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The adaptation of a 360° camera utilising an alternate light source (ALS) for the detection of biological fluids at crime scenes

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ABSTRACT

One of the most important and commonly encountered evidence types that can be recovered at crime scenes are biological fluids. Due to the ephemeral nature of biological fluids and the valuable DNA that they can contain, it is fundamental that these are documented extensively and recovered rapidly. Locating and identifying biological fluids can prove a challenging task but can aid in reconstructing a sequence of events. Alternate light sources (ALS) offer powerful non-invasive methods for locating and enhancing biological fluids utilising different wavelengths of light. Current methods for locating biological fluids using ALS's may be time consuming, as they often require close range searching of potentially large crime scenes. Subsequent documentation using digital cameras and alternate light sources can increase the investigation time and due to the cameras low dynamic range, photographs can appear under or over exposed. This study presents a technique, which allows the simultaneous detection and visualisation of semen and saliva utilising a SceneCam 360° camera (Spheron VR AG), which was adapted to integrate a blue Crime Lite XL (Foster + Freeman). This technique was investigated using different volumes of semen and saliva, on porous and non-porous substrates, and the ability to detect these at incremental distances from the substrate. Substrate type and colour had a significant effect on the detection of the biological fluid, with limited fluid detection on darker substrates. The unique real-time High Dynamic range (HDR) ability of the SceneCam significantly enhanced the detection of biological fluids where background fluorescence masked target fluorescence. These preliminary results are presented as a proof of concept for combining 360° photography using HDR and an ALS for the detection of biological stains, within a scene, in real time, whilst conveying spatial relationships of staining to other evidence. This technique presents the opportunity to presumptively screen a crime scene for biological fluids and will facilitate simultaneous location and visualisation of biological evidence.

1. Introduction

Biological fluids, such as blood, semen, saliva, vaginal secretions and urine, are a commonly encountered evidence type that can be recovered at crime scenes. They serve as an invaluable evidence type given that they contain valuable DNA evidence that may be used to identify individuals present at the scene, including both suspect and victim. Identifying the location and distribution of biological staining within a crime scene is crucial to the investigation, as the location and identity of the fluid can aid Forensic Investigators (FI) in reconstructing a sequence of events, and determining what may have occurred at the scene [1]. Due to the ephemeral nature of this type of evidence, it is fundamental that the evidence is documented extensively and recovered quickly and efficiently. Locating biological fluids can prove a challenging task for FI's as many stains are invisible to the naked eye or are similar in appearance to other extant substances. In these circumstances filtered light analysis can provide an investigator with an effective means of locating and presumptively differentiating between some biological fluids [2], and some biological fluids with similarly appearing extant substances, given that such substances often respond differently to varied wavelengths of light. This type of analysis is non-contact, unlike alternative presumptive tests, such as the Kastle-Meyer test for blood, or the acid phosphatase test for semen, which interact with constituents found in biological fluids. Confirmatory tests are used to confirm the presence of a particular biological fluid [1].

Filtered light analysis is frequently deployed at scenes of crime using Alternate Light Sources (ALS), which typically allow the selection of different wavelengths of light between approximately 300–900 nm. For example, semen is reported to fluoresce at an excitation wavelength of 455 nm, although the substrate will affect the efficacy of this approach [3–5]. Camerilli et al. [6] found that the optimal contrast for the visualisation of saliva stains could be achieved at an excitation wavelength of 470 nm, although the colour and design of the fabric type could affect the fluorescence of the stain. In addition to biological

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fluids, ALS's may offer powerful methods that can allow the enhancement and presumptive detection of trace evidence likely to be present at crime scenes, for example fibres [7]. Given their simplicity, non-destructive and/or non-invasive nature, they have been extensively utilised in criminal investigations, particularly where limited sample quantities are exhibited [1,8]. Conversely, this approach can be time consuming depending on the complexity and size of the environment. The FI could be searching for long periods of time without any indication as to where biological fluids could be present. The light intensity of the ALS will also affect its ability to locate and presumptively test for biological fluids. For example, the sensitivity of the approach is likely to decrease as the distance between the light source and biological fluid increases [9], meaning that often, searching for biological fluids using ALS' is close range and thus time consuming.

Once visualised using an ALS, it is integral that the evidence is thoroughly documented in a manner that captures its distribution and location as it was at the time of the investigation. Digital photography allows the FI to document both the scene and the evidence and present it to a judge and jury in a courtroom in a simple and detailed manner [10]. Where ALS photography is utilised, fluorescence filters can be fitted over the existing standard digital camera lens to block the excitation wavelength of light and allow the camera to capture a response from the target substrate [11]. Current methods for photographing a response from biological fluids when using an ALS require the FI to select the correct exposure in order to successfully capture a (fluorescent) response. This process will have to be repeated for multiple biological stains, adding further time onto the investigation process. Also, given that the FI is often working at close range, the photographs that are taken to capture any existing stains will need to be taken at equally close distances.

