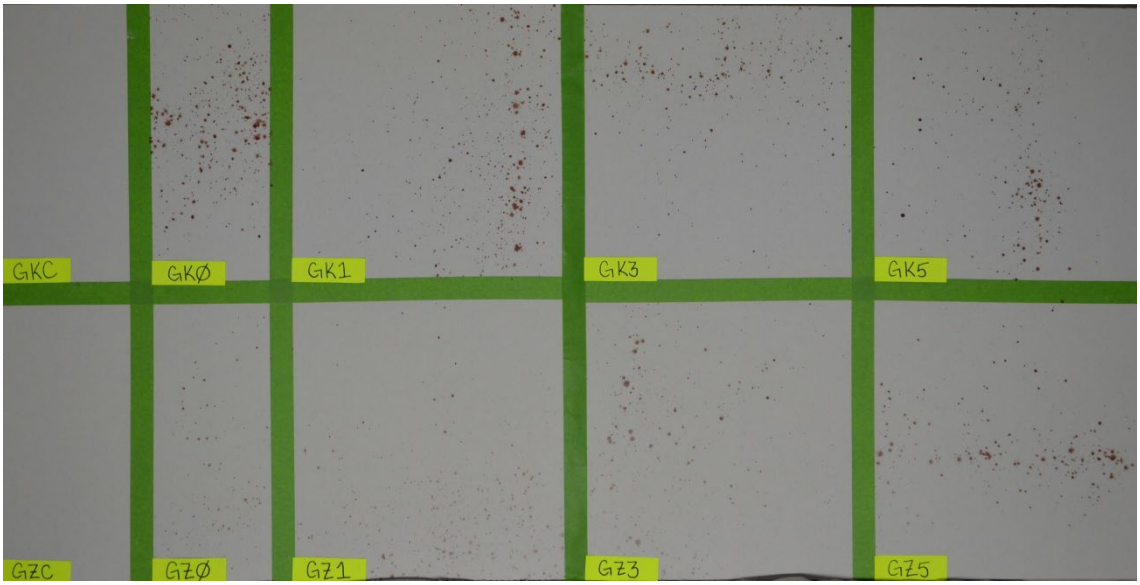

Figure 4. Spatter, Grey Colour, Kilz & Zinsser Primer

To replicate swipe patterns, a micropipette was used to place 1,000 µl of liquid cow blood onto a new paint and cleaning rag and then wiping the rag across the square. Between applications of blood, a new micropipette tip was applied to the micropipette, and a fresh rag was obtained. The used rags and used tips were discarded.

After the blood was applied to the panels, labels were made for each square. Each label consisted of a colour and three characters. The swipe patterned squares were given the colour

orange. They were then documented using the letter ‘E’ or ‘G’ to represent the eggshell colour or dark grey colour of the paint and/or primers. The letters ‘S’, ‘V’, ‘K’, or ‘Z’ were added to represent the brand of paint and/or primers. Then either a ‘C’ for the paint and/or primer control, a ‘0’ for the blood control, or a ‘1’, ‘3’, or ‘5’ was used to correspond to the number of layers of paints and/or primers that were applied. Figures 5-8 show the swipe panels prior to paint application.

