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Testing the Effects of People, Processes, and Technology on Ballistic Evidence Processing Productivity

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Abstract

Automated ballistic imaging technology is a potentially effective tool for improving the investigation and prosecution of violent crime involving guns. This technology enables crime laboratories and law enforcement agencies to link crimes committed with the same gun. Yet, in many localities, structural and procedural constraints hamper the potential effectiveness of ballistic imaging as an investigative tool. This study examines the impact of new personnel, processes, and technology on ballistic evidence processing productivity in the Stockton Police Department's Firearms Unit. Using interrupted time series analysis, we examine the impact of several organizational changes on ballistic evidence processing productivity. Our findings demonstrate that the Stockton Police Department achieved rapid improvements in its ballistic evidence processing capacity. The study shows how introducing key organizational changes in a police department or a crime laboratory can generate disproportionate impacts on ballistic evidence processing productivity.

Keywords

criminal investigation, ballistic imaging, gun crime, forensic science, firearms

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Firearms play a key role in violent crime, contributing to significant injury and death in many localities (Krug, Dahlberg, Mercy, Zwi, & Lozano, 2002; Muggah & Batchelor, 2002). Although violent crime has decreased markedly in the United States over the past two decades, firearms are still commonly used in crime (Smith & Cooper, 2013). According to the U.S. Federal Bureau of Investigation (2013), 69.3% of murders, 41.0% of robberies, and 21.8% of aggravated assaults in the United States during 2012 involved a firearm. The search for solutions to the problem of gun violence spans multiple disciplines, including criminology (Ridgeway, Braga, Tita, & Pierce, 2011), economics (Kahane, 2013), public health (Webster, Vernick, Bulzacchelli, & Vittes, 2012), and forensic science (Braga & Pierce, 2004, 2011). Improving the capacity of law enforcement agencies to investigate gun-related crime, and to secure arrests and convictions, represents an important mechanism for increasing the deterrence and incapacitation of offenders who use guns to commit acts of violence.

One potential source of leverage for improving the police investigation of gun crime is the idea that certain firearms, referred to variously as "hot guns" or "crime guns," tend to be used repeatedly in gun crimes (Bour & Papachristos, 2013; Braga, Kennedy, Waring, & Piehl, 2001). Thus, the use of technologies and processes that increase the probability of identifying these firearms (and those who use them) has the potential to exert a disproportionate impact on violence in communities. Ballistic imaging technology represents one potential method for increasing the probability of identifying crime guns and those who use them (Koper, Woods, & Kubu, 2013). Yet, recent research suggests that police agencies have struggled to incorporate this technology effectively into the investigation of gun crime (King, Wells, Katz, Maguire, & Frank, 2013; Maguire & King, 2013). Moreover, research on police investigations has demonstrated that forensic evidence is often unavailable to investigators due to processing delays and other issues (Eck, 1983; Horvath & Meesig, 1996; Schroeder & White, 2009), leading some scholars to argue for the importance of faster evidence processing times (King & Maguire, 2009; Smith, 1976).

The present study highlights the important, but often overlooked nexus between the use of forensic information by police investigators and the forensic analyses of physical evidence, typically carried out by crime labs. Increasing the productivity of crime labs may pay dividends for the police by increasing the amount of information available to investigators. Little empirical research is available on the productivity of ballistics processing units (for exceptions, see Braga & Pierce, 2004, 2011). Consequently, numerous questions remain about how to enhance the productivity of these units to increase both the volume and timeliness of information available to investigators. This article examines the effects of organizational changes on the productivity of the Stockton, California Police Department's firearms laboratory in processing ballistic evidence.

Ballistic Evidence Imaging and Processing

When most firearms are fired, four individualizing marks are usually transferred as "tool marks" from the hard metal parts located inside the firearm, to softer objects like the spent cartridge case or fired bullet. Three parts of the gun (the firing pin, the breech face, and, in the case of semiautomatic and automatic firearms, the ejector) usually leave tool marks impressed onto the spent cartridge case. The fourth tool mark is transferred from the lands inside the gun barrel onto the bullet after being fired. The firearms identification process involves a visual comparison of spent cartridge cases retrieved from a crime scene to spent cartridge cases from other crime scenes or from firearms retrieved and test-fired by law enforcement (Cork, Rolph, Meieran, & Petrie, 2008).

