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A Parameter Study Regarding the IBIS^{TM} Correlator

ABSTRACT: The electronic system IBIS^{TM} has been used by numerous agencies worldwide as the standard tool to compare firearm markings on bullets and fired cartridges. There is a general interest among users concerning the likelihood with which the IBIS^{TM} correlator may locate hits in its databases. Test results of the performance under different test conditions have been published in various papers. Experience has also been gained with the IBIS^{TM} system from years of practical usage. All of these findings are difficult to compare with each other. No systematic presentation exists that actually shows the parameters upon which the success rate of the IBIS^{TM} correlator depends. There has also been no mention of what values these parameters take on during each test. This paper first generally defines the success and error rates of the IBIS^{TM} correlator. The parameters used will be discussed. Results of previously published tests will be re-examined based on this methodology. An illustrative form of presentation for the success rate of an electronic comparison system will also be suggested. It will be shown that the success rate of the IBIS^{TM} correlator highly depends on the quality of the firearms-generated markings. It increases with the number of considered mark types, the number of available signatures per firearm, and the number of items inspected in the hit list. The success rate decreases with the database size. The paper will conclude with a series of practical recommendations for the setting up and successful operation of an electronic collection of ballistic evidence.

KEYWORDS: forensic science, IBIS^{TM}, correlator, error rate, electronic comparison, firearm markings

The IBIS^{TM} comparison system has been, for some years, the worldwide established standard for the electronic comparison of marks on fired cartridge cases and bullets. The system has been predominantly used to compare marks on ballistic evidence with those on test-fired specimens from confiscated firearms. This type of application should be quoted as OCFDB ("open case file database"). However, it has become obvious that different laboratories apply different procedures in operating such a database.

For some time now, there has been international interest in using the IBIS^{TM} technology to establish a "ballistic" reference database for all firearms sold and imported in a particular area. Under such a proposed program, test specimens would be acquired and firearm markings would be recorded with the IBIS^{TM} system. This type of application should be quoted as BFDB ("ballistic fingerprinting database"). In the "classic" OCFDB application, the evidence from an unrecovered firearm used in a crime is entered into the database and is then compared with ammunition from subsequently confiscated firearms. In the new BFDB application, this logic is reversed. Marks are gathered from firearms that were legally sold or possessed and are subsequently compared when necessary with markings on evidence items recovered from crimes. A series of publications (1–4) discuss the possibility or impossibility of this new type of application.

Extensive IBIS^{TM} instrument tests have been conducted in the past with different goals in connection with these and other studies. Their results, standing alone, however, are difficult to compare with each other. A systematic summary is lacking to determine which parameters have an influence on the success or error rate, respectively, during the operation of the IBIS^{TM} system. This article is not an additional study with respect to the application of the IBIS^{TM} in the setting up of a BFDB. This report concentrates on ideas and concepts that could lead to the optimization of the "classic" application of the IBIS^{TM} technology and the support of the comparison process with an evidence collection (OCFDB application). Results from previously published tests are used for illustration. A publication containing application examples derived from the practice of the central evidence collection of the Federal Criminal Police Office (BKA) follows this paper.

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Materials and Methods

A Definition of the Success/Error Rate of the IBIS^{TM} Correlator

The following general definition of the success rate of a correlator appears trivial on first thought: *The success rate is the probability that an existing match could actually be found by the correlator.*

This definition requires an additional explanation/specification of the term "finding a match" with respect to the electronic comparison system IBIS^{TM}. This is necessary because of the well-known fact that the IBIS^{TM} correlator only produces a hit list of the most similar marks and also evaluates a number of different mark types.

The number n of hit list positions up to which marks are visually inspected by an examiner is obviously an important parameter for the definition of "finding a match." There is no uniform procedure as regards the choice of this parameter. In (3), $n = 10$ is most frequently chosen. This number is also named in the IBIS^{TM} 3.3 Training Manual. In (4), it is stated that 20% to as much as 35% of the total range of the data is to be inspected. In (5), $n = 5$ is regarded as sufficient.

There is also no question that the "quality" of the marks to be compared is of great importance to the success or failure of the comparison. Correspondingly, it is also shown that the number of applied "signatures" originating from different cartridge cases/bullets, but which were fired from the same firearm, is also significant (also see (5)).

