This is to certify that the

thesis entitled

THE DISTRIBUTION OF GUNSHOT RESIDUES GENERATED BY DISCHARGING A FIREARM INDOORS

presented by

Linda M. Jacobson

has been accepted towards fulfillment of the requirements for

M.S. degree in Criminal Justice

Major professor

Date 6/20/00

THE DISTRIBUTION OF GUNSHOT RESIDUES GENERATED BY DISCHARGING A FIREARM INDOORS

By

Linda Michelle Jacobson

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Criminal Justice

2000

ABSTRACT

THE DISTRIBUTION OF GUNSHOT RESIDUES GENERATED BY DISCHARGING A FIREARM INDOORS

By

Linda Michelle Jacobson

When a firearm is discharged, gunshot residue (GSR) particles leak from the muzzle of the gun and parts of the gun near the firing hand. This airborne GSR can deposit on nearby surfaces in addition to settling on the shooter's hand. The purpose of this study was to determine the distribution of GSR particles when a firearm is discharged indoors. The type of firearm used and the number of shots fired was varied in order to assess the impact of these factors on GSR distribution. Samples were set out to collect GSR that might deposit two, six and ten feet to the right of the shooter. The samples were subsequently analyzed and the number of particles related to GSR was tabulated. The results showed that GSR particles deposited up to ten feet from the shooter in 79 out of the 80 test fires performed. It was also found that the number of GSR particles deposited does not add up with the number of shots fired. In comparing particle deposition for the two firearms used in this experiment, the results showed that discharging the semiautomatic handgun resulted in more particle deposition than the revolver only when multiple shots were fired.

This research is dedicated to Mary and Michael Jacobson.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

When a firearm is discharged, gunshot primer residue (GSR) particles leak from the muzzle of the gun and parts of the gun near the firing hand. This airborne GSR can deposit on nearby surfaces in addition to settling on the shooter's hand. The collection of GSR from someone's hand indicates that the individual either discharged a firearm, handled a gun that was recently fired, came into contact with a surface contaminated with GSR, or was in close proximity to a firearm while it was discharged.

Research has shown that GSR can deposit on a non-shooter's hand held close to a discharging firearm, or on surfaces close to the shooter. To date, these studies have been limited to sampling areas in close proximity to the shooter (within three feet), or in experiments involving sampling farther away from the shooter, the tests were not repeated to demonstrate their reliability.

This purpose of this study is to determine the distribution of GSR particles when a firearm is discharged indoors in a standard sized room (i.e. how far the particles travel, how many particles deposit, etc.). The number of shots fired and the type of gun used was varied in order to see if these factors impact the distribution of GSR indoors. Adhesive collection disks were set out two feet, six feet, and ten feet to the right of the shooter and were left out to collect particles depositing for a five minute period after the firearm was discharged. The disks were then analyzed for traces of GSR using Scanning Electron Microscopy coupled with Energy Dispersive X-ray analysis (SEM/EDX), and the GSR particles found were tabulated.

This study will provide valuable insight into how far GSR travels from a firearm that is discharged indoors. The results of this study will benefit GSR analysts responsible for interpreting the results of tests to determine if GSR was present on a shooting suspect's hand. This study will also aid prosecutors, defense attorneys, and judges faced with the interpretation of GSR evidence in the courtroom.

Knowing the amount GSR that can deposit on objects at certain distances from a discharging firearm can indicate the potential for GSR transfer to individuals coming into contact with these objects. For example, can a non-shooter transfer GSR to their hands by merely touching an object in a room where a shooting occurred? If the adhesive collection disks used in this experiment are looked at as an individual standing in a room where a firearm was discharged, the potential for GSR settling on the hands of a non-shooter can be evaluated. All of these factors impact the interpretation of GSR test results. Overall, this study aims to help estimate the potential for GSR contamination on the hands of those present at or near the time of a shooting.

Chapter 1

GENERAL INFORMATION ON GUNSHOT RESIDUE ANALYSIS

Introduction: What is Gunshot Residue?

Discharging a firearm releases an assortment of particulate matter and vapors into the surrounding area. The particles that result are termed gunshot primer residues (GSR), and these residues emerge from both the muzzle of the firearm and parts of the gun near the firing hand. Gunshot primer residue particles are those which contain lead (Pb), barium (Ba) and possibly antimony (Sb) and have spheroidal morphology. As a firearm is discharged, GSR combines with propulsive gases and can deposit on nearby objects as well as on the shooter (Krishnan, 1982; Meng & Caddy 1997; Basu, Boone, Denio, & Miazga, 1997; Wolten, Nesbitt, Calloway, Loper, & Jones, 1977, 1979a).

Law enforcement agencies can sample a suspected shooter's hand for traces of GSR and send it to a crime laboratory for analysis. At the lab, the sample will be analyzed for traces of GSR using Scanning Electron Microscopy coupled with Energy Dispersive X-ray Analysis (SEM/EDX). The test results can indicate whether or not an individual could have discharged a firearm.

The best way to identify GSR is by elemental content. Most cartridge case primers contain lead (Pb), barium (Ba), and antimony (Sb) (ASTM Method E-1588, Thornton, 1994; Meng & Caddy, 1997; Wolten et al., 1977). The compositional criteria for GSR particles that outlines the types of particles searched for during analysis was first detailed in a report issued by the Aerospace Corporation in 1977. An updated version of this list appears in the American Society for Testing and Materials method E-1588-95:

Particle compositions unique to GSR:

1) Lead (Pb), antimony (Sb), barium (Ba)
2) Antimony, barium

Particle compositions consistent with GSR but not unique to it:

1) Barium, calcium, silicon with a trace of sulfur
2) Lead, antimony
3) Lead, barium
4) Lead
5) Barium

Lead and small amounts of antimony can be found in bullets, while barium, lead, and higher amounts of antimony are found in the primer. Other elements commonly found in GSR particles are silicon, calcium, aluminum copper, iron, sulfur, phosphorous, zinc (if there is a higher amount of copper present), nickel (if copper and zinc are present), potassium, chloride, and tin (found in obsolete ammunition). The presence of other elements indicates that a particle did not originate from GSR. This classification scheme has been adopted in general by forensic scientists dealing with GSR analysis. An EDX spectrum from a particle containing lead, barium and antimony appears in Figure 1.

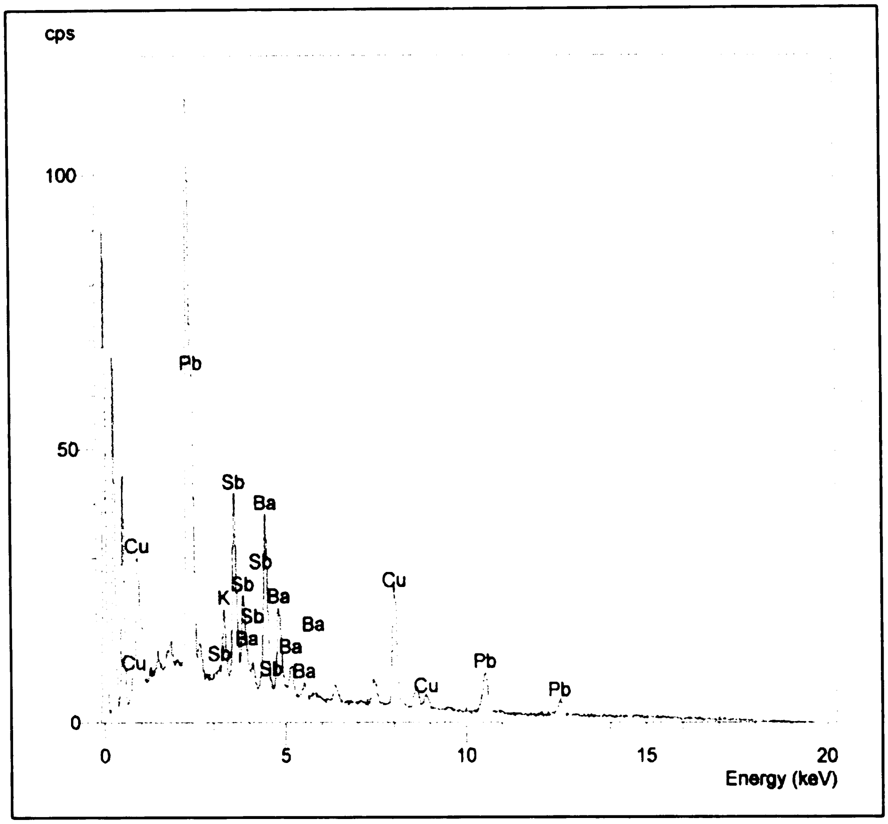

Figure 1: An EDX spectrum of a GSR particle containing lead, barium and antimony.

In addition to particle composition, morphology is another criteria used by analysts when evaluating GSR evidence. GSR particles are predominantly spheroidal in shape, as they result from rapid condensation from a vapor state (Basu, 1982; Meng & Caddy, 1997; Wolten et al., 1977, 1979a; Basu & Ferris, 1980). 70% to 100% of GSR particles are spheroidal. Other shapes of GSR particles include irregular particles and clusters, which are formed from many spheroids clumping together (Wolten et al., 1977, 1979a). A picture demonstrating the typical morphology of GSR particles appears in Figure 2.

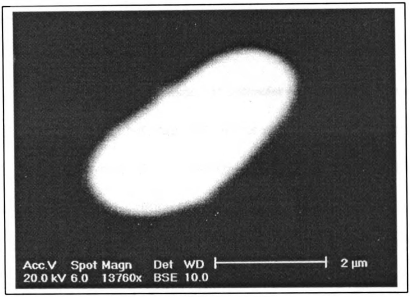

Figure 2: A GSR particle as seen using an SEM.

Applications of Gunshot Residue Analysis

GSR can be used to determine many things, but is primarily used to determine whether or not an individual could have discharged a firearm. GSR on the hands of a suspect may indicate whether or not the individual may have discharged or handled a recently discharged firearm, or have been present when a firearm was discharged. In situations where a suspect denies handling a firearm, the presence or absence of GSR on his or her hands may support or contradict their statement (Thornton, 1994; Meng & Caddy 1997; Krishnan, 1982). Other uses for GSR include reconstructing events that took place at the time of a shooting, as GSR can be used to identify bullet holes and possibly to estimate firing distances (Krishnan, 1982; Meng & Caddy, 1997; Thornton, 1994; Renfro & Jester, 1973).

Gunshot Residue Deposition

The GSR deposited on the hands of a shooter of a revolver or pistol comes from three main sources: the gap between the cylinder and rear end of the barrel, the ejection of the cartridge, and blow-back from the muzzle cloud (Meng & Caddy, 1997; Basu et al., 1997; Krishnan, 1982). In addition to depositing on the shooter, GSR can deposit on surfaces close to the firearm including individuals or objects in close proximity (Meng & Caddy, 1997; Basu et al., 1997; Krishnan, 1982; Thornton, 1986).

Many factors can influence the amount and distribution of GSR deposited when a firearm is discharged. Among these factors are the type and condition of the weapon, the ammunition, the number of shots fired, the type of surface on which the GSR is deposited, and the direction and force of air currents (Krishnan, 1982; Meng & Caddy, 1997).

Even if the same gun and ammunition type is used, the amount of GSR deposited can vary from shot to shot. Gunshot residues are products of combustion and are ejected from the gun as a result of the pressure generated in the gun. Any variation in this chamber pressure can impact the velocity of the gases and solids ejected from the gun, which can in turn impact the distribution of these products of combustion. Differences in the ammunition may be found in the weight of the primer, the physical condition of the primer, the condition and weight of the bullet, and the primer cup hardness (Munhall, 1961). Even within the same box of ammunition, differences in velocity and pressure can be found (Krishnan, 1977). Inconsistencies contributed by the firearm itself may arise from firing pin blows that vary in strength, or, in revolvers, misalignment of the chambers with the barrel (Munhall, 1961).

The deposition of GSR resulting from multiple shots can also be inconsistent. A number of successive firings do not necessarily increase the amount of GSR deposited. The amount of GSR deposited does not always add up with the number of shots fired (Basu et al., 1997; Krishnan, 1977).

The Mechanism of Gunshot Residue Deposition

Much research has been devoted to determining the mechanism of GSR deposition, particularly on the distribution of up-range GSR (GSR deposited on surfaces close to the firearm) (Thornton, 1994). Research done by Renfro and Jester on the length of time GSR remains suspended in the air after shooting suggests that GSR settling from the air may deposit on a shooter's hand (Renfro & Jester, 1973; Basu et al., 1997). Other researchers disagree with this, proposing that the GSR found on a shooter's hand is force-deposited there at the time of discharge (Basu et al., 1997; Wolten et al., 1977).

In considering the mechanism of GSR deposition, the potential for GSR settling on an individual other than the shooter must be addressed. Handling a recently discharged firearm can transfer to an individual's hand levels of GSR similar to those found on a shooter's hand. Studies done by Thornton showed that a hand held in close proximity to a discharging firearm intercepts a level of antimony consistent with having fired or handled a gun. This result was based on eight test fires with a .22 caliber revolver during which the hand of a non-shooter was held two inches laterally from the cylinder (Thornton, 1986). Another situation, which provides a potential source for GSR found on the hands of a non-shooter, is secondary transfer. The secondary transfer of GSR to an individual's hand from some other surface on which GSR is deposited is also possible (Thornton, 1994). Overall, one must proceed with caution when interpreting the results obtained while testing for the presence of GSR on an individual's hands.

Gunshot Residue Collection and Analysis

When a suspect is arrested in connection to a crime involving a firearm, his or her hands may be sampled for the presence of GSR. Most law enforcement agencies use some type of adhesive tape, commonly referred to as a stub, to collect particles from a suspect's hand. The adhesive is pressed repeatedly against the areas of interest, and after a brief questionnaire is filled out, the sample is submitted to a laboratory for analysis.

If a conductive adhesive is used, the sample taken can be analyzed directly using Scanning Electron Microscopy combined with Energy Dispersive X-ray Analysis (SEM/EDX). Using this method, the morphology of the particles can be obtained in addition to their elemental characteristics. (Wolten et al., 1977; Meng & Caddy, 1997; Krishnan, 1982; Thornton, 1994). If the SEM/EDX system is automated, the system will scan the sample, analyze the particles with a backscatter electron image as determined by pre-set thresholds, identify the elements present in the particle, and record its coordinates. The operator can then later return to the particles of interest and confirm their elemental composition by reviewing the EDX spectra (Thornton, 1994; Germani, 1991).

The SEM/EDX analysis of a GSR sampling stub can be very time consuming (approximately 4-10 hours) depending on the instrument being used and the number of particles present. The adhesive stubs used by most labs are approximately one half inch in diameter, and because of lengthy analysis time, the operator may choose to analyze the entire stub surface or just a percentage of it. In a recent poll it was found that most labs analyze 50% or more of the stub surface before confirming a negative result, but this percentage can vary from lab to lab (Singer, 1996).

The number of unique GSR particles required to yield a positive result also varies from lab to lab. After finding one unique GSR particle some labs consider the sample positive for the presence of GSR. Other labs require a higher threshold for the number of unique GSR particles required to obtain a positive result (Singer, 1996).

There are four possible outcomes for a GSR exam. If the examination was not inconclusive, the laboratory report will state that no particles consistent with GSR were found, or that particles consistent with GSR were found, or that particles unique to GSR were found. The collection of GSR from someone's hand indicates that the individual either discharged a firearm, handled a gun that was recently fired, came into contact with a surface contaminated with GSR, or was in close proximity to a firearm while it was discharged.

Results and Interpretation of Gunshot Residue Tests

Analysts must consider many factors in interpreting GSR test results. Particles that individually resemble GSR are produced by many industries. The trace elements Pb, Sb and Ba are present in many materials. Auto exhaust, batteries, plumbing materials, gasoline, glass, and solder all contain lead (Thornton, 1994; Wolten et al., 1977; Krishnan, 1982). Paint, grease, rubber and lubricating oils may contain barium. Finally, environmental sources of antimony include batteries, enamels, bearings, and lead alloys (Thornton, 1994; Krishnan, 1982).

Although lead, barium and antimony are found individually in various environmental sources, the occurrence of all three together is very rare (Krishnan, 1982; Wolten et al., 1977). In addition, the particles that individually resemble GSR that are produced by many industries also contain elements that are not consistent with GSR. For example, lead with bromine is indicative of automobile exhaust, and lead with titanium might indicate lead-based paint. When the criteria for GSR composition was developed by Wolten et al., the hands of individuals in occupations dealing with metals or compounds containing Pb, Sb and Ba were sampled. Among the occupational groups sampled were lead smelters, auto mechanics and battery assemblers. None of the samples taken contained any particles considered to be unique to GSR (Wolten et al., 1977, 1979b; Zeichner, 1997).

Another important factor for analysts to consider is the time delay between when the shooting occurred and the hand sampling was done. GSR particles on a person's hands can be lost through washing and coming into contact with other objects. The absence of GSR on an individual's hand might be explained by a time delay of four or more hours between the incident and the sampling, or by the activities the individual was involved in since the shooting.

Chapter 2

THE EXPERIMENT: DETERMINING THE DISTRIBUTION OF GUNSHOT RESIDUES INDOORS

The Purpose of this Study

This experiment was designed to estimate the distribution of gunshot residues (GSR) generated by a firearm that is discharged indoors (i.e. how far the particles travel, how many particles deposit, etc.). The distribution of GSR over three fixed distances to the right of the shooter was examined. The type of firearm used and the number of shots fired were varied, and the impact of these variations on the deposition of GSR was examined.

Applications

This study will provide valuable insight into how far GSR can travel from a firearm that is discharged indoors. The study will also shed light onto the potential for GSR contamination on the hands of those present at or near the time when a firearm is discharged indoors. In addition, this experiment can aid in answering questions typically put forth to GSR analysts in court such as: When a firearm is discharged indoors and individuals other than the shooter are present, is it possible that the hands of those who had no contact with the firearm could be contaminated with GSR? If so, how far away from the shooter can individuals be and still pick up GSR on their hands? Is it possible for an individual to get GSR on their hands by touching objects in a room where a firearm was discharged? If so, how far away from the firearm are these surfaces that collect GSR located? Studies such as this one are essential for analysts answering these types of questions.

