Specifying the Connection Between Reward Processing and Antisocial Psychopathology Across Development: Review, Integration, and Future Directions

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Abstract and Keywords

Antisocial behavior is a heterogeneous construct that includes a range of behavioral problems and psychopathologies. With regard to classification, children and adolescents may be identified as having conduct disorder or callous–unemotional traits; whereas adults may be identified as having antisocial personality disorder or psychopathy. The adverse consequences of the behaviors and diagnoses related to this construct produce great burdens for the perpetrators, victims, family members, and society at large. Research has focused on identifying various factors contributing to antisocial behavior, with reward processing among one of the most studied. This chapter synthesizes self-report, behavioral, electrophysiological, and neuroimaging literature on reward processing in antisocial behavior across development. Findings are organized regarding key reward constructs within the Positive Valence Systems domain of the Research Domain Criteria matrix. Overall, children with conduct disorder display deficits in action selection, responsivity to reward, and reward prediction that result in risky choices, impaired performance in the face of reward, and poor integration of reward information. By contrast, children with callous–unemotional traits demonstrate poor reward learning and use of reward cues. In adults, those with antisocial personality disorder display deficits in reward valuation; whereas those with psychopathy show context-dependent abnormalities in multiple components of reward processing. Ultimately, an integrative focus on abnormal reward processing across subtypes of individuals who engage in antisocial behavior might help refine the phenotype and improve the prediction of onset and recovery of these disorders.

Keywords: antisocial behavior, conduct disorder, callous-unemotional traits, antisocial personality disorder, psychopathy, reward processing

(p. 312) Introduction

Antisocial behavior covers a broad spectrum of acts that violate social norms. It includes relatively minor infractions of society's rules, such as lying, to more disruptive forms, such as aggression toward others. It is pervasive and often produces harm for the perpetrators themselves, as well as for their victims, family members, and society at large. Antisocial behavior is highly associated with adverse outcomes, such as increased suicide risk, school dropout, running away, delinquency, poor physical health, unemployment, psychopathology, substance abuse, and criminality, among many others. Individuals who engage in antisocial behavior, both youth and adults, disproportionately utilize high-cost health and mental health care (Maclean, Xu, French, & Ettner, 2014), are much more likely to be involved with the justice system, and often suffer a lifetime full of interpersonal trouble and social dysfunction that spills over into their family and community networks.

(p. 313) The enormity of the problems associated with antisocial behavior underscores the importance of identifying which individuals are most likely to engage in antisocial behavior. Often, these behaviors begin at an early age and persist over the life course. Yet, there are some who desist from antisocial conduct as they mature and others whose antisocial behavior does not begin until early adulthood. Therefore, it is essential that research specify factors that distinguish among these subgroups and assess individuals accordingly.

Much research has demonstrated that, for youth, the risk of antisocial behavior increases among those with conduct disorder (CD), CD with callous–unemotional (CU) traits (CD+CU), or CD with psychopathic (PP) traits (CD+PP). While youth with any of these syndrome subtypes act on impulse, engage in antisocial behavior, and manifest self-control deficits under a variety of circumstances, youth with CU traits and PP traits also display affective and interpersonal traits marked by callousness, low empathy, and low interpersonal emotions. Reflecting both the overlapping and unique features associated with CD, CD+CU, and CD+PP, there is variation across these syndromes in prevalence rates and the assessment tools.

Youth with CD repeatedly violate both the basic rights of others and age-appropriate societal norms by engaging in acts such as theft, cruelty to people and animals, and aggression (American Psychiatric Association, 2013). The prevalence of CD is estimated to be between 3 and 4 percent in boys and between 1 and 2 percent in girls, depending on the age of the population assessed (Erskine et al., 2013). A CD diagnosis is often obtained using clinical interviews based on the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM*; e.g., Kiddie-SADS Present and Lifetime Version; American Psychiatric Association, 2013; Kaufman et al., 1997).

Conduct disorder with CU traits was recently added to the fifth edition of the *DSM* (*DSM-5*; American Psychiatric Association, 2013) as a specifier and is characterized by the callous use of others, a lack of remorse or guilt, and an absence of empathy. CU traits are relatively stable across childhood (Frick & White, 2008). These traits are represented in approximately 32–46.1 percent of youth with CD (Frick, Stickle, Dandreaux, Farrell, & Kimonis, 2005; Herpers, Rommelse, Bons, Buitelaar, & Scheepers, 2012). The combination of CD and CU traits in youth is typically assessed using *DSM-5* criteria, the Antisocial Process Screening Device (Frick & Hare, 2001), or the Inventory of Callous–Unemotional Traits (ICU; Essau, Sasagawa, & Frick, 2006).

Conceptually, youth with PP traits display a combination of CU traits (interpersonal and affective deficits) and impulsive–antisocial traits (R. J. Blair, 2013; Budhani & Blair, 2005; Finger et al., 2008, 2011). In incarcerated and community samples of youth offenders, the prevalence of PP traits is on average between 9 and 25 percent depending on the instruments and cutoff scores used to distinguish PP and non-PP youth, the types of institutions/settings, and the composition (e.g., males and females) of the samples (Forth & Mailloux, 2000; Kosson, Cyterski, Steuerwald, Neumann, & Walker-Matthews, 2002). PP traits in youth typically are assessed using the Psychopathy Checklist: Youth Version (PCL:YV; Forth, Kosson, & Hare, 2003) or the Youth Psychopathic Traits Inventory (YPI; Andershed, Hodgins, & Tengstrom, 2007).

While the majority of youth who commit antisocial acts desist upon reaching adulthood (Moffitt, 2006; Stanger, Achenbach, & Verhulst, 1997), youth with any of these disorders are at greater risk of developing adult psychopathologies (Lahey, Loeber, Burke, & Applegate, 2005; Meyers, Stewart, & Brown, 1997), such as antisocial personality disorder (APD) and psychopathy. According to the *DSM-5*, APD encompasses a chronic and pervasive pattern of antisocial attitudes and behaviors that is pre-dated by CD. Thus, it represents a continuation into adulthood of such behaviors as chronic lying, fighting, bullying, aggression, impulsivity, and irresponsibility that began in childhood (American Psychiatric Association, 2013). APD is present in approximately 2 percent of the general population and in 32–64 percent of adults who are incarcerated (Fazel & Danesh, 2002). As with CD, APD is diagnosed using clinical interviews based on *DSM* criteria (e.g., Structured Clinical Interview for *DSM* Disorders; First, Spitzer, Gibbon, & Williams, 2002).

Psychopathy is a severe personality disorder affecting approximately 1 percent of the general population and 25 percent of incarcerated male offenders (Hare, 2006; Neumann & Hare, 2008). It involves chronic impulsive and antisocial behavior along with interpersonal (e.g., glibness, superficial charm) and emotional (e.g., shallow affect, lack of remorse) disturbances. The gold standard assessment of psychopathy is Hare's Psychopathy Checklist–Revised (PCL-R; Hare, 2003), an interview-based measure of the interpersonal/affective (Factor 1) and impulsive/antisocial (Factor 2) traits characteristic (p. 314) of this disorder. Although psychopathy is often discussed as a unitary syndrome, there is a long tradition of distinguishing psychopathic subtypes, such as primary and secondary psychopathy (Brinkley, Newman, Widiger, & Lynam, 2004; Karpman, 1941; Lykken, 1995; Skeem, Johansson, Andershed, Kerr, & Louden, 2007; Skeem, Poythress, Edens, Lilienfeld, & Cale, 2003). Primary psychopathy is associated with a lack of anxiety and is presumed to be a consequence of some intrinsic deficit that hampers self-regulation and normal adjustment (Karpman, 1941; Newman & Brinkley, 1997; Zeier, Maxwell, & Newman, 2009). Secondary psychopathy is associated with comparable levels of antisocial behavior but is thought to stem from social disadvantage, excessive neurotic anxiety, or other forms of psychopathology (Cleckley, 1941; Lykken, 1995).

While different diagnostic categories apply to youth and adults, research points to a common underlying problem related to reward processing. On the surface, the association between antisocial behavior and reward processing seems unsurprising. Reward pursuit is often inherent in antisocial behaviors (e.g., the pursuit of goods in the case of shoplifting, others' property or money in the case of theft, a "high" in the case of drug use) despite serious potential consequences (e.g., detention, incarceration, overdose). However, both reward processing and antisocial behavior are multidimensional. Thus, parsing the heterogeneity within both constructs may contribute to a meaningful refinement of clinical phenotypes so that appropriate prevention and intervention protocols can be developed.

