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Reward Seeking and Cognitive Control: Using the Dual Systems Model to Predict Adolescent Sexual Behavior

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Research has provided support for the dual systems model of adolescent risk taking, but the model has rarely been applied to sexual behavior. Using data from the NICHD SECCYD (N = 958; Mage = 15.07, SD = 0.18), this study examined the effects of cognitive control, reward seeking, and their interaction on sexual behavior. Results of structural equation models revealed that performance on behavioral tasks assessing reward seeking and cognitive control uniquely predicted sexual intercourse, but the interaction between them was not significant. For oral sex, only cognitive control was a significant predictor. The findings provide additional support for the dual systems model, and suggest that reward seeking and cognitive control make unique contributions to adolescent sexual behavior.

Adolescence is a time of increased participation in risky behaviors (Blum & Nelson-Mmari, 2004) including sexual risk taking. Recent estimates have shown that 41.2% of high school students have had sexual intercourse (CDC, 2016). Although sexual behavior is not always considered risky, early initiation of sexual intercourse (defined as having sexual intercourse before age 15) has been found to predict a decreased likelihood of obtaining postsecondary education (Spriggs & Halpern, 2008), greater levels of externalizing behavior and substance use (Kastbom, Sydsjö, Bladh, Priebe, & Svedin, 2014), and increased rates of other risky sexual behaviors (e.g., having multiple partners) in adulthood (Sandfort, Orr, Hirsch, & Santelli, 2008). To reduce such negative consequences, it is important to understand developmentally relevant factors that explain early onset of sexual intercourse in adolescence.

Recent efforts to explain increased risk taking during adolescence have focused on possible neurobiological models—particularly the dual systems model, which highlights the causal role of asynchronies in the maturation of brain systems underlying reward seeking and cognitive control (Casey, Getz, & Galvan, 2008). Specifically, the earlier maturation of reward-sensitive brain regions compared to cognitive control regions is believed to create an imbalance conducive to increased risk behavior. While empirical studies have provided robust support for the dual systems model of adolescent risk taking (Steinberg et al., 2008), its application has been limited. Most studies have defined risky behavior using laboratory tasks, and few have used the model to predict real-world risk behavior. Furthermore, studies that have examined real-world risky behavior have focused on substance use (Kim-Spoon et al., 2015; Quinn & Harden, 2013) and only one study to our knowledge has focused on adolescent sexual behavior (Donohew et al., 2000).

Additionally, little is known about the unique contributions of cognitive control and reward seeking to risk behavior. The notion of a developmental mismatch suggests that it is the combination of high reward seeking coupled with relatively low cognitive control that is central to the surge in adolescent risk taking, but typically the effects of reward seeking and cognitive control are examined separately rather than simultaneously (Romer et al., 2009; Stanford & Greve, 1996; Zuckerman, 2007). Thus, it remains unclear whether it is the sudden, relatively early increase in reward seeking, the delayed maturation of cognitive control, or both that are responsible for increased adolescent risk behavior. It is also plausible that cognitive con-

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trol and reward seeking act synergistically, such that a combination of poor cognitive control and high reward seeking is particularly conducive to risk taking. The current study addresses this possibility by examining the interactive effects of reward seeking and cognitive control.

The increase in reward seeking that takes place during adolescence is thought to be partly under the control of pubertal hormones, whereas the maturation of cognitive control is thought to be independent of puberty (Dahl, 2004). Additionally, a robust finding in the literature is that adolescents who go through puberty earlier than their peers are likely to have earlier sexual initiation (Mendle & Ferrero, 2012; Mendle, Turkheimer, & Emery, 2007). Because puberty is related to both reward seeking and sexual initiation, it is possible that any relationship between the two variables is spurious in nature and due to earlier pubertal timing.