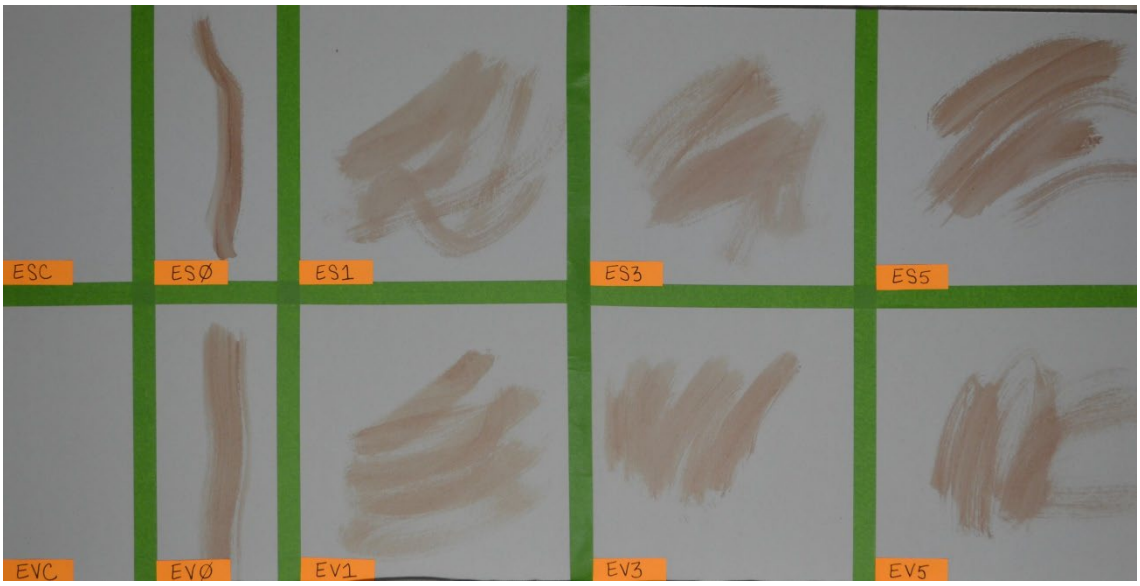

Figure 5. Swipe, Eggshell Colour, Sherwin Williams & Valspar Paint and Primer

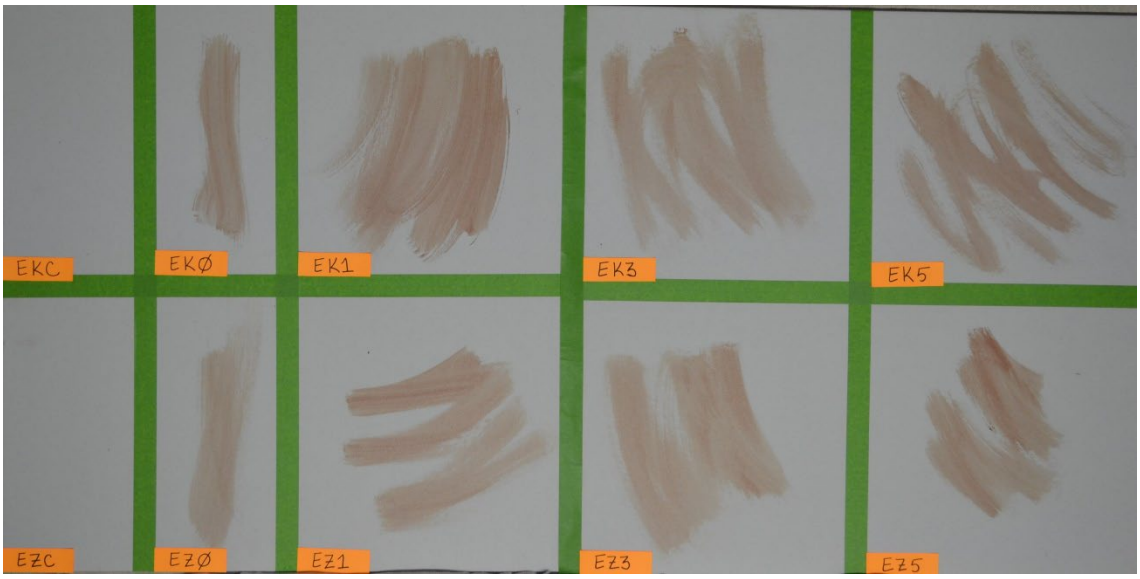

Figure 6. Swipe, Eggshell Colour, Kilz & Zinsser Primer

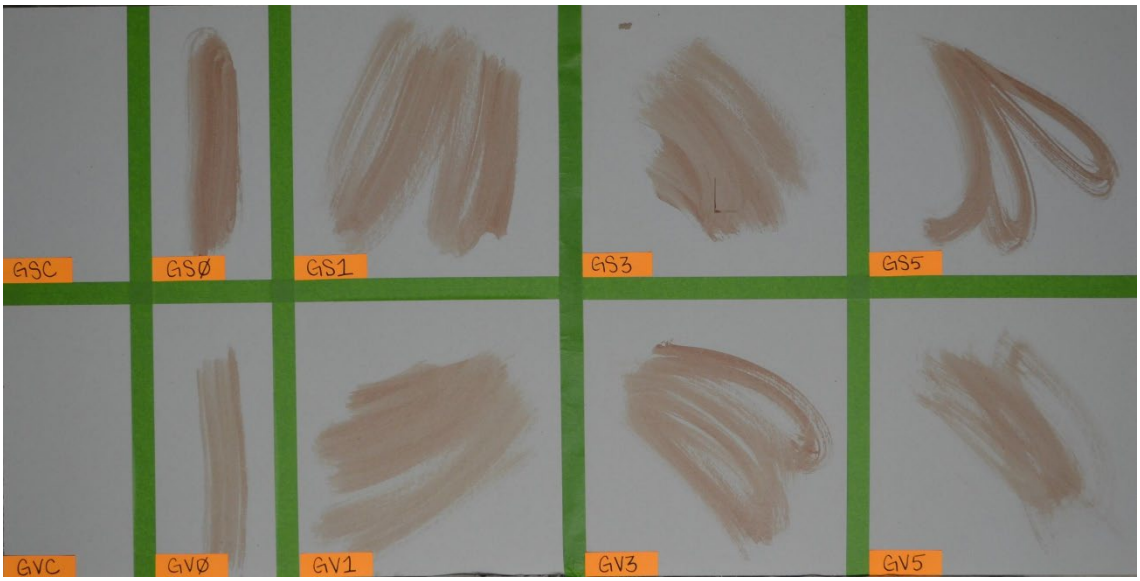

Figure 7. Swipe, Grey Colour, Sherwin Williams & Valspar Paint and Primer

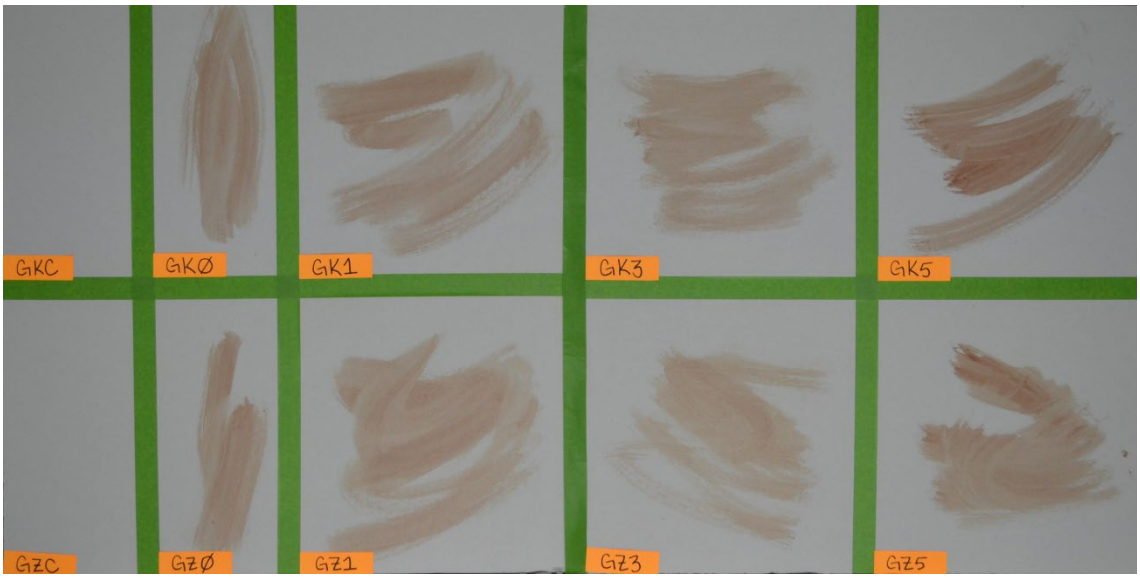

Figure 8. Swipe, Grey Colour, Kilz & Zinsser Primer

Four quarts of paint plus primers (two of each brand) and four quarts of stain blocking primers (two of each brand) were purchased. Those four brands were: Valspar Reserve, one-layer interior paint plus primer, eggshell (designated ‘V’); Sherwin Williams Ovation Plus, interior paint and primer, eggshell (designated ‘S’); Kilz Original interior primer (blocks heavy stains and odors) (designated ‘K’); and Zinsser B-I-N primer, ultimate stain blocker (designated ‘Z’). One quart of each of the paint plus primers were eggshell coloured. One quart of each of the

stain blocking primers were left in their original white. The second quart of each of the four brands was tinted with SW7075 ‘Web Gray’. This provided one light coloured quart, and one dark coloured quart, in each of the four brands, for a total of eight quarts.

The blood was allowed to dry for a minimum of 24 hours, and then, a disposable syringe was used to deposit approximately 8 mL of each paint plus primer and each stain blocking primer to the control square on their coordinating panels. A disposable 3” foam brush was used to apply the paint and/or primer using upward and downward strokes. After each brush was used for one square, the brush was discarded. At no point was a foam brush reused in any part of this experiment. The disposable syringe was used for each panel, but the syringe tip was never in contact with the surface of the squares. Each subsequent square labeled with a ‘1’, ‘3’, or ‘5’ received approximately 15 mL of paint and/or primer per layer. Each layer of paint and/or primer was allowed to dry for a minimum of 24 hours before the next layer was applied.

After the fifth layer of paint and/or primer was applied to the last square in each panel and allowed to fully dry, photographs were taken of each panel. Figures 9-16 show the spattered and swiped panels after paint application.