The primary goal of this chapter is to distinguish and classify the relationships among different forms of antisocial psychopathology across stages of development (e.g., from CD +/- CU/PP traits to APD/psychopathy) and to characterize the aberrant reward processes (e.g., reward valuation, effort valuation and willingness to work, initial responsiveness to reward, action selection, expectancy/prediction, and reward learning; see the discussion further in this chapter for definitions) contributing to these pathologies. To this end, we (a) briefly review the major subcomponents of reward processing and how they are measured, focusing on measures that have been utilized when studying antisocial psychopathology; (b) examine research on the relationship of these subcomponents to antisocial psychopathology in youth and adults; and (c) discuss conceptual and methodological issues as they relate to identifying subtypes of antisocial individuals based on dysfunctions in reward processing. It is important to note that the scope of the studies reviewed in this chapter is not all inclusive. In order to focus on pathological forms of antisocial behavior, we only review research that used the *DSM* for diagnoses of CD and APD and the PCL-R for diagnoses of psychopathy. Identifying the specific deficits in reward processing that are unique to different subtypes of antisocial psychopathology is critical in order to identify and specify how aberrant reward processing contributes to the development and maintenance of antisocial behaviors.

Positive Valence Systems and Reward Processing

In 2008, the National Institute of Mental Health ushered in a new framework for understanding psychopathologies. In contrast to the *DSM*, Research Domain Criteria (RDoC) framework eschews the assessment of psychopathology based on clinical observation and refocuses attention on both reliable and valid measures derived from a wide variety of disciplines that center on understanding the brain–behavior relationship. RDoC posits that this relationship can be studied from the perspective of different systems (e.g., valence, cognition, social process, and arousal) and across different levels of analysis (e.g., genes, neural circuits, behavior; Cuthbert, 2014; Cuthbert & Insel, 2013; Insel et al., 2010; Morris & Cuthbert, 2012).

One primary domain of functioning within RDoC is that of Positive Valence Systems, which delineates reward into eight constituent components. In this section, we briefly present the major reward components based on a stage processing model of the influence of reward from initial identification and evaluation (reward valuation, effort valuation/willingness to work, and initial responsiveness to reward attainment) to making choices based on reward (action selection/preference-based decision-making) to the updating of those choices (expectancy/prediction error and reward learning; see Morris & Cuthbert, 2012, for the RDoC matrix order). Sustained/longer term responsiveness to reward attainment and habit are not reviewed due to a paucity of research in antisocial psychopathology at the diagnostic level.

Reward Valuation

Reward valuation refers to a set of processes that assigns a perceived value, or motivational salience, to a potentially rewarding outcome. During this process, one reward outcome is compared to other (p. 315) potential outcomes (Cuthbert, 2014; Cuthbert & Insel, 2013; Insel et al., 2010). Two aspects of reward valuation have garnered much attention: reward reactivity and delay discounting. Reward reactivity has been assessed using the Reward Responsiveness subscale of the Behavioral Activation System (BAS; Carver & White, 1994) scale, a self-report measure of individual differences underlying approach motivation (e.g., “It would excite me to win a contest”). The Reward Responsiveness subscale of the BAS specifically taps the degree to which an individual reacts to appetitive (or rewarding) stimuli. Higher scores on this subscale indicate higher levels of motivational salience attributed to potential reward.

Delay discounting is the tendency for individuals to devalue rewards available in the future, favoring instead smaller rewards available immediately (MacKillop et al., 2011). Delay discounting is typically measured using behavioral instruments that require individuals to choose between a series of small immediate rewards and larger rewards available at a delay (e.g., the Monetary Choice Questionnaire; Kirby, Petry, & Bickel, 1999). For example, given the choice between receiving $5 today and $50 next week, someone with elevated delay discounting would choose to receive $5 today, subjectively valuing immediacy over the reward with the higher objective value. A discount rate can be estimated to describe the extent to which the subjective value of a reward declines given its delivery date. Higher discount rates indicate steeper declines in the subjective value of rewards with delays.

Both self-report measures (e.g., BAS and Monetary Choice Questionnaire) and tasks measuring delay discounting provide estimates of individual sensitivities to the salience of reward. Moreover, these measures examine how those initial sensitivities result in reward- or approach-dominated behavior.

Effort Valuation/Willingness to Work

Effort valuation and willingness to work are interrelated processes responsible for evaluating the costs and benefits of the actions necessary to obtain specific rewarding outcomes (Cuthbert, 2014; Cuthbert & Insel, 2013; Insel et al., 2010). For example, if given the chance to obtain a monetary reward by pressing a button multiple times per second for 60 seconds, one would need to evaluate the "cost" of pressing that button repeatedly (effort valuation) and weigh it against how much he or she was willing to work to obtain the monetary reward (willingness to work). The Drive subscale of the BAS (Carver & White, 1994) represents a measure of the degree to which an individual is driven to obtain appetitive or rewarding stimuli even in the face of high levels of difficulty or work (e.g., "I go out of my way to get things I want"), with higher scores indicating higher levels of willingness to work. Measures like the BAS-Drive self-report scale assess the consideration and prioritization of effort to seek rewards.

Initial Responsiveness to Reward Attainment

Initial responsiveness to reward attainment is the core "reward response." This process captures the positive subjective experience that occurs when a rewarding stimulus (e.g., money, food, drugs) is first attained (Cuthbert, 2014; Cuthbert & Insel, 2013; Insel et al., 2010). Responsiveness to reward attainment is often examined using measures of neural activity, such as electroencephalogram (EEG) and neuroimaging, that ascertain response to rewarding outcomes (Diekhof, Kaps, Falkai, & Gruber, 2012). Several studies have begun to isolate the neural response to reward attainment using a variety of tasks, including the outcome phase of the Monetary Incentive Delay (Knutson, Fong, Adams, Varner, & Hommer, 2001), reward learning (Cox, Andrade, & Johnsrude, 2005), passive viewing tasks (O'Doherty et al., 2003), and gambling and guessing tasks.

For example, researchers using EEG during gambling and guessing tasks have identified feedback-related negative-going deflections that demarcate initial reward response. The feedback negativity (FN) occurs within 250–300 milliseconds following reward delivery and appears to broadly reflect stimulus categorization and, more specifically, the relatively automatic and binary evaluation of outcomes as either favorable or unfavorable (Holroyd, Hajcak, & Larsen, 2006). This component is also correlated with self-reported consummatory pleasure (Bress & Hajcak, 2013), further linking it to inital responsiveness to reward.

Examination of neuroimaging data across a variety of tasks indicates that reward attainment reliably elicits neural activity in the ventral striatum, medial orbital frontal cortex (mOFC) and ventromedial prefrontal cortex (vmPFC; Diekhof et al., 2012). Moreover, neural activity in those brain regions positively correlates to the magnitude of the reward attained (i.e., as the size of the reward received increases, the neural activity in those brain regions also increases). In tasks where individuals strive to obtain rewards, these different measures, whether EEG or imaging, reflect the amount of hedonic (p. 316) pleasure (e.g., neural activity, self-reported pleasure) achieved by the receipt of rewards.

Action Selection/Preference-Based Decision-Making

Action selection refers to the processes used to weigh the potential costs and benefits of multiple different actions and selecting the optimal option among them (Cuthbert, 2014; Cuthbert & Insel, 2013; Insel et al., 2010). Though aspects of action selection appear similar to reward valuation, action selection specifically refers to the processes by which choices are made, such as response perseveration, risk evaluation, and reward-related impulsivity.

Response perseveration is the tendency to repeatedly select the same action even in the face of changing contingencies that reduce or remove the adaptive function of that response pattern (McCleary, 1966). Individuals exhibiting response perseveration in the presence of rewards are usually described as displaying a reward-dominant response style, failing to learn from punishment feedback when potential rewards are present. Response perseveration has been evaluated using door-opening and card-taking paradigms. In these paradigms, participants are told that a specific action (e.g., opening a door, taking a card) will result in either a reward or a punishment. They are then told to complete that action as many times as they desire and to stop when they want. At first, the action produces a high rate of rewards (e.g., 90 percent reward outcomes and 10 percent punishment outcomes), but over time the action gradually becomes more likely to result in punishment outcomes until either the participant quits or the contingencies completely reverse (e.g., the action results in a rate of 10 percent reward outcomes and 90 percent punishment outcomes). The longer the participant persists, the greater the degree of response perseveration he or she exhibits (Matthys, van Goozen, de Vries, Cohen-Kettenis, & van Engeland, 1998; Matthys, van Goozen, Snoek, & van Engeland, 2004; Shapiro, Quay, Hogan, & Schwartz, 1988; Wilson & Evans, 2002).

