Alterations in Reward-Related Decision-Making in Boys with Recent and Future Depressive and Anxiety Disorders

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Abstract

Background: Reduced pursuit and experience of reward is postulated to be a feature of depression. Investigating reward processing may be especially valuable to understanding early-onset depressive and anxiety disorders, which are likely to precede depression during adulthood.

Methods: Reward-related decision-making was examined within a longitudinal study of 221 11-year-old boys, 50 of whom had depressive or anxiety (i.e., internalizing) disorders at age 10 or 11. Participants completed a behavioral decision-making task involving varying probability and magnitude of obtaining reward. Results: Under conditions involving a high probability of obtaining a large reward, boys with internalizing disorders chose the reward-related option less frequently than did others. Boys with externalizing disorders at age 10 or 11 did not differ from others in their reward-related decisions. Low frequency of choosing the high-probability, large-reward option at age 11 predicted internalizing disorders and self-reported depressive symptoms one year later. Furthermore, reward-related decisions predicted later internalizing disorders even when adjusting for the continuity of internalizing disorders and the presence of concurrent externalizing disorders. Conclusions: Findings are consistent with affective neuroscience models of altered reward processing and diminished positive affect in depression. This study represents a step toward elucidating the motivational and emotional aspects of early-onset internalizing disorders.
Alterations in Reward-Related Decision-Making in Boys with Recent 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 and Watson 1991), reduced activity in the behavioral facilitation system (Depue and Iacono 1989; Fowles 1988; Gray 1990), and reduced frequency of experiencing positive reinforcement (Lewinsohn et al 1985), respectively.

Reduced positive affect may be especially critical to understanding internalizing disorders (i.e., depressive or anxiety disorders) that occur during childhood and adolescence. Internalizing disorders with onset during this developmental period are associated with academic and interpersonal impairment (Glied and Pine 2002; Ialongo et al 1995). In addition, children and adolescents with these disorders often experience severe, recurrent depression later in life (Costello et al 1999; Kovacs et al 1989; Lewinsohn et al 1999; Pine et al 1998). Pathways to later depression tend to involve both depressive and anxiety disorders, which often co-occur (Angold et al 1999) and may have similar underlying etiological influence (Silberg et al 2001). Reduced positive affect is relevant to these disorders because studies of early symptoms have indicated that anhedonia is particularly important in predicting major depressive episodes during adulthood (Pine et al 1999).

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, the execution of reward-seeking behaviors, and the hedonic aspects of experiencing a reward. In this perspective, depression is postulated to be accompanied by alterations of reward processing...
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(Drevets 2001; Forbes and Dahl in press). Depression, for example, 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 all be conceptualized as reflecting altered reward processing.

Although several studies have reported that low subjective positive affect is evident in children with depression (e.g., Lonigan et al 2003), investigations into specific components of reward processing cannot rely solely on self-report measures. Instead, such investigations must also examine reward-related choices and behavior. Yet to our knowledge, there are no such investigations in clinical samples of children. Even in adults, only limited data exist on reward-related behavior in depression. In studies with a signal-detection task, three studies have reported that adults with depression (Henriques and Davidson 2000) or dysphoria (Henriques et al 1994; Pizzagalli et al 2005) fail to display the typical enhanced response bias during a reward condition. This finding can be interpreted as indicating that adults with depression employ a conservative behavioral strategy because rewards are less salient to them. Such a strategy may also lead those with depressive symptoms to be conservative when making decisions about potentially rewarding outcomes. Thus, even when the likelihood or amount of potential reward is high for a given option, children or adults with depression may not be inclined to choose that option.

A laboratory task well-suited to examining specific components of reward-related choices in depression is the reward-contingent decision (RCD) paradigm. Developed by Rogers et al. (Rogers et al 2004; Rogers et al 2003), the RCD is a game of chance that involves decisions about reward options with varying conditions of probability and magnitude. On each trial,
participants must choose between one of two options: the “fixed” option, which always involves a moderate probability of receiving a low-magnitude reward, and the “risky” option, which involves high or low probability and high or low magnitude of reward. After making a choice, participants learn whether they won and receive a total score. Because it involves reward-related decisions under conditions of uncertainty, the task is considered to be emotional in nature (Rogers et al 2004). The decision-making phase of each trial is likely to involve motivational aspects of reward processing because it involves anticipation of reward and execution of reward-seeking behaviors.

