Assessing the Incapacitative and Deterrent Effects of Oleoresin Capsicum During Resistive Encounters with the Police*

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Because of public concern about the possible health risks associated with exposure to oleoresin capsicum (OC) and its potential for misuse, there is a need for careful, unbiased assessment of its utility for law enforcement. This paper tests whether OC reduces the level of violence against police and assess how effective OC is at incapacitating resistive and assaultive suspects in one jurisdiction. The first analysis employs a quasi-experimental design—the interrupted time series—to test whether the introduction of OC into the Baltimore County, Maryland, Police Department deterred assaults on police officers. The results suggest that it had a statistically significant deterrent effect on the level of violence against police, reducing assaults on officers an average of about 3.2 per month. The second analysis shows that overall OC is effective 70 to 85 percent of the time (depending on how "effectiveness" is defined). Multivariate regression models, however, suggest it is less effective when suspects are on drugs, when they are heavier, when they are "middle-aged", and when OC is discharged from longer distances. Suspects under the influence of alcohol appear to be somewhat *more* susceptible to the effects of OC, while the results for mentally disturbed persons are mixed. Suspect height, sex, and race were statistically unrelated to effectiveness.

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There are two main research questions addressed in this paper: (1) Did the introduction of OC spray into the Baltimore County Police Department deter assaults on officers over time? and 2) how effective is OC spray at incapacitating resistive and assaultive suspects? To answer the first question we utilize a quasi-experimental design, the interrupted time series, to estimate the impact of OC spray on assaults against the police. To address the second question, we develop alternative measures of OC effectiveness and use multivariate regression models to determine whether the effects vary by suspect characteristics and other situational factors (this analysis begins on page 14).

PART I. ASSESSING THE DETERRENT EFFECTS OF OC

Several reports have attributed to the adoption of personal issue OC[1] aerosols significant reductions in the use of physical force between police officers and suspects, officer-suspect injuries, and excessive force

[1] Oleoresin capsicum is a naturally occurring compound derived from hot peppers that acts as an inflammatory agent, causing swelling of the eyes and breathing passages. Reported advantages of OC over other chemical agents such as Chloroacetophenone (CN) and o-chlorobenzylidene malononitrile (CS)--chemical irritants that cause tearing and respiratory discomfort--are that it works more rapidly than CS/CN, has fewer cross-contamination problems, is easier to neutralize, is effective on dogs, and is more effective

complaints (see, e.g., Gauvin 1994; IACP 1995; Lumb and Friday 1997; Morabito and Doerner 1997). Unfortunately, the evidence for these effects is largely anecdotal or based on limited statistical analyses. Further, the only major study of OC to suggest a reduction in the incidence of assaults on officers following its adoption was carried out in the Baltimore County, Maryland, Police Department (BCoPD) by the International Association of Chiefs of Police during 1993-94 (IACP 1995). The IACP study compared nine months of post-OC assault data to comparable nine-month periods from the three immediately preceding years. Although the study noted an already declining trend in the number of assaults prior to the introduction of OC, it was suggested that the introduction of OC accounted for the post-intervention decline in assaults on officers (p. *vii*). Such a conclusion may be premature, however, as the decrease in the number of assaults from one period to the next might have been due to the already declining trend in assaults and/or to chance variation in the series (see Figure 1B).[2] Essentially a one-group pretest-posttest design, the IACP study may be limited by other confounding factors as well, such as the effects of history and regression to the mean (Campbell and Stanley 1966). Consequently, it is possible that the observed decrease in the number of assaults might have occurred even without the introduction of OC spray.

The one-group pretest-posttest design is known to suffer from a number of potential threats to internal validity (Campbell and Stanley, 1963). Typically, these designs involve some initial process of observation or measurement followed by exposure to an experimental variable or event, and a subsequent period of observation or measurement. Any differences in the "before and after" measurements are then attributed to the exposure or event. A number of plausible rival hypotheses, however, may explain the observed differences between the pre- and posttest periods when this design is utilized. For instance, other change-producing events may have occurred in addition to exposure to the experimental variable (i.e., *history*). This rival hypothesis becomes more likely the greater the amount of time between the first and subsequent observation period. A second confounding explanation that might account for observed differences is statistical regression or *regression toward the mean*. For example, if a police department adopted OC during a period when it was experiencing a high number of assaults on officers, one would expect to observe a subsequent decrease in assaults even without the introduction of OC.

Because the one-group pretest-posttest design fails to control for the confounding effects of history, maturation, testing, instrumentation, and statistical regression (Campbell and Stanley, 1963:8), we are unable to know with any degree of certainty the impact OC has had on the use of force between the police and the public, rates of officer and suspect injury, and the number of excessive force complaints.

This part of the paper examines the deterrent effects of the introduction of OC on assaults against police officers in the Baltimore County, Maryland, Police Department. To overcome most of the threats to internal validity that have characterized previous evaluations of OC, the current study employs a quasi-experimental design, the interrupted time series. The strengths of this design are in its ability to control for the effects of regression to the mean, selection, mortality, maturation, and testing, (Campbell and Stanley, 1963:40-42)[3], thus allowing for greater confidence in any observed differences between the pre- and post-intervention periods.

DATA AND METHOD

Data for the analysis were obtained from the Baltimore County Police Department.[4] The data include information on 917 assault and battery[5] incidents (hereafter referred to as assaults) that occurred from

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with mentally disturbed individuals and those intoxicated on alcohol or drugs (Edwards, Granfield, and Onnen, 1997; Law Enforcement Options, 1995:7).

[2] The IACP study examined monthly counts of assaults on officers. The monthly counts show a clear downward trend throughout the series that is much less pronounced than observed in the weekly data displayed in Figure 1.

[3] The primary weakness of the design is the potential effect of history, but as Campbell and Stanley (1963:39) note, "the plausibility of *history* as an explanation . . . depends upon the degree of experimental isolation which the experimenter can claim." We address the potential rival hypotheses associated with history later in the paper.

[4] Baltimore County has a population of approximately 695,000 residents in an area of 612 square miles. The county combines urban, suburban and rural environments. The Baltimore County Police Department

January 1, 1991 through March 31, 1994, and information on 570 OC spray incidents[6] occurring from July 12, 1993 through December 31, 1995.[7] To study the effect of the introduction of oleoresin capsicum[8] on the number of assaults on police officers, we utilize a quasi-experimental design, the interrupted time series. Although quasi-experiments use both control and experimental groups, unlike in true experimental designs there is no random assignment. Consequently, the groups are unlikely to be equivalent at the initiation of the research study, thus allowing for a greater number of rival explanations for the observed differences. Although true experimental designs are desirable in any research effort, they are often impractical to implement in real-world applications, the present study not withstanding. Nevertheless, the time series method is one of the strongest quasi-experimental designs in terms of ruling out rival explanations (e.g., regression to the mean, selection, mortality, maturation, and testing),[9] and is therefore preferable to many other designs (see Campbell and Stanley 1966:37-43).[10]

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has sole responsibility for delivery of police services to county residents. The department employed about 1,500 officers at the time of the study, 80 percent of whom were assigned to the Field Operations Bureau.

[5] These data represent incidents in which suspects were *charged* with assault and battery, but not necessarily convicted on that charge. Note that in Maryland, officers can charge suspects with assault and battery for relatively low-level physical contact, e.g., grabbing, pushing, pulling, or spitting. Thus, it may be conceptually more useful to consider the present study an analysis of the deterrent effects of OC on suspect resistance (see, e.g., Adams 1995:81).

[6] It is interesting to note the declining trend in reported OC use starting in May, 1994. Although this could be due to a decrease in reporting practices, an increased reluctance on the part of officers to use OC or some other reason, it is possible that OC use declined because of increased public compliance with police instructions. The BCoPD recently recorded the lowest reported OC use for a quarter--January 1 to March 31, 1997--since adopting the product.

[7] The BCoPD requires officers who use OC to complete an OC incident form along with a departmental incident report as soon as practical after the conclusion of the event. Copies of the first 174 OC incident forms were obtained from the International Association Chiefs of Police, who obtained them as part of an evaluation of the adoption of OC by the BCoPD (see IACP, 1995). The remaining 396 incident forms were collected directly from the BCoPD.