TABLE 1—*Mark types that can be evaluated with the IBIS™ system.*

Mark Type M	Description
BF—Breech face	Cartridge cases: breech face marks
FP—Firing pin	Cartridge cases: firing pin impressions
EM—Ejector module	Cartridge cases: ejector marks
MP—Max Phase	Bullets: highest score during the correlation of two bullets over all land impressions (as a result, the projectiles are so oriented to each other that the corresponding land impressions from the largest overall similarity are placed directly opposite)
PP—Peak Phase	Bullets: highest score from the comparison of individual land impressions within MP
ML—Max Lea	Bullets: highest score from the comparison of individual land impressions

As far as is known, not much attention has been devoted in the past to the importance of this parameter (however, see (5) and Appendix D of (1)). Since the introduction of the IBIS™ system in the BKA, multiple cartridge cases and bullets from the same gun have been used for the IBIS™ correlation—whenever possible. It seems that in the US, probably for manpower-saving reasons, it is the usual practice that during the IBIS™ comparison, only one cartridge case per firearm is entered. Moreover, during the compilation of the evidence collection, only one cartridge case is analyzed, even if there are more cartridge cases from the same unrecovered firearm available. Frequently, the bullets are not even entered and analyzed with the IBIS™ system, probably because of the increased workload during the data acquisition process.

Requirements

- Different mark types can be evaluated independent of each other with the IBIS™ system (see Table 1). A parameter M is used in the following to indicate the mark type.
- In the combination of firearm and fired ammunition, there are, as a result, markings of a certain “quality.” In this context, “quality” stands for the presence and clarity (distinctiveness) of individual firearm markings. Firearm examiners are well aware that the quality of marks for a given firearm often depends on ammunition parameters such as case dimensions, hardness of case material and maximum pressure during discharge. The comparison system from these firearm-generated markings produces, the so-called “signatures,” which will be compared by the correlator. It is easy to see that the success rate of an automatic comparison system is dependent on the quality of the signatures to be compared. This dependence will be identified with the symbolic parameter Q.
- IBIS™ comparisons will only be made within a caliber group. For bullets, caliber subgroups are also formed according to barrel class characteristics. The number of elements within a comparison group would be i.
- As a result of a single correlation, one obtains an ordered hit list for each mark type, which will be visually inspected up to position n.
- In the IBIS™ database, there are—for a certain mark type—groups with k_{DB} records from marks that are known to originate from the same unrecovered firearm. On the other hand, there is a group with k_{test} signatures of test cases/test bullets available from one known source.

General Definition

An actual existing common source of an ammunition specimen out of a (test) group of the number k_{test} and another specimen taken out of the (database) group of the number k_{DB} is said to be “found” through the IBIS™ correlator, if the correlation of at least one of the k_{test} signatures with at least one of the k_{DB} signatures for at least one of the evaluated mark types M results in a hit list position within the first n positions.

The parameters are summarized in Table 2.

Experimental Determination of the Success Rate p

For each of the k_{test} specimens, j-independent correlations will be run with the IBIS™ system. We define as an “experiment” the whole group of these $k_{test} \times j$-independent correlations. The placement in an experiment is then given by the best hit list position of all $k_{test} \times j$ correlations for any one of the k_{DB} hits. Let s be the number of experiments to be carried out to determine experimentally the success rate p, and let h_l be the number of placements at position l. Then, the (experimentally determined and accumulated) success rate p of the correlator is given by

$$p = p(M, Q, i, k_{test}, k_{DB}, n) = \frac{\sum_{l=1}^{n} h_l}{s}$$

It can be empirically shown that k_{test} and k_{DB} can be mutually exchanged with respect to the success rate p. For a single correlation in which signature A is correlated against a database, which holds signature B as a match, one may find a different result for the reverse correlation. In a statistical mean, this comparison, however, is commutative.

We therefore define $k = (k_{test}+k_{DB})/2$, so that

$$p = p(M, Q, i, k, n)$$

In the following sections, examples will reveal how p depends on the various parameters. It is to be expected that the success rate p increases if the parameters k and n are increased, and a combination of the mark types M is chosen and decreases if the parameter i increases.