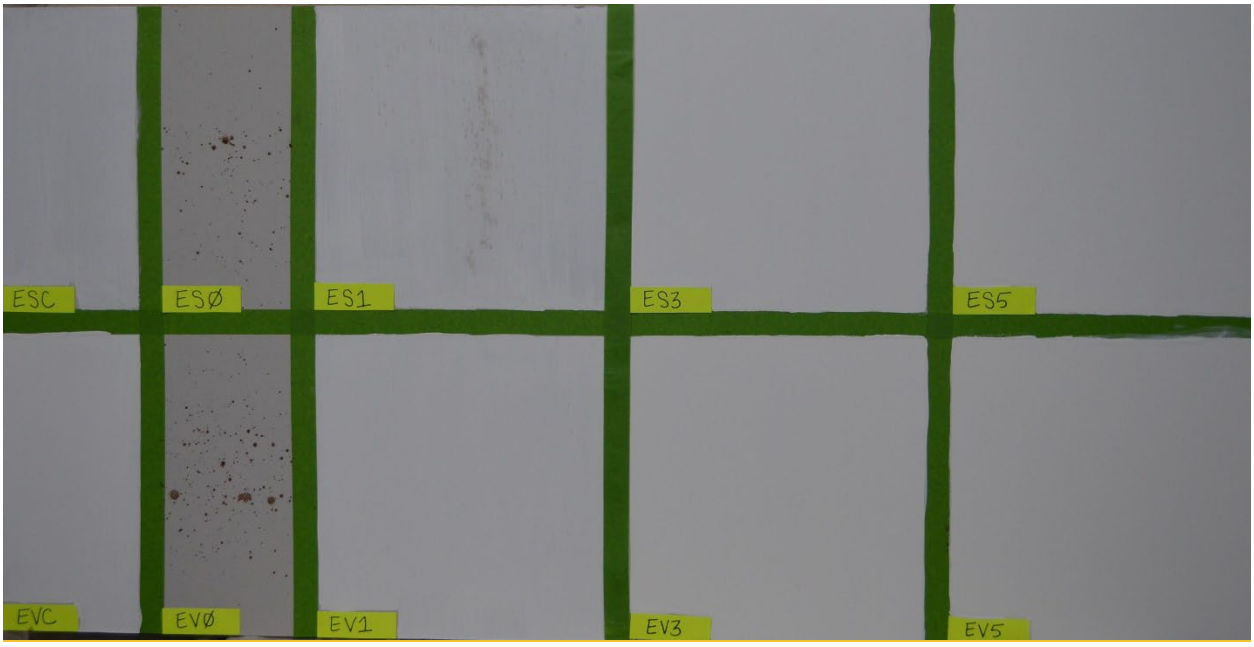

Figure 9. Spatter, Eggshell Colour, Sherwin Williams & Valspar Paint and Primer

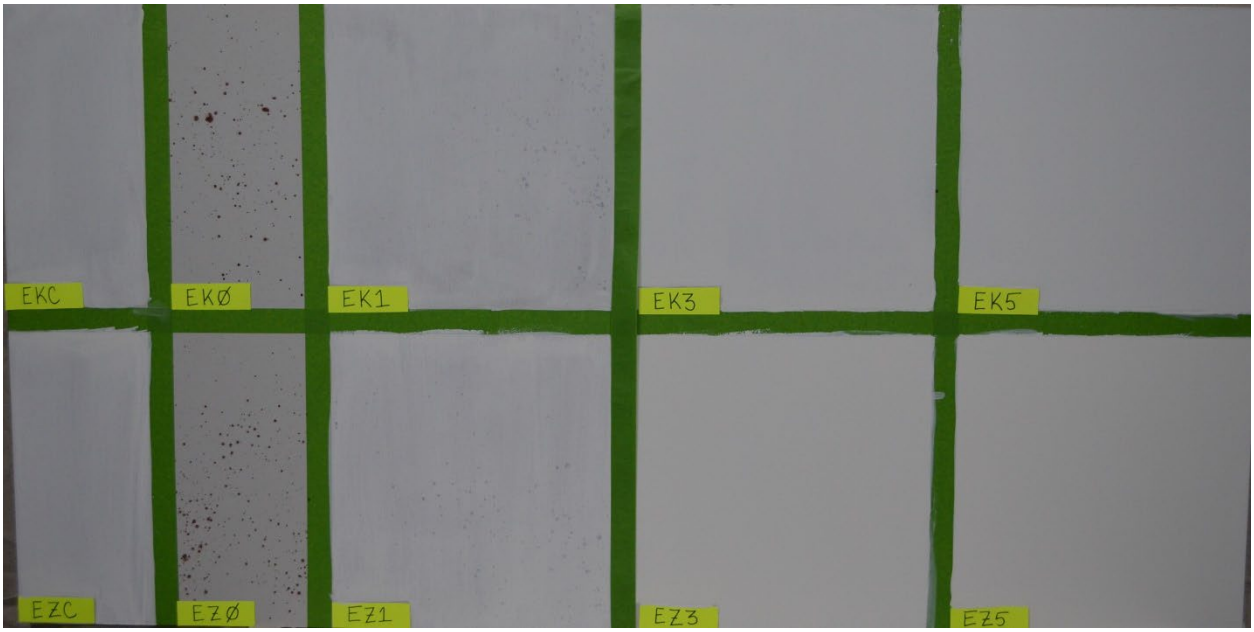

Figure 10. Spatter, Eggshell Colour, Kilz & Zinsser Primer

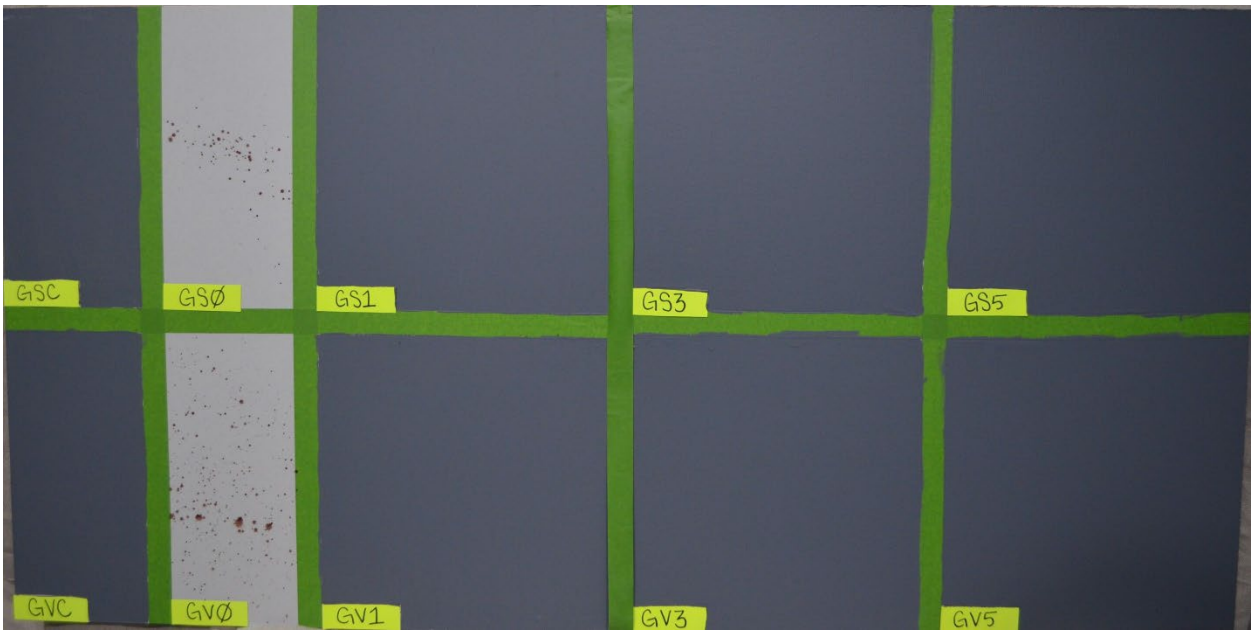

Figure 11. Spatter, Grey Colour, Sherwin Williams & Valspar Paint and Primer

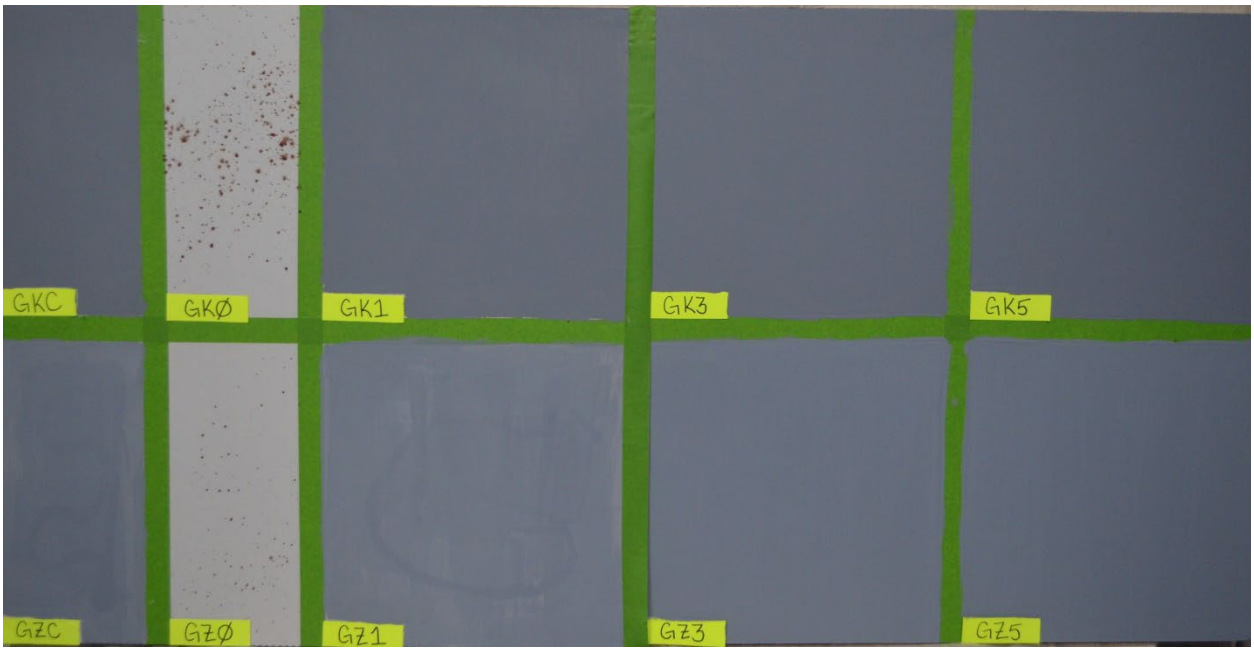

Figure 12. Spatter, Grey Colour, Kilz & Zinsser Primer

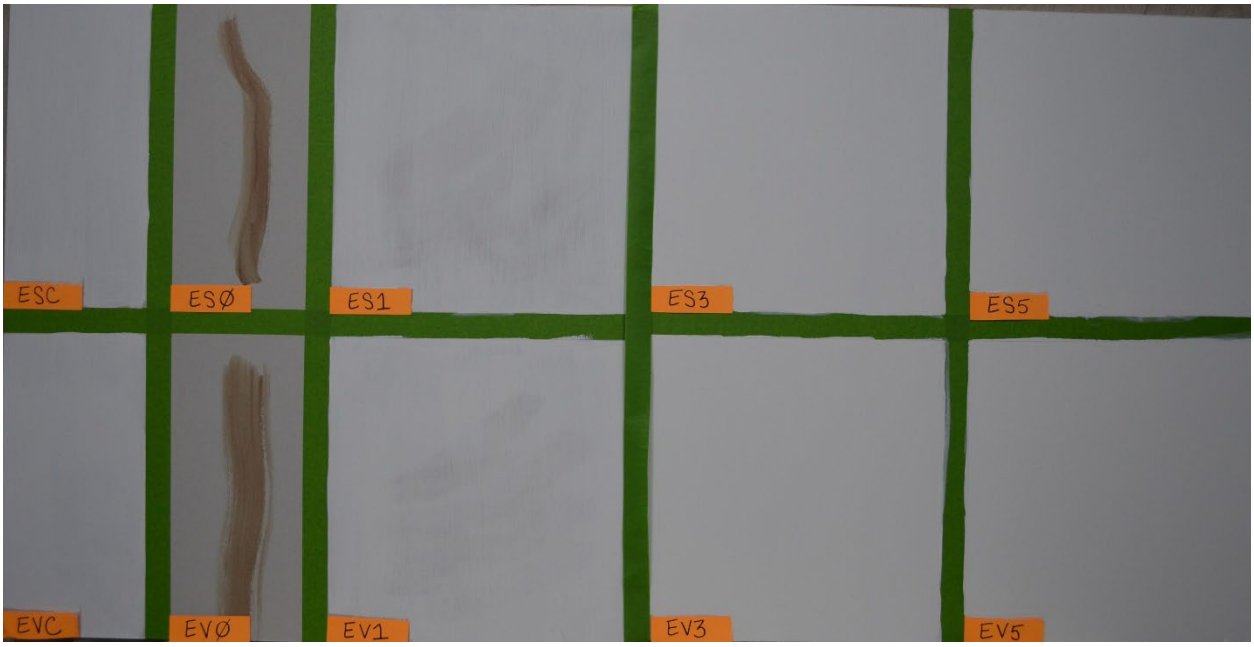

Figure 13. Swipe, Eggshell Colour, Sherwin Williams & Valspar Paint and Primer

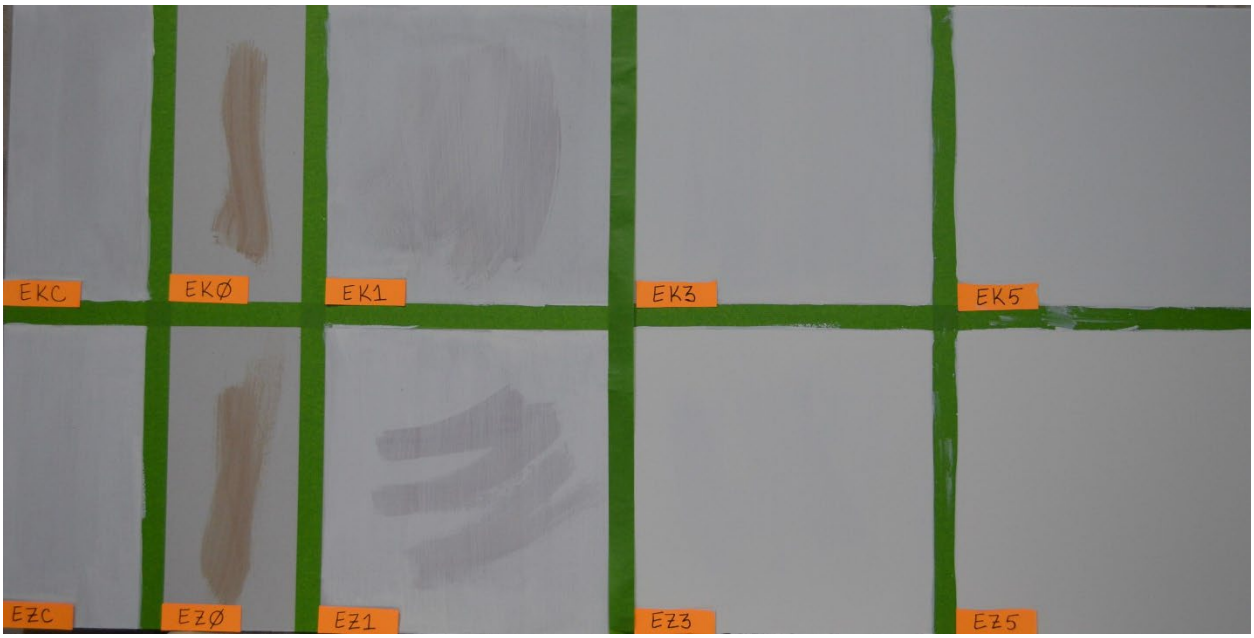

Figure 14. Swipe, Eggshell Colour, Kilz & Zinsser Primer

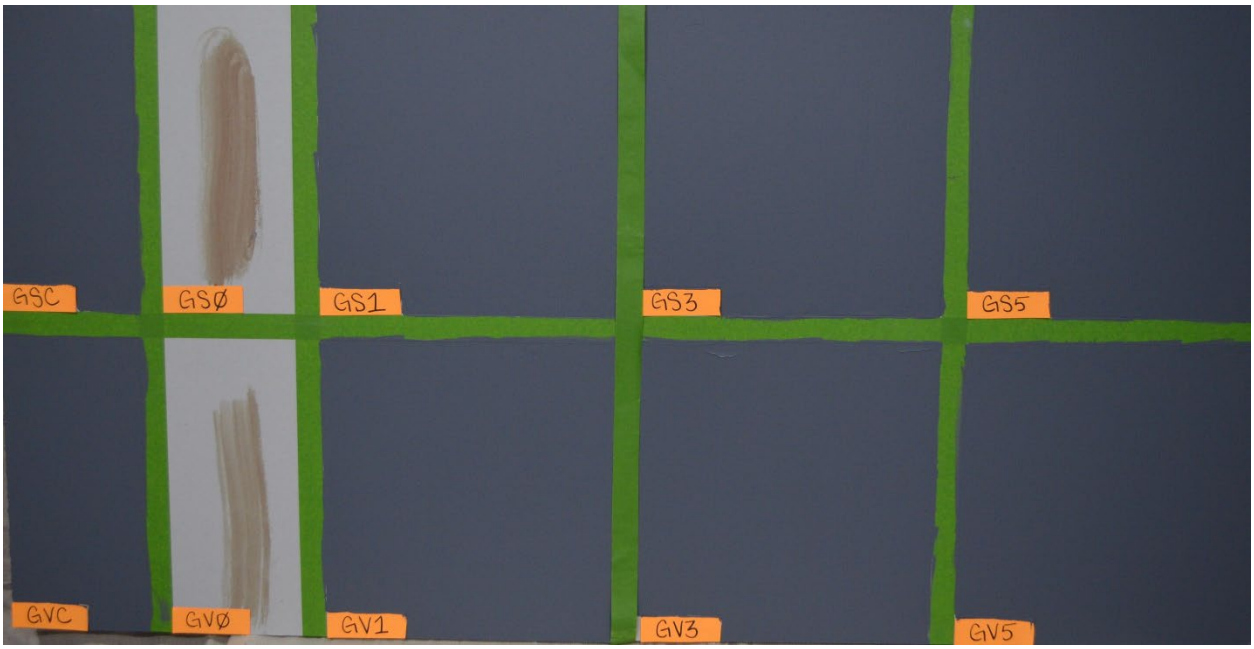

Figure 15. Swipe, Grey Colour, Sherwin Williams & Valspar Paint and Primer

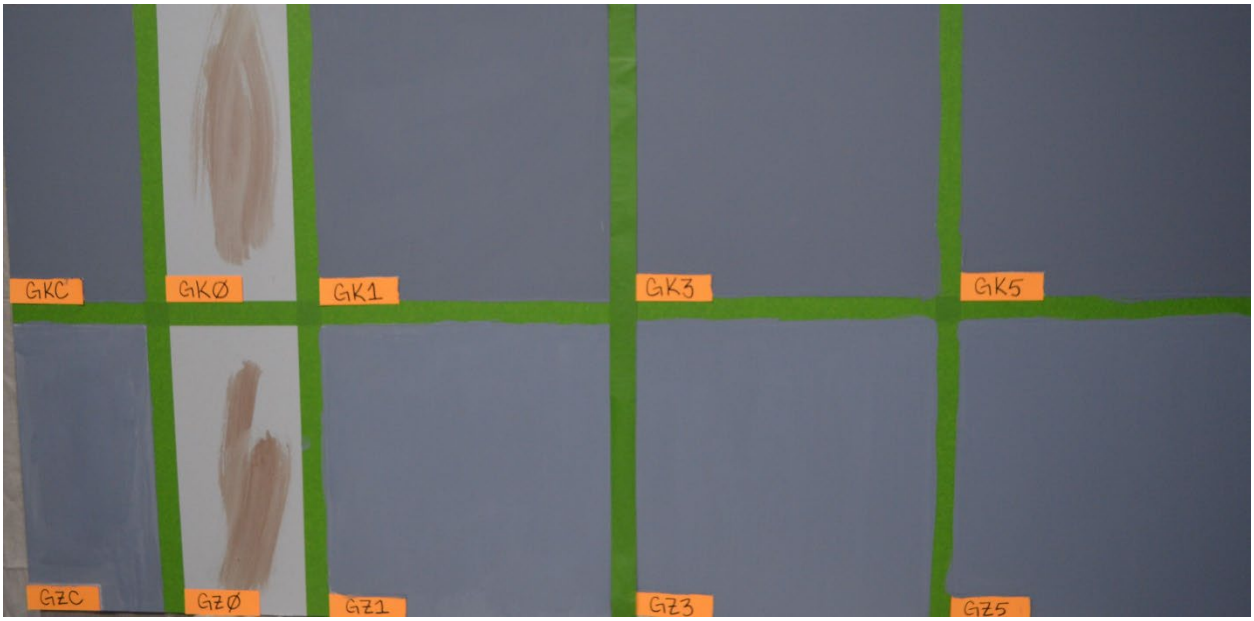

Figure 16. Swipe, Grey Colour, Kilz & Zinsser Primer

Following the instructions on the packaging, 4 ounces of Bluestar® Forensic was mixed and allowed to fully combine. Using a continuous spray fine mist spray bottle, and starting with the control section, each square was individually exposed to the reagent and the results were charted and photographically documented. The results were determined visually and were recorded within the first 30 seconds of application. When needed, an additional 4 ounces of Bluestar® Forensic was mixed and allowed to fully combine before using. During the applications of Bluestar® Forensic, the sections not currently being exposed were covered with a barrier to reduce cross contamination. Also, to reduce cross contamination, the bottom row of each panel was sprayed and photographed before the top row, to keep any potential reagent bleed from contaminating the layers of paint and/or primer.

Results

Images of each of the squares from initial bloodstain application through painting and then Bluestar® application can be found in Appendix A.

Tables 1-16 provide results for each spattered and swiped panel.

The yes/no indicate: 'Yes' Bluestar® reacted and luminescence was visually observed, or 'No', no luminescence was visually observed within the painted sections.

Spatter Patterns, Sherwin Williams Paint and Primer, Eggshell Colour	
Paint Control (ESC)	No
Blood Control (ES0)	Yes
One Paint Layer (ES1)	Yes
Three Paint Layers (ES3)	No
Five Paint Layers (ES5)	No

Table 1. Results-Spatter, ESC-ES5

