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Early Adolescent Sexual Debut: The Mediating Role of Working Memory Ability, Sensation Seeking, and Impulsivity

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Abstract

Although deficits in working memory ability have been implicated in suboptimal decision making and risk taking among adolescents, its influence on early sexual initiation has so far not been examined. Analyzing 2 waves of panel data from a community sample of adolescents ($N = 347$; Mean age_[baseline] = 13.4 years), assessed 1 year apart, the present study tested the hypothesis that weak working memory ability predicts early sexual initiation and explored whether this relationship is mediated by sensation seeking and 2 forms of impulsivity, namely acting-without-thinking and temporal discounting. The 2 forms of impulsivity were expected to be positively associated with early sexual initiation, whereas sensation seeking was hypothesized to be unrelated or to have a protective influence, due to its positive association with working memory. Results obtained from structural equation modeling procedures supported these predictions and in addition showed that the effects of 3 prominent risk factors (Black racial identity, low socioeconomic background, and early pubertal maturation) on early sexual initiation were entirely mediated by working memory and impulsivity. The findings are discussed in regard to their implications for preventing early sexual onset among adolescents.

Keywords

early sexual debut; working memory; impulsivity; sensation seeking; delay discounting

Adolescence has long been recognized as a period of heightened vulnerability to adverse health outcomes. Relative to both children and adults, adolescent rates of morbidity and mortality are disturbingly high and are linked to suboptimal decisions to engage in health-compromising behaviors (Arnett, 1992; Dahl, 2004). Contrary to the popular notion that teenagers make light of the risks associated with their behaviors, research finds that adolescents are not only sensitive to the risks but also tend to overestimate them (Reyna & Farley, 2006). Nevertheless, whether all adolescents use these risk appraisals in an adaptive manner when making decisions regarding health-compromising behaviors, such as early sexual initiation, remains open to question.

Adolescence is the developmental period when romantic and sexual exploration begins (Craver, Joyner, & Udry, 2003; B. C. Miller & Benson, 1999), with the initiation of vaginal intercourse becoming common during mid- to late adolescence (ages 16–19) in the United States (Chandra, Martinez, Abma, & Jones, 2005; Martinez, Chandra, Abma, Jones, &

Mosher, 2006). Although sexual activity among adolescents is often unprotected, sexual initiation at younger ages is found to be associated with greater involvement in risky sexual behaviors, including inconsistent condom use (Manlove, Ryan, & Franzetta, 2007; Manning, Longmore, & Giordano, 2000) and involvement with multiple sexual partners (O'Donnell, O'Donnell, & Stueve, 2001) that can increase the risk of unintended pregnancies and sexually transmitted infections (Cates, Herndon, Schulz, & Darroch, 2004; Coker et al., 1994; Greenberg, Magder, & Aral, 1992). The high individual and social costs associated with early sexual initiation are nevertheless largely preventable. Developing a better understanding of the pathways that can lead to early sexual initiation is therefore critical from a prevention standpoint.

Role of Sensation Seeking and Impulsivity in Adolescent Risk Taking

In past efforts to understand the role of individual differences in adolescent risk-taking behaviors, two explanatory pathways involving personality characteristics have garnered much research attention. The first attributes adolescent risk taking to a rise in *sensation seeking*—a personality trait characterized by “the need for varied, novel and complex sensations and experiences, and the willingness to take physical and social risks for the sake of such experiences” (Zuckerman, 1971, 1979, p. 10). Empirical evidence supports this claim by documenting a consistent link between sensation seeking and various types of adolescent risk behaviors (Hoyle, Fejfar, & Miller, 2000; Zuckerman, 2007), including early sexual onset (Farley, 1991). Developmental studies have further delineated an inverted U-shaped trajectory of sensation-seeking tendencies over the course of adolescence, which parallels the increase in risk-taking behaviors observed during this life stage (Romer & Hennessy, 2007; Steinberg et al., 2008).

The second explanation for adolescent risk taking stems from research on the multidimensional construct of *impulsivity* (Donohew et al., 2000; Stanford et al., 1996), which also shares certain characteristics with sensation seeking (Reynolds et al., 2007; Whiteside & Lynam, 2001). This construct has been studied under various labels, such as lack of premeditation or urgency (Whiteside & Lynam, 2001), lack of self-control (Rachlin, 2004), acting-without-thinking (Romer, 2010), lack of cognitive control (Bunge & Crone, 2009; Luna, 2009), and inability to delay gratification (Madden & Bickel, 2010). However, recently there has been greater attention devoted to differentiating these concepts (e.g., Reynolds et al., 2007; Whiteside & Lynam, 2001).