This experiment will provide useful information for criminalists interpreting the results of hand samples taken from potential shooters. Crime scene reconstructionists faced with recreating details of an indoor shooting will also benefit from this study. In addition, investigators, prosecutors, defense attorneys, judges, and other individuals that need to interpret GSR evidence in the courtroom will find this study useful.

Relevant Research

This study was designed after considering previous research done on gunshot residue distribution. The research done in this area is severely lacking, and there is a definite need for more thorough studies on gunshot residue distribution.

Specifically, there has been little research done on the distribution of gunshot residues generated by a firearm that was discharged indoors. In 1987, White and Gross began a study on the deposition of GSR at varying distances from a discharging firearm. Their study employed different types of firearms that were discharged in both indoor and outdoor shooting ranges. Although their study focused on the deposition of GSR downrange from the firearm, in one of their test fires, the distribution of GSR to both sides and behind the shooter was examined. After firing a Smith and Wesson two-inch .38 caliber handgun, the residues 4ft, 6ft and 8ft to the right, left and behind the shooter were sampled. White and Gross calculated the ratios of particles identified as "consistent with" GSR and "unique to" GSR. The results showed that the ratio of "unique" to "consistent with" GSR particles decreased as the distance from the shooter increased. Unfortunately this part of their experiment was not duplicated to demonstrate repeatability, and because of this it is difficult to draw any firm conclusions from their results.

In 1976, Seamster et al. conducted studies on the spatial distribution of firearms discharge residues. After firing a Colt revolver with 38 Special ammunition, "fallout residues" were sampled from the floor 3ft to the right and 4ft ahead of the shooter. The most intense collection of fallout residues was found 2ft to the right and 3ft ahead of the shooter. Unfortunately this experiment was only performed once and the dimensions of the room used are not mentioned in the published results. The dimensions of the room may impact the amount of GSR deposited certain distances from the firearm, and repeating the experiment is necessary in order to show a pattern and draw reliable conclusions from their results.

The final study done which incorporated the analysis of GSR travelling to the sides of the shooter was conducted by the Aerospace Corporation in 1977. In the Aerospace study individuals were placed 3ft and 10ft abreast of and in line with the shooter. After a .22 caliber, short-barreled revolver was discharged the hands of those individuals standing next to the shooter were tested for GSR. The results showed that those standing 3ft from the shooter had GSR on their hands while those standing 10ft away did not. The published results indicate that this experiment was performed more than once, but the specific number of times is not mentioned. The results also failed to report whether the firearm was discharged indoors or outside.

It is obvious that there is a need for further study on the distribution of gunshot residues indoors. More thorough studies with repeated trials and carefully documented experimental conditions would be of great value to those dealing with GSR evidence.

Experimental Design and Methods

Two firearms were used in this experiment: a Ruger .357 Blackhawk revolver and a Smith and Wesson 9mm semiautomatic handgun. Winchester 38 Special, Super X, 110 grain hollow point ammunition was used for all test firings using the revolver. Winchester 9mm Luger 115 grain hollow point was used for all test firings in which the semiautomatic was used (see Appendix A for a complete list of the materials used in this experiment). All of the test firings were done in the same draft-free room of approximately 195 square feet (See Appendix C for a room diagram). The firearms used were cleaned prior to each test firing, and the room used was cleaned and aired out between each shooting. The test fires were spaced at least 24 hours apart.

Airborne GSR generated from each firearm was collected after one shot was fired, and after firing 6 shots. The test fires for each experimental setup were repeated five times.

The airborne GSR was collected using carbon tape specimen mounts set up 2ft, 6ft and 10ft horizontally to the right of the shooter. The collection distances were chosen after considering the size limitations of the room in addition to the past research done in this area, where the samples have not been taken past ten feet from the shooter. The specimen mounts were placed in line with the shooter's hand, and one foot vertically below the level of the shooter's hand. The specimen mounts were exposed for particle collection just before the shots were fired, and remained exposed for particle collection for five minutes after the shots were fired.

As a negative control, one carbon tape specimen mount was left exposed for a five-minute period prior to each test firing to collect "background" particles. In addition, one unused specimen mount from each batch of carbon tapes used in this experiment was analyzed as a substrate control (see Appendix B for these results). Including the substrate control collections, 82 samples were generated in this experiment.

The specimen mounts were analyzed directly using SEM/EDX. Two instruments were used: a Phillips XL30 Scanning Electron Microscope equipped with an Oxford ISIS 300, and an R.J. Lee Personal SEM. The instruments were programmed to search for particles containing lead, barium and antimony. Fifty percent of each 1.2 cm diameter specimen mount was analyzed, and in that area the number of those particles in the following 2 categories were tabulated:

1) Particles unique to GSR:

i) Pb-Sb-Ba
ii) Sb-Ba

2) Particles consistent with GSR:

i) Pb-Ba
ii) Pb-Sb
iii) Pb only
iv) Ba only

The EDX spectra were reviewed for the particles tabulated. See Figure 1 for an EDX spectrum of a known GSR particle containing Pb, Sb and Ba.

Chapter 3

RESULTS AND INTERPRETATIONS

Results of Test Fires Using One Shot from a Revolver

In test fires using one shot from a revolver, unique GSR particles were found two, ten and six feet from the shooter in all trials. The numbers of unique GSR particles collected in each category are tabulated in Tables 1 through 4. The distribution of these particles was inconsistent. In four out of the five trials, the highest numbers of unique GSR particles was deposited two feet from the shooter. However, at six and ten feet from the shooter, the number of particles deposited did not always decrease as the distance from the shooter increased. For example, in two out of the five trials, more unique GSR particles were deposited at ten feet from the shooter than were deposited at six feet. A graph of these results appears is Figure 3. The total number of particles unique to GSR deposited varied from 1 to 14 at ten feet away from the shooter, from 2 to 8 at six feet away from the shooter, and from 1 to 30 at two feet away from the shooter.

Particles consistent with GSR were also deposited at all three distances from the shooter in all five trials. Tabulations of the particles collected that were consistent with GSR appear in Tables 1 through 4. The distribution of these particles over the three collection distances varied. In all of the trials, the number of particles consistent with GSR collected was always significantly higher two feet from the shooter than at the other two distances. However, at six and ten feet from the shooter, the number of particles deposited did not always decrease as the distance from the shooter increased. For example, in two out of the five trials more particles consistent with GSR were collected at ten feet from the shooter than at six feet. In the remaining two trials, the number of particles collected that were consistent with GSR did not relate to the distance from the shooter. A graph of these results appears in Figure 4. The total number of particles consistent with GSR that were deposited varied from 4 to 196 at ten feet away from the shooter, from 13 to 299 at six feet away from the shooter, and from 149 to 1221 at two feet away from the shooter.

Table 1: The distribution of particles collected after one shot from a revolver, ten feet away from the shooter.

Sample name: 1 shot revolver	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	**Unique GSR particles**	**Particles consistent with GSR**
Trial 1 10 ft away	5	0	0	7	107	1	5	115
Trial 2 10 ft away	0	1	0	1	3	0	1	4
Trial 3 10 ft away	2	0	0	0	20	0	2	20
Trial 4 10 ft away	7	7	0	7	1	0	14	8
Trial 5 10 ft away	1	1	1	7	186	2	2	196

Table 2: The distribution of particles collected after one shot from a revolver, six feet away from the shooter.

Sample name: 1 shot revolver	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	**Unique GSR Particles**	**Particles consistent with GSR**
Trial 1 6 ft away	1	2	0	4	16	0	3	20
Trial 2 6 ft away	2	1	0	7	10	0	3	17
Trial 3 6 ft away	6	0	0	2	10	1	6	13
Trial 4 6 ft away	3	5	0	8	4	5	8	17
Trial 5 6 ft away	2	0	0	12	284	3	2	299

Table 3: The distribution of particles collected after one shot from a revolver, two feet away from the shooter.

Sample name: 1 shot revolver	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	**Unique GSR Particles**	**Particles consistent with GSR**
Trial 1 2 ft away	26	4	0	14	891	10	30	915
Trial 2 2 ft away	3	1	0	14	135	0	4	149
Trial 3 2 ft away	9	5	0	21	198	2	14	1221
Trial 4 2 ft away	22	5	0	32	784	0	21	816
Trial 5 2 ft away	0	1	3	35	1162	3	1	1203

Table 4: Results of background particle collection prior to test fires involving one shot from a revolver.

Sample name: 1 shot revolver	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	Unique GSR Particles	Particles consistent with GSR
Trial 1 background	0	0	0	0	0	0	0	0
Trial 2 background	0	0	0	0	0	0	0	0
Trial 3 background	0	0	0	0	0	0	0	0
Trial 4 background	0	0	0	0	0	0	0	0
Trial 5 background	0	0	0	0	0	0	0	0

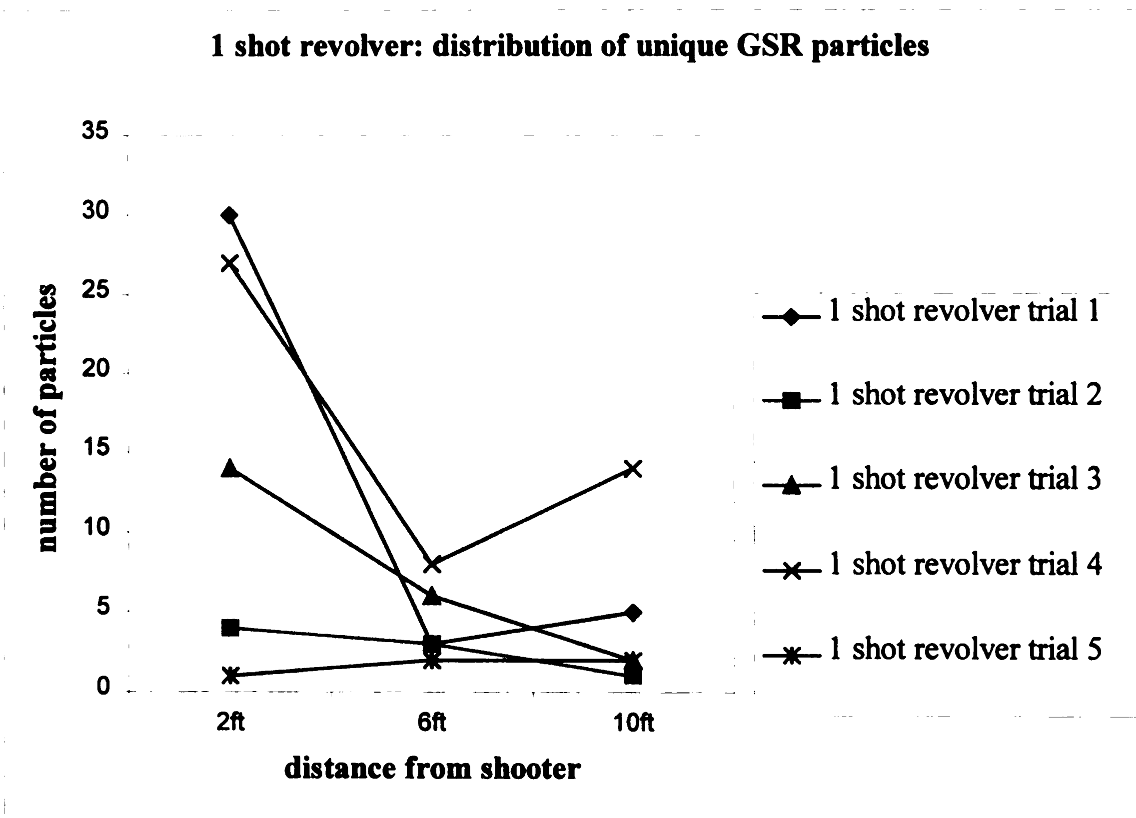

Figure 3: The distribution of unique GSR particles deposited at three distances from the shooter after one shot from a revolver.

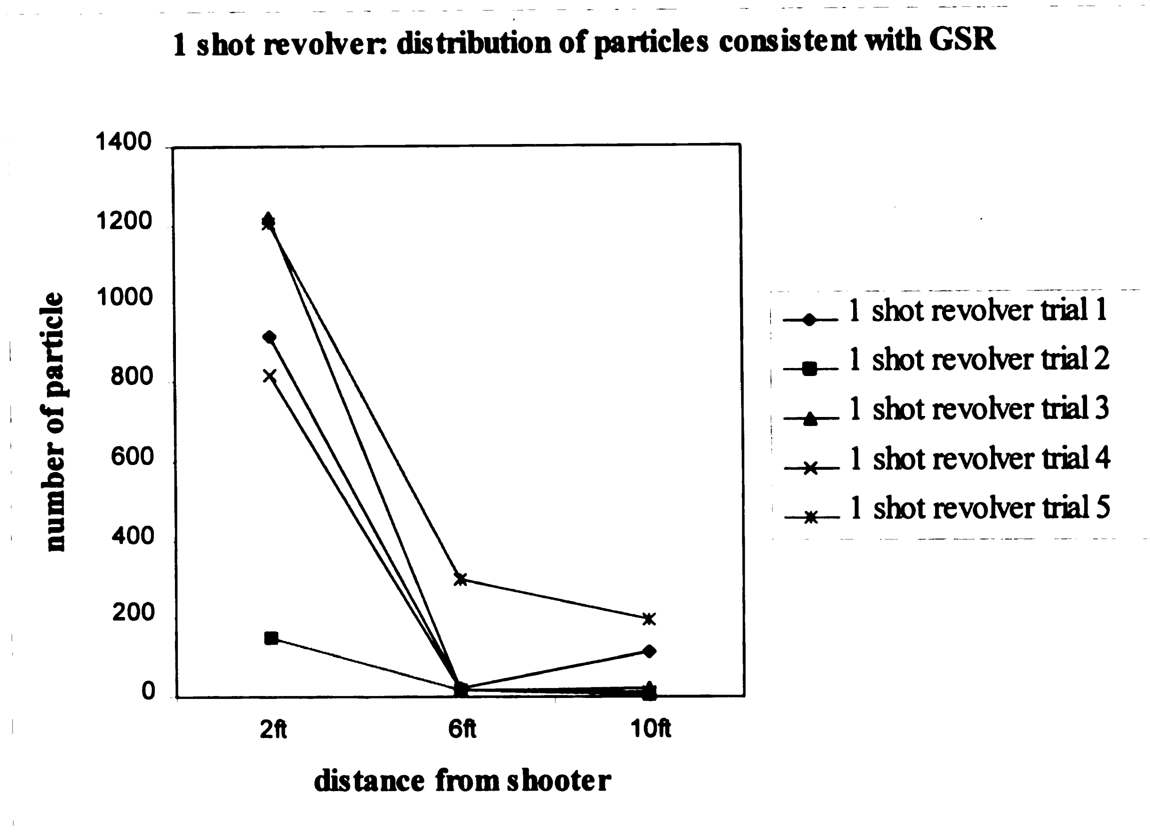

Figure 4: The distribution of particles consistent with GSR deposited at three distances from the shooter after one shot from a revolver.

Results of Test Fires Using Six Shots from a Revolver

In test fires using six shots from a revolver, particles unique to GSR were found two, six and ten feet way from the shooter in all trials. The distribution of these particles is tabulated in Tables 5 through 8. The distribution of unique GSR particles in these trials was inconsistent. In three out of the five trials, the number of unique GSR particles decreased as the distance from the shooter increased. However, in the remaining two trials, the number of unique GSR particles collected did not relate to the distance from the shooter. For example, in trial one, more unique GSR particles were deposited ten feet from the shooter than were deposited two and six feet away. In three out of the five trials, the highest number of unique GSR particles was deposited two feet away from the shooter. A graph of these results appears in Figure 5. The total number of unique GSR particles that was deposited varied from 1 to 47 at ten feet away from the shooter, from 10 to 24 at six feet away from the shooter, and from 29 to 147 at two feet away from the shooter.

Particles consistent with GSR were found at all three distances from the shooter in all trials. The distribution of the particles collected is tabulated in Tables 5 through 8. The distribution of these particles varied. In three out of the five trials the number of particles consistent with GSR that were deposited decreased as the distance from the shooter increased. In the other two trials, the number of these particles deposited did not relate to the distance. For example, in trial one, more particles consistent with GSR were deposited at six feet from the shooter than at two feet away. In comparing the five trials, the highest number of particles deposited 2 ft away from the shooter in four trials. A graph of these results appears in Figure 6. The total number of particles consistent with GSR that were deposited varied from 18 to 793 at ten feet away from the shooter, from 156 to 1508 at six feet away from the shooter, and from 369 to 2225 at two feet away from the shooter.

Table 5: The distribution of particles collected after six shots from a revolver, ten feet away from the shooter.

Sample name: 6 shots revolver	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	**Unique GSR particles**	**Particles consistent with GSR**
Trial 1 10 ft away	26	7	0	23	767	3	33	793
Trial 2 10 ft away	29	18	0	7	104	0	47	111
Trial 3 10 ft away	9	5	0	9	207	1	14	217
Trial 4 10 ft away	0	1	0	1	17	0	1	18
Trial 5 10 ft away	13	5	0	7	217	0	18	224

Table 6: The distribution of particles collected after six shots from a revolver, six feet away from the shooter.

Sample name 6 shots revolver	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	**Unique GSR Particles**	**Particles consistent with GSR**
Trial 1 6 ft away	13	4	0	65	1441	2	17	1508
Trial 2 6 ft away	3	7	0	50	180	2	10	232
Trial 3 6 ft away	9	6	0	10	145	1	15	156
Trial 4 6 ft away	11	5	1	5	271	9	16	286
Trial 5 6 ft away	19	5	0	33	445	2	24	480

Table 7: The distribution of particles collected after six shots from a revolver, two feet away from the shooter.