Spatter Patterns, Valspar Paint and Primer, Eggshell Colour	
Paint Control (EVC)	No
Blood Control (EV0)	Yes
One Paint Layer (EV1)	Yes
Three Paint Layers (EV3)	No
Five Paint Layers (EV5)	No

Table 2. Results-Spatter, EVC-EV5

Spatter Patterns, Kilz Primer, Eggshell Colour	
Paint Control (EKC)	No
Blood Control (EK0)	Yes
One Paint Layer (EK1)	Yes
Three Paint Layers (EK3)	Yes
Five Paint Layers (EK5)	No

Table 3. Results-Spatter, EKC-EK5

Spatter Patterns, Zinsser Primer, Eggshell Colour	
Paint Control (EZC)	No
Blood Control (EZ0)	Yes
One Paint Layer (EZ1)	Yes
Three Paint Layers (EZ3)	No
Five Paint Layers (EZ5)	No

Table 4. Results-Spatter, EZC-EZ5

Spatter Patterns, Sherwin Williams Paint and Primer, Grey Colour	
Paint Control (GSC)	No
Blood Control (GS0)	Yes
One Paint Layer (GS1)	Yes
Three Paint Layers (GS3)	No
Five Paint Layers (GS5)	No

Table 5. Results-Spatter, GSC-GS5

Spatter Patterns, Valspar Paint and Primer, Grey Colour	
Paint Control (GVC)	No
Blood Control (GV0)	Yes
One Paint Layer (GV1)	Yes
Three Paint Layers (GV3)	No
Five Paint Layers (GV5)	No

Table 6. Results-Spatter, GVC-GV5

Spatter Patterns, Kilz Primer, Grey Colour	
Paint Control (GKC)	No
Blood Control (GK0)	Yes
One Paint Layer (GK1)	Yes
Three Paint Layers (GK3)	Yes
Five Paint Layers (GK5)	No

Table 7. Results-Spatter, GKC-GK5

Spatter Patterns, Zinsser Primer, Grey Colour	
Paint Control (GZC)	No
Blood Control (GZ0)	Yes
One Paint Layer (GZ1)	Yes
Three Paint Layers (GZ3)	Yes
Five Paint Layers (GZ5)	No

Table 8. Results-Spatter, GZC-GZ5

Swipe Patterns, Sherwin Williams Paint and Primer, Eggshell Colour	
Paint Control (ESC)	No
Blood Control (ES0)	Yes
One Paint Layer (ES1)	Yes
Three Paint Layers (ES3)	Yes
Five Paint Layers (ES5)	Yes

Table 9. Results-Swipe, ESC-ES5

Swipe Patterns, Valspar Paint and Primer, Eggshell Colour	
Paint Control (EVC)	No
Blood Control (EV0)	Yes
One Paint Layer (EV1)	Yes
Three Paint Layers (EV3)	Yes
Five Paint Layers (EV5)	Yes

Table 10. Results-Swipe, EVC-EV5

Swipe Patterns, Kilz Primer, Eggshell Colour	
Paint Control (EKC)	No
Blood Control (EK0)	Yes
One Paint Layer (EK1)	Yes
Three Paint Layers (EK3)	No
Five Paint Layers (EK5)	No

Table 11. Results-Swipe, EKC-EK5

Swipe Patterns, Zinsser Primer, Eggshell Colour	
Paint Control (EZC)	No
Blood Control (EZ0)	Yes
One Paint Layer (EZ1)	Yes
Three Paint Layers (EZ3)	No
Five Paint Layers (EZ5)	No

