A Matched Case-Control Study of Convenience Store Robbery Risk Factors

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Convenience store clerks have been shown to be at high risk for assault and homicide, mostly owing to robbery or robbery attempts. Although the literature consistently indicates that at least some environmental designs are effective deterrents of robbery, the significance of individual interventions and policies has differed across past studies. To address these issues, a matched case-control study of 400 convenience store robberies in three metropolitan areas of Virginia was conducted. Conditional logistic regression was implemented to evaluate the significance of various environmental designs and other factors possibly related to convenience store robbery. Findings indicate that numerous characteristics of the surrounding environment and population were significantly associated with convenience store robbery. Results also showed that, on a univariate level, most crime prevention factors were significantly associated with a lower risk for robbery. Using a forward selection process, a multivariate model, which included cash handling policy, bullet-resistant shielding, and numerous characteristics of the surrounding area and population, was identified. This study addressed numerous limitations of the previous literature by prospectively collecting extensive data on a large sample of diverse convenience stores and directly addressing the current theory on the robbers' selection of a target store through a matched case-control design.

Numerous studies in the convenience store literature have assessed specific risk factors for robbery.[1–10] Although these studies focus on different types of variables, they consistently indicate that robbery is not a random event. Rather, the robber chooses a target based on various situational crime prevention factors.[11] This study was designed to improve on previous studies by obtaining a large sample size, collecting data on all hypothesized risk factors, and using a case-control design to properly assess which risk factors are significantly associated with the robbers' choice for a target.

Environmental designs, as a method to prevent convenience store robbery, have been studied for more than 20 years.[9,12–18] Many of the theoretical ideas associated with environmental design originated from the principles of Crime Prevention Through Environmental Design[12] (CPTED). According to CPTED theory, "in order to change criminal behavior, we must change the environment... by decreasing the [reward] available from criminal acts and increasing the risk involved in criminal acts." Developed after CPTED, Situational Crime Prevention Theory[11] incorporates features of CPTED and predicates reducing crime through increasing the effort, increasing the risks, and reducing the rewards associated with crime. Overviews of how the principles of CPTED and situational crime prevention relate specifically to convenience stores have been published elsewhere.[7,19]

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Crow and Bull[20] conducted the first applied research on the impact of environmental designs. They interviewed incarcerated robbers and utilized their opinions about environmental designs (including limiting available cash, enhanced visibility, elimination of escape routes, and others) to conduct an experimental study. Many other studies have since analyzed the association between environmental designs and convenience store robbery.[1–3,5–9,20] Although improving at least some aspects of the environmental design have proved effective in deterring robbery, it remains unclear which designs are most effective in preventing robbery.

Previous studies have also indicated that factors that are possibly related to nearby crime-related activities should be considered in analyzing the effectiveness of environmental designs to deter convenience store robbery. These studies characterized the overall level of neighborhood crime through various measures such as proximity to crime focal points, overall crime rates, and other surrogate measures.[1,3–4,9,20] Results indicated that such factors must be considered because their effects could confound study results.[1,4,9]

Other crime prevention factors, which are related to the stores' operational characteristics, include staffing, training, and hours of operation. Previous research has examined these variables with some differences in results.[7,9,21] This study assesses the effectiveness of these factors after adjusting for geographic and demographic factors and for environmental designs. Future analysis from our study will address the significance of these factors in reducing robbery-related injury.

Methods

The eligible population for this study consisted of all convenience stores operating between February 1, 1995 and September 30, 1996 in 14 police jurisdictions surrounding the metropolitan areas of Alexandria, Richmond, and Norfolk, Virginia. During the study period, 1271 eligible stores were identified by the Virginia Department of Criminal Justice Services from state tax and beverage license records. A convenience store was defined as a retail store that sells a combination of gasoline, fast foods, soft drinks, dairy products, beer, cigarettes, publications, grocery items, snacks, and non-food items and has a size less than 5000 square feet. Gasoline stations with store operations were also considered convenience stores for this study.