TABLE 2—*Summary of the parameters for the definition of the success and error rate of the IBIS™ correlator.*

IBIS™ Parameter	Description
M	Mark type (BF, FP, EM, MP, ML, PP)
j	Number of evaluated mark types M in an experiment; $j = 1\ldots3$
Q	(Symbolic) parameter: it symbolizes the “mark qualities” of all participating comparison partners.
i	Database size or number of signatures of a given mark type in a caliber group (or caliber subgroup).
k_{test}	Number of signatures of a given mark type from the same source to be examined. This number—as long as there is a firearm available—can be set freely by the user, because a gun can be fired as often as possible. In the case of evidence ammunition, this number depends on how often a gun was fired at the crime scene; $1 \leq k_{test}$.
k_{DB}	Number of signatures in the database from the same unrecovered firearm. This number depends on how often the gun was fired at the crime scene; $1 \leq k_{DB}$
k	$k = (k_{test}+k_{DB})/2$
n	Hit list position up to which marks are visually inspected by an examiner; $n \leq i$
s	Number of “experiments” to determine the success rate p experimentally. An “experiment” consists of $k_{test} \times j$-independent correlations.

BF, breech face; FP, firing pin; EM, ejector mark; MP, Max Phase; PP, Peak Phase; ML, Max Lea.

The error rate e of the IBIS™ correlator is given by

$$e(M, Q, i, k, n) = 1 - p(M, Q, i, k, n)$$

Applied Sources

For the following general parameter studies, a series of different sources were applied. For all of these sources, raw data were available.

(1) In Reference (1), a database that consisted of 792 cartridge cases of a single brand (*Federal Cartridge = FC*), fired from 792 service pistols *S&W* Model *4006,* caliber 0.40 S&W, has been described. A database consisting of only one brand of ammunition will further be called "brand clean" and a database that has been established by firing guns of a single class (e.g., only one model) will be called "class clean." Fifty cartridge cases of the brand *FC* fired from 50 arbitrarily selected pistols were correlated against the database. In a further trial, another 72 guns were fired with ammunition of five additional brands and were correlated. Breech face (BF) marks and firing pin (FP) marks were used for the evaluation. The parameters are summarized in Table 3.
(2) In Reference (3) the setting up of a database that consisted of 600 cartridge cases, caliber 9 mm Luger of the same brand (*Remington Peters = RP*), fired from 600 different pistols of the same class *SIG Sauer P226* has been described. For 32 arbitrarily selected pistols, there were 32 cartridge cases *RP* and 160 cartridge cases of five other brands available. These were correlated against the reference collection. BF marks and FP marks were used for the evaluation. The parameters are summarized in Table 4.
(3) In Reference (4) a reference database comprising 860 cartridge cases of caliber 0.40 S&W fired from 540 police service pistols *S&W* Models *4006* and *4013* has been described. For the test, 25 arbitrarily selected pistols and three different brands of ammunition were used to produce six test-fired cartridge cases (two per brand). One cartridge case of each brand was correlated against the database. Only BF marks were evaluated. The parameters are summarized in Table 5.
(4) In a presentation "Initial Results—Large Database Study and New Firing Pin Algorithm" given at the 2004 Annual AFTE

TABLE 3—*Parameters of the IBIS™ test "AB1717" on cartridge cases of caliber 0.40 S&W fired from pistols S&W 4006.*

Parameter	Description
Year of test	2001
Software	Version unknown
M	BF, FP
i	792
k_{DB}	= 1 (only *one* case in the database per firearm) All cases used for setting up the database are of the brand *FC* ("brand clean") All cases originate from a single firearm class: 792 police service pistols *S&W 4006,* 0.40 S&W ("class clean")
k_{test}	= 1 (only *one* case fired per test firearm) (a) 50 (out of 792) arbitrarily selected pistols were test fired once with *FC* brand (b) Another 72 (out of 792) arbitrarily selected pistols were test fired five times with five brands different from *FC*
n	Hit lists are available until rank 160
Q	The raw data contain a few qualitative comments concerning the quality of marks on individual test casings (e.g., BF not much, FP smooth, . . .). In a manufacturer's comment (FTI), it is indicated that a firearms expert (with the comparison microscope?) could not assign at least eight test cartridge cases. With other test cartridge cases, there were doubts whether these were identifiable. There was no assessment of the quality of the marks in the database. It must be assumed that the selection of the test pistols was simply by chance and as a result, all sorts of mark qualities can be found in the database.

BF, breech face; FP, firing pin.