Behavioral evidence indicates that during the RCD, healthy adults choose the risky option more often under high-magnitude and high-probability circumstances than under low-magnitude or low-probability circumstances (Rogers et al., 2003, 2004). Recently, the RCD was used to test a model of depression. 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 both types of disorders, these findings are consistent with the hypothesis that internalizing disorders involve altered reward processing. The RCD has yet to be used to examine child psychopathology directly, but it has been applied successfully to healthy children and adolescents (May et al 2004), indicating that young people can understand the task and respond to varying probability and magnitude of reward. Thus, the RCD paradigm offers the potential to examine how children with internalizing disorders 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 possibility 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 depression who had low self-reported behavioral activation functioning had a poorer outcome after eight months than did those with high functioning (Kasch et al 2002). Consistent with this finding, adults’ poor reward responding on a signal detection task predicted anhedonia one month later (Pizzagalli et al 2005). Perhaps reward processing also influences the maintenance or recurrence of depressive symptomatology.

The current study examined 11-year-old boys’ reward-seeking decisions in relation to concurrent or recent internalizing disorders as well as internalizing disorders and symptoms one year later. We hypothesized that boys with internalizing disorders would make reward-related decisions that reflect diminished reward-seeking. Specifically, we expected that when a risky option involved high probability and high magnitude of reward, boys with internalizing disorders would choose the option less frequently than would boys without internalizing disorders. We also hypothesized that this style of decision-making would be predictive of higher rates of future internalizing disorders. Specifically, we expected that low frequency of choosing a risky option under high-probability, high-magnitude reward conditions would be related to greater likelihood of internalizing disorders and higher internalizing symptoms one year later. Finally, although our focus was on internalizing disorders, we also examined associations between reward-seeking decision-making and externalizing disorders (i.e., Attention-Deficit/Hyperactivity Disorder (ADHD), Oppositional Defiant Disorder, and Conduct Disorder). Because some have proposed that externalizing symptoms such as impulsivity represent excessive activity in reward-related
motivational systems (Beauchaine 2001), we examined whether boys with externalizing disorders would more likely select high-magnitude reward conditions regardless of whether there was a low or high probability of obtaining the reward.

Methods and Materials

Participants

Participants were 221 boys from the Pittsburgh Mother and Child Project, an ongoing longitudinal project examining the development of child vulnerability and resilience (Shaw et al 2003). Table 1 contains demographic and symptom characteristics of the sample. The original sample of 310 (74% of the 421 who were approached) 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 $12,565 per year ($D = 7,690), with a mean Hollingshead (1975) socioeconomic status of 23.32 ($D = 9.29), which is indicative of working class status. 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. Data were 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. All participants included in the current sample participated in diagnostic and behavioral assessments at ages 10, 11, and 12.

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. To
establish reliability, clinical interviewers participated in an intensive training program at Western Psychiatric Institute and Clinic. Additionally, every case in which a subject approached or met diagnostic criteria was discussed by the research team, other interviewers, and the second author in the course of reaching a final decision on diagnosis. A 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. Although there was no child interview for externalizing diagnoses at age 12, youth reports of antisocial activity from the Self-Report of Delinquency questionnaire (Elliott et al 1985) were also considered in decisions about diagnoses of Conduct Disorder.

Participants were considered to have an internalizing disorder if they received a diagnosis of Major Depressive Disorder, Dysthymic Disorder, or any anxiety disorder \((n = 29, 30, \text{ and } 9 \text{ at ages } 10, 11, \text{ and } 12, \text{ respectively})\). Participants were considered to have an externalizing disorder if they received a diagnosis of ADHD, Oppositional Defiant Disorder, or Conduct Disorder \((n = 45, 58, \text{ and } 38 \text{ at ages } 10, 11, \text{ and } 12, \text{ respectively})\). Participants were included in the recent internalizing group if they received a diagnosis of an internalizing disorder at age 10 or age 11 \((n = 50; 23 \text{ with depressive disorders})\). Participants were included in the recent externalizing group if they received a diagnosis of ADHD, Oppositional Defiant Disorder, or Conduct Disorder at age 10 or 11 \((n = 38)\). Participants with comorbid internalizing and externalizing disorders at age 10 or 11 \((n = 33)\) were included in the internalizing group for data analyses because we expected internalizing disorders to exert an influence on choice behavior and because analyses indicated that the comorbid group was not responsible for effects involving internalizing group.
At age 12, participants completed 10-item forms of the Children’s Depression Inventory (CDI) (Kovacs 1985) and the Multidimensional Anxiety Scale for Children (MASC) (March et al 1997). Both are reliable and valid symptom measures designed for use with children and adolescents. CDI and MASC data were not available for 21 and 22 participants, respectively, primarily because of attrition. Total CDI and MASC scores were computed. Self-reported depressive symptoms were modestly correlated with internalizing diagnosis at age 10 or 11 and at age 12 (Kendall’s tau-b = .25 and .17, respectively, $p < .05$).