To summarize, the present study examined the joint effects of reward seeking and cognitive control on adolescent sexual behavior. Because both cognitive control and reward seeking have been found to predict risk behavior, our first hypothesis was that each would uniquely predict the likelihood of having sexual intercourse and oral sex (lifetime). Furthermore, because the dual systems model implies that cognitive control moderates the effect of reward seeking on risk behavior, our second hypothesis was that the combination of poor cognitive control and high reward seeking would be associated with especially high risk taking, as reflected in a significant interaction. Finally, pubertal timing and gender were included as control variables.

METHOD

Participants

The sample came from the National Institute of Child Health and Human Development (NICHD) Study of Early Child Care and Youth Development (SECCYD), a longitudinal study that followed children from birth until age 15 (NICH Early Child Care Research Network, 2001). In 1991, new mothers were recruited from hospitals at 10 sites in the United States; those who were 18 years or older, had a single birth, and reported no substance abuse were included. The initial sample included 1,364 children, 958 of whom participated at age 15 (50.2% were male; 81.5% were White; *M* age = 15.07 years, *SD* = 0.18). Attrition analyses revealed that compared to the original sample of 1,364 children, the analytic sample was more likely to be White, have higher household income, and have more educated mothers.

Measures

Pubertal timing. A nurse rated pubertal status based on a physical exam. For girls, breast development was rated using the American Academy of Pediatrics manual (Herman-Giddens & Bourdony, 1995). For boys, genital development was rated using Tanner staging (Tanner, 1962). Pubertal status could range from 1 to 5, in which 1 = *prepubertal status* and 5 = *full pubertal maturation*. Because girls typically start puberty earlier than boys (Gasser, Molinari, & Largo, 2013), we used pubertal status at age 13 for girls and age 14 for boys to capture the greatest variability in scores. To measure pubertal timing, we standardized pubertal status scores within race (White vs. non-White) and gender, such that higher scores reflected more advanced maturation relative to same-sex, same-race peers (Crockett, Carlo, Wolff, & Hope, 2013; Ge, Conger, & Elder, 2001). Among girls, 2.18% were classified as Tanner stage 1, 14.17% stage 2, 38.15% stage 3, 30.79% stage 4, 1.91% stage 4.5, and 12.81% stage 5. Among boys, 1.13% were classified as Tanner stage 1, 11.55% were stage 2, 29.30% were stage 3, 37.75% were stage 4, and 20.28% were stage 5.

Sexual behavior. At age 15, adolescents completed two items from the Risky Behavior Questionnaire (Conger & Elder, 1994; Halpern-Felsher, Biehl, Kropp, & Rubinstein, 2004) asking if they had sexual intercourse (going all the way) and had oral sex in their lifetime (Halpern-Felsher, Cornell, Kropp, & Tschann, 2005). Response options were 0 = *never*, 1 = *once or twice*, and 2 = *more than twice*. Because many adolescents reported *never* for both items, a dichotomous variable was created for each outcome: for sexual intercourse 0 = *never had sexual intercourse in their lifetime*, and 1 = *had sexual intercourse in their lifetime;* and for oral sex 0 = *never had oral in their lifetime*, and 1 = *oral in their lifetime*. Overall, 13.70% and 15.19% of the sample reported having had sexual intercourse (lifetime) or oral sex (lifetime) respectively. The tetrachoric correlation between the binary outcomes was r = .89.

Reward seeking. The Stoplight task is meant to be an ecologically valid measure of reward seeking

