Interpretation of Bloodstain pattern for Reconstruction of Crime Scene

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Abstract—*This paper is largely aimed at reviewing the multidisciplinary work that has already been undertaken by scientists round the world to understand impact stain patterns, castoff, transfer and saturation stain patterns that are most commonly visible in a crime scene that involves blunt force injury. Again, like most other disciplines of forensic science, the reliability and error rates associated with the interpretation of bloodstain patterns still stands questionable. Inspired by the work that has been undertaken in the field of fluid mechanics, medical science, computer science, mathematics, physics etc.*

Keywords: Transfer stain, Cast-off pattern, Impact spatter, Saturation stain, Bloodstain pattern analysis, fluid mechanics.

I.INTRODUCTION

Blood contains both liquid and solids. In case of liquid it is plasma and serum where as in case of solids it contains red blood cells, white blood cells, platelets and proteins. Normally Blood is in a liquid state when inside the body, and when it is outside the body. Anyone who has had a cut or a scrape knows, it doesn't remain a liquid for long time. Except for people with hemophilia, blood will begin to clot within a few minutes, forming a dark, shiny gel-like substance that grows more solid as time progresses. The presence of blood clots in blood stains can indicate that the attack was prolonged, or that the victim was bleeding for some time after the injury occurred. This work is used to study/understand transfer stains produced by other elongated and elongated top-heavy murder weapons such as candle stand, golf stick, wooden mallet, axe etc. Given the large variable in the number of tools that can be used as murder weapons (elongated and top heavy elongated), variability in the material of these tools, varying texture and material of the target surface, vary ing impact force generated, it is difficult to develop an automated computerized tool for analyzing transfer stain patterns. To develop a tool that is efficient at analyzing and probabilistically predicting possible tools that could have created a particular sort of transfer stain, development of a dataset consisting of a large variety of weapon transfer stains formed by different angle of inclination of tool drop, dimension of tool edge, fall height, velocity of hit etc. stands integral. However for development of a tool, development of a database that has sufficient variation and comparable representation of each possible class type stands out to be the biggest challenge. Once a dataset has been drawn up, semi-supervised learning techniques could be used to develop an appropriate tool. From practical experience, the authors are of the opinion that in the absence of a murder weapon at the crime scene, study of other circumstantial evidence such as wound analysis, absence/presence of objects at a crime scene, cast off patterns, drip trails, impact spatter etc. in correlation with weapon transfer stain patterns (if any) shall help analysts in identifying the most probable tool that has been used for the murder or for injuring the victim who might not be in a position to narrate the sequence of events. Based on analysis of weapon transfer stain patterns, the factors highlighted in the is study shall help pattern analysts in part/full sequencing of probable events that might have occurred at the crime scene. Hence, this study shall aid effective part reconstruction of criminal events. The relevance of the article lies in the fact that analysts having clear idea of how these different factors could affect the formation of different weapon transfer stain patterns, shall be in a better position at understanding the probable mechanism that might have led to the formation of the stain. This knowledge is transferable to the study of other murder weapon transfer stain interpretation and shall aid proper sequencing of segments in a criminal event.

II. REVIEW WORKS

Locard's exchange principle states that "every time an individual makes contact with another person, place or thing, it results in an exchange of physical materials" (Welding, S. 2012).