Sample name 6 shots revolver	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	Unique GSR Particles	Particles consistent with GSR
Trial 1 2 ft away	22	7	0	29	1161	2	29	1192
Trial 2 2 ft away	35	12	0	245	1033	2	47	1280
Trial 3 2 ft away	33	32	0	41	314	14	65	369
Trial 4 2 ft away	108	39	2	55	2155	13	147	2225
Trial 5 2 ft away	66	24	2	76	1826	44	90	1948

Table 8: Results of background particle collection prior to test fires involving six shots from a revolver.

Sample name: 6 shots revolver	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	Unique GSR Particles	Particles consistent with GSR
Trial 1 background	0	0	0	0	0	0	0	0
Trial 2 background	0	0	0	0	0	0	0	0
Trial 3 background	0	0	0	0	0	0	0	0
Trial 4 background	0	0	0	0	0	0	0	0
Trial 5 background	0	0	0	0	0	0	0	0

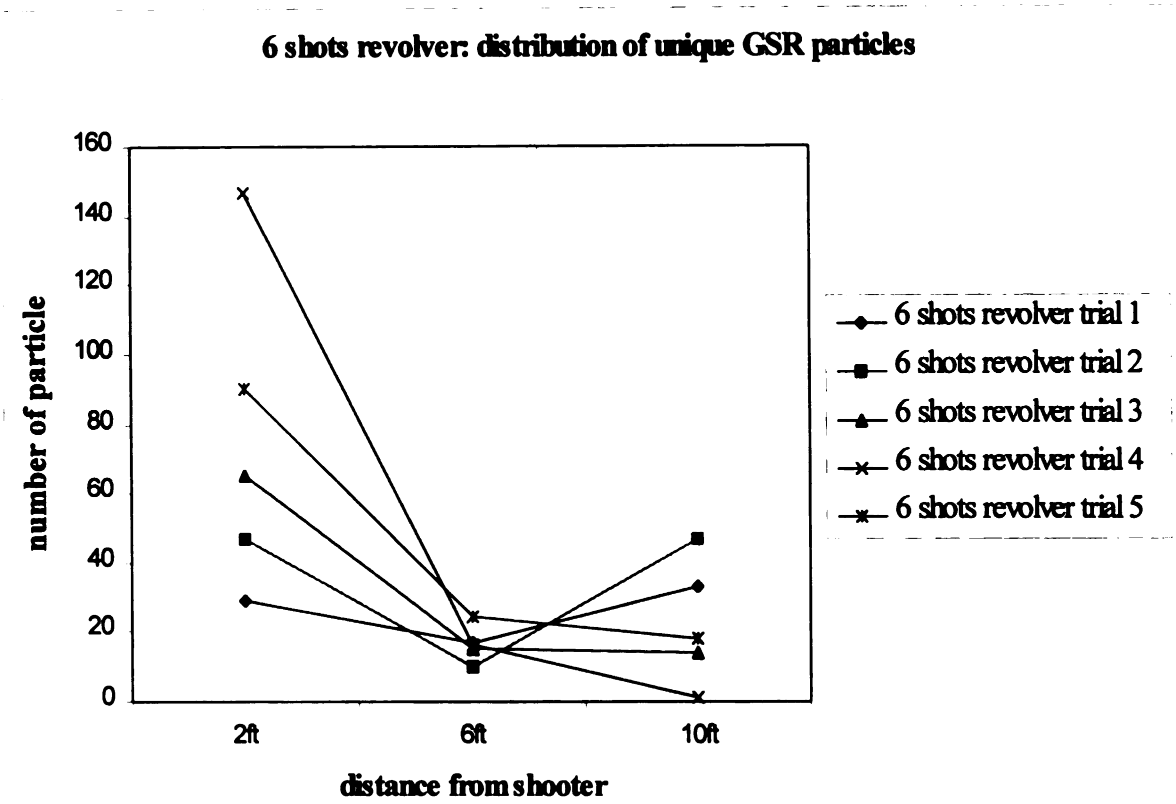

Figure 5: The distribution of unique GSR particles deposited at three distances from the shooter after six shots from a revolver.

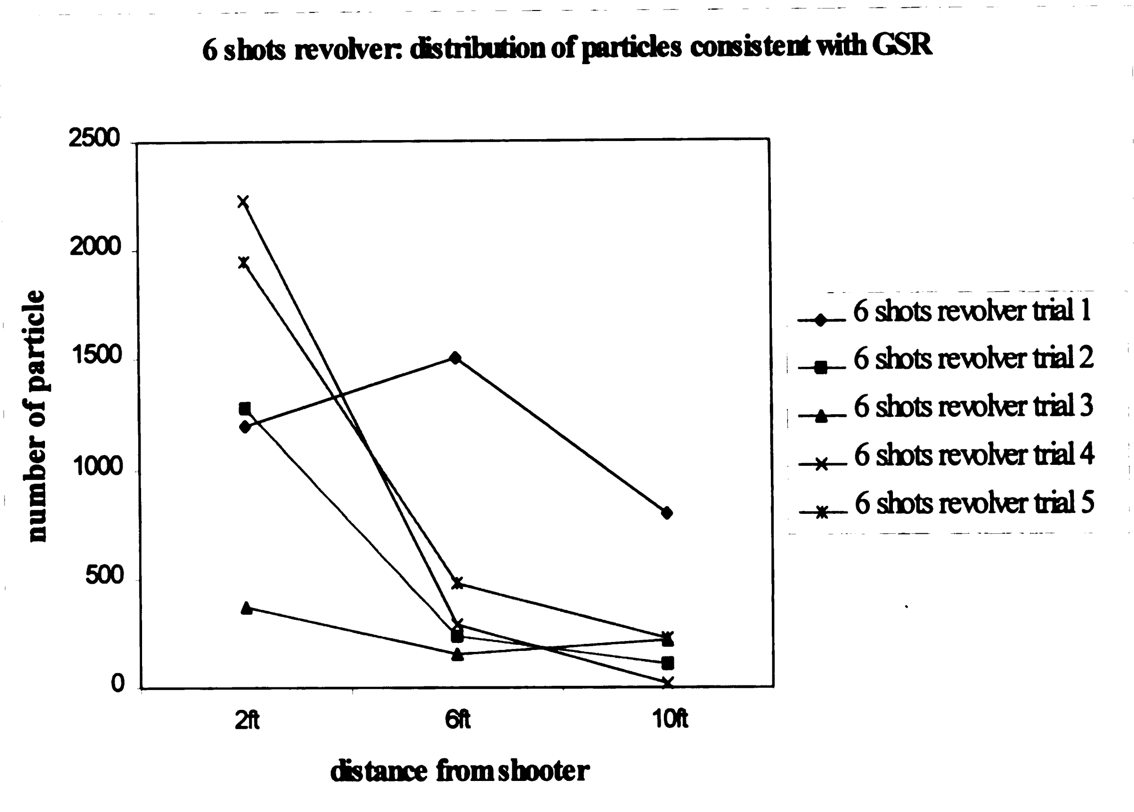

Figure 6: The distribution of particles consistent with GSR deposited at three distances from the shooter after six shots from a revolver.

A Comparison of the Results of One Shot and Six Shots from a Revolver

The trend for the number of particles deposited after one shot and after 6 shots from a revolver differed for the unique GSR particles and for the particles consistent with GSR. Graphs of these results appear in Figures 7 through 12. The tabulations of unique GSR particles showed that more particles were generally deposited after six shots were fired than after one shot. The tabulations of particles consistent with gunshot residue showed that more particles were deposited ten feet and six feet away from the shooter after six shots were fired. However, two feet from the shooter, the tabulations of particles consistent with GSR deposited were similar after both one and six shots were fired.

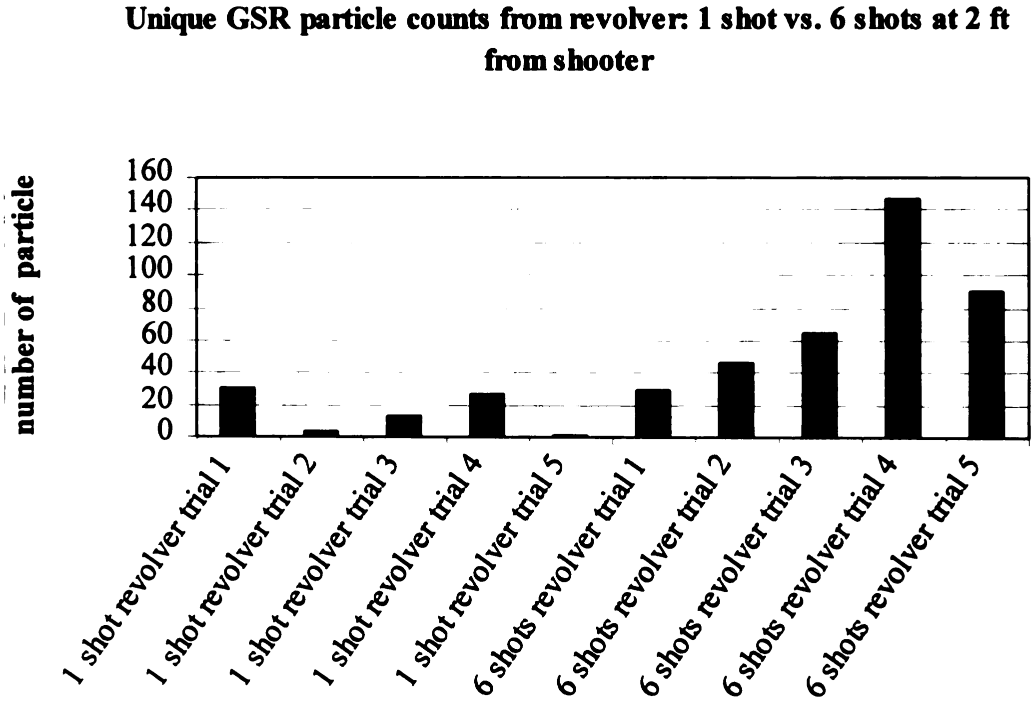

Figure 7: A comparison of the number of unique GSR particles collected at two feet from the shooter after one shot and after six shots were fired from a revolver.

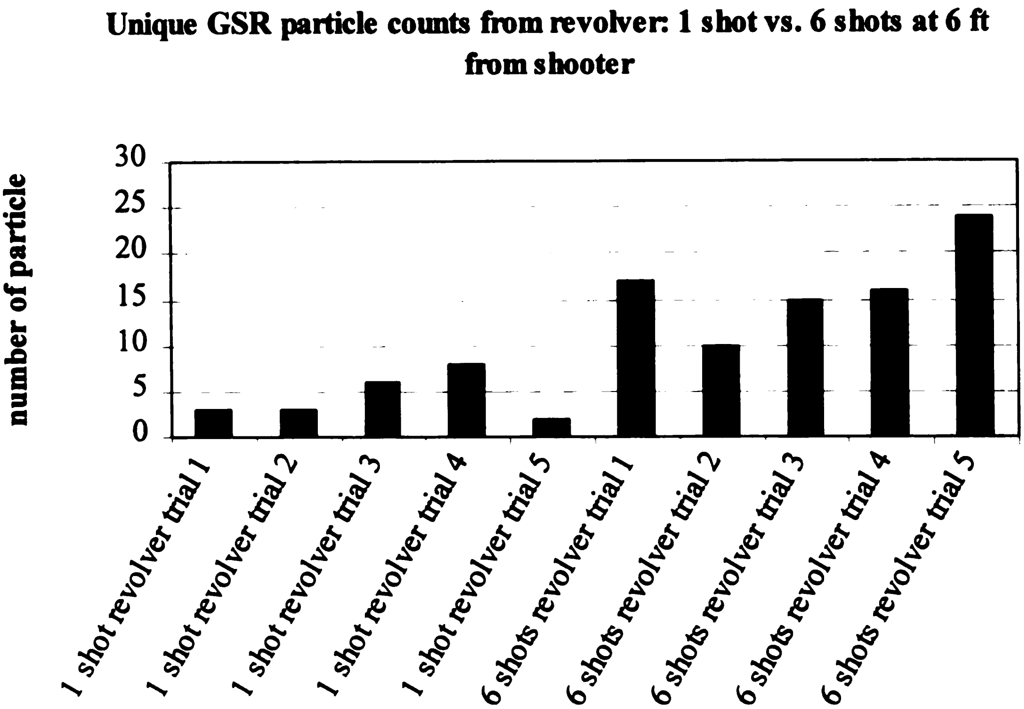

Figure 8: A comparison of the number of unique GSR particles collected at six feet from the shooter after one shot and after six shots were fired from a revolver.

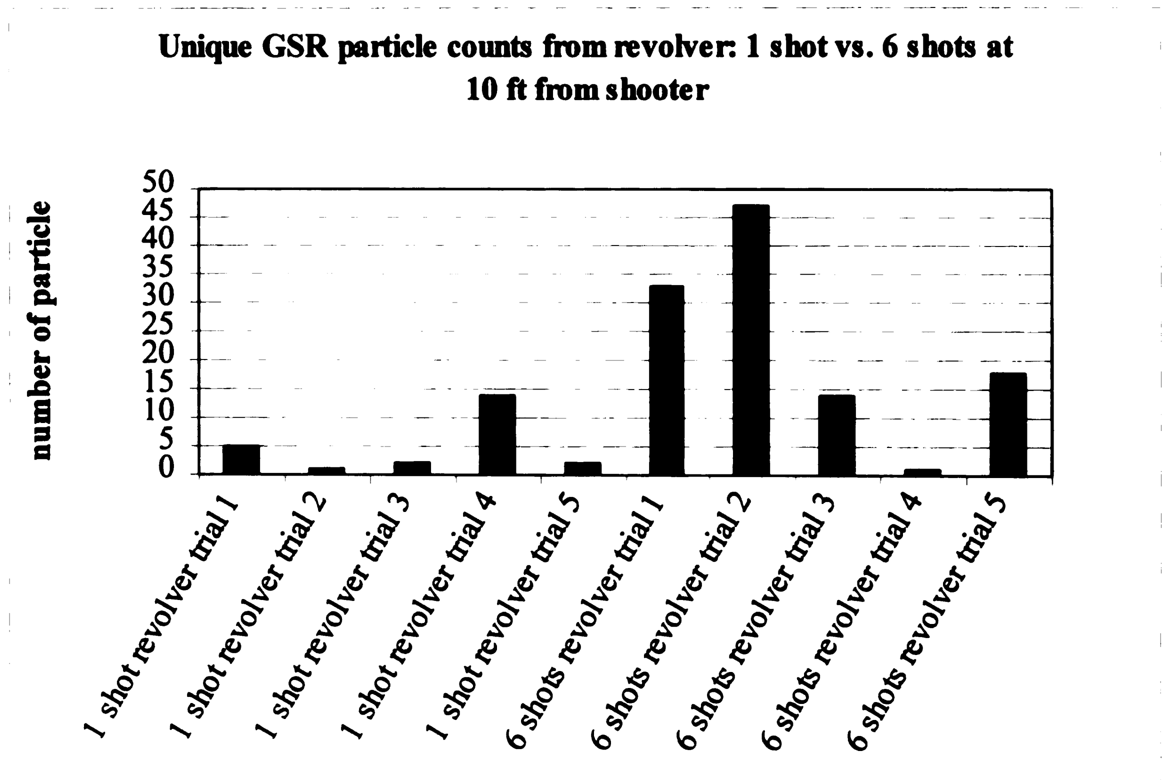

Figure 9: A comparison of the number of unique GSR particles collected at ten feet from the shooter after one shot and after six shots were fired from a revolver.

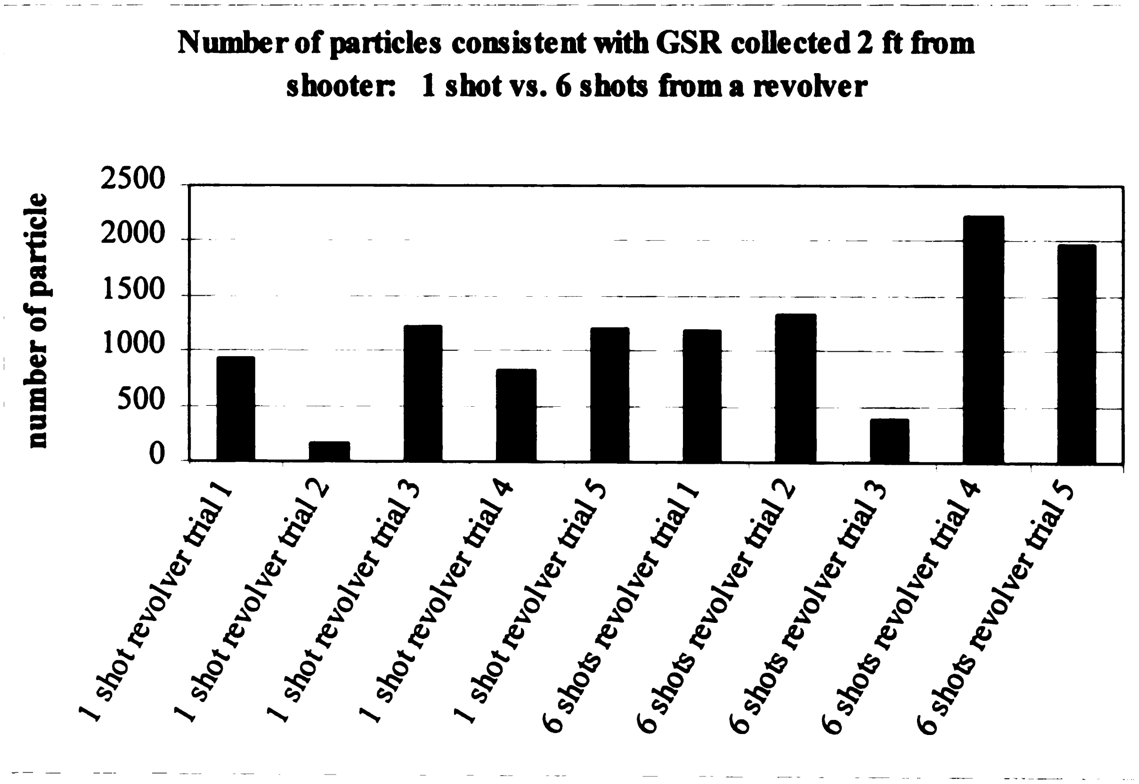

Figure 10: A comparison of the numbers of particles consistent with GSR collected at two feet from the shooter after one shot and after six shots were fired from a revolver.