(Gardner & Steinberg, 2005). At age 15, participants completed this simulated driving task on a computer during a lab visit. Participants were told they would be driving a car to a party and must get there before time runs out, but could not control the speed of the car. Each trial included several traffic intersections and one yellow light where the participant had to decide whether to brake or continue driving. Participants who decided to brake would experience a short delay getting to the party. Participants who did not brake would either cross the intersection safely (with no delay) or experience a crash resulting in a longer delay. Importantly, participants did not know the likelihood of a crash. Two outcomes were analyzed: whether the participant drove through the yellow light (0 = *no*, 1 = *yes*), and, if the participant chose to stop instead, the log-transformed latency to brake. For both outcomes, higher values indicated greater reward seeking. Although there were eight possible trials (0–7), the fourth trial was excluded because the light was programmed not to turn yellow. Furthermore, the first trial was dropped because scores on this trial did not correlate with scores on the other trials, indicating that the first trial was not a good measure. The average number of "go" decisions across rounds ranged from 0.10 to 0.87 (overall $M = 0.29$, $SD = 0.20$). The average latency to brake across rounds ranged from 0.58 to 1.17 s (overall $M = 0.91$, $SD = 0.35$). Boys ($M = 0.98$) waited significantly longer to brake than girls ($M = 0.84$), $F(1, 921) = 34.00$, $p < .001$, $\eta^2 = .04$, but there was no gender difference in the average number of "go" decisions.

Cognitive control. Cognitive control was assessed at age 15 with the Tower of London task (Asato, Sweeney, & Luna, 2006; Berg & Byrd, 2002). Participants completed this task on a computer, which displayed a puzzle with three balls in (1) a starting position and (2) a goal position. Three pegs were displayed: the tallest peg held up to three balls, the middle peg held up to two balls, and the shortest peg held one ball. Participants were instructed to move the three balls from their initial position to match the ending position in as few moves and using as little time as possible. After three practice trials, there were 20 test trials in which task difficulty increased every four trials. We analyzed log-transformed latency to the first move for the 20 test trials; longer latencies indicated better cognitive control. The average latency to first move ranged from 4.11 to 10.65 s across trials (overall $M = 7.00$, $SD = 3.81$). Boys ($M = 7.64$) waited significantly longer to make the first move than girls ($M = 6.44$), $F(1, 930) = 20.52$, $p < .001$, $\eta^2 = .02$.

RESULTS

Measurement Models

Mplus 7.4 (Muthén & Muthén, 1998–2015) was used to conduct all latent variable analyses, which began with separate measurement models for reward seeking and cognitive control and continued with simultaneous structural equation models to test our hypotheses.

Reward seeking—as measured by the six stoplight task trials—was captured by a two-part measurement model (see Olsen & Schafer, 2001). One latent factor ($M = 0$, $SD = 1$) included as indicators the stop or go binary response per trial using a probit link; a second latent factor ($M = 0$, $SD = 1$) included as indicators log-transformed latency to brake per trial using a normal residual distribution (i.e., log-normal residuals), in which latency was missing for go trials. To assess absolute fit, the two-part measurement model was estimated using robust diagonally weighted least squares. Fit measures included the comparative fit index (CFI) and root mean square error of approximation (RMSEA), in which values >.90 and <.08 indicate adequate model fit, and values >.95 and <.05 indicate good model fit respectively.

The initial two-part measurement model did not achieve adequate CFI fit, $\chi^2(51) = 255$, CFI = .88, RMSEA = .06. Inspection of local misfit suggested additional lagged relationships for the first two trials, such that a higher probability of going through the yellow light was related to reduced latency to brake on the next trial. After adding these two residual covariances, the two-part measurement model fit adequately, $\chi^2(51) = 155$, CFI = .93, RMSEA = .05. Standardized factor loadings ranged from .40 to .73 for the binary stop or go indicators and from .20 to .71 for the latency to brake indicators. The latent factors were positively correlated, $r = .16$, such that a greater tendency to go through the yellow lights was related to a greater latency to brake.

