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A novel, element-based approach for the objective classification of bloodstain patterns

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ABSTRACT

The classification of bloodstain patterns has been identified as a challenging part of bloodstain pattern analysis due to the lack of a widely accepted and well-defined methodology and the ambiguity often associated with examining bloodstain patterns. The main aim of this study was to develop an objective, science-based method, for classifying bloodstain patterns, through the development of common language that could be used by BPA experts to describe the appearance of the pattern.

This novel approach encourages a shift in the mindset of a BPA analyst by bringing them 'back to the basics' by treating components of a bloodstain pattern as discrete, observable and measurable units.

One of the principal problems with current pattern classification methods is that pattern types are generally described in terms of the mechanism of pattern formation rather than grouping according to observable pattern characteristics. This study extends current BPA classification methodologies by developing and validating mechanism-free nomenclature that arises from observing and documenting the physical characteristics of bloodstain patterns. Following the grouping of bloodstain components on the basis of their physical characteristics, the formation evolution of these components is then investigated using concepts drawn from the fluid-dynamics of bloodstain pattern formation.

This study offers a promising approach to distinguishing between different bloodstain pattern types through the use of visual aids in the form of colour maps, high-speed video and static digital images.

1. Introduction

At the heart of bloodstain pattern analysis (BPA) lies the process of pattern classification. Ideally, bloodstain pattern classification is the product of the careful evaluation and identification of the characteristics of a pattern against objective and measurable classification criteria. Following this, pattern interpretation can occur in order to assist the crime scene reconstruction task.

Despite the extensive dialogue in the BPA community around pattern classification, no one method has emerged that can claim to be fully validated and widely accepted. This is a result of a combination of problems that have created significant challenges for the analyst. One persistent problem is the tendency to describe patterns in terms of their proposed deposition mechanisms. This is evident in the current terminology list used by analysts e.g. [1], which is largely restricted to terms that describe deposition mechanisms, rather than pattern characteristics. This has the effect of pushing analysts to form conclusions about the cause of the pattern before a full analysis of the characteristics of the pattern.

Another evident problem is the knowledge that without some additional key pattern characteristics, certain pattern types can be difficult to distinguish from one another. For example, a bloodstain pattern caused by exhalation of air as a result of injury to the mouth or airways can have similar characteristics to a pattern caused by blunt force trauma in the absence of vacuoles [2]. This ambiguity can lead to conflicting opinions by different analysts.

Furthermore, a recent study has shown that BPA classification is vulnerable to biasing effects of contextual information [3].

While experienced BPA experts can reach complicated conclusions, they may experience difficulty in articulating the steps taken to arrive at these conclusions [4]. This problem has been explained by some, as a lack of a published methodology rather than the absence of a methodology per se. In addition to this, it has been suggested, that BPA training courses teach students the necessary

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skills involved in BPA (e.g. impact angle determination), but not how to apply these skills within an acceptable methodological framework [5].

The National Academy of Sciences (NAS) report [6] highlighted several issues hindering the quality of forensic science services in the United States of America. The report stated that forensic disciplines "need to develop rigorous protocols to guide these subjective interpretations and pursue equally rigorous research and evaluation programs" (NAS, 2009, p.8). Fingerprint identification, not unlike BPA, has been called out for insufficient validation of the current ACE-V method used for the analysis of fingerprint evidence [7]. It is fair to say that the classification of bloodstain patterns also remains largely a subjective interpretation and the uncertainties are large.

The goal of this study was to encourage analysts to adopt a "back to basics" mind-set by asking them to treat bloodstain patterns as a combination of discrete, observable and potentially measurable units, which we termed 'elements'. This approach was designed to avoid the use of mechanism-related jargon and to allow for the development of a common language composed of element descriptors that could be used objectively, to describe the characteristics of a pattern.

2. Experimental methods

2.1. Overview

At the outset of this study, a number of elements were defined, through visual assessment of some laboratory-prepared bloodstain patterns. An element was defined as a single bloodstain consisting of uninterrupted margins. Therefore, a bloodstain pattern could be considered to comprise of a number of individual elements.