Risk evaluation, a process that is engaged when individuals must evaluate the specific costs and benefits of possible actions, has been studied using the Iowa gambling task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994); the balloon analogue risk task (BART; Lejuez et al., 2002); and the risky choice task (RCT; Rogers et al., 2003). In the IGT, a participant continuously pulls cards from one of four decks. Each card is associated with a reward or a punishment. Some of the decks are "safe" (i.e., while rewards in the deck are generally low in magnitude, the combined reward and punishment cards in the deck result in net positive earnings over the course of several trials). Other decks in the IGT, however, are "risky" (i.e., while high-reward cards are available in the deck, the combined reward and punishment cards result in net negative earnings). Over the course of the task, participants implicitly learn which of the decks are risky through negative feedback (i.e., they appropriately learn from punishment). As a result, they stop taking cards from the risky decks (Bechara et al., 1994). Successfully learning which decks are risky and which decks are safe utilizes neural resources from the dorsolateral prefrontal cortex, insula, anterior cingulate cortex (ACC), orbitofrontal cortex (OFC), vmPFC, and ventral striatum (Li, Lu, D'Argembeau, Ng, & Bechara, 2010).[1]

During the BART, participants are presented with a balloon that they can "pump up" by pressing a button. While each successful pump earns the participant a specified reward, each pump also increases the likelihood the balloon will explode, resulting in no rewards for that balloon. During the task, participants must learn when a balloon is at risk for exploding and determine how many pumps they are willing to risk before moving on to the next balloon (Lejuez et al., 2002). Thus, while this task measures risk aversion, it also measures the extent to which an individual is willing to risk guaranteed rewards in order to receive larger potential rewards.

During the RCT, participants make a series of decisions between two options in an attempt to earn as many points as possible. During each trial, there is a "safe" or control option with a 50 percent chance of winning a small amount of points and a 50 percent chance of losing an equal amount of points. There is also a "risky" option in each trial that has a large chance of losing a large number points and a small chance of winning a larger number of points. Some risky options are considered "good" risks, with a positive expected value (i.e., the win amount and its likelihood offset the size and likelihood of the loss). Some risky decisions, however, are considered "bad" because they have a negative expected value (i.e., the win amount and its likelihood are too low to offset the size and likelihood of the loss). During action selection, individuals with disrupted (p. 317) risk evaluation would be expected to choose the bad risky option more often than individuals with intact risk evaluation (Rogers et al., 2003).

Finally, reward-related impulsivity is an individual's tendency to respond rapidly when a reward is present in situations in which delaying, or even completely inhibiting, a response would yield more optimal outcomes. Researchers suggest that reward-related impulsivity and delay discounting are related constructs, both attempting to evaluate trait impulsivity when rewards are present (Rubio et al., 2007); however, they tap trait impulsivity in fundamentally different ways. Delay-discounting tasks demonstrate the degree to which an individual may value, or prefer, an immediate reward over a delayed reward (reward valuation), but not whether the individual would actually be able to inhibit his or her behavior in a potentially rewarding situation, as is required in tasks measuring reward-related impulsivity (action selection).

Reward-related impulsivity has been measured using the delay task (DT; Gordon & Mettelman, 1988; Rubio et al., 2007) and the single-key impulsivity paradigm (SKIP; Dougherty et al., 2003). In the DT, participants are instructed to press a button, wait for a time, and then press the button again. If participants wait for an unknown period (e.g., at least 6 seconds), then they will receive a reward; however, if participants respond too soon, they do not receive a reward. Thus, the task requires individuals to learn the minimum time to wait in order to receive a reward and then to respond after said time. Individuals exhibiting impulsive action selection in the face of rewards would not be able to inhibit their responses properly, resulting in poorer performance (i.e., less rewarding outcomes) as compared to individuals who do not display reward-related impulsivity (Gordon & Mettelman, 1988; Rubio et al., 2007). When completing the SKIP, participants are instructed that they can press a button to receive money. The longer they wait to press the button, the larger the reward they receive. Individuals exhibiting reward-related impulsivity respond rapidly to receive the rewards and ultimately earn less over the course of the paradigm (Dougherty et al., 2003).

Response perseveration, risk evaluation, and reward-related impulsivity all measure different components of action selection, whereby the presence of reward shapes behavioral tendencies. In some cases, reward can become so predominant that responses become "stuck" on obtaining rewards rather than considering alternatives; in other cases, the pursuit of reward overshadows the inherent risk associated with that action; and, finally, the desire for reward can be so strong that reflecting on its relative value is challenging.

Expectancy/Reward Prediction Error

Expectancy and prediction error are interconnected processes related to the anticipated (or predicted) value of a reward-related cue (Cuthbert, 2014; Cuthbert & Insel, 2013; Insel et al., 2010). Expectancy involves processes by which an individual attaches a predicted value to a specific cue, which may be independent of the actual or perceived value of that cue. Prediction error is a neural response that occurs when an individual's expectancy is violated (Garrison, Erdeniz, & Done, 2013).

The monetary incentive delay (MID) paradigm is often used to evaluate expectancy and prediction error (Knutson et al., 2001). A trial in a classic MID task consists of three phases: a cue phase, a target phase, and an outcome phase. During the cue phase, participants are shown a prompt that informs them of whether they are playing for a reward during that trial (i.e., whether they will receive a reward if they respond fast enough to successfully "hit" the target during the next phase of the trial). The cue phase is followed by the target phase, in which a target stimulus is flashed on the screen. Participants must respond as quickly as possible to this target stimulus. Finally, during the outcome phase, participants receive feedback about whether they successfully hit the target, which in turn informs them of whether they received a reward for that trial. During the cue phase, the ventral striatum not only preferentially responds to reward-predictive cues, but also positively scales with the magnitude and probability of attaining the cued reward (Abler, Walter, Erk, Kammerer, & Spitzer, 2006; Knutson et al., 2001; Knutson, Taylor, Kaufman, Peterson, & Glover, 2005), suggesting that ventral striatal activity in response to predictive cues represents an index of expectancy.

In contrast to expectancy, reward prediction error tests an individual's neural response to reward outcome feedback. More specifically, it is examined by contrasting neural responses to unexpected (low-probability) reward feedback against neural responses to expected (high-probability) reward feedback (Abler et al., 2006). Research examining prediction error response indicates that expectancy violations during reward receipt reliably elicit neural activity in the ACC, anterior insula, and ventral striatum (Abler et al., 2006; Behrens, Hunt, Woolrich, & Rushworth, 2008; Garrison et al., 2013). While earlier stages of reward processing reflect the preference for reward and behaviors that align with this preference, this stage of reward processing represents how the individual's reward-based desires establish expectancies that may or may not be realized.

Reward Learning

Reward learning refers to the ways in which individuals acquire information about which cues or actions are likely to result in positive, rewarding outcomes and then update that information as the situational context changes (Cuthbert, 2014; Cuthbert & Insel, 2013; Insel et al., 2010). Research on reward learning centers on two different aspects, or phases, of the learning process: acquisition and reversal learning. In the first acquisition phase, individuals are conditioned through positive reinforcement to respond to specific cues in order to obtain rewarding outcomes. For example, in a passive avoidance paradigm, participants are shown a series of cues and given the choice of whether to respond. Over the course of the task, participants learn that responding to certain cues will result in monetary rewards (the reward condition/positive reinforcement condition), while responding to other cues will result in monetary losses (the punishment condition). Successful initial acquisition of reward learning results in high response rates to the rewarding cues, while failures during the initial phase of reward learning result in elevated rates of omission errors (i.e., failing to respond to rewarding cues). Elevated rates of commission errors (i.e., responding when responses are maladaptive; Newman & Kosson, 1986), however, reflect deficits in punishment learning.

