

Alterations in Reward-Related Decision Making in Boys with Recent and Future Depression

Erika E. Forbes, Daniel S. Shaw, and Ronald E. Dahl

Background: Altered reward processing is postulated to be a feature of depression. Reward processing may be valuable to understanding early-onset depressive disorders, which tend to be chronic and recurrent.

Methods: Reward-related decision making was examined within a longitudinal study of 221 11-year-old boys, 25 of whom had a depressive disorder 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 winning, boys with depression failed to distinguish between options involving small or large possible reward. Boys with anxiety or 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 depressive disorders, anxiety disorders, and depressive symptoms 1 year later. Furthermore, reward-related decisions predicted later depressive or anxiety disorders even when adjusting for the continuity of such 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 depression.

Key Words: Depression, decision making, positive affect, reward

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 depressive disorders that occur during childhood and adolescence. Depression with onset during this developmental period is associated with academic and interpersonal impairment (Gied and Pine 2002; Kovacs and Goldston 1991). In addition, children and adolescents with depression often experience severe, recurrent depression later in life (Costello et al 1999; Kovacs et al 1989; Lewinsohn et al 1999; Pine et al 1998). Reduced positive affect is relevant to the course of depression because studies of depressive symptoms early in life 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 (Drevets 2001; Forbes and Dahl 2005). For example, 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 features of depression, 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 behavioral 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 (2003, 2004), the RCD is a game of chance that involves selecting one of two options under varying conditions of reward probability and magnitude. On each trial, participants must choose between 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 of receiving a high- or low-magnitude reward. After making a choice, participants learn whether they won and receive a total score. Because the task 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

From the Departments of Psychiatry (EEF, DSS, RED) and Psychology (DSS), University of Pittsburgh, Pittsburgh, Pennsylvania.

Address reprint requests to Erika E. Forbes, M.S., Ph.D., Western Psychiatric Institute and Clinic E-719, University of Pittsburgh, Department of Psychiatry, 3811 O'Hara St. – Room E-731, Pittsburgh, PA 15213; E-mail: forbes@upmc.edu.

Received April 7, 2005; revised August 11, 2005; revised May 16, 2006; accepted May 23, 2006.

Table 1. Characteristics of the Sample

	Depressive Disorder (<i>n</i> = 25)	No Depressive Disorder (<i>n</i> = 196)
Child Ethnicity		
European American	48.0%	51.5%
African American	48.0%	37.8%
Other	4.0%	10.7%
Family Socioeconomic Status	30.82 (11.81)	31.36 (10.17)
Annual Family Income (\$)	22,024 (7,638.96)	28,326.89 (16,535.64)
Mother Married or Cohabiting	44.0%	52.6%
Symptoms at Age 12		
Depressive	1.61 (1.94)	.89 (1.35)
Anxiety	8.78 (3.89)	9.37 (5.26)
RCD Task Behavior		
Total Earnings	92.48 (20.25)	92.82 (12.89)
Deliberation Time (ms)	1079.69 (202.44)	1102.53 (247.14)

Values are mean (SD), except ethnicity and mother's marital status. Socioeconomic status is reported in units of the Hollingshead Index (Hollingshead 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.

because it involves anticipation of reward and execution of reward-seeking behaviors.

Behavioral evidence indicates that during the RCD task, 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). The RCD has also been 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 (Van Praag et al 1987) and is a pharmacologic target of treatment for depression, these findings are consistent with the hypothesis that depression involves altered reward processing. The RCD has only recently been applied to questions about child psychopathology (Forbes et al, in press), 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 depression vary in reward-related decisions.

In addition to reflecting current depression, alterations in reward processing may play a role in the development and persistence of depressive 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 lower self-reported behavioral activation functioning had a poorer outcome after 8 months than did those with higher functioning (Kasch et al 2002). Consistent with this finding, adults' poor reward responding on a signal detection task predicted anhedonia 1 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 recent depression, as well as depressive disorders and symptoms 1 year later. We hypothesized that boys with depression 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 depression