The study design utilized a case-control methodology, in which a case was defined as a robbery event in any convenience store within the 14 jurisdictions between February 1, 1995 and September 30, 1996. A given store could contribute multiple robbery events (ie, represent multiple cases) during the study period. Robbery was defined as taking, or attempting to take, goods or money by force, or the threat of force, from a store employee.[22] For each case, three matched controls were selected randomly from all stores within a 2-mile radius of the case store. Controls were selected from all stores open at the time of robbery that were not robbed at any time during the day of the case robbery. Thus, a case could be selected as a control for a robbery on a different day, or vice versa. The rationale for this case-control design was that a robber usually robs a store within 2 to 3 miles of his residence.[23–25] Matching on this 2-mile radius hypothetically will ensure that the case and control stores were in the robber's target area.

Copies of all robbery reports were provided to the Virginia Department of Criminal Justice Services by the local police jurisdictions. Case and control sites were then visited by interviewers, who were off-duty or retired police officers familiar with the area. The interviewers collected information on numerous factors relevant to convenience store robbery and surrounding crime. Distances to graffiti, multifamily and subsidized housing, loitering and gangs, and drug trafficking were estimated by the interviewers. Information was also collected on additional characteristics relevant to vehicular and pedestrian traffic, including use of surrounding land, speed limit on adjacent roads, and whether or not the store was located in a shopping center or at an intersection. The presence and visibility of pay phones and gas pumps on the property was also recorded.

The stores' environmental designs were assessed by collecting data on the presence or absence of ATM machines and bullet-resistant shielding, location of the counter (middle of the store versus against the wall), and number of opportunities for concealed escape. Whether or not evidence of weapons (being kept at the store) existed was also determined by the interviewer. Responses to several different questions were used to evaluate visibility from the inside, outside, and within the store. For instance, five different questions concerning visibility from the outside of the store were completed by the interviewer (Table 1). All possible responses to each question were assigned a numerical value between zero and one, with the worst situation (such as completely obstructed) coded as zero and the best situation (such as no obstruction) coded as one. The total of all five responses was then categorized as either good, fair, or poor, on the basis of the frequency distribution of the total score. Security systems and cash handling procedures were also coded as good, fair, or poor, depending on the number of procedures in place at that store. A list of questions used and the cut-points for determining the good, fair, or poor rating are listed in Table 1.

During each visit, clerks and managers who were on duty at the time of the robbery were interviewed. Age and ownership status (company versus independent) of the store, as well

TABLE 1
Survey Questions and Cut-Points for Variables

Question	Value	Response
Survey questions used to create scales		
Q1. From street, describe the view of clerk at cash register station.	0	Completely obstructed
	¼	Mostly obstructed
	½	Moderately obstructed
	¾	A little obstructed
	1	No obstruction
Q2. From vehicle driving past the store in closest lane, describe the view of the counter.	0	Not visible
	½	Visible during part of drive-by surveillance
	1	Visible during entire drive-by surveillance
Q3. From in front of store entrance, describe the view of clerk at cash register station.	0	Completely obstructed
	¼	Mostly obstructed
	½	Moderately obstructed
	¾	A little obstructed
	1	No obstruction
Q4. From in front of the cash register, is there a clear view of at least one point on the street?	0	No view
	½	Partial view
	1	Clear view
Q5. From in front of the cash register, describe the view of the entire length of street running along the store property.	0	Completely obstructed
	¼	Mostly obstructed
	½	Moderately obstructed
	¾	A little obstructed
	1	No obstruction
Q6. From in front of cash register, is there a clear view of the sidewalk/landing immediately in front of main store entrance?	0	No view
	½	Partial view
	1	Clear view
Q7. From in front of cash register, describe the view of entire length of sidewalk area running by store front.	0	Completely obstructed
	¼	Mostly obstructed
	½	Moderately obstructed
	¾	A little obstructed
	1	No obstruction
Q8. Ability to observe a person from the cash register immediately after he or she exits the store.	0	Can disappear from view within 10 feet of door
	½	Can disappear from view 10 to 20 feet of door
	1	Can disappear from view 20 feet or more from door
Q9. Visibility within store from counter (direct or with mirrors).	1	All customers visible
	½	Not visible in one aisle
	0	Not visible in 2 or more aisles
Q10. Is counter area raised off floor?	1	Yes
	0	No
Q11. Number of blind spots.		
Q12. Number of aisles.		
Q13. Presence of security systems visible to a robber (mark all that apply).	1	Video system (if none, go to 35-mm camera)
	⅓	Monitor that can be seen by customers and robbers
	⅓	Monitor is operating
	⅓	Evidence that system is interactive
	1	35-mm camera present
	1	Robbery alarm system
	1	Personal alarm system
	1	Mirrors to observe customers
	1	Pass-through window
	1	Observation window
	1	Height markers

Table 1 continues

TABLE 1
Continued.

