Transfer and persistence of glass fragments on garments

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Panes of float glass were broken in order to study transfer and persistence of glass fragments on clothing: several breaking devices were tested (hammer, stone and pendulum). The experiments, including two persons, consisted in breaking a pane and wearing the clothing for variable periods of time t: one pane was broken for each experiment. The results show that the number of fragments transferred is highly variable. However some trends, confirming previous research, can be outlined: 1. The number of fragments transferred depends on the number of strikes and on the distance between the pane and the person standing nearby; 2. The number and size of the fragments retained depend on the period of time t, on the composition and/or weaving of the garment; 3. Even eight hours after breaking a glass pane it is possible to find as many as seven glass fragments.

Um die Übertragung und den Verbleib von Glasteilchen auf Bekleidungsstücken zu untersuchen wurden Flachglasscheiben mit Hilfe verschiedener Schlagwerkzeuge zerbrochen (Hammer, Stein, Schlagpendel). Die Versuche wurden mit 2 Personen durchgeführt, die nach dem Zerbrechen der Scheiben die Kleidung über unterschiedlich lange Zeiträume trugen. Für jeden Versuch ist jeweils eine neue Scheibe verwendet worden. Die Ergebnisse zeigen, daß die Zahl der übertragenen Partikel stark variiert. Es können jedoch folgende allgemeine Schlüsse gezogen werden, die frühere Untersuchungen bestätigen: 1. Die Anzahl der übertragenen Glasteilchen ist abhängig von der Zahl der Schläge und vom Abstand der betreffenden Person von der Scheibe. 2. Die Zahl und die Größe der auf dem Spurenträger verbleibenden Teilchen hängt von der Länge der Tragezeit und von der textilen Konstruktion des jeweiligen Kleidungsstückes ab. 3. Auch 8 Stunden nach der Übertragung sind verschiedentlich noch bis zu 7 Glasteilchen gefunden worden.

En vue d'étudier le transfert et la persistance des fragments de verre sur les habits, des vitres (verre flotté) ont été brisées en utilisant trois méthodes de bris: par pendule, par jet de pierre et avec un marteau. A chaque expérience, une nouvelle vitre a été brisée par l'auteur en présence d'un complice, puis les habits ont été portés pendant une période de temps t. Les résultats, bien que variables, montrent les tendances suivantes: 1. Le nombre de fragments transférés dépend du nombre de coups et de la distance séparant la personne de la vitre. 2. Le nombre et la taille des fragments retrouvés dépendent du laps de temps t, de la composition et/ou de la maille du vêtement porté. 3. Les expériences menées ont montré qu'il était possible de retrouver jusqu'à sept fragments, huit heures après le bris.

Con el fin de estudiar la transferencia y persistencia de los fragmentos de vidrio sobre la ropa, se han roto paneles de vidrio de tres formas diferentes: con un martillo, con una piedra y con un péndulo. Los experimentos, llevados a cabo por dos personas, consistieron en romper un panel y llevar la ropa durante un periodo de tiempo t, variable. Los resultados muestran que el número de fragmentos transferidos es sumamente variable. Sin embargo se pueden destacar algunas tendencias que confirman investigaciones previas: 1. El número de fragmentos depende del número de veces que se golpee el cristal y de la distancia entre el panel y la persona que se encuentra al lado; 2. El número y tamaño de los fragmentos depende del periodo t y de la composición y urdimbre del tejido; 3. Incluso después de ocho horas de haber roto el panel es posible encontrar por lo menos siete fragmentos de vidrio.

Key Words: Forensic Science; Glass; Windows; Interpretation; Transfer; Persistence; Garments.

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Introduction

Transfer and persistence are crucial points when interpreting glass evidence following backward fragmentation [1,2]. The examiner must evaluate the compatibility between the number and size of the glass fragments recovered on the one hand and the time elapsed between breaking of the window and the search for glass fragments on the suspect's garments on the other.