[8] The OC product used by the BCoPD consisted of a five-percent solution with a "cone" delivery system (i.e., fog as opposed to stream or foam). The department authorizes the use of OC following verbal commands and prior to hands-on tactics.

[9] As mentioned previously, the primary weakness of the interrupted time series method is its failure to control for history effects (Campbell and Stanley 1963:39). Thus, it is important to discover whether any other changes were taking place in the BCoPD coterminous with the intervention. In January, 1992 there was an effort to reduce officer use of force and brutality complaints within the Essex command (one of nine precincts), but this occurred well before the introduction of OC in July, 1993. There also was a hiring freeze beginning in the Spring of 1992 that reduced the number of personnel from 1,580 to 1,482 in 1993, a decrease of 6.2 percent. Neither process likely offers an explanation for the observed decrease in assaults following the intervention point of October, 1993. Finally, in January, 1996, a new Chief redirected the department more toward enforcement and administrative activities, but this occurred well after the period under study.

[10] Although the time series method controls for a number of important rival hypotheses, the design can be strengthened by including one or more "control series", allowing for greater confidence in inferences drawn from the analysis. For example, if a neighboring jurisdiction that did not experience the intervention also exhibited a significant increment or decrement post-intervention drop in the outcome of interest, one is hard pressed to conclude that the reason the jurisdiction that experienced the same pattern was due to the intervention. One could also examine additional sets of variables unlikely to be affected by the intervention to see if they exhibit the same trend as the series of interest. If they are divergent, one's confidence that the intervention had an impact is increased (McDowall, Loftin, and Wiersema, 1996). Therefore, until additional studies are conducted in different jurisdictions the results of the present analysis should be viewed cautiously.

The Interrupted Time Series Model

The impact of an event or intervention in an interrupted time series analysis can be represented by a dummy variable or step function, I_t, coded 0 prior to the intervention and 1 thereafter. This step function is typically specified when the impact is believed to be abrupt. Other functions can be specified when an impact is hypothesized to be gradual, and both abrupt and gradual interventions may be permanent or temporary.[11]

Given that the BCoPD trained and issued OC to all officers over a five-month period (mid-July through mid-December, 1993), hypothesizing a gradual-permanent impact on the number of assaults on officers is reasonable. Although the specification of a gradual impact likely provides a better approximation of the effect of the intervention, in practice it often is difficult to empirically separate a gradual-permanent effect from an abrupt-permanent effect (McDowall, Loftin and Wiersema, 1996:387). Since gradual impacts are often well represented by specifying an abrupt intervention, we use a simple 0/1 coding to represent the effect of the introduction of OC spray on the number of assaults.

Another issue in developing an interrupted time series model involves specification of the intervention date. This can be controversial for processes that have a clear intervention point, such as the passage of a law, as it is difficult to know when the law actually begins to influence behavior. Since the intervention in this study occurred over five months, specifying when the intervention began affecting behavior is even more problematic. One possibility is to estimate effects using several different intervention points and then selecting the intervention date based on the largest estimate (Britt, Bordua, and Kleck 1996). Although this process "might generously be called 'exploratory analysis'", the results are "quite uninterpretable" (McCLeary and Hay 1980:143; see also Campbell and Stanley 1966:42 and McDowall et al. 1996:385-386).

Preferring, therefore, a confirmatory approach, we specify ahead of time an intervention date based on the distribution of the reported frequency of OC use. Examining Figure 1A, we see that there were few applications of OC during July 1993, the month when officers began to be issued personal OC canisters. The numbers of sprays then steadily increase through October, but do not exceed a value of 16 prior to the end of the five-month intervention period. Thus, unable to determine the actual proportion of officers trained and issued OC spray over time, we chose the first week with any days falling in October, 1993 as our intervention date (week 143, represented by the vertical line in Figure 1B). This seemed a reasonable choice, as it is likely that by this time half or more of the officers on the force were carrying OC.[12]

Figure 1 About Here

To assess the impact of the intervention, we develop an ARIMA[13] or *A*uto*R*egressive, *I*ntegrated, *M*oving *A*verage model (see McDowall et al. 1980 for the application of ARIMA models to interrupted time series; see McCLeary and Hay 1980 for a more general presentation). The first step in developing an ARIMA model, *identification*, requires an examination of the raw time series and an examination of the

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[11] The abrupt permanent model has a single coefficient, ω, that measures the change in the series mean following the intervention. A gradual permanent model includes a second parameter, δ, that measures how quickly the series reaches its final level.

[12] Choosing an incorrect intervention point is not a major concern as it should yield a conservative estimate of the impact of an intervention. Further, the effect should become smaller the further one moves away from the "true" intervention point (McDowall, Loftin, and Wiersema, 1996:386).

[13] The ARIMA procedure is the most popular model building strategy among time series methods. Although more demanding computationally because it uses maximum likelihood estimation, it gives better results than other methods (McDowall et al., 1980:12-13; SPSS, 1993:3,125).

autocorrelation function (ACF) and partial autocorrelation function (PACF)[14] estimated from the series. This allows one to determine whether the series requires differencing, is moving average or autoregressive, and the order of the process.

Figure 1B shows the distribution of assaults on BCoPD officers by week, while Figure 2 presents the ACF and PACF for the raw series. The ACF in Figure 2A exhibits a rough pattern of decay, suggesting that the series is the realization of a stationary process that will not have to be differenced. Further, the decaying lag structure indicates an autoregressive process and, therefore, an ARIMA(p,0,0) model for this time series. The PACF in Figure 2B exhibits two statistically significant spikes at the first and second lags, which suggest an ARIMA(2,0,0) model. Note, however, that because the second spike just barely achieves statistical significance, the lag pattern is not inconsistent with an ARIMA(1,0,0) or first-order autoregressive process.

We estimate an initial univariate ARIMA model that includes the autoregressive parameters ϕ_1 and ϕ_2. The autoregressive coefficients must lie within the "bounds of stationarity" for a second-order autoregressive process,[15] and they must be statistically significant before the revised model can be accepted. Furthermore, the ACF and PACF lags of the residuals are expected to be zero (white noise) if the model is adequate (although it is expected that one or two lags may be statistically significant by chance) (McDowall et al. 1980:33,47).

Figure 2 About Here

Results for the ARIMA(2,0,0) model (not presented) show that the second autoregressive parameter, ϕ_2, fails to achieve statistical significance at conventional levels ($\phi_2 = 0.144$, p = .07). Therefore, this model is rejected and a first-order autoregressive model is estimated. The estimates from this revised model are presented in Panel A of Table 1. We see that the autoregressive parameter is statistically significant (b = .300; p = .0001) and lies within the bounds of stationarity. Examination of the ACF and PACF of the residuals for the model, presented in Figure 2C and 2D, show that the errors are not statistically significant from zero (Q = 21.08; p = .63).[16] We therefore tentatively accept the model.

Table 1 About Here

Next the intervention parameter ω_0 is added to the model to test for the effect of the introduction of OC on the number of assaults against BDCoPD officers. These results are shown in Panel B of Table 1. Again we see that the autoregressive parameter is within the bounds of stationarity and is statistically significant (b = .259; p = .0006). The ACF and PACF of the residuals for the model (not shown) are virtually identical to those of the univariate model, and the Q statistic is not statistically significant (p = .82)

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[14] ACF(k) is a measure of the correlation between Y_t and Y_{t+k} and ACF(1) is the correlation coefficient estimated between the time series (lag-0) and its first lag (lag-1). PACF(k) is a measure of correlation between series observation k units apart after the correlation at intermediate lags has been controlled or partialed out (McDowall,et al., 1980:24,41).

