Personality Disorders: Theory, Research, and Treatment

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Evaluating Dysfunction in Cognition and Reward Among Offenders With Antisocial Personality Disorder

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Antisocial personality disorder (APD) is a costly clinical condition. Previous studies identify executive dysfunction and reward sensitivity as factors contributing to APD. However, empirical evidence supporting the role of these factors in APD is mixed. The present study aimed to identify and specify APD-related dysfunction in cognitive and reward factors. In a sample of incarcerated males ($N = 116$), we administered three tasks targeting distinct cognitive (perception, executive functioning, and probabilistic decision-making) and reward (magnitude and consciousness) factors. APD was associated with impaired perception when high magnitude rewards were at stake, regardless of reward consciousness. APD was associated with worse executive functioning during conscious high rewards, as well as worse inhibition during high rewards when working memory demands were high. There was no APD-related performance difference during probabilistic decision-making. These findings expose the multifaceted nature of cognitive-affective dysfunction in APD, highlighting the importance of systematic research and providing insight into treatment targets.

Keywords: antisocial personality disorder, cognition, reward, perception, executive functioning

Supplemental materials: http://dx.doi.org/10.1037/per0000332.supp

Antisocial personality disorder (APD) is a costly clinical condition associated with a persistent pattern of social, legal, and moral norm violations (American Psychiatric Association, 2013). The prevalence of APD is markedly elevated in incarcerated offenders, with evidence that rates of APD are approximately 13 times higher in prisoners compared with the general population (Compton, Conway, Stinson, Colliver, & Grant, 2005; Fazel & Danesh, 2002). Individuals with APD represent a particularly high-risk subtype of offenders, committing higher rates of violent and nonviolent crimes, obtaining diagnoses of severe forms of substance use disorders (Brennan, Stuppy-Sullivan, Brazil, & Baskin-Sommers, 2017), and having increased mortality rates (National Institute for Health Clinical Excellence, 2009) compared with individuals without APD. Despite the significance of APD as a driver of costly behavior, we still know relatively little about the cognitive and affective factors underlying the disorder. This is due, in part, to the failure of previous research to systematically specify factors of cognition and affect that are disrupted in APD.

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Based on existing research, executive dysfunction and reward hypersensitivity emerge as possible candidate factors implicated in the pathogenesis of APD. Across studies and meta-analyses, individuals with APD show deficits in many components of executive functioning (Dolan, 2012; Garcia-Villamisar, Dattilo, & Garcia-Martinez, 2017; Morgan & Lilienfeld, 2000; Ogilvie, Stewart, Chan, & Shum, 2011; Patrick, Durbin, & Moser, 2012; Rowe, 1997) including inhibition (Barkataki et al., 2008; Chamberlain, Derbyshire, Leppink, & Grant, 2016; De Brito, Viding, Kumari, Blackwood, & Hodgins, 2013; Dolan & Park, 2002; Rubio et al., 2007; Swann, Lijffijt, Lane, Steinberg, & Moeller, 2009; Zeier, Baskin-Sommers, Hiatt Racer, & Newman, 2012), planning (Dolan & Park, 2002), working memory (Dolan & Park, 2002), and set shifting (Dolan & Park, 2002). Moreover, the extant literature describes individuals with APD as exemplars of a dominant reward-based system (Quay, 1993). Empirical evidence indicates that individuals with APD are hypersensitive to rewards (Raine, 2018; Völlm et al., 2010), resulting in their strong desire for immediate rewards (Petry, 2002), even when their reward-driven behavior is accompanied by negative consequences (Mazas, Finn, & Steinmetz, 2000). Together, research provides strong support for the purported relationships among APD, executive dysfunction, and reward hypersensitivity. Moreover, the nature of these relationships seems intuitive, given that individuals with APD repeatedly display behaviors reflecting a failure to inhibit urges (e.g., fighting and crime), and they often do so in pursuit of rewards (e.g., to obtain other's property in the case of theft or to achieve a "high" from substance use).

Although the work noted earlier suggests diminished executive functioning and heightened reward sensitivity among individuals with APD, the exact cognitive-affective factors at issue remain somewhat underspecified. First, take cognition. It is clear from

decades of research that cognition contains multiple separable factors, including perception (supporting encoding and early attention), executive functioning (discrete functions supporting complex tasks and goal-directed behavior [e.g., monitoring, updating, suppressing competing memory representations in working memory, planning, set shifting, and inhibition]) and decision-making (supporting the evaluation of and choices between alternative actions; Burgess, 1997; Jurado & Rosselli, 2007; Maes & Brazil, 2013; Miyake et al., 2000; Ogilvie et al., 2011; Purves et al., 2008; Royall et al., 2002; Salthouse, 2005; Smith & Jonides, 1999; Stuss & Knight, 2002). In general, cognition can be impacted in a variety of ways based on these factors, and dysfunction associated with any one of these factors may disrupt processing associated with other factors. With these cognitive factors in mind, close examination of the existing research on APD and executive functioning actually highlights that some tasks used to tap executive functioning also manipulate perception (e.g., Cambridge gambling task [CGT]) or decision-making (e.g., Iowa gambling task [IGT]; Snyder, Miyake, & Hankin, 2015).

