Alterations in Reward-Related Decision Making in Boys with Current and Future Internalizing Disorders

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Abstract

Reward-related decision making was examined within a longitudinal study of 221 11-year-old boys, 50 of whom had current internalizing disorders. Participants completed a behavioral decision-making task involving varying probability and magnitude of obtaining reward. Concurrent internalizing but not externalizing diagnoses were related to reduced frequency of choosing the reward option with a large, likely reward. Furthermore, low frequency of choosing this reward option predicted internalizing diagnoses, self-reported depressive symptoms, and parent-rated internalizing problems one year later. These results are discussed with respect to emotion-based, motivational, and behavioral models of altered reward processing and diminished positive affect in depression. The study represents a step toward understanding some motivational and emotional aspects of early-onset internalizing disorders within a framework of affective neuroscience.
Alterations in Reward-Related Decision Making in Boys with Current and Future Internalizing Disorders

Approaches to understanding the development of affective disorders have emphasized not only clinical symptoms of increased negative affect, but also symptoms and behavior reflecting diminished positive affect. Emotion-based, motivational, and behavioral models of depression postulate reduced experience of positive affect (Clark & Watson, 1991), reduced activity in the behavioral facilitation system (BFS) (Depue & Iacono, 1989), and reduced frequency of experiencing positive reinforcement (Lewinsohn, Hoberman, Teri, & Hautzinger, 1985), respectively.

From an affective neuroscience perspective, positive affect can be parsed into several components related to reward (Rolls, 1999). These include the motivation to obtain rewards, executing reward-seeking behaviors, and the hedonic aspects of experiencing a reward. It is not clear which aspects of positive affect may be altered in internalizing disorders. Depression could involve decreased motivation to obtain reward, reduced frequency of reward-seeking behavior, or diminished experience of rewarding outcomes. Anhedonia, social withdrawal, and reduced activity level, all central symptoms of internalizing disorders, can be understood within this framework.

Investigations into specific components of reward processing cannot rely solely on self-report of mood, but instead must examine reward-related choices and behavior. Yet, there are no such investigations to our knowledge in clinical samples of children, and only limited data from these types of behavioral studies in clinical samples of depressed adults. One study of healthy adults suggests that those with dysphoria do not display the typical enhanced response bias during the reward condition of a signal-detection task (Henriques, Glowacki, & Davidson, 1994).
The authors interpreted this as indicating a conservative behavioral strategy that results from decreased reward saliency. Such a strategy may also lead those with depressive symptoms to be conservative when making decisions with potentially rewarding outcomes, even when the likelihood or amount of reward is high.

The reward-contingent decision (RCD) paradigm was developed by Rogers et al. (Rogers et al., 2004; Rogers et al., 2003) to examine specific components of reward-related decisions within an affective neuroscience framework. The RCD is a game of chance that involves choosing one of two options under varying conditions of reward probability and magnitude. The “fixed” option always involves a moderate probability of receiving a low-magnitude reward, while the “risky” option varies in both the probability and magnitude of reward. Healthy adults choose the risky option more often under high-reward and high-probability circumstances than under low-reward or low-probability circumstances (Rogers et al., 2003, 2004). Recently, the RCD was used to test a model of internalizing disorders. Findings indicated that tryptophan-depleted adults, who temporarily experienced reduced serotonin activity in the central nervous system, failed to discriminate between high-magnitude and low-magnitude rewards (Rogers et al., 2003). Given that low serotonin function has been implicated in depression and anxiety (van Praag et al., 1987) and is a pharmacologic target of treatment for depression, this outcome is consistent with the hypothesis that internalizing disorders involve altered reward processing. The RCD has yet to be used to examine psychopathology directly, but it has been applied to older children and adolescents (May et al., 2004) and offers the potential to examine how children with problem behavior vary in reward-related decisions.

In addition to reflecting current internalizing problems, alterations in reward processing may play a role in the development and persistence of internalizing symptoms. This was
suggested by a study examining the course of adults’ depression in relation to behavioral activation, which is presumed to involve reward motivation. Adults with lower self-reported behavioral activation functioning had a poorer outcome after eight months than did those with higher functioning (Kasch, Rottenberg, Arnow, & Gotlib, 2002). Perhaps reward processing influences the maintenance or recurrence of depressive symptomatology.