In that context, Pounds and Smalldon [3], as well as Scranage [personal communication], Luce et al [4] and Locke and Unikowski [5,6], published research on the transfer and persistence of glass fragments. Their results tended to show that the size and the number of fragments decrease with distance. Pounds [personal communication] also ascertained that retention was a function of the garment and that loss followed an exponential curve. The study of Brewster et al showed that transfer of glass particles is a function of their size and the composition of the fabric [7].

Because of the complexity of transfer and persistence phenomena, new experiments were undertaken to try to answer the following questions:

Does the number of transferred fragments depend on how the window was broken?

Is the number of fragments transferred related to the distance between the window and a person standing nearby?

Are fewer fragments recovered if more time elapses between breakage and search?

Does the number and size of the fragments retained depend on the weave and composition of the garment?

Experimental

All the panes used were bought from the same supplier (Miroiterie du Léman, Lausanne). They consisted of float glass panes measuring 0.60 m long, 0.60 m wide and 3 mm thick which, before breakage, were clamped with wooden strips in a wooden frame. Initially, two pendulums of 2 kg and 5 kg were used as breaking devices. In both cases, the breaker was 0.70 m from the window and the accomplice at 1.50 m. As found by Luce et al [4], Scranage [personal communication], and Locke and Unikowski [5], very few fragments were transferred: therefore we decided to adopt the hammer as our main breaking device.

Forty-five panes were broken completely with multiple blows from a 460 g hammer. The number of times the breaker had to hit the pane in order to break it completely varied from experiment to experiment. Seven panes were broken by throwing a 960 g stone. The point of impact, in the middle of each pane, was maintained at 1.40 m above ground level. The breaking apparatus is shown in Figure 1.

The 52 experiments involved two persons. The 'breaker' wore a cotton tracksuit and the 'accomplice' a bulky woollen pullover and denim jeans. The distances between window, breaker and accomplice are shown in Figure 2. Garments were removed a few metres away from the breaking device. Since the type of activity adopted by the person wearing the garments influences retention, an attempt was made to standardise activity by hooking garments to an agitator. With this system the loss of fragments was too limited: the number recovered after 24 hours of shaking was the same as the number recovered after 30 minutes of normal wearing, even though there was no strenuous activity such as running.

In order to recover glass fragments the garments were shaken and brushed over a large sheet of paper, as recommended by Pounds [personal communication]. Glass particles from all the hammer experiments were separated into four size fractions using 100 mm diameter Retsch test sieves (Schieritz & Hauenstein AG, Arlesheim, Switzerland). As recommended by Locke and Unikowski [5] 'gentle

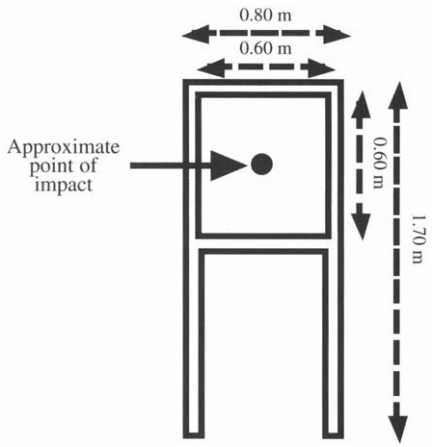

FIGURE 1 Breaking apparatus.

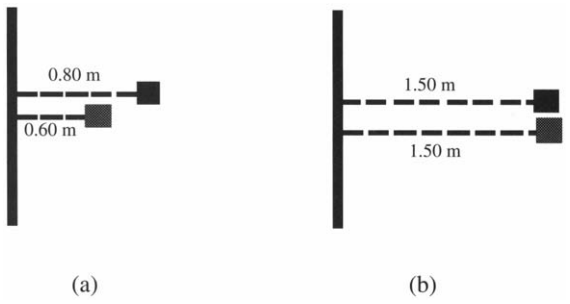

FIGURE 2 Distance between window, breaker and accomplice. (a) Multiple blow break with hammer (45 experiments). (b) Single blow break throwing a stone (7 experiments). ■ Breaker's position. ■ Accomplice's Position.