[15] The bounds of stationarity for the parameters ϕ_1 and ϕ_2 are:

$$-1 < \phi_2 < +1$$
$$\phi_1 \text{ and } \phi_2 < +1$$
$$\phi_2 - \phi_1 < +1.$$

[16] We use the Q statistic to test whether the entire residual ACF is different from a white noise process. This is given by the formula

$$Q(df)=N \sum_{i=1}^{k} [ACF(i)]^2 \text{ with } df = k - p - q.$$

The Q statistic is distributed chi-square with degrees of freedom determined by the length of the ACF (k) and the number of autoregressive and/or moving average parameters in the model (see McDowall et al., 1980:49 for an example).

indicating the model residuals are not different from white noise. Importantly, the intervention parameter ω_0 is statistically significant, suggesting that the introduction of OC spray reduced assaults on officers an average of almost one per week or about 3.2 per month ($b = -.804$; $p = .0056$). Since there were on average approximately 21 assaults per month, OC reduced the number of reported assaults by about 15 percent.

Although this is a moderately large effect, recall that the post-intervention period is relatively short (28 weeks). It is conceivable that an even greater deterrent effect might be observed with a longer post-intervention period. First, with greater OC spray use the pool of offenders who have been sprayed previously would grow, and we would expect these individuals to be less inclined to resist police during subsequent encounters (as well as those who observe such encounters). Second, with an extended period of OC use there would be more "word of mouth" communication on the street about the extremely unpleasant effects of OC spray, and therefore some offenders may be less likely to resist police even though they have no direct experience with OC spray.

On the other hand, it is possible that the deterrent effects might diminish in the long run with the number of assaults on officers returning to previous levels, other factors being equal. For instance, repeated exposure to OC may result in a certain degree of tolerance to its effects. Therefore, suspects who have been sprayed previously may become less deterred by its threatened use. That a second exposure to OC might be better tolerated is one reason why some police departments require officers to be sprayed prior to being issued OC. It is believed that a previous exposure will enable officers to avoid panic and continue to function when sprayed by an assailant or subjected to OC cross contamination.

It is also possible that as OC use by police becomes more common, suspects may begin to take protective measures such as wearing brimmed hats low over the face, eyeglasses, bandannas, and so forth. In any case, given the uncertainty regarding the long-term impact of OC on the incidence of the use of force, assaults on officers, and other outcomes such as officer/suspect injuries and excessive force complaints, we encourage police administrators with appropriate data to collaborate with researchers to study the long-term trends and outcomes associated with OC use.

DISCUSSION

Oleoresin Capsicum has been widely adopted by law enforcement agencies in the United States and used in thousands of encounters with suspects. It has a number of reported advantages over other chemical agents, and generally is favorably viewed by line and administrative personnel as a relatively safe and effective force alternative. Its adoption has not been without controversy, however, primarily because of concerns about its potential for misuse by police and health risks due to exposure (ACLU 1993; Associated Press 1997; Derbeken 1997).

For example, it has been reported that OC may have carcinogenic and mutagenic potential in humans and that exposure to OC can cause breathing difficulties among asthmatics, corneal damage, vocal cord damage, and skin irritation (Brown 1997; Doubet 1997; Petty 1997). More seriously, OC exposure has been implicated as contributing to a number of police in-custody deaths (ACLU 1993; Steffee et al. 1995). Other evidence, however, suggests that the health risks due to OC exposure are minimal (Brown 1997; Petty 1997), with the probability of experiencing serious side effects being as low as 1 in 6,250 (Keenan 1997). Further, coroners' reports indicate that factors other than OC exposure, such as drug intoxication, positional asphyxia, and preexisting health conditions are the major contributing factors associated with in-custody deaths (Granfield, Onnen, and Petty 1994; Petty 1997; Steffee et al. 1995).

Police use of OC on non-violent activists in Humboldt County, California, in 1997 raised concerns about the potential for misuse of chemical irritants by law enforcement officers (Derbeken 1997), as did other encounters that year (see, e.g., Associated Press, 1997). As a result, citizens' groups have attempted to restrict law enforcement use of pepper spray (Associated Press 1997; Derbeken 1997), almost succeeding in Berkeley, California, when in 1997 the City Council only narrowly defeated a bill that would have banned BPD officers from using the chemical irritant (Coile 1997; Lee 1997).

Although we do not address the above issues, we argue that well designed, unbiased, empirical research is important for assisting law enforcement administrators, the public, and governments in making informed decisions regarding the utility and safety of OC spray. Such studies are critical at this time because so many law enforcement agencies have already acquired OC (McEwen and Leahy 1994; Pate and

Fridell 1993; Reaves and Goldberg 1996; Reaves and Smith 1995), and because the product is likely being used in a substantial fraction—perhaps most—of the forceful encounters with the public (depending on where it is placed on departments' use-of-force continuums). Unfortunately, although a number of analyses suggest that the adoption of OC provides a number of benefits to both the police and the public, such as reductions in the use of force, injures, and excessive force complaints (Gauvin 1994; IACP 1995; Lumb and Friday 1997; Morabito and Doerner 1997), rigorously designed studies of such claims are lacking.

The current study contributes to the previous research on the utility of OC spray by employing a more rigorous statistical test of its deterrent effects on assaults on police officers. The results suggest there was a significant reduction in the number of assaults on officers following its adoption (15 percent or about 3.2 assaults per month). While this finding likely adds to the appeal of OC as a less-than-lethal force alternative, the results should be viewed as being preliminary. First, it is unknown whether the number of assaults on officers will continue to decline with further use of OC by the BCoPD, whether the current level will be maintained, or whether the number of assaults will eventually return to pre-intervention levels. One argument for a possible diminishing impact of OC on resistive and assaultive behavior is that challenges to police authority may return to previous levels once OC becomes more of a known quantity among those whom the police must confront (Kock and Rix, 1996:6). Therefore, future tests of OC's deterrent effects should utilize longer post-intervention observation periods than used in the present analysis. Second, it is important to determine whether the adoption of OC by law enforcement agencies in different jurisdictions produces similar results. Successful replications will provide evidence for the generalizability of the findings from the current study.

In sum, the results of the analysis suggest that OC provided a tangible benefit to the BCoPD in that it reduced assaults on officers following its introduction into the department. Thus, this is one factor (among many) that should be considered in weighing the costs and benefits associated with OC use in law enforcement. It also is conceivable that the reduction in assaults may in turn reduce the number of injuries to both officers and suspects, as the application of OC may prevent some encounters from escalating to higher levels of force.[17] Although we do not have the requisite data to tests this hypothesis, such a finding would add to the appeal of oleoresin capsicum as a force alternative.

PART II. ASSESSING THE INCAPACITATIVE EFFECTS OF OC

Police have long sought safe and effective means of subduing resistive and combative suspects. Although a variety of technologies have been developed toward this end (Robin, 1996), perhaps the most effective less-than-lethal tool to be adopted by police departments for encounters with suspects is oleoresin capsicum (OC) or "pepper spray". Attesting to its popularity—and presumably its effectiveness—several national surveys indicate that OC has been widely adopted by law enforcement agencies in the United States over the last decade (McEwen and Leahy 1994; Pate and Fridell 1993; Reaves and Smith 1995).

The adoption and use of OC spray by police, however, has not been without controversy. Concerns have been raised about the appropriateness of offensive tactical use of OC on subjects posing no danger to themselves or others (e.g., passive resisters), and the potential for disparate use of OC on minority groups (ACLU 1993; Associated Press 1997; Derbeken 1997; Phillips 1994).[18] Much of the controversy, though,

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[17] It is also possible that the introduction of OC into a department could have a "net-widening" effect, i.e., that once officers have the option of using OC, they may be more likely to physically engage suspects by spraying them rather than by reasoning with them, employing verbal tactics, waiting for backup, and so on (especially if policy allows the use of OC prior to hands-on tactics). This could lead to an *increase* in the incidence of use of force and the number of injuries (probably minor) to suspects and officers following the introduction of OC into a department. Well-designed studies on the impact of OC on suspect and officer injuries have yet to be conducted.