For example, some research of executive dysfunction in APD reports poor performance among individuals with APD during tasks like the IGT (Bechara, Damasio, Damasio, & Anderson, 1994; Gansler, Jerram, Vannorsdall, & Schretlen, 2011; Mazas et al., 2000) and the CGT (De Brito et al., 2013; Rogers et al., 1999). The IGT, though, examines several cognitive factors within executive functions (e.g., set shifting, planning, and working memory) and decision-making (e.g., value-based learning, reversal learning, and risk-aversion; De Brito & Hodgins, 2009). Likewise, on the CGT, performance "quality" depends not only on executive functions and decision-making but also the perceptual capability of an individual to discern among various visual stimuli. With multiple cognitive factors assessed during tasks like the IGT and CGT, it is unclear whether poor performance for those with APD reflects executive dysfunction or whether abnormal perception, decision-making, or an interaction among these cognitive factors promotes dysfunction in these individuals. Moreover, even studies using purportedly "purer" measures of executive function, such as set-shifting or planning tasks, do not support the claim that individuals with APD show fundamental deficits in executive functions (Chamberlain et al., 2016; Crowell, Kieffer, Kugeares, & Vanderploeg, 2003; De Brito et al., 2013; Maes & Brazil, 2013; Stevens, Kaplan, & Hesselbrock, 2003). Across multiple types of executive functioning tasks, individuals with APD tend to show dysfunction under high cognitive load (e.g., when planning several steps and maintaining complex stimuli over long periods of time; De Brito et al., 2013; Dolan & Park, 2002) and during inhibition of prepotent responses (De Brito et al., 2013; Dolan & Park, 2002). At this point, extant literature in APD has not provided a clear picture of dysfunction, either in terms of specific executive functions or with regard to cognitive dysfunction more broadly.

Second, reward also can be subdivided into multiple separable factors. Common factors include reward magnitude (the amount of reward available; Beilock, 2007; Berridge, 2004; Knutson, Adams, Fong, & Hommer, 2001; Knutson, Taylor, Kaufman, Peterson, & Glover, 2005; Mobbs et al., 2009; Robbins & Everitt, 1996; Schultz, 2006) and reward consciousness (the degree to which awareness of reward information can bias behavior; Berridge, Robinson, & Aldridge, 2009; Berridge & Winkielman, 2003; Bijleveld, Custers, & Aarts, 2009; Pessiglione et al., 2008; van Gaal & Lamme, 2012; Zedelius et al., 2014). Each of these alone or combined can contribute to an individual's reward sensitivity. Different laboratory paradigms use controlled manipulations of these factors to quantify their common and unique impact on an individual's behavior. This approach allows researchers to clarify and contextualize cognitive and reward abnormalities. Unfortunately, many tasks selected for research on reward sensitivity in APD conflate multiple reward factors or subtly assess components of reward without fully manipulating those components, making it difficult to know which components of reward processing, if any, are affected in APD.

As an example, risky decision-making tasks conflate reward magnitude and reward probability by exclusively pairing low magnitude rewards with high probabilities and high magnitude rewards with low probabilities, such that the influence of magnitude or probability cannot be disentangled (e.g., IGT and balloon analogue risk task; Lejuez et al., 2002). Unfortunately, because many decision-making tasks do not use systematic reward magnitude manipulations, it is unclear whether the observed reward sensitivity in individuals with APD reflects sensitivity to reward magnitude, reward probability, or a combination of these reward features (Dolan & Park, 2002; Mazas et al., 2000; Swogger, Walsh, Lejuez, & Kosson, 2010). Another example relates to how reward consciousness has been a factor of reward noted in research on APD, but not examined systematically. Individuals with APD appear reward hypersensitive when they are not consciously aware of reward information (e.g., they display a "decision bias" during early trials of the IGT when they are unaware of reward contingencies, Mazas et al., 2000; they show abnormal neural responding during a rewarded color discrimination task in which they are not aware of when or how much rewards are available, Völlm et al., 2010). By contrast, individuals with APD do not show reward hypersensitivity when contingencies are more explicit (e.g., during later trials of the IGT when they are more aware of reward outcomes and probabilities associated with each option, Mazas et al., 2000; during the balloon analogue risk task when they are aware of the gains and losses at stake for taking risks, Swogger et al., 2010). These findings suggest that for individuals with APD, an unconscious bias toward reward information may disrupt behavior but also that conscious awareness (i.e., explicit presentation) of reward may regulate their behavior. However, the tasks used in these studies do not implement validated reward consciousness manipulations and only examine unconscious reward processing indirectly (i.e., after rewards are obtained). Thus, across studies, the common tasks used to assess reward sensitivity in APD do not systematically manipulate reward magnitude or reward consciousness. The observed reward sensitivity in individuals with APD may reflect sensitivity to rewards of specific magnitudes, an unconscious bias to rewards, or sensitivity to rewards more broadly.

Although a substantial body of research highlights abnormalities in cognition and reward in APD, a closer examination of a largely equivocal literature highlights a need for more systematic research isolating specific factors. The goal of the present study is to systematically assess factors of cognition and reward to identify specific dysfunction(s) in individuals with APD. In a sample of incarcerated offenders, we administer three cognitive tasks and simultaneously manipulate reward using well-established manip-

ulations. Given the strong association between APD and executive functions documented in previous research, one task selected is a modified *n*-back task. This is an executive function task that combines elements from the most widely used tasks for assessing the cognitive factors that are most robustly associated with APD: inhibition (e.g., go/no-go and stop-signal tasks; Congdon et al., 2012) and working memory (Owen, McMillan, Laird, & Bullmore, 2005). Another task is a visual search task to assess individual ability to identify target stimuli among distractors (Wolfe, 1998) because successful performance on many go/no-go and working memory tasks, including the *n*-back task, involves discerning among visual stimuli. Finally, a probabilistic gambling task is used because a multitude of studies purported to assess executive functioning in APD often target decision-making processes, with the most equivocal decision-making findings in APD related to decision-making under risk (Buckholtz, Karmarkar, Ye, Brennan, & Baskin-Sommers, 2017; De Brito et al., 2013; Mazas et al., 2000). The selected decision-making task includes two-choice decisions with explicit outcome values and probabilities, removing any need for reward learning or contingency updating, which are often conflated in tasks intended to measure decision-making under risk (De Brito et al., 2013; Dunn, Dalgleish, & Lawrence, 2006). All participants complete the perceptual visual search task first, followed by the executive function *n*-back task and the decision-making probabilistic gambling task.[1]

