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A Hunter's Moon: the Effect of Moon Illumination on Outdoor Crime

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Abstract We use National Incident-Based Reporting System (NIBRS) data and an AutoRegressive Integrative Moving Average (ARIMA) study design to investigate the effect of moon illumination on reported crime occurring outdoors between the hours of 10 pm to 2 am in 13 U.S. states and the District of Columbia. Prior research analyzed a confounded dependent variable that amalgamated indoor and outdoor crimes. This situation is problematic in that there is little reason to speculate a relationship between moon illumination and indoor crime because artificial illumination is used within dwellings. Findings show that while moon illumination has little influence on total crime and indoor crime, the intensity of moonlight does have a substantive positive effect on outdoor criminal activity. As moon illumination intensifies, outdoor crime increases markedly. Plausible explanations for this relationship are discussed.

Keywords NIBRS · Lunar effect · Full moon · Moon illumination · Outdoor crime

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Background

Debate persists as to the relationship between moon illumination and criminal behavior. It seems logically plausible that an increase in moon illumination acts to intensify criminal activity. Similar to predators in the animal world, criminals must have light to ply their trade because it would be virtually impossible for them to operate effectively in a completely dark environment. Yet, while light is certainly necessary for visual acuity, the excessive amount of artificial illumination generated from a flashlight might leave a criminal vulnerable to detection. It is thus possible that a full moon furnishes just enough natural light to enable an offender to perpetrate a crime, but not too much light to expose the offender to discovery and possible capture.

It is also conceivable that the natural illumination engendered by a full moon acts to attenuate people's fear of crime, which in turn amplifies activities away from the home. Studies show that activities away from the home escalate the risk of crime victimization (Miethe, Stafford, and Long, 1987). Although no study to our knowledge investigates the effect of changes in moonlight on peoples' fear of crime directly, researchers do find that an increase in artificial lighting mollifies an individual's fear of crime (Painter, 1996). This reduction in the fear of crime may not only motivate more people to venture out of their homes at night, but it may also encourage them to journey into dangerous areas that normally would be avoided on darker nights. The enhanced visibility engendered by a full moon may also amplify crime by affording criminals a better opportunity to determine the vulnerability of a potential victim, estimate the value of property that the victim may be carrying, and to assist them in ascertaining the proximity of capable guardians who might observe the crime and intervene in some way. Increased moon illumination also has the potential to facilitate drug dealing, prostitution, and other types of criminal activities that require the solicitation of costumers.

On the other hand, it is important to point out that there may be a negative association between moon illumination and crime. Such a relationship may exist between moon illumination and crime because darkness attenuates informal surveillance. This position receives empirical support from studies showing that an increase in artificial street lighting decreases criminal activity (Painter and Farrington, 1999; Quinet and Nunn, 1998). Thus, when natural illumination is amplified as a consequence of a full moon, criminals are easier to identify on the street because of the informal surveillance engendered by more pedestrian traffic (Painter, 1996) and by the enhanced visual acuity of citizens. Police officers may also be more visible during a full moon, thus causing a potential offender to decide against committing a crime. As Cozens, Saville and Hillier (2005:331) note, "If offenders perceive that they can be observed (even if they are not), they may be less likely to offend, given the increased potential for intervention, apprehension and prosecution."

Finally, recent research evinces little evidence of a substantive relationship between the amount of natural light generated by the different phases of the moon and criminal activity (Núñez, Pérez Méndez, and Aguirre-Jaime, 2002; Schafer, Varano, Jarvis, and Cancino, 2010). It is often argued that the causal processes theorized to be responsible for a relationship between moon illumination and crime are tenuous at best when one considers that a 100-watt light bulb generates about 70 times the luminance of a full moon (Bennett, 1977). It thus seems likely that criminals need far more light to ply their trade effectively than the small amount of natural light produced by a full moon. For example, even a stealthy crime such as burglary is more apt to occur during the day than at night. Official statistics show that when law enforcement agencies were able to establish the approximate time that a residential burglary occurred (about 75 % of the burglaries), the vast majority of residential burglaries (62 %) occurred during the day between the hours of 6 am to 6 pm (Department of Justice, 2006). These data suggest that offenders probably need much more light than the small amount of natural light provided by a full moon to perpetrate their crimes.