The current study examined 11-year-old boys’ reward-seeking decisions in relation to concurrent internalizing diagnoses as well as diagnoses and symptomatology one year later. We hypothesized that boys with internalizing disorders would make reward-related choices reflecting diminished reward-seeking, by choosing a risky option less frequently when it involved high reward magnitude. In addition, we expected this style of decision-making to be predictive of higher rates of future depressive symptoms and internalizing disorders.

Method

Participants

Participants were 221 boys from the Pittsburgh Mother and Child Project (PMCP), an ongoing longitudinal project examining the development of child vulnerability and resilience (Shaw, Gilliom, Ingoldsby, & Nagin, 2003). The original sample of 310 (51.3% European-American, 48.7% ethnic minorities; 33% single parent-headed families) was recruited when children were 1½ years old from low-income families participating in a government nutrition program. At the first assessment, mean per capita family income was $12,565 per year ($SD = 7,690), with a mean Hollingshead (1979) socioeconomic status of 23.32 ($SD = 9.29), indicative of a working class sample. Subsequent assessments were conducted at ages 2, 3½, 5, 5½, 6, 8, 10, 11, and 12 years. At ages 10, 11, and 12, data were available on 261, 256, and 252 families, respectively, with data available for at least one of these time points for 279 families (90% of
original sample). Participating and nonparticipating families did not differ on maternal education, annual income, and mother-reported oppositional behavior at the initial recruitment.

**Diagnostic and Symptom Assessment**

DSM-III-R (1987) and DSM-IV (1994) diagnoses were determined at each assessment by administering the Schedule for Affective Disorders and Schizophrenia in School-Aged Children – Present and Lifetime Version (K-SADS–PL; (Kaufman et al., 1997), a structured interview. A trained clinician interviewed both the child and the parent or guardian (hereafter, parent) about the child’s symptoms. At ages 10 and 11, all diagnoses were determined using information from both the child and parent interviews. At age 12, internalizing diagnoses were determined from the child interview, and externalizing diagnoses were determined from the parent interview, resulting in fewer diagnoses at age 12 than at ages 10 or 11. Participants were classified as internalizing if they received diagnoses of major depressive disorder, dysthymia, or any anxiety disorder ($n = 29, 30, 9$ at ages 10, 11, and 12, respectively). Participants were classified as externalizing if they received diagnoses of attention-deficit/hyperactivity disorder, oppositional defiant disorder, or conduct disorder ($n = 45, 58, and 38$ at ages 10, 11, and 12, respectively). To test hypotheses about current diagnosis, participants were included in the internalizing group if they received an internalizing diagnosis at either age 10 or age 11 ($n = 50$) and externalizing if they received an externalizing diagnosis at either age 10 or 11 ($n = 71$).

Participants and parents also completed symptom questionnaires at age 12 (see Table 1). Participants completed the Children’s Depression Inventory (CDI; (Kovacs, 1985) and the 10-item form of the Multidimensional Anxiety Scale for Children (MASC; (March, Parker, Sullivan, Stallings, & Conners, 1997). Parents completed the Child Behavior Checklist (CBCL; (Achenbach, 1991). All are reliable and valid measures for children and adolescents. Total scores
were computed for MASC and CDI data. Raw scores for CBCL internalizing and externalizing factors were obtained using software with age and gender norms. CDI, MASC, and CBCL data were available for 168, 167, and 187 participants, respectively.

Procedure

At age 11, participants completed a computer version of the RCD during a home assessment. The RCD involves winning points by choosing one of two “games”, or options, on each trial. Each game was depicted as a rectangle, with height representing the probability of winning and the number of points to be won displayed above the rectangle. The fixed game always involved a .50 probability of winning 10 points. The other, risky game, varied in the probability of winning (high or low, defined as .66 or .33) and in the magnitude of points (large or small, defined as 80 or 20 points). Based on the two levels of probability and two levels of magnitude, there were four trial types: low probability/low reward, low probability/high reward, high probability/low reward, and high probability/high reward. Visual feedback, in the form of a smile-face icon, and total score were presented after each trial. The task included 96 trials divided into 8 blocks of 12 trials each. Trials were presented in pseudorandom order, with each block containing at least two trials of each type. The main variable derived, choice, was the frequency of choosing the risky game (instead of the fixed game) for each trial type.