During each of these tasks, reward magnitude (low vs. high) and awareness of reward information (conscious vs. unconscious) is manipulated.[2] First, reward magnitude is selected because decades of research across disciplines document its importance as a modulator of behavior among healthy individuals (Beilock, 2007; Berridge, 2004; Mobbs et al., 2009; Pessiglione et al., 2007; Robbins & Everitt, 1996; Schultz, 2006; Zedelius, Veling, & Aarts, 2011; Zedelius et al., 2014), and some studies suggest individuals with APD respond strongly to reward magnitude manipulations (Mazas et al., 2000). Second, reward consciousness is selected based on recent cognitive neuroscience evidence suggesting individual variability in sensitivity to conscious and unconscious rewards (Bustin, Quoidbach, Hansenne, & Capa, 2012; Zedelius et al., 2014) that also may impact the quality of executive functioning (Capa & Bouquet, 2018; Capa, Bustin, Cleeremans, & Hansenne, 2011), a factor of cognition purportedly important in the pathogenesis of APD. Although there are hints that reward magnitude and consciousness influence reward sensitivity *across* APD studies, neither reward magnitude nor reward consciousness is varied systematically *within* any current study of reward sensitivity in APD. Thus, in the present study, reward magnitude and consciousness are manipulated systematically and simultaneously (i.e., fully crossed across all trials of the three cognitive tasks) to isolate the impact of these factors on individuals with APD.

Together, this design allows us to examine components of cognition and reward processing, and how they interact, to identify vulnerabilities related to APD. Current conceptualizations of APD cite a vastly mixed literature concerning cognitive and reward processes, and it is essential that we refine our understanding of these processes to identify the most likely circumstances in which cognition and reward result in antisocial behavior.

Method

Participants

Participants were 116 men from a maximum-security correctional facility, between the ages of 18 and 75; with an IQ greater than 70, a reading level of at least fourth grade, no clinical diagnoses of schizophrenia, bipolar disorder, or psychosis; who were not currently using psychotropic medications; and who did not have medical problems that could impact comprehension.[3] Participants completed a diagnostic interview to assess criteria for APD on one visit and the three laboratory tasks on a second visit (see Table 1 for sample characteristics and Methods in the online supplemental materials for full details). All participants were provided written informed consent according to the procedures set forth by the Yale University Institutional Review Board.

Tasks

Masked reward cues[4]. Before each trial in the three tasks, the point value at stake for the trial was displayed using a modified reward-masking paradigm (Figure 1; Bijleveld et al., 2009). Point values were low (1 point) or high (10 points), noted by blocked digits (01 and 10, respectively). These reward cues were displayed either consciously (i.e., for a duration that is consciously perceivable, 300 ms) or unconsciously (i.e., 30ms; see Methods in the online supplemental materials for full details).

[1] Cognition is a multidimensional construct that can be divided into separable but interrelated factors. The selected tasks follow examples in existing literature that manipulate only one aspect of cognition at a time. For example, the perceptual visual search task only taxes encoding; in the executive function *n*-back task, inhibition and working memory are manipulated, and perceptual load is held constant across trials; and, probabilistic decision-making varies across the decision-making probability gambling task, whereas perceptual load and working memory are constant. Thus, although it is expected that several cognitive factors are represented in some of the tasks, each task manipulates only one cognitive factor at a time. This represents a departure from the tasks previously used to examine cognitive functioning in APD, which often manipulate multiple cognitive factors simultaneously.

[2] As noted earlier, reward sensitivity can be multifaceted (Berridge et al., 2009), with reward magnitude and consciousness being just two of several established reward factors (see also reward probability and reward delay; Schultz, 2006). For the present study, reward magnitude and consciousness are selected because across studies of reward sensitivity in APD, different levels of reward magnitude and reward consciousness appear to be associated with divergent findings, and well-established methods manipulating these factors are available to examine the impact of these factors directly and simultaneously.

[3] A priori power analyses based on previous studies on related topics (e.g., individual differences in perception, *n*-back, and cost-benefit decision-making) were conducted using G*Power statistical software (Faul, Erdfelder, Lang, & Buchner, 2007). Power analyses indicated that a sample size of 98 to 128 participants would result in sufficient (80%) power to detect a moderate effect for the omnibus interactions between repeated measures within-subjects task conditions and a between-subjects variable.

[4] To ensure that participants were unable to consciously perceive the 30-ms unconscious reward cues, subliminality was tested in a random subset of the participants after completion of the three main tasks. A total of 25 participants were presented with 20 masked reward cues, in the same manner as in the unconscious (30 ms) reward cue used throughout the study. Participants indicated the value of each presented reward cue (01 or 10). Performance for discriminating between the unconscious reward cues was no better than chance, $M_{accuracy} = .52$, $SD = .09$, $t(24) = 1.28$, $p = .212$, 95% CI [−0.01, 0.06].