**Procedure**

Study procedures were explained to the participants and their parents, and all parents provided written informed consent for the procedures at each assessment. All participants provided verbal assent. Procedures were approved by the University of Pittsburgh Institutional Review Board.

At age 11, participants completed a computer version of the RCD during a home assessment. Participants who did not complete the RCD because of time constraints or technical problems are not included below. 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 the magnitude of possible earnings (large or small, defined as 80 or 20 points). Instructions to participants included a description of the probability and magnitude information and a demonstration of a trial. Participants were instructed to choose one of the two games on every
trial. They were told that the aim of the task was to win points, that the task is a game of chance, and that “there is no guaranteed way to win.”

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. There were no conditions involving loss. 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. Trial order was identical for all participants. Visual feedback on outcome (in the form of a smile-face icon) and updated total winnings (in points) were presented after each trial. Participants received an extra $5 in gift certificates if they obtained a total of over 50 points and an extra $10 in gift certificates if they obtained a total of over 100 points. The main variable derived from the RCD task, choice, was the frequency of choosing the risky game (instead of the fixed game) in each trial type.

Data Analyses

To test hypotheses about differences based on current diagnostic group, repeated-measures analyses of variance (ANOVAs) were conducted on choice score using the general linear model (GLM) procedure in SPSS 12.0.1. Probability and magnitude were within-subjects variables, age 10 or 11 internalizing group was a between-subjects variable, and age 10 or 11 externalizing group was a between-subjects variable. Internalizing group and externalizing group were both included in these ANOVAs so that we could examine the specificity of any alteration in reward behavior to internalizing disorders. The inclusion of both group variables allowed us to statistically adjust for the effect of externalizing disorders when considering the effect of internalizing disorders. Because we had a hypothesis about the relation of internalizing disorders to choice during the high-probability, high-magnitude condition, we included a priori contrast
tests of group differences in this condition within the GLM model. Effect sizes were computed as partial eta squared ($\eta^2$), which refers to the proportion of variance explained. Because we proposed specific, directional hypotheses, one-tailed tests were employed to establish statistical significance.

To test whether RCD performance at age 11 predicted the presence of internalizing disorders at age 12, binary hierarchical logistic regression models were conducted. Choice on the high-probability, high-magnitude trials was the sole predictor in the first model. To examine whether effects related to reward-related choice were explained by continuity of internalizing disorders or concurrent externalizing disorders, a second model was conducted with age 10 or 11 internalizing group entered at step 1, age 12 externalizing group entered at step 2, and high-probability/high-magnitude choice entered at step 3.

**Preliminary Analyses**

Preliminary analyses addressed group differences in demographic characteristics, missing trials, deliberation time, and total winnings. ANOVAs indicated that participants with internalizing disorders did not differ from other participants in family socioeconomic status or income. Chi square analyses indicated that participants with internalizing disorders did not differ from other participants in ethnicity or mother’s marital status.

The mean number of missing trials was 2.61 ($SD = 7.52$). Results did not differ when we excluded participants missing > 10% of trials. Because ANOVAs indicated that internalizing, externalizing, and non-disordered participants did not differ in number of missing trials, we included all participants in the analyses.