Measurement models were then estimated for cognitive control, as measured by log-transformed latency to first move in the 20 Tower of London test trials. Robust maximum likelihood was used to estimate an initial confirmatory factor model in which all 20 latencies were predicted by a single factor ($M = 0$, $SD = 1$) and residual covariances were estimated between adjacent trials. This single-factor model did not have adequate fit, $\chi^2(151) = 1{,}336$, CFI = .83, RMSEA = .09. Upon examining individual trajectories of latency across trials, it was evident that there was markedly less between-person variability from trials 1 to 8 than from trials 9 to 20 (later trials were more difficult). Accordingly, two cognitive control factors were created: one for the easier trials 1–8, and a second for the harder trials 9–20. The two-factor model achieved good fit, $\chi^2(150) = 396$, CFI = .96, RMSEA = .04, with a factor correlation of $r = .77$. Standardized loadings ranged from .36 to .64 for the easier trials factor, and from .55 to .77 for the harder trials factor.

Structural Equation Models Predicting Adolescent Sexual Behavior

Structural equation models (see Figures 1 and 2) were then estimated using robust maximum likelihood, in which ever had sexual intercourse (0 = *no*, 1 = *yes*) and ever had oral sex (0 = *no*, 1 = *yes*) were estimated in separate models and predicted through a probit link by observed pubertal timing and latent factors of reward seeking and cognitive control. Given their strong positive correlation ($r = .77$), a higher-order factor ($M = 0$, $SD = 1$) was estimated for the two cognitive control factors (which were identified by fixing a trial loading to 1 and estimating their factor disturbances instead). Results are shown in Table 1 for both outcomes. A total of 15.2% and 12.8% of the outcome variance was explained by the model for sexual intercourse and oral sex respectively. Results indicated that earlier pubertal timing was uniquely related to a greater probability of having sexual intercourse and oral sex. As hypothesized, greater cognitive control was uniquely associated with a lower probability of having sexual intercourse and oral sex. With respect to reward seeking, findings were mixed—although a greater tendency to go through the yellow lights uniquely predicted a greater probability of having sexual intercourse, the tendency to take longer to brake (if braking) was not a significant predictor. Neither measure of reward seeking predicted the likelihood of having oral sex.

The extent to which cognitive control and reward seeking interacted to predict having sexual intercourse or oral sex was then examined by specifying latent variable interactions between the

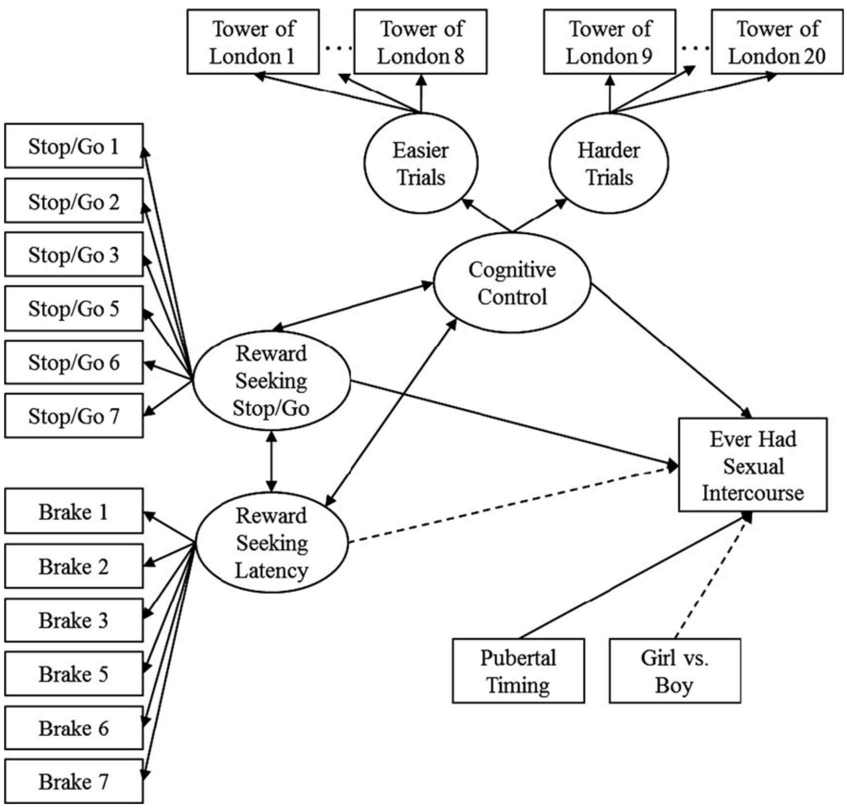

FIGURE 1 Structural equation model predicting ever having sexual intercourse (lifetime). Solid lines indicate paths significant at $p < .05$; dashed lines indicate nonsignificant paths. Double-headed arrows indicate covariances whereas single-headed arrows indicate directed paths.