Table 1
Sample Characteristics and Task Statistics

Variables	*N*	*M*	*SD*	Min	Max
Age	116	34.52	9.75	20	58
Sex (Male)	116				
Race					
White	52				
Black	60				
American Indian	1				
Native Hawaiian or Pacific Islander	2				
Biracial	1				
Ethnicity					
Hispanic	20				
Not Hispanic	96				
Highest level of education					
Grade 8 and below	11				
Some high school	62				
High school diploma	35				
Some college	5				
College degree	2				
Graduate degree	1				
IQ	116	106.11	9.92	83	128
CD symptom count	116	3.86	3.22	0	12.00
Adult antisocial symptom count	116	3.92	1.61	0	7.00
APD diagnosis					
Absent	58				
Present	58				
Visual search task IES by condition	116				
Unconscious low reward		0.60	0.07	.46	0.87
Unconscious high reward		0.60	0.07	.47	0.90
Conscious low reward		0.59	0.07	.44	0.83
Conscious reward high reward		0.59	0.07	.46	0.82
n-back task accuracy	109				
Match (infrequent) trials					
Low load unconscious low reward		0.80	0.18	.25	1.00
Low load unconscious high reward		0.81	0.17	.38	1.00
Low load conscious low reward		0.81	0.17	.29	1.00
Low load conscious high reward		0.82	0.18	.25	1.00
High load unconscious low reward		0.67	0.22	.10	1.00
High load unconscious high reward		0.67	0.23	.10	1.00
High load conscious low reward		0.66	0.22	.00	1.00
High load conscious high reward		0.66	0.22	.13	1.00
Mismatch (frequent) trials					
Low load unconscious low reward		0.98	0.03	.83	1.00
Low load unconscious high reward		0.98	0.03	.80	1.00
Low load conscious low reward		0.99	0.02	.90	1.00
Low load conscious high reward		0.99	0.04	.73	1.00
High load unconscious low reward		0.94	0.07	.62	1.00
High load unconscious high reward		0.94	0.06	.73	1.00
High load conscious low reward		0.94	0.06	.67	1.00
High load conscious high reward		0.94	0.07	.70	1.00
Gambling task percent risky	116				
Low probability gambles					
Unconscious low reward		0.25	0.23	.00	0.92
Unconscious high reward		0.22	0.22	.00	1.00
Conscious low reward		0.30	0.25	.00	0.92
Conscious reward high reward		0.30	0.25	.00	0.92
Medium probability gambles					
Unconscious low reward		0.32	0.24	.00	1.00
Unconscious high reward		0.30	0.22	.00	0.92
Conscious low reward		0.36	0.25	.00	1.00
Conscious reward high reward		0.32	0.25	.00	0.92
High probability gambles					
Unconscious low reward		0.40	0.26	.00	1.00
Unconscious high reward		0.42	0.27	.00	1.00
Conscious low reward		0.45	0.25	.00	1.00
Conscious reward high reward		0.49	0.27	.00	1.00

Note. IES = inverse efficiency score; CD = conduct disorder; APD = antisocial personality disorder.

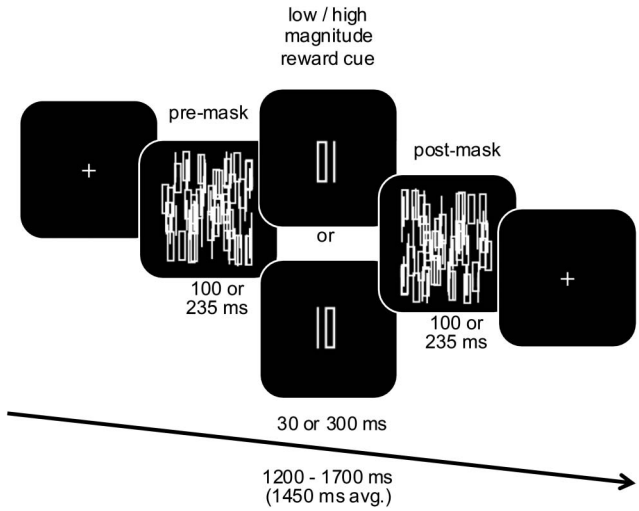

Figure 1. Reward mask procedure. Each masked reward cue lasted 500 ms and was preceded and followed by fixation (total procedure lasts 1,200–1,700 ms, 1,450 ms on average). Reward cues were either "01" for low rewards or "10" for high rewards, with blocked edges. Before and after each reward cue, a mask consisting of overlapping 0s and 1s with blocked edges was presented. For unconscious cues, masks were presented for 235 ms before and after cues, with reward cues presented for 30 ms. For conscious cues, masks were presented for 100 ms before and after cues, with reward cues presented for 300 ms. Participants were told that reward information will be presented to inform them of the reward value at stake for each trial and that this information may be difficult to see at times.

Visual search task. For the perception task, a modified version of a visual search task was used (Kristjánsson, Sigurjónsdóttir, & Driver, 2010; Figure 2A). During the task, participants viewed a series of displays with three colored diamonds. Participants were instructed to search for the oddly colored diamond, either a red target among two green distractors or vice versa. Participants indicated (by button press) whether the oddly colored diamond had a notch missing at the top or the bottom of the shape. Because performance for this task may include changes in speed or accuracy, an inverse efficiency score (IES; mean response time for correct responses divided by percentage of correct responses) was calculated for each participant (see Methods in the online supplemental materials for full details).

***n*-back task.** For the executive functioning task, we used a modified version of the *n*-back task (Figure 2B; Baskin-Sommers et al., 2014; Pochon et al., 2002). During the task, participants viewed a series of letters. Participants were instructed to monitor the letters and respond with a button press if the preceding letter in the *n*-back position was different from the current letter (e.g., a mismatch trial). Participants were instructed to withhold their response when the preceding letter matched the current stimulus (e.g., a match trial). The majority of trials were mismatch trials (80%), whereas match trials were infrequent (occurring 20% of the time). The task also included a manipulation of working memory load. In the low-load (1-back) condition, participants were instructed to determine whether the currently presented letter matched the immediately preceding letter in the sequence. In the high-load (2-back) condition, participants were required to monitor and maintain the stimulus information in working