Ballistic imaging captures two- or three-dimensional images of spent cartridge cases or fired bullets; these images are then converted into unique digital signatures (Cork et al., 2008). The Integrated Ballistic Identification System (IBIS^{TM}), created by Forensic Technology, Inc., is currently the most popular application of automated ballistic imaging technology. The ballistic imaging software can search these digital signatures to identify possible matches using a correlation score. Correlations are usually presented as a list of possible matches rank ordered from most to least likely. Firearms technicians or examiners review these possible correlations, view digitized images of the two pieces of evidence on the computer screen, and designate the most likely matches in the computer system by marking them as "high-confidence candidates." These high-confidence candidates must be confirmed manually by trained firearms examiners. The confirmation process requires the firearms examiner to compare each piece of original evidence (i.e., a spent cartridge case or fired bullet) using a comparison microscope. Once the examiner concludes that the evidence matches, the relationship is designated a "hit." Ballistic imaging hits can help investigators link together multiple crimes involving a single gun and therefore constitute a potentially robust investigative tool.

In the United States, ballistic imaging is conducted in forensic crime labs and police agencies through a networked system of IBIS terminals called the National Integrated Ballistics Imaging Network (NIBIN). NIBIN was created in 1999 to improve the functioning of ballistic imaging in the United States (USDOJ, Office of the Inspector General [OIG], 2005), and it is overseen and funded by the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF). NIBIN provides a system linking individual IBIS sites at the national level (Braga & Pierce, 2011). NIBIN makes it possible to compare ballistic images collected by different law enforcement agencies (Braga & Pierce, 2004, 2011). In 2005, there were 231 NIBIN sites, but this number has decreased due to reductions in ATF funding for the program (King et al., 2013; USDOJ, ATF, 2011). Currently, there are 150 NIBIN sites nationwide, and the program has produced approximately 50,000 hits. Each of these hits represents an instance of two or more gun crimes that were linked by a common gun.

Until recently, the NIBIN program has been characterized by considerable variation in usage and performance across local sites. As far back as 2005, auditors documented nontrivial differences in the rate at which sites entered evidence into NIBIN (USDOJ, OIG, 2005). A more recent study based on data from 223 NIBIN sites in 2012 found considerable variation across sites in the volume of inputs:

> While sites acquired a median of 4,719 brass inputs, three sites acquired less than 100 pieces of brass and 25% of sites acquired less than 2,317 pieces of brass. On the other extreme, 22% of sites acquired more than 10,000 brass inputs and one site acquired more than 121,000 brass inputs. (King et al., 2013, p. 51)

Similarly, there are marked differences across sites in terms of confirming hits. Over the nearly 5-year period from October 2007 to July 2012, NIBIN sites confirmed a median of 76 hits from spent cartridge cases, but one quarter of NIBIN sites produced 9 or fewer hits from spent cartridge cases, and 11 sites confirmed more than 1,000 hits each from cartridge cases (King et al., 2013). Similarly disparate patterns are also evident for hits from fired bullets. These pronounced differences in productivity no doubt also affect the amount of information available to police detectives investigating violent crimes.

Criminal investigation plays a key role in police efforts to address violent crime. Information is the lifeblood of criminal investigations; thus, strategies that increase the quality or quantity of information available to investigators can play a useful role in helping them close cases more successfully. Investigators rely on information from a variety of sources, including victims, witnesses, informants, and other criminal justice officials. Forensic analyses provide another useful source of information that investigators can use to assist in their investigations (Peterson, Mihajlovic, & Gilliland, 1984; Peterson, Ryan, Houlden, & Mihajlovic, 1987). Ballistic imaging is a type of forensic analysis that is thought to play an important role in investigating gun crime and contributing to more comprehensive efforts to reduce gun violence (Koper et al., 2013). Unfortunately, there is a dearth of empirical research on the use of ballistic imaging by police agencies, including the productivity of ballistics units. As a result, little is known about the causes or correlates of variations in NIBIN usage and performance across sites.

To our knowledge, only two published studies have examined the productivity of ballistic units, and both took place in the same agency: the Boston Police Department (Braga & Pierce, 2004, 2011). In the first study, researchers found a significant increase (523%) in the number of cold hits generated per month as a result of the Boston Police Department's transition from manual comparison methods alone to the IBIS (Braga & Pierce, 2004). The second study considered the productivity differences that resulted from the Boston Police Department's switch from two-dimensional to three-dimensional ballistic imaging of fired bullets. The researchers found that three-dimensional ballistic imaging methods were associated with a significant improvement in the ability of the ballistics unit to identify cold bullet hits (Braga & Pierce, 2011). While these two studies are helpful for thinking about how to improve the productivity of a ballistics unit, the published empirical research on this topic is limited to only two studies from one agency. Thus, there is significant room for more research on these issues.

