Visualization of Seminal Stains on Dark Textiles

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ABSTRACT

Searching for latent seminal stains during a crime scene investigation can often be achieved using a UV light or an alternate light source (ALS) with a combination of filters. Followed by a chemical test, a crime scene investigator will collect and preserve the evidence for further analysis. However, we have found false-negative outcomes on dark textiles due to the lack of fluorescent emission from the seminal stains.

In this project, known human seminal fluids were deposited on different types of dark textiles (n=38) ranging from 100% cotton and cotton blends to 100% polyester and polyester blends. Samples were then examined using UV, ALS (455nm and 532nm) with an orange filter, and laser light (532nm) to determine what fabrics showed false negatives. Successful visualization of all seminal stains ranged from 21-61% depending on the excitation light source, and 9-45% for barely visible stains. To overcome false negatives, hyperspectral imaging (HSI) in the Vis-IR range (400-1000nm) was utilized to analyze the fabrics in the lab. Principal component analysis (PCA) was then applied to the HSI data cube in order to visualize the seminal stains.

INTRODUCTION

The search for biological samples at a crime scene or on evidence at a lab is an important first step for DNA collection. The search method must be nondestructive, have a low likelihood of false negatives, and be accessible to crime scene technicians in the field. Initial observations with traditional crime scene search methods using UV light or alternate light sources (ALS) do not always result in visualization of seminal stains which can lead to overlooked DNA evidence (1). Seminal stains on dark textiles do not always show fluorescence from an ALS, resulting in a false negative and a missed piece of evidence (2). The lack of fluorescence is likely due to the properties of the dye used to color the fabric and the weave pattern of the textile, which impacts how semen is absorbed (1–4).

Hyperspectral imaging (HSI) uses a range of wavelengths to create a data cube of information with the X and Y axis as the spatial coordinates of the image (pixels) and the Z-axis as the reflectance spectra information at the chosen range of wavelengths (5,6). This study focuses on the visible-infrared (Vis-IR) range (400-1000nm) while previous studies have focused on the near-infrared (NIR) region (1000-2500nm) to visualize seminal stains (1,4). Principal component analysis (PCA) performs multivariate analysis within a data cube that determines the greatest differences between wavelength data in each image and will be used to aid in visualization (7).

RESULTS AND DISCUSSION

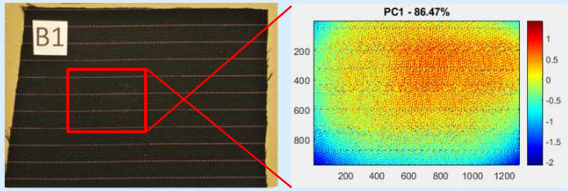

Figure 1. Sample B1, black fabric made of 95% polyester and 5% spandex, unlaundered, stained with neat semen viewed in visible light (left) and PC1 contour map of highlighted region (right, inverted)

Figure 2. Sample B1 viewed with a Nova light (455nm) with an orange filter (left) and a UV LED light (right)

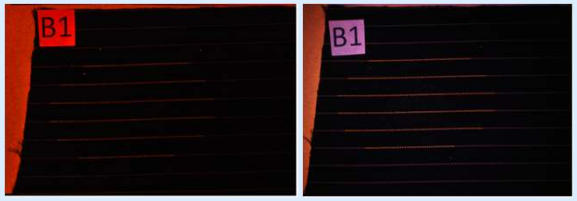

Figure 3. Sample B1 viewed with a laser light (532nm) with an orange filter (left) and an Astra light (455nm) with an orange filter (right)

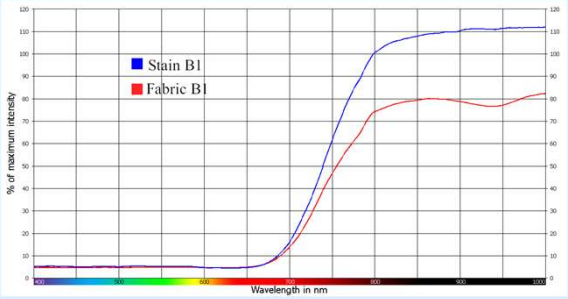

Figure 4. Reflectance spectra of the center of stain B1 and the background fabric of B1 from the hyperspectral data cube

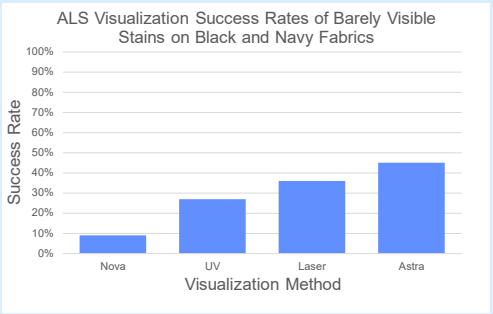

Table 1. Success rates of various search methods for black and navy fabrics where semen stains were barely visible (n=11)

- Traditional search methods for seminal stains were successful between 9-45% of barely visible samples (**Table 1**)
- Under regular light the stain on sample B1 is only slightly visible (**Figure 1**). Sample B1 showed false negatives for UV and ALS methods, prompting further analysis with HSI (**Figure 2-3**).
- The data received from HSI shows a variance in the reflectance between the stain and the fabric starting around 700nm (**Figure 4**). This indicates it is possible to obtain information from the stain separate from the fabric.
- The PC1 contour map shows the areas of the greatest variables in the principal components (**Figure 1**). The semen stain has the largest variance from the rest of the fabric which makes the stain visible
- This method does not rely on fluorescence at one set wavelength, therefore quenching is not an issue and additional information can be collected using HSI.
- Next steps are to verify the method with additional positive controls with stains that fit in the imaging area of the VSC and creating a mobile HSI camera so larger areas of evidence can be imaged

MATERIALS AND METHODS

Samples

Dark fabric swatches (n=38) pre-stained with neat semen were collected from the Montgomery County Crime Lab. Of the 38, 27 were laundered before staining and 11 were stained immediately after purchase. Fabric composition varied from 100% polyester; polyester blends with spandex, nylon, cotton, acetate, and wool; 100% cotton; cotton blends with spandex and polyester; nylon with rayon and lycra mixes; and 100% suede. In-lab samples were prepared by staining 100% cotton (red, green, blue, and black) laundered and unlaundered fabrics with neat semen. Sample collection of semen was approved by the IRB at Sam Houston State University (file number: IRB-2020-248).

Instrumentation

All samples were analyzed with 1) a UV light, 2&3) two types of flashlights (455nm) for excitation with an orange filter for fluorescence observation 4) a laser (532nm) for excitation with an orange barrier filter for fluorescence observation, and 5) hyperspectral imaging (HSI) using a VSC6000 (Foster+Freeman, Evesham, Worcestershire, United Kingdom) from 400 – 1000nm in 4nm increments at 7.75x magnification. Images in 12nm increments were saved from each sample data cube for data processing.

Data Processing

Using the VSC® software provided by the manufacturer, the center of each stain and a point on the background fabric were selected to plot the reflectance spectra. HSI images from each sample were then uploaded into MatLab (MathWorks Inc., Natick, MA, USA) and analyzed using the Hypertools PCA function.

CONCLUSIONS

- Evidence search techniques for seminal stains on dark textiles may show false negatives.
- Imaging in the 400-1000 nm range provided improvement for visualization.
- Hyperspectral imaging shows promise in visualizing seminal stains on dark textiles.
- Principle component analysis was useful in visualization of the stained area.

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