[18] The ACLU (1993:23) report was unable to conclude with certainty that evidence of racial bias exists in the use of OC. An analysis of a random sample of incidents in Buffalo, NY, found that OC was used on African-American and Caucasian suspects in proportion to the rate at which they were arrested in the population (Phillips 1994:16-17). This is a methodologically difficult issue to research, however, and a carefully designed empirical study is required prior to reaching any conclusions regarding the unbiased or discriminatory use of OC.

has focused on the potential health risks associated with exposure to OC. It has been reported that OC can cause skin irritation, corneal and vocal cord damage, breathing difficulties among asthmatics,[19] and that it might have carcinogenic and mutagenic potential in humans (Brown 1997; Doubet 1997; Petty 1997). Furthermore, OC exposure has been implicated as a contributing factor in a number of police in-custody deaths (ACLU 1993; Steffee et al. 1995).

Reviews of the medical literature, however, suggest that health risks due to OC exposure are minimal (Brown 1997; Petty 1997, Ruddick 1993), with one estimate of the chance of experiencing serious side effects being as low as 1 in 6,250 (Keenan 1997). Importantly, it has been reported that factors other than OC exposure, such as drug intoxication, positional asphyxia, and preexisting health conditions are the major contributors to in-custody deaths (Granfield, Onnen, and Petty 1994; Petty 1997; Steffee et al. 1995).

Since legal challenges and debates over police use of OC are likely to continue, well designed evaluations of its utility are crucial, requiring unbiased assessments of whether OC's benefits outweigh its potential risks. Unfortunately, there have been few rigorous field studies of OC, making an assessment of its overall utility difficult. As Pliant (1993:5) notes, the lack of research on OC and "the novelty of OC spray and manufacturers' product claims that range from the credible to the ridiculous, have left many administrators frustrated and confused, not knowing whether their officers should be carrying CS/CN, OC, or nothing at all."

Although a number of factors need to be taken into account in determining OC's usefulness, one important consideration is simply how well it works at incapacitating suspects. If OC does not work as well as expected, then its overall value to law enforcement and the public interest is diminished. On the other hand, if empirical studies demonstrate that OC is effective most of the time, its value is substantially enhanced and police should continue to use it, assuming other health and safety factors are not a significant issue.

Most previous evaluations of OC indicate it is effective between 85 and 100 percent of the time (see, e.g., Gauvin, 1994; IACP 1995; Kingshott, 1992; Phillips, 1994; Robin, 1996). A recent analysis of 325 OC spray incidents by Morabito and Doerner (1997), however, found that OC was effective only 73 percent of the time, suggesting that it may not work as well as previously thought. Although Morabito and Doerner did not offer explanations for the poorer performance of OC observed in their study, some logical possibilities include variation across jurisdictions in product strength and composition, training methods, types of dispersal systems (e.g., fog vs. stream), the proportion of suspects under the influence of certain drugs, whether policy requires a verbal warning prior to using OC, and the point on the use-of-force continuum that policy dictates when officers are authorized to use OC.[20]

Another factor that likely accounts for some of the discrepancy in findings across studies, however, is that evaluators have simply used different criteria for assessing OC effectiveness (Phillips, 1994). For example, using *full and immediate incapacitation* of a suspect as the criterion for successful outcomes would produce more conservative estimates of effectiveness than, say, defining OC effectiveness as having had *some effect* on suspects. Unfortunately, in most studies effectiveness is not defined, and even when it is, it is often too vague to give a precise sense of its meaning.[21] Given the lack of explicit measures and the substantial variance in rates of effectiveness reported in the literature, it is clear that further study is needed to obtain more precise estimates of OC's incapacitative effects (Phillips, 1994:17; Pliant, 1993:5).

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[19] The RCMP exposed five asthmatic members from their Division E to OC. None of the officers, however, experienced side effects as a result of the exposure (Boner 1994:7). Although suggestive, a larger experimental study would be required to determine the effects of OC on asthmatics.

[20] Some departments allow officers to use OC on suspects prior to the use of hands-on tactics, while others have more restrictive policies regarding its use, e.g., following hands-on tactics. One would expect a higher rate of OC "failures" in departments with more restrictive policies because the incidents in which it is used will tend to be more serious in nature, e.g., encounters with emotionally or mentally disturbed suspects, suspects under the influence of drugs, and so on.

[21] For instance, Morabito and Doerner (1997:690) state that OC spray "was considered effective if it induced the expected physiological effects and enabled the officer to take the suspect into custody without further incident." There is no description of the "expected physiological effects", nor what "without further incident" means, making it difficult to asses their criteria of effectiveness.

Based on survey data from 878 OC spray incidents, the current study expands upon the previous research in several ways. First, we employ two explicit but different measures of OC effectiveness, deriving one indicator from officer reports of suspect behavior after exposure to OC and another based on whether officers thought OC assisted them in making the arrest. Second, to more closely approximate the actual range of behavioral response to OC exposure, we develop outcome measures that move beyond the simple dichotomous outcomes employed in most previous research (for an exception, see Williams, 1994). Third, we examine the effects of OC on suspects reported by officers to be under the influence of drugs as well as those reported to be mentally disturbed or under the influence of alcohol. Fourth, we employ a number of multivariate regression techniques to estimate the combined and independent effects of substance use, mental states, suspect characteristics and other factors on OC effectiveness.

DATA AND METHOD

Data for this analysis are also from the Baltimore County Police Department (BCoPD). OC spray was introduced into the department and issued to all officers over a five-month period in 1993.[22] The product selected and used throughout the study period was a three ounce container of five-percent OC concentration with a fog delivery system, rated at 2,000,000 scoval heat units (plain clothes officers had the option of carrying a .42 ounce pen unit). Officers were authorized to deploy OC when suspects failed to comply with verbal instructions and officers were about to utilize hands-on tactics to defend themselves against active hostile resistance or after aggressive resistance to arrest was anticipated or occurring.

As part of an evaluation of the introduction of OC into the department, the International Association Chiefs of Police (see IACP, 1995), collected information on OC use from field encounters using a survey instrument that was constructed, pre-tested, revised and filled out by officers in the field. The BCoPD required officers to complete OC incident forms along with departmental incident reports as soon as practical following encounters in which OC was used.

The IACP collected information on 174 OC spray incidents that occurred between July 1993 and March 1994. Copies of the data collection forms were obtained by the authors, coded, and entered into a database. The BCoPD subsequently provided us with an additional 704 reports on OC discharges that occurred between April 1994 and December 31, 1996. In total, there were 878 incidents available for this analysis.

Eliminated were encounters involving crowd situations, animals,[23] misses, and canister malfunctions. In addition, we randomly selected a single observation from multiple officer or multiple suspect incidents to help avoid problems associated with non-independence of observations. These exclusions left 690 spray incidents for analysis.

Measures Of Effectiveness

As mentioned earlier, most previous evaluations of the incapacitative effects of OC sprays have used simple "effective-ineffective" dichotomies. Upon examining the brief narratives from the BCoPD incident forms, however, it was evident that there exists significant variation in human response to OC spray. On rare occasions subjects are not affected at all by OC, while many others are immediately and completely incapacitated by it. Most, however, fall somewhere along a continuum between these two extremes. Some suspects are unaffected for a short time and then succumb, some continue to struggle and resist arrest until physically subdued by officers, while others immediately become complacent and follow instructions of the arresting officer. Obviously, using an effective-ineffective dichotomy fails to capture the full range of human response to OC. To explore how ratings of effectiveness are affected by categorization of the

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[22] Officers received three hours of training that covered where OC can be utilized on the use-of-force continuum; the effectiveness of OC, its make-up, characteristics and advantages; the proper stance, grip and straying technique; the use of verbal skills prior, during and after the use of OC on an individual; decontamination procedures; first-aid procedures; officer safety and officer exposure procedures; signs and symptoms of causes of in-custody deaths and measures to avoid in-custody deaths; and procedures for reporting use of OC on subjects or animals.

[23] Although OC was effective in all but one incident involving dogs in this study, it is important for law enforcement officers to be cognizant that OC has minimal or no effect on aggression-trained dogs placed on attack command (Bonar 1994:5).

behavioral reactions to OC spray, we construct two dependent variables that are dichotomous and a third outcome consisting of five categories, ordered from *totally effective* to *totally ineffective*.

