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Discrimination and classification among common items of evidence using particle combination profiles

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ABSTRACT

This project used established analytical tools and statistical methods to determine the evidential value of very small particle (VSP) profiles found on handguns, cell phones, drug packaging, and ski masks.

Sampling protocols were designed, tested and used to sample VSP from evidence items from a single county-level crime laboratory: 30 handguns, 31 cell phones, 36 drug packaging specimens and 32 ski masks. Specimens were prepared for analysis employing established protocols for semi-automated scanning electron microscopy with elemental characterization by energy dispersive x-ray analysis (SEM/EDS).

Statistical methods of particle combination analysis were applied to (1) remove particle "noise" from the datasets, (2) define a set of highly discriminating target particle types, (3) measure the strength of correspondence between profiles, and (4) measure the potential of VSP as an evidence type under defined experimental conditions.

Most (84%) of the VSP specimens recovered from common evidence items showed sufficient variety and complexity in their VSP profiles to allow meaningful classification among closed sets of approximately 30 specimens. Correct associations were achieved for 93.5% of test specimens (drug packaging: 97.2%; cell phones: 92.6%; handguns: 92.9%; ski masks 88.2%). Test specimens with VSP numbers greater than 125 showed predominantly correct classifications.

These findings establish (1) that VSP are present on the surfaces common items of physical evidence, (2) that the VSP can be efficiently recovered, prepared and analyzed by computer-assisted SEM/EDS analysis, (3) that the variety of particles is sufficient for the definition of classifiers based on reference sources, and (4) that the classifiers perform very well for these particle sets, showing that VSP recovery, analytical methods and computational methods are working effectively.

The use of adhering VSP to establish quantitative associations among items of physical evidence is a new approach, exploiting a form of trace evidence that is typically ignored. It is highly significant for its potential to expand the number of cases to which trace evidence can meaningfully contribute and for its ability to include a quantitative statistical approach to data interpretation.

1. Introduction

Prevailing methods of trace evidence analysis have been limited by three major aspects:

- Difficulties in the measurement of probative value
- Increased specialization, focusing on smaller numbers of particle types, in correspondingly smaller numbers of cases
- Relatively long analytical times and high levels of effort for required tasks

These limitations combine to reduce the application of trace evidence, resulting in a set of major challenges faced by the discipline: low perceptions of probative value, small numbers of case requests, and high costs relative to case contributions [1–6]. The impact within forensic laboratories has been substantial, resulting in reductions in funding, restriction of services, and even complete closure of trace analysis sections within laboratories [1,5].

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Solutions to these challenges have been elusive because the underlying limitations are inter-related in a complex way, with improvements to one problem exacerbating another. Efforts to increase probative value have increased specialization of personnel, analytical times and costs. These increases have offset efficiencies offered by new methods and technologies, and reduced the number of cases where it is practical to apply them [6].

Within this context, methods focusing on the analysis of combinations of very small particles (VSP) show exceptional promise to address the limitations facing trace evidence analysis [7,8]. Prior research has characterized VSP combinations using analytical instrumentation and expertise commonly available in forensic laboratories. Statistically rigorous methods have been developed for the measurement of the level of correspondence between VSP profiles, and these methods can easily be extended to assign the probative value of the resulting associations. This research has shown that it is possible to simultaneously exploit large numbers of very small particle types, with practical analysis times and levels of effort. It has also shown that analytical results allow quantitative statistical measurement of correspondence and evidential value.

It is important to note that this approach addresses each of the bulleted limitations listed above: probative value can be measured, cases are not restricted by small numbers of particle types, and both the required analytical times and level of effort are practically achievable. However, it remains to determine if VSP occur on common items of physical evidence, in sufficient numbers and complexity, to provide useful levels of associative value.

The goal of this project was to determine the potential evidential value of particle combination profiles found on common, important items of physical evidence. VSP were harvested from 129 evidence items representing four important and commonly occurring types of evidence: handguns, drug packaging, cellular phones and ski masks. Previously developed analytical and interpretive methods [7] were used to measure the discrimination among VSP profiles and to investigate the sufficiency of these profiles to provide evidential value.