Similar to passive avoidance learning paradigms, probabilistic reward learning paradigms also evaluate initial acquisition of reward learning. Participants are repeatedly presented with two options and asked to choose between them. One option has a high chance of receiving a reward (usually between 60 and 90 percent), and the other has a low chance of receiving a reward (usually between 10 and 40 percent; Delgado, Miller, Inati, & Phelps, 2005). Over time, participants with intact reward learning determine, through positive reinforcement, which option has the higher chance of receiving a reward and choose that option more frequently. Individuals who learn the "correct" option sooner display significantly greater neural activity in the ventral striatum during initial reward feedback, suggesting that striatal response to reward feedback plays a critical role in positive reinforcement learning (Delgado et al., 2005).

In the second phase of reward learning, reversal learning/contingency updating, an individual learns that contingencies have changed and that a different response pattern would result in optimal levels of reward attainment (Cools, Clark, Owen, & Robbins, 2002). The experimental paradigms used to examine reversal learning are similar to the probabilistic learning paradigms described previously. However, here, the contingencies are reversed at some point during the task such that the option that previously resulted in higher rates of reward outcomes now results in lower rates of reward outcomes and vice versa. Individuals with intact reversal learning react to these new contingencies by updating their response patterns, while individuals with deficits in reversal learning show more perseverative response patterns (Cools et al., 2002). Successful reversal of reward contingencies recruits neural resources in the vmPFC, ventrolateral prefrontal cortex (vlPFC), ACC, and OFC to both inhibit the initial response pattern and encode the new reward contingencies (Clark, Cools, & Robbins, 2004; Cools et al., 2002; Ghahremani, Monterosso, Jentsch, Bilder, & Poldrack, 2010). Together, in the acquisition and reversal phases of reward learning, contingent associations of reward (e.g., cue) and outcome (e.g., feedback) are continually updated, integrated, and translated into behavior.

All six of these constructs, from identification to evaluation to choice to updating choice, capture related but distinct aspects of reward processing. Independent examination of each of these constructs makes it possible to identify which specific reward processes are abnormal among and within various antisocial psychopathologies.

Reward Processing in Youth Antisocial Psychopathology

There is a long history of conceptualizing antisocial behavior in youth as reflecting a dysfunctional imbalance between reward and punishment processing. This next section summarizes whether aberrant reward processing is specific to or most pronounced in certain components of reward processing and in subgroups of antisocial youth.

Conduct Disorder

Youth with CD display elevated levels of lying, bullying, stealing, drug use, and other antisocial behaviors that violate age-appropriate norms (American Psychological Association, 2013). Many, if not all, (p. 319) of these behaviors can be motivated by an individual's desire to obtain rewards (e.g., money, recreation outside of home and school, status among peers) even in the face of potential legal or parental punishment. (*Note:* Reward learning is not reviewed in this chapter due to a lack of research using a formal CD diagnosis.)

Reward Valuation

Youth with CD scored higher than healthy controls on the Reward Responsiveness subscale of the BAS, suggesting that they attribute higher levels of motivational salience to rewards in general (Bjornebekk & Howard, 2012). During monetary choice tasks, these youth exhibited steeper rates of delay discounting, signifying a greater preference for immediate rewards among youth with CD than among healthy controls (White et al., 2014). Thus, youth with CD display a hypersensitivity to reward (e.g., money), resulting in reward-dominant impulsive behavior (e.g., theft).

Effort Valuation/Willingness to Work

Only one study examined effort valuation/willingness to work among youth with CD. Here, youth with CD scored significantly higher than healthy controls on the Drive subscale of the BAS, indicating that youth with CD diagnoses, as compared to their healthy counterparts, were more willing work in order to obtain rewards (Bjornebekk & Howard, 2012). Though research in this domain is limited, the association between willingness to work for rewards and CD may indicate that these youth not only find rewards, such as money and status, to be more salient (reward valuation), but also are more motivated to seek rewards, whether by theft, retaliation, or other means.

Initial Responsiveness to Reward Attainment

Youth with CD appear to display a blunted response to reward attainment (Cohn et al., 2015; Gao et al., 2015). Using a gambling task, Gao and colleagues (2015) examined an early negative response to rewards[2] and found that the FN in youth with CD did not differentiate reward and punishment feedback (see also Hyde, Shaw, & Hariri, 2013). Similarly, using a MID task, Cohn et al. (2015) reported a CD-related blunting of the striatal response to reward feedback during the outcome phase. Together, these findings show that youth with CD display a blunted initial reward response when they obtain rewarding outcomes and discriminate less between reward and punishment feedback. Though youth with CD are hypersensitive to rewards, they may constantly pursue those rewards because they fail to feel satisfaction on their receipt and fail to discriminate between different forms of feedback. This type of deficit is reminiscent of the pattern displayed by youth who become addicted to substances, whereby they continually chase the high associated with their drug of choice.

Action Selection/Preference-Based Decision-Making

There is substantial evidence that youth with CD display aberrant action selection in the presence of reward (Fairchild et al., 2009; Hobson, Scott, & Rubia, 2011; Matthys et al., 1998, 2004; Shapiro et al., 1988; Wilson & Evans, 2002). For example, Fairchild and colleagues (2009) found that when youth with CD completed an RCT, they chose the risky option instead of the safe option significantly more often than healthy controls. This preference was particularly prominent when the risky option was a bad risk (i.e., the risky option had a negative expected value). Thus, youth with CD exhibit disrupted risk evaluation during action selection in the context of reward, and as a result, they may be deficient in their evaluation of the potential risks.

Additionally, studies using tasks that measure response perseveration (e.g., card-taking and door-opening tasks) consistently demonstrate that youth with CD perseverate on previously rewarding actions even as those actions become continually less rewarding and, thus, less adaptive (Matthys et al., 1998, 2004; Shapiro et al., 1988; Wilson & Evans, 2002). In other words, once youth with CD identified a rewarding response pattern (whether it was opening doors during a task in the laboratory or stealing money in the real world), they failed to utilize punishment feedback (e.g., loss of money, overdose, incarceration) to update their contingencies and find a more optimal response pattern

(Ghahremani et al., 2010). Furthermore, youth with CD also overlooked negative feedback when initially determining an optimally rewarding response pattern. Hobson and colleagues (2011) found that, during the IGT, youth with CD did not implicitly learn which decks were risky (i.e., resulting in a negative net yield) and (p. 320) continued to pick from both risky and safe decks throughout the task.

Together, these action selection findings point to the possibility that youth with CD generally fail to incorporate punishment feedback into any aspect of future action selection as they pursue rewards. This aberrant action selection applies to initial response pattern development as well as to response pattern updating to account for changing contingencies. The continuation of a maladaptive response pattern is consistent with the repetitive criminogenic tendencies youth with CD display in service of attaining rewards, despite legal and health risks.

Expectancy/Reward Prediction Error

In studies that use neuroimaging, youth with CD exhibit deficits in reward expectancy and reward prediction error. For instance, during a passive avoidance learning task, youth with CD displayed a diminished neural representation of expected value in the vmPFC to reward-predicting cues, indicating that youth with CD do not track which reward cues generally precede rewarding outcomes of differing magnitudes. They also demonstrated a diminished reward prediction error response to unexpectedly large rewarding outcomes in the ventral striatum but exhibited an enhanced punishment prediction error response to unexpected punishment outcomes in the same neural structure (White et al., 2013). This enhanced punishment prediction error response implies that youth with CD are sufficiently, possibly even in an exaggerated way, processing punishment feedback; however, they fail to integrate this punishment feedback or utilize it to inform or update expectancies as they pursue rewards. These deficits in tracking and updating reward expectancies suggest engagement in antisocial behavior for CD youth is disconnected from the reward or punishment feedback following the behavior, and that, in order to modify their behavior, using concrete and repetitive rewards to link behavior and outcome is essential (Kazdin, 2008).

Summary and Integration

Overall, youth with CD exhibit enhanced reward valuation and willingness to work, diminished initial responsiveness to rewards and expectancy/reward prediction error, and abnormal action selection indicative of riskier pursuit of rewards. Generally, while youth with CD find potential rewards *more* motivationally salient than healthy controls and are more driven to obtain them, they also display *diminished* core reward responses (i.e., they find rewards less neurally “rewarding”; Cohn et al., 2015; Gao et al., 2015). While seemingly contradictory, it is possible that, because youth with CD display this blunted reward response, they would need to obtain more rewards in order to experience a normative or homeostatic reward response (Cohn et al., 2015). Accordingly, youth with CD would be expected to attribute greater levels of motivational salience to potential rewards and be more driven to obtain those rewards, regardless of the potential costs, because these same rewards do not produce as much pleasure as they do for healthy youth (Cohn et al., 2015; Zuckerman, 1978; Zuckerman & Neeb, 1979). In turn, this elevated drive to obtain rewards might contribute to the abnormal action selection exhibited by youth with CD.