Current Study

The primary purpose of this study is to investigate the relationship between moon illumination and crime, correcting for a major methodological problem encountered in earlier research. We contribute to the extant literature by using NIBRS data on Part 1 crime incidents for 2014 that are calibrated in daily intervals and an ARIMA statistical procedure to examine the effect of moon illumination on total crime, outdoor crime, and indoor crime for 13 U.S. states and the District of Columbia. These 14 jurisdictions include 1737 cities, 307 non-MSA counties, 239 MSA counties, and four MSA state police departments and have 100 % coverage within the Eastern Standard Time Zone. The type of data and the analytic strategy employed here are methodologically advantageous for several reasons. First, while most crimes can occur indoors or outdoors, NIBRS has a "location type" code that allows for the identification of crimes transpiring outdoors. Because of data limitations, prior studies failed to distinguish between indoor and outdoor crimes. No published study to the best of our knowledge has ever examined whether variation in moon illumination influences reported crimes that occur outdoors at night.

There are two salient reasons for differentiating between indoor and outdoor crime when investigating the effect of moon illumination on crime. First, if moonlight does influence criminal activity by making the night more or less conducive to criminal activity, the effect should only be discernible for crimes that occur outdoors because artificial illumination is used within dwellings. Thus, by combining outdoor and indoor crimes in the same analysis, it seems probable that previous research obfuscated any relationship between moonlight and crime. Making an empirical distinction between indoor and outdoor crime also enables us to differentiate between lunar theories that focus their attention on the environment as opposed to the behavior of individuals. Environmentally rooted theories, such as the supposition that moon illumination influences crime, suggest that lunar phases influence outdoor crime rather than crimes that transpire indoors.

In contrast, behavioral type theories maintain that the cycles of the moon do not impact the environment but rather the behavior of individuals. This latter perspective is often referred to as the lunar (lunacy) hypothesis or the Transylvania effect (Lilienfeld and Arkowitz, 2008). A full moon is speculated to affect a person's behavior in a variety of ways such as influencing the pineal gland (Templer, Veleber, and Brooner, 1982) or impacting the alignment of water molecules in a person's nervous system (Lieber, 1978) among others (Lilienfeld and Arkowitz, 2008; Rotton and Kelly, 1985). Within this framework, the distinction between indoor and outdoor crime is irrelevant because all crime, notwithstanding whether it occurs indoors or outdoors, should be affected by a full moon. Thus, if a researcher unearthed evidence that the intensity of moon illumination just influenced outdoor crime, it would add support to environmentally rooted lunar theories.

Second, while no research design guarantees correct causal inferences, the ARIMA time series research design used here affords us the opportunity to assess the effect of moon illumination on outdoor crime over time for a number of different states. Because of the difficulty in obtaining data calibrated in daily or hourly intervals, prior research analyzed data drawn from a single geographical location (Núñez et al., 2002; Schafer et al., 2010). These types of samples are problematic because they tend to be unrepresentative thereby making generalizability of results difficult. Thus, the findings generated in prior studies may be the result of the unique nature of the specific jurisdictions studied.

Finally, because NIBRS enables us to distinguish between indoor and outdoor crime and because moon illumination is expected to have little influence on indoor crime, we are able to use the frequency of indoor crime as a control series. Thus, it is not necessary to include in the outdoor crime equation tangentially related control variables such as the amount of precipitation in a 24-h period, temperature, or weekend (see Schafer et al., 2010). These commonly used control variables are problematic because they tend to be vitiated with measurement error. Take a control variable like precipitation as an example. The problem is that precipitation data are only available in 24-h periods, which makes it impossible to determine whether any documented precipitation in a given geographical location occurred during the day or night.

