Interpol Review of Firearm Examination 2016 – 2019

Executive Summary of the following INTERPOL publication:
https://www.interpol.int/content/download/14458/file/Interpol%20Review%20Papers%202019.pdf

ASCLD Forensic Research Committee
Future Forensics Subcommittee

Firearm Examination, Comparison, and Identification (Summarized by Robert M. Thompson)

The executive review encapsulates the "Interpol review of forensic firearm examination 2016-2019" authored by Mattijssen in *Forensic Science International: Synergy.* This summary will use the same citations and references contained in the *Synergy* publication (in press).
https://www.sciencedirect.com/science/article/pii/S2589871X20300085

In the last decade there has been an increasing effort toward strengthening the foundational science and validation studies of pattern matching specialties in the forensic sciences. This was arguably given impetus since the 2009 National Research Council's (NRC) "Strengthening Forensic Science in the USA: A Path Forward" report [2], and in a later report from the President's Council on Science and Technology (PCAST) titled "Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature Comparison Methods" [1]. The primary areas of research to address the concerns in these reports focus on:

1. the development of computer-based methods toward a more quantitative measurement of toolmark similarity and what statistical estimate of identification error might be derived from an objective assessment;
2. the validation of current methods through statistical studies in proficiency testing and designed blinded examinations;
3. the influences that affect the performance of the examiners' judgements such as bias.

Firearm Examination topics also include important research and technology that supports forensic expert actions in shooting scene reconstruction, terminal ballistics and wound ballistics. These primary research efforts have been toward:

1. shooting scene trajectory methods and estimation of measurement error dependent on method, projectile type, range, and target composition;
2. wound ballistics performance studies of soft tissue and bone simulants compared to actual tissue and bone;
3. technological based methods to visualize, document, and measure effects in tested simulants;
4. factors affecting projectile impact and behavior on various case-like targets and shooting case scenarios.

Validation Studies
While there have been validation studies in firearm examination for many decades, there have been an increasing number of sophisticated designed studies resulting with strong statistical foundations. The validation studies help determine the extent at which the examiners accurately match he components to a variety of firearms and their toolmaking surfaces. Studies were conducted using numerous makes

and models of firearms that are used as ground-truth sources for fired cases and bullets, which were examined by automated image comparison [3,4,5,6] and human comparison methods [6,7]. All the studies indicated that the firearms imparted sufficiently reproducible and variable features between firearm sources that could be used for accurate judgements from either computer or examiner comparisons, with resulting low false positive error occurrence.

Firearm Examination Method

Several studies investigated what affected examination & identification methods. The effects originated from test fire bullet capture mediums and devices [8], burned vehicles [9], newer ammunition with polymer and polymer coated bullet designs [10,11,12,13], bullets with unconventional alloys such as tin [14] all present challenges not encountered with more conventional bullet compositions. Differences in a firearm's firing pin position and after-market replacement parts may also be a concern for the examiner [15,16]. A study examining the internal ballistics in firearm-ammunition pairings as it related to chamber pressure, headspace, primer alloys, bullet & primer seating may be factors in toolmark quality for comparison [18]. The regions of interest for evidence ammunition components that are primarily compared in fired cartridge cases are breechface, ejector, extractor, and firing pin impressions. Less often, other toolmarks are consistently imparted and reproduced on the chambered or fired case suitable for comparison; slide scuff [19], ejection port "swoosh" [20], barrel lugs [21], and cartridge head bunter marks [22].

Class and Sub-class

Class characteristics of firearms are those features determined as part of the firearm design and can be engraved on the fired ammunition component evidence. Studies using these features for accurate distinguish between potential firearm sources were tested on Glock, Smith & Wesson Sigma, and Springfield XD pistols that possess similar class features on fired cases [23,24], the BALLISTICA system on ten different makes of pistols [25], extractor marks between two manufacturers of M-16 rifles [26], and the make and model accuracy of GRC databases on barrel rifling impressions on bullets [27]. The influence of subclass influence on the comparison process must be considered prior to identifying a firearm source. The Association of Firearm and Toolmark Examiners (AFTE) glossary of terms define subclass characteristics as discernable features of an object which are more restrictive than class characteristics in that they are: (1) produced incidental to manufacture, (2) are significant in that they are related to a smaller group source, and (3) can arise from a source that changes over time [28]. A thorough review of the sources and importance of their consideration to the examination is contained in Nichols' technical review [29]. Research studies on subclass features on Smith & Wesson M&P .22 LR caliber rifle firing pins [30], molded breeches on .32 Auto caliber pistols [31], Glock "marking Barrels" [32], and consecutively manufactured Hi-Point 9mmLuger caliber pistol barrels that were button rifled [33].