Table 12. Results-Swipe, EZC-EZ5

Swipe Patterns, Sherwin Williams Paint and Primer, Grey Colour	
Paint Control (GSC)	No
Blood Control (GS0)	Yes
One Paint Layer (GS1)	Yes
Three Paint Layers (GS3)	No
Five Paint Layers (GS5)	No

Table 13. Results-Swipe, GSC-GS5

Swipe Patterns, Valspar Paint and Primer, Grey Colour	
Paint Control (GVC)	No
Blood Control (GV0)	Yes
One Paint Layer (GV1)	Yes
Three Paint Layers (GV3)	No
Five Paint Layers (GV5)	No

Table 14. Results-Swipe GVC-GV5

Swipe Patterns, Kilz Primer, Grey Colour	
Paint Control (GKC)	No
Blood Control (GK0)	Yes
One Paint Layer (GK1)	Yes
Three Paint Layers (GK3)	Yes
Five Paint Layers (GK5)	No

Table 15.Results-Swipe, GKC-GK5

Swipe Patterns, Zinsser Primer, Grey Colour	
Paint Control (GZC)	No
Blood Control (GZ0)	Yes
One Paint Layer (GZ1)	Yes
Three Paint Layers (GZ3)	No
Five Paint Layers (GZ5)	No

Table 16. Results-Swipe, GZC-GZ5

* It should be noted that in several of the photographs, there is luminescence on the frog tape surrounding the painted squares. These are areas that have bloodstains on the tape, but they have no bearing on the parts of the squares being tested.

Conclusion

The questions this experiment sought to answer were: does the colour of the paint (a light colour versus a dark colour) have any effect on the efficacy of Bluestar® Forensic? How does using a paint plus primer compare to the results of previous studies? Does a stain blocking primer cover bloodstains more effectively than a paint plus primer? Does the amount of blood under the paint (spatter versus swipe) affect the efficacy of Bluestar® Forensic?

The results showed that colour had minimal impact when comparing panels that had high impact spatter, however, when comparing the panels with swipe patterns, the prediction of the grey colour concealing more bloodstains than the eggshell colour was proven correct. This research also showed that the paint plus primer prevented Bluestar® more effectively than the previous studies of Pettolina et al. in 2017, and Dombaxe et al. in 2020, disproving the initial prediction.

Within this study, the prediction that stain blocking primers were more effective than paint plus primers was proven mostly incorrect. The stain blocking primers were slightly less effective than the paint plus primers in all the spatter patterns and the grey swipe patterns. However, the results were significantly different with eggshell swipe patterns, with the bloodstains being visible through all five layers of paint plus primers, but only through one layer of the stain blocking primer.

These results also indicate that the concentration of blood has an impact on Bluestar® Forensic. Two swipe patterns were visible through five layers of paint plus primer whereas none of the spatter patterns were visible through five layers of paint and/or primer, confirming the initial prediction.

Limitations

There are several limitations regarding this study. This study only repeated the experiment once. It is possible, that using repeated attempts with the same methods, different results could be obtained. There is always human error when dealing with something like painting. More or less paint could adhere within the brush, keeping the exact same amount from being applied to all squares. There is also difficulty in keeping the paint perfectly uniform across the entirety of the squares, leading to some areas being more heavily covered than others. This could cause a result to be different within the squares where small areas of luminescence were observed, because of a thinner layer of paint potentially changing the conclusions of the study.

This study only tested two different colours of paint. This study also only tested two kinds of paint plus primer and two kinds of stain blocking primers. It is possible that other brands or colours could have differing results. The sheetrock was left unpainted (by design) before blood was applied, which is not a likely real-world scenario. The stain blocking primers were also not painted over as designed, therefore possibly skewing the results.

It is also possible that some of the luminescence was so faint that it was beyond photographic detection and was so fleeting that it was missed by observers during Bluestar® application.

Future Studies

There are many further studies that can be done into the limitations of Bluestar® Forensic. This study only tested a handful of variables. All of the variables could be reproduced to confirm the results. The sheetrock could be painted before the blood is applied to better replicate a real-world crime scene. Different kinds of paint plus primer or stain blocking primers could be tested. Differing colours of paint could be used. Testing whether the solid content of paints affects the results of using Bluestar® is something that this study did not address.

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Appendix A

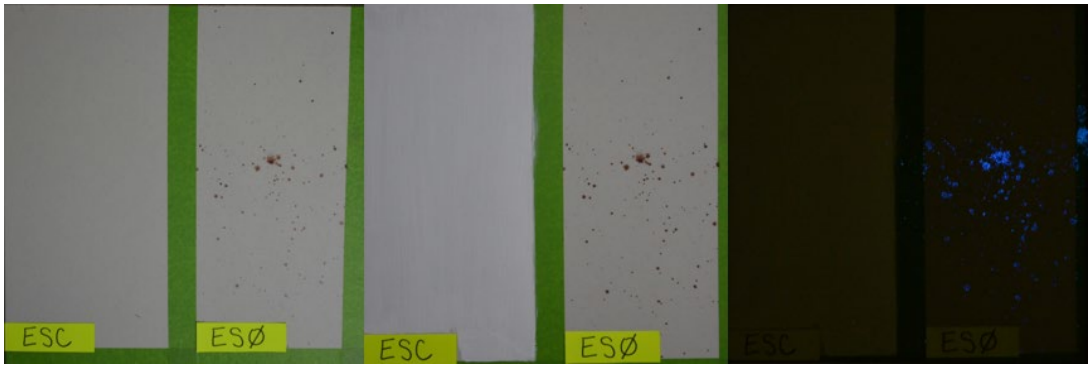

Figure 17. Spatter, Eggshell Colour, Sherwin Williams Paint and Primer, Paint and Blood Controls

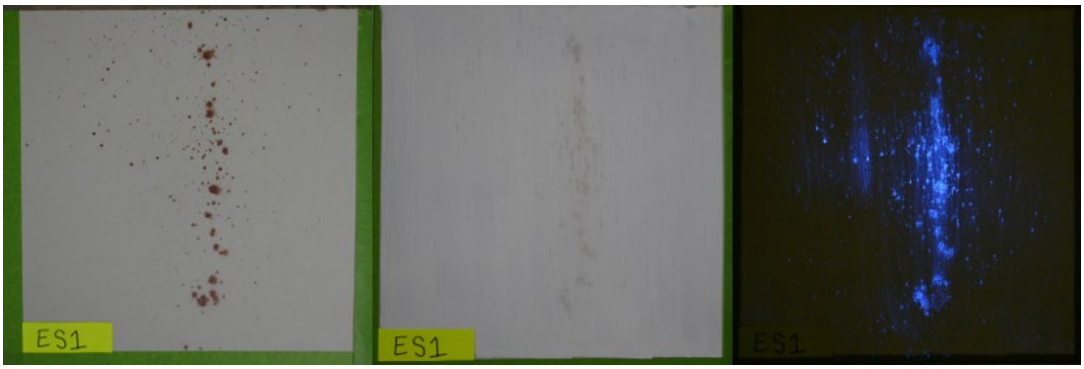

Figure 18. Spatter, Eggshell Colour, Sherwin Williams Paint and Primer, 1 Layer of Paint

Figure 19. Spatter, Eggshell Colour, Sherwin Williams Paint and Primer, 3 Layers of Paint

Figure 20. Spatter, Eggshell Colour, Sherwin Williams Paint and Primer, 5 Layers of Paint

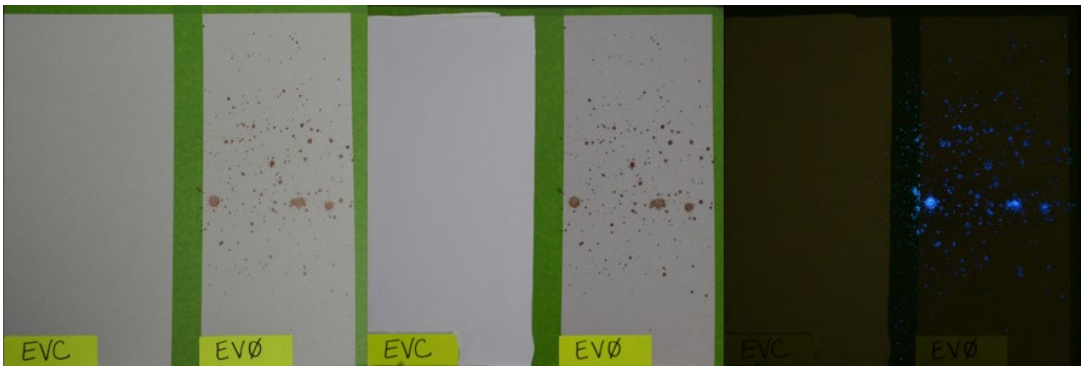

Figure 21. Spatter, Eggshell Colour, Valspar Paint and Primer, Paint and Blood Controls