would choose the option less frequently than would boys without depression. We also hypothesized that this style of decision making would be predictive of higher rates of future depression. Specifically, we expected that low frequency of choosing the risky option under high-probability, high-magnitude reward conditions would be related to greater likelihood of depressive disorders and higher depressive symptoms 1 year later. Finally, although our focus was on depression, we also examined the associations of reward-related decision making with anxiety disorders and externalizing disorders (i.e., attention-deficit/hyperactivity disorder [ADHD], oppositional defiant disorder, and conduct disorder). Because some have proposed that externalizing disorder 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 (PMCP), 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 (representing 74% of 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 (SD = \$7690), with a mean Hollingshead (1975) socioeconomic status of 23.32 (SD = 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 the 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 the Western Psychiatric Institute and Clinic regarding administration of the interview. 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, depression and anxiety diagnoses were determined from the child interview, and externalizing diagnoses were determined from the parent interview, resulting in fewer depression diagnoses at age 12 than at ages 10 or 11. Although we did not have a child interview for externalizing diagnoses at age 12, we also considered youth reports of antisocial activity from the Self-Report of Delinquency questionnaire (Elliott et al 1985) in decisions about diagnoses of conduct disorder.

Participants were considered to have depression if they received a diagnosis of major depressive disorder or dysthymic disorder ($n = 11, 14, \text{ and } 3$ at ages 10, 11, and 12, respectively). They were included in the recent depression group if they received such a diagnosis at age 10 or age 11 ($n = 25$). Participants were considered to have anxiety if they received a diagnosis of any anxiety disorder ($n = 22, 18, \text{ and } 9$ at ages 10, 11, and 12, respectively). They were included in the recent anxiety group if they had such a diagnosis at age 10 or 11 ($n = 38$). Participants were considered to have an externalizing disorder if they received a diagnosis of ADHD, oppositional defiant disorder, or conduct disorder ($n = 45, 58, \text{ and } 38$ at ages 10, 11, and 12, respectively). They were included in the recent externalizing group if they received such a diagnosis at age 10 or 11 ($n = 71$).

At age 12, participants also completed the Children's Depression Inventory (CDI) (Kovacs 1985) and the 10-item form of 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.

Procedure

Study procedures were explained to the participants and their parents, and all parents provided 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 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 option always involved a .50 probability of winning 10 points. The other, risky option, varied in the probability of winning (high or low, defined as .66 or .33) and in the magnitude of points to be won (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 magnitude, low probability/high magnitude, high probability/low magnitude, and high probability/high magnitude. The outcome of each trial involved winning or losing the specified amount of points, but participants could not lose money overall. Participants were told that they would be given \$10 regardless of their performance but that they could win extra money depending on the outcome. 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 recent diagnostic group, a repeated measures analysis of variance (ANOVA) was conducted on choice using the general linear model (GLM) procedure in SPSS 12.0.1 (SPSS Inc. Chicago, IL). Probability and magnitude were within-subjects measures, and recent depression group, recent anxiety group, and recent externalizing group were between-subjects variables. Because we had a hypothesis about the relation of depression to choice during the high-probability, high-magnitude condition, we included a priori contrast tests of group differences in high-probability and high-magnitude conditions within the GLM model. Effect sizes were computed as partial eta squared (η^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 depressive disorders at age 12, binary, hierarchical logistic regression models were conducted with choice on the high-probability, high-magnitude condition as the predictor.

Preliminary Analyses

Preliminary analyses addressed group differences in demographic characteristics, missing trials, deliberation time, and total winnings. ANOVAs indicated that participants with depression did not differ from other participants in family socioeconomic status or income. Chi square analyses indicated that participants with depression 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).

Table 2. Eleven-Year-Old Boys' Frequency of Choosing a Risky Option on a Reward Task as a Function of Reward Probability, Reward Magnitude, and Depressive Disorder at Age 10 or 11

Variable	<i>F</i>	η^2
Probability	111.66 ^b	.34
Magnitude	32.39 ^b	.13
Depression	.00	
Probability × Magnitude	36.65 ^b	.14
Probability × Depression	.22	
Probability × Anxiety	.00	
Probability × Externalizing	.25	
Magnitude × Depression	.04	
Magnitude × Anxiety	.95	
Magnitude × Externalizing	.01	
Probability × Magnitude × Depression	2.96 ^a	.01
Probability × Magnitude × Anxiety	.30	
Probability × Magnitude × Externalizing	.14	

df = 1,219 for all analyses. For significant effects, effect size is reported as η^2 , which represents the proportion of the variance explained. Anxiety and externalizing disorders were included in the model to examine specificity of choices to depressive disorders. Externalizing = ADHD, oppositional defiant disorder, or conduct disorder.

ADHD, attention-deficit/hyperactivity disorder.

^a*p* < .05.

^b*p* < .01.