TABLE 4—*Parameters of the IBIS™ tests "de Kinder" on cartridge cases 9 mm Luger fired from pistols SIG Sauer P226.*

Parameters	Description
Year of test	2003
Software	Version 3.4.167
M	BF, FP
i	600
k_{DB}	= 1 (only *one* case in the database per firearm) All cases used for setting up the database were of the brand *RP* ("brand clean") All cases originate from a single firearm class: 600 pistols *SIG Sauer P226* 9 mm Luger ("class clean")
k_{test}	= 1 (only *one* case fired per test firearm) (a) 32 (out of 600) arbitrarily selected pistols were test fired once with *RP* brand (b) The same 32 arbitrarily selected pistols were test fired five times with five brands different from *RP*
n	Hit lists are available until rank 30
Q	It has to be assumed that there are a variety of different mark qualities in the database as well as in the correlated cartridge cases.

BF, breech face; FP, firing pin.

TABLE 5—*Parameters of the IBIS™ Tests "George" with cartridge cases of caliber 0.40 S&W fired from pistols S&W Mod. 4006 and 4013.*

Parameters	Description
Year of test	2003 or later
Software	Version unknown
M	BF
i	860
k_{DB}	= 1. . .4 (the original test has been primarily designed to determine the likelihood to find a *single*-partner case in the database $k_{DB} = 1$; special evaluations were made within this study to determine the probability of finding a specimen out of a group of one to four) All cases originate from a single firearm class: 540 pistols *S&W Mod. 4006 or 4013,* 0.40 S&W ("class clean") The 860 cartridge cases in the database are from three different brands (*FC* 56%, *RP* 38%, *WIN* 6%) The database also includes the six cartridge cases of the 25 test pistols. Apart from this, there were one to a maximum of three cartridge cases fired from a single pistol in the database
k_{test}	= 1 25 (out of 540) arbitrarily selected pistols were test fired six times with 3 different brands (*FC*, *RP*, *WIN* each 2 ×) One cartridge case of each brand from each of the 25 pistols was correlated
n	The hit lists are available until rank 860
Q	For each correlation, it is stated in the raw data if the agreement could be verified by means of the 2nd breech face image (side light) on the IBIS™ monitor. In almost 24% of the correlations, this is not the case. This is at least a hint that there are a variety of mark qualities in the database and in the correlated test cartridge cases as well.

BF, breech face.

TABLE 6—*Parameters of FTI's LDB Test with cartridge cases of caliber 9 mm Luger.*

Parameters	Description		
Year of test	2004		
Software	Version unknown		
M	BF, FP		
i	(a) Basic database $i = 868$; (b) enlarged database $i = 56{,}000$		
k_{DB}	= 1 (the test has been designed to find a *single*-partner case in the database)		
	(a) $2 \times 434 = 868$ cases from 434 pistols		
	(b) Database from (a) enlarged with "noise" signatures (presumably of a variety of firearm classes and ammunition brands)		
k_{test}	= 1 (a single test case was used to find its partner case)		
	434 test pistols of a variety of firearm classes were test fired twice with a variety of ammunition brands. Each of the 868 cases was correlated separately against the database.		
n	Hit lists are available until rank 24		
Q	For each pair of marks a firearms expert's statement was made concerning the quality of the marks. Six different grades were used. The distribution of judgments (in percent) is given in the table below:		
	Grade	BF	FP
	Excellent	46	54
	Very good	15	16
	Good	10	10
	Fair	12	9
	Poor	14	7
	No match	3	4

BF, breech face; FP, firing pin; LDB, large database.

Training Seminar, Vancouver, Canada, Forensic Technology Inc. (manufacturer of IBIS™) published a large database (LDB) study. 434 pistols (of different models) cal. 9 mm Luger were each fired twice with a range of ammunition brands to make basic databases for BF and FP marks containing 868 specimens. Each signature was correlated against the database, and the success rate to find the sister signature was determined. In a further step, the databases, were extended by "noise" signatures collected from IBIS™ operational databases giving $i = 56{,}000$, and the correlation was repeated. The parameters are summarized in Table 6. A second LDB study using 1,000 and 10,000 BF and FP signatures from cartridge cases 0.32 Auto has also been executed by Forensic Technology Inc., Montreal, Canada, but will not be further considered within this study.

Results and Discussion

In the following, the effects of the parameters on the success or error rate of the IBIS™ correlator are considered in detail.

Effects of the Inspected Hit List Position n

In the following diagrams, the success rate *p* will be shown as a function of the inspected hit list position *n*. This presentation is considered as especially illustrative.

