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Reversal Learning Deficits in Criminal Offenders: Effects of Psychopathy, Substance use, and Childhood Maltreatment History

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Abstract Deficits in reinforcement learning are presumed to underlie the impulsive and incorrigible behavior exhibited by psychopathic criminals. However, previous studies documenting reversal learning impairments in psychopathic individuals have not investigated this relationship across a continuous range of psychopathy severity, nor have they examined how reversal learning impairments relate to different psychopathic traits, such as the interpersonal-affective and lifestyle-antisocial dimensions. Furthermore, previous studies have not considered the role that childhood maltreatment and substance use may have in this specific cognitive deficit. Using a standard reversal learning task in a sample of $N = 114$ incarcerated male offenders, we demonstrate a significant relationship between psychopathy severity and reversal learning errors. Furthermore, we show a significant interaction between psychopathy and childhood maltreatment, but not substance use, such that individuals high in psychopathy with an extensive history of maltreatment committed the greatest number of reversal learning errors. These findings extend the current understanding of reversal learning performance among psychopathic individuals, and highlight the importance of considering childhood maltreatment when studying psychopathy.

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The abilities to learn from past behavior and respond appropriately to both rewarding and punishing stimuli are essential components of adaptive decision-making. Deficits in reinforcement learning have been demonstrated across a range of psychopathologies, especially those characterized by impulsive behavior and poor decision-making (e.g., Fillmore and Rush 2006; Itami and Uno 2002; Gorrindo et al. 2005). Psychopathy, in particular, has been linked to an inability to flexibly shift behavior in response to changing reinforcement contingencies (Finger et al. 2008; Mitchell et al. 2002; Newman and Kosson 1986; Baskin-Sommers et al. 2015). Psychopathy is a personality disorder characterized by impulsive antisocial behavior, callousness, and shallow affect (Hare 2003). Psychopathic individuals commit a disproportionate amount of both violent and non-violent crime, comprising 15–25 % percent of the adult prison population (Hart and Hare 1996). Some estimates suggest that adult psychopathic offenders are responsible for $460 billion per year in societal costs in the U.S. alone (Kiehl and Hoffman 2011).

Accordingly, the disinhibited decision-making associated with psychopathy has been a central focus of psychopathy research for decades (e.g., Newman and Kosson 1986; Blair et al. 2006; Vitacco and Rogers 2001; Patrick et al. 2009; O'Brien and Frick 1996). Several studies have shown that while psychopathic individuals exhibit intact learning and decision-making in certain contexts, they perform poorly on reversal-learning paradigms, in which the subject must alter his response patterns when stimulus-reward contingencies change, or "reverse". For example, Mitchell et al. (2002) reported that, when compared to non-psychopathic inmates, psychopathic inmates showed impaired reversal learning, but did not exhibit

impairments on simple stimulus discrimination or learning to attend to new stimuli, suggesting that an inability to flexibly alter behavior in the face of changing contingencies may be a key impairment contributing to the problematic behaviors associated with psychopathy. Similarly, studies using probabilistic reversal learning paradigms (e.g., 80/20 reinforcement contingencies rather than 100/0) have documented reversal learning impairments in adult psychopathic inmates (Budhani et al. 2006; Brazil et al. 2013) as well as in children with psychopathic traits (Budhani and Blair 2005; Finger et al. 2008).

Despite well-documented evidence of reversal learning impairments in psychopathic individuals, to date, no studies have examined the relationship between reversal learning performance and psychopathy continuously (i.e., previous studies have only compared distinct groups of psychopathic and non-psychopathic individuals). Consequently, the specific relationships between reversal learning and the interpersonal-affective and impulsive-antisocial features of psychopathy have not yet been investigated, making it unclear whether reversal learning impairments and associated with the externalizing features of psychopathy (e.g., impulsivity, irresponsibility), or if they are unique to the core interpersonal-affective features of psychopathy (e.g., callousness, manipulativeness). Clarifying these relationships may be an important step towards understanding the mechanisms contributing to both the callous and reckless behavior often displayed by psychopathic individuals.

