Using Predictive Policing to Prevent Residential Burglary - Findings from the Pilot Project P4 in Baden-Württemberg, Germany

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Abstract

In October 2015 the 'Pilot Project Predictive Policing' (P4) was started in the German federal state of Baden Württemberg. A predictive policing strategy was applied in the context of residential burglary. An evaluation study of the first six months of the pilot was carried out by the Max Planck Institute for Foreign and International Criminal Law. The article describes how the strategy was applied and summarizes the main findings of the evaluation study. Despite some positive findings the impact remains unclear and the expectable crime reducing effects appear to be moderate. Within the police force the acceptance of predictive policing is a divisive issue. Future research is recommended.

Keywords: Predictive Policing, PRECOBS, residential burglary, evaluation study

Introduction

As in other federal states of Germany, also in Baden-Württemberg the number of residential burglaries has increased immensely (until 2015) since about 2008 after more than 15 years of decrease. In response to this development, different measures were introduced to stop or, ideally, reverse this trend. In this context, methods of predictive policing are being applied and tested in some of the federal states of Germany (cf. Egbert 2017; Sommerer 2017). Although the burglary rate is relatively low compared to some other German states, on October 30, 2015 the 'Pilot Project Predictive Policing' (P4) was started in Baden-Württemberg (Innenministerium Baden-Württemberg 2015). Coordinated by the State Office of Criminal Investigations (Landeskriminalamt), the project was conducted in the police departments of Karlsruhe and Stuttgart (Figure 1). The area included the urban districts (Stadtkreise) Stuttgart, Karlsruhe and Pforzheim and the more or less rural districts (Landkreise) Karlsruhe (LK), Calw and Enzkreis.[2] The police department of Stuttgart is equivalent to the urban district. As in Bavaria (*Bayrisches Staatsministerium des Inneren* 2015) and some areas of Switzerland (Balogh 2016), the commercial predictive policing software PRECOBS, offered by the German company 'Institut für musterbasierte Prognosetechnik' (IfmPt), was employed to predict near-repeat burglary events and to apply subsequent target-oriented operational planning.[3]

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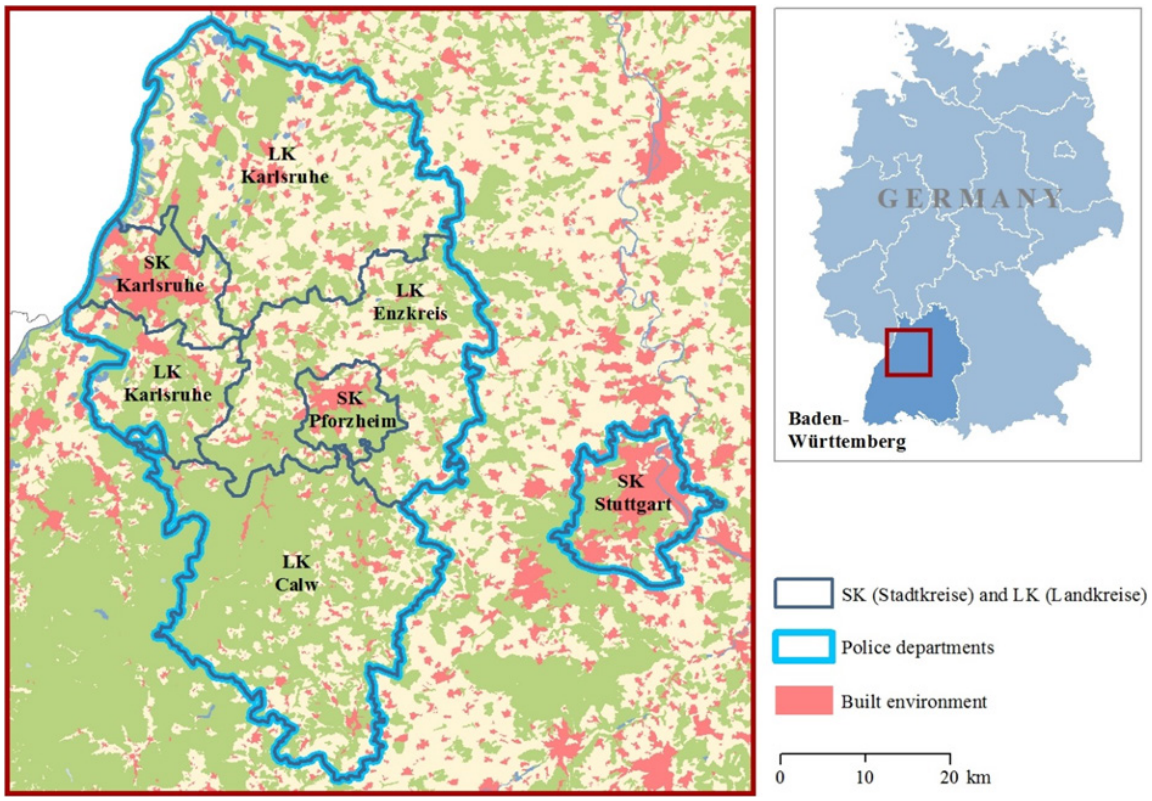
2 EU NUTS 3 regions. For further information, see http://ec.europa.eu/eurostat/web/nuts/national-structures-eu, http://ec.europa.eu/eurostat/documents/345175/7451602/nuts-map-DE.pdf [14.03.18]