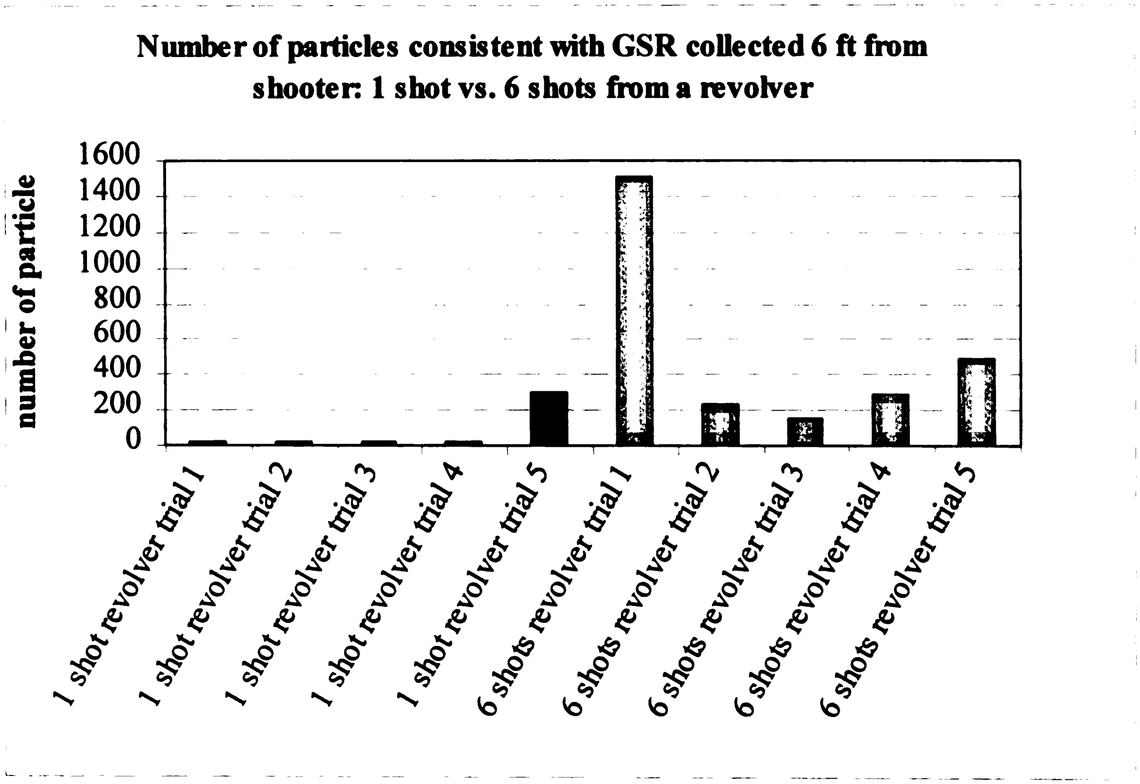

Figure 11: A comparison of the numbers of particles consistent with GSR collected at six feet from the shooter after one shot and after six shots were fired from a revolver.

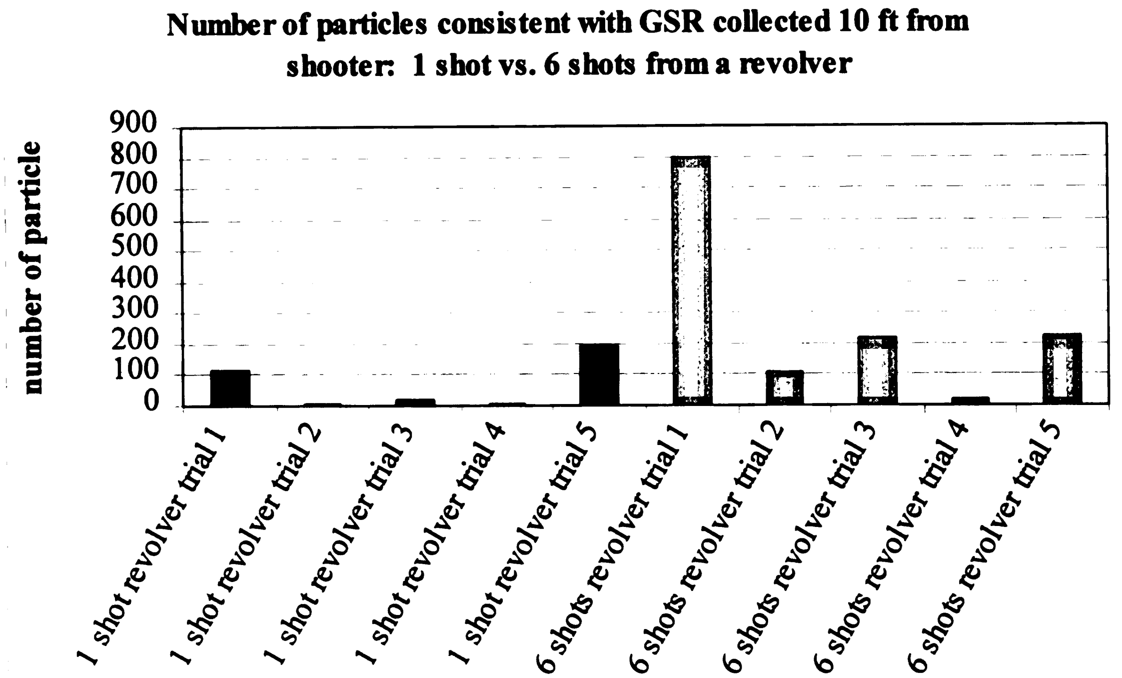

Figure 12: A comparison of the numbers of particles consistent with GSR collected at ten feet from the shooter after one shot and after six shots were fired from a revolver.

Results of Test Fires Using One Shot from a Semiautomatic Handgun

In test fires using one shot from a semiautomatic handgun, particles unique to GSR were found at all three distances from the shooter in four out of five trials. In one trial, no unique GSR particles were deposited ten feet from the shooter, but they were deposited two and six feet away. The number and identity of the unique GSR particles that were collected are tabulated in Tables 9 through 12. Overall, the distribution of these particles was inconsistent. In two out of the five trials, the number of unique GSR particles deposited decreased as the distance from the shooter increased. In the remaining three trials, the number of these particles deposited did not relate to the distance from the shooter. For example, in trial five, more unique GSR particles were collected six feet from the shooter than were collected two feet away. In addition, in four out of the five trials, the highest number of unique GSR particles was deposited 2 feet away from the shooter. A graph of these results appears in Figure 13. In comparing the five trials, the number of unique GSR particles collected varied from 9 to 107 particles at two feet away from the shooter, from 2 to 21 particles at six feet away from the shooter, and from 0 to 9 particles at ten feet away from the shooter.

Particles consistent with GSR were deposited at all three distances from the shooter in all five trials. The number and identity of these particles are tabulated in Tables 9 through 12. In four out of the five trials, the number of particles collected decreased as the distance from the shooter increased. In the remaining trial, the number of particles deposited did not relate to the distance from the shooter. A graph of these results appears in Figure 14. In comparing the five trials, the number of particles consistent with GSR that were collected varied from 45 to 8846 particles at two feet away from the shooter, from 33 to 760 particles at six feet away from the shooter, and from 1 to 203 particles at ten feet away from the shooter.

Table 9: The distribution of particles collected at ten feet away from the shooter after one shot from a semiautomatic handgun.

Sample name: 1 shot semiautomatic	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	Unique GSR particles	Particles consistent with GSR
Trial 1 10 ft away	0	2	0	0	34	0	2	34
Trial 2 10 ft away	3	6	0	2	6	10	9	18
Trial 3 10 ft away	0	0	0	0	22	0	0	22
Trial 4 10 ft away	1	3	0	5	198	0	4	203
Trial 5 10 ft away	1	1	0	0	1	0	2	1

Table 10: The distribution of particles collected at six feet away from the shooter after one shot from a semiautomatic handgun.

Sample name: 1 shot semiautomatic	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	Unique GSR Particles	Particles consistent with GSR
Trial 1 6 ft away	2	0	0	1	99	1	2	101
Trial 2 6 ft away	2	6	0	2	31	0	8	33
Trial 3 6 ft away	2	4	0	2	82	0	6	84
Trial 4 6 ft away	9	12	0	12	743	5	21	760
Trial 5 6 ft away	9	1	0	2	53	0	10	55

Table 11: The distribution of particles collected at two feet away from the shooter after one shot from a semiautomatic handgun.

Sample name: 1 shot semiauto-matic	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	Unique GSR Particles	Particles consistent with GSR
Trial 1 2 ft away	5	24	0	12	231	0	29	243
Trial 2 2 ft away	59	48	1	179	8665	1	107	8846
Trial 3 2 ft away	4	6	0	8	946	0	10	954
Trial 4 2 ft away	27	34	1	36	1461	7	61	1505
Trial 5 2 ft away	3	6	0	7	37	1	9	45

Table 12: Results of background particle collection prior to test fires involving one shot from a semiautomatic handgun.

Sample name: 1 shot semiauto-matic	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	Unique GSR Particles	Particles consistent with GSR
Trial 1 background	0	0	0	0	0	1	0	1
Trial 2 background	0	0	0	0	0	2	0	2
Trial 3 background	0	0	0	0	0	0	0	0
Trial 4 background	3	0	0	1	0	0	3	1
Trial 5 background	0	0	0	0	0	1	0	1

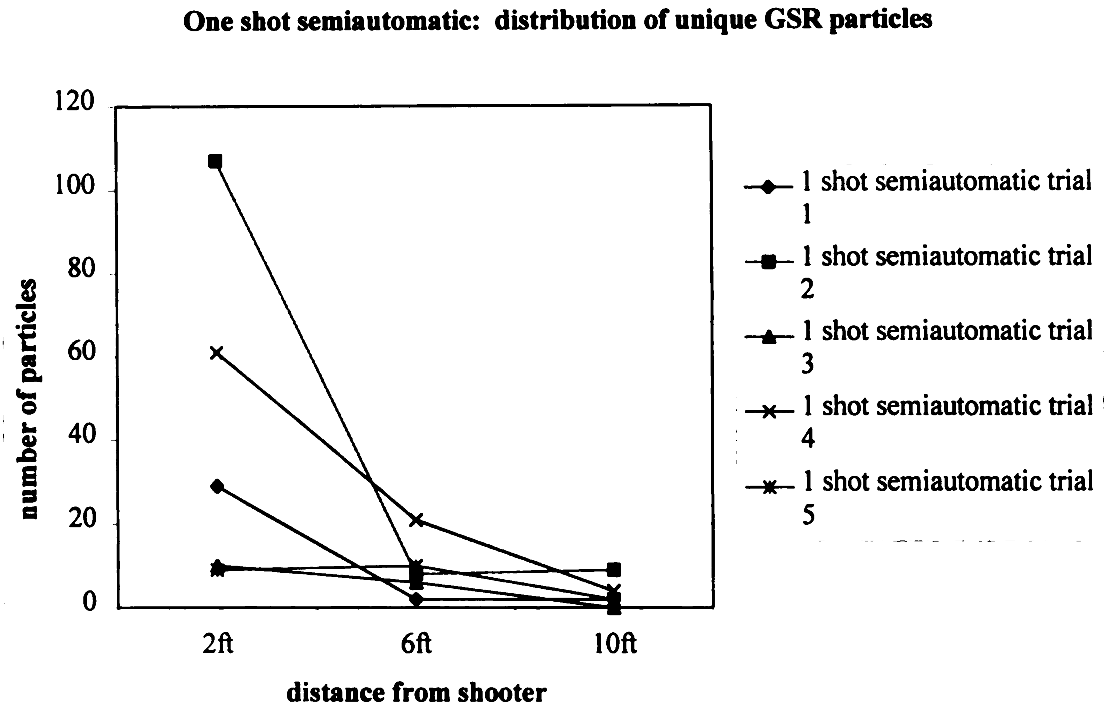

Figure 13: The distribution of unique GSR particles deposited at three distances from the shooter after one shot from a semiautomatic handgun.

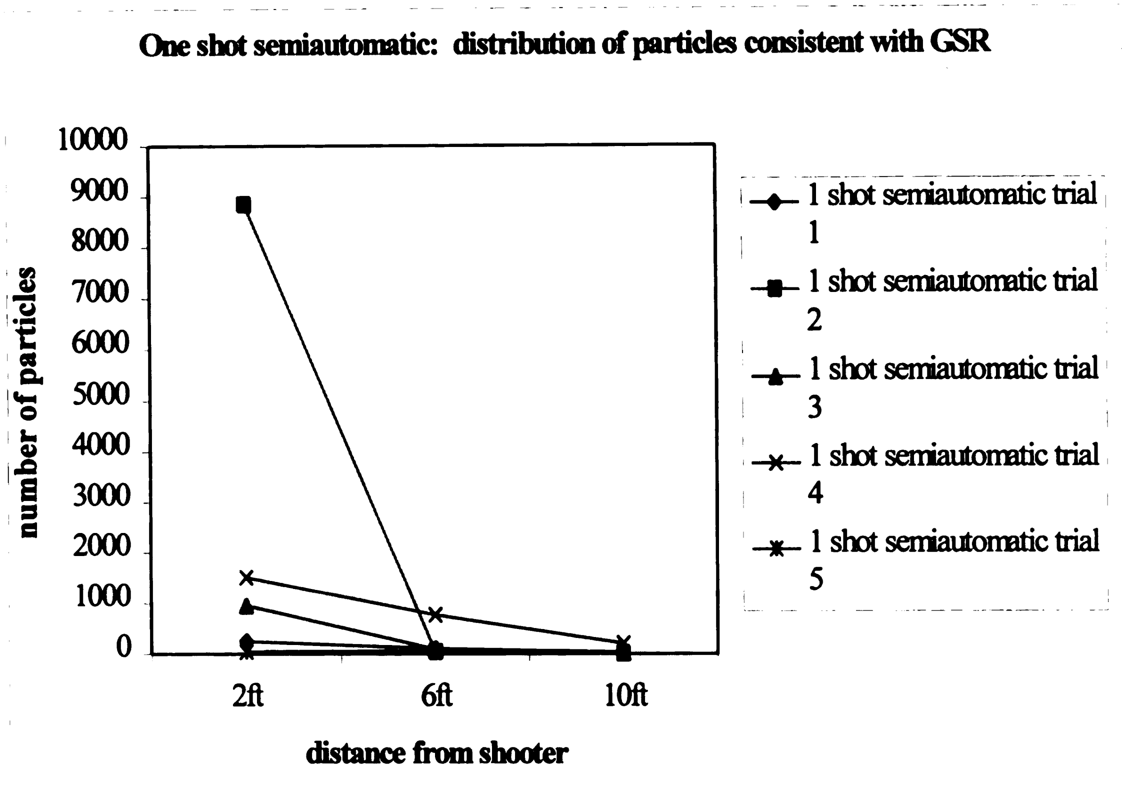

Figure 14: The distribution of particles consistent with GSR deposited at three distances from the shooter after one shot from a semiautomatic handgun.

A Comparison of the Results of One Shot from both a Semiautomatic Handgun and a Revolver

A comparison of the numbers of GSR particles deposited after one shot from a revolver and from a semiautomatic handgun appears in graph form in Figures 15 through 20. Overall, the numbers of both unique to and consistent with GSR particles deposited were similar at all three distances from the shooter for both the semiautomatic and the revolver. There was no significant difference between the number of particles deposited at any of the three distances from the shooter when comparing the results obtained using one shot from both firearms.

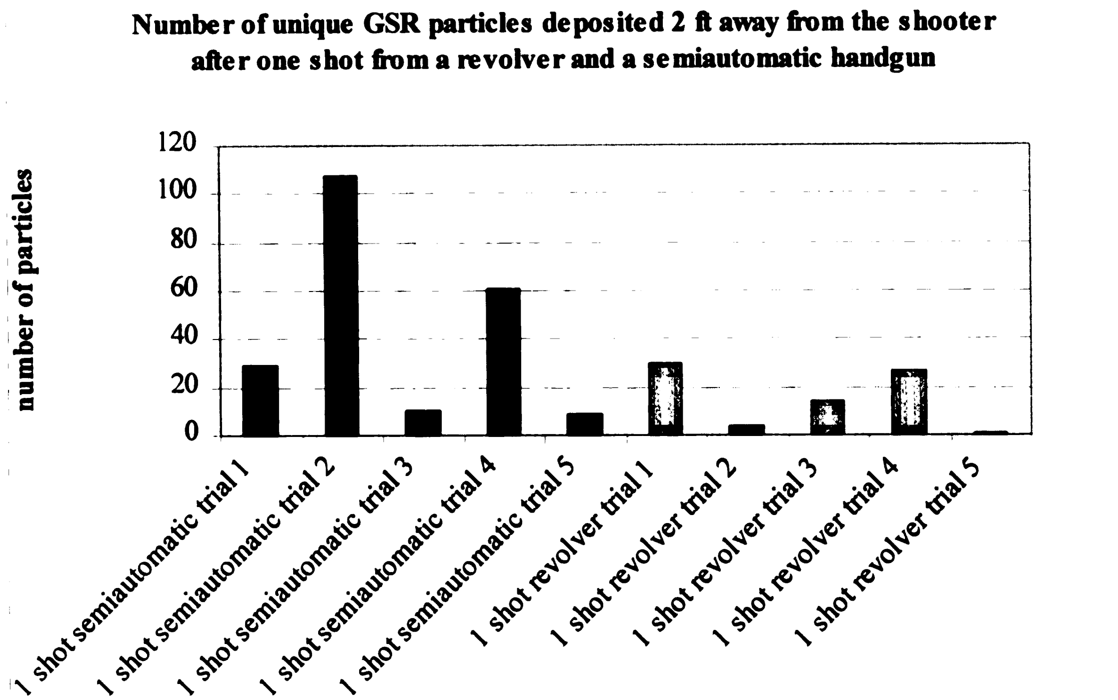

Figure 15: A comparison of the number of unique GSR particles collected at two feet from the shooter after one shot was fired from a revolver and a semiautomatic handgun.