Locard believed that no matter what a perpetrator does or where he goes, by coming in contact with things at or around a crime scene he can leave all sorts of evidence, including DNA, fingerprints, footprints, hair, skin cells, blood, body fluids, pieces of clothing fibers and more (Welding, S. 2012). While the criminal leaves something at the crime scene he is also expected to take something away from the scene with him (Welding, S. 2012). On a very loose connect it m might be said that when killing an individual with a hammer hit the criminal might take away the murder weapon with him but at the same time he might end up leaving behind bloody stains of the blood bearing hammer at the crime scene. 'A bloodstain resulting from contact between a blood-bearing surface and another surface' has been termed as 'Transfer Stain' by the International Association of Bloodstain Pattern Analysts (IABPA) (SWGBPA, 2009). Thus this work is particu larly directed at studying different transfer stain patterns at a crime scene. The scientific study/interpretation of bloodstain patterns at a crime scene, provide invaluable evidence for sequencing, reconstruction of events that might have occurred at the crime scene. As per the Federal Bureau of Investigation(FBI) each year a greater number of people die as a consequence of blunt force trauma compared to the number of people who are killed with a rifle or shot gun. From documentation phase to final interpretation, bloodstain pattern analysis is deeply rooted in the principles of physics, fluid mechanics, medical science, computer science, mathematics etc. Bloodstains are classified into three basic types: passive stains, transfer stains and projected or impact stains. Passive stains include drops, flow and pools, and typically result from gravity acting on an injured body. Transfer stains result from objects coming into contact with existing bloodstains and leaving wipes, swipes or pattern transfers behind such as a bloody shoe print or a smear from a body being dragged. Impact stains resultfrom blood projecting through the air and are usually seen as spatter, but may also include gushes, splashes and arterial spurts. The authors conducting the study are particularly interested in recording, analysis and interpretation of the Transfer Stain and Saturation Stain patterns one can expect to see in the event of head hit by a blunt ended object (such as hammer, golf stick, candle stand etc.)[1-2]. Given the large possibility of instruments that can be easily obtained and hence deliver blunt force injuries to the human skull, the authors decided to particularly focus on the possible Transfer and Saturation stain patterns formed at a crime scene as a result of assault particularly with blunt ended objects. Thus in a violent crime scene with sufficient amount of bloodshed, bloodstain pattern analysis often plays a significant role in proving or refuting the statements of the suspect, victim, bystander/eyewitness(if any) within the juridical setting. The stains along with the wound suffered by the victim/s could also be used for part/full reconstruction of crime scenes. These case studies particularly set out the background for this paper. On December 13, 2010, Dave Toplikar's report reinforced the importance of proper recording and hence interpretation of weapon transfer stains at a crime scene (Toplikar, D. 2010). Dave's report in the Las Vegas Sun highlighted how the presence of a hammer imprint in blood pool was capable of influencing the decis ion of the jury and the fate of Mr.Edward Preciado Nuno, an ex-FBI special agent (Toplikar, D. 2010). While Daniel Holstein, senior crime scene analyst in Metro police and a certified expert in bloodstain pattern analysis, gave the case a new dimension by focusing on the hammer imprint that matched the size of the hammer that lay close to the apparent victim's hand, Thomas Pitaro the defense attorney clearly marked out that the hammer imprint theory was not mentioned in the police report and was only added much later (Toplikar, D. 2010). There are two lessons to be learnt from the juridical proceedings of this particular case. Firstly, transfer stains often go unattended and hence unrecorded by most law enforcement officials. Secondly, when analyzed in relation to suspect, eyewitness testimony or other relevant circumstantial evidence, weapon transfer stains could actually give criminal juridical proceedings a new dimension (Toplikar, D. 2010), a new perspective.

This paper aims at documenting possible domain knowledge that could help crime scene investigators identify or sequence events based on hammer imprints /hammer like imprints in a blood pool or blunt object transfer stains together with other circumstantial evidence. The hypotheses that the authors intend to test in this work can be summarized as follows

The presence of a hammer or hammer-like transfer stain or imprint in blood pool does not necessarily imply that that the particular tool has been used as the murder weapon in the particular crime scene

Bloodstain imprints formed when a hammer is p laced in a blood pool and then placed on a different surface and the case when a sufficient quantity of blood drips or falls under gravity from a height of 10 cms (say) over a hammer Lessing on a plain, non-absorbent surface are particularly different.