The success rate *p* shows in the small *n*—in favorable cases—a steep increase followed by a flat outlet. Ideally, for a perfect correlator, the equation would be $p(n) = 1$ for all $n \geq 1$. Such a (theoretically ideal) correlator would have each positive match at position 1 of the hit list.

Additionally, the ability of an examiner who visually searches an entire evidence collection with optical means can be expressed analytically. For an examiner who does not miss a match $p(n) = n/i$ will apply: the success rate *p* shows a linear growth with increasing *n* and will reach a value of 1 (certainty) as soon as the complete collection is searched.

Effects of the Quality of Marks Q

It is a known fact among firearms experts that there can be large variations regarding the quality of marks depending on the particular firearm and the brand of ammunition. This can result in a situation where fired cartridge cases or bullets from such a firearm cannot be identified with existing microscopic procedures.

It is the usual practice for the purposes of firearm identification to carry out comparisons with the same brand of ammunition that was used in the crime. Experience has shown that under this condition, a microscopic identification can be made at the earliest.

Previously published results of the influence of the ammunition brand will be shown as an example of the influence of the quality of firearms-generated markings on the success rate of the IBIS™ correlator.

In Refs. (1, 3) and (4), the test firearms used for the correlations were fired with the same brand of ammunition that was used to compile the database as well as "foreign brands." Based on the raw data, separate evaluations of the success rates of "brand clean" and "foreign brands" correlations can be made. During "brand clean" comparisons, only correlations are considered where test signature and database signatures originate from cartridge cases of the same brand. During "foreign brands" comparisons, only those correlations are considered where test signature and database signatures originate from cartridge cases of different brands. It could be expected that "brand clean" correlations generally give better results. These are shown in the following figures.

Figure 1 shows noteworthy variations in possible success rates, even for just "brand clean" comparisons from one brand to another. Despite using the same selection of firearms (25 pistols), the ammunition *FC* leads to a high success rate $p(5) = 0.8$, while the rate decreases to $p(5) < 0.3$ for ammunition *RP*.

All three sources yield by far smaller success rates for "foreign brands" correlations than for "brand clean" correlations (see e.g., Fig. 2).

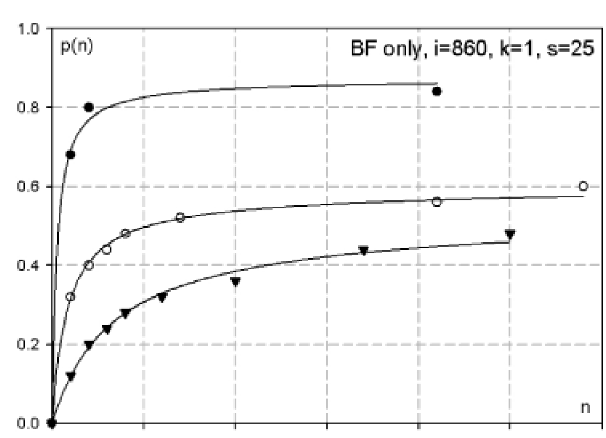

FIG. 1—*Effect of the quality of marks Q; success rate p(n) from Reference (4) for "brand clean" correlations.*

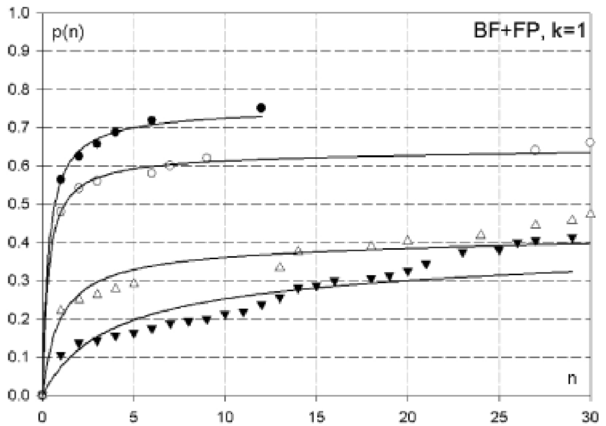

FIG. 2—*Effect of the quality of marks Q; success rate p(n) from References (1) and (3) for "brand clean" and "foreign brands" (indicated by the "not" prefix in the legend) correlations.*