Results below did not differ when we excluded participants missing >10% of trials. Because ANOVAs indicated that participants with depression, anxiety, or externalizing disorders did not differ in number of missing trials, we included all participants in the analyses.

Boys with depression did not differ from others in mean deliberation time or total points won during the task. In addition, a repeated measures GLM ANOVA with probability and magnitude of reward as within-subjects variables indicated that boys with depression did not differ from other boys in deliberation time for the four trial types.

Results

Age 11 Reward Choice and Recent Depressive Disorder

To test the hypothesis that recent depression is associated with low reward-seeking behavior, a repeated measures ANOVA was conducted (see Table 2 for effects of interest). 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 × depression interaction and a significant probability × magnitude × depression interaction. 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 for low, *M* = 17.48, *SD* = .51 for high; *F*(1,217) = 7.53, *p* < .001], whereas participants with depression did not (*M* = 17.18, *SD* = 1.23 for low, *M* = 15.78, *SD* = 1.22 for high; *F* = 1.95, *p* > .15). Figure 1 depicts the choices of the depression and no-depression groups in the four task conditions. There were no significant main effects or interaction effects involving anxiety or externalizing disorders.

Age 11 Reward Choice and Age 12 Depression

To test the hypothesis that choice on high-probability/high-magnitude trials predicts later depression, analyses were con-

ducted for depressive disorders and depressive symptoms at age 12. Binary, hierarchical logistic regressions indicated that reward choice on the high-probability/high-magnitude trials at age 11 predicted both depressive disorders (*n* = 3) and anxiety disorders (*n* = 9) at age 12 (for depressive disorders, *B* = -.20, *SE* = .09, *R*² = .15, odds ratio [OR] = .82, 95% confidence interval [CI] = .68–.98; for anxiety disorders, *B* = -.16, *SE* = .06, *R*² = .11, OR = .85, 95% CI = .76–.96). Boys with either anxiety disorders or depressive disorders at age 12 were less likely to choose the risky option during this condition at age 11. A similar regression predicting age 12 externalizing diagnosis from high-probability/high-magnitude reward choice at age 11 yielded null findings. In addition, a multivariate ANOVA, conducted to include both depressive and anxiety symptoms, indicated that high-probability/high-magnitude reward choice at age 11 was related to depressive symptoms [*F*(1,164) = 3.40, *p* < .05, η^2 = .02] but not anxiety symptoms (*F* = .17) at age 12.

Because the number of participants with a depressive disorder at age 12 was low, an additional binary, hierarchical logistic regression was computed on the likelihood of having an internalizing disorder—that is, any depressive or anxiety disorder—at age 12. Results indicated that low frequency of choosing the risky option on high-probability/high-magnitude trials at age 11 was associated with increased likelihood of having an internalizing disorder at age 12 (*p* < .005; 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 diagnosis or current externalizing diagnosis (Table 3, Model 2). Internalizing diagnosis at age 10 or 11 was related to internalizing diagnosis 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 diagnosis at age 12 was unrelated to internalizing diagnosis 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).

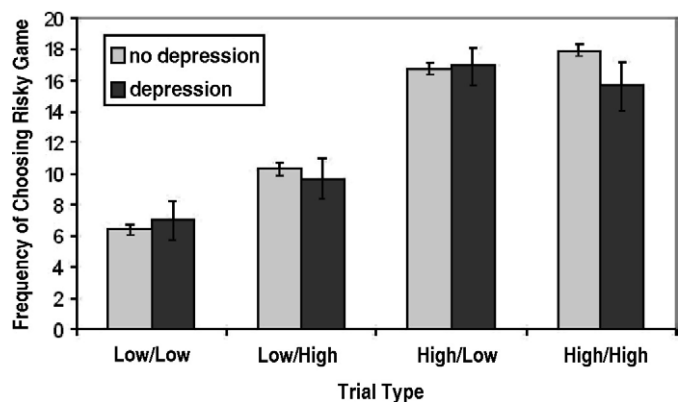


Figure 1. Boys' frequency of choosing the risky option during the reward-contingent decision task (Rogers et al 2003, 2004) at age 11, by trial type. Means are presented for boys with (*n* = 25) or without (*n* = 196) depressive disorders at age 10 or 11. Task conditions: low/low = low probability/low magnitude of reward, low/high = low probability/high magnitude of reward, high/low = high probability/low magnitude of reward, high/high = high probability/high magnitude of reward. Error bars represent 1 standard error of the mean.