TABLE 1 Number of fragments recovered at time t=0. The window has been broken by a hammer with the breaker standing 50 cm away; accomplice stood 80 cm away.

Experiment no.	*Breaker's sweater*	*Breaker's trousers*	*Accomplice's pullover*	*Accomplice's jeans*
1	92	10	28	22
2	149	23	62	26
3	56	19	30	15
4	110	17	37	85
5	95	18	32	4
6	44	10	15	11
7	121	67	46	47
8	67	19	29	9
9	141	60	42	10
10	160	81	34	34
11	241	18	47	8
12	177	45	72	46
13	144	25	45	7
14	192	45	63	12
15	113	5	25	31
Mean	127	31	40	24
Range	44–241	5–81	15–72	4–85

TABLE 2 Number of fragments recovered at time t=0. The window has been broken by throwing a stone.

Experiment no.	*Breaker's sweater*	*Breaker's trousers*	*Accomplice's pullover*	*Accomplice's jeans*
1	3	3	4	12
2	4	7	14	16
3	16	10	8	7
4	1	5	2	3
5	0	0	2	0
6	1	0	1	1
7	5	4	1	4
Mean	4	4	5	6
Range	0–16	0–10	1–14	0–16

agitation and tapping of the sieve was applied rather than vigorous shaking to minimise further fragmentation'. After sieving, particles were transferred to a plastic Petri dish and counted under a low power microscope.

Persistence was studied using the hammer as a breaking device. After each breaking the garments were worn for a period of time t = tx–t0 (where x = 30, 60, 120, 240 and 480 minutes) and then searched for fragments. For each period t, the experiments were carried out six times.

Results

Table 1 shows the number of fragments recovered a few seconds (taken as t = 0) after a pane was broken with multiple hammer blows. There was much variation between experiments: in Experiment eleven, 241 fragments were recovered from the breaker's sweater whereas in Experiment six only 44 fragments were recovered. More fragments were always transferred to the upper garments, with the greatest number of fragments found on the breaker's sweater.

Table 2 shows the results when seven panes were broken with a stone. The number of glass particles transferred was not only very low, by comparison with the previous experiments, but also highly variable (between zero and 16 for the breaker's sweater, zero and ten for his trousers, one and 14 for the accomplice's woollen pullover and zero and 16 for

TABLE 3 Number of fragments recovered from clothing at time t hours after a pane of glass was broken by repeated hammer blows.

t(hours)/ Experiment no.	*Breaker's sweater*	*Breaker's trousers*	*Accomplice's pullover*	*Accomplice's jeans*
0.5/1	19	4	5	8
/2	16	29	8	9
/3	12	7	17	25
/4	32	9	16	13
/5	29	11	12	11
/6	13	5	4	5
1.0/1	12	6	11	25
/2	30	8	21	28
/3	12	2	5	6
/4	5	3	9	8
/5	8	10	7	4
/6	9	5	8	4
2.0/1	16	6	10	8
/2	2	8	8	9
/3	3	3	10	8
/4	4	4	4	4
/5	11	8	4	4
/6	4	1	9	2
4.0/1	6	8	8	7
/2	5	5	6	2
/3	5	6	9	1
/4	15	9	14	18
/5	4	8	1	2
/6	4	3	6	8
8.0/1	0	0	2	1
/2	1	3	7	5
/3	1	3	2	2
/4	4	6	2	4
/5	3	1	7	6
/6	3	2	4	6

TABLE 4 Summary of the results in Table 3 (repeated hammer blows). Mean number of glass fragments (and range) found after time t.

t(hours)	*Breaker's sweater*	*Breaker's trousers*	*Accomplice's pullover*	*Accomplice's jeans*
0.5	20 (12–32)	11 (4–29)	10 (4–17)	12 (5–25)
1.0	13 (5–30)	6 (2–10)	10 (5–21)	13 (4–28)
2.0	7 (2–16)	5 (1–8)	8 (4–10)	6 (2–9)
4.0	7 (4–15)	7 (3–9)	7 (1–14)	6 (1–18)
8.0	2 (0–4)	3 (0–6)	4 (2–7)	4 (1–6)