Beyond examining these specific trait relationships, it is important to consider additional factors that may be contributing to the impairments evidenced in psychopathic individuals. Multiple studies have demonstrated a strong link between childhood maltreatment and psychopathy, (Weiler and Widom 1996; Poythress et al. 2006; Graham et al. 2012; Dargis et al. 2015) as well as between substance use and psychopathy (Hemphill et al. 1994; Mailloux et al. 1997; Taylor and Lang 2006). Moreover, the experience of childhood maltreatment and history of substance abuse are both associated with cognitive dysfunction in children and adults (Brown et al. 2000; Lundqvist 2005; Pears et al. 2008; Perez and Widom 1994). Substance use, specifically, has been associated with reversal learning impairments (e.g., Fillmore and Rush 2006). Accordingly, it is possible that the reversal learning deficits documented in psychopathic individuals are better explained or exacerbated by a significant maltreatment or substance use history. In support of this notion, previous research suggests that childhood maltreatment may be a key factor in the behavioral and neuropsychological characteristics of psychopathic individuals. For instance, Kolla et al. (2013) reported a significant interaction between psychopathy and maltreatment in which childhood physical abuse was associated with greater levels of reactive aggression, but only among individuals high in psychopathy. Similarly, there is preliminary evidence suggesting that some of the structural brain abnormalities documented in psychopathic offenders may in fact relate to childhood physical abuse, rather than the presence of psychopathic traits per se (Kolla et al. 2014). It is unclear, however, if similar psychopathy and maltreatment interactions emerge within the context of reversal learning, or if substance use history differentially affects the cognitive functioning of psychopathic individuals.

The goals of the current study are thus fourfold: (1) to test the reversal learning deficit in psychopathy using a large sample of adult criminal offenders with a broad, continuous range of psychopathy scores to date; (2) to examine the specific relationships between the interpersonal-affective and impulsive-antisocial traits of psychopathy and reversal learning; (3) to determine whether history of childhood maltreatment and/or substance use affect the reversal learning deficits in this population; and (4) to determine if there is an interaction between psychopathy and childhood maltreatment and/or substance use history on reversal learning, such that reversal learning deficits are most pronounced in psychopathic individuals with a history of childhood maltreatment or substance use. The results of this study will therefore yield novel data to clarify the relationships among psychopathy, childhood maltreatment, substance use, and reversal learning.

Methods

Participants

Participants included $N = 114$ adult males incarcerated at medium security prisons in Wisconsin. Participants were selected from a larger pool of participants who completed a standard battery of personality assessments (e.g., PCL-R). From this larger sample, we selected a sub-sample of offenders (selected based on PCL-R score in order to adequately represent low, intermediate, and high psychopathy participants) to complete the reversal learning task. Individuals were eligible for participation if they were between the ages of 18 and 55, had no documented diagnosis of a psychotic disorder, and were not currently taking psychotropic medications. Additionally, participants were eligible if they had a 4th grade reading level or above and scored 70 or above on a standardized measure of intelligence (Wechsler 1981; Zachary and Shipley 1986). All participants provided informed consent prior to any data collection. Inmates were notified that participation was completely voluntary and would have no impact on their incarceration status. Two participants were excluded because of outlier data with undue influence on the regression models (Cook 1977). Participant characteristics are included in Table 1.

Assessments

Psychopathy The Psychopathy Checklist-Revised (PCL-R) was used to assess psychopathy (Hare 2003). The PCL-R is

Table 1 Participant Information

	PCL-R	Age	IQ	Substance (ASI)	CTQ Total Score	% Reported Abuse/Sexual Abuse	Race (% Cauc/AA/other)
Non-Psychopathic (n = 24)	**16.11 (4.05)**	**29.17 (7.91)**	98.18 (13.20)	**8.77 (10.15)**	**40.86 (13.86)**	59.09/27.27	54.2/29.3/16.6
Intermediate (n = 39)	**24.93 (2.63)**	32.00 (7.74)	99.68 (12.85)	**17.35 (14.38)**	50.04 (16.19)	82.05/30.77	56.4/43.6/0.0
Psychopathic (n = 51)	31.99 (1.88)	33.06 (7.25)	98.44 (11.17)	20.66 (13.26)	51.18 (18.98)	75.47/22.64	49.0/47.1/4.0