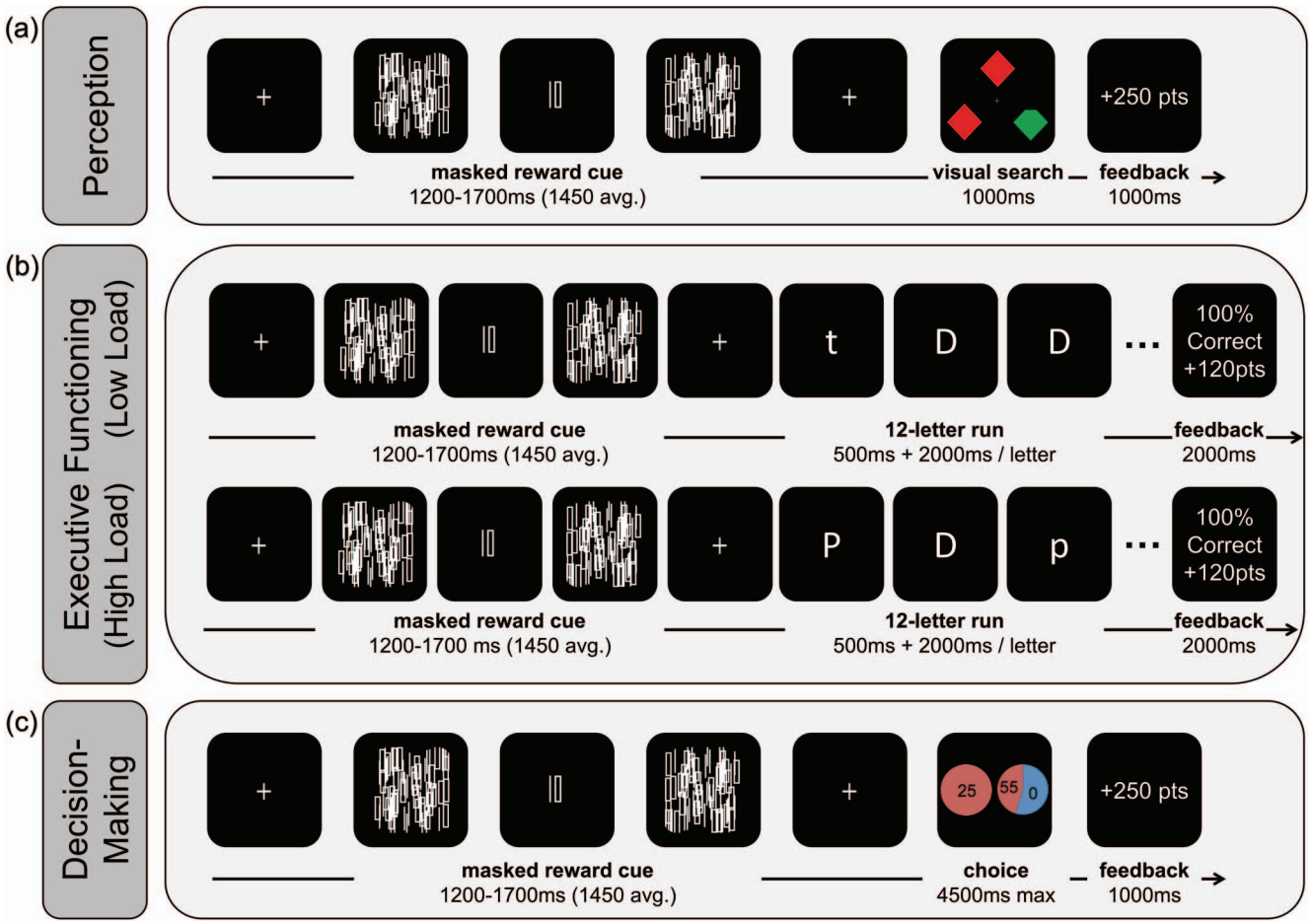

Figure 2. Example of a trial in each of the three tasks. (a) For the perception task, each trial began with a masked reward cue presented between fixation crosses (1,450 ms on average). Participants were presented with a visual search display and asked to respond by indicating via button press whether a colored diamond had a notch missing from the top or bottom of it (1,000 ms). Participants were then provided with feedback (1,000 ms) about whether they responded correctly within the time limit and how many points they earned for doing so. (b) For the executive functioning task, each trial began with a masked reward cue presented between fixation crosses. Participants were presented with a series of letters (500 ms/each, with a 2,000 ms delay between letters). Participants were asked to press a button for each letter, unless the letter matched the letter immediately before it in a 1-back trial (first row in middle) or the letter two before it in a 2-back trial (second row in middle). Following a run of 12 letters (i.e., trial), participants were provided with feedback (2,000 ms) about the percentage of correct responses and how many points they earned for the run. (c) For the probabilistic decision-making task, each trial began with a masked reward cue presented between fixation crosses. Participants were presented with two circles showing a choice between a small certain reward and a larger probabilistic reward (4,500 ms). Participants chose one of the two options via button press and were informed how many points they earned (1,000 ms). See the online article for the color version of this figure.

memory to determine whether the letter stimulus two positions earlier matched the current letter. For each participant, accuracy on the task was calculated (see Methods in the online supplemental materials for full details).

Gambling task. To assess probabilistic decision-making, a gambling task was used to examine risk-taking behavior (modified gain conditions from Voon et al., 2006; Figure 2C). During the task, participants viewed a series of two circles (i.e., gamble options). Participants were instructed to make a choice between one of two gamble options: a "sure" and a "risky" option. Participants were to press the right button for the option on the right of the screen and left button for the option on the left of the screen. For each participant, the percentage of "risky" choices was calculated (see Methods in the online supplemental materials for full details).

Results

Visual Search Task

First, we analyzed IES in a general linear model (GLM) with reward magnitude (low vs. high) and reward consciousness (conscious vs. unconscious) as within-subjects categorical factors and

IQ (z-scored) as a continuous covariate.[5] Consistent with previous research, there was a significant main effect for reward consciousness, $F(1, 114) = 30.68$, $p < .001$, $\eta^2 = .21$, 95% confidence interval [CI: .11, .31], indicating higher IES (worse speed accuracy) for unconscious compared with conscious reward cues (Bijleveld et al., 2009; Bijleveld, Custers, & Aarts, 2010; Pessiglione et al., 2007; Zedelius et al., 2011). There was no main effect for reward magnitude ($p = .425$) or an interaction between reward magnitude and consciousness ($p = .129$).