Q14. Presence of cash handling procedures visible to a robber (mark all that apply).	1	Uniformed security guard
	1	Armed security guard
	1	Sign on cash limit policy posted
	½	Amount of cash limit posted
	½	Hours of cash limit posted
	1	Drop safe used
	½	Sign posted that a drop safe is used
	½	Drop safe visible

Variable	Category	Definition
Cut-points for categorical variables used in the analysis		
Visibility from outside to inside of the store	Good	$Q1 + Q2 + Q3 \geq 2.5$
	Fair	$1.5 < Q1 + Q2 + Q3 < 2.5$
	Poor	$Q1 + Q2 + Q3 \leq 1.5$
Visibility from inside to outside of the Store	Good	$Q4 + Q5 + Q6 + Q7 + Q8 \geq 3.5$
	Fair	$2.75 < Q4 + Q5 + Q6 + Q7 + Q8 < 3.5$
	Poor	$Q4 + Q5 + Q6 + Q7 + Q8 \leq 2.75$
Visibility from counter to inside of store	Good	$Q9 + Q10 + [1 - [Q11/(Q12 + 1)]] \geq 2$
	Fair	$1.5 < Q9 + Q10 + [1 - [Q11/(Q12 + 1)]] < 2$
	Poor	$Q9 + Q10 + [1 - [Q11/(Q12 + 1)]] \leq 1.5$
Security systems	Good	$SUM(Q13) \geq 4$
	Fair	$2 < SUM(Q13) < 4$
	Poor	$SUM(Q13) \leq 2$
Cash handling	Good	$SUM(Q14) = 4$
	Fair	$1 < SUM(Q14) < 4$
	Poor	$SUM(Q14) \leq 1$

as training (any versus none), race, and number of clerks on duty at the time of the robbery were determined from the interview. If these particular clerks or managers were not available, then a proxy interview was obtained from a current employee. Interviews of clerks and managers were not permitted by one chain of stores, which accounted for 39% of the stores in the study population. Information on the number of clerks and robbery circumstances was abstracted from police reports that contained most of the data needed. All stores in this chain were still visited and their designs were evaluated.

The store address was used to identify each store's latitude and longitude as well as the corresponding census tract. Data from the most recent census (1990) were then merged with the previously described data. Variables related to socioeconomic characteristics of the surrounding population, which included median household and per capita income, population density, and average family size, were retained for analysis. Data also included the percentage of the surrounding population that consisted of high school graduates, single males, age 15 to 24, unemployed, and on public assistance. Census data on the characteristics of the surrounding buildings and structures included median rent, value of structures, and year of construction, as well as the percentage of housing units rented and structures vacant.

Percentages of cases and controls at each level of each variable were displayed for descriptive purposes, although these results were not directly used for calculating odds ratio or significance levels. Associations between robbery and possible risk factors were evaluated using conditional logistic regression,[26] which accounts for the matching between each case and set of three controls. Univariate results were displayed for all variables listed above. Robust variance estimates were also calculated using a jackknife estimation procedure in S-Plus[27] to account for the correlation from repeated selection of individual convenience stores. (A total of only 258 different stores accounted for the 400 robbery events.) These results were not listed, because this procedure had minimal effect on variance estimates. Odds ratios and 95% Wald-based confidence intervals[26] were calculated using the conditional logistic model.