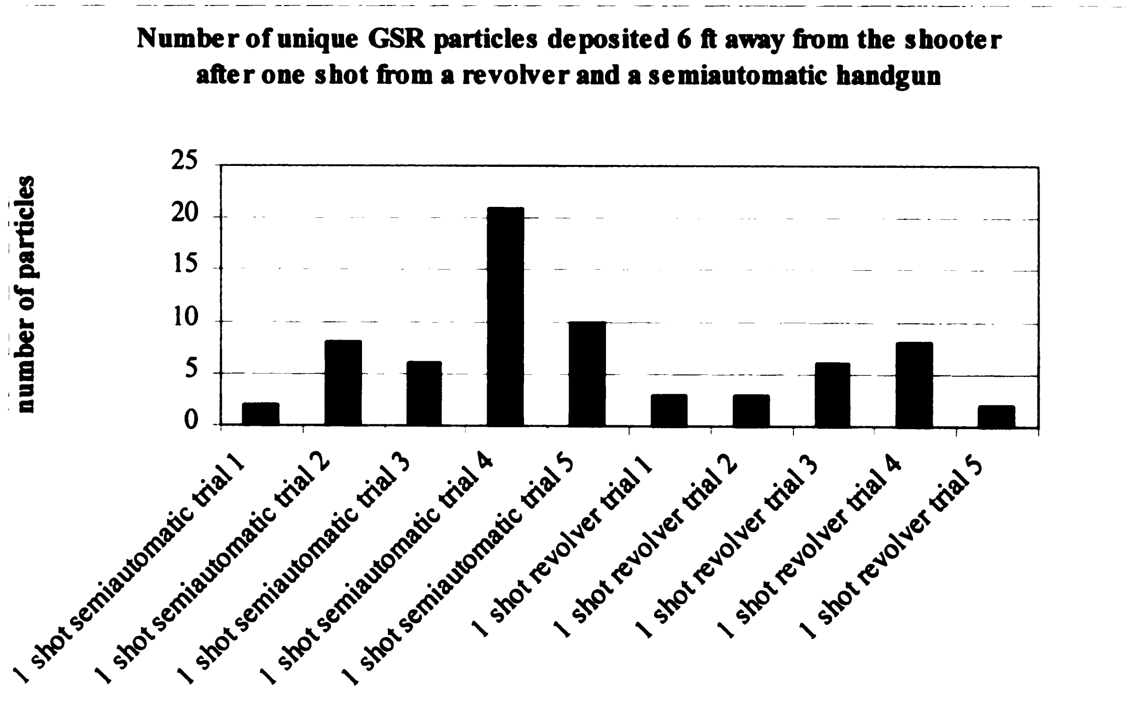

Figure 16: A comparison of the number of unique GSR particles collected at six feet from the shooter after one shot was fired from a revolver and a semiautomatic handgun.

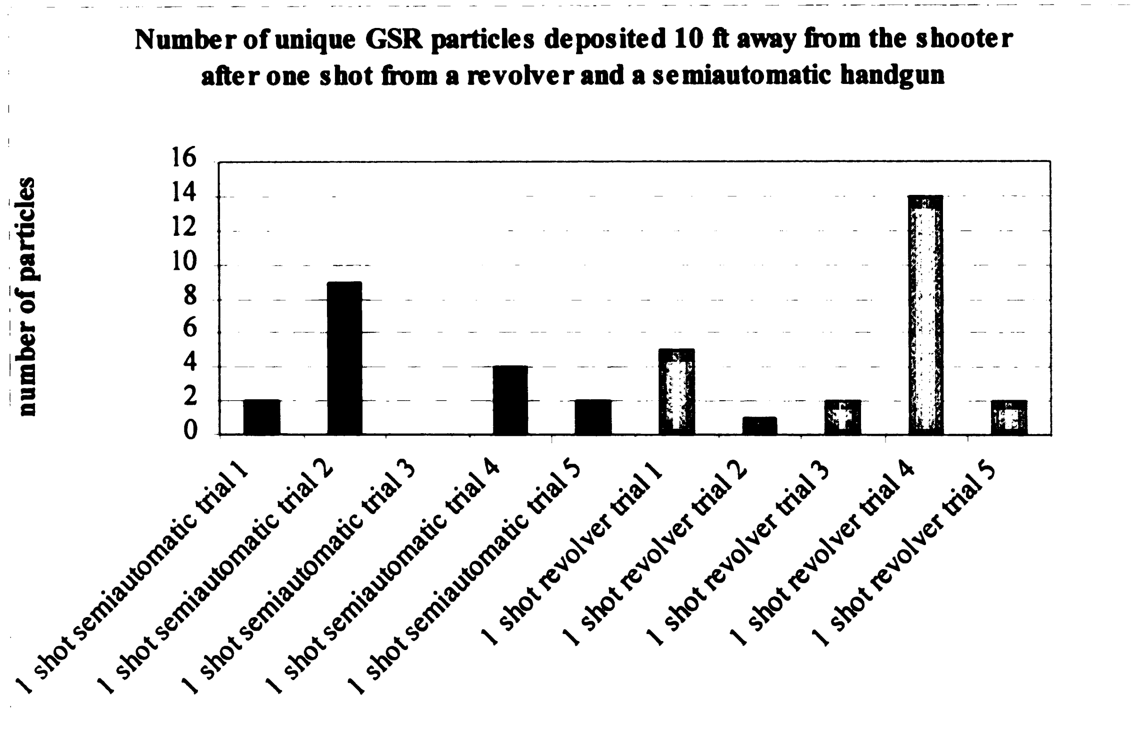

Figure 17: A comparison of the number of unique GSR particles collected at ten feet from the shooter after one shot was fired from a revolver and a semiautomatic handgun.

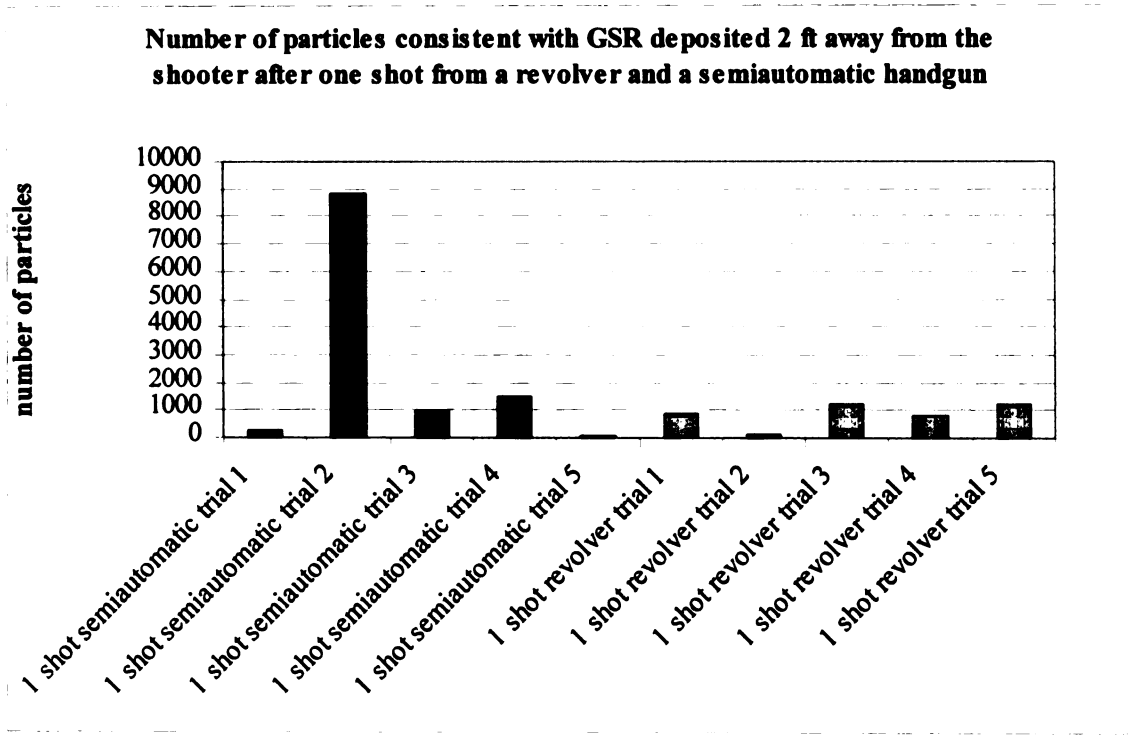

Figure 18: A comparison of the number of particles consistent with GSR collected at two feet from the shooter after one shot from a revolver and a semiautomatic handgun.

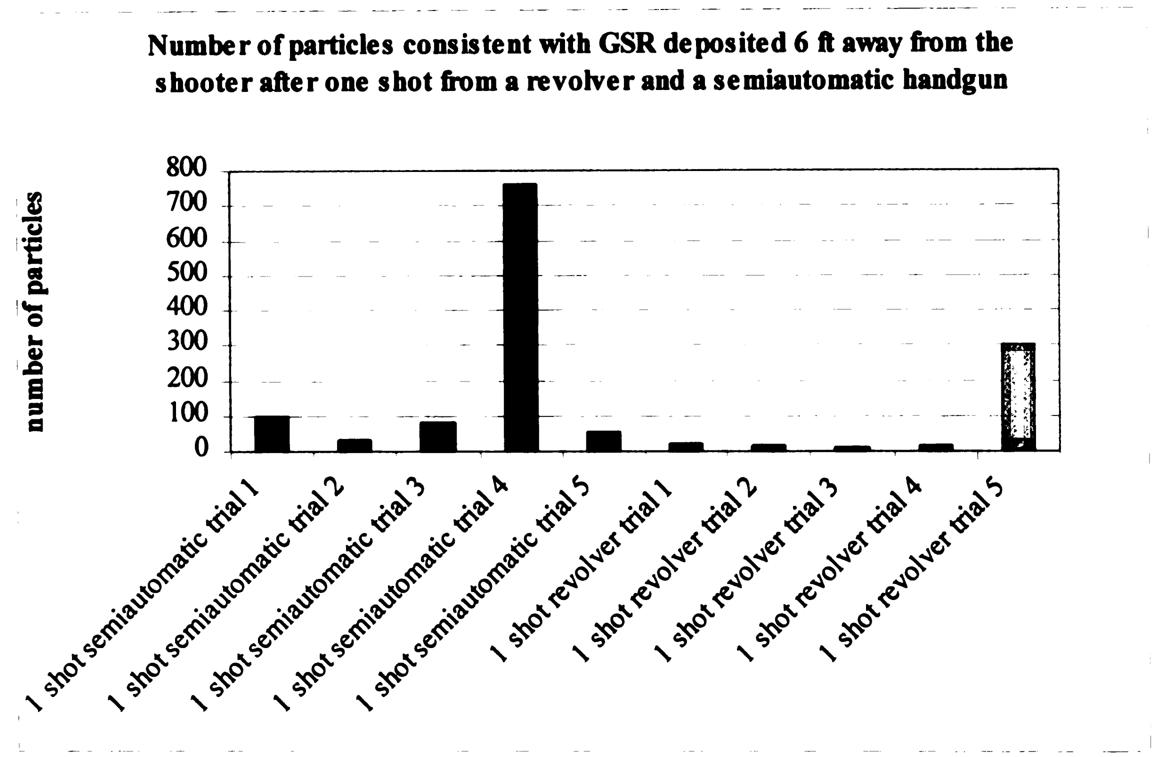

Figure 19: A comparison of the number of particles consistent with GSR collected at six feet from the shooter after one shot from a revolver and a semiautomatic handgun.

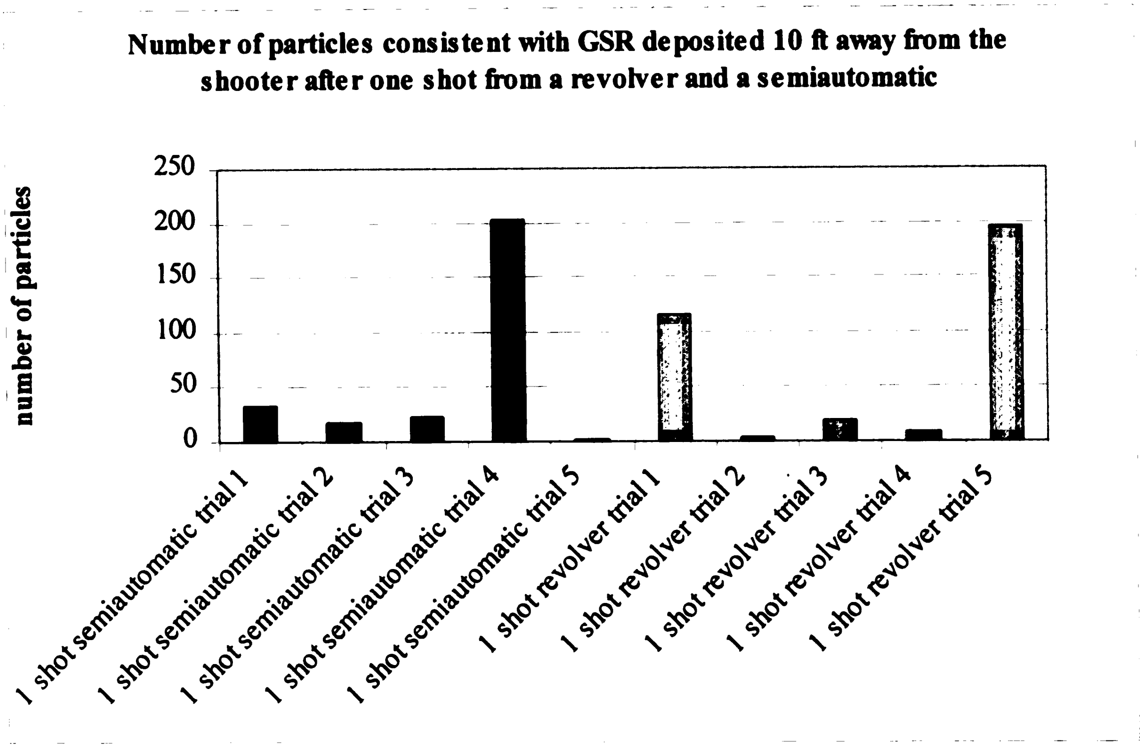

Figure 20: A comparison of the number of particles consistent with GSR collected at ten feet from the shooter after one shot from a revolver and a semiautomatic handgun.

Results of Test Fires Using Six Shots from a Semiautomatic Handgun

In trials involving six shots from a semiautomatic handgun, some data extrapolations were made. The instrumentation used was designed to end the analysis after ten thousand particles are analyzed. For some of the samples taken after six shots from a semiautomatic, this threshold was reached after only a small portion of the search area was examined. Throughout the analysis of the samples generated during this study it was noted that the particle deposition was even throughout the stub surface. Assuming this, the particle tabulations for stubs with greater than ten thousand particles were extrapolated for the portion of the stub area not searched.

In test fires using six shots from a semiautomatic handgun, unique GSR particles were found at all three distances from the shooter in all five trials. The number and identity of the unique GSR particles that were collected are tabulated in Tables 13 through 16. The distribution of these particles was inconsistent. In three out of five trials, the number of unique GSR particles deposited decreased as the distance from the shooter increased. In the remaining two trials, more unique GSR particles were deposited at ten feet from the shooter than at six feet away. In all trials, the highest number of unique GSR particles was deposited at two feet from the shooter. A graph of these results appears in Figure 21. In comparing the five trials, the number of unique GSR particles deposited varied from 57 to 1878 at two feet away from the shooter, from 24 to 139 at six feet away from the shooter, and from 8 to 127 at ten feet away from the shooter.

Particles consistent with GSR were deposited at all three distances from the shooter in all five trials. The number and identity of these particles are tabulated in Tables 13 through 16. The distribution of these particles was inconsistent. In three out of the five trials, more particles consistent with GSR were deposited at ten feet than at six feet. In the remaining two trials, the number of particles deposited decreased as the distance from the shooter increased. In all trials, the highest number of particles consistent with GSR was deposited at two feet from the shooter. A graph of these results appears in Figure 22. In comparing the five trials, the number of particles consistent with GSR deposited varied from 2,465 to 64,161 at two feet from the shooter, from 572 to 3163 at six feet from the shooter, and from 44 to 10,007 at ten feet from the shooter.

Table 13: The distribution of particles collected at ten feet from the shooter after six shots from a semiautomatic handgun.

Sample name: 6 shots semiauto-matic	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	Unique GSR particles	Particles consistent with GSR
Trial 1 10 ft away	6	2	0	4	49	0	8	53
Trial 2 10 ft away	51	53	17	129	5506	19	104	5671
Trial 3 10 ft away	1	9	0	13	30	1	10	44
Trial 4 10 ft away	76	51	3	108	9881	15	127	10007
Trial 5 10 ft away	41	75	2	73	630	23	116	728

Table 14: The distribution of particles collected at six feet from the shooter after six shots from a semiautomatic handgun.