Although there is not much empirical research on the factors that influence the productivity of ballistics units, experienced practitioners have developed a number of explanations. For instance, Gagliardi hypothesizes that three elements are paramount: people, processes, and technology. He likens these three elements to the legs in a three-legged stool: Without all three elements in place, the stool will fall over (Gagliardi, 2010). He notes that "finding the right combination of people, processes, and technology, and applying it in a properly balanced manner" (p. 25) is essential for solving gun crime. Gagliardi's thesis is consistent with more general theories of complex organizations, which suggest that agencies are more likely to be effective when their environments, technologies, structures, and processes are properly aligned with one another (Maguire, 2003). Gagliardi's thesis also has implicit roots in the management literature, where firms are urged to engage in process reengineering to achieve greater structural and strategic alignment. Organizations sometimes embrace technological solutions and overlook the importance of integrating people, processes, and technology (Chen & Popovich, 2003).

Testing Gagliardi's thesis is challenging because it requires that researchers gain access to an agency that is changing all three of the elements in his equation. That is what happened in Stockton, California in February 2013, thus providing an opportunity for a natural experiment to test the effects of changes in people, processes, and technology.[1]

The Research Site

Stockton is located in northern California, approximately 83 miles east of San Francisco and 49 miles south of Sacramento. According to the U.S. Census Bureau (2014), there were 291,729 people living in Stockton as of 2010. The city is demographically diverse and comprises a mix of White (37%), Black (12.2%), Asian (21.5%), and Hispanic (40.3%) residents (U.S. Census Bureau, 2014). In 2012, Stockton's median income was $47,246; however, 23.3% of residents earned an income lower than the national poverty level. Stockton was hit particularly hard by the serious economic crisis in the United States. Indeed, the city has been called the "sub-prime mortgage capital of the United States" (Clark, 2008). In June 2012, Stockton became the largest U.S. city in history to file for bankruptcy protection.

The economic crisis in the city took its toll on the Stockton Police Department (SPD). The SPD lost about 27% of its civilian staff from 2008 to 2011, together with nearly 100 sworn officers (about 22%). Before losing these officers, a consultant had noted that the agency already had about a hundred fewer officers than it needed to keep up with the crime problem. Police Chief Eric Jones told us that after the precipitous decline in staffing, the department was "just completely reactive, bouncing from call to call." Recent crime trends in the city are relatively high, with 4,155 violent crimes reported in 2011 and 4,630 in 2012 (U.S. FBI, 2013). In 2011, Stockton had 58 homicides; by 2012, the number of homicides had risen to 71 (U.S. FBI, 2013). Stockton had become the 10th most violent city in the United States and the second most violent city in California (behind Oakland). This crisis led the SPD to narrow its focus. When we interviewed Chief Jones in June 2013, he told us "our focus is just two words—guns and gangs—because that's what is driving our violent crime." According to the SPD, these focused efforts were successful, as the number of homicides fell in 2013 to 32, marking a 54.9% decrease from 2012 (Ibarra, 2014).

As part of this intense focus on guns and gangs, the SPD decided to hire its own full-time firearms examiner. The Firearms Unit is located within the Evidence Section of the police department's Detective Bureau. The agency had IBIS technology[2] and well-trained firearms analysts who could do test-fires and enter ballistic evidence into IBIS. These analysts were qualified to identify preliminary matches between different pieces of ballistic evidence, known in the industry as "high-confidence candidates." But these analysts were not qualified to make the final determination of "hits" or matches between different pieces of ballistic evidence. This function had historically been performed by the state crime laboratory, which, due to limited resources, only had the capacity to process a small percentage of Stockton's ballistic evidence. Thus, ballistic evidence was being recovered at crime scenes or from test-fires and entered into IBIS, but much of it was never processed by a trained firearms examiner. The police department's search for a full-time examiner failed, so they made the decision to hire a contract examiner on a part-time basis. The person they selected works as a full-time firearms examiner in a Southern California police agency. Under this arrangement, the examiner flies up to Stockton periodically and works for a few days at a time before flying back home to his full-time job.