Data Analyses

To test hypotheses about differences based on current diagnostic group, repeated measures analyses of variance (ANOVAs) with trial type as a repeated measure and diagnostic group as a between-subjects variable were used. One-way ANOVAs were then used to test group differences on individual trial types as appropriate. To test whether RCD performance at age 11 predicted diagnosis at age 12, logistic regressions were used with diagnosis (present or absent) as
the dependent variable and choice as the predictor. Associations between continuous choice variables and continuous self-report variables were tested with correlation analyses.

Results

**Overall RCD Task Performance**

The mean number of missing trials was 2.61 (SD = 7.52). Results below did not differ when participants with > 10% missing trials were excluded. The internalizing and non-internalizing groups did not differ in number of missing trials, Fs < 1.80, ps > .15. As found with adults (e.g., Rogers et al., 2004), participants chose the risky game more frequently when the probability of winning was high than when it was low, t(221) = -17.29, p < .001, and when the magnitude of the possible reward was high than when it was low, t(221) = 9.23, p < .001.

**Age 11 Diagnostic Group and RCD Performance**

To test the hypothesis that current internalizing disorders are associated with low reward sensitivity, repeated measures ANOVAs for choice across trial types were conducted separately for internalizing and externalizing groups. There was a statistical trend for the Internalizing Group X Trial Type interaction, F(3,217) = 2.29, p = .08, η² = .03. As depicted in Figure 1, follow-up ANOVAs for individual trial types indicated that the internalizing group chose the risky game less frequently during high probability/high reward trials than did the non-internalizing group, F(1,219) = 5.09, p < .05, η² = .02. The internalizing group did not differ from the non-internalizing group for other trial types. To address specificity to internalizing disorders, an ANOVA with externalizing and non-externalizing groups was conducted, indicating no Group X Trial Type interaction effect or Group main effect.

To examine whether the internalizing group difference was specific to depression, separate repeated measures ANOVAs were conducted to compare participants with depression
diagnoses \((n = 22)\) and anxiety diagnoses \((n = 35)\) with other participants. Both indicated a nonsignificant Group X Trial Type interaction.

*Age 11 RCD Performance and Age 12 Diagnosis*

Because internalizing diagnosis at age 10 or 11 was associated with less frequent choice of the risky game on high probability/high reward trials, a binary logistic regression was computed to test whether this pattern of choice predicted age 12 diagnosis. Choice on high probability/high reward trials was the independent variable and internalizing diagnosis at age 12 was the dependent variable. Frequency of choosing the risky game on these trials at age 11 was associated with likelihood of having an internalizing disorder at age 12, \(-2 \text{ log likelihood} = 64.46, \text{Wald } \chi^2 (N = 221, \text{df} = 1) = 10.54, p < .01\). Specifically, participants with an internalizing disorder at age 12 chose the risky game less frequently \((M = 13.29, SD = 5.19)\) than did those without an internalizing disorder \((M = 18.27, SD = 4.55)\). Because the number of participants with internalizing diagnoses was low, the relation of choice at age 11 to self-reported and parent-reported symptoms at age 12 was examined to corroborate this relation. Correlation analyses indicated that the frequency of choosing the risky game in the high probability/high reward trials at age 11 was significantly, albeit modestly, negatively related to self-reported depressive symptoms and parent-reported internalizing problems at age 12, \(r = -.15\) for both, \(ps < .05\). Choice on this trial type was unrelated to self-reported anxiety or parent-reported externalizing problems at age 12.

**Discussion**

In a sample of 11-year-old boys from predominantly low-income families, internalizing disorders were associated with reduced frequency of choosing an option with high likelihood of a large reward during a decision-making task. This choice pattern was associated with concurrent
internalizing disorders and predicted internalizing symptoms one year later. The link between age 11 reward decisions and age 12 internalizing disorder was supported by both self-report and parent-report measures, further corroborating the validity of the relation across time and informant. This alteration in reward-related decision making may reflect reduced reward-seeking in depressed boys. Interestingly, the reward choice for which the internalizing group differed – large reward probability and large magnitude – is the one in which a decision to play for a reward should be most consistently made, based on likely payoff and reward amount.