Figure 22. Spatter, Eggshell Colour, Valspar Paint and Primer, 1 Layer of Paint

Figure 23. Spatter, Eggshell Colour, Valspar Paint and Primer, 3 Layers of Paint

Figure 24.Spatter, Eggshell Colour, Valspar Paint and Primer, 5 Layers of Paint

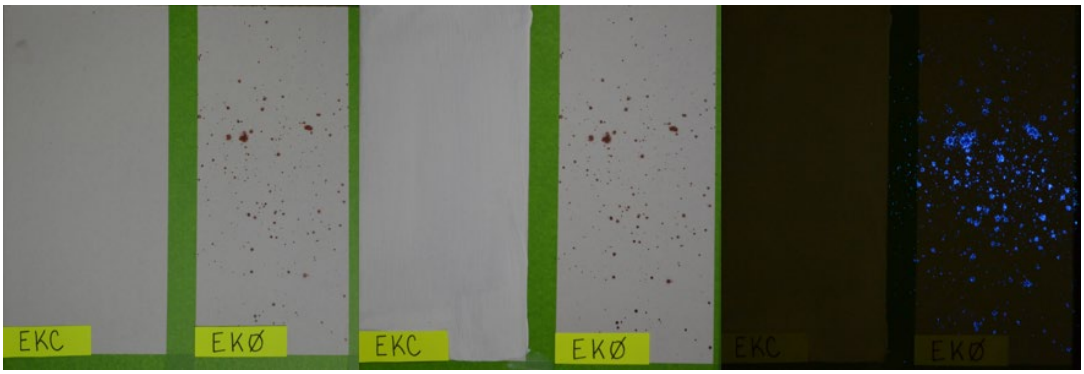

Figure 25. Spatter, Eggshell Colour, Kilz Primer, Paint and Blood Controls

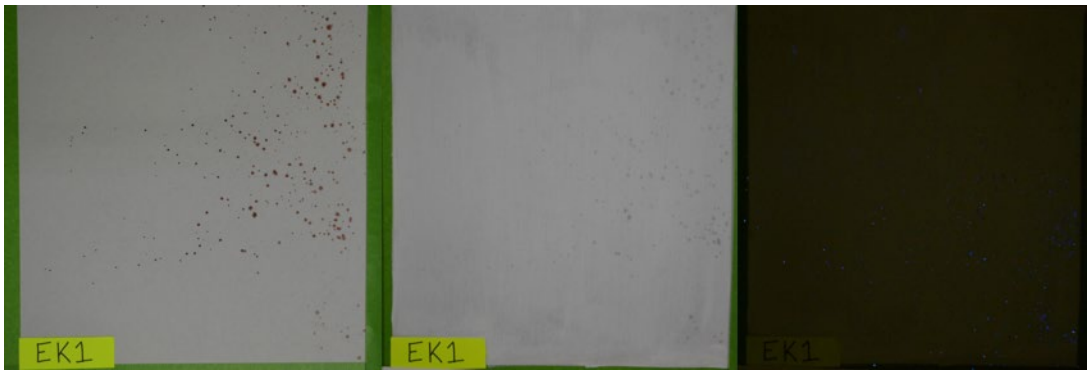

Figure 26. Spatter, Eggshell Colour, Kilz Primer, 1 Layer of Paint

Figure 27. Spatter, Eggshell Colour, Kilz Primer, 3 Layers of Paint

Figure 28. Spatter, Eggshell Colour, Kilz Primer, 5 Layers of Paint

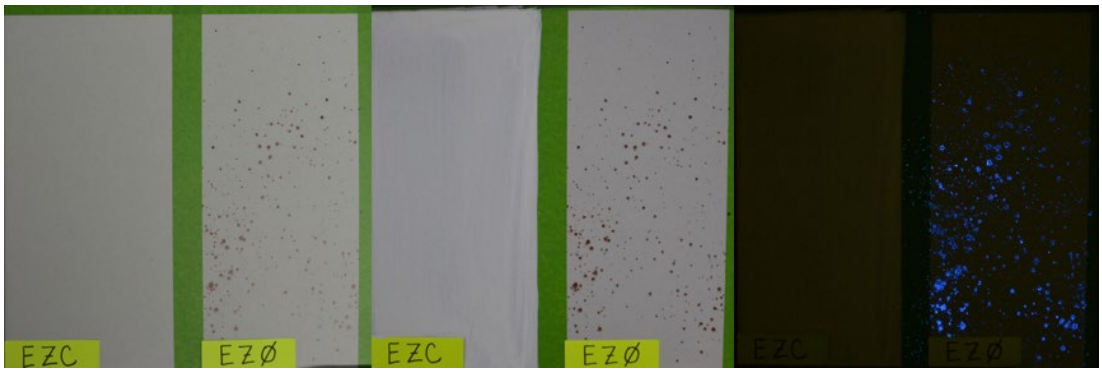

Figure 29. Spatter, Eggshell Colour, Zinsser Primer, Paint and Blood Controls

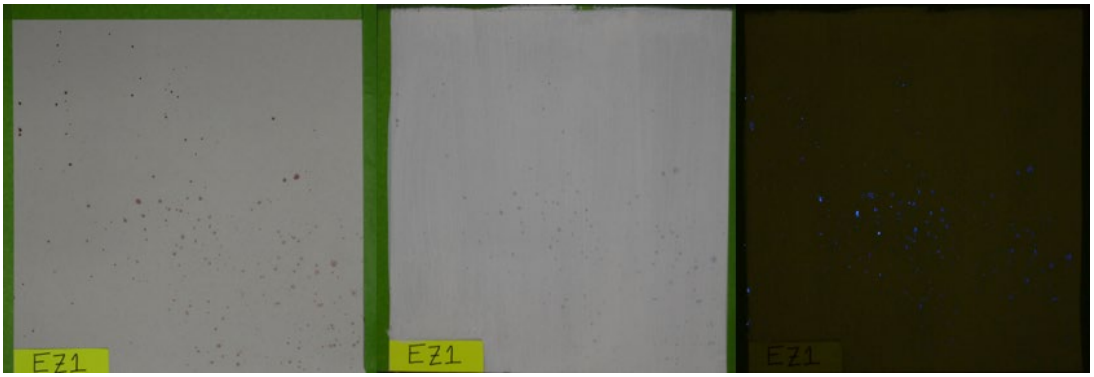

Figure 30. Spatter, Eggshell Colour, Zinsser Primer, 1 Layer of Paint

Figure 31. Spatter, Eggshell Colour, Zinsser Primer, 3 Layers of Paint

Figure 32. Spatter, Eggshell Colour, Zinsser Primer, 5 Layers of Paint

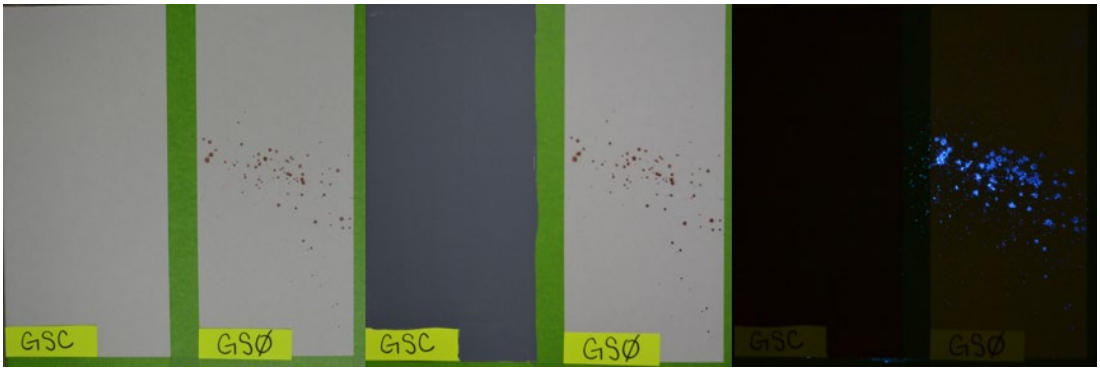

Figure 33. Spatter, Grey Colour, Sherwin Williams Paint and Primer, Paint and Blood Controls

Figure 34. Spatter, Grey Colour, Sherwin Williams Paint and Primer, 1 Layer of Paint

Figure 35. Spatter, Grey Colour, Sherwin Williams Paint and Primer, 3 Layers of Paint

Figure 36. Spatter, Grey Colour, Sherwin Williams Paint and Primer, 5 Layers of Paint

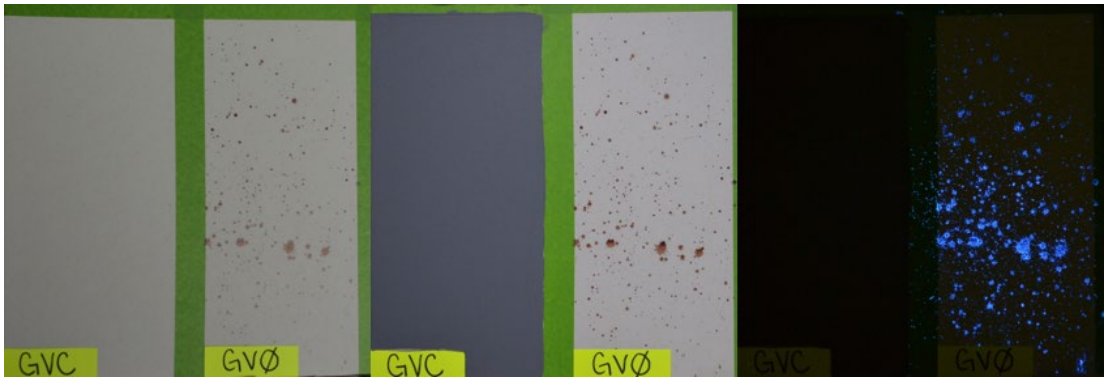

Figure 37. Spatter, Grey Colour, Valspar Paint and Primer, Paint and Blood Controls

