BLOODSTAINS ON FABRIC
The Effects of Droplet Velocity and Fabric Composition

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Abstract
The interpretation and analysis of bloodstain patterns in a criminal investigation may include or be exclusively based upon the bloodstain patterns observed on fabric. The interpretation of the bloodstain patterns observed on a person's clothing may provide vital evidence which will be used to corroborate or refute that person's statement concerning their involvement during a criminal occurrence.

Although the interpretation of bloodstains on fabric is a very important subject area within the science of Bloodstain Pattern Analysis, there is little published research available on the topic.

The objective of this research project is to determine if the appearance of bloodstains observed on fabric is a function of the blood droplet velocity, fabric structure, or a fabric's ability repel or absorb blood. This research project has been divided into two parts:

Part I
Bloodstains created on a collection of various fabrics, based upon fabric composition, fabric texture, new versus used fabrics, and chemically treated fabrics will be experimentally compared on the basis of:

a) the reliability of angle of impact calculations,
b) the effects of blood droplet velocity based upon a passive and a medium and high velocity impact event, and
c) microscopic bloodstain analysis.

Part II
A collection of various fabrics placed at different distances will be exposed to blood droplets generated by a high-speed fan and compared on the basis of bloodstain size versus distance traveled relative to fabric composition and chemically treated fabrics.

Part I

Materials

The following fabric materials and paper standard were collected and cut into 13cm x 8cm (5in. x 3in.) samples then mounted on four 61cm x 61cm (24in. x 24in.) foam core photographic boards to form four identical target surfaces:

1	100% Cotton (new[1])
2	100% Cotton (new, treated with fabric starch[2])
3	100% Combed Cotton (new)
4	100% Combed Cotton (washed[3])
5	100% Cotton Denim (new)
6	100% Cotton Denim (washed)
7	100% Blue Cotton Denim (worn[4])
8	65% Polyester / 35% Cotton (new)
9	65% Polyester / 35% Cotton (treated with Scotchgard®[5])
10	65% Polyester / 35% Cotton (washed)
11	50% Cotton / 50% Polyester (worn)
12	90% Acetate / 10% Nylon (worn)
13	100% Acrylic - Medium Weave (worn)
14	100% Acrylic - Coarse Weave (worn)
15	100% Nylon (new)
16	100% Nylon - water repellent (new)
17	100% Textured Silk (new)
18	100% Fine Silk (worn)
19	60% Rayon / 40% Polyester (worn)
20	100% Rayon (new)
21	100% Polyester (new)
22	100% Polyester (treated with Scotchgard®)
23	Paper

[1] **NEW** fabrics were cut from new fabric bolts at a local retail supplier.
[2] Entire surface was sprayed with **EASY ON FABRIC STARCH™.**
[3] Fabric was **WASHED** in a standard clothes washer with **TIDE™** detergent and dried in a standard clothes dryer with **BOUNCE™** fabric softener.
[4] **WORN** fabrics were purchased at a second-hand clothes retailer.
[5] Entire surface was sprayed with **3M SCOTCHGARD®** fabric treatment.

Method

Once the targets were assembled, they were subjected to four blood droplet-generating events utilizing human blood drawn by venipuncture into sterile vacuum tubes containing EDTA.

TRANSFER BLOODSTAINS

A 1.6mm internal diameter (2.8mm external diameter) plastic pipette was filled with liquid blood drawn near body temperature. The pipette bulb was compressed until a blood droplet formed at the end of the plastic tube. At the instant a complete droplet was formed, the blood droplet was touched to the fabric surface, transferring the blood onto the target. This technique was repeated three times to create three separate stains.

The transfer targets were also subjected to a passively falling blood droplet which was generated by a 1.6mm diameter pipette and allowed to fall from a height of 25cm (10in.) to the target which was set at an angle of incidence of 45 degrees.

PASSIVE[6] BLOODSTAINS

A 1.6mm diameter plastic pipette was moistened with liquid blood drawn near body temperature. The pipette tube was directed upwards 1.5m (5ft.) above a fabric target which was placed horizontally on the floor. The pipette bulb was then compressed aspirating projected blood droplets upwards. The resultant blood droplets, upon reaching their terminal height (due to the effects of air resistance and gravity) then fell to strike the target at a velocity not exceeding their terminal velocity of 7.65 m/sec. (25.1 ft/sec).

MEDIUM VELOCITY IMPACT EVENT

One (1)ml of blood, drawn near body temperature was placed on the striking plate of a hammer apparatus specifically designed for bloodstain impact event testing. Upon release of the hammer, projected blood droplets traveled to a target vertically mounted 95cm (37in.) in front of the apparatus.

HIGH VELOCITY IMPACT EVENT

A 6cm (2.5in.) area of highly absorbent commercial cleaning cloth was vertically mounted and saturated with blood drawn near body temperature. A .22 cal high velocity handgun round was then discharged from a position near contact through the saturated cloth. The resultant blood droplets then traveled to a target which was vertically mounted 70cm (28in.)behind the blood source.