Data

We analyze longitudinal data for 365 days in calendar year 2014 drawn from NIBRS (National Archive of Criminal Justice Data, 2014) and from the U. S. Naval Observatory in Washington, DC (U. S. Naval Observatory, 2014). The data encompass the following 13 states and the District of Columbia: Connecticut, Delaware, Maine, Massachusetts, Michigan, New Hampshire, Ohio, Pennsylvania, Rhode Island, South Carolina, Vermont, Virginia, and West Virginia. These jurisdictions were selected because they have 100 % coverage within the Eastern Standard Time Zone.

Dependent Variables

Three dependent variables are analyzed in this study. These endogenous variables include the total number of reported Part I crime incidents, the total number of outdoor crime incidents, and the total number of indoor crime incidents occurring between the hours of 10 pm to 2 am. This 4-h time-period is used because it brackets the Naval Observatory's nightly 12 am (midnight) measurement of moon illumination. The total crime variable is used in our analysis to help maintain comparability with previous research in this area. We then use the location type code in NIBRS to identify outdoor and indoor Part 1 crime incidents. Outdoor crimes are defined as those occurring on a highway/road/alley/street/sidewalk, field/woods, or lake/waterway/beach and represent 12.7 % of Part 1 crime incidents included in the study. The selection of indoor locations, however, was somewhat ambiguous because it is unclear whether the crime actually occurred indoors. To illustrate, a robbery occurring at a bank at midnight would probably involve a victim using the outdoor ATM machine. To resolve this uncertainty, we decided to rely on locations that are more inclined to be "open for business" between the hours of 10 pm to 2 am along with the type of crime involved. Thus, indoor crime incidents are defined as Part 1 violent crimes (homicide, rape, robbery, and aggravated assault) occurring at a residence or home and robberies transpiring at a bar/nightclub, convenience store, department/discount store, grocery/supermarket, liquor store or restaurant. These indoor crimes represent 9.3 % of the Part 1 crime incidents analyzed in this study.

Independent Variables

The independent variable of theoretical interest is moon illumination, which is measured as the ratio of the apparent illuminated area of the disk to the total area of the disk as seen from the Earth at 12 am (midnight) by the Naval Observatory. The intensity of moon illumination varies throughout the night with moon illumination becoming more intense as the evening progresses and then becoming less intense as sunrise approaches. The specific phase of the moon is identifiable by the fraction of it that is illuminated: New Moon = 0.00, First Quarter Moon = 0.05 (fraction illuminated is increasing), Last Quarter Moon = 0.50 (fraction illuminated is decreasing) and Full Moon 1.00. The means, standard deviations, and definitions for all the variables used in this study are presented in Table 1.

ARIMA Analyses and Findings

We relied on two statistical software programs to conduct our time-series analysis, IBM SPSS Statistics (IBM Corp., 2011) and Forecast Pro XE

Table 1 Description of variables included in the study, 2014 ($N = 365$ days)

Variable	Mean	SD	Defined
Crime 10 pm–2 am	463.13	113.50	Number of Part 1 crime incidents that occurred between 10 pm and 2 am.
Outdoor crime 10 pm–2 am	58.64	18.37	Number of Part 1 crime incidents that occurred between 10 pm and 2 am on a highway/road/alley/street/sidewalk, field/woods, or lake/waterway/beach.
Indoor crime 10 pm–2 am	42.89	13.40	Number of Part 1 violent crime incidents (homicide, rape, robbery and aggravated assault) that occurred between 10 pm and 2 am at a residence/home, and robberies that occurred between 10 pm and 2 am at a bar/nightclub, convenience store, department/discount store, grocery/supermarket, liquor store, or restaurant.
Moon illumination	.49	.35	Fraction of the moon illuminated at midnight Eastern Standard Time.