Two questions from the BCoPD incident report form were used for the construction of the outcome variables. The first question asked officers to *describe the actions of the suspect after applying OC*. Responses initially were coded into six discrete categories based on whether suspects were described as being totally incapacitated (28.3%), submissive (42.2%), resistive (13.2%), fleeing (5.1%), combative (6.3%) or unaffected by OC (4.3%). The category *incapacitated* is used to indicate full and immediate immobilization of the suspect. Examples of this kind of reaction include "subject immediately fell to his knees and offered no further resistance" or "suspect laid on ground and did not fight". The category *submissive* is used to indicate less intense reactions to OC spray, but where subjects offered no physical resistance to officers. Examples include "subject was cooperative" and "suspect became passive after being sprayed". The third category, *resistive*, represents suspects who refused to comply with officer demands or were physically uncooperative, but not assaultive or combative (e.g., tensing muscles to avoid being cuffed, pulling away). Suspects who tried to evade offices after exposure are classified as *fleeing*. *Combative* suspects represent those who fought or continued fighting with officers or others at the scene after being sprayed. Finally, suspects who had no observable reaction to OC were classified as being totally unaffected. The second question asked officers *whether suspects were incapacitated enough to ease the arrest*, with responses coded as *Yes* or *No*.[24]

Table 2 displays the three dependent variables used in this analysis. The first dichotomous outcome (OC EASED ARREST?) is based on whether officers thought OC helped them make the arrest, coded 1 if *No* and zero otherwise. The second dichotomous outcome (SUSPECT INCAPACITATED?) is based on the actual behavioral descriptors reported by officers, recoded as 1 for *No* if OC was ineffective (i.e., suspects resisted, fled, fought or were unaffected by OC), and zero for *Yes* if they were incapacitated or submissive after exposure.

-TABLE 2 ABOUT HERE-

As shown in Table 3, the third outcome variable OC EFFECTIVE? was created by cross classifying whether or not OC *eased the arrest* with the (uncollapsed) *actions of the suspect after being sprayed*. Although we could have used just the behavioral descriptors to derive the response continuum to OC exposure, cross classifying it with whether or not it eased the arrest served as a validity check on what officers reported.

Based on officer responses to both questions, OC was classified as: 1) *Totally Effective* (28.2%) when it incapacitated suspects; 2) *Effective* (42.5%) when suspects were submissive after exposure; 3) *Minimally Effective* (14.7%) when suspects resisted, evaded arrest, or fought with officers or others after being sprayed, but OC still helped to make the arrest; 4) *Ineffective* (10.3%) when suspects resisted, fought, evaded arrest and OC did *not* help ease the arrest; and 5) *Totally Ineffective* (4.3%) when officers reported that it had no effect.

-TABLE 3 ABOUT HERE-

Independent Variables

Anecdotal accounts by police officers suggest that mentally disturbed suspects and those under the influence of drugs or alcohol frequently are less susceptible to the effects of OC spray, and therefore are of special concern to law enforcement personnel. Because there have been few systematic analyses of the incapacitative effects of OC on drugged, intoxicated, and mentally disturbed suspects, it is unclear just how

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[24] The original OC incident report form asked officers to indicate whether or not OC helped ease the arrest and to provide a brief explanation. During the data collection period, however, the OC incident report was modified and incorporated the department's standard use-of-force report. The narrative portion was dropped and replaced with a simple "yes-no" check box. Prior to the change responses were coded yes or no based in part on the brief narratives provided by officers. Examples of responses categorized as a *Yes* include "Yes, suspect stopped resisting", "Yes, complied with orders", "Suspect resisted but couldn't see, allowing this officer to gain control", and incidents for which officers simply wrote "Yes". Incidents were coded as a *No* if the officer indicated the application of OC provided no advantage in making the arrest or where officers simply wrote "No" on the report form.

effective OC is on these subjects. Morabito and Doerner (1997:690) did examine, in simple bivariate analyses, the effectiveness of OC on intoxicated and mentally disturbed suspects (but not those on drugs), and found that OC worked about as well on these subjects as in their sample overall (70% and 74%, respectively). OC was found to have a similar rate of effectiveness on suspects thought to under the influence of drugs or alcohol (73.3%) in an analysis of Buffalo Police Department incidents (Phillips, 1994:7), although the number of cases examined was small (only 10 suspects were reported to be on drugs, 26 under the influence of alcohol).

We include in our study officers' perceptions of whether suspects were mentally disturbed, under the influence of drugs, under the influence of alcohol, or in some other state at the time of the encounter (CONDITION OF SUSPECT). The "other" category represents those suspects *not* mentally disturbed or under the influence of drugs or alcohol, and it includes those who were calm, belligerent, resistive, fleeing or combative. As shown in Table 2, 39.5 percent of the suspects were reported by officers to be under the influence of alcohol, 12.6 percent were reported to be under the influence of drugs, and 8.4 percent were thought to be mentally disturbed. Thus, fully 60 percent of the suspects sprayed by officers were reported to be either mentally disturbed, under the influence of alcohol or on drugs.[25]

Analysis by Phillips (1994:7) suggests that OC is somewhat less effective (66.6%) when sprayed from moderate distances (between five and eight feet), and somewhat more effective when sprayed from less than five feet (75.0%) or eight feet or more (71.4%). Others, however, report that OC does not work properly when sprayed from short distances (Jamieson, 1991:3) and that it is "virtually useless" when used by officers close enough for physical contact with arrestees (Morabito and Doerner, 1997:691).

To explore this issue we include an indicator of the distance from the suspect from which OC was sprayed (DISTANCE SPRAYED), coded into *short* (0–2½ feet), *moderate* 3–4½ feet) and *long* (5–20 feet) distances. Sixty percent of the officers discharged their OC canisters from a distance of 2½ feet or less (well below the recommended distance of four to six feet), about a fourth (25.9%) sprayed OC from a distance of 3 to 4½ feet, and 13.9 percent used OC from a distance of 5 feet or more.

Finally, although we are unaware of previous research examining or controlling for the effects of biological factors in modeling OC effectiveness, we include the suspects' sex, race, age, weight, and height. As shown in Table 2, most exposed suspects were male (85.9%), Caucasian (63.2%), about 30 years of age, 176 pounds, and 5 feet 10 inches tall.

RESULTS

Prior to estimating the multivariate models, we examine in Table 4 the unconditional distributions of the three outcome variables (displayed in row 1 for easy reference) and the simple bivariate relationships between the independent and dependent variables. For the bivariate analysis, the variables AGE, WEIGHT, and HEIGHT were recoded into five categories, and the number and percentage of subjects falling into each of the categories are presented in this table.

The dichotomous outcome SUSPECT INCAPACITATED? (listed in column two as *Incapacitated?*) produced an OC success measure of 70.7 percent (incapacitated/submissive), which is lower than all previous evaluations of OC, including the 73 percent reported by Morabito and Doerner (1997). Asking officers whether they thought OC assisted them in making arrests (EASED ARREST?) produced a much higher success rating of OC effectiveness (85.3%). Note, however, that if in using the SUSPECT INCAPACITATED? criteria one were to include those who were *resistive* in the "success" category, the percentage of incidents in which OC is considered effective is nearly identical (84.3%) to that reported for

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[25] In studying the impact of intoxicating substances and mental states on OC effectiveness, it is important to point out that a substantial proportion of suspects were reported to be under the influence of both alcohol *and* drugs, and were sometimes perceived as being mentally disturbed as well. Since it is difficult to isolate the effects of multiple states on the outcome of interest, suspects reported to be under the influence of drugs and alcohol and/or were mentally disturbed were coded as being "On Drugs". Suspects reported as being mentally disturbed and under the influence of alcohol were coded as "Mentally Disturbed". Suspects who were reported to be under the influence of alcohol and were *not* mentally disturbed and *not* on drugs were coded as "Drinking". An earlier analysis of mean effectiveness scores of 480 suspects suggested that OC spray was least effective on drugged suspects, followed by mentally disturbed suspects and intoxicated suspects (Kaminski and Edwards 1996).