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

Predictor	B	ΔR^2 for Step	OR	95% CI
Model 1: Basic Model				
Reward-Related Decision	-.19	.17 ^b	.83 ^b	.74-.93
Model 2: Full Model				
Step 1: Continuity of Internalizing Disorder				
Internalizing Disorder at Age 10 or 11	1.53	.07 ^a	4.64 ^a	1.19-17.99
Step 2: Concurrent Externalizing Disorder				
Internalizing Disorder at Age 10 or 11	1.41	.01	4.11 ^a	1.00-16.82
Externalizing Disorder at Age 12	.52		1.68	.37-7.57
Step 3: Reward-Related Decision				
Internalizing Disorder at Age 10 or 11	1.21	.14 ^b	3.34	.74-15.10
Externalizing Disorder at Age 12	.37		1.45	.28-7.52
Reward-Related Decision	-.18		.83 ^b	.74-.94

Reward-related decision was the frequency of choosing the risky option during the high-probability/high-magnitude reward condition of the reward-contingent decision (RCD) paradigm (Rogers et al 2003, 2004). Internalizing refers to depressive or anxiety disorders; externalizing refers to attention-deficit/hyperactivity disorder, oppositional defiant disorder, or conduct disorder. Results did not change when depressive symptoms at age 12 were included in the model.

OR, odds ratio; CI, confidence interval; RCD, reward-contingent decision.

^a $p < .05$.

^b $p < .005$.

Discussion

In a sample of 11-year-old boys from predominantly low-income families, those with depressive disorders exhibited unusual reward-related choices. Specifically, under conditions of high probability of receiving reward, those who had depression failed to choose high-magnitude reward options more often than low-magnitude reward options. This choice pattern was evident in boys with depressive disorders at age 10 or 11, and it also predicted depressive disorders and depressive symptoms at age 12.

In contrast to findings for boys with depression, boys with anxiety and 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 1 year later. Our null findings for externalizing stand in contrast to findings that reward sensitivity during a signal detection task is enhanced in ADHD (Tripp and Alsop 1999, 2001). Potential reasons for these null findings include the heterogeneous nature of the externalizing group in the current study and the nature of the reward task, which involved decisions rather than correct or incorrect responses. Thus, our findings on altered reward processing, at least in this behavioral context, were specific to nonexternalizing disorders. Given the nature of the paradigm we employed, perhaps reduced motivation to obtain future reward is particularly characteristic of youth with depression.

Interestingly, the reward condition that the group with depression failed to distinguish from a lower magnitude reward condition, that in which reward probability and reward magnitude were both large, is a condition 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 the risky option when probability and magnitude of reward are high. This observed alteration in reward-related choice may reflect reduced reward seeking in boys with depression. 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 reward may more specifically indicate that depression involves poor flexibility in shifting behavior when reward conditions change. In some situations, depression could involve a rigid, generalized strategy for responding to reward, regardless of any changing contingencies. In the RCD task, boys with depression may have consistently decided to choose the fixed option, even though such a strategy would not be optimal under high-probability, high-magnitude conditions. Difficulty in shifting strategies when 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 and without depression won a similar amount of points in the task. This suggests that boys with depression 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 depression group was different from that employed by other participants, 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 depressive 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 depressive disorders in childhood, as well as in adulthood, are associated with decreased reward responding.

Our finding that reward-related choice was related to current depression and future depressive symptoms but not current

anxiety or future anxiety symptoms 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). Although it may seem inconsistent that reward-related choice at age 11 predicted anxiety disorders at age 12, all but one boy with anxiety at age 12 also had a depressive disorder. Thus, in comorbid depression and anxiety, depression-related response to potential reward may guide behavior. Our findings also provide support for behavioral models of depression, 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 depressive symptomatology. This is especially salient for early-onset depressive 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 findings that rodents who have experienced defeat exhibit long-term reductions in reward responsiveness (Von Frijt et al 2000).

The generalizability of our findings is limited by our sample, which included only male, low socioeconomic status participants during a single developmental period. It will be important to consider whether low reward sensitivity is associated with depression in girls, other developmental periods, and other socioeconomic groups. The heightened reward responsiveness present during adolescence (Dahl and Spear 2004; Steinberg 2004) suggests that considering pubertal development may also be fruitful. In addition, the comorbidity of depression with many other disorders suggests that it would be valuable to examine whether depression exerts a similar influence on reward sensitivity in young people who have depression in combination with other psychopathology.