3 www.ifmpt.de, http://www.ifmpt.de/projekte/, English site: http://www.ifmpt.com/ [14.03.2018]

Figure 1: Pilot area, Stadtkreis (SK) = urban district, Landkreis (LK) = rural district (data source: Federal Agency for Cartography and Geodesy of Germany, own graphic representation)



The project was designed to produce open-ended and unbiased results and therefore included an external scientific evaluation conducted by the Max Planck Institute for Foreign and International Criminal Law in Freiburg, Germany. Automatically generated predictive policing data were analyzed to obtain assessments of practicality and information concerning crime preventive aspects. In addition, semi-structured interviews with the police officers operating the software and an online survey with more than 700 participants were carried out. This paper describes the functional principle of PRECOBS in a nutshell and summarizes the main findings of the evaluation study.[4]

Predictive Policing

Since the TIME Magazine (Grossman et al. 2011) ranked the application of predictive policing in Santa Cruz (US-CA) as one of the most important inventions in 2011, the term has received increased attention in media as well as in academia. During the last years predictive policing strategies were applied mainly in the USA but also in European countries and recently the topic is broadly discussed in China and Japan.[5] With the widespread application of different predictive policing strategies a precise definition has become difficult. A general description might be that predictive policing is "a multi-disciplinary, law enforcement-based strategy that brings together advanced technologies, criminological theory, predictive analysis, and tactical operations that ultimately lead to results and outcomes – crime reduction, management efficiency, and safer communities" (Uchida 2014: 3871). The interplay between those different aspects has also been described as "prediction-led policing business process"

4 The author would like to thank the State Office of Criminal Investigations of Baden-Württemberg (Landeskriminalamt) for the close cooperation, provision of data and support with the online-survey and interviews with operators. Thanks are also due to the IfmPT for providing additional data. The evaluation study can be obtained online (German version): https://www.mpicc.de/en/forschung/forschungsarbeit/kriminologie/predictive_policing_p4.html [14.03.2018]

5 For example: http://www.scmp.com/news/asia/east-asia/article/2130980/japan-trials-ai-assisted-predictive-policing-2020-tokyo-olympics; https://www.japantimes.co.jp/news/2018/02/28/asia-pacific/social-issues-asia-pacific/china-using-big-data-predictive-policing-xinjiang-region-round-perceived-threats-hrw/

(Perry et al. 2013) with the authors emphasizing that accurate predictions require adequate subsequent action to decrease crime. Another important issue is the subject of predictions. Here, predictive policing can be divided into two subcategories, namely "place-based predictive policing" and "person-based predictive targeting" (Ferguson 2017). While the first one includes predictions about the likelihood of crimes occurring in certain areas during a certain time, the latter one makes predictions about particular people who might be offenders or victims. Thereby the scientific community agrees that predictions have to be considered as non-binary probabilities rather than certainties (e.g. Perry et al. 2013: 8, Degeling & Berendt 2017). This 'difficulty' varies with the type of offences and becomes most important when making predictions about distinct individuals or groups of people. Recent literature gives broad information about the basic principles, challenges, different developments and ethical aspects of predictive policing (Perry et al. 2013, Hunt et al. 2014, Uchida 2014, Mohler et al. 2015, Saunders et al. 2016; Degeling & Berendt 2017, Ferguson 2017, Shapiro 2017). This paper focusses on one example of place-based predictive policing and gives short insight into different components of an applied prediction-led policing process.

Predictive Policing with PRECOBS in Baden-Württemberg

In Germany predictive policing is solely applied as place-based predictive policing in the context of residential burglary.[6] Accordingly, PRECOBS does not predict distinct burglaries committed by certain offenders but rather assesses the likelihood that certain areas will experience burglaries during a certain timespan. For an understanding of the evaluation study's findings, a short description of what kind of data is analyzed to predict burglaries and how predictions are made with PRECOBS is provided briefly. More information can be found in the detailed evaluation report (Gerstner 2017) or in Schweer (2015).