The contract examiner's new approach to ballistic evidence processing in Stockton was based on three components. First, he put in place new technology to assist with evidence processing, helping the analysts to work more efficiently and to generate more hits. Second, he put in place a variety of new processes intended to make the work of the ballistic unit more productive. Third, he assumed responsibility for certifying matches or hits rather than sending the evidence to an outside laboratory with limited processing capacity. Thus, the changes adopted within the SPD's Firearms Unit overlap neatly with Gagliardi's metaphor of the three-legged stool: They involved simultaneous changes in people, processes, and technology. Although the police department was in the midst of a full-blown crisis as a result of Stockton's pending bankruptcy, the changes that occurred within the Firearms Unit took place within a supportive environment that valued and prioritized these efforts. For instance, Chief Jones told us that a key part of his plan to focus on guns and gangs was to "beef up firearms processing" and reinvest in the use of IBIS to help them link gun crimes to gangs. Similarly, the police captain in charge of investigations told us that ballistic evidence is an important part of addressing the city's gun violence problem. He noted that ballistic imaging not only "helps us focus with fewer resources" but also "helps us to prove cases too."

The Intervention

As noted earlier, the intervention of interest in this study consisted of three components: people, processes, and technology. In this case, because the new processes flow from the arrival of a new firearms examiner and the technology he developed and implemented, we first consider people, then technology, and then processes.

People

Prior to the intervention, the SPD's Firearms Unit had two full-time technicians who handled evidence processing, IBIS entries, and the selection of high-confidence candidates (test-fires were handled by others). In addition, the unit had one part-time staff member and houses a full-time technician from another agency who used SPD's IBIS terminal to enter evidence arising from that agency's cases. Visual confirmation of high-confidence candidates was outsourced to the California Department of Justice's ballistic unit in Ripon. This lab, which services multiple agencies, was unable to keep up with the demand from Stockton. As a result, only a fraction of Stockton's high-confidence candidates were being confirmed by a firearms examiner, and these submissions took a long time to process. This meant that valuable evidence useful for solving gun crimes was not being fully processed. According to one assessment, due to these issues, "many investigators did not rely on NIBIN/IBIS hits to assist in any active investigations" (Beggs-Cassin, 2014, p. 11). In February 2013, after its search for a full-time firearms examiner failed to attract a suitable candidate, the SPD contracted with an experienced firearms examiner from a Southern California police agency. The new firearms examiner agreed to make periodic visits to Stockton for the purpose of confirming high-confidence candidates generated by IBIS technicians. The decision to contract with an experienced firearms examiner was intended to generate an increase in ballistic matches or hits.

Technology

The SPD has been connected to NIBIN and using IBIS actively since 2000. When the new firearms examiner arrived in February 2013, he brought with him software called GunOps that he had developed together with some colleagues. GunOps is essentially case management software for ballistics units, and it is useful for managing and searching IBIS-related information and enhancing hit production (www.sherlockops.com).[3] GunOps is distributed through a partnership between SherlockOps, Inc., the company that developed the software, and Bair Analytics, Inc., a leading provider of crime analysis software. GunOps houses a database of crime incidents that are mapped onto a police jurisdiction. The database contains information about the incident, the firearm, ballistic evidence, and the status of the investigation. Users can add polygons representing gang territory or other phenomena over the map to aid in the process of identifying patterns in gun crime. In addition, the database may be searched by type of vehicle, vehicle description, crime location, caliber of weapon, location of injury, and so forth. Individual incidents are color-coded so that users know the status of the case and the location of evidence. Homicides are also displayed as flashing dots to differentiate them from other incidents. The purpose of augmenting IBIS with GunOps is to enhance the quality and quantity of intelligence available to investigators, improve the likelihood of generating hits, create leads more rapidly, document cases more fully, and increase the information available to prosecutors (www.sherlockops.com).

Processes

When the new firearms examiner implemented the use of GunOps in the SPD, he also put in place a series of new processes meant to optimize the search for ballistic matches. The process associated with the use of GunOps begins when evidence (firearms, spent cartridge cases, or fired bullets) is received by the SPD's Firearms Unit. Information about the evidence is quickly entered into GunOps before it is entered into IBIS. Using this information, the firearms examiner uses GunOps to develop a map of crimes involving similar evidence that occurred in close proximity to the most recent criminal event. The map is forwarded to IBIS technicians who enter each piece of evidence into IBIS to identify potential hits, called high-confidence candidates. GunOps is then used to map incidents with all potential weapon matches based on caliber or weapon type. If an IBIS technician identifies a high-confidence candidate, the evidence is forwarded to the firearms examiner. The firearms examiner then manually inspects the evidence with a comparison microscope to determine if the evidence is in fact a hit, which is then confirmed. Once the hit is confirmed, a "confirmed hit" report is produced and disseminated to the investigators assigned to each case involved in the hit.