A forward selection algorithm was implemented to determine a multivariate model, using the likelihood ratio test between appropriate nested models to calculate significance levels.[26] This procedure was implemented to identify which terms were still statistically significant in the presence of other factors. Since variables not significant at 0.05 may still be associated with the outcome after adjusting for other covariates,[26,28–29] any factors with univariate results of

TABLE 2
Univariate Results: Characteristics of the Surrounding Population and Structures

Variable	Category	%Case[a]	%Con	OR	95% CI
% high school graduates**	<70%	29.4	26.0	1.00	
	70–85%	39.5	42.4	0.75	[0.5, 1.0]
	>85%	31.1	31.6	0.61	[0.4, 0.9]
Median household income	<$25,000	22.1	25.4	1.00	
	$25–40,000	47.9	48.3	1.11	[0.8, 1.5]
	>$40,000	30.0	26.3	1.23	[0.8, 1.8]
Median per capita income	<$10,000	18.7	22.9	1.00	
	$10–15,000	44.4	45.7	1.15	[0.8, 1.6]
	>$15,000	36.9	31.4	1.39	[0.9, 2.1]
% on public assistance***	≤10%	77.0	80.9	1.00	
	>10%	23.0	19.1	1.55	[1.1, 2.1]
Median rent**	≤$500	58.7	57.0	1.00	
	>$500	41.3	43.0	0.68	[0.5, 1.0]
Median value of structures*	≤$75,000	48.3	54.1	1.00	
	>$75,000	51.7	45.9	1.24	[0.9, 1.7]
% age 15–24	≤15%	60.4	57.5	1.00	
	>15%	39.6	42.5	0.88	[0.7, 1.1]
Population density (per square km^2)	<1	30.7	25.1	1.00	
	1–2.5	41.5	41.8	0.87	[0.6, 1.2]
	>2.5	27.8	33.1	0.71	[0.5, 1.1]
Average family size	≤2.5	39.5	40.5	1.00	
	>2.5	60.5	59.5	0.95	[0.7, 1.3]
Median year that buildings were constructed***	<1960	39.7	38.0	1.00	
	1960–70	32.0	30.6	0.75	[0.5, 1.0]
	>1970	28.3	31.4	0.51	[0.3, 0.7]
% unemployed	≤10%	82.3	80.2	1.00	
	>10%	17.7	19.8	0.93	[0.7, 1.3]
% of housing units rented	<40%	42.1	37.3	1.00	
	40–60%	31.6	30.4	0.93	[0.7, 1.3]
	>60%	26.3	32.3	0.75	[0.5, 1.0]
% single males**	≤15%	47.7	50.8	1.00	
	>15%	52.3	49.2	1.41	[1.1, 1.9]
% of buildings vacant	<5%	31.6	25.8	1.00	
	5–10%	44.6	47.6	0.78	[0.6, 1.1]
	>15%	23.8	26.6	0.78	[0.5, 1.1]

* $P < 0.25$, ** $P < 0.05$, *** $P < 0.01$.
[a] %Case, percentages of cases; %Con, percentages of controls; OR, odds ratio; CI, confidence interval.

$P < 0.25$ were considered eligible for entrance into the multivariate model. Each eligible covariate was tested against the appropriate reduced model. The order for selecting variables and testing for model inclusion was determined by statistical significance, beginning with the most significant covariate. Variables significant at $P < 0.10$ were then added to the model. This process continued until no other covariates were significant at $P < 0.10$.

To assess stability of the selection process, several other methods were implemented: (1) As suggested by Greenland and others,[28–31] possible confounders (variables related to socioeconomic status, proximity to local crime, and traffic volume, in that order) were tested for model inclusion first. The significance of each intervention and policy was then calculated using the likelihood ratio statistic after adjusting for significant confounders. Results were very similar and therefore not listed. (2) A step for backward elimination was allowed so that variables initially included in the model could be removed if not significant ($P > 0.25$) against the new reduced model. Results did not change using either of these two approaches and were therefore not listed.

Results

A total of 460 robbery cases were identified during the study, of which we collected data on 400 robbery cases and 1201 matched controls (four controls were inadvertently visited for one of the cases). We did not collect data on 60 of the cases because of significant delays in the time between the occurrence of the robbery and when interviewers were able to obtain the needed information, which caused reliability concerns that the prospective nature of our study was designed to eliminate. Census tract information on socioeconomic factors was matched to almost 99% of the case stores and 98% of the controls. Univariate results (Table 2) indicated that an increased risk of robbery was significantly associated ($P < 0.05$) with the

TABLE 3
Univariate Results: Proximity of Crime-Related Factors and Traffic Volume