Sensation Seeking, Impulsivity, and Working Memory: Associations and Dissociations

The perhaps most stereotypical form of impulsivity is characterized by a tendency to make quick decisions without devoting much thought to the associated consequences. This tendency can be labeled as *acting-without-thinking*. The measures commonly used to assess this tendency, including the Eysenck (Eysenck, Easting, & Pearson, 1984; Eysenck & Eysenck, 1980) and the Barratt (Patton, Stanford, & Barratt, 1995) Impulsivity Scales, are found to be associated with adolescent risk-taking propensities (Reynolds et al., 2007; Stanford et al., 1996) as well as early sexual onset (Donohew et al., 2000).

During adolescence, acting-without-thinking tends to be moderately correlated with sensation seeking (Romer et al., 2011). This overlap may be due to the same underlying mesolimbic dopaminergic activity (Buckholtz et al., 2010; Pattij & Vanderschuren, 2008; Zald et al., 2008) that may not only elevate the appetite for novel and thrilling behaviors but also aggravate impulsive tendencies. At the same time, however, the two tendencies diverge in regard to their relation with executive cognitive functions (ECFs), especially working

memory ability. Whereas acting-without-thinking tends to be inversely related to working memory ability, sensation seeking shows a positive association, with high sensation seekers displaying better performance on working memory tasks as compared with low sensation seekers (Romer et al., 2011). This is consistent with other research in which sensation seeking has been found to be somewhat positively related to intelligence (IQ; Raine, Reynolds, Venables, & Mednick, 2002), but acting-without-thinking has been found to be negatively associated with IQ (Lynam, Moffitt, & Stouthamer-Loeber, 1993).

The positive association between sensation seeking and executive cognitive abilities suggests that sensation seekers may be better able to exert control over the impulsive drives that rise during adolescence, as compared with youth high in acting-without-thinking. Indeed, research on drug use and other addictive behaviors finds that although sensation seekers may engage in high levels of these activities, it is the youth high in acting-without-thinking who are more prone to the ill-effects of these behaviors, such as substance dependence (Magid, MacLean, & Colder, 2007; Smith et al., 2007).

A second form of impulsivity, reflective of a tendency toward discounting temporally distal outcomes, can also be distinguished from sensation seeking (Wilson & Daly, 2006) and acting-without-thinking (Reynolds, Penfold, & Patak, 2008). This form of impulsivity is typically assessed using a temporal discounting paradigm in which respondents are asked to choose between an immediate smaller reward and a larger but delayed reward (Madden & Bickel, 2010). Individuals who tend to prefer immediate smaller rewards more than average are more likely to seek immediate gratification, resulting in greater likelihood of involvement in risky activities such as drug use (Yi, Mitchell, & Bickel, 2010). Early markers of this tendency assessed among preschoolers are found to successfully predict academic and social competence during the adolescent years (Mischel, Shoda, & Peake, 1988).

The two impulsivity dimensions, namely acting-without-thinking and temporal discounting, are found to be moderately correlated (Hinson, Jameson, & Whitney, 2003). This may be in part due to their underlying associations with weak working memory (Romer et al., 2009; Shamosh et al., 2008), which can limit the ability to consider long-term consequences of behaviors (Bechara & Martin, 2004; Romer et al., 2011; Whitney, Jameson, & Hinson, 2004). In contrast to acting-without-thinking, which covaries with sensation seeking, temporal discounting is not correlated to any degree with sensation seeking (Romer, Duckworth, Szatman, & Park, 2010; Wilson & Daly, 2006), suggesting that the tendency to discount delayed rewards may not be as strongly dependent on mesolimbic dopaminergic activation as sensation seeking and acting-without-thinking.

Research on another construct closely related to the inverse of impulsivity, namely self-control, has underscored the significance of impulsivity in predicting a myriad of unhealthy outcomes during adolescence and adulthood, including unplanned pregnancy and sexually transmitted infections (Moffitt et al., 2011). Self-control is also featured as a critical mediating factor in theories of adolescent delinquency (Gottfredson & Hirschi, 1990). Although assessments of self-control overlap with measures of sensation seeking and impulsivity, little is known about how these different dimensions uniquely influence adolescent involvement in risk behaviors. Understanding the distinction between these modestly interrelated constructs and their unique pathways of influence on adolescent risk taking is important not only for theoretical reasons but also for designing appropriate interventions. For instance, if the forms of impulsivity associated with weakness in working memory are more likely to lead to early involvement in risky behaviors than sensation seeking, then it may be possible to ameliorate these effects by providing early training in working memory ability (Klingberg, 2010; Morrison & Chein, 2011). It is for this important

reason that we focus on working memory ability as a predictor of early sexual initiation in the present study.