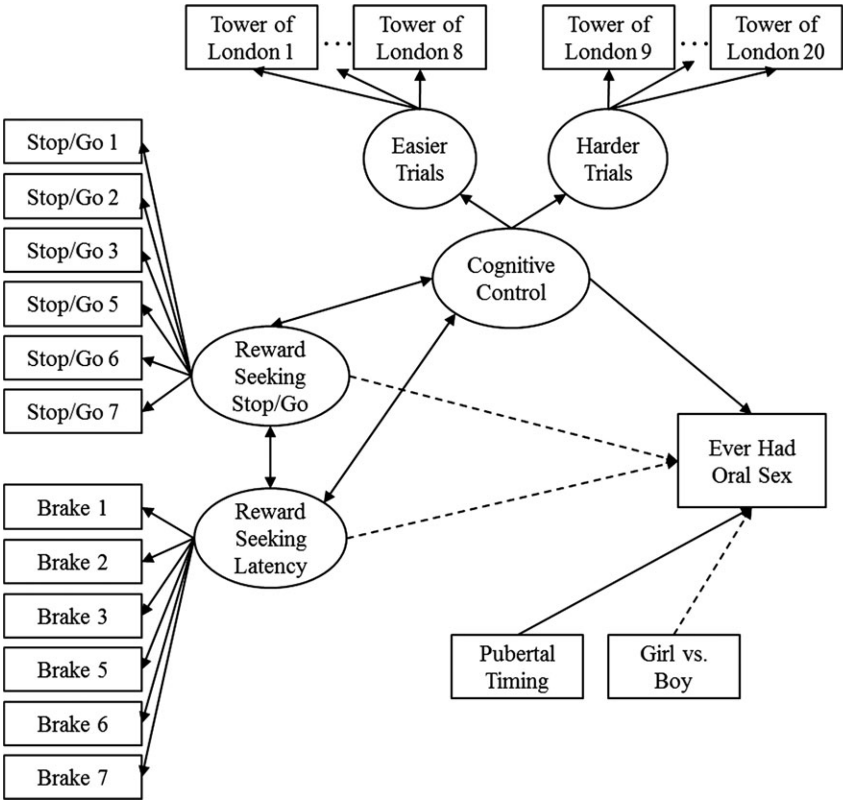

FIGURE 2 Structural equation model predicting ever having oral sex (lifetime). Solid lines indicate paths significant at $p < .05$; dashed lines indicate nonsignificant paths. Double-headed arrows indicate covariances whereas single-headed arrows indicate directed paths.

TABLE 1
Structural Model Parameters

	Ever Had Sexual Intercourse (Lifetime)				*Ever Had Oral Sex (Lifetime)*			
	EST	*SE*	*STD*	*p<*	*EST*	*SE*	*STD*	*p<*
Predictor:								
Intercept	−2.06	0.19			−2.05	0.18		
Pubertal timing	0.33	0.12	0.16	.01	0.36	0.11	0.18	.01
Girl versus boy	0.06	0.25	0.01	.83	0.37	0.24	0.10	.11
Cognitive control	−0.49	0.15	−0.25	.01	−0.42	0.14	−0.22	.01
Reward seeking go	0.39	0.16	0.20	.01	0.28	0.15	0.14	.06
Reward seeking latency	0.22	0.16	0.11	.18	0.20	0.14	0.10	.15
Factor covariances:								
Cognitive control with reward seeking stop/go	−0.14	0.06	−0.14	.02	−0.14	0.06	−0.14	.02
Cognitive control with reward seeking latency to brake	0.14	0.05	0.14	.01	0.14	0.05	0.14	.01
Reward seeking stop/go with latency to brake	0.14	0.07	0.14	.04	0.14	0.07	0.14	.05