Means and standard deviations are presented for PCL-R, Age, IQ, ASI, and CTQ columns. Bolded $p < .05$ compared to psychopathic group; ASI is mean number of years abusing substances (cumulative across substances). % Reported Abuse/Sexual Abuse reflects the number of individuals in each group who met clinical cut offs on the CTQ total score (>36)/ sexual abuse score (≥8) of the CTQ; Cauc, Caucasian; AA, African-American

a scale of 20 items rated 0–2 based on the degree to which the trait is present. Trained undergraduates and research staff performed all clinical assessments based on information obtained during interviews and reviews of institutional files. In order to compare these results to previously reported work, supplemental group analyses were conducted with the following PCL-R total score criteria: non-psychopathic (PCL-$R \leq 20$, n = 24), intermediate (PCL-$R > 20$ and <30; n = 39), or psychopathic (PCL-$R \geq 30$; n = 51) (Hare 2003). Because participants were selected from a larger participant pool, inter-rater reliability ratings (from 4 separate raters) were only available for $n = 5$ participants. Nonetheless, these ratings yielded a high intraclass correlation for PCL-R total scores ($r = .99$), Factor 1 scores ($r = .94$), and Factor 2 scores ($r = .97$). These intraclass correlation values are consistent with previous studies from our lab (Dargis et al. 2015; Philippi et al. 2015; Wolf et al. 2015).

Intelligence Intelligence was assessed using the Wechsler Adult Intelligence Scale-Revised (n = 99; Wechsler 1981) or the Shipley Institute of Living Scale (n = 15; Zachary and Shipley 1986).

Substance Use Substance abuse was assessed using a modified version of the Addiction Severity Index-Lite (ASI-Lite; Cacciola et al. 2007). The ASI-Lite includes a semi-structured interview that focuses on types of substance tried (nicotine, alcohol, cocaine/crack, heroin, other opiates, inhalants, hallucinogens, stimulants, methadone, methamphetamine), total months of regular use of each substance (i.e., three or more times per week), and route of administration. A raw total score, which refers to the cumulative number of years using all substances (excluding nicotine), was calculated for each subject.

Maltreatment History The Childhood Trauma Questionnaire (CTQ) was used to assess experienced childhood maltreatment (Bernstein and Fink 1998). The CTQ is a 28-item scale comprised of five subscales which assess different types of trauma, including physical abuse (e.g., "I was punished with a belt, a board, a cord, or some other hard object"), physical neglect (e.g., "I didn't have enough to eat"), emotional abuse (e.g., "People in my family said hurtful or insulting things to me"), emotional neglect (e.g., "I felt loved" [reverse scored]), and sexual abuse (e.g., "Someone tried to make me do sexual things or watch sexual things"). All subscales consist of five items scored on a five-point rating scale from never true (1) to very often true (5). Two items on the physical neglect scale and all items on the emotional neglect scale are reverse scored. The CTQ also provides cutoff scores indicative of clinical levels of childhood abuse. The percent of individuals, across levels of psychopathy, in the current sample who met clinical levels of childhood abuse (CTQ total score ≥ 36) are presented in Table 1.

Attentional Set-Shifting and Reversal Learning The Intra-Extra Dimensional Shift Task (IED) was used to assess attentional set-shifting and reversal learning (see Dias et al. 1996). Participants learn to select one of two stimuli presented on a computer screen based on feedback that appears after each selection ('correct' or 'incorrect'; with a 100/0 contingency). The stimuli include up to two dimensions (i.e., object shape and line). The correct stimulus is determined by one dimension (i.e., either the correct shape, regardless of line, or the correct line, regardless of shape). On each trial, the stimuli appear randomly in two of four locations on the screen. In order to make a selection, participants were directed to press the arrow key on the keyboard that corresponded to the location of the stimulus that they would like to select. The task consists of nine stages presented in a fixed order. Participants had to demonstrate their knowledge of each rule before continuing on to the next stage of the task by selecting the correct stimulus six times in a row. If a participant did not learn the rule within 50 trials, the task terminated. The nine stages of the IED task are as follows:

1. Discriminate between two shapes (shape 1 is correct).
2. Discriminate between the same two shapes, but the rule is reversed (shape 2 is correct).
3. A pair of white lines appears next to the shapes appearing in stages 1 and 2. The rule does not change (shape 2 is still correct).