Boys with internalizing disorders, boys with externalizing disorders, and boys without disorders did not differ in mean deliberation time or total points won. However, a repeated-
Forbes et al. indicated a statistical trend toward a magnitude X internalizing interaction for deliberation time ($F(1,218) = 3.34, p = .07$). Follow-up ANOVAs indicated that during trials involving a chance for high-magnitude reward, participants with internalizing disorders spent more time deliberating ($M = 2320.37$ ms, $SD = 560.03$) than did participants without internalizing disorders ($M = 2160.90$, $SD = 466.19$; $F(1,219) = 4.12, p < .05$).

Results

**Age 11 Reward Choice and Recent Internalizing Disorder**

To test the hypothesis that recent internalizing disorders are associated with low reward-seeking behavior, repeated-measures ANOVAs were conducted (see Table 2). As found with adults’ performance on the RCD task (e.g., Rogers et al., 2004), main effects for probability and magnitude indicated that participants chose the risky option more frequently than the fixed option during high-probability or high-magnitude conditions. There was a significant probability X internalizing interaction, but the probability X magnitude X internalizing interaction was nonsignificant. However, contrast analyses indicated that during high-probability/high-magnitude trials, as predicted, the internalizing group chose the risky game less frequently than did the non-internalizing group ($F(1,218) = 2.83, p < .05, \eta^2 = .01$) (Figure 1). Although Figure 1 seems to suggest that there was an opposite pattern for the two groups during the low-probability/low-magnitude trials, the contrast for this effect was nonsignificant. There were no main effects for internalizing or externalizing group, and all interactions involving externalizing group were nonsignificant.

To examine whether the effect for internalizing held for both the depression and anxiety subgroups, a repeated-measures ANOVA was conducted with probability and magnitude as

measures GLM ANOVA with probability and magnitude of reward as within-subjects variables.
within-subjects factors, and with depressive disorder and anxiety disorder as between-subjects factors. The probability X magnitude X depression interaction was significant \( F(1,217) = 4.24, \ p < .05, \eta^2 = .02 \). Contrast tests within the model indicated that within the high-probability condition, participants without depression responded differently to low and high reward magnitude \( (M = 16.33, SD = .51 \text{ for low}, M = 17.48, SD = .51 \text{ for high}; F(1,217) = 7.53, p < .001) \), whereas participants with depression did not \( (M = 17.18, SD = 1.23 \text{ for low}, M = 15.78, SD = 1.22 \text{ for high}; F = 1.95, p > .15) \). The interaction effects involving anxiety group were all nonsignificant \( (Fs < 1.54) \). Thus, depression appeared to exert a greater influence than anxiety on reward-related behavior.

*Age 11 Reward Choice and Age 12 Internalizing Disorder*

To test the hypothesis that choice on high-probability/high-magnitude trials predicts later internalizing disorders, a binary hierarchical logistic regression was computed on age 12 internalizing disorder. Results indicated that frequency of choosing the risky game on high-probability/high-magnitude trials at age 11 was associated with likelihood of having an internalizing disorder at age 12 \( (p < .005; \text{Table 3, Model 1}) \). Participants with an internalizing disorder at age 12 chose the risky game less frequently \( (M = 13.29, SD = 5.19) \) at age 11 than did those without an internalizing disorder \( (M = 18.27, SD = 4.55) \).

This effect for reward choice remained significant after adjustment for prior internalizing disorder or current externalizing disorder \( (\text{Table 3, Model 2}) \). Internalizing disorder at age 10 or 11 was related to internalizing disorder at age 12 when it was originally entered \( (p < .05) \), but it was no longer significant once reward choice was entered in the model. Externalizing disorder at age 12 was unrelated to internalizing disorder at age 12. The effect for reward choice still
remained significant after adjustment for depressive symptoms at age 12 (for symptoms, B = .26, OR = .26, 95% CI = .82 – 2.06).

Because the number of participants with internalizing disorders at age 12 was low, the relation of choice at age 11 to self-reported symptoms at age 12 was examined to corroborate this finding. A multivariate ANOVA with high-probability/high-magnitude choice at age 11 indicated that choice was related to depressive symptoms ($F(1,197) = 2.68, p = .05, \eta^2 = .01$) but not anxiety symptoms ($F = 1.54$) at age 12.