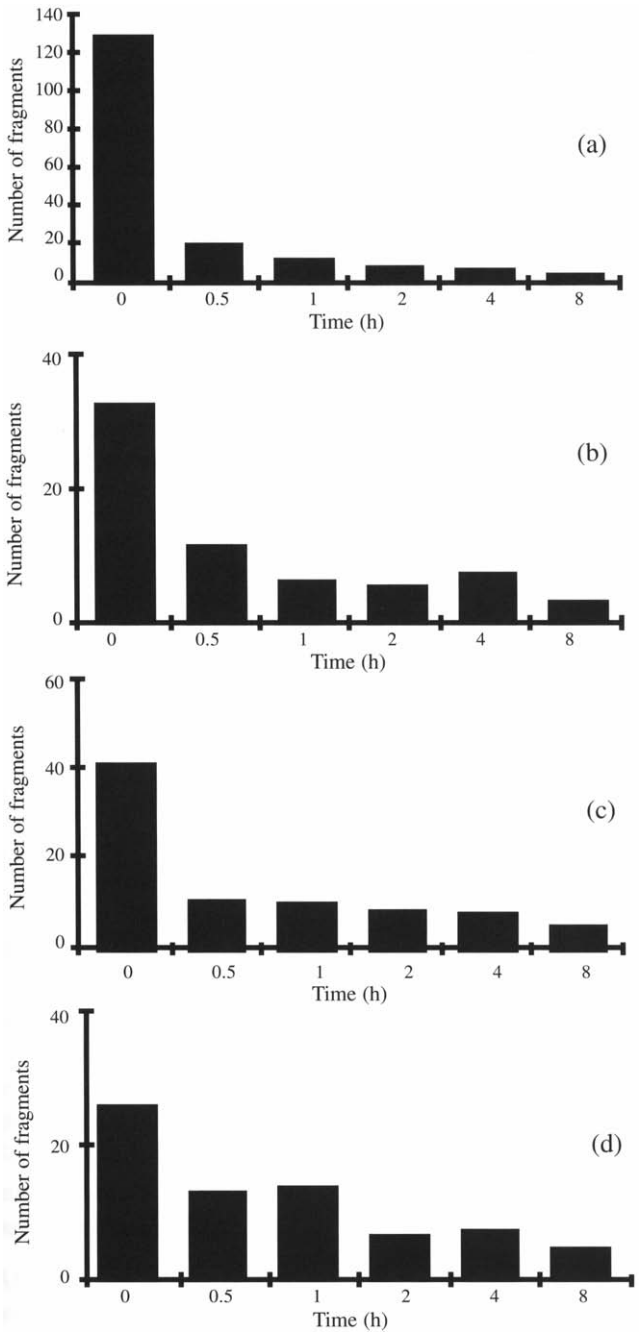

FIGURE 3 Presence of glass fragments on: (a) breaker's cotton sweater; (b) breaker's cotton trousers; (c) accomplice's woollen pullover; and (d) accomplice's denim jeans; when glass is broken with a hammer by a person standing at 50 cm and the accomplice is standing at 80 cm.

his jeans). Comparing the average number of fragments found on the breaker's sweater, it can be seen that about 100 fragments were transferred when using a hammer, and four when throwing a stone. The distance between the breaker and the pane was three times greater when throwing the stone.

The results of the persistence studies are presented in Table 3 and summarised in Table 4. Once again there was considerable variation in the number of fragments retained. Immediately after the breaking there were on average three times as many fragments on the breaker as on the accomplice; after eight hours the situation reversed with two fragments being found on the breaker and four on the accomplice. Most fragments were lost during the first half hour. The top of the breaker's tracksuit presents the most striking loss: half an hour after the breakage less than 20% of the fragments remained. The results are illustrated in Figures 3a to 3d.