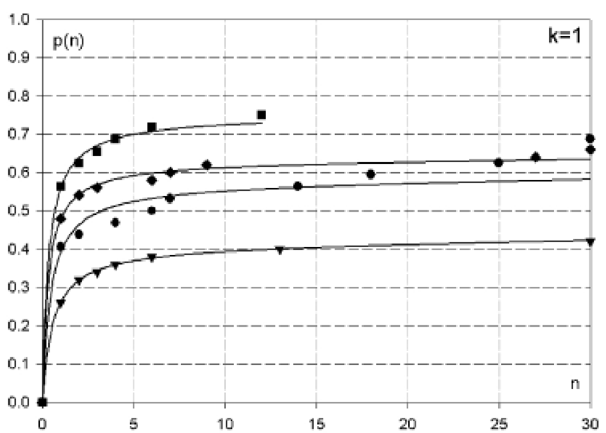

FIG. 3—*Effect of the parameter M on the success rate p(n) from References (1) and (3); only "brand-clean" comparisons.*

Effects of Considered Mark Types M

For cartridge cases IBIS™ offers the evaluation of three independent mark types. It is easy to see that the success rate p increases, if—as a final result of a comparison—only the best ranking position out of multiple independent correlations is used. Figure 3 shows as an example the influence of this parameter on the success rate p.

Effects of the Number k of Considered Marks of the Same Firearm

In References (1,3) and (4), all evaluations were primarily designed to determine the likelihood that a single test signature ($k_{test} = 1$) finds a single partner signature ($k_{DB} = 1$) in the database. The assumption that the success rate p can be improved, is justified if whole groups of cartridge cases/bullets that are known to originate from the same firearm are considered, either as contents of the database ($k_{DB} > 1$) or to be applied during tests ($k_{test} > 1$).

The type of experiment in Reference (4) allows this kind of evaluation. If one considers in the example of the "foreign brands" comparisons for a given test cartridge case ($k_{test} = 1$) the four other cartridge cases of different brands, fired from the same firearm as a group that belongs together in the database, one would obtain a result for $k_{DB} = 4$.

Figure 4 clearly shows the increase of the success rate *p(n)* for the correlation of a single test signature with k_{DB} signatures in the database.

Effects of the Size i of the Database

FTI's LDB test indicates that the success rate p decreases at each hit list position if the database size i increases. As a rule of thumb, p reduces by about 20% if the database size increases by a factor of 65 (Fig. 5). A similar result has been found for another LDB study with cartridge cases 0.32 Auto (p reduces by about 10% for a database increase by a factor 10).

Summary and Recommendations

(a) An attempt to give a general definition of the success and error rate of the IBIS™ correlator is presented. The essential parameters M, Q, i, k, n on which the success rate p depends were named. Future studies of model considerations and tests of electronic comparison devices are suggested, to provide the following for each test:
  i) *p(n)* as the measuring quantity, and
  ii) the values of the parameters M, Q, i, k to enable a comparison of the results.

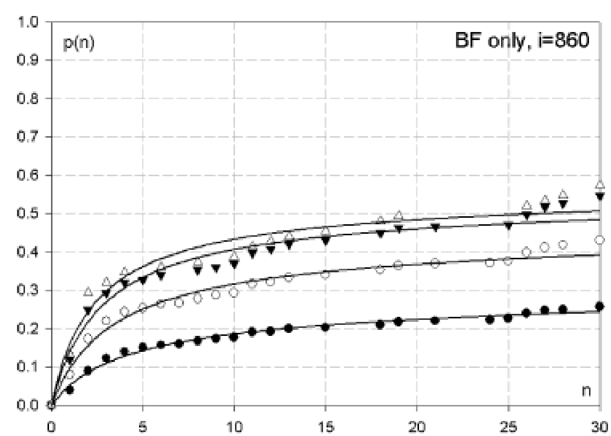

FIG. 4—*Effect of the parameter k on the success rate p(n); only "foreign brands" comparisons; Reference (4).*