Youth with CD reliably show maladaptive action selection indicative of a general failure to change their behaviors in response to punishment feedback when pursuing rewards (Hobson et al., 2011; Matthys et al., 1998, 2004; Shapiro et al., 1988; Wilson & Evans, 2002). Previous reviews examining this failure of punishment learning (i.e., this reward-dominant response style) attributed these deficits in action selection to an overarching insensitivity to punishment feedback (Byrd, Loeber, & Pardini, 2014). However, the evidence suggests that this hypothesis does not fully account for the performance of youth with CD on these tasks. Youth with CD are not strictly insensitive to punishment feedback (e.g., they do not show diminished prediction error responses to punishment outcomes), and they display an elevated drive to obtain rewards, which lead these youth to ignore the potential costs associated with their actions (Cohn et al., 2015). The combination of these reward-related dysfunctions may explain why youth with CD engage in fights, substance use, and criminal acts despite the inherent risks of these actions. That is, the inability to learn the risks associated with antisocial behaviors through punishment feedback stems from the CD-related drive to obtain rewards and maintain reward homeostasis.

Callous–Unemotional and Psychopathic Traits

Although youth with CD+CU/CD+PP (i.e., conduct disorder plus callous-unemotional traits or psychopathic traits) exhibit many of the same behaviors as youth with CD-only, including bullying and stealing, youth with CD+CU/CD+PP display differences in their frequency of antisocial behavior and patterns of emotional presentation (Frick et al., 2005). Differences in reward processing between (p. 321) youth with CD+CU/CD+PP and youth with CD-only may elucidate possible mechanisms differentiating the patterns of behavior in these forms of psychopathology. (*Note:* Reward valuation and effort valuation/willingness to work are not reviewed in material that follows due to a lack of research using formal diagnoses of CD+CU/CD+PP).

Initial Responsiveness to Reward Attainment

Similar to youth with CD, neuroimaging evidence shows that youth with CD+CU have a diminished responsiveness to reward attainment (Cohn et al., 2015; Finger et al., 2011). However, this deficit in responsiveness to reward attainment is driven by the deficit in responsiveness to reward attainment associated with CD rather than CU traits. For example, Cohn et al. (2015) found that youth with CD+CU *and* CD-only displayed a significantly blunted striatal response to rewarding outcomes during the outcome phase of an MID task and that the striatal response between groups did not differ. Thus, although CD+CU youth exhibit reduced responsiveness to reward, the effect appears to be driven by CD rather than CU levels.

In youth with CD+PP, there is a similar blunting of responsiveness to reward. Youth with CD+PP displayed reduced OFC activity in response to reward outcomes during a passive avoidance task (Finger et al., 2011). This study, though, did not have a CD-only comparison group, so it is not possible to determine whether this effect was due to the unique presence of PP traits or to the general presence of CD symptomology. Regardless, this reduced reflection of a positive subjective experience is consistent with the general profile of youth CD+CU/CD+PP as cold, unemotional, and displaying less positive affect.

Action Selection/Preference-Based Decision-Making

The combination of CD+CU or CD+PP appears to exacerbate the maladaptive response perseveration patterns present in CD-only. Across multiple response perseveration paradigms (e.g., door-opening paradigms, card-taking paradigms), youth with CD+CU or CD+PP had significantly longer perseverative response patterns than any of the comparison groups, including a CD-only group (Barry et al., 2000; O'Brien & Frick, 1996). Youth with CD+CU/CD+PP showed the highest rates of police contact and antisocial behavior (Frick et al., 2005). Their exacerbated response perseveration could lead to this persistent engagement in previously rewarding antisocial behaviors (e.g., carrying a weapon to enhance social influence) despite the negative outcomes (e.g., police contact).

Expectancy/Reward Prediction Error

Youth with CD+CU/CD+PP also demonstrate an enhanced punishment prediction error response. A neuroimaging study conducted by Finger et al. (2008) found that, during the reversal phase of a probabilistic reversal learning task, unexpected punishment outcomes elicited a significantly larger prediction error response for youth with CD+PP in the caudate and vmPFC, although this response pattern did not significantly impact task performance (i.e., total reward obtained did not differ). This may mean that youth with CD+PP have intact, or even enhanced, responsiveness to unexpected punishment feedback when rewards are at stake. It should be noted that this study did not include a comparison group consisting of youth with CD-only. Interestingly, Finger and colleagues (2008) reported no CD+PP–related deficits in reward expectancy or reward prediction error. Thus, it is possible that deficits in reward expectancy and reward prediction error in youth with CD-only (White et al., 2013) are not present in youth with CD+CU/CD+PP. Evidence that youth with CD+CU/CD+PP show an enhanced punishment prediction error response is reflected by research showing that using punishment as an intervention for these youth is contraindicated because they respond to that feedback with escalated levels of anger and revenge, rather than by changing their behavior.

Reward Learning

The body of research on reward learning has what might appear to be equivocal findings. For instance, Finger et al.'s (2008) examination of probabilistic reversal learning in youth with CD+PP did not reveal behavioral or neural abnormalities during reward learning. However, in a later study utilizing a passive avoidance learning task, they did find behavioral and neural evidence of reward and punishment learning deficits in youth with CD+PP (Finger et al., 2011). Behaviorally, youth with CD+PP made more errors, particularly commission errors, perhaps due to an underlying deficit in reinforcement learning (specifically punishment learning). Additionally, youth with CD+PP showed diminished responses to reward reinforcement in the OFC and caudate, again confirming that these youth find rewarding outcomes less reinforcing (Finger et al., 2011). Thus, consistent with their (p. 322) abnormalities in responding to, perseverating on, and predicting rewards, chronic engagement in antisocial behavior by youth with CD+CU/CD+PP is not inherently reflective of a reward bias, but rather a reduced ability to learn from the feedback (e.g., punishment).

Summary and Integration

While both youth with CD and youth with CD+CU/CD+PP possess some similar dysfunctions in reward processing, they differ in key ways. Specifically, there is no evidence that youth with CD+CU/CD+PP have the elevated reward valuation or drive to obtain rewards exhibited by youth with CD-only. One explanation for the maladaptive response perseveration of youth with CD+CU/CD+PP is that these youth have a general insensitivity to punishment feedback such that they do not experience the hedonic impact of losses when punishment outcomes occur (Byrd et al., 2014). However, this explanation is hard to reconcile with the punishment prediction error findings for youth with CD+CU (Finger et al., 2008), which indicate intact, or even enhanced, punishment prediction error response. These findings, though, mean that youth with CD+CU/CD+PP have a deficit in their ability to integrate and utilize punishment feedback to inform future action selection (Finger et al., 2008). Though these youth may value and respond to rewards normatively, this inability to adjust behavior to punishment feedback results in action selection that is perseverative and appears reward dominant. Functionally, the callousness, lack of remorse, and repetitive antisocial behavior in pursuit of a goal or desired outcome among youth with CD+CU/CD+PP may be a reflection of an inability to change behavior based on incoming feedback and information.

Reward Processing in Adult Antisocial Psychopathology

Conduct disorder and CD+CU/PP represent developmental antecedents of adult antisocial psychopathology. Thus, as in youth, some of the antisocial behavior displayed by adults may be a consequence of distinct reward-related underpinnings.

Antisocial Personality Disorder

Antisocial personality disorder is characterized by lifelong impulsive and antisocial behaviors, many of which may be conceptualized as targeted at obtaining rewards (e.g., money, drugs, sex). (*Note:* The constructs of effort valuation/willingness to work, initial responsiveness to reward attainment, and expectancy/reward prediction error are not reviewed below because research on these subcomponents of reward has not yet been conducted with individuals meeting DSM diagnoses for APD).