To forecast burglaries PRECOBS utilizes the *near repeat phenomenon,* which is the observation that crime events are often followed by further events in spatial and temporal proximity (illustrated in Figure 2, subgraph A). Numerous empirical studies lend support to this observation for residential burglary (Townsley et al. 2003, Bowers & Johnson 2004, 2005, Sagovsky & Johnson 2007, Short et al. 2009, Bernasco et al. 2015, Nobles et al. 2016, Ornstein & Hammond 2017, Piza & Carter 2017) but also other types of offences (for an overview see Johnson & Bowers 2014: 3244). The rationale behind near repeat burglaries lies in the assumption that burglars act rational and behave like an *optimal forager* (Johnson et al. 2009), this results in patterns which are to some extent predictable.

Though only a certain amount of burglaries trigger subsequent events, PRECOBS uses the near repeat phenomenon for crime prediction. In advance of active field operation the software is configured with data from the past. The procedure identifies attributes of residential burglaries which point towards near repeat series. The system primarily analyzes the circumstances of an offence and the geographic location. *Trigger criteria,* indicating expected future near repeats, as well as *anti-trigger criteria*, speaking against near repeats, are being identified and listed in reference tables covering attribute groups stolen goods, modus operandi and locality (method of entry, type of house, etc.). Additionally, areas with high chances of near repeat burglaries are identified. A retrospective simulation study verifies in which of those 'near repeat affine' areas promising predictions are possible (Schweer 2015), the performance is measured via accuracy of simulated predictions. Promising areas, so called *near repeat areas* (Figure 2, subgraph B), will be activated in the real-time operation.

During daily operation PRECOBS only needs a limited amount of data which derives from police investigations and is mainly recorded when a residential burglary is reported to the police and information is entered into the case processing system (in Baden-Württemberg ComVor). Besides the attributes related to trigger criteria, the address[7], date and time of the initial event are needed. The precision of information has an impact on the precision of the predictions. During the

6 Usage with other offences like robbery and theft from cars is apparently planned in some areas in Germany (https://www.heise.de/newsticker/meldung/Predictive-Policing-Die-deutsche-Polizei-zwischen-Cyber-CSI-und-Minority-Report-3685873.html [14.03.18]). In the context of Islamist radicalization the Radar-ITE program (*Bundeskriminalamt* 2017) is sometimes connected with the term predictive policing in media (https://www.heise.de/newsticker/meldung/Precrime-BKA-meldet-erste-Erfolge-der-Gefaehrderanalyse-mit-Radar-iTE-3921293.html [14.03.18]).

7 Due to requirements of the federal data protection officer the processing within PRECOBS and the predictions do not refer to addresses but are assigned to micro units with a minimum of five households.

Figure 2: (A) Example of near repeat burglaries; 9 offences from 5 years. The blue event (originator) and red events (near repeats) happened within three days (real time and distance data, location spatially blurred). (B) near repeat area (solid line, fictitious example) and according fringe area (dashed line), (C) Initial offence triggering an automated prediction (fictious) and operational circle (blue). Background maps by Stamen Design under CC BY 3.0

pilot, data was directly transferred into PRECOBS three times a day. After the import, the software compares attributes of recent burglaries with reference tables of triggers and anti-triggers. If attributes match and the burglary took place in a near repeat area, an *automated prediction* is made. Predictions are checked for plausibility by the operators – the police officers operating the software – and accepted or denied. When accepted, an alert is being relayed to the local police station. The PDF document contains a map, recommendations for patrol as well as information about the initial event. The patrol area is called *operational circle* and contains a circular area around the originator (the burglary that triggered the alarm) with a radius of 500 meters (Figure 2, subgraph C). In this area a heightened risk of near repeat burglaries is assumed for usually seven days. Although close to near repeat areas, automated alerts cannot be produced in fringe areas (Figure 2, subgraph B). Nevertheless, the software provides the operator with an overview of burglaries in these areas with information about matching trigger criteria. The operator checks if a burglary might be a trigger for near repeats and decides whether an alert should be created manually (*operator alert*). The PDF, the relay and what follows the alert is equivalent to *automated alerts*. The option for *free prognoses*, detached from *near repeat* or *fringe areas*, is not described as this was used only four times during the evaluation period.

As patterns of burglary differ over seasons, PRECOBS has separate configurations for standard time and daylight saving time. Furthermore, geographical distribution and attributes of near repeat burglaries are not stable over time, which leads to a recalibration (areas, triggers, etc.) with each new configuration.