EASED ARREST? Neither measure, though, produces an effectiveness rate as high as the 90 to 100 percent most frequently reported in the literature.

-Table 4 About Here-

Examining the effectiveness of OC spray across the categories of the independent variables, we observe that there are no statistically significant differences by suspect race. OC is somewhat more likely to be effective on females than on males across the three outcome measures, but the differences are not greater than expected by chance alone. Statistically significant effects for age, however, are observed. For both dichotomous outcomes we see that OC is more effective on the youngest (14 - 21) and oldest (38 - 66) age groups, and less effective on suspects in the middle-aged categories, suggesting a nonlinear relationship between OC effectiveness and age. A similar pattern can be observed between suspect age and the five-category outcome variable (OC EFFECTIVE?).

The effect of suspect weight is statistically significant only when the criterion is whether or not OC eased the arrest (EASED ARREST?), with effectiveness decreasing slightly from 89.0 percent to 81.3 percent as suspect weight increases from 160 pounds or less to 200 - 350 pounds. Although the effect of weight is not different than expected by chance for the outcome OC EFFECTIVE?, it is interesting to note that the percentage of incidents where OC is Ineffective (IN) or Totally Ineffective (TIN) increase substantially with increases in suspect weight.

Regarding suspect height, we see that OC is more likely to be rated as being Totally Ineffective as suspects become taller (up to six feet). However, the effect of HEIGHT does not obtain statistical significance with any of the outcome variables.

Highly significant results are observed for CONDITION OF THE SUSPECT. Relative to suspects in the "other' category (i.e., those not mentally disturbed or on drugs or alcohol) and the sample overall, there is general agreement across all three outcomes that OC is as effective or somewhat more effective when suspects are under the influence of alcohol. Conversely, when suspects are under the influence of drugs, OC is consistently less effective regardless of the criterion used.

The results are somewhat mixed, however, for mentally disturbed suspects, with OC reportedly being less likely to *ease the arrest*, but slightly more likely to *incapacitate* mentally disturbed suspects, relative to "other" suspects (those not mentally disturbed, on drugs or alcohol) or compared to the sample overall. For the five-category outcome variable OC EFFECTIVE?, OC is substantially more likely to be ineffective (IN) or totally ineffective (TIN) and less likely to be rated as minimally effective (ME) relative to "others" or the total sample.

The overall pattern of results across the three dependent variables for the variable DISTANCE SPRAYED suggest that OC was somewhat less effective when sprayed from longer distances of five feet or greater, but not shorter distances (0 – 2½ ft.) or moderate distances (3 – 4½). The effect, however, does not achieve statistical significance in any of the bivariate relationships examined.

In sum, although the bivariate analysis for mentally disturbed suspects are mixed, regardless of which outcome measure is used OC is less effective on suspects reported to be under the influence drugs. Contrary to expectations, suspects under the influence of alcohol appear to be as susceptible or somewhat *more* susceptible to the effects of OC compared to those in the "other' category (i.e., those not under the influence of alcohol, on drugs, or mentally disturbed) and the sample overall. Effectiveness is significantly related to age across all three outcome variables, with OC being somewhat more effective on younger and older suspects than on suspects of "middle" age. Evidence of an association between effectiveness and suspect weight was less consistent, as a statistically significant inverse relationship was found only for the criterion of whether or not OC eased the arrest. Finally, no statistically significant effects for the remaining variables RACE, SEX, HEIGHT, or DISTANCE SPRAYED were observed.

To examine the combined and independent effects of the independent variables on the three outcome measures we next estimate a number of multivariate regression models. Note that to control for potential suppressor variables we include all of the explanatory factors that were examined in the bivariate analysis, regardless of their level of statistical significance (Pedhauzer 1982:104-105).

Multivariate Analysis

Although we argue that dichotomous measures of OC effectiveness are undesirable in that they fail to adequately represent the full continuum of behavioral response to OC exposure, dichotomous outcomes are appropriately and easily analyzed using logistic regression (Hosmer and Lemeshow, 1989).[26] Deciding on a method of analysis becomes more complicated, however, when considering the third outcome variable OC EFFECTIVE?, which consists of five categories ordered from Totally Effective to Totally Ineffective. A common approach to analyzing ordinal dependent variables with five or more categories is to treat them as if they were interval (Demaris, 1992:77). The categories are simply numbered sequentially and then analyzed using ordinary least squares regression. Although the pros and cons of this practice have been debated in the statistical literature, it is frequently considered inappropriate (Aldrich and Nelson, 1984; Liao, 1994) because the application of linear regression models to ordinal outcomes has produced misleading results (Long, 1977:115). The primary appeal of using the linear regression model with ordinal outcomes, though, lies in its ease of interpretability and is therefore considered here.

While multinomial logistic regression can be used to appropriately model ordered outcomes, it does not take into account the ordinal nature of the dependent variable, and thus fails to take full advantage of all the information available in the outcome (Liao, 1994:37). The ordered logistic regression model, developed explicitly to model categorical outcomes that are ordered, is preferable if the assumptions of the model hold. As will be seen in the analysis section below, however, the ordered logit model fails to meet the proportional odds assumption (see Long, 1997:140-145 for a discussion). We therefore estimate a multinomial logistic regression model as well.

Table 5 presents the results of four regression models. The first two are binary logit models applied to the two dichotomous outcomes SUSPECT INCAPACITATED? and OC EASED ARREST?, both coded 1 if OC was *not* effective and zero otherwise. Models 3 and 4 estimate the effects of the independent variables on the five-category dependent variable OC EFFECTIVE?, which ranges from 1 (Totally Effective) to 5 (Totally Ineffective). Model 3 is estimated using the ordered logit model, while Model 4 is estimated using the linear regression model. Effects that are statistically significant at the .05 level or below are shaded to ease comparisons across models. To conserve space only the odds ratios in the logit models and unstandardized coefficients in the linear regression model and associated *p*-values are reported.

Examining the results of the binary regression models first, we see that using different measures of effectiveness produce substantively different results. In Model 1, which uses the more conservative measure of OC effectiveness SUSPECT INCAPACITATED? (i.e., the suspect was totally incapacitated or submissive), the odds of OC failing to incapacitate suspects increase when it is sprayed from longer distances (5 - 20 feet) relative to medium distances (3 – 4½ feet), controlling for the other variables in the model. Note, however, that the odds of OC failure did *not* increase significantly when sprayed from shorter distances (0 – 2½ feet) relative to medium distances.

Age also is significantly associated with the odds of failure holding the other variables in the model constant, though not in a simple linear fashion. Specifically, the odds that OC incapacitates suspects decrease with increases in age, but only up to a point, i.e., the statistically significant quadratic term AGE^2 indicates that with further increases in age OC spray again attains effectiveness. This suggests that OC is more effective with younger and older suspects, but less effective with suspects of "middle age", a heretofore unexplored finding that should be examined further in future studies.

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[26] The logistic regression model predicts the log-odds of an observation being in one category of the dependent variable *versus another* (the reference category), given a set of explanatory variables. The logit coefficient estimates the change in the log-odds of the dependent variable given a unit increment or decrement in a continuous independent variable, holding constant the effects of other variables in the model. Ordinal and nominal explanatory variables are interpreted as the change in the log-odds of the dependent variable given a specific category of the explanatory variable, controlling for the other variables in the model. The results are then interpreted as how much the log-odds of an outcome change given a unit change in an explanatory variable. Exponentiating the logit coefficients allows the results to be interpreted as changes in odds rather than log-odds. Note that odds ratios with values less than one indicate an inverse relationship, i.e., a *reduction* in the odds that the outcome of interest will occur, while odds ratios greater than one indicate a positive relationship, i.e., an *increase* in the odds that the outcome of interest will occur.

Relative to suspects who are not mentally disturbed or under the influence of drugs or alcohol (i.e., the "Other" category), the odds that OC fails to incapacitate suspects under the influence alcohol *decrease*. In other words, intoxicated suspects appear to be *more* susceptible to the effects of OC than "others" in the sample. The variable DRUGS, however, has the opposite effect. Specifically, the odds that OC fails to incapacitate suspects increase significantly when they are on drugs, relative to when they are not on drugs or alcohol or mentally disturbed.