To test further whether future externalizing disorder was related to high-probability/high-magnitude reward choice, a linear regression was computed on age 11 reward choice with internalizing at age 12 and externalizing at age 12 entered simultaneously as predictors. Only future internalizing was related to reward choice ($\beta = -.23, p < .005$). This relation remained significant when recent (age 10 or 11) internalizing and externalizing disorders were included in the model. A logistic regression predicting age 12 externalizing diagnosis from high-probability/high-magnitude reward choice at age 11 also yielded null findings.

Discussion

In a sample of 11-year-old boys from predominantly low-income families, those with depressive or anxiety disorders (i.e., internalizing disorders) exhibited unusual reward-related choices. Specifically, those who had internalizing disorders showed reduced frequency of choosing an option with high likelihood of yielding a large reward. This choice pattern was evident in boys with internalizing disorders at age 10 or 11, and it also predicted internalizing disorders at age 12. The link between age 11 reward choice and age 12 internalizing disorders was evident even when the continuity of internalizing disorders and the presence of concurrent externalizing disorders were taken into account. Furthermore, the link between reward choice
and later internalizing was supported by self-report measures of depressive symptoms, thus corroborating the validity of the relation across time.

In contrast to findings for boys with internalizing disorders, boys with externalizing disorders (i.e., ADHD, Oppositional Defiant Disorder, Conduct Disorder) did not exhibit unusual reward-related choices. In addition, reward-related choices at age 11 were not related to externalizing disorders one year later. Thus, our findings on altered reward processing, at least in this behavioral context, were specific to internalizing disorders. Given the nature of the paradigm we employed, perhaps reduced motivation to obtain future reward is particularly characteristic of youth with internalizing disorders.

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 made most consistently. In other words, based on likely payoff and reward amount, participants who want to maximize their winnings should always choose this risky option under these conditions. This observed alteration in reward-related choice may reflect reduced reward-seeking in boys with internalizing disorders. In natural settings, these boys may also decline to participate in social events, sports, and other pleasant activities because they are not motivated to experience reward.

The observation that reward decisions were altered only under conditions of high-probability, high-magnitude reward may more specifically indicate that internalizing disorders involve poor flexibility in shifting behavior when reward conditions change. In other words, internalizing disorders could involve a fixed, generalized strategy for responding to reward, regardless of any changing contingencies. In the RCD task, boys with internalizing disorders may have consistently decided to play the fixed game, even though such a strategy would not be
optimal under high-probability, high-magnitude conditions. This strategy may also reflect an aversion to risk. Difficulty in shifting strategies when rewards from the risky game became more likely and of greater magnitude echoes the findings on depressed and dysphoric adults’ performance in signal-detection tasks. In those studies, adults with depression failed to exhibit a response bias when responses began to be rewarded (Henriques and Davidson 2000; Henriques et al 1994; Pizzagalli et al 2005).

Boys with internalizing disorders also spent more time deliberating about reward-related choices than did other boys, but only when the magnitude of possible reward was high. Based on their choices and the time they spent making those choices, boys with internalizing disorders might be less sensitive to possible reward or less motivated to seek reward. Boys with and without internalizing disorders won a similar amount of points during the task. This suggests that boys with internalizing disorders differed from other boys in their reward-related decisions despite exposure to a similar quantity of reward over the course of the task. Furthermore, even though the strategy applied by the boys in the internalizing group was different from that employed by other boys, this strategy was not necessarily detrimental.

This study builds on previous investigations of reward-motivated behavior in healthy adults (Rogers et al., 2003, 2004) and adults with depressive symptoms (Henriques and Davidson 2000; Henriques et al 1994; Pizzagalli et al 2005) in two ways. The study extends the behavioral approach to measuring reward responding to a younger population, and it directly addresses questions about affective psychopathology by including participants with diagnosed disorders. As in previous studies, the study’s findings underscore the value of employing behavioral measures to examine affective features of psychopathology. More importantly, the findings
indicate that affective disorders in childhood, as well as in adulthood, are associated with decreased reward responding.