Sample name: 6 shots semiauto-matic	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	Unique GSR particles	Particles consistent with GSR
Trial 1 6 ft away	59	58	0	79	1603	0	117	1682
Trial 2 6 ft away	29	110	7	92	3026	27	139	3152
Trial 3 6 ft away	6	18	0	36	988	6	24	1030
Trial 4 6 ft away	21	15	14	11	2835	3	36	2863
Trial 5 6 ft away	23	39	1	35	524	12	62	572

Table 15: The distribution of particles collected at two feet from the shooter after six shots from a semiautomatic handgun.

Sample name: 6 shots semiauto-matic	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	Unique GSR particles	Particles consistent with GSR
Trial 1 2 ft away	98	57	1	94	2362	8	155	2465
Trial 2 2 ft away	520	1358	189	2459	61229	28 4	1878	64161
Trial 3 2 ft away	18	39	1	106	4868	12	57	4987
Trial 4 2 ft away	367	1050	105	1217	51844	27 8	1417	53444
Trial 5 2 ft away	92	236	8	359	10426	85	328	10878

Table 16: Results of background particle collection prior to test fires involving six shots from a semiautomatic.

Sample name: 6 shots semiauto-matic	Pb, Sb, Ba	Sb, Ba	Pb, Ba	Pb, Sb	Pb	Ba	Unique GSR particles	Particles consistent with GSR
Trial 1 background	0	0	0	0	0	0	0	0
Trial 2 background	0	0	0	0	1	0	0	1
Trial 3 background	0	0	0	0	0	0	0	0
Trial 4 background	0	0	0	0	1	0	0	1
Trial 5 background	0	0	0	0	0	0	0	0

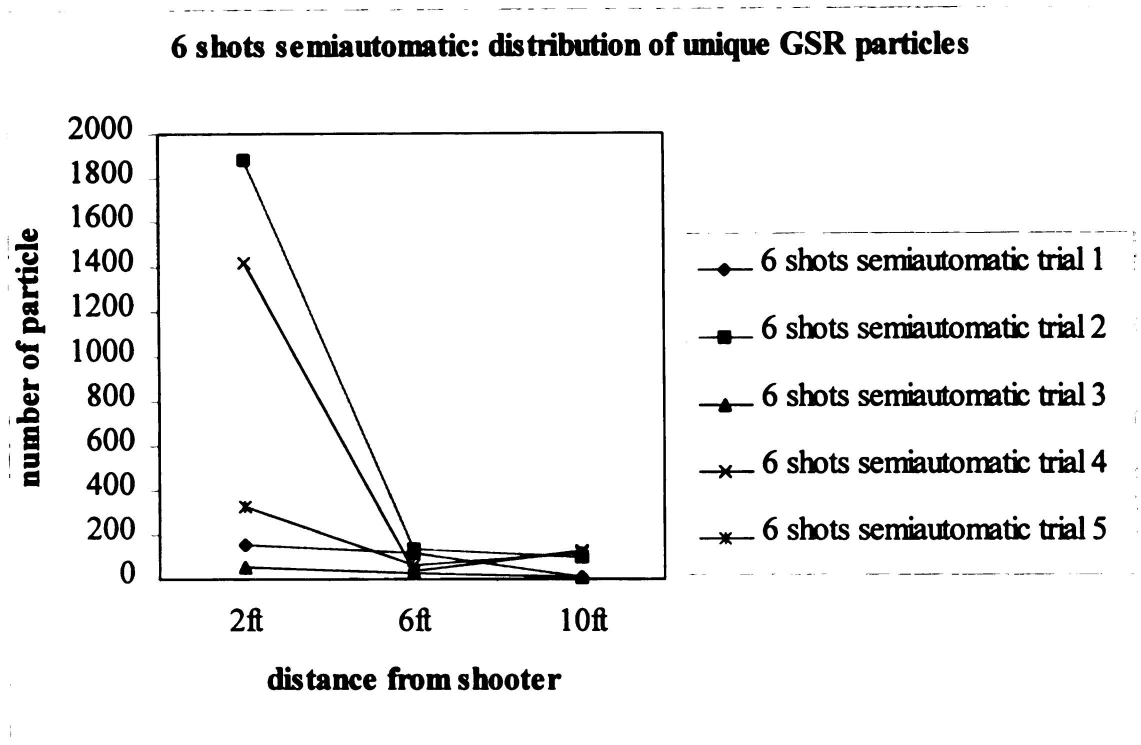

Figure21: The distribution of unique GSR particles deposited at three distances from the shooter after six shots from a semiautomatic handgun.

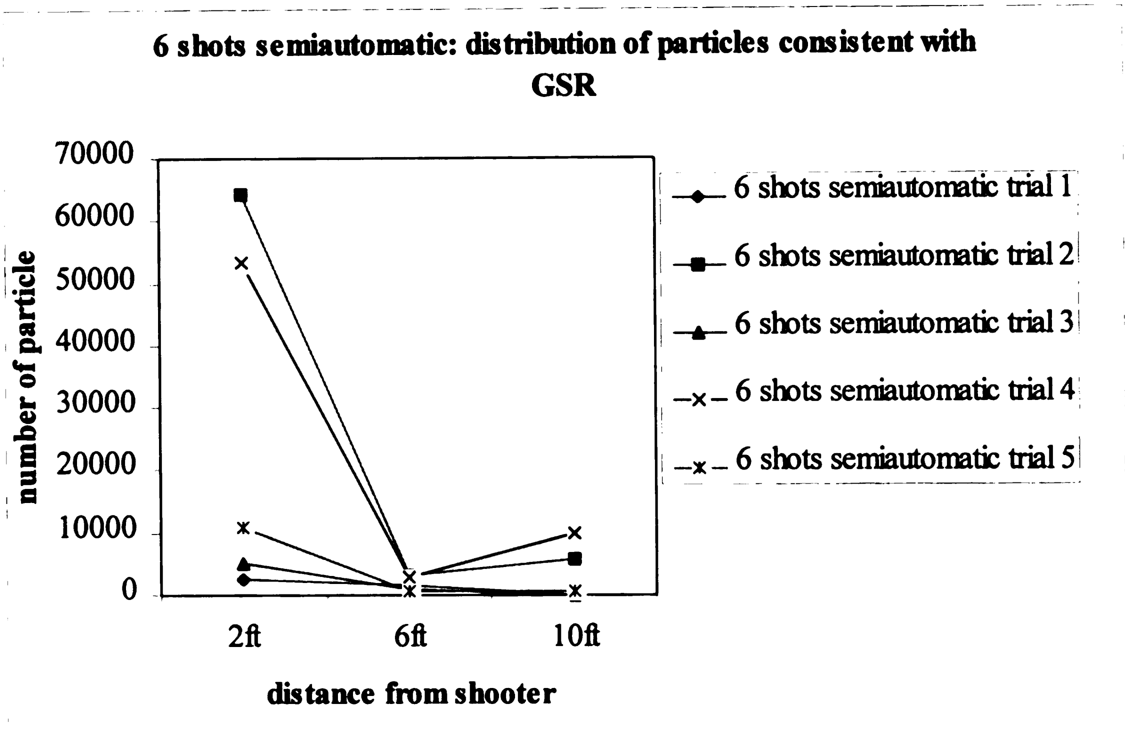

Figure 22: The distribution of particles consistent with GSR deposited at three distances from the shooter after six shots from a semiautomatic handgun.

A Comparison of the Results of One Shot and Six Shots from a Semiautomatic Handgun

A comparison of the numbers of GSR particles deposited after one shot and six shots were fired using a semiautomatic handgun appears in graph form in Figures 23 through 28. The numbers of particles unique to GSR were generally higher after six shots than after one shot. The number of particles consistent with GSR was higher after six shots in most of the trials. However, in some of the trials, the numbers of particles consistent with GSR after one and six shots are close at varying distances from the shooter.

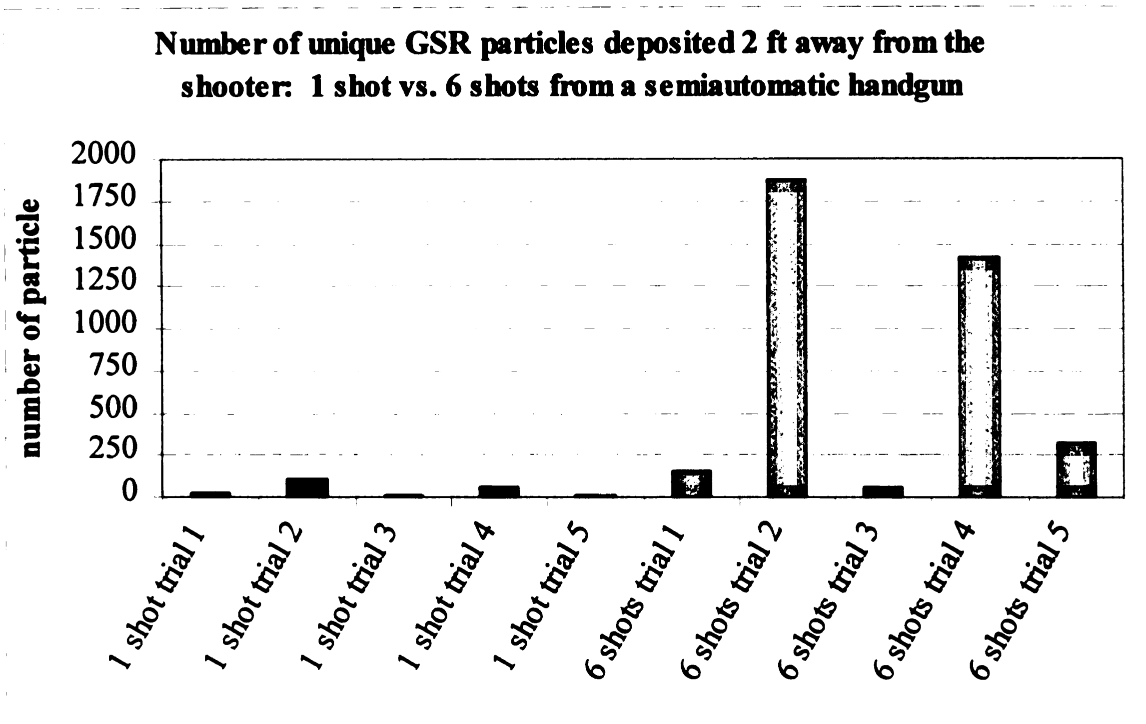

Figure 23: A comparison of the number of unique GSR particles deposited at two feet from the shooter after firing one and six shots from a semiautomatic handgun.

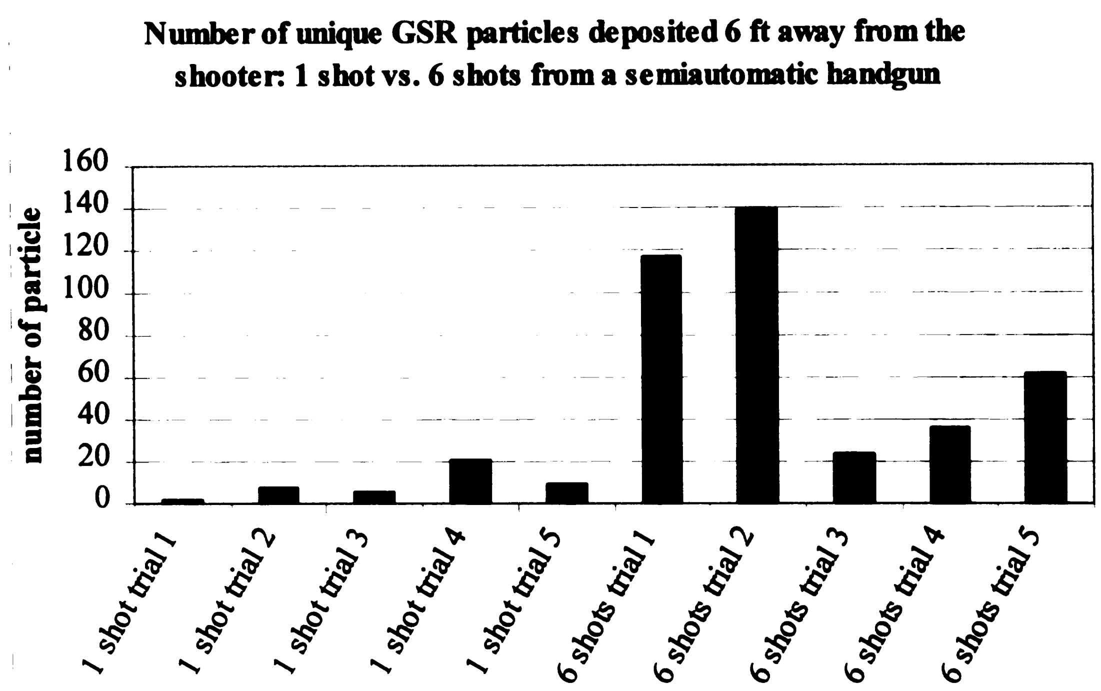

Figure 24: A comparison of the number of unique GSR particles deposited at six feet from the shooter after firing one and six shots from a semiautomatic handgun.

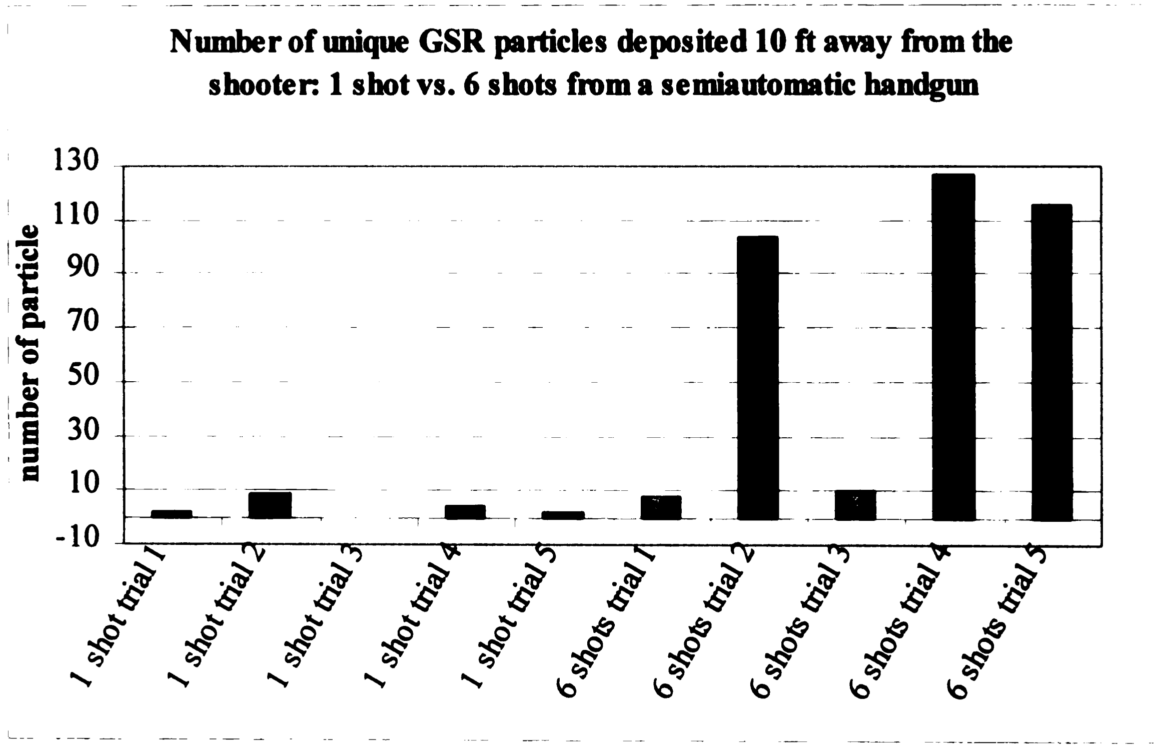

Figure 25: A comparison of the number of unique GSR particles deposited at ten feet from the shooter after firing one and six shots from a semiautomatic handgun.

Number of particles consistent with GSR deposited 2 ft away from the shooter: 1 shot vs. 6 shots from a semiautomatic handgun

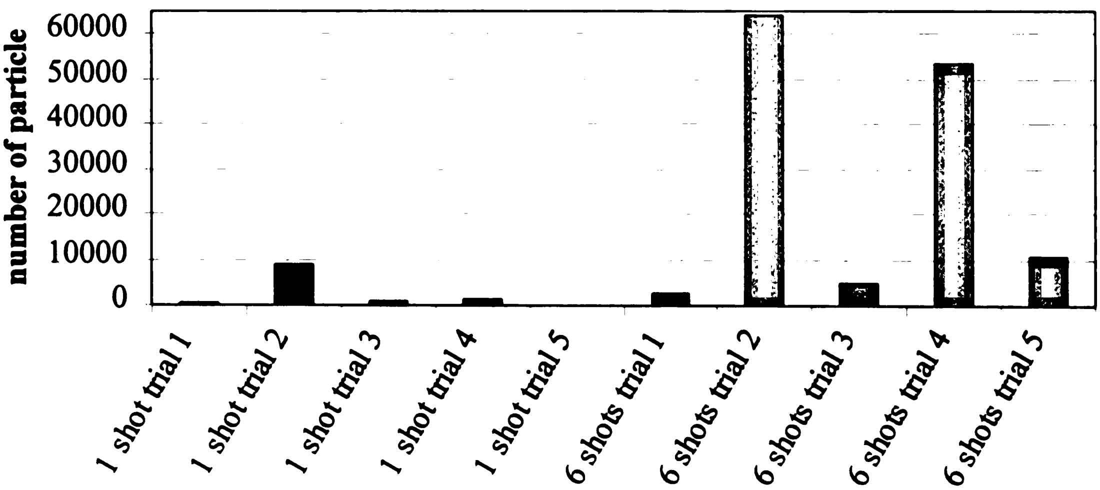

Figure 26: A comparison of the number of particles consistent with GSR deposited at 2 ft away from the shooter after firing one and six shots from a semiautomatic handgun.