4. The white lines now appear superimposed on the shapes appearing in stages 1–3. The rule remains the same (shape 2 is still correct).
5. The same shapes and lines from stage four appear, but the rule is reversed (shape 1 is now correct).
6. New shapes and superimposed lines are introduced. The participant must learn to respond to the new shape 1. (Intra-dimensional shift)
7. The same shapes and lines from stage six appear, but the rule is reversed (shape 2 is correct).
8. New shapes and lines are introduced. Now, the participant must learn to respond to the correct line, not shape (line 1 is correct; Extra-dimensional shift).
9. The same shapes and lines from stage 8 appear, but the rule is reversed (line 2 is correct).

The primary variables computed for the IED task include the number of errors made during stage 6 (the intra-dimensional shift); the number of errors made during stage 8 (the extra-dimensional shift); and the composite number of errors made during stages 2, 5, 7 and 9 (reversal learning).

Data Analyses

We conducted primary analyses using PCL-R score continuously rather than categorically, and performed follow-up analyses using discrete PCL-R groups. Primary analyses examining the relationship between psychopathy and task performance were conducted using multiple linear regression. Follow-up analyses examining task performance between three offender groups (non-psychopathic, intermediate, and psychopathic) were conducted using multiple regression and simple contrasts that compared the psychopathic group to the two other offender groups. All variables included in the models were mean-centered. Results from the regression analyses are included in Table 2.

Age, race, and IQ, were included as covariates in all models. Childhood maltreatment and substance abuse were included as covariates in separate analyses. The non-psychopathic participants were significantly younger than the psychopathic participants and had significantly less history of substance abuse and childhood maltreatment (p's < .05). There were no differences in race or IQ between participant groups, however, both variables were retained as covariates given that antisociality varies as a function of race and IQ, and cognitive task performance varies by IQ (Piquero et al. 2005; Koenen et al. 2006). Zero-order correlations among all predictor variables are included in Table 3.

Results

First, we examined the main effect of PCL-R scores on intra-dimensional, extra-dimensional, and reversal learning task performance. Consistent with previous findings, there was no significant main effect of PCL-R score on intra- or extra-dimensional shift performance (p's > .5). However, there was a significant main effect of PCL-R score on reversal learning. Controlling for age, race, and IQ, higher PCL-R total scores were significantly associated with a greater number of reversal learning errors, $t(109) = 2.17$, $p = .03$, $\eta^2 = .04$ (Fig. 1). As reported in Table 3, the zero-order correlation between PCL-R score and reversal learning performance was at trend level, $p = .051$.

Second, we examined whether reversal learning performance uniquely related to the interpersonal-affective features of psychopathy (Factor 1) or the lifestyle-antisocial features (Factor 2). Controlling for age, race, and IQ, Factor 1 scores were significantly associated with reversal learning performance, $t(109) = 2.06$, $p = .04$, $\eta^2 = .04$. The relationship between Factor 2 scores and reversal learning errors was at trend level, $t(107) = 1.76$, $p = .08$, $\eta^2 = .03$. To examine the unique variance associated with each Factor, we ran a model that included both Factors, as well as age, race, and IQ. Controlling for Factor 2 scores, the relationship between Factor 1 scores and reversal learning performance was no longer significant, $t(106) = 1.36$, $p = .18$, $\eta^2 = .02$. Similarly, controlling for Factor 1 scores, the relationship between Factor 2 scores and reversal learning performance was not significant, $t(106) = .73$, $p = .47$, $\eta^2 = .004$.