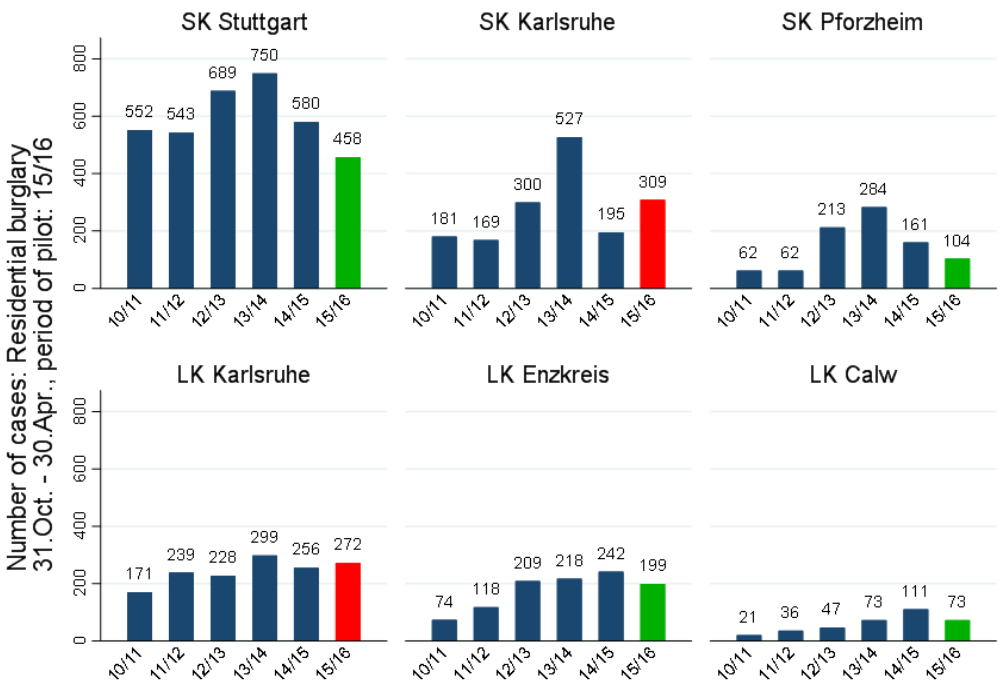
To sum up, PRECOBS is not designed to predict all burglaries but to predict potential burglaries following an initial event in spatial and temporal proximity. The method of how predictions with PRECOBS are made is not based on a complicated algorithm and doesn´t include elements of machine learning or artificial intelligence. The logic behind the predictions is comprehensible for the police. Although some additional data is included in the system (e.g. types of streets, population structure) to enrich the individual decision-making of the operators, the data processed for prediction is sparse and originates from everyday police work. The main goal of police operations following the alerts is deterrence.

PRECOBS alerts

During the six months evaluation period there were 183 alerts which mainly affected the urban districts Karlsruhe, Pforzheim and Stuttgart. In rural areas only few predictions and subsequent alerts occurred, caused by the fact that only few of the offences fell into the relevant near repeat or fringe areas. For example, in the district of Calw (Landkreis), these were only three out of sixty-nine burglaries (4.3 %). By contrast, in the urban district of Karlsruhe (Stadtkreis) 63.9 % out of 274 offences were committed in relevant areas. For this reason, the effectiveness of predictive policing in rural areas can hardly be assessed.

The processing and relay of the alerts usually went quick. The timespan between data import and relay of the alerts was reasonably short (median = 2 hours). On average the timespan between the originator event

Figure 3: Number residential burglaries in subdivisions of the pilot area. Evaluation period of pilot (31.10.2015 – 30.04.2016) compared to equivalent period in the years before (data source: ComVor-database LKA BW, own calculation)



and the relay was about 30 hours on average and 61 % of the alerts were relayed in less than 20 hours. This could be considered as reasonable, since the duration of the alerts was seven days and near repeat events – when appeared – happened within 60 hours on average (median = 50) after the initial event.[8]

What followed the alerts was a measurable increase in patrol activity. Via anonymized GPS data from police cars, an approximate measure for police density was applicable to compare states of active and inactive alerts in the respective operational circles. In about 94 % of the alerts the presence of police increased by 73 % on average (median = 49 %) during an alert. Manually recorded data by patrol officers allowed to estimate different police activities during a single alert. On average 48 hours of patrol activity were carried out by 2.8 officers. Besides patrolling in vehicles, foot patrol was also applied by uniformed or plain clothed officers (Zivilbeamte). Spatial and temporal focused identity checks (mean = 16.5) and vehicle inspections (mean = 9.4) were carried out and sometimes the resident population was contacted. These kind of measures are carried out regularly (especially during dark winter months) in areas not affected by PRECOBS alerts without a focus on predicted areas and periods.