Proficiency Testing

Of interest for the legal establishment and laboratory quality management is the accuracy of the human component of the firearm examination methodology, and how well the expert community arrives at reliable conclusions when presented with items in tests where the ground truth has been previously determined. One method to test examiner proficiency is the use of "blind testing". Studies reporting proficiency test and one using casework samples sensitive to examiner bias was conducted on fired cases from Glock pistols [35, 36]. A proficiency test with many examiners evaluating 20 case comparison sets resulted in 0% false identifications with measurements of specificity and sensitivity [37] a further

statistical test of the data reported the 95% confidence intervals for the false identification and false exclusion probabilities [38]. Both bullet and cartridge case sets were designed as representative to casework exhibits were submitted for comparisons to volunteer examiners with low overall error rates. Differences in specificity and sensitivity were observed between examiners, and between cartridge case and bullet comparisons [39].

3D Surface Topography

A major sea-change in firearm examination is the use of optical surface topography instruments that can measure and render in 3D toolmark surfaces on fired bullets and cartridge case. Additionally, image systems that compose virtual images of these measurements offer the examiner the ability to conduct virtual comparisons in a similar fashion as the comparison microscope. The ability of the modern computer systems to use these measurements to employ "match" algorithms was not practical or feasible a few decades ago. The use of topographic measurement methods, match algorithms, and statistical estimate of the weight of evidence has been a subject of study at the National Institute of Standards and Technology (NIST). The recent years have shown much progress in these efforts. Calibrations standards and physical artifacts have been designed for the quality performance of the emerging 3D optical topographical instruments[40]. The NIST open-source method of objective measurement of impressed and striated toolmarks using the congruent matching cell (CMC) mathematical method have been refined and expanded for most regions of interest in firearm evidence comparisons including congruent matching profiles (CMP) and congruent matching cross-section (CMX) [41, 42, 43, 44, 46]. The CMC method was performed on two CTS proficiency tests where breechface and firing pin impressions with methods that could aid the examiner in evaluation the results visually [45]. The calculation of match scores naturally lead to what distributions of such score are produced between known match (KM) and known non-matching (KNM) pairs. Two CMC data set distributions demonstrated a good separation of KM and KNM scores and a proposed method to estimate the probability of false identification was proposed by Song, et al. [48]. In the USA and Internationally, other mathematical methods for similarity such as feature-based methods and tests on fired cases have also been of interest [50,51]. Additionally, there have been studies evaluating what effect different parameters will have on computer aided methods, primarily class characteristics [52]. Other studies in computer-based methods evaluated a statistically derived test fire population for an automated search system [53,54], and for fired bullets [55,56].

Ballistic Search Systems

Ballistic imaging database search systems are designed to find match candidates to firearm and ammunition evidence so that shooting incidents might be associated when there would be little chance for such links to be discovered otherwise. Performance evaluations were conducted after laboratory adjustment to case entry prioritization [57,58], and the IBIS entry of standard reference bullets and cartridge cases (SRM 2460/2461) available from NIST and discrimination performance between KM and KNM cases [59]. Some factors affecting the EvoFinder system on bullet and cartridge case entries included differences of effectiveness between bullet and case searches, between breechface and firing pin impressions, different ammunition brands, database size being searched, and the performance accuracy of trained students compared to expert experienced examiners [60]. IBIS Heritage and IBIS Trax-HD3D were compared for their accuracy comparing cartridge case breech face and firing pin impressions on a database from several firearm manufacturers. The Heritage system had better performance for the firing pin impression searches and the Trax-HD3D system was more accurate with the breech face searches [61]. A performance study of the IBIS BrassTRAXX v3.0 system demonstrated

that it too was more accurate with firing pin impressions in comparison to breechface impressions. Adjustments to lighting and case strategies were discussed for improvements [62]. King et al. investigated the actual benefit that database links in firearms and evidence added to the investigations involved. Due to the many week delay for incident and report, such link information gave very little value in the investigation, arrest, or conviction of suspects [63].

Section 3 of the paper is a collection of various studies involving firearms ammunition, serial number restoration, firearm sound classification, ammunition factory marks and designs, replica evidence, and firearm related crime statistics [64-80].

Bias, Reporting, and Quality management

Within subsection 3.5 reports and research regarding bias, reporting, and quality assurance is reviewed. Of particular interest are the studies and recommendation of cognitive bias influences on examiners and methods for the reduction of those effects [83-88], the subsequent influence of human factors in expert opinion [91,92], and the introduction and use of more objective, statistically based, and probabilistic descriptions to augment the examiners expert judgements and opinions [93,94]. Quality management that relates to examination measurements are recommended to have determinations of uncertainty with reporting [95,96,97] and are part of SWGGUN guidelines [98,99].

Reports on modified, homemade, and factory produced firearms is contained in the section 4 “Technical Examination” that begins on page 7 and can be reviewed there [100-114].