2. Material and methods

2.1. Rationale for choice of evidence items

Four evidence types were selected for this project: handguns, drug packaging, cellular phones and ski masks. These items were selected for several reasons: (1) they regularly occur as evidence left and collected at major crime scenes, (2) associations of these items to one another, to individuals and to locations is of broad investigative significance, (3) they include a wide range of surface types, including most that are likely to be found on evidence, and (4) as a set, they are a reasonable choice for a general assessment of the probative value of VSP as they occur on common items of evidence.

The number of items of each type (25+) was selected to be (1) a reasonable number to ensure a variety of specifics and conditions for each evidence type, (2) sufficient for a meaningful assessment of probative value, and (3) achievable within the scope of the project.

Actual items of evidence were used in this project, rather than similar items selected as proxies by research staff. It was deemed essential, at this stage of research, that the project determine whether the numbers and types of VSP that are present on actual evidence items have sufficient variety and value for association. The role of this project is to provide the criteria, and test whether it is reasonable to expect sufficient evidential value to justify research and development of field applications.

Items from one jurisdiction were used (San Diego County Sheriff's Office Crime Laboratory), with the intention that the data be applicable to the development of applications within local jurisdictions. If, for example, the profiles of VSP from one geographical area are more similar to one another, it is important that the potential of VSP as an evidence type be measured with this variable fixed. Ultimately the understanding of systematic variations across wider geographical areas will undoubtedly be of interest, but this is not a logical initial step. We need to ensure that the methods will have meaning within local environments that are routinely encountered in criminal investigation.

2.2. VSP harvesting protocols

Two alternative sampling methods were used: one based on the use of polyester cleanroom swabs [9], and the other based on the direct use of SEM stubs, analogous to those used commonly in protocols for the recovery of possible gunshot residue (GSR) from a subject's hands [10,11]. Direct use of commercially-prepared SEM stubs is suitable for non-porous, non-friable, flat surfaces where there can be direct contact of the sticky SEM stub and the surface to be sampled. This sampling method was used for the drug packaging evidence items (plastic bags).

Swabbing was more suitable for curved and recessed surfaces. In the swabbing procedure, slightly dampened, non-shedding clean room swabs are used for particle recovery. With the manipulation of the swab and changes of pressure, the swabs are able to adapt well to variations in surface topography and to curved or recessed surfaces. Swabbing also allows a useful (though clearly approximate) way to monitor the sampling process by observing the discoloration of the sampling swabs. Successive swabbing of the same areas, with successively less discoloration, is a means to assess the thoroughness of particle recovery. Swabbing was used for the handgun, cell phone and ski mask evidence items.

Following the swabbing itself, swab heads were removed by cutting and particles were recovered into a suspension using a washing procedure as in [12] followed by vacuum filtration. This method allows a more comprehensive sampling of particles, prepares a specimen where particles are well-dispersed, and avoids the recovery of larger particles that are outside the scope of the analysis.

A modified filtration system was employed for the recovery and dispersal of particles onto 0.4 micrometer polycarbonate filters. Low vacuum filtration utilized a filter holder specifically designed for 13 mm diameter filters (Advantec All-Glass Microanalysis Filter Holder, 13 mm; available from Cole-Palmer). This allowed less sample manipulation, accommodated larger particle suspension volumes, avoided the cutting of filters, and had a greater capacity of recovered particle numbers than the previously used method [12]. The sintered glass filtration surface was covered with a 13 mm diameter cellulose fiber filter support pad and moistened with pre-filtered distilled water. A low vacuum sufficient for dropwise filtration was applied and the 0.4 micrometer polycarbonate filters were placed on top of the filtration pad. After dropwise filtration of the particle suspensions, the entire polycarbonate filter was transferred to an SEM stub that was pre-fitted with a carbon adhesive disk.

2.3. SEM/EDS analysis of particles

The computer-assisted SEM/EDS analysis followed the protocols in [7]. Analyses were performed on an Aspex Corporation