Evaluating dysfunction in cognition and reward among offenders with Antisocial Personality Disorder: Supplemental Material

Supplemental Methods

Participants

Participants were 116 male inmates from a maximum-security correctional institution in Connecticut (see Table 1 for sample characteristics). A prescreen of institutional files and assessment materials were used to exclude individuals who: were not between the ages of 18 and 75, scored below 70 on a brief measure of IQ (Shipley Institute of Living Scale; Zachary, 1986) , performed below the fourth-grade level on a standardized measure of reading (Wide Range Achievement Test-III; Wilkinson, 1993), had diagnoses of schizophrenia, bipolar disorder, psychosis not otherwise specified, were currently taking psychotropic medication, or had a history of medical problems (e.g., uncorrectable auditory or visual deficits, head injury with loss of consciousness greater than 30 minutes, seizures) that could impact their comprehension of the study materials. Participants completed a semi-structured diagnostic interview on one visit and the three laboratory tasks on a second visit. Across the three tasks, participants were instructed to attend to reward cues, which might be hard to see at times, and to try to earn as many reward points as possible in order to be added to a "leader board" that was on display to all study participants in the testing room (*Note*: Connecticut Department of Correction does not allow researchers to pay inmates). All participants were provided written informed consent according to the procedures set forth by the Yale University Human Investigation Committee.

Measures

Antisocial Personality Disorder (APD). Participants were assessed for APD during a semi-structured diagnostic interview. The interview evaluated the age and frequency of engagement in behaviors outlined in the Diagnostic Statistical Manual-5 (DSM-5; American

Psychiatric Association, 2013). A diagnosis of APD was given if there was evidence of conduct disorder (CD) prior to age 15 (three or more symptoms) and sufficient adult antisocial symptoms (three or more). Inter-rater reliability for 32% of the sample was .989 (Cohen's kappa).

Masked Reward Cues. Before each trial in the three tasks, the point value at stake for the trial was displayed using a modified reward masking paradigm (see Fig. 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, 300ms) or unconsciously (i.e., 30ms). Immediately before and after the presentation of the reward cues, masks consisting of overlapping block 0's and 1's were presented (100ms and 235ms for conscious and unconscious reward cues, respectively; total time for each masked cue was held at 500ms). Participants were told to look for reward cues before each trial to find out how many points were at stake. Participants were reminded that these point values might be difficult to see at times. Masked reward cues always appeared between fixation crosses on a black background, with 700-1200ms of total fixation, for a total cue and fixation period from 1200-1700ms (1450ms average).

Visual search task. For the perception task, a modified version of a visual search task was used (Kristjánsson et al., 2010) (see Fig. 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.

Every trial started with a masked reward cue described above. Following the masked reward cue, a display containing three diamond shapes was presented for 1000ms. Participants were allowed to provide a response for the duration (1000ms) the diamonds were on the screen. Participants received feedback (correct/incorrect and the number of points earned) after each trial (1000ms). After feedback, the next trial continued immediately, starting with a masked reward cue.

A total of 400 trials were presented in blocks of 40 trials (10 blocks total). Across all trials, diamond position, notch position, and pop-out color were counterbalanced (approximately 33 per subtype of trial). Reward cues (magnitude and consciousness) also were counterbalanced (100 trials per magnitude by consciousness condition).

Since 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. All participants obtained accuracy greater than 80% and were included in the analyses, resulting in a sample of 116 participants for the visual search task.

***n*-back task.** For the executive functioning task, we used a modified version of the *n*-back task (see Fig. 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 responses 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 memory in order to determine whether the letter stimulus 2 positions earlier matched the current letter.

Every trial started with a masked reward cue described above. Following the masked reward cue, participants viewed a series of 12 letters presented for 500ms each with an inter-letter-interval of 2000ms. For each letter, participants were allowed to provide a response anytime during the duration of the letter presentation or during the inter-letter-interval (2500ms response window). Participants received feedback (correct/incorrect and the number of points earned) for 2000ms after each trial (i.e., string of 12-letters). Following feedback, a blank screen was presented for a 2000ms intertrial interval.