Variable	Category	%Case[a]	%Con	OR	95% CI
Distance (in miles) to graffiti***	≤1	74.1	67.9	1.00	
	>1	25.9	32.1	0.67	[0.5, 0.9]
Distance (in miles) to Multifamily housing*	≤0.5	78.7	82.1	1.00	
	>0.5	21.3	17.9	1.34	[1.0, 1.9]
Distance (in miles) to subsidized housing**	<0.5	42.4	37.7	1.00	
	0.5–2	30.6	29.8	0.87	[0.7, 1.2]
	>2	27.0	32.5	0.66	[0.5, 0.9]
Distance (in miles) to loitering, youth, and gangs	<0.1	33.6	32.0	1.00	
	0.1–1	45.1	43.9	0.97	[0.7, 1.3]
	>1	21.3	24.1	0.79	[0.5, 1.1]
Distance (in miles) to drug traffic	≤0.1	33.6	31.8	1.00	
	0.1–1	46.6	47.4	0.91	[0.7, 1.2]
	>1	19.8	20.8	0.86	[0.6, 1.3]
Distance (in miles) to closest interstate*	<0.5	28.7	24.7	1.00	
	0.5–2	36.0	37.1	0.80	[0.6, 1.1]
	>2	35.3	38.2	0.74	[0.5, 1.0]
Speed limit on adjacent road*	<30	15.1	17.5	1.00	
	30–35	57.8	53.3	1.28	[0.9, 1.8]
	>35	27.1	29.2	1.06	[0.7, 1.6]
Land use surrounding store**	Open com.	28.6	33.6	1.00	
	Commerc.	29.1	31.6	1.08	[0.8, 1.5]
	Residential	21.3	20.5	1.22	[0.9, 1.7]
	Vacant	11.0	7.6	1.77	[1.1, 2.7]
	Mixed	10.0	6.7	1.73	[1.1, 2.6]
Located in shopping center***	No	85.4	79.8	1.00	
	Yes	14.6	20.2	0.66	[0.5, 0.9]
Located at an intersection	No	25.6	27.6	1.00	
	Yes	74.4	72.4	1.11	[0.9, 1.5]
View of pay phone	Obstructed	61.0	63.1	1.00	
	Visible	39.0	36.9	1.10	[0.9, 1.4]
Gas pumps*	Absent	44.9	49.2	1.00	
	Present	55.1	50.8	1.22	[1.0, 1.6]
No. of parking spaces	≤10	44.6	46.7	1.00	
	>10	55.4	53.3	1.12	[0.9, 1.4]

* $P < 0.25$, ** $P < 0.05$, *** $P < 0.01$.
[a] For definitions of terms, see Table 2.

following population characteristics: a low percentage of high school graduates, a high percentage on public assistance, a low median rent, older buildings and structures, and a high percentage of single males. Of these variables, age of buildings and structures and percentage of high school graduates exhibited the strongest associations with robbery in terms of odds ratios. Median value of structures ($P = 0.16$) and the proportion of renter-occupied units ($P = 0.18$) also met the criteria ($P < 0.25$) for entering the forward selection process.

Analysis results concerning factors related to local crime and traffic volume are presented in Table 3. The univariate analysis indicated that stores close to graffiti and subsidized housing, and not located in a shopping center, were significantly associated ($P < 0.05$) with increased risk of robbery. Stores where the surrounding land use was primarily open commercial were significantly associated with a lower risk of robbery. Surrounding land use exhibited the largest odds ratio, followed by distance to subsidized housing, location of shopping center, and distance to graffiti. Distance to multifamily housing ($P = 0.09$) and the interstate ($P = 0.19$), speed limit on adjacent road ($P = 0.24$), and presence of gas pumps ($P = 0.12$) also met the criteria for entering the forward selection process.