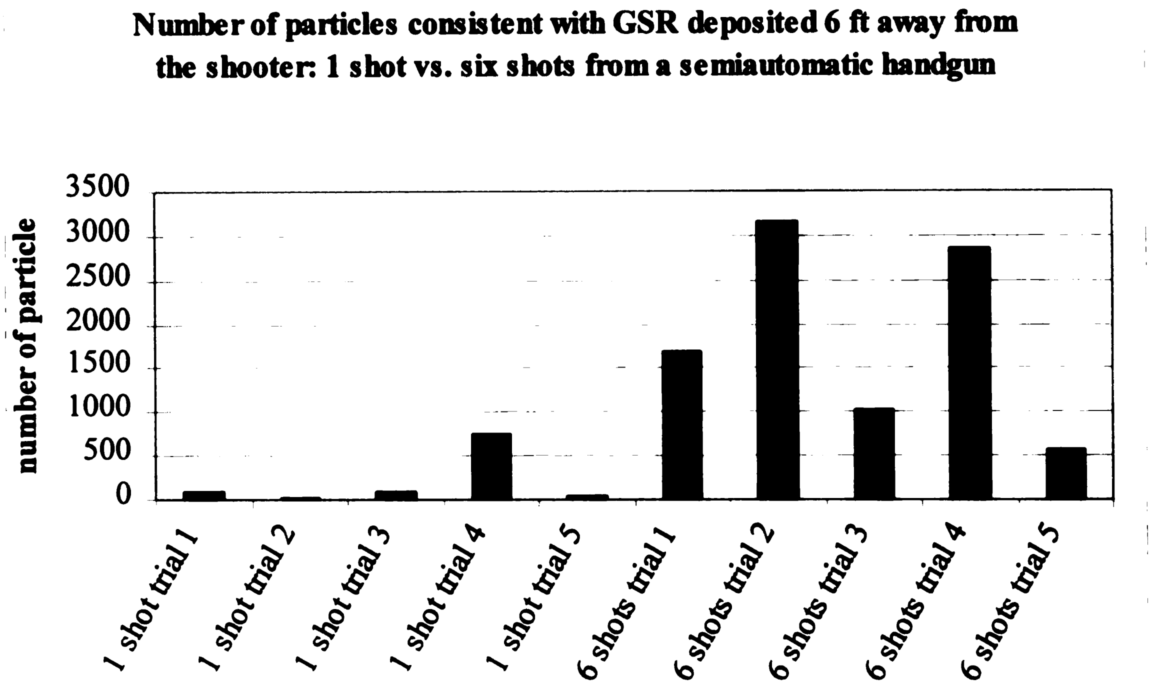

Figure 27: A comparison of the number of particles consistent with GSR deposited at 6 ft away from the shooter after firing one and six shots from a semiautomatic handgun.

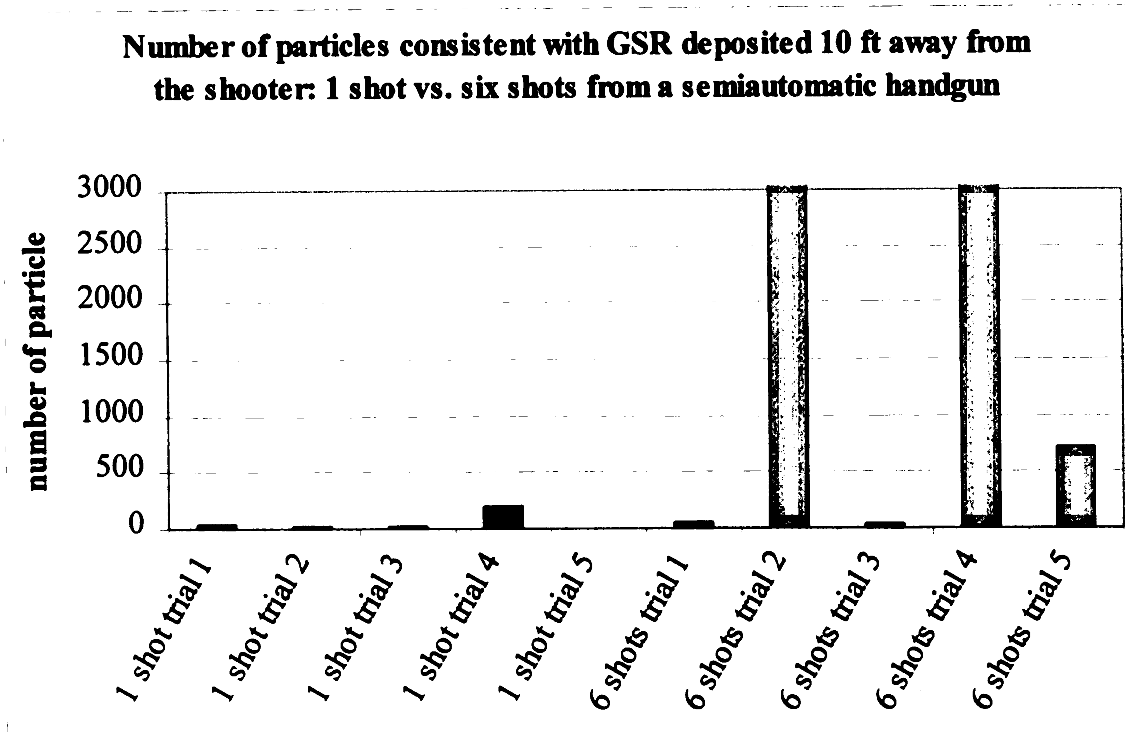

Figure 28: A comparison of the number of particles consistent with GSR deposited at 10 ft away from the shooter after firing one and six shots from a semiautomatic handgun.

A Comparison of the Results from Six Shots Fired Using a Revolver and a Semiautomatic Handgun

A comparison of the number of GSR particles deposited after six shots were fired using a revolver and a semiautomatic handgun appears in graph form in Figures 29 through 34. The results show that overall more GSR particles were deposited after discharging the semiautomatic than were deposited after discharging the revolver. However, in some of the trials, the numbers of GSR particles deposited are similar for the two firearms at varying distances from the shooter.

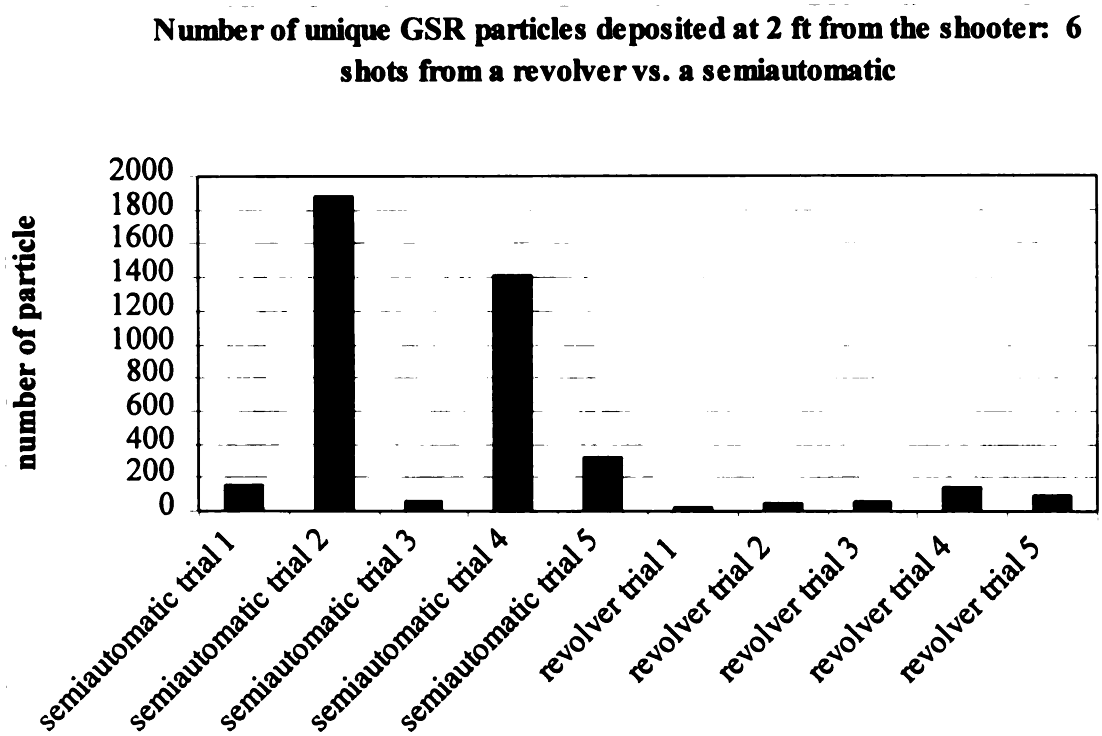

Figure 29: A comparison of the number of unique GSR particles deposited at 2 ft from the shooter after firing six shots from a semiautomatic handgun and a revolver.

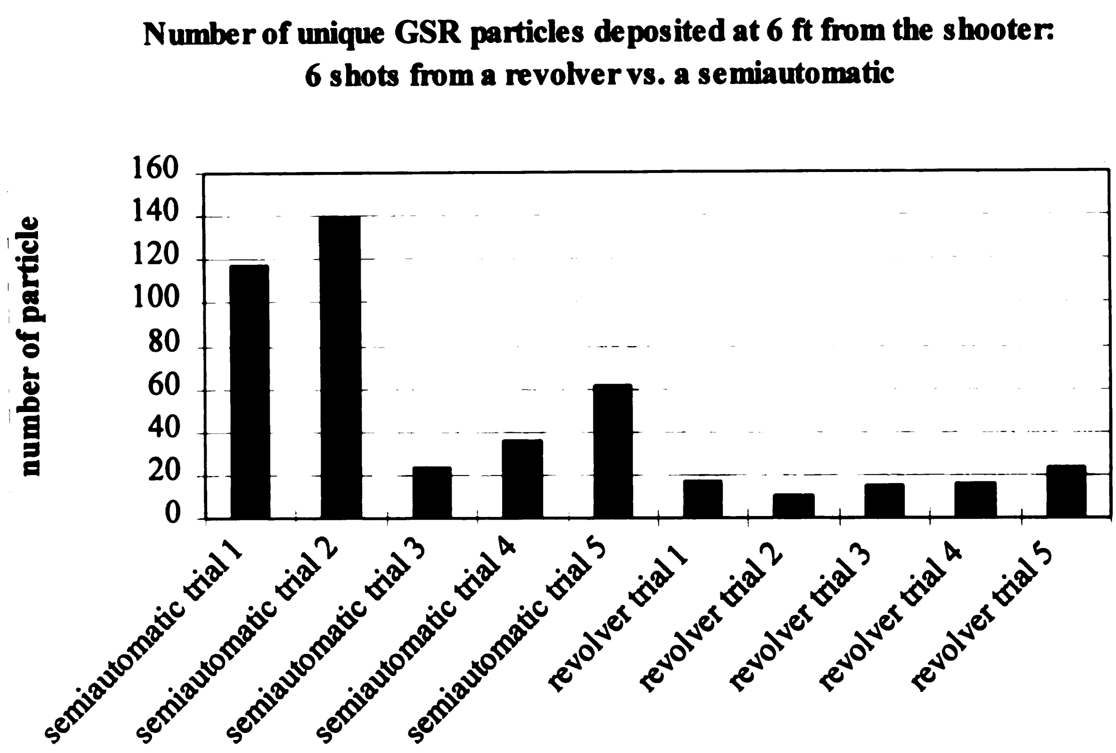

Figure 30: A comparison of the number of unique GSR particles deposited at 6 ft from the shooter after firing six shots from a semiautomatic handgun and a revolver.

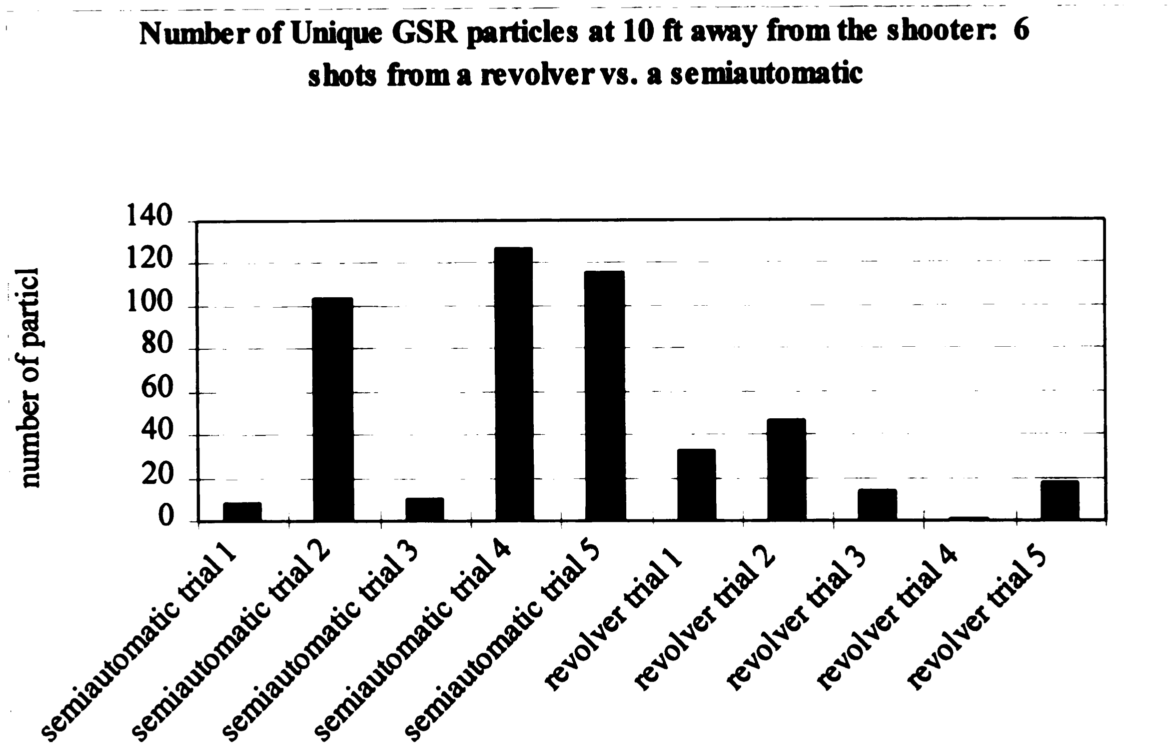

Figure 31: A comparison of the number of unique GSR particles deposited at 10 ft from the shooter after firing six shots from a semiautomatic handgun and a revolver.

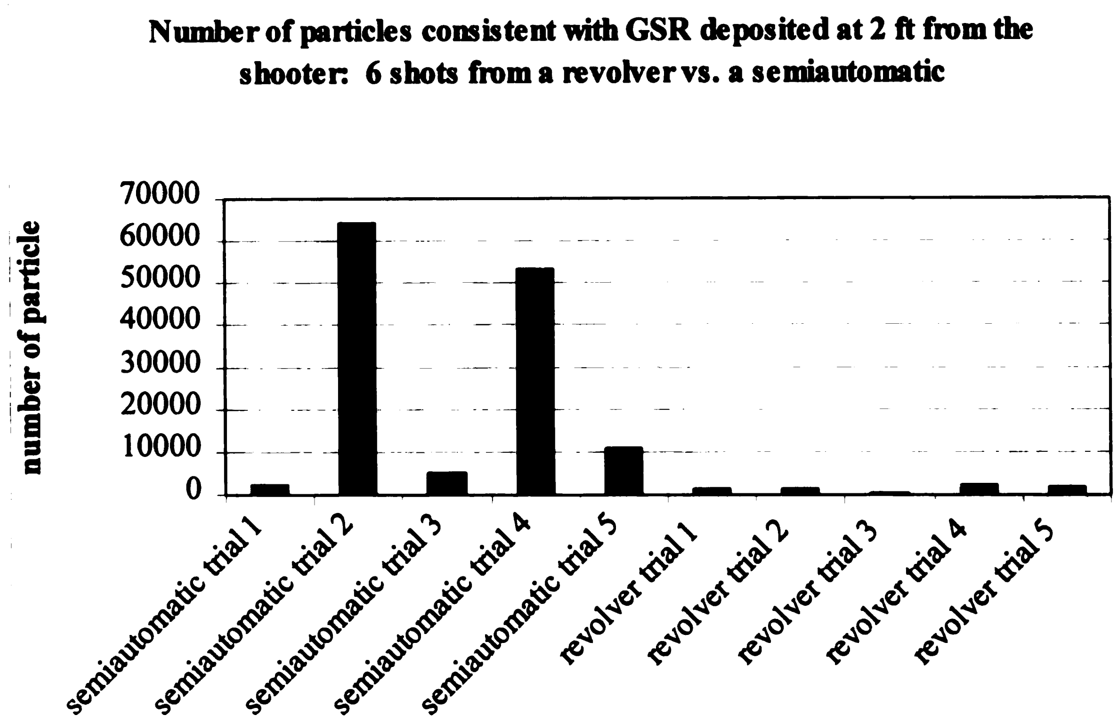

Figure 32: A comparison of the number of particles consistent with GSR deposited at 2 ft from the shooter after firing six shots from a semiautomatic handgun and a revolver.