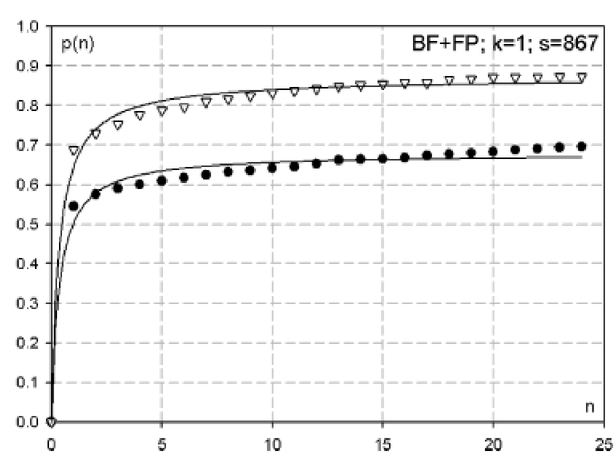

FIG. 5—*Effect of the size of the database i on the success rate p(n).*

(b) The quality of marks Q of the comparison partners appears to be of immense importance for the success rate of the IBIS™ system. Figure 1 clearly shows the effect of different mark qualities in an example of the usage of different brands of ammunition. For the success of an OCFCB, every effort must be made to use test ammunition that is of the same brand as the one used to commit a crime. Hints on how this can be achieved can be found in (6).

(c) All available mark types M—which the IBIS™ system allows for—should be combined in a correlation test.

(d) In the setting up of an OCFBD, multiple cartridge cases/bullets of the same unrecovered crime firearm should be used, as long as these are available ($k_{DB} > 1$). Also, multiple test-fired cartridge cases/test bullets should be used for correlation ($k_{test} > 1$). For the Federal Criminal Police Office (BKA), $k_{DB} \leq 3$ has been fixed for evidence cartridge cases and $k_{test} = 2$ for test cartridge cases.

(e) The number of hit list positions to be visually inspected can—at least for practically relevant OCFDB applications—be limited to (as long as a steeply rising $p(n)$ is presented for small n) $n = 5 \ldots 10$. The negligible increase in the success rate p for higher n does not justify an increase in work time.

(f) For the purpose of a fast result-oriented evaluation of $k_{test} \times j$ hit lists with a (potentially high) total number of $n \times k_{test} \times j$ entries, a combined evaluation option from the IBIS™ manufacturer would be welcome. A first idea would be an option to emphasize in hit lists specimens of the same group (of k_{DB} elements) that either appear in the same or different hit lists. Further research is necessary to find an algorithm that determines an "average" score for the comparison of groups of specimen (test group with k_{test} specimen and database groups with k_{DB} specimen). From the combination of all available hit list scores, a unified hit list should be generated that reflects an "overall" similarity of groups of specimen for all evaluated mark types.

(g) As could be expected, the success rate p will decrease with increasing size i of the database while the other parameters are kept constant. For the practical use of the IBIS™ system in an OCFBD application, it is therefore necessary to try to keep the database size i of a comparison group as small as possible. As the database increases as an effect of the daily caseload, a rule is necessary that selected ammunition specimens can be removed. Agencies usually apply specific procedures to remove ballistic evidence from a collection after the expiry of certain time limits.

(h) The number i of signatures in a relevant database could be reduced—even for cartridge cases—by arranging the data into caliber subgroups, just as is already carried out for bullets. A signature should be accompanied by simple standardized alphanumeric entries, giving the firearm class (model) used for firing (see (7,8)). In practice, there will probably be a large group of "unknowns," evidence cases that could not be assigned to a specific firearm class. Prior to a correlation, the user of the IBIS™ system should have the choice to select one or more caliber subgroups for comparison.

References

1. Tulleners FA. Technical evaluation: feasibility of a ballistics imaging database for all new handgun sales, Report No. AB1717. Sacramento, CA: California Department of Justice; 2001.
2. de Kinder J. Ballistic fingerprinting database. Sci Justice 2002;42:197–203.
3. de Kinder J, Tulleners FA, Thiebaut H. Reference ballistic imaging database performance. For Sci Int 2004;140:207–15.
4. George W. Fingerprinting firearms—reality or fantasy. AFTE J 2004;36(4):289–96.
5. Silverwater H, Koffman A. IBIS correlation results—improvements. AFTE J 2000;32(1):32–9.
6. Nennstiel R. Auswahl von Munition für den Vergleichsbeschuss. Auswerfer 2004;15:51–3.
7. Nennstiel R. A computer supported method of firearm type determination. AFTE J 1986;18(4):4–32.
8. Nennstiel R. Firearm type determination. Proceedings of the 11th Symposium on Ballistics, Brussels, Belgium, May 9–11, 1989; III: 135–41.

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