Univariate results for environmental designs and other crime prevention factors are presented in Table 4. Categories for visibility from the inside and outside of the store, security systems, and cash handling policies are defined in Table 1. Future research will investigate the effectiveness of individual security measures. Stores with registers located along the wall of the store and poor visibility from the outside of the store were significantly ($P < 0.05$) associated with an increased risk for robbery. Presence of employee training, security systems, bullet-resistant shielding, ATM machines, and good cash handling policies were significantly ($P < 0.05$) associated with a decreased risk of robbery. Of all variables in the study, the cash handling policy exhibited the

TABLE 4
Univariate Results: Environmental Designs and Other Crime Prevention Factors

Variable	Category	%Case[a]	%Con	OR	95% CI
ATM***	Absent	76.2	68.1	1.00	
	Present	23.8	31.9	0.62	[0.5, 0.8]
Opportunities for concealed escape**	≤1	61.1	66.2	1.00	
	>1	38.9	33.8	1.32	[1.0, 1.7]
Visibility from outside to inside***	Good	27.8	32.6	1.00	
	Fair	33.8	36.3	1.13	[0.8, 1.5]
	Poor	38.4	31.1	1.56	[1.2, 2.1]
Visibility from inside to outside*	Good	25.8	31.4	1.00	
	Fair	34.8	33.1	1.29	[1.0, 1.7]
	Poor	39.4	35.5	1.37	[1.0, 1.8]
Visibility from counter to inside store	Good	30.2	34.1	1.00	
	Fair	37.2	34.4	1.27	[0.9, 1.7]
	Poor	32.6	31.5	1.18	[0.9, 1.6]
Counter location***	Middle	26.2	32.2	1.00	
	Wall	73.8	67.8	1.39	[1.1, 1.8]
Bullet-resistant shielding**	Absent	96.5	94.1	1.00	
	Present	3.5	5.9	0.58	[0.3, 1.0]
Security systems**	Good	28.3	31.4	1.00	
	Fair	40.8	44.1	1.03	[0.8, 1.4]
	Poor	30.9	24.5	1.49	[1.1, 2.1]
Cash handling***	Good	40.2	54.4	1.00	
	Fair	38.4	30.8	1.82	[1.4, 2.4]
	Poor	21.4	14.8	2.21	[1.6, 3.1]
Training***	Yes	64.3	75.3	1.00	
	No	35.7	24.7	1.81	[1.4, 2.3]
Evidence of weapons*	No	95.2	96.7	1.00	
	Yes	4.8	3.3	1.49	[0.8, 2.6]
Number of clerks*	1	54.2	49.6	1.00	
	>1	45.8	50.4	0.81	[0.6, 1.0]

* $P < 0.25$, ** $P < 0.05$, *** $P < 0.01$.
[a] For definitions, see Table 2.

TABLE 5
Univariate Results: Other Store Characteristics

Variable	Category	%Case[a]	%Con	OR	95% CI
Store type***	Company	73.2	79.4	1.00	
	Independent	26.8	20.6	1.45	[1.1, 1.9]
Store age***	≤2 y	11.3	5.9	1.00	
	>2 y	88.7	94.1	0.48	[0.3, 0.7]
Race of employees	Mixed	12.8	14.3	1.00	
	White	37.3	34.2	1.19	[0.8, 1.7]
	Non-white	49.9	51.5	1.03	[0.7, 1.6]

* $P < 0.25$, ** $P < 0.05$, *** $P < 0.01$.
[a] For definitions, see Table 2.

strongest association with robbery, with an odds ratio of 2.21 for poor cash handling policy. After cash handling policy, training, presence of an ATM, visibility to the inside, security systems, and evidence of weapons had the strongest associations in terms of odds ratios. Visibility from the inside to the outside of the store, evidence of a weapon (for use by store clerks), and number of clerks ($P = 0.09$, 0.18, and 0.09, respectively) were also included in the forward selection process.

Results of univariate analysis for other store characteristics are presented in Table 5. Newer and independent stores were associated ($P < 0.05$) with increased risk of robbery.