Third, we examined the role of substance use history in the psychopathy-reversal learning relationship. To do this, we re-ran analyses including ASI score as a covariate. Controlling for age, race, IQ, and ASI score, all reported relationships

Table 2 Regression coefficients and standard errors

	B	*SE B*	β	R^2	$\triangle R^2$
1.					
PCL-R	**.24**	.11	1.59	.06	.04
Factor 1	**.46**	.22	1.48	.08	.04
Factor 2	.37	.21	1.34	.03	.03
2.					
PCL-R	**.27**	.11	1.82	.04	.05
Factor 1	**.53**	.22	1.72	.03	.05
Factor 2	.39	.22	1.48	.01	.03
ASI Score	-.07	.06	-.98	.03	.01
ASI*PCL-R	-.004	.01	-.45		.002
3.					
PCL-R	.20	.11	1.65	.06	.03
Factor 1	.37	.23	1.51	.06	.02
Factor 2	.30	.21	1.48	.05	.02
CTQ Total Score	.04	.04	1.25	.12	.008
CTQ* PCL-R	**.02**	.006	2.88		.06

1. age, race, and IQ included as covariates, 2. age, race, IQ and ASI included as covariates; 3. age, race, IQ, and CTQ score included as covariates; Bolded $p < .05$

Table 3 Zero-Order Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11
1.PCL-R Total		**.84**	**.89**	**.22**	**.32**	-.13	-.03	.15	.09	.04	.18
2. PCL-R Factor 1			**.55**	**.23**	.17	-.09	.00	.04	.14	.03	.18
3. PCL-R Factor 2				**.22**	**.37**	-.18	-.02	**.22**	.06	.04	.13
4. CTQ Total					.16	-.09	.09	**.28**	.17	-.04	.16
5. ASI						-.10	.09	**.41**	-.16	-.04	-.09
6. Race							**-.19**	.10	-.02	-.05	.13
7. IQ								.17	-.15	-.18	-.16
8. Age									-.09	.08	-.03
9. Intra Shift										.16	**.27**
10. Extra Shift											-.12
11. Reversal											

Bolded $p < .05$; Intra Shift, Extra Shift, Reversal = number of errors during that stage

remained consistent. Reversal learning performance was significantly related to: PCL-R scores, $t(100) = 2.45$, $p = .02$, $\eta^2 = .06$, Factor 1 scores, $t(100) = 2.40$, $p = .02$, $\eta^2 = .05$ and Factor 2 scores at trend level, ($p = .07$). When examining the unique variance associated with Factor 1 and 2, neither Factor scores related to reversal learning performance (p's > .10).

Similar analyses were conducted to examine the role of childhood maltreatment history in the psychopathy-reversal learning relationship. Controlling for age, race, IQ, and CTQ total score, reversal learning performance was related to PCL-R scores $t(108) = 1.84$, $p = .07$, $\eta^2 = .03$ only at a trend level. The relationship between Factor 1 and Factor 2 scores and reversal learning performance were not significant, (p's = .10). When examining the unique variance associated with Factor 1 and 2, neither Factor scores related to reversal learning performance (p's > .20).

Finally, we examined the unique relationships between substance use, childhood maltreatment history, and reversal learning performance, as well as the interactive effects of substance use, childhood maltreatment, and psychopathy. Controlling for age, race, IQ, and mean PCL-R score, there was no main effect of ASI score on reversal learning