Each element was further distinguished on the basis of measurable properties (e.g. length and width in the case of elliptical stains) or a characteristic appearance (e.g. colour, shape). These definitions used simple, plain language and where applicable, shape-based terminology. Following this, element descriptions incorporating this terminology were collated to form a preliminary classification scheme. This scheme was primarily based on elements grouped on the basis of their appearance. High-speed video was used to understand the element formation evolution and to assist with distinguishing any observable and measurable element characteristics. The scheme was later refined using a lay-participant workshop and resulted in the creation of an 'Atlas of Elements.' The Atlas was tested and validated via a second, expert-participant workshop. Finally, possible associations between elements were assessed using colour maps to visualise the element groups in a pattern. It was hoped that such associations might lead to a better understanding of the overall pattern and form the basis of an objective pattern identification.

2.2. Bloodstain pattern creation

Two sets of bloodstain patterns were created in the laboratory using two different mechanisms, chosen to represent two common bloodstain patterns found at crime scenes. Porcine blood (an accepted blood substitute [8]) was used to generate these patterns. This blood was treated with aqueous acid citrate-dextrose (ACD) anticoagulant and kept refrigerated at all times prior to use (warmed up to 37°C when required and blood used within 20 days from collection). Three replicate patterns were produced for each set.

The first set of patterns (four in total) was created using an automated NE-300 Just Infusion™ syringe pump that pushed blood through plastic tubing, across the surface of two different 'weapons' (a cylindrical baton and a knife). Two or more blood droplets were allowed to fall under gravity from the weapons, onto the rough side of a white cardboard sheet where they were left to dry overnight and imaged after 24 h. The different (weapon) surface types and the manipulation of drip height (30 and 100 cm) were conditions arbitrarily chosen to reproducibly create a variety of bloodstain elements.

The second set of patterns (11 in total) was created using an in-house impact device [9] designed to simulate an impact event. The device relies on the downward motion of an aluminium alloy rod impacting a pool of blood, propelled by the compression of restraining springs. For the patterns generated in this way, a pool of about 5 ml of blood was used and some variation was achieved by varying the degree of spring compression, in a qualitative fashion. Bloodstains were similarly collected on the rough side of white cardboard sheets and left to dry prior to imaging.

A Photron FASTCAM SA1 HSDV high-speed video camera was used during bloodstain pattern creation to capture the evolution of the pattern formation. Following drying, digital still imaging with a Nikon D7000 Camera and Nikkor 60 mm macro lens was used to capture the resulting static pattern. The image resolution was 35 pixels/mm measured by ImageJ 1.48 v software (Public domain, http://imagej.nih.gov/ij; accessed August 2015).

2.3. Deriving preliminary descriptions of elements

The laboratory-generated patterns were used to derive preliminary descriptions of a number of elements. Patterns were initially divided into a grid composed of 10 cm by 10 cm squares. Each square of the grid was methodically inspected for discrete units, which could be uniquely defined as an element. Each element within a square was documented in terms of its general appearance, size, colour and nature of its margins using simple shape-based descriptors.

2.4. The classification scheme

Element descriptors were combined to form a whole description, which collectively described a group of elements, which shared visible characteristics pertaining to their shape, margins and approximate dimensions. Each group was allocated a unique alphanumeric code, which was associated with observable element characteristics. This process ultimately led to the construction of a preliminary classification scheme.

This classification scheme was further refined with the aid of a lay-participant workshop. The specific objectives for the workshop were (a) to test whether elements could be described in a consistent manner and without reference to a bloodstain pattern formation mechanism (b) to generate new descriptors for defining elements and (c) to determine whether element descriptions could then be used to reliably classify elements into meaningful groups.

A total of eight individuals, primarily postgraduate students within the Forensic Science programme at The University of Auckland, New Zealand formed the lay-participant cohort. These participants had a science background, minimal BPA knowledge and no practical forensic experience. The group was chosen to provide a fresh look at terminology, by minimising the discipline jargon and potential biasing effect of existing methodologies. Ethics approval for the use of human participants was obtained from the University of Auckland Human Participants Ethics Committee, New Zealand (Ref: 8037).

The workshop comprised five separate activities, which were conducted and completed simultaneously by all participants and with time restrictions imposed (1–2 min per task).

A total of seven different element images were chosen for the various workshop tasks and were selected on the basis that they