In particular, Professor MacDonnell's contribution to the research and interpretation of bloodstain pattern analysis since 1971 stands commendable till date [5a-5b]. The Association of Crime Scene Reconstruction defines reconstruction as "the use of scientific methods, physical evidence, deductive and inductive reasoning and their inter-relationships to gain explicit knowledge of the series of events that surround the commission of a crime."[4] T. Bevel and M. Gardener in their book on 'Blood Stain Pattern Analysis 3rd ed ition- An Introduction to Crime Scene Reconstruction' have explicitly explained the different types of bloodstain patterns as described by the International Association of Bloodstain Pattern Analysts [4]. The book also contains a detailed classification of bloodstain patterns. How patterns vary with difference in angle of impact, fall height, temperature, surface texture, surface absorption capability etc. has been neatly documented in the book [4]. Dr. Brodbeck's article on 'Introduction to bloodstain pattern analysis', highlights important factors when documenting the bloodstain patterns at a crime scene[6]. James, Sutton and Kish's book on 'Principles of Bloodstain Pattern Analysis: Theory and Practice' also explicitly explains the use of bloodstain evidence and its effective use with other circumstantial evidence for sequencing the events in a particular crime scene[7]. Stuart H. James's book on 'Scientific and Legal Applications of Bloodstain Pattern Interpretation' outlines the rules for documentation and presentation of bloodstain patterns within a juridical setting. Illes et al. presented a set of criteria for selection of patterns in an impact spatter using a statistical model[8]. Proper selection of stains in an impact spatter is particularly important for calculation of the area of origin of the impact that created the particular spatter stain. Shen, Brstow , Cipolla developed an algorithm for automated estimation of a body's 2D location on a floor plan when the body is impacted given that the blood stains are formed as a result of impact spatter[9]. This study is particularly inspired from the work of Barksdale, Sims and Vo in which they compared a reference array of knife impressions with impressions obtained from two real life crime scenes[10]. The main highlights of the study were that the knife impression stains may display enough characteristics for an individual to match it to a suspected knife. Also the weight of a knife is highly unlikely to be sufficient to produce a void pattern in a blood soaked surface by way of reverse capillary action[10]. John J. Nordby documented the scientific basis/explanation that governs the mechanism of bloodstain pattern/spatter formation in a crime scene[11].

Figure 1: Experimental Setup replicating the event of a head hit. As the authors were not inclined towards recording the stains (particularly cast off and impact spatter patterns) formed on the walls and ceilings for a particular height of the victim, perpetrator, number of hits made by the perpetrator, hence this setup was constructed.

The experiment was performed in 2 phases. In the first phase the coconut shell was hit w ith each hammer consecutively for 10 times and then each hammer was dropped from a height of 40 cms, 60 cms and 80 cms respectively. In order to m inimize or control property damage the hammer was dropped on a paper sheet (A3 size) placed on a thermocol sheet (refer Figure 2).

Figure 2: Thermocol sheet placed on the floor to avoid damage of the floor tiles. Paper sheet is placed on the thermocol sheet and hammer is dropped on the paper sheet by measuring the fall height from the top of the thermocol sheet.

The fall height was measured from the top of the thermocol sheet. In the next part of the experiment, each hammer was again used for 10 head hits, then dropped in a 30cc. blood pool, picked up and again made to fall from a height of 40cms, 60cms, and 80cms respectively. The two incidents that the authors intended to recreate by way of the experiment can be outlined as follows,

Incident 1: The perpetrator h its the victim 10 times and the hammer slips and falls under gravity from a height of 40, 60 and 80cms respectively.

Incident 2: The perpetrator hits the victim 10 times and the hammer slips and falls off from his hand under gravity and falls into a blood pool (30cc) (refer figure 3). The perpetrator picks up the hammer and it yet again s lips and falls off from the hand of the perpetrator from a height of 40, 60 and 80cms respectively. In the second phase, the bloody edge impression of each hammer was taken after 10 head hits. Two impressions of each edge were recorded in the course of the experiment. In the first instance, the hammer was simply placed on a plain/smooth non-absorbent surface (paper) w ith the bloody edge being the only contact point between the surface and the hammer for a brief period of 5secs. In the second part of the experiment, after 10 head hits the paper surface was struck with the bloody edge of the hammer at a particular velocity. The paper surface wasn't hit with an extremely large force as because a full force hit was found to rupture the paper surface.