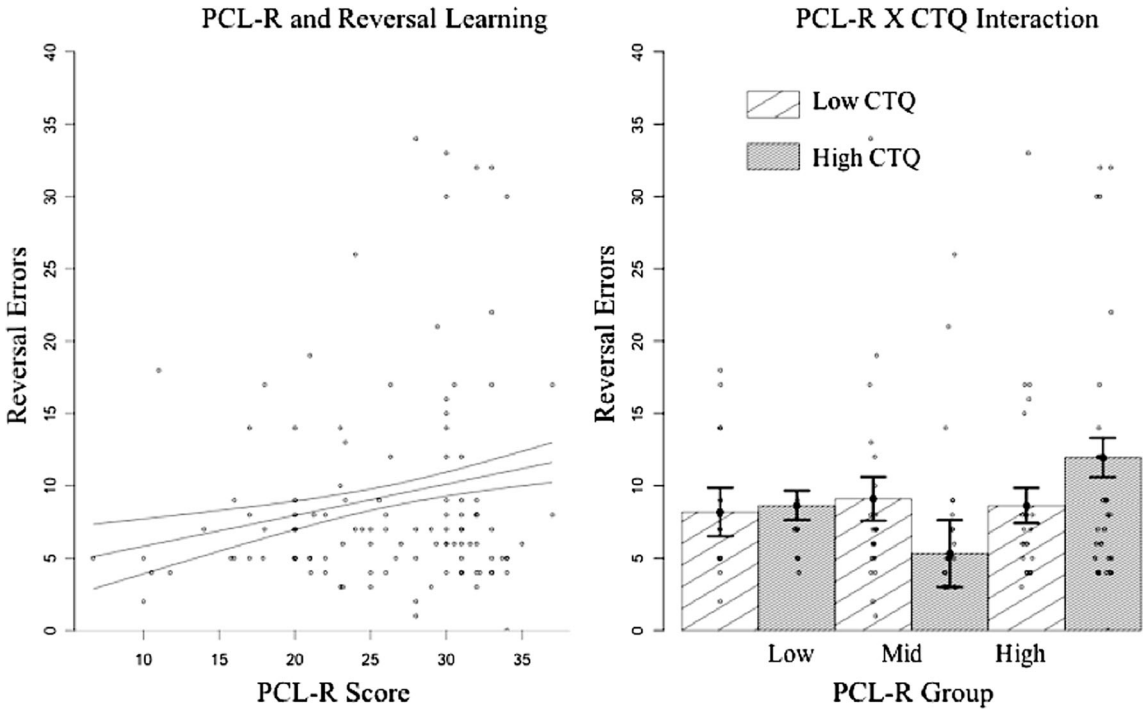

Fig. 1 The main effect (*left*) of PCL-R scores on reversal learning errors (no covariates included). The linear regression results are presented with error lines, indicating standard error of the mean. The interaction (*right*) between PCL-R score and CTQ total score. "Low" and "High" Abuse groups are based on median splits of CTQ total scores. Group means for reversal errors are presented with error bars indicating standard error of the mean

performance, (p = .25). Similarly, the interaction between ASI score and PCL-R score was not significant, (p = .59). There was also no main effect of CTQ total score, (p = .31). However, there was a significant interaction between PCL-R score and CTQ total score, such that individuals with both high PCL-R and high CTQ scores performance significantly worse on the reversal learning task, $t(107) = 2.74$, $p < .01$, $\eta^2 = .06$.

Follow up Analyses

As a follow-up analysis, we examined whether the observed findings remained consistent when examining psychopathy as a group variable, rather than a continuous variable. These analyses included age, race, and IQ as covariates. Consistent with the primary analyses, psychopathic offenders did not perform differently than the non-psychopathic or intermediate participants on the intra-dimensional or extra-dimensional shift component of the task (p's > .3). Psychopathic participants made more reversal learning errors than the non-psychopathic group $t(108) = -2.05$, p = .04, d = .45, but not the intermediate group (p = .19). Controlling for ASI score, psychopathic participants made more reversal learning errors than both the non-psychopathic group, $t(99) = -2.23$, p = .03 and the intermediate group, $t(99) = -2.25$, p = .03, d = .28. Controlling for CTQ total score, psychopathic participants did not significantly differ from either group on reversal learning performance (p's > .05).

As a second follow-up analysis, we examined whether the observed relationships between CTQ score and reversal learning were driven by any particular form of maltreatment (physical abuse, physical neglect, emotional abuse, emotional neglect, sexual abuse), while controlling for age, race, and IQ. Examination of CTQ subscales indicated a significant interaction between CTQ sexual abuse scores and PCL-R scores $t(107) = 4.00$, $p < .001$, $\eta^2 = .11$, such that individuals with psychopathic traits who experienced a greater degree of childhood sexual abuse made significantly greater reversal learning errors. The interaction between the other forms of maltreatment did not reach statistical significance, (p's > .05).