Figure 38. Spatter, Grey Colour, Valspar Paint and Primer, 1 Layer of Paint

Figure 39. Spatter, Grey Colour, Valspar Paint and Primer, 3 Layers of Paint

Figure 40. Spatter, Grey Colour, Valspar Paint and Primer, 5 Layers of Paint

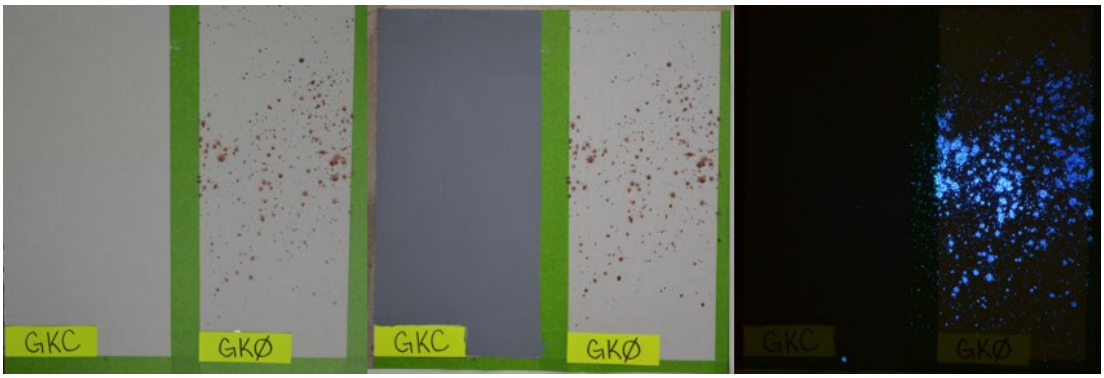

Figure 41. Spatter, Grey Colour, Kilz Primer, Paint and Blood Controls

Figure 42. Spatter, Grey Colour, Kilz Primer, 1 Layer of Paint

Figure 43. Spatter, Grey Colour, Kilz Primer, 3 Layers of Paint

Figure 44. Spatter, Grey Colour, Kilz Primer, 5 Layers of Paint

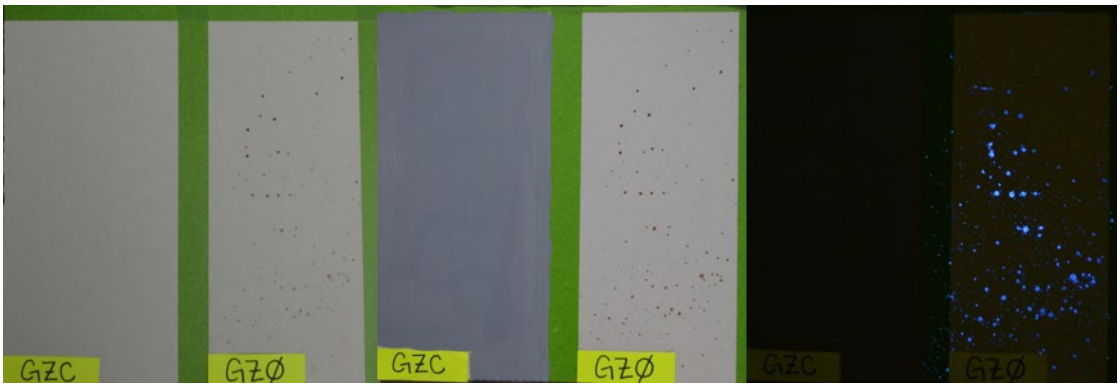

Figure 45. Spatter, Grey Colour, Zinsser Primer, Paint and Blood Control

Figure 46. Spatter, Grey Colour, Zinsser Primer, 1 Layer of Paint

Figure 47. Spatter, Grey Colour, Zinsser Primer, 3 Layers of Paint

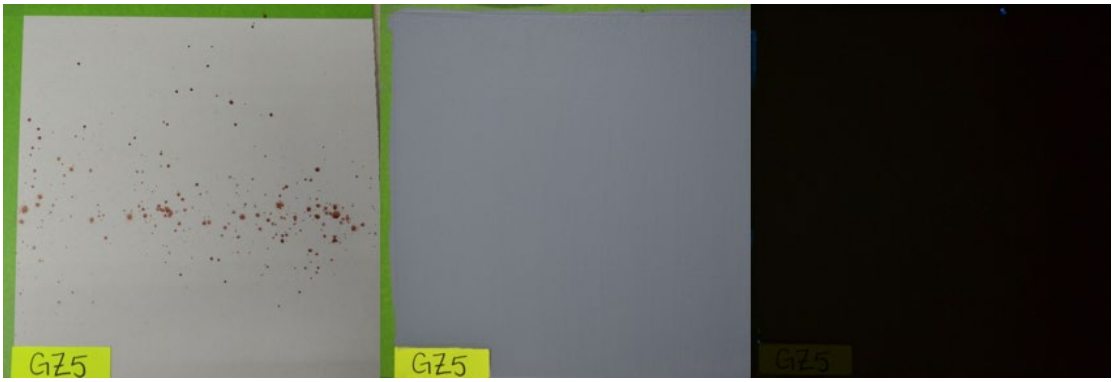

Figure 48. Spatter, Grey Colour, Zinsser Primer, 5 Layers of Paint

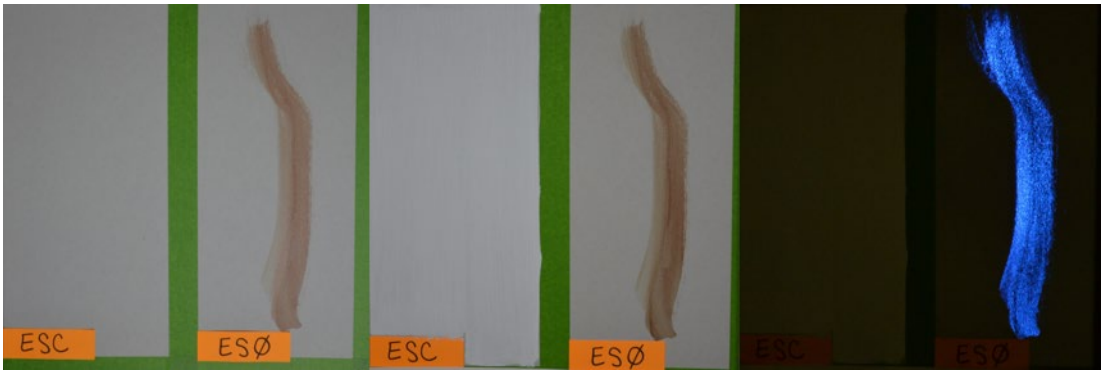

Figure 49. Swipe, Grey Colour, Sherwin Williams Paint and Primer, Paint and Blood Controls

Figure 50. Swipe, Grey Colour, Sherwin Williams Paint and Primer, 1 Layer of Paint

Figure 51. Swipe, Grey Colour, Sherwin Williams Paint and Primer, 3 Layers of Paint

Figure 52. Swipe, Grey Colour, Sherwin Williams Paint and Primer, 5 Layers of Paint

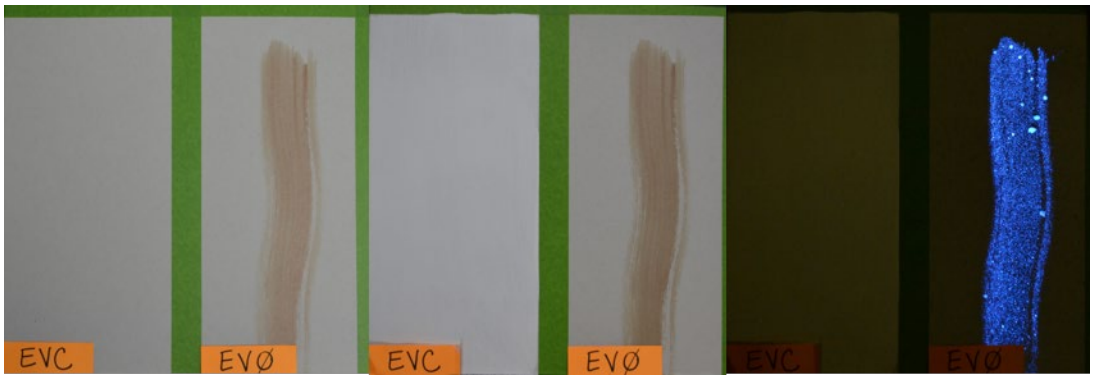

Figure 53. Swipe, Grey Colour, Valspar Paint and Primer, Paint and Blood Controls