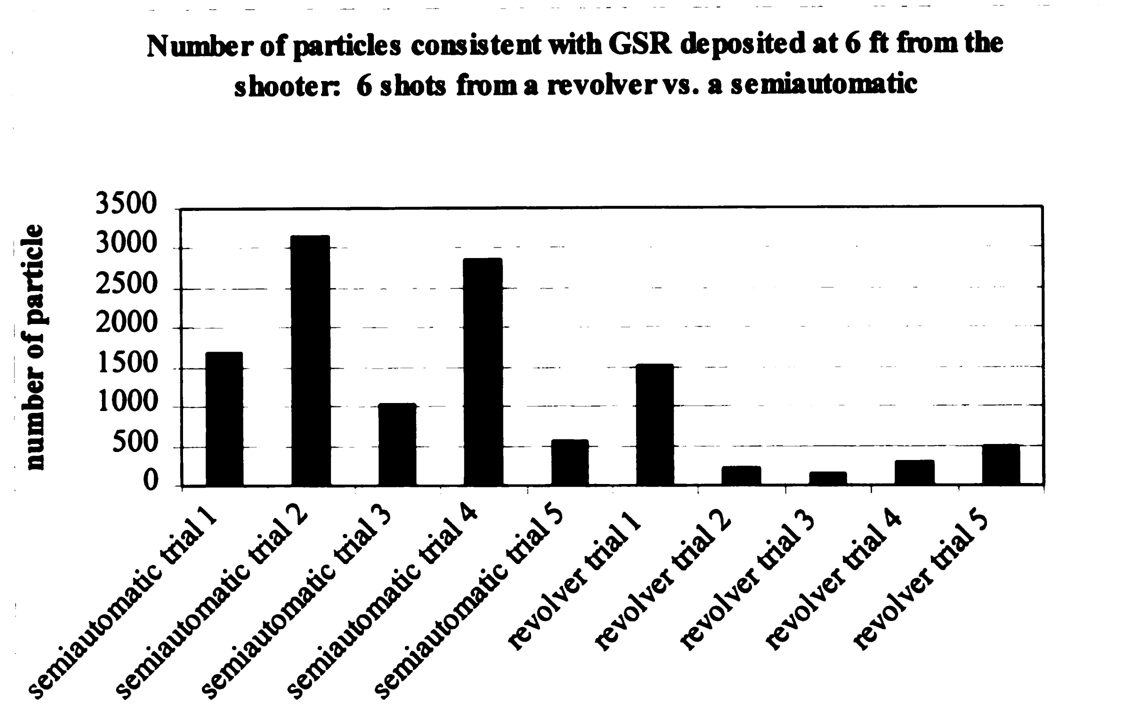

Figure 33: A comparison of the number of particles consistent with GSR deposited at 6 ft from the shooter after firing six shots from a semiautomatic handgun and a revolver.

Number of particles consistent with GSR deposited at 10 ft from the shooter: 6 shots from a revolver vs. a semiautomatic

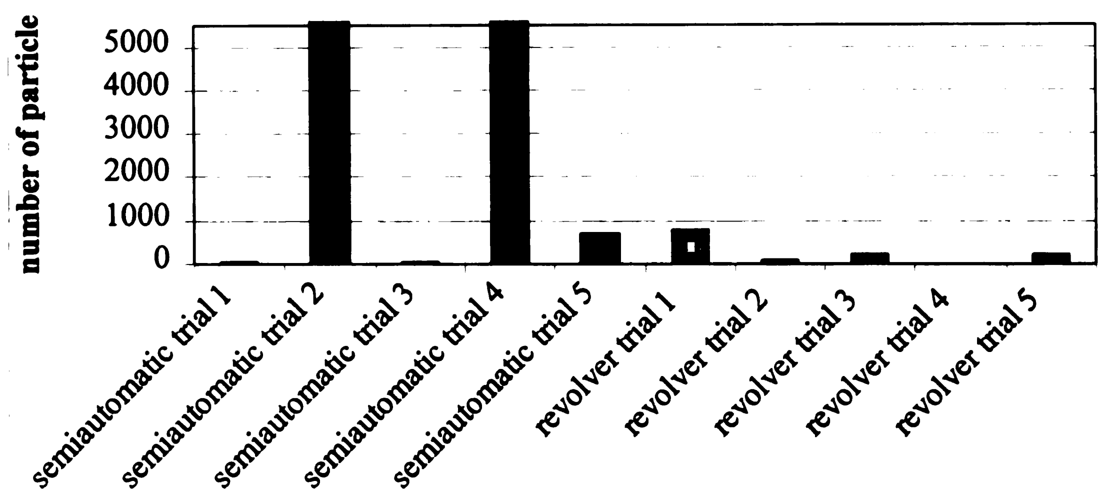

Figure 34: A comparison of the numbers of particles consistent with GSR deposited at 10 ft from the shooter after firing six shots from a semiautomatic handgun and a revolver.

Chapter 4

SUMMARY AND CONCLUSIONS

This study was designed to assess the distribution of GSR when a firearm is discharged indoors. The distance the GSR particles traveled from the gun as well as the number of particles deposited was recorded. The number of shots fired and the type of firearm used were varied in order to evaluate the impact of these factors on GSR distribution.

The results showed that unique GSR particles deposited as far as ten feet away from the shooter in 79 out of the 80 trials carried out. This result shows that it is possible for an individual pick up unique GSR particles by coming into contact with objects up to ten feet away from the shooter. In addition, if the collection discs are seen as individuals standing in a room during a shooting, it is possible for GSR to deposit on individuals standing up to ten feet away from the shooter. Further research should be done in order to assess this implication more fully.

The results also showed that the distribution of GSR was inconsistent for both firearms used, regardless of the number of shots fired. The highest number of particles generally deposited at two feet from the shooter. However, at six and ten feet from the shooter, the number of particles deposited did not always decrease as the distance from the shooter increased. In many trials, more particles were deposited at ten feet than at six feet. This outcome may be due to the positions of the collection stubs in the room. The stub at the ten-foot distance was placed approximately one foot from the side wall of the room. Air currents created by the discharging firearm combined with the confined space of the room may have contributed to the high numbers of particles deposited at the ten-foot distance. Overall, the results showed that the number of particles deposited did not always relate to the distance from the shooter, especially when considering the numbers of particles deposited at six and ten feet away.

In comparing the impact of the number of shots fired on particle deposition, the following observations were made. For test fires involving the revolver, the number of unique GSR particles deposited was higher after six shots than it was after one shot. More particles consistent with GSR were deposited after six shots at six and ten feet away from the shooter. However, similar numbers of particles consistent with GSR were deposited at two feet from the shooter after both one and six shots. For test fires involving the semiautomatic handgun, overall, more GSR particles were deposited after six shots than after one shot. However, in some of the trials, at a given distance from the shooter the number of particles deposited was similar for both one and six shots. These results indicate that the number of GSR particles deposited does not always correlate to the number of shots fired.

In comparing the impact of the type of firearm used on the deposition of GSR, two observations were made. For trials in which one shot was fired, the number of particles deposited was similar for the revolver and the semiautomatic. For the trials involving the discharge of six shots, more particles were deposited after discharging the semiautomatic handgun. The semiautomatic was expected to deposit more particles due to the cartridge ejection to the right of the firearm. The second observation made was that the particle distribution was inconsistent for both the semiautomatic and the revolver.

As was mentioned earlier, inconsistencies in GSR distribution may arise from both the firearm and the ammunition used.

The inconsistencies in particle deposition throughout all of the trials carried out in this study suggest that GSR distribution is of little use for individuals reconstructing a shooting event. For example, determining where a shooter was positioned while discharging a firearm by collecting GSR samples alone would not prove reliable when these inconsistencies are considered. However, sampling areas for GSR where a shooting was known to occur may aid in assessing the implications for GSR transfer to non-shooters.

The results obtained in this study both agree and disagree with past studies on GSR distribution. Many individuals have reported inconsistencies in GSR distribution such as those observed in this experiment. Krishnan and Munhall both reported that the amount of GSR deposited could vary from shot to shot even if the same ammunition type is used. Variation in the ammunition used provides one explanation for this phenomenon (Krishnan, 1977; Munhall, 1961). Munhall also suggested that inconsistencies in GSR deposition could be blamed on the firearm itself. For example, firing pin blows may vary in strength (1961). In addition, Krishnan and Basu stated that the amount of GSR deposited does not always add up with the number of shots fired (Krishnan, 1977; Basu et al., 1997). The results of this study support this theory as well.

The results of this study also disagree with past studies on GSR distribution. This experiment demonstrated that GSR can deposit as far as ten feet away from a shooter when a firearm is discharged indoors. The Aerospace Corporation reported that GSR can travel as far as three feet away from the shooter, but not as far as ten feet away (1977).

The study performed here also demonstrated that the number of GSR particles deposited was inconsistent, and that it is possible for higher numbers of particles to deposit at further distances from the shooter than at closer collection points. In experiments done by White and Gross, their results showed that the number of unique GSR particles deposited decreased as the distance from the shooter increased (1987).

The results of this experiment have provided great insight into the how GSR particles are distributed when a firearm is discharged indoors. It was hoped that the use of negative controls, repeated trials, and thoroughly documented experimental conditions would provide reliable experimental results that would be of great use to those dealing with GSR evidence. It was also hoped that this study might create a model for how GSR experiments are performed and documented in the future. GSR is considered an important form of evidence and is used by many law enforcement agencies when they are faced with firearms related crimes. Therefore, it is of vital importance that research on GSR distribution continues so that the implications of GSR samples yielding positive results can be more fully understood.

Chapter 5

SUGGESTIONS FOR FUTURE RESEARCH

There are several possibilities for future research in the area of GSR distribution. In order to evaluate the impact of ammunition type on GSR distribution, this experiment can be repeated using one firearm and varying the ammunition used. Using more firearms can also expand upon this experiment. Another addition that can be made to this study is the presence of individuals in the room during the time of shooting at varying distances from the firearm. The hands of the individuals can then be sampled for GSR.

Other options for future research on GSR distribution include expanding the sampling to distances farther than ten feet away from the shooter, sampling to all sides of the shooter, and evaluating the impact of air currents on the distribution. There are many aspects of GSR distribution that are in need of further research. This creates many options for individuals desiring to conduct research in this area.

APPENDICES

APPENDIX A

MATERIALS USED IN THIS EXPERIMENT

Firearms Used:

- Ruger .357 Blackhawk revolver
- Smith and Wesson 9mm semiautomatic handgun

Ammunition Used:

- Winchester Super X 38 sp. 110 gr. Silvertip® HP
- Winchester Super X 9mm Luger 115 gr. Silvertip® HP

Specimen Collection Materials:

- 12mm double coated carbon conductive adhesive tabs
- ½" aluminum specimen mounts with slotted heads
- plastic storage tubes designed to hold one aluminum specimen mount

Experimental Setup Materials:

- Detroit Corporation Bullet Trap Box
- 200 square foot room

SEM/EDX Analysis Equipment:

- Philips XL30 Scanning Electron Microscope combined with the Oxford ISIS 300 X-ray analyzer
- RJ Lee Personal SEM

APPENDIX B

RESULTS OF SUBSTRATE CONTROL EXAMINATION

Sample name: substrate control	**Pb, Sb, Ba**	**Sb, Ba**	**Pb, Ba**	**Pb, Sb**	**Pb**	**Ba**	**Unique GSR particles**	**Particles consistent with GSR**
Carbon tape batch #1	0	0	0	0	0	0	0	0
Carbon tape batch #2	0	0	0	0	0	0	0	0

Table 17: Results of substrate control samples collected for each batch of carbon tape used in this experiment.

APPENDIX C

DIAGRAM OF ROOM WHERE EXPERIMENT PERFORMED

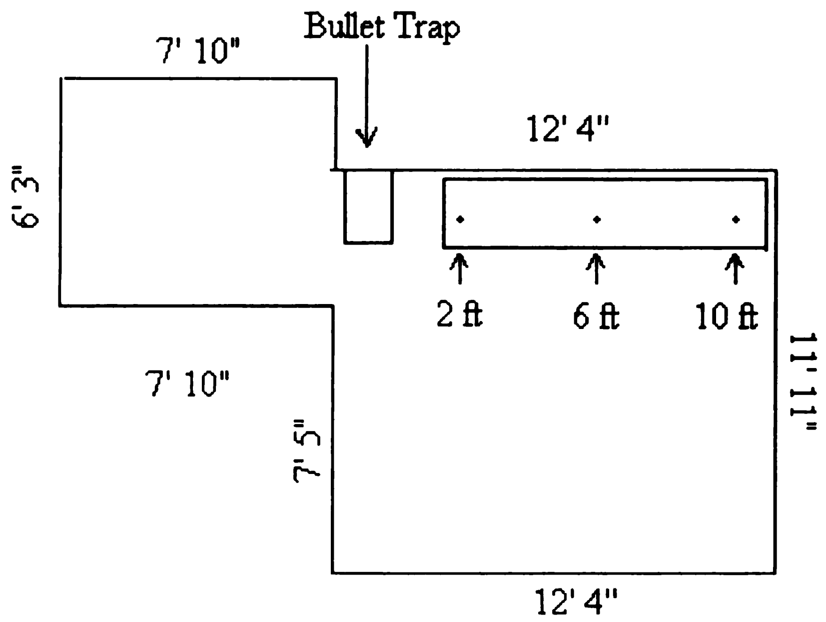

Figure 35: Diagram of room where test fires were performed, not to scale.

LITERATURE CITED

LITERATURE CITED

American Society for Testing and Materials. (1995). Standard Guide for Gunshot Residue Analysis by Scanning Electron Microscopy/Energy Dispersive Spectroscopy. *The Annual Book of ASTM Methods vol. 03.06*, Philadelphia: ASTM.

Basu, S. (1982). Formation of gunshot residues. *Journal of Forensic Sciences*, 27, 72-91.

Basu, S., Boone, C., Denio, D., Miazga, R. (1997). Fundamental studies of gunshot residue deposition by glue-lift. *Journal of Forensic Sciences*, 42, 571-581.

Basu, S. & Ferris, S. (1980). A refined collection technique for the rapid search of gunshot residue particles in the scanning electron microscope. *Scanning Electron Microscopy*, I, 375-384.

Germani, M. (1991). Evaluation of instrumental parameters for automated scanning electron microscopy/gunshot residue particle analysis. *Journal of Forensic Sciences*, 36, 331-342.

Krishnan, S., Gillespie, K., & Anderson, E.J. (1977). Rapid detection of firearm discharge residues by atomic absorption and neutron activation analysis. *Journal of Forensic Sciences*, 16, 215-217.

Krishnan, S. (1982). Detection of gunshot residue: present status. In R. Saferstein (ed.), *Forensic Science Handbook* (pp. 572-591). Englewood Cliffs: Prentice Hall, 1982.

Matricardi, V. & Kilty, J. (1977). Detection of gunshot residue particles from the hands of a shooter. *Journal of Forensic Sciences*, 22, 725-738.

Meng, H. & Caddy, B. (1997). Gunshot residue analysis—a review. *Journal of Forensic Sciences*, 42, 553-570.

Renfro, W. & Jester, W. (1973). Collection and activation analysis of airborne GSR. *Journal of Radioanalytical Chemistry*, 15, 79-85.

Seamster, A. et al. (1976). Studies on the spatial distribution of firearm discharge residues. *Journal of Forensic Sciences*, 21, 868-882.

Singer, R., Davis, D., & Houck, M. (1996). A survey of gunshot residue analysis methods. *Journal of Forensic Sciences*, 41, 195-198.

Thornton, J. (1986). Close proximity gunshot residues. *Journal of Forensic Sciences*, 31, 756-757.

Thornton, J. (1994). The chemistry of death by gunshot. *Analytica Chimica Acta*, 288, 71-81.

White, R. & Gross, M. (1987). Deposition of Gunshot Residue at Various Distances from Discharging Firearms [lecture]. Raleigh: Unpublished paper.

Wolten, G., Nesbitt, R., Calloway, A., Loper, G., & Jones, P. (1977). Final Report on Particle Analysis for Gunshot Residue Detection [report]. Report No. ATR-77(7915)-3. El Segundo: The Aerospace Corporation.

Wolten, G., Nesbitt, R., Calloway, A., Loper, G., & Jones, P. (1979). Particle analysis for the detection of gunshot residue. I: SEM/EDX characterization of hand deposits from firing. *Journal of Forensic Sciences*, 24, 409-422.

Wolten, G., Nesbitt, R., Calloway, A., & Loper, G. (1979). Particle analysis for the detection of gunshot residue. II: Occupational and environmental particles. *Journal of Forensic Sciences*, 24, 423-430.

Zeichner, A. & Levin, N. (1997). More on the uniqueness of gunshot residue particles. *Journal of Forensic Sciences*, 42, 1027-1028.

GENERAL REFERENCES

GENERAL REFERENCES

Basu, S. (1985). The Mechanism of GSR Deposition and its Probing Characteristics to Reconstruct Shootings [lecture]. 43rd Annual Meeting of the Electron Microscopy Society of America, August 5-9.

Goleb, J. & Midkiff, C. Jr. (1975). Firearms discharge residue sample collection techniques. *Journal of Forensic Sciences*, 20, 701-707.

Kilty, J. (1975). Activity after shooting and its effect on the retention of primer residue. *Journal of Forensic Sciences*, 20, 219-230.

Midkiff, C. (1977). Detection of gunpowder/gunpowder residues. A state-of-the-art review and recommendations for further research [report]. Prepared for the Committee on new development and research, American Society of Crime Lab Directors.

Munhall, B. (1961). Fundamental ballistics pertaining to investigations involving firearms. *Journal of Forensic Sciences*, 6, 215-217.

Nesbitt, R.; Wessel, J., & Jones, P. (1976). Detection of GSR by use of the SEM. *Journal of Forensic Sciences*, 21, 595-610.

Schlesinger, et al. (1970). Special Report on Gunshot Residue Measured by Neutron Activation Analysis, Report No. GA-9829 [report]. 10 August, San Diego: Gulf General Atomic, inc.

Wallace, J. (1990). Chemical aspects of firearms ammunitions. *AFTE Journal*, 22, 364-389.

White, R. & Owens, A. (1987). Automation of GSR detection and analysis by SEM/EDX. *Journal of Forensic Sciences*, 32, 1595-1603.

Wolten, G., Nesbitt, R., & Calloway, A. (1979). Particle analysis for the detection of gunshot residue. III: The case record. *Journal of Forensic Sciences*, 24, 864-869.