Two findings suggest that depressive symptoms specifically may underlie the altered reward choice found for boys with internalizing disorders. First, depression but not anxiety diagnoses at age 10 or 11 were associated with high-likelihood, high-magnitude reward choices. Second, this pattern of reward choice was associated with self-reported depressive but not anxiety symptoms one year later. This pattern of findings suggests that our results are consistent with models emphasizing that decreases in positive affect are a fundamental characteristic of depression (Clark and Watson 1991; Depue and Iacono 1989) and serve to distinguish depression and anxiety (Clark and 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 et al 1996), and depressed adults report fewer pleasant experiences (Lewinsohn and 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 et al 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 socioeconomic groups, and other developmental periods. The heightened reward responsiveness present during adolescence (Dahl and Spear 2004; Steinberg 2004) 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 and Stevenson 1997), and the presence of depressive symptoms may still exert an important influence on reward sensitivity in boys who experience externalizing problems.

At times our conclusions were also limited by our focus, which was on multiple types of internalizing disorders rather than on depression specifically. The rationale for taking this approach was influenced by the limited number of participants who had only one specific type of internalizing disorder, including depression. If the depression-only subgroup had been larger and more power had been available, we would have been able to test hypotheses about specific associations between reward-related decisions and depression. Another part of the rationale, however, was related to the value of conceptualizing early-onset internalizing disorders as a single construct. Depressive disorders and anxiety disorders frequently co-occur, so that children with one type of disorder also tend to experience the other. Anxiety disorders frequently precede depression in time (Kovacs et al 1989; Weissman et al 1997), and many children who have anxiety disorders at the ages in the current study are likely to develop depressive disorders later.
Depressive and anxiety disorders are thought to share important features, including a possible status as different phases of the same disorder (Williamson et al in press).

The current study represents a key step toward characterizing unusual reward and positive affect in early-onset affective disorders. The use of a behavioral, laboratory-based task, the emphasis on positive affect, and the inclusion of diagnostic data at three time points are strengths. Our findings highlight possible future directions for research on internalizing disorders within an affective neuroscience framework.
Acknowledgments

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References


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Table 1. *Characteristics of the Sample*

<table>
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<th>Internalizing Disorder</th>
<th>No Internalizing Disorder</th>
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<td></td>
<td><em>(n = 50)</em></td>
<td><em>(n = 171)</em></td>
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<tr>
<td><strong>Child Ethnicity</strong></td>
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<tr>
<td>European American</td>
<td>54.0%</td>
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<td>African American</td>
<td>40.0%</td>
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<tr>
<td>Other</td>
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<td>11.1%</td>
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<td><strong>Family Socioeconomic Status</strong></td>
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<td>27.71 (10.44)</td>
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<td><strong>Annual Family Income</strong></td>
<td>27,345 (14,923.86)</td>
<td>28,655.05 (16,475.81)</td>
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<td><strong>Mother Married or Cohabitating</strong></td>
<td>48.0%</td>
<td>52.6%</td>
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<td><strong>Symptoms at Age 12</strong></td>
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<tr>
<td>Depressive</td>
<td>1.71 (1.81)</td>
<td>.77 (1.26)</td>
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<td>Anxiety</td>
<td>10.67 (5.12)</td>
<td>8.93 (5.08)</td>
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<td><strong>RCD Task Behavior</strong></td>
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<tr>
<td>Total Earnings (points)</td>
<td>90.58 (15.78)</td>
<td>93.42 (13.23)</td>
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<td>Deliberation Time (ms)</td>
<td>1147.18 (277.23)</td>
<td>1086.14 (230.08)</td>
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*Notes:* Values are mean *(SD)*, except ethnicity and mother’s marital status. Internalizing disorder refers to the presence of a depressive or anxiety disorder. Socioeconomic status is reported in units of the Hollingshead Index (1975). Depressive symptoms were measured with the Children’s Depression Inventory (CDI) (Kovacs 1985), and anxiety symptoms were measured with the Multidimensional Anxiety Scale for Children (MASC) (March et al 1997). RCD, reward-contingent decision.
Table 2. 11-year-old Boys’ Frequency of Choosing a Risky Option on a Reward Task as a Function of Reward Probability, Reward Magnitude, Internalizing Disorder at Age 10 or 11 (n = 50), and Externalizing Disorder at Age 10 or 11 (n = 38)

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<td>Magnitude</td>
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<td>Internalizing</td>
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<tr>
<td>Externalizing</td>
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<tr>
<td>Probability X Magnitude</td>
<td>26.35**</td>
<td>.11</td>
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<tr>
<td>Probability X Internalizing</td>
<td>5.72*</td>
<td>.03</td>
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<tr>
<td>Probability X Externalizing</td>
<td>.87</td>
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<td>Magnitude X Internalizing</td>
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<tr>
<td>Magnitude X Externalizing</td>
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<tr>
<td>Probability X Magnitude X Internalizing</td>
<td>.72</td>
<td></td>
</tr>
<tr>
<td>Probability X Magnitude X Externalizing</td>
<td>.53</td>
<td></td>
</tr>
</tbody>
</table>

* $p < .05$  ** $p < .01$.