The multivariate regression model, as determined by the forward selection algorithm, is presented in Table 6. This procedure is explained in detail in numerous statistical texts, including Hosmer and Lemeshow,[26] 1989. As the most statistically signif-

TABLE 6
Adjusted OR and CI for the Multivariate Model*

Variable	Category	OR	95% CI
Cash handling	Good	1.00	–
	Fair	1.57	(1.15, 2.14)
	Poor	2.24	(1.53, 3.28)
Bullet-resistant shielding present	No	1.00	–
	Yes	0.36	(0.19, 0.68)
Located in shopping center	No	1.00	–
	Yes	0.62	(0.43, 0.89)
Median year that buildings were constructed	<1960	1.00	–
	1960–1970	0.93	(0.64, 1.35)
	>1970	0.51	(0.32, 0.81)
% single males	≤15%	1.00	–
	>15%	1.97	(1.38, 2.82)
Store age	≤2 y	1.00	–
	>2 y	1.68	(1.07, 2.65)
Distance (in miles) to graffiti	≤1	1.00	–
	>1	0.63	(0.44, 0.90)
% housing units rented	<40%	1.00	–
	40–60%	0.77	(0.53, 1.11)
	>60%	0.56	(0.37, 0.85)
Median value of structures	≤$75,000	1.00	–
	>$75,000	1.49	(1.03, 2.15)
Distance (in miles) to multifamily housing	≤0.5	1.00	–
	>0.5	1.46	(0.98, 2.16)

* OR, odds ratio; CI, confidence interval.

icant variable, cash handling policy was entered as the first variable in the model. After adjusting for cash handling, presence of bullet-resistant shielding, being located in a shopping center, age of neighborhood buildings/structures, percentage of single males, age of store, distance to graffiti, proportion of housing units rented, median value of structures, and distance to multifamily housing, in that order, were added to the model. No other variables were significant at $P < 0.10$. These variables do not necessarily represent the most conclusive or causal factors, but rather the subset of variables that were still statistically significant in the presence of other significant factors[26] (ie, statistical results not explained by confounding). Odds ratios in Table 5 are thus adjusted for the other terms in the model. Bullet-resistant shielding, cash policy, and year of construction each had an odds ratio above 2, or less than 0.5, indicating a very strong association with robbery.

Discussion

The case-control design implemented in this study directly addresses the current literature which states that a robber targets a store from a given 2- to 3-mile radius on the basis of various situational crime prevention factors. The case-control study design estimates the statistical significance of each factor within each matched set (ie, cluster of stores). Assuming that the matched sets have been constructed correctly, this design (3 to 1 matching) maximizes the statistical power of the significance tests. Past literature shows that negligible power is gained through adding controls beyond 3 to 1 matching.[32] In a retrospective or cross-sectional analysis, the temporal relationship between robbery and other factors also becomes more difficult to establish. Policies and interventions, which are typically measured at a single time point in other studies, may be modified as a result of robbery and may therefore be falsely identified as risk factors. For instance, when analyzing the number of robberies over several years, the number of employees on duty (usually characterized by "always two or more" versus "sometimes two or more") may vary significantly over even the course of a day. Even studies on convenience store robbery defined as experimental have suffered from such limitations; the implementation of specific interventions in this setting is often guided by practicality and so is possibly confounded by other factors related to risk of robbery. For this study, data specific to the time of robbery were prospectively collected and thus avoided such limitations.

Univariate results indicated that visibility to the inside of the store was strongly associated with robbery, as stores with poor visibility to the inside of the store were at twice the odds of robbery. Although opportunities for concealed escape and visibility to the outside of the store were only marginally statistically significant, each of these variables had an odds ratio of over 1.3 for the poorest level. Other environmental designs, including counter location, bullet-resistant shielding, security systems, cash handling, and training, were statistically significant on a univariate level. These factors also exhibited a very strong association with odds of robbery 40% to 120% greater for the optimal level of each variable. Although not statistically significant, the odds of robbery for stores with evidence of a weapon was one and a half times greater. Multiple staffing, also not statistically significant, was associated with a 20% lower odds of robbery. In the multivariate model, having a good cash handling policy and presence of bullet-resistant shielding remained significantly associated with reduced risk for robbery after adjusting for other significant risk factors. In general, these results were consistent with existing literature.[9] Study results thus indicate that interventions generally recognized as effective deterrents of robbery were in fact sig-

nificantly related to a reduced odds of robbery.

The results of this study indicated that analysis of convenience store robbery must consider a wide range of store-specific environmental designs as well as general characteristics that may be related to the level of general crime in the surrounding area. In addition to traditional environmental designs, this study considered socioeconomic status of the surrounding area and proximity to crime focal points, some of which were significantly associated with robbery. The strength of association for these variables was evidenced by substantial odds ratios, as well as statistical significance. For instance, the odds of convenience store robbery was twice as high for older neighborhoods (median structure older than 1960) than newer neighborhoods (median structure newer than 1970). Census tracts with over 10% of the working population on public assistance were at over one and half times the risk for robbery. Similar associations held for census tracts with under 70% high school graduates (versus over 85%) and stores close to graffiti.