The area that may be captured by a digital camera is limited to the field of view of its accompanying lens. For example, a fish eye lens can facilitate the capture of an 180° horizontal field of view. Alternatively, 360° photography can capture a full panorama, and ensures the entire area (crime scene) is captured rather than only those items deemed relevant at the time by the FI [12]. 360° photography can be achieved using a standard digital camera, which requires the user to facilitate 'stitching' the images together, using appropriate software applications or manual overlays. Automated 360° photography systems eliminate the requirement for manual stitching, and allow information about spatial relationships of evidence within a scene to be extracted [13]. Also, digital cameras generally have a lower dynamic range than the human eye, and as a result photographs can appear under or overexposed in comparison. In contrast, many 360° photography systems facilitate the capture of images in High Dynamic Range (HDR), which alleviates such issues of over or under exposure. Dynamic range can be defined as the ratio between the lightest (white) and darkest (black) pixel within an image. HDR images contain pixels which represent a greater range of colours and more accurate luminance levels, which appear more realistic [11,14]. Despite their reported advantages, 360° photography systems are considerably costlier in terms of equipment purchase, maintenance and training compared to conventional digital photography. Such systems may be less portable and practical to use in some crime environments, e.g. confined spaces.

Utilising a system which integrates an ALS within 360° HDR photography could not only allow for the detection of biological fluids at larger crime scenes, but could dramatically reduce the time taken to identify, document, collect and analyse such evidence. The aim of this study was to investigate the detection and visualisation of biological fluids on various substrates using a 360° photography system combined with an ALS.

2. Method

In line with ethical requirements of the host institution and in accordance with health and safety procedures, human semen was obtained from one male donor, aged 26. Human saliva was obtained from a female donor aged 24. Biological fluid samples were collected into separate 100 ml Thermo Scientific™ Sterilin™ Polystyrene Containers and labelled accordingly. All biological fluid samples were collected on the morning of the study and were immediately stored in a fridge at 3 °C until required. White cotton, dark blue cotton, HP premium matte polypropylene white plotter paper (140 g/m^2), and coloured cardboard (160 g/m^2; red, orange, yellow, green, blue and violet in colour) were utilised as the substrates for fluid deposition. The white cotton, dark blue cotton and white plotter paper substrates were cut into approximate 10 cm × 10 cm square swatches and the coloured cardboard substrate was cut into approximate 5 cm × 5 cm square swatches.

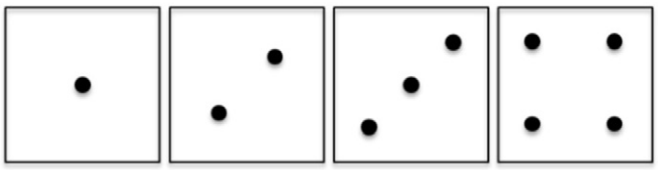

Fig. 1. Drops of biological fluid deposited onto swatches.

Using Biohit Proline® automated pipettes, 5, 50, 100, 150, 200 and 250 μl of the biological fluid were deposited onto each substrate type. The pipette was held directly above the substrate and the biological fluid deposited at a 90° angle to the substrate. A series of between 1 and 4 drops of biological fluid were deposited onto multiple swatches

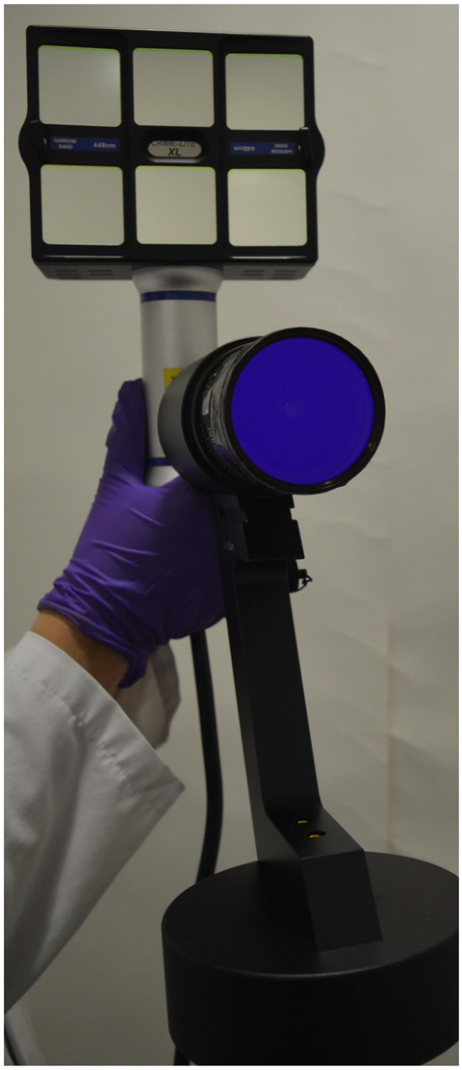

Fig. 2. The Crime Lite XLs position in relation to the SceneCam.