Second, the association between encoding and APD was examined by including APD (present vs. absent) in the GLM as a between-subjects categorical factor. There was a significant interaction between reward magnitude and APD, $F(1, 113) = 7.11$, $p = .009$, $\eta^2 = .06$, 95% CI [.01, .14] (Figure 3). For individuals with APD, there was a significant effect of reward magnitude, such that individuals with APD showed higher IES (worse speed accuracy) for high compared with low reward cues during visual search ($p = .015$, $\eta^2 = .05$, 95% CI [.01, .13]). For individuals without APD, there was no effect of reward magnitude ($p = .195$). Neither the main effect for APD nor any other APD by task interaction was significant (all ps $> .25$).

n-back Task

First, accuracy on the n-back task was examined using a GLM with reward magnitude (low vs. high), consciousness (conscious vs. unconscious), trial type (mismatch vs. match), and working memory load (low load vs. high load) as within-subjects categorical factors, and IQ (z-scored) as a continuous covariate. Consistent with previous research (Baskin-Sommers et al., 2014), there was a significant main effect of trial type, $F(1, 107) = 356.89$, $p < .001$, $\eta^2 = .77$, 95% CI [.71, .81], indicating higher accuracy for mismatch versus match trials. In addition, a significant main effect of working memory load, $F(1, 107) = 128.33$, $p < .001$, $\eta^2 = .55$, 95% CI [.44, .62], indicated higher overall accuracy for low versus high load trials. There also was a significant two-way interaction for trial type and working memory load, $F(1, 107) = 56.18$, $p < .001$, $\eta^2 = .34$, 95% CI [.23, .44], indicating that the effect of trial type (mismatch vs. match trials) was greater in the high load condition. No other task effects were significant (all ps $> .334$).

Second, the association between executive functioning and APD was examined by including APD (present vs. absent) in the GLM as a between-subjects categorical factor. There was a significant three-way reward magnitude by reward consciousness by APD interaction effect, $F(1, 106) = 4.00$, $p = .048$, $\eta^2 = .04$, 95% CI [.00, .11]. For individuals with APD, performance was relatively better for conscious low magnitude reward trials; however, during unconscious rewards or conscious high-value rewards, individuals with APD showed relatively worse performance. Individuals without APD showed less variable performance across conditions (see also Bijleveld, Custers, & Aarts, 2011 for examples in other populations; Moors & De Houwer, 2006; Zedelius et al., 2011).

In addition, there was a significant four-way interaction among reward magnitude, trial type, working memory load, and APD, $F(1, 106) = 5.83$, $p = .017$, $\eta^2 = .05$, 95% CI [.00, .13] (Figure 4). To unpack this interaction, we examined the effects of APD, reward magnitude, and working memory load on accuracy in each trial type, respectively. For match trials, there was a significant three-way interaction for APD, reward magnitude, and working memory load, $F(1, 106) = 7.30$, $p = .008$, $\eta^2 = .06$, 95% CI [.01, .15]. Within match trials, individuals with APD were more accurate in response to high-value reward cues under low working memory load, but less accurate in response to high reward cues under high working memory load condition. By contrast, individuals without APD were less accurate in response to high reward cues in the low-load condition, but more accurate in response to high reward cues in the high-load condition (consistent with previous studies of healthy adults; Bijleveld et al., 2009). For mismatch trials, neither the main effect of APD nor the three-way interaction for reward magnitude, working memory load, and trial type were significant, ps $> .16$. Finally, neither the main effect for APD ($p = .632$) nor the five-way interaction between reward magnitude, reward consciousness, trial type, working memory load, and APD were significant ($p = .889$).

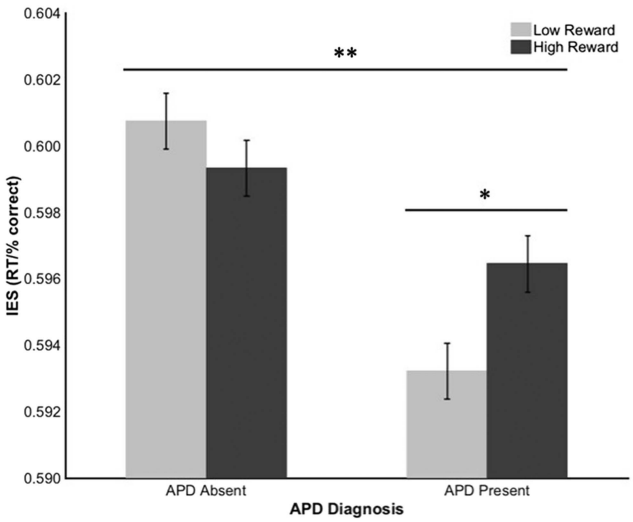

Figure 3. Perception and APD effects. There was a significant interaction between reward magnitude and APD. Individuals with APD showed higher IES (worse speed accuracy) for high compared with low reward cues during visual search, whereas individuals without APD were unaffected by reward magnitude. Error bars represent 1 within-subjects *SE*. * $p < .05$; ** $p < .01$.

[5] IQ was included as a covariate in analyses for all task variables (visual search, n-back, and gambling), as IQ was related to both task performance and APD. Moreover, in additional analyses, we examined the specificity of the effects reported in the text by including related disinhibitory psychopathologies (i.e., substance use disorders or psychopathy). The visual search and n-back by APD effects remain the same. The only exception is when controlling for substance use disorders, the n-back reward magnitude by reward consciousness by APD effect becomes nonsignificant. Finally, we examined whether the number of symptoms of APD (i.e., continuous count of conduct disorder and adult antisocial symptoms) predicted the same effects reported in the text. When using a continuous count of APD symptoms, the visual search and n-back by APD effects remain the same. Therefore, the APD-related effects reported for the visual search and n-back tasks hold up for a continuous measure of antisocial behavior and are specific to APD.