(Stellwagon and Goodrich, 2011). We began our analysis by constructing univariate AutoRegressive Integrative Moving Average (ARIMA) models for the total crime, outdoor, and indoor crime series. The univariate ARIMA model, which accounts for the stochastic processes associated with a series, is typically developed through an iterative model-building strategy (Box, Jenkins, and Reinsel, 2016). In selecting an appropriate univariate ARIMA model several factors are taken into account. One consideration is whether the series has a single constant variance throughout its course. A nonstationary variance is engendered by dramatic fluctuations in variation between observations in a series. To determine whether each of the three series was stationary in variance, we used a goodness-of-fit measure (BIC) to compare competing models. The BIC indicated that the total and outdoor crime series were stationary in variance. The indoor crime series needed to be naturally logged to achieve a stable variance.

Another consideration is whether a series has a single constant level throughout its course. That is, a series should not “trend” or “drift” upward or downward over time. A commonly used test for the presence of an unstable level is the “augmented” Dickey-Fuller test (Dickey, Bell, and Miller, 1986). This test evaluates whether a series has a unit root. Results generated from this test indicated that the outdoor crime series was trended and required first-order differencing.

A third consideration is whether a series has any cyclical or periodic fluctuation that repeats itself each time at the same phase of the cycle or period. This repetitive variation, commonly known as seasonality, is most likely to occur at weekly intervals with daily data. Our examination of each of the series autocorrelation functions (ACFs) indicated that all three series needed to be seasonally differenced.

Once the three series were determined to be stationary in variance and level, we examined each series autocorrelation function (ACF) and partial autocorrelation function (PACF) for autoregressive and for moving-average processes. In an autoregressive process the current value in a series is influenced by an exponentially weighted sum of one or more previous values. That is, the effect of one or more prior observations (i.e., the order of the autoregressive parameter) on the current observation diminishes over time: ($Y_t = \phi_1 Y_{t-1} + \ldots + \phi_p Y_{t-p} + a_t$). In contrast, each value in a moving-average process is determined by the average of the current disturbance and one or more previous disturbances.

Table 2 ARIMA model predicting all Part 1 crime 10 pm–2 am

	Estimate	*T*-value
Moving average	−.185***	−3.589
Moving average seasonal	.650***	14.684
Moon illumination	−1.807	−.466

ARIMA (0,0,1)(0,1,1). Ljung-Box Q (18) = 24.813, $P = .073$

***$P < .001$, **$P < .01$, *$P < .05$ (two-tailed test)

Table 3 ARIMA model predicting Part 1 outdoor crime 10 pm–2 am

	Estimate	*T*-value
Constant	−.591***	−3.440
Moving average (1)	.789***	15.133
Moving average (2)	.106*	2.020
Moving average seasonal	.997**	2.550
Moon illumination	1.194***	3.393

ARIMA (0,1,2)(0,1,1). Ljung-Box Q (18) = 13.604, P = .556

****P* < .001, ***P* < .01, **P* < .05 (two-tailed test)

The effect of a moving-average process lasts for a finite number of periods (i.e., the order of the moving-average parameter) and then vanishes abruptly:

$$\left(Y_t = a_t - \theta_1 a_{t-1} - \ldots - \theta_q a_{t-q}\right).$$

After constructing the univariate ARIMA models, we used the automatic multivariate transfer function procedure in IBM SPSS Statistics to assess the impact of moon illumination on each of the dependent variables. Tables 2, 3, and 4 present the maximum-likelihood coefficients along with t-values to evaluate statistical significance. A Ljung-Box Q statistic (Ljung and Box, 1978), which tests the null hypothesis that a set of sample autocorrelations is associated with a random process, indicated that the residuals for each of the three series were uncorrelated.

The results depicted in Table 2 show that the intensity of moon illumination has little influence on total crime. This finding is similar to that reported in recent research. Table 3 presents the results for the analysis estimating the effect of moon illumination on outdoor crime. A visual examination of Table 3 shows a noteworthy positive relationship between the intensity of moon illumination and the frequency of crimes occurring outdoors between the hours of 10 pm to 2 am. As moon illumination increases, there is an escalation in criminal activity. Table 4 shows that moon illumination does not have a statistically significant effect on Part 1 indoor crime incidents occurring from 10 pm to 2 am. This finding is expected given that artificial illumination is used indoors.