A somewhat different picture emerges when examining the estimates presented in Model 2, which uses as its dependent variable whether or not OC eased the arrest (OC EASED ARREST?). Unlike in Model 1, the distance from which OC is sprayed is statistically unrelated to effectiveness, as are the effects of alcohol and age (although age is nearly significant).[27] The odds that OC fails to ease the arrest increase significantly, though, when suspects are mentally disturbed relative to when they are not mentally disturbed or on drugs or alcohol. The effect of drugs remains statistically significant in this model, suggesting that the odds of OC failing to ease the arrest more than double when suspects are on drugs compared to when they are not on drugs, intoxicated, or mentally ill.[28]

The remaining variables HEIGHT, WEIGHT, RACE, and SEX are statistically unrelated to the odds of OC failure in both models. Note that unlike AGE, the variables HEIGHT and WEIGHT remained statistically insignificant even when modeled nonlinearly.

In sum, the binary logit analysis suggests that distance, the age of the suspect, and alcohol and drug use are related to OC effectiveness in Model 1, while only drugs and whether suspects are mentally disturbed are associated with effectiveness in Model 2. This indicates that researchers can obtain substantively different results regarding the effects of explanatory factors when using different criteria to assess the incapacitative effects of OC sprays.

-Table 5 About Here-

In Model 3 we estimate an ordered logistic regression model[29] to examine the effects of the independent variables on the five-category outcome variable OC EFFECTIVE?. For this model, we assume that the outcome represents an underlying continuous, latent variable (see Long, 1997:127-135) of suspect susceptibility to the effects of OC exposure. The results are similar to those reported in Model 1 in that estimates for DISTANCE (5-20 feet), AGE, DRINKING, and ON DRUGS are statistically significant, in the same direction, and of similar magnitude. The one exception is that WEIGHT becomes statistically significant in Model 3, suggesting that each one-pound increase in suspect weight is associated with a one percent increase in the odds of OC failure, holding constant the other variables in the model.

It appears, then, that using an outcome variable that more realistically represents the range or continuum of behavior observed by officers uncovered a potentially important predictor of OC effectiveness. Whether or not the effect of WEIGHT holds in future studies, of course, remains to be seen, and the result should be considered tentative until corroborated by other researchers.

Another caveat regarding the results of Model 3 is in order. An approximate likelihood-ratio test of the proportional odds assumption for the ordered logit model suggests the assumption is violated ($\chi^2 = 69.29$, $p = .0002$). When the assumption of proportional odds is rejected, alternative models should be considered (Long, 1997:145). One common approach when there are more than four ordered categories on the dependent variable is to use linear regression (Demaris, 1992:77). Although attractive because of its ease of interpretability, misleading results may be obtained when applying the linear regression model to categorical data (Long, 1977:115). A more defensible approach is to use multinomial logistic regression

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[27] Note that in order for the overall effect of age to be statistically significant, the quadratic term must be statistically significant as well, which it is not ($p = .084$); age was not statistically significant in this or any other model when the quadratic term was not included.

[28] An examination of the fully standardized coefficients for the variables ON DRUGS ($b = .132$) and MENTALLY DISTURBED ($b = .120$) in Model 2 (not displayed) suggests that both have similar effects when the criterion is whether OC eases the arrest. A chi-square test of the linear hypothesis that the effects of both variables are equal confirms this ($\chi^2 = .02$, $p = .899$).

[29] We used Stata, version 5, for estimating the ordered logit and other logistic models in this paper; SPSS, version 8, was used for estimating the linear regression model discussed later.

(Aldrich and Nelson,1984). Consequently, both methods are employed here, beginning with the linear regression model.

Model 4 presents the linear regression results for the same dependent variable used in Model 3 (OC EFFECTIVE?). The results are similar to the ordinal logit model (and Model 1) in that AGE continues to be statistically significant and nonlinear in its relationship to the outcome. We also see that, unlike in the binary logit models (but similar to the ordered logit model) WEIGHT remains statistically significant in the linear regression model. Notice, however, that DISTANCE (5-20 feet) is no longer statistically significant, although it is nearly so ($p = .057$). The effect of being under the influence of alcohol (DRINKING) approaches, but now also fails to achieve statistical significance at conventional levels ($p = .067$). As in all the previous models, though, the effect of ON DRUGS continues to remain substantively and statistically significant ($\beta = .422$, $p = .003$).

Model 5 in Table 6 displays the results from the multinomial logit model, using the same five-category dependent variable employed in Models 3 and 4 (OC EFFECTIVE?). The multinomial logistic regression model is distinguished from the more typical binary logistic regression model in that it is capable of analyzing dependent variables comprised of more than two categories. Although this adds a level of complexity to the analysis, multinomial models can essentially be thought of as a combination of several simultaneously estimated binary logit models (Steinberg and Colla, 1994:42). As in the binary logit models, we present only the odds ratios and associated *p*-values, with statistically significant effects shaded to ease interpretability. Note also that the reference category for the dependent variable in this model is *Totally Effective*.

The results in Model 5 suggest that the odds that OC is *Minimally Effective* (relative to being *Totally Effective*) are 2.49 times greater when sprayed from longer distances (5-20 feet) than when sprayed from moderate distances (3 – 4½ feet), controlling for the other variables in the model. Observe that there is no statistically significant increase in the odds of OC being *Totally Ineffective* or *Ineffective*, suggesting that discharges from longer distances are not associated with the outright failure of OC (recall that the category *Minimally Effective* is comprised of incidents where officers reported OC assisted them in making the arrest even though suspects were resistive, trying to avoid capture, or were combative).

-TABLE 6 ABOUT HERE-

The effects for AGE indicate that the odds that OC is *Ineffective* (relative to being *Totally Effective*) increase 1.32 times for each year increase in suspect age, but as indicated by the quadratic term (odds ratio = 0.99), additional increases in age decrease the odds that OC is *Ineffective* (or conversely, additional increases in age increase the odds that OC is *Totally Effective*). We observe a similar relationship between AGE and the odds that OC is *Minimally Effective*. Age, however, does not appear to associated with the outright failure of OC (*Totally Ineffective*).

Suspect weight is not associated with OC being *Ineffective* or *Minimally Effective* relative to being *Totally Effective*, but there does appear to be a relationship between weight and the likelihood that OC will fail outright. Specifically, the model suggests that relative to being *Totally Effective*, each additional pound in suspect weight increases by one percent the odds that OC is *Totally Ineffective*, controlling for the other factors in the model. We also see that increases in suspect weight are associated with increases in the odds that OC is *Effective* (i.e., submissive) rather than being *Totally Effective*.

Regarding the effects of DRINKING, the odds that OC is *Minimally Effective* (relative to being *Totally Effective*) decrease by 48 percent (1-.52) for suspects who were drinking compared to suspects who were not drinking, mentally disturbed, or on drugs. Conversely, by reversing the sign and exponentiating the logit coefficient (not reported), the odds of OC being *Totally Effective* (relative to being *Minimally Effective*) almost double when suspects were drinking compared when they were not drinking, on drugs or mentally disturbed (odds = 1.93), again suggesting that alcohol use actually increases to a certain degree suspect susceptibility to the effects of OC.

Examining the effect of DRUGS indicates that the odds that OC is *Totally Ineffective* rather than *Totally Effective* are 6.21 times greater when suspects are on drugs compared to when they are not on drugs or alcohol or mentally ill, holding all other factors constant. That this is the only statistically significant

contrast for this factor suggests that drug use substantially increases the likelihood that OC will outright fail rather than being only partially ineffective.

Finally, the odds that OC is *Minimally Effective* rather than *Totally Effective* are 92 percent lower for mentally disturbed suspects than for those who are not mentally disturbed or on drugs or alcohol. The only other model in which the mental state of the suspect was statistically significant was in Model 2 (EASED ARREST?), the results of which suggested that OC was more likely to fail when used on mentally disturbed suspects. The results for Model 2 and Model 5, therefore, are somewhat incongruent in terms of the effect of OC on mentally disturbed suspects. It is interesting, however, that although not statistically significant, the direction of the effect for MENTALLY DISTURBED in Model 1 is more in agreement with the estimates reported in Model 5 than they are with the result reported in Model 2. Hopefully future research will help clarify the nature of the relationship between mentally disturbed suspects exposed to OC and the level of resistance.