Efficiency of predictive policing in the context of P4

In the police department of **Stuttgart** the total number of cases during the evaluation period declined considerably (Figure 3). It is hard to assess whether this was related to PRECOBS because this development also occurred during in the comparative period one year before and crime rates vary naturally over time. An indicator of the efficacy is the decline of significant near repeat patterns (500 meters / 7 days) in the near repeat areas. In the reference periods of the preceding years, there were significant near repeat patterns in the near repeat areas as well as in the total district. The ratio of near repeats was higher in the near repeat areas (Table 1, row A&B, columns A-D), which stresses that the areas were meaningfully defined by the software developer. For the evaluation period there was still a significant pattern present when examining the district in total, but for the near repeat areas (Table 1, row B, column E) a significant pattern didn't exist. The same applies to the **police department of Karlsruhe** (Table 1, rows C&D).

8 The calculation uses the midpoint of the timespan the crime occurred as reference.

Table 1: Results of near repeat analyses, overall areas and near repeat areas. Own calculations with „Near Repeat Calculator" (Ratcliffe 2008). Data source: ComVor-database LKA BW, PRECOBS database

		significant near repeat-pattern (7 days /1 –500 meter)				
		W†12–15 A	W12–13 B	W13–14 C	W14–15 D	W15–16†† E
SK Stuttgart	A Total	1.69**	1.79**	1.29*	1.51**	1.64**
	B ***NR-Areas***	***2.25****	***2.51****	***1.52****	***1.85****	***1.23***
PP Karlsruhe	C Total	2.03**	1.66**	1.59**	1.57**	1.62**
	D ***NR-Areas***	***2.35****	***2.42****	***1.75****	***2.19****	***1.39***
SK Karlsruhe	E Total	1.71**	1.29	1.45**	1.14	1.48*
	F ***NR-Areas***	***1.92****	***2.22****	***1.67****	***1.65***	***1.49***
SK Pforzheim	G Total	1.55**	1.65**	1.47*	0.96	1.3
	H ***NR-Areas***	***1.71****	***2.68****	***1.4****	***1.16***	***0.69***

SK = Stadtkreis, urban district, PP = Polizeipräsidium (regional police department), larger Area with urban and rural districts, Stuttgart PP is equal to SK.

** p<0.001, * p<0.05 (Monte Carlo simulation with N=999 iterations)

Example: 1,85: The chance of another incident is about 85 percent greater than if there were no discernible pattern.

†W = Winter-Configuration: November, December, January, February, March

††W15–16: P4 evaluation period

In the **police department of Karlsruhe** the absolute number of burglaries remained more or less constant compared to the preceding period. This was due to a strong activity of burglaries during November and December 2015 in the **urban district of Karlsruhe** and the surrounding **rural district of Karlsruhe** (Figure 3). If the number of cases had been higher without PRECOBS remains unclear. Compared to the preceding period, the number of cases declined in the other areas of the police department. This is especially true for the **urban district of Pforzheim**, whereas the numbers had also declined in the penultimate period (Figure 3).