This study builds on previous investigations of reward-motivated behavior in healthy adults (Rogers et al., 2003, 2004) and adults with depressive symptoms (Henriques et al., 1994) in two ways. First, it extends this approach to a younger population, confirming that young adolescents perform similarly to adults in reward decision-making. Second, it directly addresses questions about affective psychopathology by including participants with diagnosed internalizing disorders. As in these previous studies, our findings underscore the value of employing behavioral measures to examine affective features of psychopathology.

These alterations in reward decisions were associated with self-reported depression but not anxiety symptoms one year later, indicating that depressive symptoms may underlie the effect found concurrently. This suggests that our findings are thus consistent with models that emphasize decreases in positive affect in depression (Clark & Watson, 1991; Depue & Iacono, 1989) and affective differences between depression and anxiety (Clark & Watson, 1991). Our findings also provide support for behavioral models, in which reduced pursuit of reward is an important mechanism for decreased positive affect (Lewinsohn et al., 1985). Depressed children and adolescents report reduced positive mood (e.g., (Joiner, Catanzaro, & Laurent, 1996), and depressed adults report fewer pleasant experiences (Lewinsohn & Graf, 1973). Thus, perhaps
decisions against engaging in rewarding activities are important to the reduced reinforcement for active behavior experienced in depression.

Alterations in reward choice and behavior may play a role in the continuity of internalizing disorders and symptomatology. This is especially salient for early-onset internalizing disorders, which are likely to be chronic and severe (Weissman et al., 1999), and in which chronicity is related to poor adult functioning (Lewinsohn, Rohde, Seeley, Klein, & Gotlib, 2003). Reward sensitivity and depression may have important reciprocal influence, as suggested by recent findings that rodents who have experienced defeat exhibit long-term reductions in reward responsiveness (Von Frijtag et al., 2000).

The generalizability of our findings is limited by our sample, which included only male, low-SES participants during a single developmental period. It will be important to consider whether low reward sensitivity is associated with internalizing disorders in girls, other developmental periods, and other socioeconomic groups. The heightened reward responsiveness present during adolescence (Dahl & Spear, 2004 (in press); Steinberg, 2004 (in press)) suggests that considering pubertal development may also be fruitful. Finally, the operationalization of internalizing disorders resulted in the inclusion of some boys with comorbid externalizing diagnoses. However, we believe that excluding this subgroup in favor of having a “pure” internalizing group would have resulted in an artificially rarefied group. Internalizing and externalizing disorders co-occur at high rates during childhood (Gjone & Stevenson, 1997), and the presence of depressive symptoms may still exert an important influence on reward sensitivity in boys who experience externalizing problems.

The current study represents a key step toward characterizing reward-related differences in early-onset affective disorders. The use of a behavioral task, the emphasis on positive affect,
and the inclusion of diagnostic data at three time points are strengths, and they highlight possible future directions for research on internalizing disorders.
References


Boys’ Reward-Seeking


reward processing in separable phases of decision-making cognition. *Biological Psychiatry*, 55(6), 594-602.


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<td>(n = 212)</td>
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<td>CBCL</td>
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<td>5.70 (6.19)</td>
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<tr>
<td>MASC</td>
<td>10.38 (3.82)</td>
<td>9.25 (5.19)</td>
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</table>

*Note: Values are means, with SD in parenthesis. Values for internalizing and externalizing problems are raw scores. CBCL = Child Behavior Checklist; CDI = Child Depression Inventory; MASC = Multidimensional Anxiety Scale for Children. CBCL data were obtained through parent report; CDI and MASC data were obtained through self-report.*
Figure Caption

*Figure 1.* Frequency of choosing the risky game during the RCD task at age 11, by trial type, for boys with \((n = 48)\) or without \((n = 165)\) internalizing disorder diagnoses at age 10 or 11. Task conditions were as follows: low/low = low probability/low reward, low/high = low probability/high reward, high/low = high probability/low reward, high/high = high probability/high reward. As indicated by an asterisk, the groups differed significantly for the high/high condition.
Boys’ Reward-Seeking

The bar chart illustrates the mean frequency of choosing the risky game across different trial types for boys with low and high internalizing scores. The x-axis represents the trial types: Low/Low, Low/High, High/Low, and High/High. The y-axis represents the mean frequency of choosing the risky game. The chart shows that boys with high internalizing scores tend to choose the risky game more frequently than those with low internalizing scores, especially in the High/Low and High/High trial types.

* indicates a significant difference.