Figure 3: Dried up 30 cc blood pool created on a plastic sheet. The blood pool was not created on paper as the paper surface would cringe on the drying of the 30 cc(ml) blood pool. The height of the victim/perpetrator was not taken into account in the study as the authors did not want to record the cast off, fingerprint transfer stain patterns that might be formed as a result of head hit.

A crime scene where bodily injury has occurred is likely to have some amount of bloodstain evidence present; however, the amount will vary depending on the circumstances of the crime. The type of injury inflicted and the amount of force used will determine the volume and pattern of bloodstains:

Sharp force in juries (s tabbing) - these injuries are caused by an object with a relatively small surface area, such as an ice pick or a knife. Less blood is deposited on the instrument, resulting in a smaller, more linear pattern of stains.

Blunt force injuries (hitting or beating) - objects inflicting this type of injury are usually larger, such as a bat or hammer. If the object impacts liquid blood, the larger surface area will collect more blood, producing drops of varying sizes. Gunshot injuries - mist-like spatter caused by bullets entering and exiting the body.

When the hammer is dropped face down into a 30 cc. Blood pool, a greater surface area of the hammer comes in contact with blood molecules. So as compared to a hammer that has been used for approximately 10 head hits one can logically expect more blood molecules to be stuck to a piece of hammer that has been used for 10 s simultaneous head hits followed by being dropped into a 30cc. blood pool and then picked up. Now again when these two bloody hammers having similar dimensions were allowed to drop from the same height, the blood spatter marks for the bloody hammer that had been initially used to hit the head 10 times were found to be much less pronounced as compared to the stains produced by bloody blood pool soaked hammer when it was dropped bloody face down. As the quantity of blood stuck to the blood pool soaked hammer as compared to the head hit bloody hammer was more, hence the blood in the first case forms a more significant spatter. A gain, blood spatters only when other forces exceed the surface tension that holds the blood molecules together (CLT, 2014). The gravitational force with which the bloody hammer hits the surface exceeds the surface tension. Given the comparatively larger quantity of blood attached to the bloody face of the blood pool soaked hammer, blood was found to spatter more in its case. Thereby it can be concluded that the When blood is impacted, droplets are dispersed through the air. When these droplets strike a surface, the shape of the stain changes depending on the angle of impact, velocity, distance travelled and type of surface impacted. Generally, the stain shape will vary from circular to elliptical, with tails or spines extending in the direction of travel. Smaller satellite stains may also break away from the initial drop. By measuring the width and length of the stain, the angle of impact can be calculated, helping investigators determine the actions that may have taken place at the scene.

Thus logically there is enough evidence to prove that hypothesis 1 does hold true in linking a hammer present at a crime scene to it actually being used as a murder weapon at the crime scene. Hypothesis 2 outlines that the transfer patterns obtained when a hammer is placed in a blood pool and then picked up and placed b bloody face down on a plain non-absorbent surface are particularly different from the transfer stains produced when blood drips over a hammer and the lower side is placed on a plain, non-absorbent surface. It can be clearly observed that the transfer stains formed when blood was allowed to trickle down the hammer surface are much less defined as compared to the transfer stains produced when hammer was dropped on a blood pool. When it comes to obtaining clear, defined transfer stain patterns for the case when blood is allowed to fall under gravity over a hammer, the dimensions of the hammer, it's shape, material, the quantity of blood as also the absorption capability of the surface on which the pool is formed matters.

CONCLUSIONS

We intend to document the stain type we can see or might expect to see on the clothes of an individual when he is a victim, perpetrator or a simple bystander in the event of a head hit of a victim using a stick, rod, axe etc. (The instruments of head hit shall be decided in discussion and study of court proceedings of several violent cases that have so far been solved) in an indoor setting. Based on the velocity of hit, stain type on cloth of an individual, number of hits, distance between the victim , perpetrator and bystander, relative position of the three at the time of hit, movement of any party before probable subsequent hits, direction of movement of weapons and people, room temperature, humidity, room dimensions, person height , w eight ,using Bayesian networks, correlation and regression we would try to probabilistically infer the position of an individual (victim, perpetrator, bystander(if any)).

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