Note: df = 1,218 for all analyses. For significant effects, effect size is reported as $\eta^2$, which represents the proportion of variance explained. Internalizing refers to depressive or anxiety disorders; externalizing refers to Attention-Deficit/Hyperactivity, Oppositional Defiant, or Conduct Disorder. The internalizing group included boys with both internalizing and externalizing disorders, while the externalizing group included boys with externalizing disorders only.
Table 3. *Logistic Regression Models Predicting Presence of Internalizing Disorder at Age 12 from Reward-Related Decisions at Age 11, Adjusted for Continuity of Internalizing Disorder and Concurrent Externalizing Disorder*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
<th>ΔR² for Step</th>
<th>OR</th>
<th>95% CI</th>
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<tbody>
<tr>
<td><strong>Model 1: Basic Model</strong></td>
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<tr>
<td>Reward-Related Decision</td>
<td>-.19</td>
<td>.17**</td>
<td>.83**</td>
<td>.74 – .93</td>
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<tr>
<td><strong>Model 2: Full Model</strong></td>
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<td></td>
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<tr>
<td>Step 1: Continuity of Internalizing Disorder</td>
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<td>Internalizing Disorder at Age 10 or 11</td>
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<td>4.64*</td>
<td>1.19 – 17.99</td>
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<td>4.11*</td>
<td>1.00 – 16.82</td>
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<td>Externalizing Disorder at Age 12</td>
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<td>1.68</td>
<td>.37 – 7.57</td>
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<td>Step 3: Reward-related Decision</td>
<td>.14**</td>
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<td>1.21</td>
<td>3.34</td>
<td>.74 – 15.10</td>
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<tr>
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<td>.37</td>
<td>1.45</td>
<td>.28 – 7.52</td>
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<tr>
<td>Reward-related Decision</td>
<td>-.18</td>
<td>.83**</td>
<td>.74 – .94</td>
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</tr>
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</table>

*p < .05  **p < .005

*Note: Reward-related decision was the frequency of choosing the risky option during the high-probability/high-magnitude reward condition of the reward-contingent decision paradigm (Rogers et al 2004; Rogers et al 2003). Internalizing refers to depressive or anxiety disorders; externalizing refers to Attention-Deficit/Hyperactivity, Oppositional Defiant, or Conduct Disorder. Results did not change when depressive symptoms at age 12 were included in the model. OR, odds ratio; CI, confidence interval.*
Figure Caption

Figure 1. Boys’ frequency of choosing the risky game during the reward-contingent decision paradigm (Rogers et al 2004; Rogers et al 2003) at age 11, by trial type. Means are presented for (A) boys with \( n = 50 \) or without \( n = 171 \) internalizing disorders (i.e., depressive or anxiety disorders) and (B) boys with \( n = 38 \) or without \( n = 183 \) externalizing disorders (i.e., Attention-Deficit/Hyperactivity, Oppositional Defiant, or Conduct Disorders) at age 10 or 11. Boys who had both types of disorders are included in the internalizing group in (A). Reward conditions: low/low = low probability/low magnitude of reward, low/high = low probability/high magnitude, high/low = high probability/low magnitude, high/high = high probability/high magnitude. Error bars represent 1 standard error of the mean. * = groups differed significantly for high-probability/high-magnitude trials only.
Forbes et al. 30

**A**

![Bar chart showing mean frequency of choosing risky game for different trial types and group conditions.](image)

- **Trial Type**: Low/Low, Low/High, High/Low, High/High
- **Groups**: no internalizing vs. internalizing

**B**

![Bar chart showing mean frequency of choosing risky game for different trial types and group conditions.](image)

- **Trial Type**: Low/Low, Low/High, High/Low, High/High
- **Groups**: no externalizing vs. externalizing