Data and Methods

Our analysis focuses specifically on the impact of organizational changes in the SPD Firearms Unit on ballistic evidence processing productivity. We measure productivity by counting the monthly number of confirmed matches or "hits" on spent cartridge cases confirmed by the SPD.[4] Because all the hit counts in the present data come from the NIBIN system, they are considered "cold" hits. Per ATF guidelines for the operation of NIBIN, only cold hits may be designated as confirmed hits in the NIBIN system. Counting hits is viewed widely as an appropriate indicator of productivity for a ballistic evidence processing system. Hit counts have been used as a performance indicator in previous research on ballistic evidence processing performance in localities (Braga & Pierce, 2004, 2011) and for NIBIN overall (USDOJ, OIG, 2005). Second, the ATF has generally used hit counts as an indicator of the success of NIBIN, both nationally and for particular NIBIN sites. For example, a March 2011 ATF publication listed the "most successful NIBIN partners" as the five sites with the greatest number of hits (USDOJ, ATF, 2011). Finally, a recent report counted the number of confirmed hits to assess the output performance or productivity of individual NIBIN sites (King et al., 2013).

To determine whether changes in the SPD Firearms Unit were associated with a change in productivity, we examined the monthly number of IBIS hits for the 10-year time period between 2004 and 2014. During the period from January 2004 through January 2013 (109 months), the SPD employed firearms analysts to test-fire guns, enter cartridge cases associated with crimes and test-fires into the IBIS terminal, and generate high-confidence candidates. However, the agency did not employ its own full-time or contract examiner and did not use the GunOps software or the processes associated with it. The changes in people, processes, and technology were implemented in February 2013, and our data series terminates at the end of November 2014. Thus, we have 109 months of data before the changes were implemented and 22 months of data afterward.

Figure 1 presents the monthly number of hits made on the basis of SPD high-confidence candidates between January 2004 and November 2014. During the preintervention period from January 2004 through January 2013, the mean number of monthly hits equaled 3.95 (with a median of 3 and a standard deviation of 4). During the postintervention period from February 2013 to November 2014, the mean number of monthly hits equaled 16.7 (with a median of 17.5 and a standard deviation of 6.5). This represents a 321.9% increase in mean monthly hit productivity and a 483.3% increase in median monthly hits produced by SPD's Firearms Unit (see Table 1). A t test comparing hits before and after the intervention was statistically significant ($t = -8.9$, $df = 24.4$, $p < .000$). This preliminary analysis suggests that changes in people, processes, and technology generated substantial increases in the SPD's ballistic evidence processing productivity as measured using IBIS hits. The simplistic

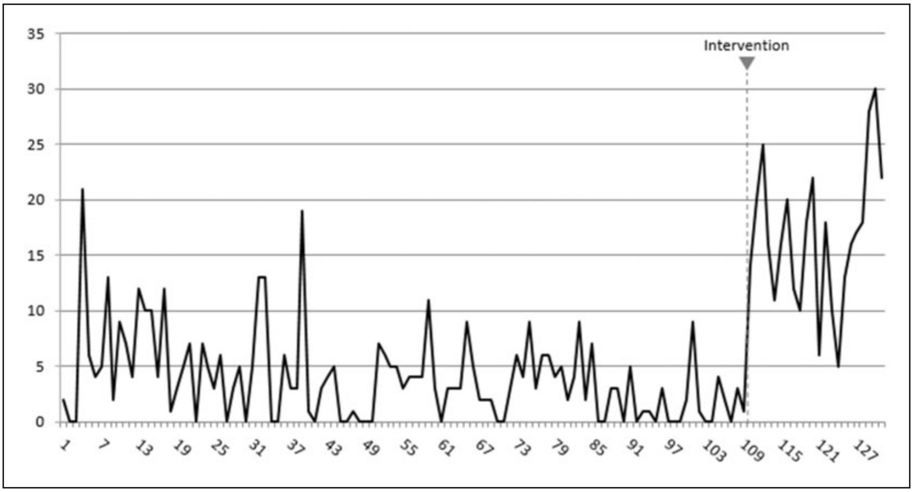

Figure 1. Monthly IBIS hits for the Stockton Police Department, January 2004–November 2014.