Reward Valuation

Consistent with CD youth, behavioral and neural evidence indicate that adults with APD, compared to those without, find potential rewards more motivationally salient (Petry, 2002; Vollm et al., 2010). On the behavioral level, Petry (2002) reported that, during a delay discounting paradigm, adults with APD and comorbid substance abuse showed steeper rates of delay discounting than both adults with substance abuse-only and healthy controls. This finding indicates that adults who engage in a wide variety of antisocial behaviors (i.e., individuals who meet diagnostic criteria for APD and who abuse substances) find the saliency of immediate, but smaller, rewards more attractive. However, work by Swann, Lijffijt, Lane, Steinberg, and Moeller (2009, 2011) did not replicate this finding. Instead, when adults with APD were repeatedly given a choice between waiting 5 seconds to receive $0.05 and waiting 15 seconds to receive $0.15, adults with APD did not significantly differ in task performance from adults without an APD diagnosis. The discrepancy between these two findings may be due to the different time frame (i.e., length of delay) and reward magnitude used in each of these studies. While Swann et al.'s (2009, 2011) delays were 5 and 15 seconds long, Petry's (2002) were much longer, ranging from 6 hours to 25 years. Similarly, the rewards in Swann et al.'s series of studies (2009, 2011) were $0.05 and $0.15, while Petry's (2002) delay discounting paradigm utilized rewards ranging from $0.01 to $1,000. Therefore, it is possible that the APD-related preference for immediate rewards may be limited to either long-term delays (i.e., delays longer than a few seconds) or large rewards (i.e., rewards greater than $1 in value).

On the neural level, adults with APD displayed enhanced activity in the OFC and pregenual cingulate during a rewarded go-no-go task, a task that requires responses in certain situations and inhibition in others, but not during an unrewarded go-no-go task (Vollm et al., 2010). However, rather than model neural activity during specific phases within individual trials, Vollm et al.'s study (2010) modeled neural activity across trials (e.g., cue, response, and feedback phases). Therefore, it is difficult to determine which aspect(s) of reward processing (p. 323) drive this APD-related enhanced neural response in the presence of rewards. It is possible that the elevated activity is due to an exaggerated response to reward receipt in individuals with APD (i.e., individuals with APD show enhanced responsiveness during the feedback phase). However, Vollm et al. (2010) proposed that the enhanced neural activity in the OFC and cingulate is due to higher levels of motivational salience being attributed to potentially rewarding outcomes among individuals with APD (i.e., individuals with APD value rewards more overall). This explanation is consistent with the delay discounting findings, which suggest that adults with APD display enhanced reward valuation, attributing higher levels of motivational salience to potential rewards in general (Vollm et al., 2010) and to immediately rewarding outcomes in particular (Petry, 2002). Accordingly, an individual with APD who displays persistent irresponsibility and impulsivity by dealing drugs or engaging in burglaries to "get rich quick" may favor the immediacy of this financial gain over the potential for longer term and more stable rewards attained by working for a paycheck through gainful employment.

Action Selection/Preference-Based Decision-Making

Studies examining action selection in adults with APD show mixed results. For example, during the BART, performance did not differ between those with and without APD diagnoses, suggesting that adults with APD display intact risk evaluation in the presence of reward (Swogger, Walsh, Lejuez, & Kosson, 2010). However, when adults with APD completed an IGT, they spent more time learning which decks were risky, as evidenced by a longer latency to avoid them, compared to healthy controls (Mazas, Finn, & Steinmetz, 2000). Differences in the design of the BART and the IGT may explain the inconsistency in results. In the former, there is an explicit emphasis on risk, with instructions stating that inflating the balloon too much will result in an explosion, eliminating the potential for reward receipt (Lejuez et al., 2002). In the latter task, participants are not told that two decks are risky and two decks are safe but are given a vague warning that some decks are "better than others," necessitating a degree of implicit learning (Bechara et al., 1994). Thus, it may be that adults with APD display intact risk evaluation when they are explicitly instructed to evaluate risk during action selection, but they display delays when risk evaluation must be done implicitly.

The reward impulsivity literature for adults with APD is similarly equivocal. Rubio and colleagues (2007) found that adults with APD diagnoses responded more prematurely during rewarded DT trials than adults without APD diagnoses, indicating an association between APD and impulsive action selection in the presence of reward. In another study of impulsive action selection using the SKIP, however, APD was unrelated to performance (Swann et al., 2009, 2011). Similar to the risk evaluation literature discussed above, the implicit nature of the DT may explain these apparently discrepant findings. During a SKIP, participants are explicitly informed that the longer they wait, the larger the reward they will receive (Dougherty et al., 2003). When participants completed a DT, however, they were simply instructed to "wait a while" to receive a reward and had to implicitly learn that responding before a specific time (e.g., 6 seconds after the initial response) would preclude reward receipt (Gordon & Mettelman, 1988; Rubio et al., 2007). These studies support the idea that individuals with APD display impulsive action selection only when they are not explicitly instructed on how to optimally respond in order to maximize reward receipt. In terms of real-world functioning, behaviors such as deciding to drive under the influence of alcohol versus calling for a taxi more often rely on in-the-moment implicit cost–benefit analysis. Accordingly, the strong positive relationship between APD and driving under the influence charges (McCutcheon et al., 2009) may reflect impairment in this type of reward processing.

Reward Learning

There is no evidence of reward learning deficits in adults with APD. During a probabilistic reversal learning task, individuals with APD showed no significant behavioral or neural differences in any aspect of reward learning when compared to healthy controls (Gregory et al., 2015). While individuals with APD do violate societal norms (e.g., repeatedly arriving late to work), their continued behavior cannot be attributed to a lack of understanding of the rewards they forgo (e.g., increased wages) or the punishments associated with such behavior (e.g., getting fired).

Summary and Integration

Overall, the reward-processing literature for adults with APD is limited to a few specific subcomponents. However, there are some important findings that demonstrate consistency across development, (p. 324) as well as some discrepancies. The existing literature suggests that, similar to youth with CD, adults with APD display enhanced reward valuation (Petry, 2002; Vollm et al., 2010) and maladaptive action selection when task instructions do not provide explicit guidance on how to optimize reward receipt (Mazas et al., 2000; Rubio et al., 2007). The enhanced reward valuation found among adults with APD means that these individuals find potential rewards more motivationally salient than do healthy controls. By extension, these individuals may be more driven to obtain them, as in youth with CD, but further examination of willingness to work in adults with APD is necessary to support this hypothesis. Evidence for an elevated drive to obtain rewards, combined with the heightened motivational salience of rewarding outcomes already documented in adults with APD, would explain the tendency for these adults to pursue rewarding outcomes regardless of the risks involved, leading to maladaptive action selection in the presence of reward. This disregard for risks in favor of reward pursuit may explain the chronic engagement in illegal (yet rewarding) behaviors characteristic of individuals with APD, such as robbery and drug use, despite the inherent risks involved in those behaviors, such as incarceration, drug addiction, and overdose.

Psychopathy

Research examining antisocial behavior in adults with psychopathy has largely focused on potential psychopathy-related deficits in punishment/loss processing (K. S. Blair, Morton, Leonard, & Blair, 2006). Still, as in other forms of antisocial psychopathology, antisocial acts displayed by adults with psychopathy do often occur in the context of reward pursuit. (*Note:* The construct of effort valuation/willingness to work is not reviewed here because research on this subcomponent of reward processing has not been conducted in populations diagnosed with psychopathy using PCL-R criteria.)

Reward Valuation

In general, there is no evidence of abnormal reward valuation among individuals with primary psychopathy. For example, individuals with primary psychopathy did not significantly differ from healthy controls on the Reward Responsiveness subscale of the BAS (Newman, MacCoon, Vaughn, & Sadeh, 2005). However, individuals with secondary psychopathy scored significantly higher on the Reward Responsiveness subscale of the BAS. Similar to youth with CD and adults with APD, individuals with secondary psychopathy value potential rewards (e.g., money, sex) more highly than do healthy controls (Newman et al., 2005); however, primary psychopathy is not associated with hypersensativity to reward.

Initial Responsiveness to Reward Attainment

There is no evidence of abnormal responsiveness to reward attainment in adults with psychopathy. Pujara, Motzkin, Newman, Kiehl, and Koenigs (2014) reported that during the outcome phase of a passive gambling task, offenders with psychopathy did not display a significantly different striatal response to either reward or punishment outcomes. This finding implies that, while individuals with psychopathy show increased engagement in reward-pursuant behaviors (e.g., promiscuous sexual activity), these individuals do not necessarily derive any more or less pleasure from the attainment of those rewards (i.e., their reward response to sex itself is not aberrant).