Discussion

In a large sample of adult criminal offenders, we have shown a significant association between psychopathy and reversal learning errors, and clarified this relationship through the examination of substance abuse and childhood maltreatment. We report four main results. First, psychopathy severity (PCL-R total score), examined both as a continuous and as a discrete variable, was associated with a greater number of reversal learning errors. Second, the unique variance associated with either Factor did not relate to reversal learning performance. Third, controlling for substance use history largely strengthened the relationship between PCL-R scores and reversal learning performance, whereas controlling for childhood abuse history largely lessened the relationship between PCL-R scores and reversal learning performance. However, neither substance use history nor childhood abuse history were uniquely related to reversal learning performance. Fourth, there was a significant interaction between psychopathy severity and childhood maltreatment severity (CTQ total score, sexual abuse score), but not substance abuse severity, such that individuals high in psychopathy who also experienced high levels of maltreatment performed significantly worse on reversal learning. Taken together, these results highlight the importance of considering childhood maltreatment in the context of understanding the cognitive performance of psychopathic offenders. Here we discuss each of these main findings in turn.

Consistent with previous findings, higher psychopathy scores were associated with reversal learning errors, but not intra or extra-dimensional shift errors (Budhani et al. 2006). This finding provides further evidence that individuals high in psychopathy have particular difficulty in flexibly altering behavior in the face of changing contingencies, but do not show global impairments in learning. Our study is noteworthy in that it included a large sample of psychopathic criminal offenders, and it is the first study to examine this relationship continuously, across a broad range of PCL-R Total and Factor score severity. The current findings document a basic deficit in reversal learning in an adult offender sample, whereas previous studies of children with psychopathic traits suggest that reversal learning impairments are observed primarily in more complex, probabilistic conditions (e.g., Budhani and Blair 2005; Blair et al. 2001).

Mitchell et al. (2002) suggested that the more significant deficit in reversal learning among adult psychopathic individuals might be a secondary cause of their increased substance abuse. Though substance abuse alone has also been associated with impaired reversal learning (e.g., Fillmore and Rush 2006), the current study addressed this potential confound by controlling for substance abuse severity among offenders. Additionally, we examined the possibility that substance use history interacts with psychopathic traits, resulting in a more severe learning impairment, however this was not supported. Given previous work on the relationship between neuropsychological performance and substance abuse (e.g., Grant et al. 2012; Meier et al. 2012; Stavro et al. 2013), it is somewhat surprising that we did not observe a significant relationship between substance use and reversal learning performance in the current study. There is evidence that specific substances have divergent associations with cognitive dysfunction (Ersche et al. 2006; Ornstein et al. 2000), so it is possible that reversal learning impairment is somewhat substance-specific. For instance, previous studies reporting impaired reversal learning performance subsequent to substance abuse have

largely examined the effects of cocaine use (e.g., Calu et al. 2007; Camchong et al. 2011; Jentsch et al. 2002). The substance use variable utilized in the current study, however, accounted for total substance abuse chronicity, so it is possible that using more sensitive measures of substance abuse might clarify these relationships. Alternatively, duration of abstinence from substances may be an important variable to consider when examining relationships among substance abuse and cognitive task performance (Vonmoos et al. 2014). Although previous work suggests that reversal learning impairment subsequent to substance abuse can be observed for at least a year after discontinuation of substances (Toomey et al. 2003), none of the participants in the current study reported substance use within one year of data collection. In any case, further research is needed in order to clarify the impact of substance abuse on reversal learning impairment.

In addition to controlling for substance abuse history, the current study specified the reversal learning impairments associated with psychopathy by controlling for history of childhood maltreatment. Interestingly, relationships between psychopathy and reversal learning decreased from significant to trend level when accounting for childhood abuse history. Furthermore, we found a significant interaction between childhood maltreatment and psychopathy severity, such that individuals high in psychopathy who experienced more extensive histories of childhood abuse (and particularly sexual abuse) showed the greatest impairments in reversal learning. Though it is necessary to replicate these findings, the current results are consistent with previous work by Kolla and colleagues (Kolla et al. 2014; Kolla et al. 2013), who have documented significant maltreatment by psychopathy interactions. These results highlight the importance of considering maltreatment history when studying psychopathic offenders.