Note. The dashed vertical line indicates the launch of the intervention in February 2013. IBIS = Integrated Ballistic Identification System.

Table 1. Preliminary Analysis of Changes in Hits.

Statistics	Preintervention period ($n = 109$)	Postintervention period ($n = 22$)	Percent change
Mean hits per month*	3.95	16.7	321.9
Median hits per month	3.00	17.5	483.3

Note. *$t = -8.90$, $df = 24.4$, $p < .000$.

analysis conducted so far ignores the possibility of serially correlated errors in the time series, and therefore may be biased. Thus, we performed a time series analysis on the monthly hit data.

Ordinary regression models used with cross-sectional data often cannot be used with time series data due to temporal dependence in the residuals. We rely instead on interrupted time series analysis using the Box-Jenkins approach, which involves the use of autoregressive integrated moving average (ARIMA) models (Box & Jenkins, 1976; Glass, Willson, & Gottman, 1975). Selecting the appropriate ARIMA model involves specifying its three components: p refers to the autoregressive component of the model, i refers to the integration or trend component, and q refers to the moving average component. ARIMA model specifications are often depicted using the following convention: *ARIMA*

Table 2. ARIMA Interrupted Time Series Results.

Variable	Coefficient	*SE*	*t* Statistic	*p*
Constant	3.98	0.54	7.37	.000
Intervention	12.77	1.30	9.86	.000
AR(1)	0.20	0.09	2.34	.021
Log likelihood	−377.27	R^2	0.55	
F statistic	77.02	Durbin–Watson	1.99	
p (*F* statistic)	.000			

Note. ARIMA = autoregressive integrated moving average.

(p,d,q). Selecting the appropriate specification of the ARIMA model requires proper diagnosis of these three components.

Our initial diagnoses revealed the need to address serial correlation in the residuals. The Ljung–Box Q statistics were significant at multiple lags, indicating significant serial correlation in the residuals (Ljung & Box, 1978). The Breusch–Godfrey LM test also confirmed the presence of serial correlation. Visual inspection of the autocorrelation plots suggests that an AR(1) model is most appropriate for this series. Visual inspection of the autocorrelation plots also suggests that the series is stationary. We confirmed this conclusion with an augmented Dickey–Fuller test. As a result, we did not include a trend component in the ARIMA model. Finally, the autocorrelation plots also revealed no need for a moving average component. Thus, we selected an ARIMA (1,0,0) specification for the series. This specification indicates a series with a first-order autoregressive component (AR(1)) and no trend or moving average components. We carried out the analysis using *EViews* 8. Table 2 presents the findings from this analysis. In short, we found that the intervention exerted a statistically significant positive effect on the mean monthly number of IBIS hits ($B = 12.77$, $SE = 1.30$, $p < .000$).

Because the number of hits is a count variable, we also estimated the effect of the intervention using an autoregressive Poisson model that allows for overdispersion. This supplementary analysis relied on the "arpois" procedure in Stata and was intended as a check on the robustness of the findings from the ARIMA model (Katsouyanni et al., 1996; Schwartz et al., 1996). Consistent with the earlier findings, the intervention variable continued to exert a significant, positive effect on the number of hits ($B = 1.44$, $SE = 0.14$, $t = 10.4$, $p < .0000$).

Discussion and Conclusion

Gagliardi (2010) argues that the productivity of ballistics units can be enhanced by "finding the right combination of people, processes, and technology" (p. 25). Our analysis of data from the SPD's Firearms Unit suggests that the adoption of new people, processes, and technology was associated with a rapid and substantial increase in productivity as measured using confirmed ballistic hits. This increase was achieved with the addition of one new contract employee and the technology and related processes that he implanted within an already existing ballistics unit. The study is useful for documenting a mechanism through which a ballistics unit can achieve rapid improvements in productivity through a deliberate process of strategic change. Prior to the implementation of these reforms, the SPD Firearms Unit's hit productivity was limited. In the aftermath of the intervention, hit production improved significantly.