Action Selection/Preference-Based Decision-Making

Evidence is mixed regarding the relationship between psychopathy and action selection, with some work noting abnormal action selection in psychopathy (Mitchell, Colledge, Leonard, & Blair, 2002; Newman, Patterson, & Kosson, 1987) and other work showing no associations between action selection and psychopathy (Losel & Schmucker, 2004; Moltó, Poy, Segarra, Pastor, & Montanes, 2007; Swogger et al., 2010). For example, Newman et al. (1987) reported that offenders with psychopathy, measured using the unitary PCL-R total score, engaged in maladaptive response perseveration of previously rewarding actions during a card-taking paradigm. More recently, though, Moltó et al. (2007) found that during a similar card-taking paradigm, the maladaptive response perseveration of offenders with psychopathy was actually driven by Factor 2 traits (i.e., impulsive–antisocial) rather than PCL-R total (i.e., unitary measure) scores. The discrepancy between these two studies may be because only certain aspects of psychopathy are associated with maladaptive response perseveration in the presence of rewards (Moltó et al., 2007), but not psychopathy per se.

Research by Mitchell and colleagues (2002) reported that offenders with psychopathy did not avoid risky decks during the IGT, perhaps because they had poor implicit risk evaluation. However, a (p. 325) study by Lösel & Schmucker (2004) purported that the presence of psychopathy did not significantly relate to performance on the IGT when individual differences in visual attention were taken into account. More specifically, the IGT performance of offenders with psychopathy who scored high on Brickenkamp’s d2 test (Brickenkamp & Zillmer, 1998) of attention, a well-validated assessment of immediate and sustained visual attention, did not significantly differ from that of offenders without psychopathy. Only offenders who had both psychopathy diagnoses and performed poorly on Brickenkamp’s attention task displayed action selection deficits during the IGT (Lösel & Schmucker, 2004). Thus, it is possible that the effects reported by Mitchell et al. (2002) were moderated by abnormalities in attention rather than by an underlying deficit in risk evaluation. This idea was supported by research conducted by Swogger et al. (2010), who found no evidence of a psychopathy-related deficit in risk evaluation during the BART. Together, these findings demonstrate that while certain components of psychopathy (e.g., Factor 2 traits; Buckholtz et al., 2010; Geurts et al., 2016) or processes examined within psychopathy (e.g., visual attention) might be associated with action selection deficits, resulting in risky and antisocial behavior, psychopathy as a unitary construct is not associated with any specific deficits in action selection.

Expectancy/Reward Prediction Error

Prediction error in adult psychopathy appears to be intact or even enhanced. Adults with psychopathy displayed a normative error-related negativity response (an event-related potential reliably tied to error monitoring) to feedback events during a reward learning task, demonstrating intact error monitoring and prediction error for reward and punishment feedback (von Borries et al., 2010). Furthermore, Gregory et al. (2015) found that individuals with psychopathy showed an enhanced punishment prediction error response in the cingulate cortex and insula to unexpected punishment events during a reversal learning task that contained both punishment and reward signals. Therefore, individuals with psychopathy show intact reward prediction error and overrespond when punishment expectancies are violated. Individuals with psychopathy have an uncanny ability to con and manipulate others. This approach to interpersonal interaction requires adaptive engagement in developing a predictive schema about the target and updating expectancies based on the gains attained in a situation, but ultimately may result in maladaptive outcomes, like fights and contact with the criminal justice system.

Reward Learning

Much like youth with CD+CU/CD+PP, adults with psychopathy display deficits across multiple aspects of reward learning (K. S. Blair et al., 2006; R. J. Blair et al., 2004; Brazil et al., 2013; Budhani, Richell, & Blair, 2006; Mitchell et al., 2006; Newman & Kosson, 1986; Newman, Patterson, Howland, & Nichols, 1990; Newman & Schmitt, 1998; Poythress et al., 2010; von Borries et al., 2010). For example, offenders with psychopathy displayed behavioral deficits in reinforcement learning during a probabilistic learning task, particularly in the acquisition of reward and punishment contingencies during initial trials (von Borries et al., 2010). However, two studies contradicted this finding. First, Budhani et al. (2006) showed that adults with psychopathy had intact initial acquisition of reward and punishment contingencies during a probabilistic reversal learning task. Second, Brazil et al. (2013) found no psychopathy-related deficits in initial reward or punishment learning during a go-no-go task requiring probabilistic learning. The contradictions among these findings, however, are likely due to differences in task difficulty or complexity. For example, the reward learning task utilized by von Borries et al. (2010) required participants to learn and track three different reward/punishment contingencies (a 100 percent to 0 percent reward/punishment contingency, an 80 percent to 20 percent reward/punishment contingency, and a 50 percent to 50 percent reward/punishment contingency). In contrast, the paradigms examined by Budhani et al. (2006) and Brazil et al. (2013) only required participants to track one or two sets of reward/punishment contingencies. It is possible that the added complexity associated with tracking three sets of contingencies produced the psychopathy-related delay in initial reward learning, and that individuals with psychopathy may only display deficits in reward learning when task demands are high.

Beyond any potential deficits in the initial acquisition of reward learning, adults with psychopathy reliably demonstrate deficits during punishment and reversal learning paradigms (K. S. Blair et al., 2006; R. J. Blair et al., 2004; Brazil et al., 2013; Budhani et al., 2006; Mitchell et al., 2006; Newman et al., 1990; Newman & Kosson, 1986; Newman & Schmitt, 1998; Poythress et al., 2010). For example, individuals with psychopathy made more commission errors during standard passive avoidance (p. 326) learning paradigms, which utilize both reward and punishment reinforcement conditions (Newman & Kosson, 1986; Newman & Schmitt, 1998). Yet, these psychopathy-related deficits only appeared when the passive avoidance task required participants to track both reward *and* punishment contingencies. If a passive avoidance task was altered such that participants only needed to track punishment contingencies (i.e., if both omission errors and commission errors resulted in punishment outcomes and there was no reward component), there was no effect of psychopathy on task performance (Newman & Kosson, 1986). Thus, individuals with psychopathy generally show poor punishment/reward learning during passive avoidance learning tasks, but only when there are multiple competing streams of information (i.e., in conditions involving both punishment and reward reinforcement).

Adults with psychopathy exhibit similar impairments during probabilistic reversal learning paradigms, which utilize both reward and punishment reinforcement conditions. In one study, adults with psychopathy, compared to those without psychopathy, were more likely to choose options that would result in punishment but only after reward and punishment contingencies were reversed (Budhani et al., 2006). Much like the psychopathy-related punishment learning deficits in passive avoidance, the context specificity of this finding indicated that adults with psychopathy had difficulty updating their reward and punishment contingencies once they were initially established.

Using a probabilistic, cued reward reversal learning task, Brazil et al. (2013) manipulated the explicit versus implicit nature of contingencies. When explicitly informed that Cue X predicted rewarding outcomes and Cue Y predicted punishment outcomes (but not informed that those contingencies would reverse at some point), adults with psychopathy showed the expected reversal learning deficit that is consistent with Budhani et al.'s (2006) findings. However, when participants were not informed that the cues were in any way paired with reward or punishment contingencies, psychopathy was unrelated to task performance. Together, these results indicate that adults with psychopathy inflexibly fixate on contingencies when they are explicit, but are able to learn both reward and punishment contingencies and reverse or update those contingencies when associations are implicit. Overall, the reward learning literature in adult psychopathy confirms that these individuals have deficits in reward, punishment, and reversal learning, but that these deficits are only in specific experimental contexts that relate to task demands and task instructions. Therefore, while individuals with psychopathy may be able to learn that a behavior, like writing a fake check, is rewarding, they do not utilize competing information, like the fact that they are on probation, to inform future decision-making, and thus they recidivate without considering the consequences.