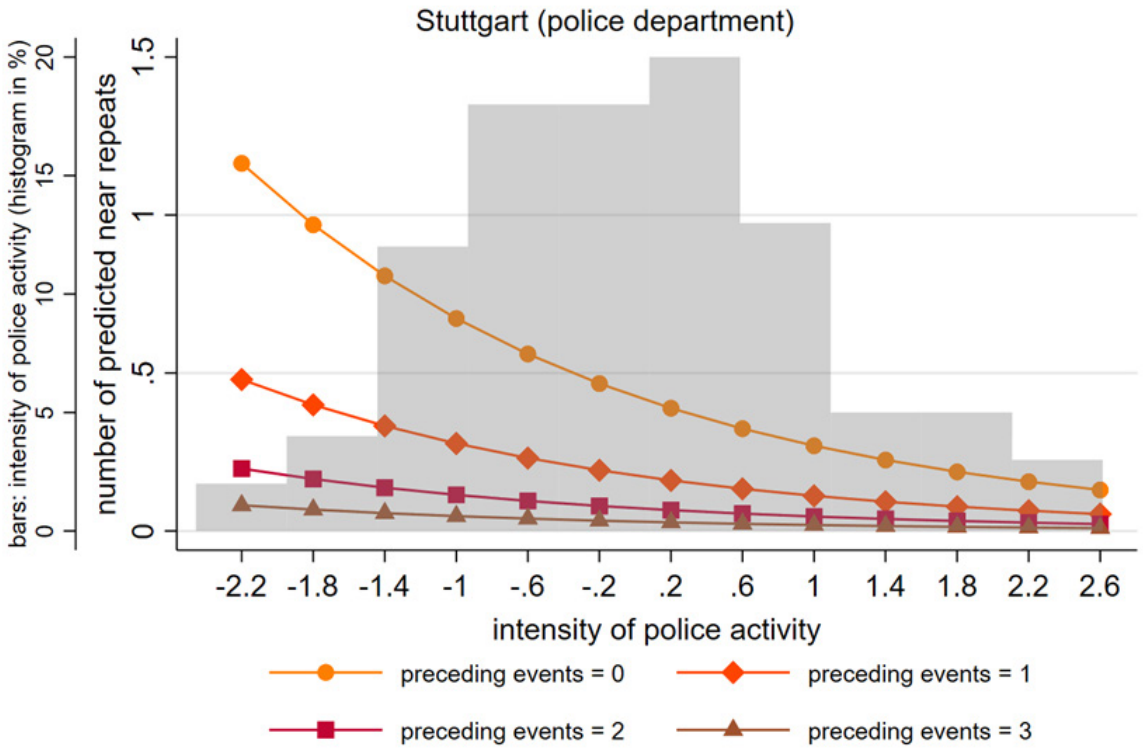
Despite the considerable increase of burglaries (+100 cases compared to the year before) in the **urban district of Karlsruhe**, there was no significant near repeat pattern observed in the near repeat areas for the evaluation period (Table 1, row F, column E). The ratio was even slightly lower than in the period before, which experienced only very few burglaries. This could be rated as another indicator for crime reduction through near repeat prediction, but causality cannot be derived from these findings.

In the **police department of Karlsruhe** correlations between police density and the number of near repeat burglaries subsequent to an alert triggering event (7 days / 500 meters) were indicated. Alerts with a stronger increase in police density showed a lower tendency for near repeat events (Spearman´s rho = -0.24, $p < 0.05$, n=72). Another correlation, only significant on the 10 % level, was found for the number of predecessor burglaries which were possibly related to the originator event due to spatial and temporal proximity. With more events preceding the originator, the probability for near repeat events decreases (Spearman´s rho = -0.21, $p < 0.1$, n=72). In multivariate analysis no significant effects were found.

A similar finding can be reported for the **police department of Stuttgart**. Though no significant correlations with the police density via GPS data was found, a correlation between manually recorded police activity[9] and the number of near repeats was found. An index (PCA factor score) including the variables "sum of operating hours", "number of identity checks", "number of vehicle controls", and "number of direct contacts to residents" gives a summary of how alerts differ in intensity of patrol activity. With a higher intensity less near repeats were to be expected (Spearman´s rho = -0.21, $p < 0.05$, n=100). This finding also holds in a multivariate framework where the dependent variable was the number of near repeats following an alert (negative binomial regression). Effects can be reported for the "intensity" (b= -0.46, $p < 0.01$) and the "number of potentially preceding events" (b= -0.89, $p < 0.1$). The remaining predictors, "time between the originator and the relay of the alert" as well as the "ratio of patrol officers in plain clothes" do not show an effect. On aver-

9 The manual documentation started with a delay, which resulted in a reduced number of cases. The sample size in the police department of Karlsruhe was too small for these analyses.

Figure 4: Predicted values for different values for „intensity of police activity", conditioned by „number of preceding events" (data source: ComVor-database LKA BW, PRECOBS database, own calculation)



age the effect of intensity is rather small. With a change in "intensity" from the 10th percentile to the 90th percentile – which corresponds to the boundary of the middle 80 % of the distribution - the amount of estimated near repeats by the model only changes by -0.78 burglaries (average marginal effect = -0.18, p <0.01). Within the interquartile range the number of predicted events changes only by -0.23 (25th percentile=-0.69, 75th percentile=0.63) – this effect appears to be rather small. As nonlinear-regression is affected by inherently multiplicative (or conditional) effects (for further explanation see Oberwittler & Gerstner 2014, Gerstner & Oberwittler 2018) interesting moderating effects between "intensity" and the "number of potentially preceding events" are observable (Figure 4). With no preceding events the effect of the intensity of police activity appears to be strong. With more than one preceding events the effect is practically not present. As the results are based on small sample sizes and only a short period of time, they have to be treated with caution. Nonetheless, these findings point to the importance that detecting small series of burglaries at an early stage can improve crime prevention. Future research should follow this issue with experimental designs.