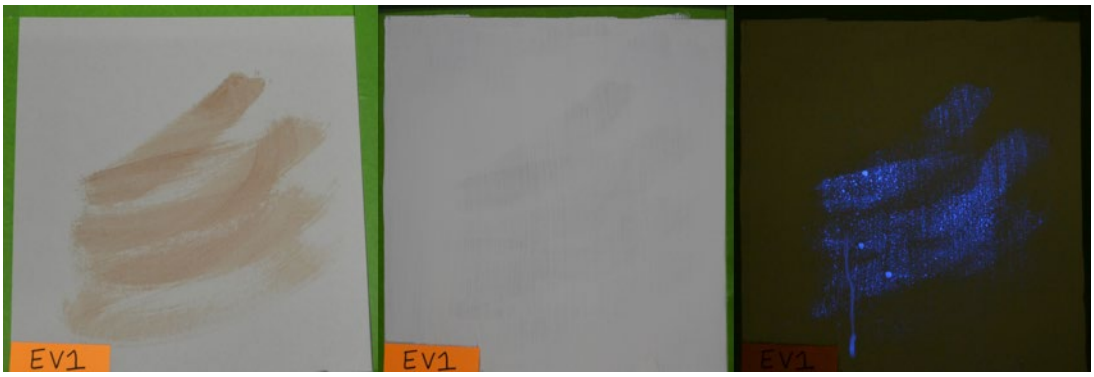

Figure 54. Swipe, Grey Colour, Valspar Paint and Primer, 1 Layer of Paint

Figure 55. Swipe, Grey Colour, Valspar Paint and Primer, 3 Layers of Paint

Figure 56. Swipe, Grey Colour, Valspar Paint and Primer, 5 Layers of Paint

Figure 57. Swipe, Grey Colour, Kilz Primer, Paint and Blood Controls

Figure 58. Swipe, Grey Colour, Kilz Primer, 1 Layer of Paint

Figure 59. Swipe, Grey Colour, Kilz Primer, 3 Layers of Paint

Figure 60. Swipe, Grey Colour, Kilz Primer, 5 Layers of Paint

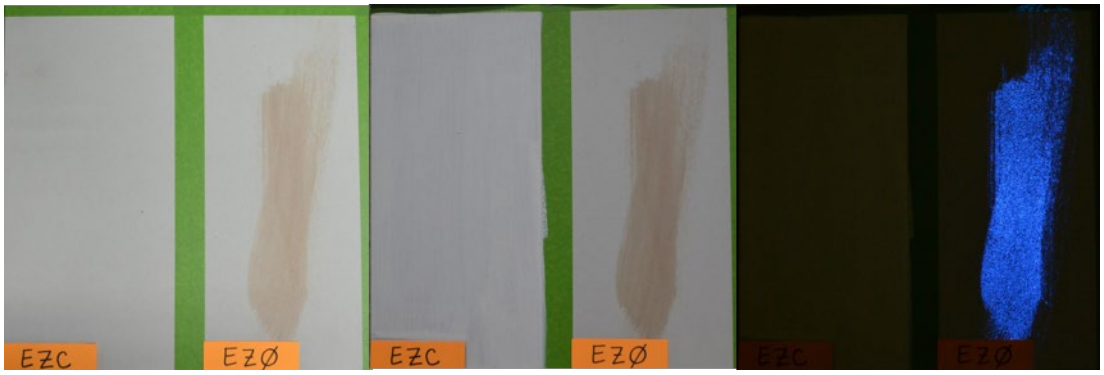

Figure 61. Swipe, Grey Colour, Zinsser Primer, Paint and Blood Controls

Figure 62. Swipe, Grey Colour, Zinsser Primer, 1 Layer of Paint

Figure 63. Swipe, Grey Colour, Zinsser Primer, 3 Layers of Paint

Figure 64. Swipe, Grey Colour, Zinsser Primer, 5 Layers of Paint

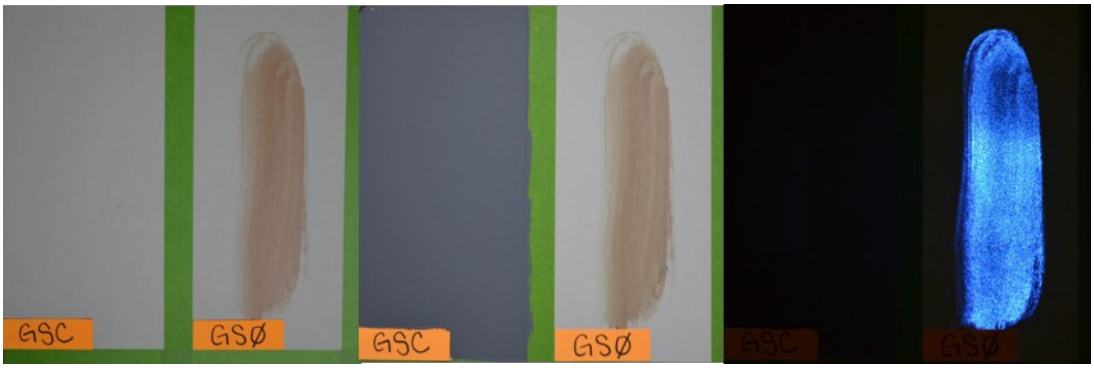

Figure 65. Swipe, Grey Colour, Sherwin Williams Paint and Primer, Paint and Blood Controls

Figure 66. Swipe, Grey Colour, Sherwin Williams Paint and Primer, 1 Layer of Paint

Figure 67. Swipe, Grey Colour, Sherwin Williams Paint and Primer, 3 Layers of Paint

Figure 68. Swipe, Grey Colour, Sherwin Williams Paint and Primer, 5 Layers of Paint

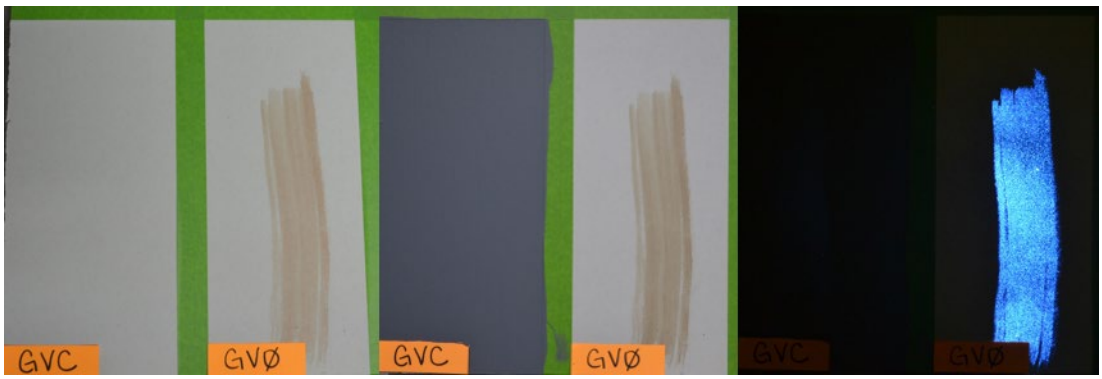

Figure 69. Swipe, Grey Colour, Valspar Paint and Primer, Paint and Blood Controls

Figure 70. Swipe, Grey Colour, Valspar Paint and Primer, 1 Layer of Paint

Figure 71. Swipe, Grey Colour, Valspar Paint and Primer, 3 Layers of Paint

Figure 72. Swipe, Grey Colour, Valspar Paint and Primer, 5 Layers of Paint

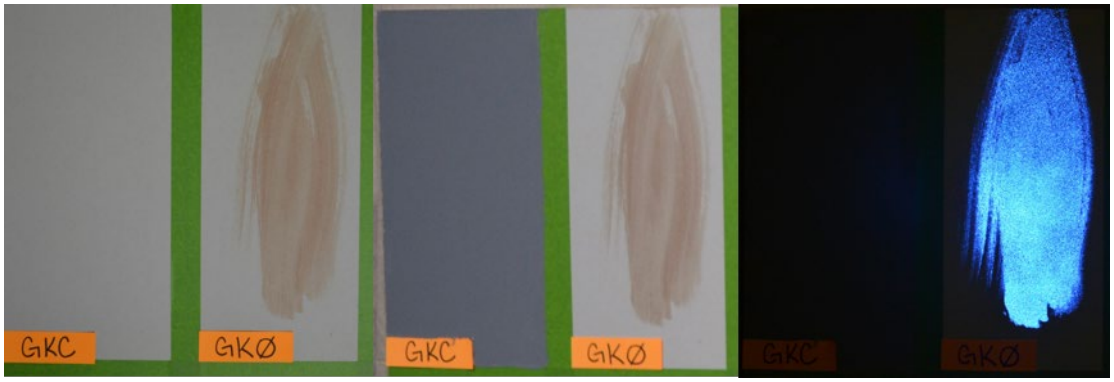

Figure 73. Swipe, Grey Colour, Kilz Primer, Paint and Blood Controls

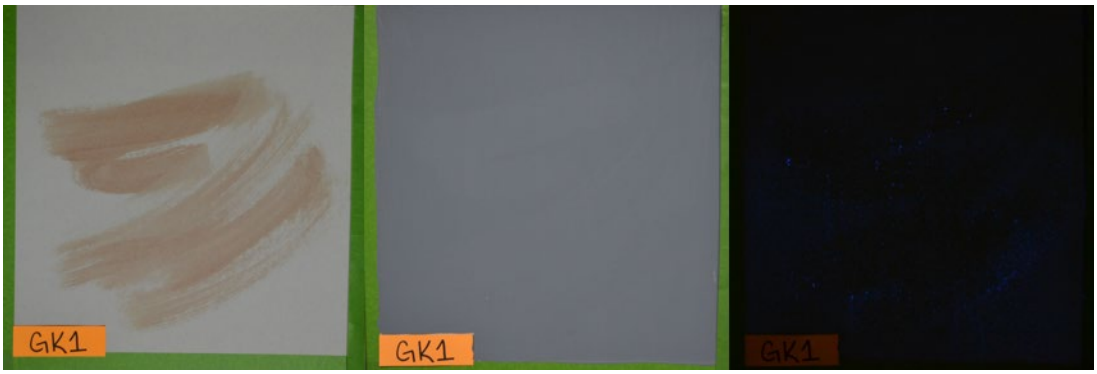

Figure 74. Swipe, Grey Colour, Kilz Primer, 1 Layer of Paint

Figure 75. Swipe, Grey Colour, Kilz Primer, 3 Layers of Paint

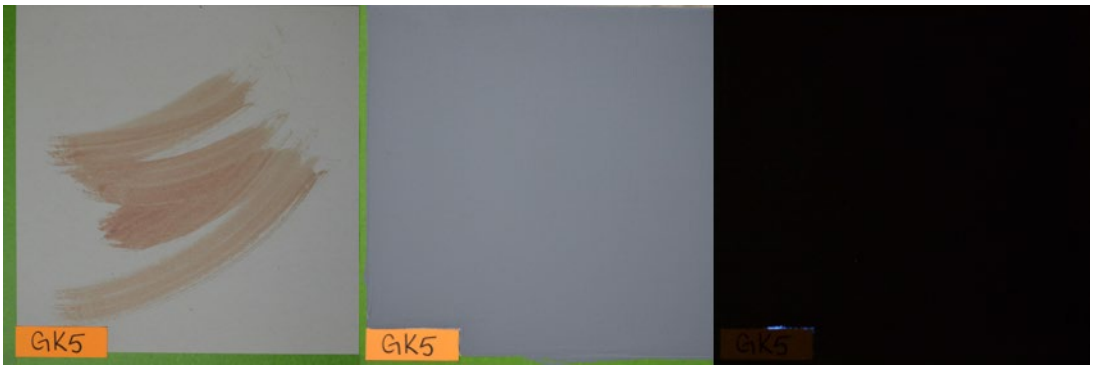

Figure 76. Swipe, Grey Colour, Kilz Primer, 5 Layers of Paint

Figure 77. Swipe, Grey Colour, Zinsser Primer, Paint and Blood Controls

Figure 78. Swipe, Grey Colour, Zinsser Primer, 1 Layer of Paint

Figure 79. Swipe, Grey Colour, Zinsser Primer, 3 Layers of Paint

Figure 80. Swipe, Grey Colour, Zinsser Primer, 5 Layers of Paint

* It should be noted that in several of the photographs, there is luminescence on the frog tape surrounding the painted squares. These are areas that have bloodstains on the tape, but they have no bearing on the parts of the squares being tested.