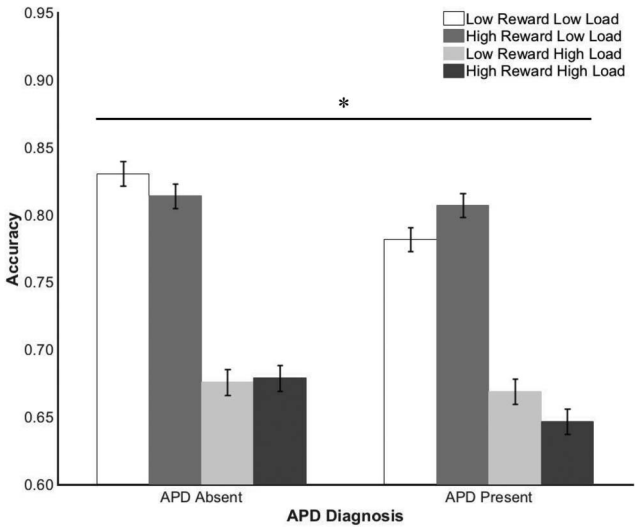

Figure 4. Executive functioning and APD effects. There was a significant four-way interaction for reward magnitude, trial type, working memory load, and APD. The effects were present in the match trials. Individuals with APD showed better performance for high versus low rewards at low load, and worse performance for high versus low rewards at high load, whereas individuals without APD showed worse performance for high versus low rewards at low load and better performance for high versus low rewards at high load. Error bars represent 1 within-subjects *SE*. * $p < .05$.

Gambling Task

First, risky choice behavior during the probabilistic decision-making task was examined in a GLM with reward magnitude (low vs. high), reward consciousness (conscious vs. unconscious), and probability (low vs. medium vs. high) as within-subjects categorical factors and IQ (*z*-scored) as a continuous covariate. Consistent with previous research (Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005), there was a significant main effect for reward consciousness, $F(1, 114) = 31.97$, $p < .001$, $\eta^2 = .22$, 95% CI [.12, .32], suggesting individuals chose risky options more often when reward information (i.e., reward magnitude) was presented consciously. Consistent with previous research (Estle, Green, Myerson, & Holt, 2006), there was a significant main effect for probability, $F(1.49, 169.36)$[6] $= 67.75$, $p < .001$, $\eta^2 = .37$, 95% CI [.28, .45], suggesting individuals chose risky options when the probability of winning was higher, with percentage of risky choices highest on high probability, followed by medium probability and low probability trials. There also was a significant two-way interaction between reward magnitude and probability, $F(2, 228) = 5.53$, $p = .005$, $\eta^2 = .05$, 95% CI [.01, .09], indicating a greater percentage of risky choices for low versus high rewards at low and medium probabilities, but for high probability gambles, the risky option was chosen more often for high versus low rewards. Lastly, the two-way interaction between probability and reward consciousness approached significance, $F(2, 228) = 3.00$, $p = .052$, $\eta^2 = .03$, 95% CI [.00, .06], indicating a trend toward greater effects of reward consciousness when reward probability was low.

Second, the association between decision-making and APD was examined by including APD (present vs. absent) in the GLM as a between-subjects categorical factor. There was no significant main effect for APD diagnosis ($p = .925$) and no significant interactions including APD (all ps $> .20$).

Discussion

Previous research highlights executive dysfunction and reward hypersensitivity as core factors contributing to the behavioral dysfunction apparent in individuals with APD. Although these indeed are important factors to consider for APD, the present results suggest that this broad conceptualization is underspecified. Here, we identify complex interactions containing multiple factors within cognition and reward that are important for precisely understanding dysfunction in APD. Specifically, in individuals with APD, high-value rewards were disruptive during both perception and inhibition under high cognitive load. In addition, in these individuals, conscious awareness of high-value rewards was associated with reduced overall executive functioning performance. However, individuals with APD did not show abnormal probabilistic decision-making. Together, these results highlight several important patterns to consider when studying APD and the cognitive and reward abnormalities associated with the disorder.

Although perceptual processes are not often studied in APD, a growing body of literature suggests that individuals with APD actually do have difficulty detecting basic features of their environments. Individuals with APD display problems initially perceiving information, whether they are estimating the passage of time (i.e., perceiving temporal durations; Bauer, 2001) or engaging in preattentional auditory filtering (i.e., perceiving redundancy in auditory stimuli; Lijffijt et al., 2009, 2012). The present study indicates that perceptual difficulty also is apparent when anticipating high-value rewards, regardless of the conscious awareness of reward magnitude, revealing a particular maladaptive perceptual sensitivity. Dysfunction in perceptual efficiency fundamentally changes what information is seen, attended to, and, potentially acted upon. In APD, this dysfunction may precede any abnormality during executive functioning and, in some circumstances, actually lead to failures in effectively engaging adaptive behavior.

Individuals with APD display reliable dysfunction when there are demands on inhibition (Chamberlain et al., 2016; Dolan & Park, 2002; Rubio et al., 2007; Swann et al., 2009; Zeier et al., 2012) and working memory (De Brito et al., 2013; Dolan & Park, 2002). Results from the present study suggest these dysfunctions are particularly apparent in response to high-value rewards. In one context, high-value rewards disrupt inhibition during high-load at both conscious and unconscious levels. In another context, conscious awareness of high-value rewards results in poor executive functioning more broadly. It appears that individuals with APD are less able to override maladaptive response inclinations in anticipation of high-value rewards to maintain more appropriate and personally beneficial behavior.