Summary and Integration

Overall, individuals with psychopathy show abnormalities in several subcomponents of reward processing; however, many of these abnormalities are limited to specific subtypes of psychopathy (e.g., secondary psychopathy), components of psychopathy (e.g., Factor 2 traits), and experimental contexts. When psychopathy was examined as a unitary construct, psychopathy-related abnormalities were only apparent within the domains of punishment prediction error and reward learning (K. S. Blair et al., 2006; R. J. Blair et al., 2004; Brazil et al., 2013; Budhani et al., 2006; Gregory et al., 2015; Mitchell et al., 2006; Newman et al., 1990; Newman & Kosson, 1986; Newman & Schmitt, 1998; Poythress et al., 2010). Specifically, adults with psychopathy displayed an enhanced prediction error response to unexpected punishment outcomes (Gregory et al., 2015) and deficits in reward, punishment, and reversal learning (K. S. Blair et al., 2006; R. J. Blair et al., 2004; Brazil et al., 2013; Budhani et al., 2006; Mitchell et al., 2006; Newman et al., 1990; Newman & Kosson, 1986; Newman & Schmitt, 1998; Poythress et al., 2010). However, these learning deficits in adults with psychopathy were context specific. The deficits were most apparent when tasks required particularly complex learning, such as requiring participants to learn and track *multiple* sets or types of contingencies (Newman & Kosson, 1986; von Borries et al., 2010) or when task instructions involved explicit goal-relevant guidance (Brazil et al., 2013).

It is important to emphasize that task demands can greatly impact performance among individuals with psychopathy (Baskin-Sommers, Curtin, & Newman, 2011, 2013; Tillem et al., 2016). This can be seen in fear conditioning where context-specific deficits in affective processing are present among individuals with psychopathy. When processing affective information, individuals with psychopathy generally exhibit diminished affective responses across a wide variety of experimental contexts unless they are explicitly instructed to attend to the affective stimuli or that stimulus is simply presented (p. 327) (Baskin-Sommers & Newman, 2013; Newman & Baskin-Sommers, 2011). This pattern has led researchers, such as Baskin-Sommers et al. (2011), to propose that the context-specific effects of psychopathy are attributed to a fixed early attention bottleneck, which constrains allocation of attention to goal-relevant or simple features of a context. This bottleneck limits information processing in psychopathy such that the perception and integration of goal-irrelevant or complex stimuli are fractionated.

The attention bottleneck model provides a similar explanation for the context-specific reward and reversal learning deficits found in individuals with psychopathy. When a reward condition is present in a reward-processing task, the primary goal of the task is most often to obtain rewards, and avoiding punishment is peripheral to this primary goal. By contrast, in a punishment-only condition, the primary goal relates to minimizing punishment. Individuals with psychopathy display deficits in the former, but not the latter, condition. Thus, apparent punishment insensitivity in individuals with psychopathy may be a result of task demands, rather than insensitivity, per se (K. S. Blair et al., 2006; R. J. Blair et al., 2004; Brazil et al., 2013; Budhani et al., 2006; Mitchell et al., 2006; Newman et al., 1990; Newman & Kosson, 1986; Newman & Schmitt, 1998; Poythress et al., 2010). This fixed bottleneck focus on primary goals, then, results in differences in prediction error response and responsiveness to punishment feedback. While individuals with psychopathy overfocus on certain features, necessitated by the bottleneck, this inflexible focus inhibits the ability to integrate punishment information and utilize it to inform or update response contingencies (von Borries et al., 2010). Functionally, the context-specific abnormalities in reward present as a myopic perspective on decision-making and goal-directed behavior, such that individuals with psychopathy are adept at using information that is directly relevant to their goal (see Gregory et al., 2015; Pujara et al., 2014; von Borries et al., 2010) to effectively regulate behavior, but display reward-dominated impulsive decision-making (e.g., driving a stolen car while wanted by police) when information is beyond their immediate goal-directed focus.

Considerations for Future Research

The annual cost of antisocial behavior for our society is enormous, and these forms of psychopathology account for the majority of this expense. Research on antisocial psychopathology consistently demonstrates that individuals who chronically engage (p. 328) in antisocial behavior display dysfunctions in reward processing. However, the specific dysfunctions, and the relationships between those dysfunctions, vary among subtypes of antisocial psychopathology (Figure 19.1). One reward-related dysfunction relates to an “antisocial-only” trajectory (e.g., CD, APD) characterized by hypersensitivity to the salience of reward and a maladaptive pursuance of risky outcomes. Alternatively, reward dysfunction represented on a “psychopathic” pathway is characterized by a decoupling of the presentation of contingencies (reward or punishment) and the integration of that information to inform behavior. Though speculative at this point, these two pathways may represent important developmental and etiological trajectories.

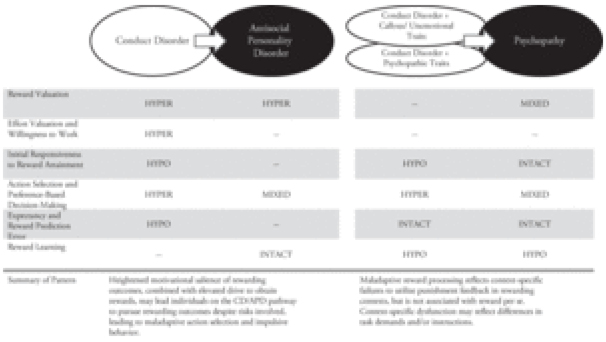

Figure 19.1 Summary of findings across development. HYPER indicates the subcomponent is hyperactive, enhanced, or overactive in the diagnostic group. HYPO indicates the system is hypoactive, blunted, or underactive in the diagnostic group. Intact indicates the system was not different between those in the diagnostic group compared to control groups in the literature reviewed. Mixed indicates the subcomponent may be hyperactive, hypoactive, or intact across multiple studies, operationalization, or methodologies. --denotes subcomponents of reward processing that have not been studied in a diagnostic group.

While collectively there is substantial research on reward processing in antisocial psychopathology, further research is needed. In fully implementing an RDoC approach, future research must consider two key factors: sample selection and experimental design. First, this chapter was limited to examining antisocial psychopathology at a diagnostic level. However, the RDoC framework marks a departure from the conceptualization of psychopathology that uses discrete diagnostic categories in favor of evaluating psychological function (or dysfunction) as a dimensional measure. To properly evaluate the connection between reward processing and antisocial behavior within an RDoC framework, it is critical for future studies to examine how potential reward dysfunction may differentially occur at various levels of severity of antisocial behavior or traits, regardless of current diagnostic thresholds. While this type of dimensional approach requires larger sample sizes to power statistically significant results, it would also allow participant recruitment to become simpler, given that individuals without diagnosable psychopathology might still exhibit symptoms or traits related to antisociality (e.g., individuals without a formal APD diagnosis may still be impulsive or antisocial). Broadening the operationalization of antisocial behavior and traits can have its advantages, though it is essential that researchers clearly and accurately label the traits, behaviors, or pathologies being assessed so as not to dilute the literature and equate constructs that may be meaningfully different.

Second, using experimental designs that capitalize on the multicomponent nature of the RDoC Positive Valence Systems framework would be beneficial. Most of the existing evidence stems from studies that examined one or two of these subcomponents in isolation. When put to the test of quasi- and experimental research, many of these reward subcomponents are found to either have smaller effect sizes than originally reported or not be *causally* related to the development of antisocial behavior (Jaffee, Strait, & Odgers, 2012). As scientific research continues to refine its methods and perspectives in hopes of capturing the elusive underlying mechanisms of antisocial behavior, future research should incorporate batteries of reward-related measures and behavioral tasks within single samples to allow for a broader examination of the constructs of interest. Studying the interactions among different subcomponents would allow for a more comprehensive understanding of the ways in which aberrant functioning in single subcomponents produces compensation or further complications in other subcomponents of reward processing.

Recent advances in understanding the unique reward-related associations with antisocial behavior suggest homotypic continuity across development in antisocial subtypes. Each subtype's reward dysfunction may promote the pathogenesis of antisocial behavior in unique ways. A more in-depth examination of the link between reward dysfunction and antisocial behaviors may lead to a better understanding of the mechanisms underlying and maintaining these behaviors. Ultimately, these efforts will inspire more effective interventions for the individuals diagnosed with antisocial psychopathologies (see Baskin-Sommers, Curtin, & Newman, 2015, for example) and help to alleviate the burden that antisocial behavior produces for society as a whole.

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Notes:

([1]) The IGT is complex and places demands on several related processes. It is difficult to parse which neural resources recruited in the task are explicitly recruited for action selection/risk evaluation and which neural resources are recruited for other aspects of the task (e.g., the working memory required to explicitly recall deck performance over the course of the task).

([2]) Gao and colleagues (2015) examined an early negative-going component that they commented reflected "binary evaluation of resultant good versus bad outcomes" (p. 2). Based on the methodology, previous literature, and the difficulty temporally separating N2 and FN components, we believe the component in the Gao et al. study reflects processing consistent with FN and therefore label it as such in this chapter.

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