The current study represents a key step toward characterizing reward-related differences in early-onset depression. 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 depression within a developmental, affective neuroscience framework.

This research was supported by National Institute of Mental Health (NIMH) Grants MH50907 and MH01666 (Daniel Shaw, principal investigator [PI]); NIMH Training Grant T32 MH018269 (Paul A. Pilkonis and Marsha D. Marcus, PIs), a Klingenstein Third Generation Foundation Postdoctoral Fellowship (Erika E. Forbes, PI), and NIMH Research Network R24 MH67346 (Ronald E. Dahl, PI).

We are grateful to the staff of the Pittsburgh Mother and Child Project for their years of service and to our study families for making the research possible. We thank Doug Williamson for advice on data analyses and Maribeth Thomas for assistance with the graphical presentation of data.

- American Psychiatric Association (1987): *Diagnostic and Statistical Manual for Mental Disorders (DSM-III-R)*. 3rd Revised ed. Washington, DC: American Psychiatric Association.
- American Psychiatric Association (1994): *Diagnostic and Statistical Manual for Mental Disorders (DSM-IV)*. 4th ed. Washington, DC: American Psychiatric Association.
- Beauchaine T (2001): Vagal tone, development, and Gray's motivational theory: Toward an integrated model of autonomic nervous system functioning in psychopathology. *Dev Psychopathol* 13:183–214.
- Clark LA, Watson D (1991): Tripartite model of anxiety and depression: Psychometric evidence and taxonomic implications. *J Abnorm Psychol* 100:316–336.
- Costello EJ, Angold A, Keeler GP (1999): Adolescent outcomes of childhood disorders: The consequences of severity and impairment. *J Am Acad Child Adolesc Psychiatry* 38:121–128.
- Dahl RE, Spear LP (2004): Adolescent brain development. *Ann N Y Acad Sci* 1021:1–22.
- Depue RA, Iacono WG (1989): Neurobehavioral aspects of affective disorders. *Annu Rev Psychol* 40:457–492.
- Drevets WC (2001): Neuroimaging and neuropathological studies of depression: Implications for the cognitive-emotional features of mood disorders. *Curr Opin Neurobiol* 11:240–249.
- Elliott DS, Huizinga D, Ageton SS (1985): *Explaining Delinquency and Drug Use*. Thousand Oaks, CA: Sage.
- Forbes EE, Dahl RE (2005): Neural systems of positive affect: Relevance to understanding child and adolescent depression? *Dev Psychopathol* 17: 827–850.
- Forbes EE, May JC, Siegle GJ, Ladouceur CD, Ryan ND, Carter CS, Dahl RE (in press): Reward-related decision-making in pediatric major depressive disorder: An fMRI study. *J Child Psychol Psychiatry*.
- Fowles DC (1988): Psychophysiology and psychopathology: A motivational approach. *Psychophysiology* 25:373–391.
- Glied S, Pine DS (2002): Consequences and correlates of adolescent depression. *Arch Pediatr Adolesc Med* 156:1009–1014.
- Gray J (1990): Brain systems that mediate both emotion and cognition. *Cognition and Emotion* 4:269–288.
- Henriques JB, Davidson RJ (2000): Decreased responsiveness to reward in depression. *Cognition and Emotion* 14:711–724.
- Henriques JB, Glowacki JM, Davidson RJ (1994): Reward fails to alter response bias in depression. *J Abnorm Psychol* 103:460–466.
- Hollingshead AB (1975): *Four Factor Index of Social Status*. New Haven, CT: Yale University Sociology Department.
- Joiner TE Jr, Catanzaro SJ, Laurent J (1996): Tripartite structure of positive and negative affect, depression, and anxiety in child and adolescent psychiatric inpatients. *J Abnorm Psychol* 105:401–409.
- Kasch KL, Rottenberg J, Arnow BA, Gotlib IH (2002): Behavioral activation and inhibition systems and the severity and course of depression. *J Abnorm Psychol* 111:589–597.
- Kaufman J, Birmaher B, Brent D, Rao U, Flynn C, Moreci P, et al (1997): Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL): Initial reliability and validity data. *J Am Acad Child Adolesc Psychiatry* 36:980–988.
- Kovacs M (1985): The children's depression inventory. *Psychopharmacol Bull* 21:995–998.
- Kovacs M, Gatsonis C, Paulauskas SL, Richards C (1989): Depressive disorders in childhood. IV. A longitudinal study of comorbidity with and risk for anxiety disorders. *Arch Gen Psychiatry* 46:776–782.
- Kovacs M, Goldston D (1991): Cognitive and social cognitive development of depressed children and adolescents. *J Am Acad Child Adolesc Psychiatry* 30:388–392.
- Lewinsohn PM, Graf M (1973): Pleasant activities and depression. *J Consult Clin Psychol* 41:261–268.
- Lewinsohn PM, Hoberman HM, Teri L, Hautzinger M (1985): An integrative theory of unipolar depression. In: Reiss S, Bootzin RR, editors. *Theoretical Issues in Behavioral Therapy*. New York: Academic Press, 313–359.
- Lewinsohn PM, Rohde P, Klein DN, Seeley JR (1999): Natural course of adolescent major depressive disorder: I. Continuity into young adulthood. *J Am Acad Child Adolesc Psychiatry* 38:56–63.
- Lewinsohn PM, Rohde P, Seeley JR, Klein DN, Gotlib IH (2003): Psychosocial functioning of young adults who have experienced and recovered from major depressive disorder during adolescence. *J Abnorm Psychol* 112: 353–363.