Theoretical conceptualizations (Blackburn 1975; Lykken 1995; Porter 1996), and to some extent, empirical evidence (Kimonis et al. 2012; Skeem et al. 2007), regarding psychopathic subtypes suggest that adverse environmental experience is an important etiological mechanism contributing to the development of secondary, but not primary, psychopathy. Though the aim of the current study was not to differentiate between psychopathic subtypes, the interactive effect between psychopathy and childhood maltreatment suggests that those individuals commonly classified as "secondary" may be more likely to exhibit cognitive impairments subsequent to childhood trauma. Though further research is needed in order to specify potentially causal relationships between childhood maltreatment and psychopathic traits, the results of the current study suggest that maltreatment exposure can exacerbate the severity of deficits associated with psychopathy. Given the prevalence of maltreatment exposure among individuals high in psychopathy (Weiler and Widom 1996; Poythress et al. 2006; Graham et al. 2012; Dargis et al. 2015), it is crucial to continue examining how childhood maltreatment/trauma influences the development of psychopathic traits. Furthermore, given that the relationship between reversal learning performance and psychopathy diminished to trend level when controlling for childhood maltreatment in the current study, it is also important to consider how childhood maltreatment impacts the development of impairments commonly associated with psychopathy.

The evidence that both children and adults high in psychopathy exhibit difficulty in flexibly altering behavior, and that this difficulty is posited to be a mechanism contributing to the behavioral consequences (i.e., criminality, violence, recidivism) associated with psychopathy, suggests that improvement of reversal learning ability may be a potential intervention strategy for reducing these behavioral consequences. Recently, researchers have highlighted cognitive performance and learning style as intervention strategies for reducing both the behavioral and affective abnormalities associated with psychopathy (Baskin-Sommers et al. 2015; Moul and Dadds 2013). Similar tactics could be employed, emphasizing reversal learning ability in particular, among children with psychopathic traits in an effort to alter the subsequent development of psychopathic and antisocial behaviors in adulthood.

Though the CTQ is a well-validated instrument and has been used in incarcerated samples, a primary limitation of the present study is the use of self-report, retrospective data. Because of this, the possibility that psychopathic offenders misrepresented or had poor recall of their maltreatment history cannot be ruled out. To mitigate this possibility, all participants were informed that their participation would have no impact on their incarceration status, thus reducing motivation to falsify maltreatment histories. Because the current study is cross-sectional in design, it is not possible to examine the causal impact of childhood maltreatment on reversal learning performance. Though it is possible that reversal learning is uniquely impaired in psychopathic individuals and is further exacerbated subsequent to the experience of childhood maltreatment, there may be other developmental factors contributing to these relationships. Accordingly, future research should employ longitudinal designs in order to better parse factors contributing to the cognitive performance of psychopathic individuals.

In sum, the current study extends the reversal learning impairments associated with psychopathy to a larger group of incarcerated offenders, while controlling for substance use and childhood maltreatment history; examines the unique relationships between psychopathic traits (Factor 1 and Factor 2) and reversal learning performance; and provides evidence that the experience of extensive childhood maltreatment, even among highly psychopathic individuals, significantly impacts the cognitive performance of offenders. Because individuals high in psychopathy frequently experience adverse environmental circumstances and maltreatment throughout development (Graham et al. 2012; Howard et al. 2012), it is crucial to

continue to consider the specific ways in which psychopathic individuals are impacted by their environment, and how these experiences may contribute to or exacerbate the development of psychopathic traits.

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Compliance with Ethical Standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of Interest Monika Dargis, Richard C. Wolf and Michael Koenigs declare that they have no conflicts of interest.

Experiment Participants This study received approval by the university's Institutional Review Board.

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Informed Consent Informed consent was obtained from all individual participants included in the study.

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