Table 4 ARIMA model predicting Part 1 indoor crime 10 pm–2 am (Ln)

	Estimate	*T*-value
Moving average (1)	−.212***	−4.183
Moving average (2)	−.150**	−2.877
Moving average seasonal	.746***	18.996
Moon illumination	.001	.124

ARIMA (0,0,2)(0,1,1). Ljung-Box Q (18) = 23.376, P = .076

****P* < .001, ***P* < .01, **P* < .05 (two-tailed test)

Conclusion

The effect of moon illumination on criminal activity continues to remain a topic of interest. We argued here that prior research inappropriately amalgamated both indoor and outdoor crimes. An empirical distinction between indoor and outdoor crime needs to be made by researchers because variation in the intensity of moonlight can only influence crimes that transpire outdoors since artificial lighting is used indoors.

In this study we investigated whether the amount of natural illumination produced by the different phases of the moon plays a salient role in affecting the frequency of outdoor crime. The nature of the data permitted us to interpret our findings with much greater confidence, shedding additional light on the conclusions reached in previous research. What do these data tell us about whether moonlight influences crime? Our analysis finds credible evidence to support theoretical arguments that moonlight amplifies criminal activity. More specifically, we observe that as the intensity of moonlight increases, the number of crimes committed outdoors rises markedly. This finding, coupled with our results showing no noteworthy relationship between moon illumination and indoor crime, adds empirical support to the position that moonlight magnifies criminal activity.

It is plausible that the enhanced visibility engendered by the natural light of a full moon intensifies criminal activity by affording offenders a better opportunity to ascertain the vulnerability of a potential victim, gauge the value of a victim's property, and by assisting them in determining the proximity of capable guardians. It is also possible that the natural illumination generated by a full moon motivates people to venture away from their homes by diminishing the fear of crime, which in turn enhances their vulnerability to criminal victimization (Van Dijk and Steinmetz, 1983). Such an understanding is similar to the argument often proffered that artificial lighting increases people's routine activities in their surrounding environment by lessening perceptions of victimization risk (Keane, 1998; Mesch, 2000; Welsh and Farrington, 2004). Concomitantly, by acting to entice people away from their homes, the natural illumination provided by a full moon may ultimately leave a greater number of residences susceptible to crimes such as burglary (Hough, 1987). One must also recognize that moon illumination may increase criminal behavior beyond the supplying of viable targets by heightening criminality among those venturing out into the community.

Finally, muted lighting as furnished by a full moon may result in the diversification of outdoor type crimes such as drug dealing and prostitution that necessitate the solicitation of costumers. Engaging in these types of activities may not only increase a person's chance of becoming a victim, but also opportunities for others to identify and report crimes to the police. It is important to keep in mind that an increase in the reporting of crimes through identification of criminal behavior due to enhanced lighting may not necessarily result in the identification of the perpetrator (Welsh and Farrington, 2004). Although the natural light furnished by a full moon may offer the lighting necessary to access a target, it may still be dim or soft enough to obscure the identity of the offender.

Our findings also have implications for research that focuses specifically on the relationship between the physical environment and crime. By theorizing that criminal activity occurring outdoors at night might be impacted by moon illumination, we took another small step toward answering the call for more thoughtful analyses on the relationship between the physical environment and crime. Environmental criminology emphasizes how the physical environment shapes the amount of crime we experience in society (Andresen, 2014). Because our analysis reveals a positive effect of the intensity of moonlight on outdoor crime, we believe that social scientists studying crime can benefit by explicitly incorporating both natural and artificial illumination along with other aspects of the physical environment into their empirical studies of crime. However, such an emphasis on the physical environment is going to necessitate that researchers reorient themselves away from their often myopic focus on the effect of social factors on criminal activity.

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