- Lonigan CJ, Phillips BM, Hooe ES (2003): Relations of positive and negative affectivity to anxiety and depression in children: Evidence from a latent variable longitudinal study. *J Consult Clin Psychol* 71:465–481.
- March JS, Parker JD, Sullivan K, Stallings P, Conners CK (1997): The Multidimensional Anxiety Scale for Children (MASC): Factor structure, reliability, and validity. *J Am Acad Child Adolesc Psychiatry* 36:1645–1646.
- Pine DS, Cohen E, Cohen P, Brook J (1999): Adolescent depressive symptoms as predictors of adult depression: Moodiness or mood disorder? *Am J Psychiatry* 156:133–135.
- Pine DS, Cohen P, Gurley D, Brook J, Ma Y (1998): The risk for early-adulthood anxiety and depressive disorders in adolescents with anxiety and depressive disorders. *Arch Gen Psychiatry* 55:56–64.
- Pizzagalli DA, Jahn AL, O'Shea JP (2005): Toward an objective characterization of an anhedonic phenotype: A signal-detection approach. *Biol Psychiatry* 57:319–327.
- Rogers RD, Ramnani N, Mackay C, Wilson JL, Jezzard P, Carter CS, et al (2004): Distinct portions of anterior cingulate cortex and medial prefrontal cortex are activated by reward processing in separable phases of decision-making cognition. *Biol Psychiatry* 55:594–602.
- Rogers RD, Tunbridge EM, Bhagwagar Z, Drevets WC, Sahakian BJ, Carter CS (2003): Tryptophan depletion alters the decision-making of healthy volunteers through altered processing of reward cues. *Neuropsychopharmacology* 28:153–162.
- Rolls ET (1999): *The Brain and Emotion*. New York: Oxford.
- Shaw DS, Gilliom M, Ingoldsby EM, Nagin D (2003): Trajectories leading to school-age conduct problems. *Dev Psychol* 39:189–200.
- Steinberg L (2004): Risk-taking in adolescence: What changes, and why? *Ann NY Acad Sci* 1021:51–58.
- Tripp G, Alsop B (1999): Sensitivity to reward frequency in boys with attention deficit hyperactivity disorder. *J Clin Child Psychol* 28:366–375.
- Tripp G, Alsop B (2001): Sensitivity to reward delay in children with attention deficit hyperactivity disorder (ADHD). *J Child Psychol Psychiatry* 42:691–698.
- Van Praag HM, Kahn RS, Asnis GM, Wetzler S, Brown SL, Bleich A, et al (1987): Denosologization of biological psychiatry or the specificity of 5-HT disturbances in psychiatric disorders. *J Affect Disord* 13:1–8.
- Von Frijtag JC, Reijmers LG, Van der Harst JE, Leus IE, Van den Bos R, Spruijt BM (2000): Defeat followed by individual housing results in long-term impaired reward- and cognition-related behaviours in rats. *Behav Brain Res* 117:137–146.
- Weissman MM, Wolk S, Wickramaratne P, Goldstein RB, Adams P, Greenwald S, et al (1999): Children with prepubertal-onset major depressive disorder and anxiety grown up. *Arch Gen Psychiatry* 56:794–801.