The transfer and persistence results are presented according to size in Table 5. The size range refers to the fraction which passed through a mesh size and not to the measured size of individual fragments. In spite of the high variability, it can be seen that the longer the lapse of time between transfer and searching, the larger the proportion of small fragments (0.2 mm–0.5 mm). If, therefore, garments are searched for glass after eight hours, fragments bigger than 0.5 mm will seldom be found. It is also worth noting that the proportion of fragments bigger than 0.5 mm recovered from the accomplice's woollen pullover was twice that for the breaker's cotton tracksuit top. After eight hours, no fragment bigger than 0.2 mm remained on the breaker's garment, whereas there were still approximately 10% of the fragments in the size range 0.5–1 mm on the accomplice's pullover.

Discussion

Nelson and Revell found that numerous glass fragments are projected in the direction of the breaker, but did not fully evaluate the importance of the breaking device or the distance between the window and the breaker, in the transfer of fragments to garments [1]. In the light of this and later studies, it was important to study these and other points such as the loss of glass fragments which had actually been transferred by breaking a pane.

Strictly speaking, we did not study persistence, but the presence of glass on the same garment at a given time t. This methodology was chosen for two main reasons. First, we wanted to evaluate the influence of actual transfer on persistence hence it was not possible to place a predetermined number of fragments on the garment. Second, it was felt that glass particles should be recovered by shaking, even if visual procedures could be used to search for fragments without removing them from the garment. As shown by Pounds (personal communication), the searching process influences considerably the number of fragments recovered, especially the number of small particles.

The results of our tests show that the number of fragments transferred is highly variable, which is not new to glass transfer experiments even when the breaking conditions are held as constant as possible. Locke and Unikowski [5,6] reported that particle counts between runs can vary by a factor of four. In their studies, the pane was broken with a

TABLE 5 Proportion of glass fragments in each size fraction recovered from upper garments after time t (expressed as mean and range percentages for each group of six experiments).

t (hours)	*< 0.2 mm*	*< 0.5 mm*	*< 1.0 mm*	*< 3.0 mm*
Breaker				
0.0	82 (67–88)	16 (8–30)	3 (0–8)	0 (0–2)
0.5	75 (63–89)	22 (11–37)	3 (0–14)	0 (0–0)
1.0	92 (80–100)	6 (0–20)	2 (0–9)	0 (0–0)
2.0	96 (75–100)	4 (0–25)	0 (0–0)	0 (0–0)
4.0	94 (75–100)	6 (0–25)	0 (0–0)	0 (0–0)
8.0	100 (100–100)	0 (0–0)	0 (0–0)	0 (0–0)
Accomplice				
0.0	60 (50–71)	31 (18–43)	10 (0–17)	0 (0–3)
0.5	78 (50–100)	21 (0–50)	1 (0–8)	0 (0–0)
1.0	79 (60–88)	21 (0–50)	0 (0–0)	0 (0–0)
2.0	89 (71–100)	6 (0–14)	4 (0–14)	0 (0–0)
4.0	88 (70–100)	11 (0–30)	2 (0–9)	0 (0–0)
8.0	89 (50–100)	6 (0–17)	6 (0–50)	0 (0–0)

TABLE 6 Comparison of the number of fragments recovered on the person closest to the window. * Mean values. **Not mentioned in the article.

Authors	*Breaking device*	*Smallest distance(m)*	*No. of fragments recovered on upper garment*	*No. of fragments recovered on trousers*
Scranage (1990)	Pendulum (6.25kg)	0.50	15 (wool)	1
Luce et al (1991)	Pendulum (2kg)	0.45	11 (cotton)	2
Current research	Hammer (several strikes)	0.50	127* (cotton)	31*
Pounds & Smalldon (1978)	Hammer	0.45	22 (jacket)	—**
Luce et al (1991)	Hammer (one strike)	0.45	13 (cotton)	3
Luce et al (1991)	Hammer (several strikes)	0.45	72 (cotton)	3
Current research	Stone	1.50	16 (cotton)	16
Pounds & Smalldon (1978)	Brick	1.35	4 (jacket)	—**

pendulum and glass was recovered on trays, conditions that should have led to less variability than our experiments. As previously observed [6], we found that the same breaking conditions can lead to a small hole in one pane and a large hole in another; the number of times the breaker had to strike the window to break and destroy it completely was not reproducible.