Two possible limitations in the analysis were the calculation of the 2-mile radius and correlation between observations. The 2-mile radius for each case store was calculated from longitude and latitude coordinates, thus ignoring possible physical barriers, such as rivers, which might greatly increase the driving distance between stores. Since the actual driving distance was not known, the effect of this limitation cannot be directly assessed, although the frequency of such occurrences is probably limited. Robust variance estimates, which were calculated to account for repeated selection of individual stores (ie, those robbed multiple times and/or selected as a control multiple times), yielded almost no change in results. However, other sources of correlation may exist. These sources include possible correlation within each of the three geographically distinct areas and possible spatial correlation between matched sets that are close in distance.

Previous studies of convenience store robbery have been limited in several important aspects, including limited generalization, lack of data on confounding factors, selection bias, misclassification of covariates, and inadequate sample size. This study addressed each of these limitations by collecting data specific to the time of robbery on a wide range of possible confounders from a large number of diverse convenience stores in rural, residential, and urban areas. Many previous studies examined only stores owned by a single chain and/or stores located in a single municipality. Results of this study showed that the risk for convenience store robbery differed significantly by ownership status (company versus independent stores). Although this variable did not make the multivariate model and is likely due to confounding from other factors, the result indicated that generalization is limited when only considering stores from a single large chain.

Other studies have considered only convenience stores from a single municipality. Results of the current study indicated that numerous features of the surrounding area, such as age and value of surrounding buildings/structures, were significantly associated with robbery. Study populations sampled from a single metropolitan area would likely be more limited in terms of such factors, thus reducing the generalizability of their findings. The study population for this case-control design included numerous chains of convenience stores located in or around one of three major metropolitan areas in Virginia. The 14 jurisdictions included in this study were selected to represent both urban, rural, residential, and commercial areas.

Most studies on convenience store robbery have failed to collect data relevant to the proximity of local crime focal points. As evidenced by the significance of these factors in this study, results of such analyses may be incomplete or confounded. Past studies that have addressed this topic often collected only county-specific data. In this study, data collection related to the proximity of crime focal points or other relevant factors was either specific to the given convenience store or census-tract specific. The specificity of census tract data was, however, partially limited by the possibility of a given convenience store being influenced more by surrounding census tracts.

Previous studies of convenience store robbery had been limited in terms of statistical power. A recent review[9] of the literature indicated that 6 of 14 studies enrolled fewer than 50 stores, and only 1 study enrolled over 200. This study, which analyzed data from 400 cases and 1201 matched controls, provided sufficient statistical power to detect significant results even when interventions were rarely implemented in the study population (eg, bullet-resistant shielding).

Further analysis of these data must be done to assess the effectiveness of multiple clerk staffing and other variables separately by time of day (ie, morning, day, and night). The possible effectiveness of multiple clerks, for instance, is confounded by the fact that robbery rates are higher at night, when there is more often onlyone clerk on duty. Staffing is also likely to be associated with the store's prior history of being robbed and the volume of business conducted at that store, which could further confound results. The results presented in this study were therefore not conclusive about the role of multiple clerks in deterring robbery. In addition, future analysis must analyze risk factors separately by different robbery circumstances, such as escalated shoplifting versus straight robbery, or single versus multiple robbers.

Injury outcomes will also be considered in future analyses of these data. Possible risk factors for robbery-related injury may differ significantly from robbery risk factors. Results from a previous study[33] indicate that preventative interventions for robbery may actually (although not significantly) increase the probability of robbery-related injury. For these reasons, robbery-related injury is currently being analyzed separately.

In conclusion, this study evaluated a wide range of crime prevention factors and possible crime-related confounding factors. Results serve to strengthen the current literature, which consistently identifies at least some environmental designs as significantly associated with convenience store robbery. In addition, this study directly addresses the robber's selection of a target store given a particular area through utilizing a matched case-control study design.

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