There were a total of 40 trials (i.e., 12-letter runs). Trials were blocked into five runs of the same load level, with reward cue magnitude (low vs. high) and consciousness (unconscious/30ms vs. conscious/300ms) varying between runs. Therefore, a total of ten 12-letter trials were presented per reward by consciousness condition, split between low and high load.

For each participant, accuracy on the task was calculated. All 116 participants completed the *n*-back task, however, seven participants performed below 40% accuracy on low load match trials or below 20% accuracy on high load match trials. Data for these seven participants were excluded from the main analyses, resulting in a sample of 109 participants for the *n*-back task.

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; see Fig. 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.

Every trial started with a masked reward cue described above. Following each masked reward cue, participants viewed the two gamble options for 4500ms. Participants were able to make a choice at any time during the gamble display. One 'sure' option always provided a small but certain number of points (5-113 points, depicted as a circle filled in one color with one number of points in the center), while the other 'risky' option always provided a chance (P = .35, .40, or .45) of winning some amount of points (range 15-250 points), and a chance of winning zero points (depicted as a circle with two segments proportionate to win and no-win probabilities, with the associated numbers of points at the center of each segment). Participants were informed that for 10-point trials, the reward values presented in the decision-making task would be multiplied by ten (e.g., a choice between a certain 25 points and a 40% chance of gaining 55 points would really be a choice between a certain 250 points and a 40% chance of gaining 550 points). 'Sure' and 'risky' options were matched for expected value (i.e., each of the two options was equally rewarding when considering both value and probability). Participants received feedback (i.e., points earned) for 1000ms. After feedback, the next trial continued immediately, starting with a masked reward cue.

A total of 160 trials were presented. There were 36 trials for each reward by consciousness condition. Additionally, there were 16 catch trials. For catch trials, the 'risky' option was always worse than the 'sure' option (e.g. 'sure' choice of 62 points versus 'risky' choice with a 20% chance to win 25 points) to ensure subjects were paying attention to and understood the task.

For each participant, the percentage of 'risky' choices was calculated. All 116 participants chose the higher expected value option in over 60% of the catch trials; therefore, data for all 116 participants were analyzed for the decision-making task.

Supplemental Results

Performance across tasks

APD was related to worse performance for high compared to low rewards during the visual search perception task and the high-load inhibition trials of the *n*-back task. To examine whether it was the same individuals who showed poorer performance in response to high rewards across these tasks, and if performance across these tasks was related to APD, we examined behavior for the 109 participants who completed both the visual search and *n*-back tasks. First, we computed difference scores reflecting the extent to which individuals performed poorly for high vs. low rewards in each task (i.e., higher visual search inverse efficiency and lower *n*-back inhibition accuracy during high load). Second, we created four bins for each task difference score based on +/- 1 SD and summed these binned groups, such that higher bin sums reflected worse performance for high vs. low rewards across both tasks. Third, from these sums we divided participants into three groups, with individuals in the first group having the lowest bin sums (least impaired performance for high vs. low rewards), individuals in the second group having moderate sums (reflecting moderate declines in performance for high vs. low rewards), and individuals in the third group having the highest bin sums (worst performance for high vs. low rewards across both tasks). Finally, we created dummy-coded variables to represent membership in the three groups, and conducted a binomial logistic regression.

The binomial logistic regression model provided good fit for the data [$N = 109$; $R^2 = .06$ (Cox & Snell); $R^2 = .07$ (Nagelkerke); Model $\chi^2(2) = 6.249$; $p = .044$]. Individuals in the third group, who were characterized by poor performance for high rewards across both tasks, were 1.46 times more likely to have APD than individuals in the first group, who demonstrated the least impaired performance for high vs. low rewards in the two laboratory tasks, OR = 1.46, $p = .018$, 95% CI [1.07, 1.99]. Individuals in the second group, characterized by moderate performance for high rewards across both tasks, were no more likely to have APD compared to individuals in the first group, OR = 1.47, $p = .104$, 95% CI [0.92, 2.35]. These results suggest that individuals with APD performed poorly in response to high rewards across both tasks, and that individuals with this behavioral pattern were more likely to have APD than individuals who showed less impairment in response to high rewards in these tasks.