Another recent assessment by a member of the Firearms Unit found that the mean elapsed time from high-confidence correlation to confirmed hit dropped from 95.1 days before the intervention to 29.6 days after ($t = 7.4$, $df = 172.1$, $p < .000$; Beggs-Cassin, 2014). Our interviews with SPD personnel revealed a sense that the increased number of hits, coupled with the more rapid production of hits, has increased the utility of hit reports among investigators and their supervisors. SPD personnel from multiple units noted that ballistic evidence is now being used much more frequently in building cases against gun offenders. One detective noted that prior to receiving a hit report for one case, no suspect had been identified due to an uncooperative victim. However, based on the hit report, the detective was able to link multiple crimes to one suspect. The detective further explained that the crime lab has implemented a triage system that prioritizes guns to be tested that have the potential for immediate value in investigations. This triage system has directly benefitted detectives who explained that relying on an outside laboratory significantly lengthened the time it took to produce a hit report. The intervention, therefore, appears to have played a key role in increasing hit productivity, decreasing processing time, and enabling the resulting information to be provided to investigators more quickly.

The results of our analysis are consistent with more general theorizing on the role of strategic alignment in organizations. All complex organizations, including police agencies, face the challenge of hiring the most qualified people, establishing the most sensible and effective processes, and acquiring the right technologies (Desouza & Paquette, 2011). In the most successful organizations, leaders understand the value of aligning each of these elements to achieve strategic objectives (Chen & Popovich, 2003). This is the basic premise behind knowledge management, a contemporary business philosophy and discipline "that focuses on bringing together people, processes, and technology in a systematic way" to produce, share, and leverage information that enables an organization to succeed (Guptill, 2005, p. 10). Knowledge management derives from a long line of research and theory that views information as central to the structure and functioning of organizations (e.g., Stinchcombe, 1990). The knowledge management perspective is consistent with research which finds that police agencies with a team culture engage in greater knowledge sharing, which in turn improves investigative performance (Glomseth, Gottschalk, & Solli-Saether, 2007).

The research described in this article makes some useful contributions to theory, research, and policy. From a theoretical perspective, the research is useful for reflecting on the alignment between people, processes, and technology in criminal justice organizations. Technology is often introduced into organizations without much attention to the contexts in which it will be embedded. Recent research reminds us that ballistic imaging technology can be a potent tool, but only when embedded in supportive organizational (or interorganizational) contexts (King et al., 2013). The study also contributes new insights to a very small body of research on the productivity of ballistics units. Additional research is sorely needed to expand the generalizability of this body of research beyond the two U.S. cities (Boston and Stockton) where it has been carried out thus far. From a policy perspective, the study serves as a useful reminder that it is possible to generate rapid changes in forensic evidence processing productivity with the right strategic decisions. In this case, some relatively straightforward improvements in people, processes, and technology made an important difference.

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Notes

1. The term *natural experiment* is somewhat of a misnomer in the sense that most natural experiments, including this one, rely on quasi-experimental designs.
2. At the time of our study, the SPD had two pieces of IBIS technology: BRASSTRAX™, which is used to acquire images of cartridge cases, and MATCHPOINT™, which is used to carry out comparative analyses of two- and three-dimensional images. IBIS technology was initially introduced to the SPD Firearms Unit through its partnership with the ATF and its role in the NIBIN program in 2000. Although SPD was initially issued a Forensic Technology 2D Heritage™ system, the Firearms Unit's imaging technology was updated in April 2012 to the 3D BRASSTRAX™ system.
3. The GunOps software aids in the identification of hits by adding information to each piece of physical evidence (such as the location of the shooting, the type and caliber of firearm, and possible connections to gangs). The firearms examiner can then use that information to prioritize which items of evidence are input into NIBIN first, with the goal of maximizing the likelihood of a hit. GunOps increases the efficiency of a firearms unit by maximizing the probability of producing hits quickly.
4. Bullet hits are not included in the present analysis because they are so rare. Nationally, bullets play a small role in ballistic imaging inputs and hits because bullets are rarely

entered and rarely produce hits. For example, only 11.8% of NIBIN inputs are bullets, as compared with 88.2% of inputs that are spent cartridge cases (King et al., 2013, p. 51). Consequently, a small percentage of ballistics imaging hits come from bullets (67.3% of NIBIN sites produced zero bullet hits, and 93.7% of NIBIN sites produced 10 or fewer bullet hits; King et al., 2013). Some evidence suggests that the IBIS 3D BULLETTRAX™ system for imaging bullets can improve the number of bullet hits (Braga & Pierce, 2011), but at the time of our research, the SPD did not have access to this technology.

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