Assessment by PRECOBS Operators

PRECOBS operators are officers who operate the software, evaluate automated predictions, manually generate predictions and relay the alerts. The basic tenor of semi-structured interviews was that PRECOBS was assessed as a useful supplement, especially during phases with a high load of burglaries. According to this, the application in rural areas, with only few burglaries, was perceived skeptically. The software was unanimously rated as user-friendly, even though there were some initial difficulties. The support offered by the developer was gauged as good. Asked about the transparency of the automated alerts, the operators emphasized that in most cases these were comprehensible. Some of them expressed that after a certain period of usage, they required a keen eye for cases which would trigger an alert, before importing the data into the software. Finally, the operators appreciated the additional tools (not part of the evaluation study) implemented in PRECOBS for the analyses of local crime activities.

Online Survey with Police Officers

An online survey with more than 700 police officers made it possible to capture how predictive policing with PRECOBS was perceived by patrol officers and officers in the upper service. One important finding was that predictive policing is a divisive issue (see Figure 5). About one half of the respondents sees a promising concept in applied predictive policing, the other half has the opposite view. The question of continuation was rated more positive in the police department of Karlsruhe, where 62 % of the respondents agreed to a further use of the software. In the police department of Stuttgart only 41 % agreed to this. The highest agreement was found in the group of the higher management level (65 %, höhere Führungsebene), followed by the respondents of the middle management level (57 %, mittlere Führungsebene). The lowest agreement was found in the group with mainly patrol officers (46 %, Sachbearbeiter).

A remarkable finding was that those confronted with lots of alerts during their everyday service, assessed the benefits of predictive policing with PRECOBS more negatively and disagreed more often to a continuation (Figure 6). This is possibly due to the fact that some of the respondents reported about additional workload or about other work left undone during active alerts. This problem was mainly perceived by officers in Stuttgart. Another explanation might be that success is not immediately measureable. Predictive policing with PRECOBS aims at preventing burglaries by deterrence rather than catching criminals. In this context it is hardly surprising when frequent PRECOBS alerts break established routines and therefore negative perceptions are reported by some of the respondents. This is another connection point for future research.

Figure 5: Perceived value of predictive Policing. Mean score out of 7 items (Cronbach's Alpha = 0,912): "Predictive policing (PP) is a useful addition to regular police work", PP is more annoying than useful"*, "PP is a suitable auxiliary tool for targeted planning", "An added value is not given with PP"*, "In my opinion PP remains gazing into a crystal ball"*, "It is worth thinking about using PP with other offences", "The financial resources of the pilot could have been used better elsewhere"* (n = 552, *reverse coded, PP Stuttgart/Karlsruhe = police departments, Data source: P4 online-survey).