DISCUSSION

Previous evaluations of OC have found it to be an effective tool for dealing with resistive and combative suspects, often reporting it to be successful 90 to 100 percent of the time (Gauvin, 1994; IACP 1995; Kingshott 1992; Nowicki, 1993; Phillips, 1994; Robin, 1996). The current analysis, using one measure of effectiveness based on behavioral descriptors of suspects after exposure to OC and another based on whether officers felt OC helped make the arrest easier, produced less optimistic results. Specifically, the measure based on suspect behavior after exposure produced an effectiveness rate of only 70.7 percent, which is lower than the rates reported in previous studies. Even counting encounters in which suspects were resistive after exposure as successes produced an effectiveness rate of only 84.3 percent using this measure. This is higher than the 73 percent reported by Morabito and Doerner (1997), but still below that of most other evaluations of OC.

A more optimistic outcome of 85.3 percent is obtained in our study when using the criteria of whether officers thought OC helped ease the arrest. Although this rate too is lower than that reported in most other studies, a less-lethal force alternative that assists officers in more than eight out of ten arrests in which it is used suggests that OC should remain a viable option for law enforcement. Nevertheless, officers should always be prepared to resort to alternative tactics when relying on OC spray to subdue suspects. OC spray is not a panacea.

Although our results suggest OC is effective generally, police frequently report fewer successes with OC during encounters with suspects thought to be mentally disturbed or under the influence of drugs or alcohol (Morabito and Doerner, 1997; Phillips, 1994). Controlling for suspect race, sex, age, height, weight, and the distance from the suspect from which OC was sprayed, regression analyses found consistent support for the notion that OC is less likely to affect suspects under the influence of drugs. Unexpectedly, suspects under the influence of alcohol appear to be somewhat more susceptible to the effects of OC spray, while the results for mentally disturbed suspects were mixed, depending on which outcome measures and statistical methods are used (the effect was not statistically significant in three of the five models, while in the remaining two models the effects were statistically significant but in opposite directions [Models 2 and 5]).

The results indicate, then, that although officers should always be prepared to resort to alternative tactics when relying on OC spray to subdue suspects, this is especially true when suspects appear to be under the influence of drugs.[30] Future studies hopefully will attempt to confirm or disconfirm these results using improved measures of whether suspects are *in fact* mentally disturbed, under the influence of drugs or

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[30] Regarding officer preparedness to resort to alternative tactics in case OC fails, it should be noted as well that multiple applications of OC spray were not associated with increased incapacitative effects. An earlier crosstabular analysis (not shown) of the number of applications with OC effectiveness (based on the suspects' actions after exposure) revealed OC was ineffective in 74.2 percent of the incidents when discharged three or more times and ineffective 48.5 percent of the time when discharged twice. When applied only once, however, it was ineffective only 20 percent of the time (chi-square = 62.51; p = .000). Thus, if OC fails to incapacitate suspects with the first spray or two, additional applications of OC are unlikely to be effective, again suggesting that officers need to be prepared to use alternative tactics.

alcohol, as well as develop more refined and multiple indicators of OC effectiveness. What is particularly needed are valid measures of the *type(s)* of drugs arrestees are on at the time of the encounter.

The regression models also produced consistent evidence of an age effect, although the relationship appears to be nonlinear. Except for Model 2, where the effect was near significant, all the estimated regression models suggest that younger and older suspects are somewhat more susceptible to the effects of OC than are suspects of "middle age". Although speculation, it may be that younger and older suspects are less likely than middle-aged suspects to be engaged in goal-directed behavior, which itself may be a correlate of OC effectiveness (Phillips, 1994).

Statistical evidence for a weight effect was obtained when we moved beyond the simple dichotomous "effective-ineffective" outcomes to measures that more realistically represent the continuum of behavioral responses displayed by suspects exposed to OC. Specifically, in all three models in which the dependent variable was an ordinal outcome (Models 3-5), increases in suspect weight were significantly associated with increases in OC ineffectiveness. Thus, although conceptually and statistically easier to deal with, utilizing simple dichotomous measures of the incapacitative effects of OC may mask important covariates of effectiveness. Further, this finding could have training implications in that officers might be warned that very large individuals may be somewhat less susceptible to the effects of OC, and therefore should be ready to move to other tactical options when confronting such individuals.[31]

OC was somewhat less effective at incapacitating suspects when sprayed from longer distances relative to moderate distances in three of the estimated models (with the effect being nearly significant in a fourth model), results that are in opposition to some previous research (Jamieson, 1991; Phillips, 1994). A number of factors might account this finding (e.g., reduced accuracy from greater distances; dispersal effects), but any explanation would be speculative at this exploratory stage. Suffice to say, because of its potential implications for training, greater attention should be paid to the distance factor in future research on OC effectiveness.

It is also noteworthy that more than half (60.1%) of the discharges occurred from a distance of less than two-and-a-half feet, well below the four to six feet recommended during training.[32] Defensive tactics instructors may wish to examine the approach used by officers to find out why the majority of OC discharges are occurring below the recommended distance. Although Morabito and Doerner (1977:691) suggest that OC is virtually useless during physical encounters that occur at very close distances, we observed no such effect based on our bivariate and multivariate analyses.[33] It is important to point out, though, that there may be other reasons for discouraging the use of OC from such short distances (e.g., the potential for corneal damage from any aerosol under pressure, a desire to maintain a "zone of safety").

Statistically significant effects for suspect height, race, and sex were not observed regardless of how we measured, coded, or analyzed OC effectiveness. Although we doubt that such effects would be observed in future analyses, given the exploratory nature of this and other studies of OC spray, we recommend that other researchers consider their inclusion when examining potential covariates of OC effectiveness.

Although the current study appears to be unique in its use of multivariate regression models to examine factors associated with OC failure, several caveats are in order regarding the analysis. First, although all of our regression models produced an improvement in fit over a "naive" model (i.e., a constant-only model), none of the models "explain" much of the variation in the outcome variables, as suggested by the pseudo R-square values (values range from only .02 to .06). This indicates that other potentially relevant factors should be considered in future analyses.

In addition, it is important to reiterate that the data collected regarding suspect mental states and substance use are based on officer *perceptions* and thus subject to substantial measurement error, which can affect the obtained estimates and attenuate model fit. To reduce measurement error, empirical measures of

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[31] It is possible that this finding is simply due to perceptions among officers that larger subjects who resist are more difficult to deal with generally, whether or not they have been exposed to OC.

[32] Note that the distances reported actually may be overestimates as when officers reported a range, e.g., 18 to 24 inches, we used the longer distance assuming that officers are likely to underestimate the distance between themselves and subjects during resistive encounters.

[33] In addition, previous crosstabular analyses (not shown) indicate officers were no more likely to report that OC was ineffective when applied from *very short* distances (e.g., less than one foot) than when it was applied from longer distances.

suspect drug and alcohol use should be obtained through the use of breathalyzers, saliva, and/or urine tests. The services of a psychologist or other expert might be obtained to help develop consistent methods for identifying irrationally behaving persons.

Finally, given the disparity in reported rates of OC success found in the literature, it is important for future researchers and police agencies to develop unambiguous and uniform definitions of OC effectiveness, as well as explicit criteria for measuring the incapacitative effects of OC (preferably using multiple indicators). The use of simple dichotomous measures of effectiveness should be discouraged, as they likely present a distorted picture of behavioral responses to OC exposure.

Research that produces more accurate estimates of what OC will and will not do during resistive and forceful encounters should assist police administrators and the public in making informed decisions regarding the adoption, training, and use of OC. Nevertheless, even the most conservative estimates of OC effectiveness suggest it remains an important tool for law enforcement, provided health concerns are not a major issue.

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