Shooting Incident Reconstruction

The methods available for the scene examiner to estimate bullet trajectories are contained in this section. Probe methods were evaluated for their accuracy dependent on factors such as incident angles, target surfaces, and 3D scanning technologies [115,116]. Accuracy is affected depending on the interaction of the bullet and target surface, and trajectory after the interaction, such as a ricochet. A number of these parameters where tested and reported [117-125]. Dispersion of shotgun shot, and cartridge case ejection patterns also are subject of shooting reconstruction. Effects of both were researched for accuracy and evidentiary value [127,128]. The determination of maximum range or shooting distance of several firearm types (shotgun, handguns, and rifles) are of importance in many shooting investigation and reconstruction. These variables, and methods for range estimation were reported [129-131,133].

Wound Ballistics

In many instances, the wound ballistics in terminal ballistic examination is complementary to shooting scene reconstruction. One primary method for such study is the use of tissue simulants to help estimate projectile behavior when interacting with a body. Increased research activity has been recently focusing on available simulants and their accuracy for estimating the factors in terminal ballistic projectile behavior using actual casework scenarios; ammunition and wound profiles [148,149, 150]; gelatin/polymer for organs [151]; simulant performance compared to animal bodies [152]; effects of preservatives; and gel block size [153-155]. The method of computed tomography and photo elasticity was investigated for the accurate measurement of simulant deformation upon bullet impact and travel in ballistic soap and gel [156,157,158]. A subsequent section deals with the research in skull and bone simulants that would necessarily have different requirements than soft tissue simulants in estimating bullet caliber in cranial bones, fracture patterns, and with skin/soft tissue layers [161-163]. Two brands

of bone simulants, Synbone and Sawbone, were tested for performance related to fracture patterns, change in bullet velocity upon perforation, beveling, and with tissue simulants [164-166]. Terminal wound ballistics studies focused on bullet impact effects on various projectile calibers, compositions, and designs in addition to the effects of various ammunition types on tissue/bone and their simulants, and blood targets [167-174]. Actual case reports that were published included effects of wounds where an intermediate target [175], water ricochets [176], using post-mortem computed tomography (PMCT) [177, 178] and other projectile sources [179-182, 184]. Indicators of suicide employing a firearm were reported [183,185].

Selected References of Interest

[28] Association of Firearm and Toolmark Examiners, Theory of identification, Range of striae omparison Reports and modified glossary definitions – an AFTE Criteria for identification committee report, AFTE J. 24 (3) (1992).

[29] R. Nichols, Subclass characteristics: from origin to evaluation, AFTE J. 50 (2) (2018).

[35] R.D. Stoel, et al., Building the research culture in the forensic sciences: announcement of a double blind testing program, Sci. Justice 56 (3) (2016).

[36] W. Kerkhoff, et al., A part-declared blind testing program in firearms examination, Sci. Justice 58 (4) (2018).

[39] T.P. Smith, G. Andrew Smith, J.B. Snipes, A validation Study of Bullet and cartridge case comparisons using samples Representative of actual casework, J. Forensic Sci. 61 (4) (2016).

[40] M.T. Stocker, et al., Addressing challenges in quality assurance of 3D topography measurements for firearm and toolmark identification, AFTE J. 50 (2) (2018).

[48] J. Song, et al., Estimating error rates for firearm evidence identifications in forensic science, Forensic Sci. Int. 284 (2018).

[58] C. Wang, M. Beggs-Cassin, L.M.Wein, A simple Way to Maximize the Number of hits from ballistic imaging when processing Capacity is limited, AFTE J. 50 (3) (2018).

[63] W.R. King, et al., Forensic evidence and criminal investigations: the impact of ballistics information on the investigation of violent crime in nine cities, J. Forensic Sci. 62 (4) (2017).

[87] W.C. Thompson, What role should investigative facts play in the evaluation of scientific evidence? Aust. J. Forensic Sci. 43 (2e3) (2011).

[91] E.J. Mattijssen, et al., Implementing context information management in forensic casework: minimizing contextual bias in firearms examination, Sci. Justice 56 (2) (2016).

[92] R.D. Stoel, et al., Minimizing contextual bias in forensic casework, in: K.J. Strom, M.J. Hickman (Eds.), Forensic Science and the Administration of Justice: Critical Issues and Directions, SAGE Publications, Inc, 2014.

[95] J. Knapp, et al., An examination of how the ANAB ISO/IEC 17025:2005 forensic testing accreditation requirements (AR 3028) relates to the firearm and toolmark community, AFTE J. 50 (2) (2018).

[98] Scientific Working Group for Firearms and Toolmarks (SWGGUN), SWGGUN guidelines: Criteria for identification, AFTE J. 49 (2) (2017) 69.

[115] E.J.A.T. Mattijssen, W. Kerkhoff, Bullet trajectory reconstruction - methods, accuracy and precision, Forensic Sci. Int. 262 (2016).