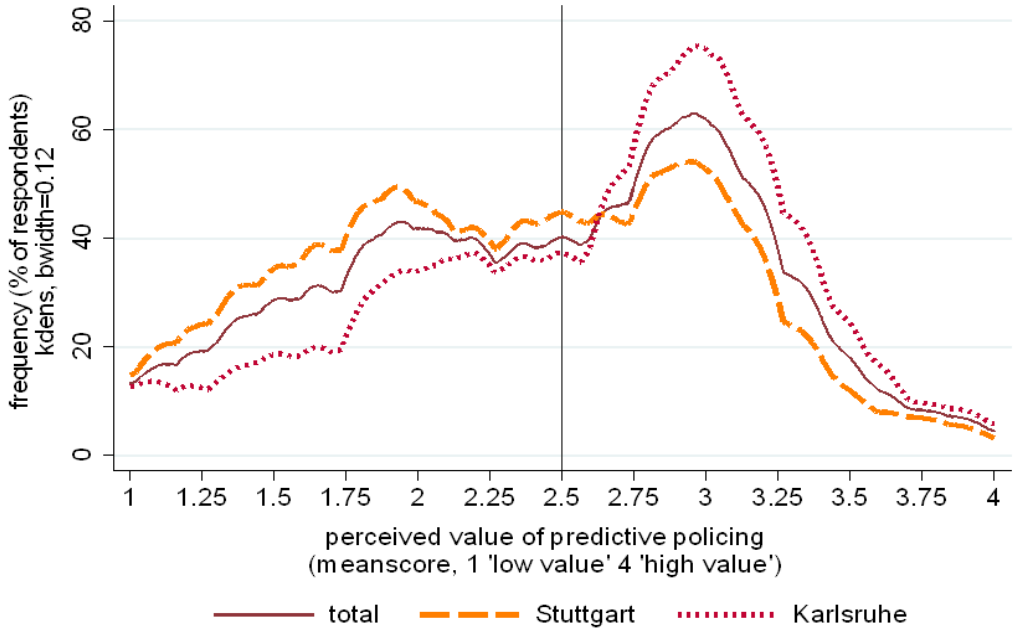
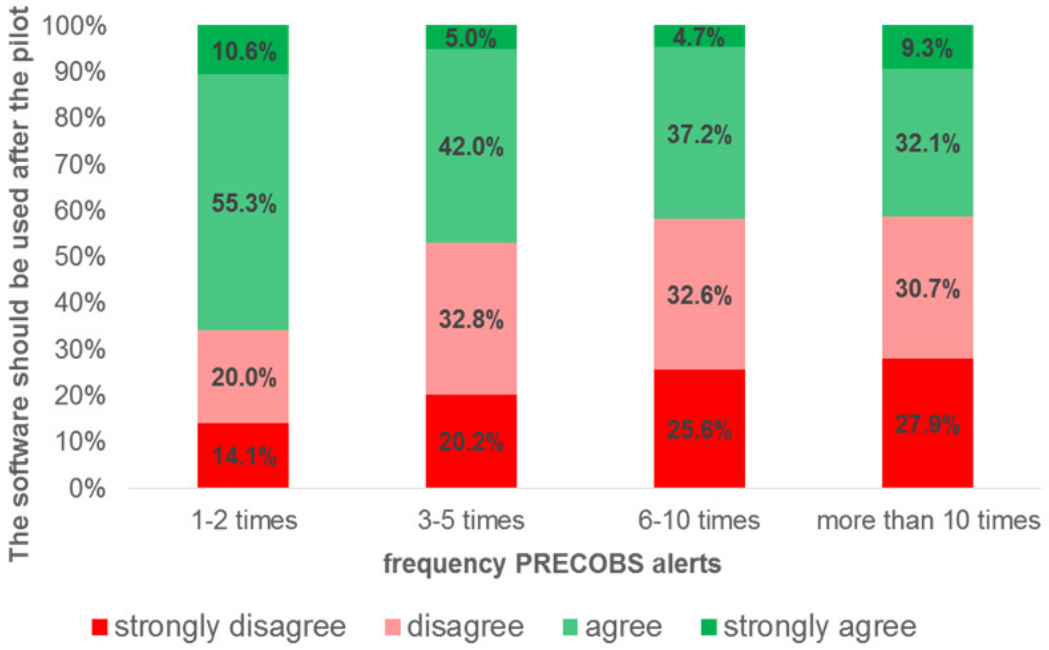


Figure 6: "The software should be used after the pilot" in relation to the frequency patrol officers had to serve PRECOBS alerts (n=430, Data source: P4 online-survey)



Concluding remarks

After the evaluation of the P4 pilot project and despite some positive indications, it still hard to assess whether and to what extent predictive policing can contribute to the reduction of residential burglaries. Some relevant conclusions can be drawn on the basis of available data related to alerts based on predictions, also on data about police activity as well as the analyses of numbers and patterns of burglaries. Furthermore, it could be demonstrated that predictive policing is more than making predictions. With regard to crime reducing effects, it is important to note that the results have to be treated with caution due to the short evaluation period, the lack of an experimental research design and a small size of trial areas. As crime rates usually show natural variation, a comparison with previous periods or other regions can only give limited insights. Only few studies with an experimental research design have been carried out in the field of predictive policing (Hunt et al. 2014, Mohler et al. 2015, Saunders et al. 2016). Since predictive policing has become a hot topic in many European countries, such studies are desirable for future research in order to gain knowledge about how predictive policing can reduce crime. Nonetheless, with the analyses of near repeat patterns and near repeat events subsequent to alerts, the evaluation study found that certain crime reducing effects are indicated, however these effects appear to be moderate. The integration of the software into everyday business worked without much difficulty and police actions following an alert-triggering burglary took place in a timely manner. The small group of officers who operated the software, assessed it as a useful supplement – especially during times with a high load of residential burglary. In a larger group, including patrol officers, the perceived value of predictive policing with PRECOBS was a divisive issue. In particular, officers who were confronted with many alerts tended to disapprove of a continuation of predictive policing. This might be due to perceived additional workload but also due to the fact that the preventive effects of deterrence cannot directly be perceived. The acceptance and assessments of predictive policing within police forces provide additional connection points for future research.

The Baden-Württemberg Police is using the software for another trial period in the same pilot area since August 2017 in order to get a higher degree of certainty about benefits of predictive policing in the context of residential burglary. This includes a further scientific evaluation by the Max Planck Institute for Foreign and International Criminal Law in Freiburg. Besides the extended timespan, an experimental research design is applied to increase the meaningfulness of the results.

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