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[6] **PASSIVE** in this context is used to describe the blood droplet velocity only i.e. acted upon by the force of gravity only and thus not able to exceed the terminal velocity of 7.65 m/sec. (25.1 ft/sec.).

Results

Upon completion of the lab experimentation the fabric samples were observed, photographed, and compared. The following observations were made:

TRANSFER

100% Cotton, 100% Acrylic, 100% Polyester

The *transfer* experimentation technique that was utilized in this research provided a graphic illustration of the wide range with which material composition affects the ability to absorb and disperse liquid blood:

(a) New 65% polyester/35% cotton, 100% nylon with and without water repellent, and all fabrics treated with Scotchgard® showed **little or no blood absorption**. In most cases the blood droplet remained intact until the blood dried and, in the case of the water-repellent nylon, dropped from the material during transport.

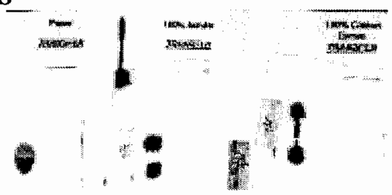
(b) 100% acrylic (medium weave), 100% silk (fine and textured), 60% rayon/40% polyester and 100% polyester were all observed to be **highly absorbent of blood.** The silk, polyester and rayon/polyester fabrics displayed such a high degree of absorbency that the blood droplets diffused into each other producing a single large stain.

(c) All other tested fabrics exhibited moderate blood absorption.

(d) The coarseness of the fabric weave appears to restrict the ability of the blood to diffuse and be absorbed within the fabric. This was observed during the comparison of the 100% acrylic samples, course and medium weave.

(e) **Washing** a new fabric **greatly enhances** its ability to absorb and disperse blood. This was clearly evident where the comparison of new versus washed fabrics were made i.e. 100% combed cotton and 65% polyester/35% cotton.

IMPACT ANGLE COMPARISONS



Paper, 100% Acrylic, 100% Cotton Denim

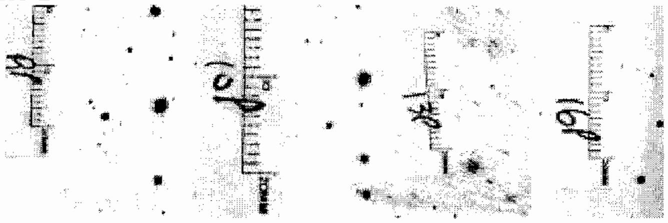
Using the bloodstain on the paper target as a standard for comparison purposes the following observations were made:

(a) Bloodstains observed on the **highly absorbent** materials i.e. 100% silk, 60% rayon/40% polyester and 100% polyester exhibited the **greatest degree** of distortion and would not be suitable for impact angle determination. The 100% acrylic fabrics produced bloodstains near-circular in appearance which could erroneously be interpreted as contacting the fabric at or near 90 degrees.

(b) Fabrics with **poor absorbency** properties also exhibited a **high degree of stain distortion**. The stain distortion in this case was due to the blood droplet "rolling" across the fabric and not readily being absorbed. However, the general directionality of the blood droplet could be determined.

(c) The texture or coarseness of the fabric weave also affects bloodstain distortion.

PASSIVE BLOODSTAINS



65/35 PolyCotton (new), 65/35 PolyCotton (washed), 100% Acrylic, 100% Nylon

As with previous observations, it appears that stain distortion is dependent upon the ability of the fabric material to absorb blood and upon the coarseness of the texture of the weave:

(a) Absorbent fabrics such as 100% cotton, 65% polyester/35% cotton, 100% acrylic, 100% silk (textured), 100% polyester all displayed distortion. 100% silk (fine), for a reason not yet determined, was an exception to this observation: The distortion as a result of absorbency was observed as a central concentrated stain and a diffused outer stain ring.

(b) Distortion as a result fabric texture appears to be dependent upon two factors: droplet size and thread width. Where the droplet size was smaller than the thread size, the bloodstain remained circular and defined; if the droplet was sufficient to saturate a single thread, the blood was absorbed along the length of the thread, resulting in a distorted stain; if the blood volume exceeded the thread size, the bloodstain was distorted along the "grain" of the fabric.

(c) The greatest stain distortion was observed in fabrics where both high absorbency and fabric coarseness were present, i.e. 100% silk (textured).

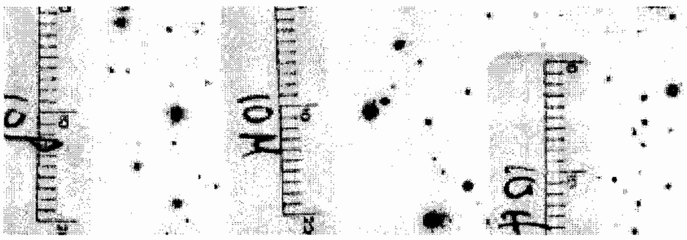
(d) Generally, the least amount of stain distortion was observed in the non-absorbent and Scotchgard® treated fabrics, i.e. 90% acetate/10% nylon, 100% nylon and 100% rayon.