In none of the experiments, including the extremes (Experiments 1 and 11), was there any correlation between the number of blows and the number of fragments. Had the number of blows been constant, therefore, it would probably have had no effect on reproducibility. Nevertheless, the variability between runs was smaller than that between different experiments and some trends could be discerned which go some way towards answering the questions we posed at the outset.

Does the number of transferred fragments depend on how the window is broken?

The comparison presented in Table 6 relates to the person closest to the window. The number of fragments transferred to the person standing nearby seems to be determined not so much by the breaking device (hammer, brick or pendulum) as the number of blows. Thus using a pendulum of 6.25 kg, a pendulum of 2 kg, or striking the pane once with a hammer leads to the transfer of about ten fragments to the upper garment. Striking the pane several times leads to many more particles (72 to 127).

The majority of the fragments were transferred onto upper garments: this result, in accordance with the research of Luce et al [4], may be used as an indicator of the height of the impact relative to the height of the breaker.

Is the number of the fragments transferred related to the distance between the window and the person standing nearby?

If mean values are considered, there were three times more particles on the breaker standing 50 cm away than on the accomplice standing at 80 cm. This result is in agreement with the available literature and establishes a clear relationship between distance and the number of fragments transferred.

If more time elapses between breaking and the search for glass, are fewer and smaller fragments recovered?

The number of glass fragments recovered from all garments after eight hours was significantly lower than the number recovered immediately after the breaking. Most of the fragments were lost in the first half-hour. This trend is apparent even though, in some experiments, there were more fragments after four hours than after one or two hours, or almost the same number after 30 minutes as after one hour. For each time period a new pane was broken, hence the initial number of fragments transferred varied from experiment to experiment.

After 8 hours, all the fragments recovered from the breaker were in the size range 0.2–0.5 mm, whereas immediately after transfer 20% of the fragments were bigger than 0.5 mm. The same tendency was observed for the accomplice. This relationship between size and persistence is supported by McQuillan and Edgar's survey [8].

Do the number and size of the fragments retained depend on the weave and composition of the garment?

Our experiments show that glass fragments are retained longer on a coarse woollen pullover than on a cotton tracksuit top. The composition and weave of the garment not only had a bearing on the number of fragments retained, but also their size. The proportion of fragments bigger than 0.5 mm retained on the smooth cotton tracksuit top was smaller than that observed for the pullover. No fragment bigger than 0.2 mm was recovered from the smooth cotton garment after eight hours, but around 10% of fragments bigger than 0.5 mm were retained on the woollen pullover. In order to establish whether there is a relationship between the composition or weave of garments and the persistence of glass fragments, any future research needs to involve more than two upper garments and to standardise activity.

Conclusion

The results of this study confirm that the number of fragments depends not so much on the breaking device, as on the number of strikes and the distance between the pane and the person standing nearby. Even eight hours after breaking a glass pane it is possible to find as many as seven glass fragments on clothing, but we found that most fragments are lost within 30 minutes and that small fragments are retained longer. The number and size of recovered fragments depend on the time elapsed between window breaking and search and on the weave/composition of the garment. Preliminary testing has also shown that activity could be an important factor.

In future studies, glass should be transferred by actual breaking and the number of fragments fallen off (rather than remaining) counted after different lapses of time. It will then be possible to determine the percentage of fragments lost according to time. It will also be necessary to find a means of predicting the number of fragments at $t = 0$. Our current research is directed at seeing if there is a clear relationship between the number of fragments transferred to garments and the number of fragments transferred to the floor. This would enable the examiner to predict the number of fragments transferred to the perpetrator from the crime scene.

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