Note. EST = unstandardized estimate; SE = standard error; STD = standardized estimate.

higher-order factor of cognitive control and each of the reward seeking factors. The interaction model was estimated using robust maximum likelihood with numeric integration for the latent variable interactions. Neither of the interactions was significant, indicating that the effects of cognitive control and reward seeking were additive; thus those results are not shown.

DISCUSSION

The present study extends the literature on the dual systems model of adolescent risk taking by examining the relationships of cognitive control and reward seeking to adolescent sexual behavior, a common real-world risk behavior, and by considering the unique effects of cognitive control and reward seeking as well as their interaction. Although previous research has established that cognitive control (Romer et al., 2009; Stanford & Greve, 1996) and reward seeking (Zuckerman, 2007) each predict risk behavior when examined separately, to our knowledge no study has examined the simultaneous or interactive effects of cognitive control and reward seeking on risk behavior in a normal, community population. As hypothesized, low cognitive control and high reward seeking both predicted a higher probability of ever having sexual intercourse (lifetime). Conversely, only cognitive control uniquely predicted a higher probability of ever having oral sex (lifetime). None of the interactions was significant for either outcome.

Interestingly, reward seeking predicted sexual intercourse but not oral sex. A possible reason for this finding is that adolescents perceive the behaviors differently. Previous work has shown that adolescents —particularly young adolescents—do not define oral sex as "sex" (Remez, 2000) as they would penile-vaginal intercourse, and adolescents tend to perceive oral sex as less risky (e.g., less likely to result in sexually transmitted infections) than penile-vaginal intercourse; Halpern-Felsher et al., 2005). Thus, adolescents tend to assume sexual intercourse is more risky than oral sex and only those high reward–seeking adolescents may be inclined to take that extra risk and engage in penile-vaginal intercourse.

It is noteworthy that the tendency to go through yellow lights predicted having sexual intercourse but latency to brake did not. This finding raises the possibility that there are distinct aspects of reward seeking, at least as measured by the Stoplight task. Perhaps choosing to go (vs. stop) depends mainly on reward seeking whereas latency to brake engages other processes such as attention or reaction time.

The available sample over-represented White families, families with higher incomes, and more educated parents, and replication with more diverse samples is needed. Moreover, the prevalence of having sex was low (18.55%), possibly because the adolescents were only age 15. Finally, the primary study variables were measured at the same occasion (age 15), so temporal order among them could not be established. In future longitudinal studies, it would be beneficial to assess reward seeking and cognitive control earlier in adolescence, prior to sexual initiation, or to assess all three variables at multiple occasions.

Implications

Despite these limitations, the findings suggest that cognitive control and reward seeking have independent, additive effects on adolescent sexual behavior. This suggests that interventions that focus solely on either reward seeking or cognitive control may not be sufficient to reduce adolescent sexual risk taking; instead, targeting both of these processes may be necessary, and distinct aspects of reward seeking may need to be considered. Regarding methodological implications, studies using the Tower of London or Stoplight task often aggregate the scores from multiple trials (e.g., Kim-Spoon et al., 2015; Steinberg et al., 2008), perhaps without determining whether the scores from different trials hold together well enough to adequately measure the intended construct. In this study, a single-factor model for the Tower of London task did not fit well. Instead, the covariance among the trials was better described by a two-factor model that took task difficulty into consideration. In future studies, it would be beneficial to test routinely for unidimensionality of laboratory tasks prior to aggregating responses across trials and to adjust the analytic strategy accordingly.

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