MEDIUM VELOCITY IMPACT EVENT

Bloodstains produced as a result of a medium velocity impact event generally displayed the same properties as those which were observed during the "passive" experimentation. **However, in certain fabrics such as 100% cotton (new) and 65% polyester/35% cotton (washed), the outer diffused ring which was previously described in the "passive" observations, was replaced by secondary satellite spatter around the inner primary bloodstain.**

HIGH VELOCITY IMPACT EVENT

Bloodstains produced as a result of a high velocity impact event were not observed to produce any significant difference from those which were produced by the medium velocity impact event.



65/35 PolyCotton (washed): Passive, Medium, High

Conclusions (Part I)

Based upon the experimentation which has been completed, there are some initial basic guidelines which may be stated:

(a) The degree of distortion of bloodstains observed on fabric is a function of **both** the ability of the fabric to absorb blood and the texture of the fabric.

(b) **Limited observations** may be made relating the effect of **blood droplet velocity** on bloodstains observed on fabric: Higher velocity blood droplets may produce satellite spatter upon impact with the cloth surface. This property is individual to each fabric type and is dependent upon the ability of the fabric to absorb blood and the texture of the fabric. The appearance of satellite spatter is also dependent on blood droplet volume.

(c) Washing a fabric directly affects bloodstain appearance and therefore new fabrics should never be used for bloodstain experimentation testing for comparison to actual investigative observations.

(d) Scotchgard® type fabric treatments directly effect bloodstain appearance and those effects should be taken into account when interpreting bloodstains observed on potentially treated materials, i.e. furniture fabrics. Fabric starches do not appear to affect bloodstain appearance.

Part II

Materials

The following fabric materials of similar texture and weave were collected and cut into 80cm x 10cm (32in. x 4in.) strips and mounted on four 100cm x 100cm (40in. x 40in.) foam core photographic boards to form four identical target surfaces:

1. 100% Wool
2. 100% Polyester
3. 100% Silk
4. 100% Acrylic
5. 100% Blue Cotton Denim (worn)
6. 80/20 Cotton/Polyester
7. 100% White Cotton Denim (new/washed)
8. 80/20 Cotton/Polyester (6) with Bounce™ fabric softener
9. 100% White Cotton Denim (7) (new/washed) with Bounce™ fabric softener

Method

The four target surfaces were laid horizontally and inline on the floor in front of a high-speed fan apparatus[7] which was placed on a table 1m (40in.) from the ground. The centre of each target surface was placed at .5m (20in.), 1.5m (5ft.), 2.5m (8.2ft.), and 3.5m (11.5ft.) from the base (at floor-level) of the droplet-generating fan. Blood droplets were then generated by expelling 10ml of liquid blood by syringe into the rotating fan blades. The injection of blood was conducted ten (10) times to produce a sufficient number of bloodstains on the targets for an accurate representation and analysis. Ten (10) of the **smallest observable bloodstains**[8] for each tested fabric, at each respective target-to-source distance, were then measured and averaged.

Results

	1 100% Wool	2 100% Poly	3 100% Silk	4 100% Acrylic	5 100% Cot/Den	6 80/20% Cot/Poly	7 100% Cotton	8 80/20% C/Pw/Bnc	9 100% Cot/wBnc
0.5m	<0.1mm	<0.1mm	<0.1mm	<0.1mm	<0.1mm[9]	<0.1mm	<0.1mm	<0.1mm	<0.1mm
1.5m	0.4mm	0.5mm	0.4mm	0.2mm	0.4mm	0.8mm	0.8mm	0.6mm	0.6mm
2.5m	1.0mm	1.0mm	0.8mm	0.8mm	1.4mm	1.4mm	1.5mm	1.2mm	1.2mm
3.5m	1.6mm	1.6mm	1.6mm	2.0mm	2.0mm	2.4mm	2.6mm	2.4mm	2.2mm

**High and low values of size range are highlighted*

Conclusions (Part II)

From the experimental results provided, it is quite evident that distance to source determination based upon bloodstain sizes observed on fabrics is directly dependent upon the target surface composition and the use of any chemical fabric softening treatments.

A bloodstain analyst conducting an examination of clothing or any other fabric medium must consider the particular fabric, fabric texture, and the use of fabric treatments when assessing target distance from a blood source based upon bloodstain size.

[7] Built by RCMP S/Sgt. Dan Rahn. Liquid blood is injected by syringe from the top of the fan housing into the rotating fan blades causing the blood droplets to be propelled horizontally.
[8] Bloodstains generated by "wave cast-off" on the target surface were ignored.
[9] Material was a washed/worn blue denim. Observation and measurement of the smallest stains was very difficult even under ideal conditions. All other fabrics tested were white.