Taken together, APD-related reward magnitude-based dysfunction in perception and executive functioning underscores a specific cognitive profile. It appears that when anticipating a high payoff, individuals with APD struggle to manage the information in their

[6] Mauchly's test indicated that the assumption of sphericity had been violated for this effect, $\chi^2(2) = 48.03$, and therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .74$).

environment accurately and efficiently, resulting in maladaptive behavior (see also Results in the online supplemental materials for a comparison of performance across tasks). It may be that both the value of the reward and awareness of high-value rewards create additional cognitive load, undermining adaptive behavior for individuals with APD. Therefore, it is inaccurate to simply say that these individuals are hypersensitive to rewards or are deficient in executive functions; rather the value of the reward is an important factor undermining their ability to notice and use information in the environment.

Beyond identifying the specific factors that contribute to dysfunction in APD, the design of the present study also affords an opportunity to reveal instances of intact cognitive and reward functioning in these individuals. During probabilistic decision-making, individuals with and without APD similarly adjust risk-taking behavior in response to reward probability, reward magnitude, and reward consciousness (Buckholtz et al., 2017; De Brito et al., 2013; Swogger et al., 2010). Moreover, during executive functioning, individuals with APD display their best inhibition while pursuing high-value rewards under low load (see Figure 4, right panel, for inhibition accuracy in the high reward/low load condition). Across experimental contexts, individuals with APD appear able to manage their reward sensitivity and engage in adaptive behavior when under markedly less pressure, as a function of generous time allotments (e.g., 4,500 ms during decision-making compared with 1,000 ms and 2,500 ms in the perception and executive function tasks, respectively; De Brito et al., 2013; Dolan & Park, 2002; Newman, 1987; Swann et al., 2009) or reduced cognitive load (e.g., 1-back inhibition, providing explicit information about outcome values during decision-making, rather than simultaneously tapping reward learning and contingency updating; De Brito et al., 2013; Dunn et al., 2006; Mazas et al., 2000). Therefore, individuals with APD do not appear to have widespread cognitive dysfunction or reward sensitivity. Leveraging knowledge about the circumstances in which individuals with APD show typical versus aberrant behavior may be important for considering why certain interventions are more effective with these individuals than others.

Several treatment approaches are used for individuals with APD. One treatment method that seems to have positive effects in APD with comorbid substance use disorders is contingency management (CM; see Brazil, van Dongen, Maes, Mars, & Baskin-Sommers, 2018 for review). In CM, reinforcement contingencies are assigned to positive behaviors (e.g., abiding by the law and maintaining abstinence from drugs) to increase their frequency based on predetermined therapeutic goals (Budney, Sigmon, & Higgins, 2001). This approach may be effective because it leverages the use of explicit, unambiguous, reward contingencies for behavior, factors that are functional in individuals with APD. However, based on the present study, it is essential to be mindful of the amount of reward being offered, as rewards above a certain threshold, in certain contexts, may inadvertently disrupt adaptive behavior in APD. Beyond CM, other intervention strategies may be worth implementing among individuals with APD to bolster processes that appear deficient. Previous studies in populations with diminished inhibitory control and working memory capacities indicate that training individuals to inhibit responses to rewarding stimuli (e.g., alcohol and high-calorie foods; Houben, Havermans, Nederkoorn, & Jansen, 2012; Houben & Jansen, 2011) or maintain and update progressively larger cognitive sets in working memory (Bickel, Yi, Landes, Hill, & Baxter, 2011; Houben, Wiers, & Jansen, 2011) can lead to reductions in maladaptive behavior. Therefore, by working to remediate processes identified as suboptimal in APD, an alternative or complementary intervention strategy maybe to directly target their deficits.

Several methodological and conceptual limitations should be noted. First, in an effort to study how differences in reward magnitude and consciousness affect behavior for individuals with APD, we compared responses to high versus low rewards, rather than comparing responses to rewards versus no rewards. Although our method allowed for an investigation of how individuals respond to rewards of various sizes, we cannot make conclusions about reward sensitivity among individuals with APD in the presence versus the absence of rewards. Previous research established that APD was associated with differential responses to reward (vs. no reward) but had not specified particular dimensions of reward; therefore, we focused on reward magnitude and reward consciousness. Second, the present sample consisted of adult male offenders only, which may limit the generalizability of these findings to other populations. Future research is needed to examine specific factors of cognition and reward in other samples with APD, such as individuals who are at-risk for the disorder and female offenders. Third, it is worth considering whether the nonmonetary rewards (i.e., points and leader board rankings) used in the present study were adequate sources of reinforcement compared to real monetary rewards. Evidence suggests that points and leader boards do enhance motivation and affect psychological and behavioral outcomes (Hamari, Koivisto, & Sarsa, 2014). Nevertheless, future work should attempt to replicate the present findings using monetary rewards, while also considering ethical guidelines concerning payment for incarcerated samples. Finally, it is important to note that results from the separate tasks in the current study accounted for only a modest proportion of variance (4%–6%) in behavior. However, when estimating behavior across experimental tasks, the proportion of variance explained was slightly larger (7%). Thus, in isolation, dysfunction within specific cognitive-affective factors are unlikely to be necessary or sufficient to generate psychiatric illness (Holmes & Patrick, 2018); however, considering mechanisms as multifactorial increases the potential of more fully capturing the risk associated with specific behaviors and illness (Zalta & Shankman, 2016).

In sum, the present study indicates that complex interactions among cognitive and reward factors contribute to the behavior of individuals with APD. Hypersensitivity to high-value rewards during perceptual and executive function efforts confer a risk factor that may contribute to chronic engagement in antisocial behaviors despite their consequences (e.g., incarceration or overdosing) in individuals with APD. Specifying the factors that account for the maladaptive behavior in APD is crucial for advancing our conceptualization of the disorder and identifying effective and targeted intervention strategies.

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