Working Memory and Early Sexual Initiation

Previous research has found early sexual debut and IQ to be negatively related (Halpern, Joyner, Udry, & Suchindran, 2000; Shearer et al., 2002), but its association with working memory has not been explored. Although IQ and working memory are highly related (Ackerman, Beier, & Boyle, 2005; Colom, Abad, Quiroga, Shih, & Flores-Mendoza, 2008), they are nonetheless recognized to be separate constructs (Conway, Kane, & Engle, 2003). Performance on working memory tasks usually requires not just the ability to maintain and manipulate cognitive representations of relevant information, but also the ability to ignore distraction from interfering stimuli (Kane, Conway, Hanbrick, & Engle, 2007). The importance of working memory in predicting impulsive behaviors (Bechara & Martin, 2004; Hinson et al., 2003) is therefore not surprising given its central role in planning and exercise of cognitive control (Fuster, 2008). In fact, in one study of preadolescents, working memory was found to be the strongest correlate of impulsivity and early risk taking, than any of the other ECFs assessed (Romer et al., 2009).

The primary goal of the present study was to evaluate the role of working memory ability as a predictor of early adolescent sexual initiation. Because the effects of working memory on adolescent risk taking tend to depend on their relationships with different forms of impulsivity, the unique role of (a) sensation seeking, (b) acting-without-thinking, and (c) temporal discounting as potential mediators of the influence of working memory on early sexual debut are also explored.

Effects of Demographic and Developmental Influences

Our second goal was to evaluate the extent to which working memory and its associated links with impulsivity and sensation seeking can serve as pathways for the influence of more distal and relatively unalterable risk factors. In particular, we examine the influence of three such factors, *racial identity* (Abma, Martinez, & Copen, 2010; Eaton et al., 2010), *socioeconomic background* (Brewster, 1994a; Cubbin, Santelli, Brindis, & Braveman, 2005), and *early pubertal maturation* (Golub et al., 2008; Udry, 1979). By examining potential mediational pathways, the present study was designed to identify critical points of intervention that can help mitigate the negative impact of these relatively fixed risk factors on early sexual involvement.

Past research suggests that children of Black racial identity and those from low socioeconomic households tend to perform poorly on working memory tasks as compared with Whites and those from more advantaged families (Bradley & Corwyn, 2002; Evans & Schamberg, 2009; Mezzacappa, 2004). A high proportion of Black children in the United States are raised in families from low socioeconomic backgrounds (Sells & Blum, 1996), which can have pervasive detrimental effects on the development of ECFs, including working memory ability (Evans & Schamberg, 2009; Farah, 2010). A relevant question that needs to be addressed in light of this evidence is whether high rates of early sexual initiation reported among Black adolescents and those from low socioeconomic backgrounds are in part due to weakness in working memory and associated impulsive tendencies.

The swell of pubertal hormones responsible for reproductive system development during adolescence is also thought to trigger maturational changes in the adolescent brain (Blakemore, Burnett, & Dahl, 2010; Sisk & Zehr, 2005), potentially influencing working memory abilities (Farber & Ignat'eva, 2006) and sensation-seeking drives (Forbes & Dahl, 2010; Martin et al., 2002). Some researchers argue that sexual initiation is different from

other risk-taking behaviors such as delinquency and drug use, in that it becomes normative with increasing age (Rodgers & Rowe, 1993) and confers an evolutionary advantage (Belsky, Steinberg, & Draper, 1991). Nevertheless, the complex ways in which pubertal maturation can affect early sexual initiation necessitates the exploration of mediational pathways by which its influence is transmitted. Considering that pubertal hormones can trigger brain maturation, it is possible that early maturation can have a protective influence on sexual initiation by strengthening working memory abilities. At the same time, pubertal maturation can have a risk-enhancing effect, both directly due to increased social attention associated with physical maturity (Brooks-Gunn & Furstenberg, 1989; Udry, 1988) and indirectly due to the associated rise in sensation seeking (Forbes & Dahl, 2010). Given that females tend to mature relatively earlier than males, we also explore any potential gender differences in the effects of pubertal maturation.

The model for the present study, presented in Figure 1, examines the prospective relations between exogenous predictors (at baseline) and sexual initiation at 1-year follow-up in a cohort of virgin adolescents aged 12–14 years at baseline. The focus of the model is to determine (a) the role of working memory ability as a predictor of early sexual debut and (b) whether the influence of exogenous predictors (e.g., socioeconomic background) on early sexual debut are mediated by working memory ability and its relationships with sensation seeking and impulsivity. Because some of the adolescents were already sexually initiated at baseline, we did not include these adolescents in the first round of analyses to more precisely establish the predictive influence of the variables in our model. In supplemental analyses, however, we included all adolescents who had initiated sexual intercourse, both at baseline and at follow-up, to assess the accuracy of our model for the full sample.

As shown in Figure 1, we posit that working memory ability will have a significant inhibiting influence on the likelihood to initiate intercourse (Hypothesis 1) and that this effect will be mediated by acting-without-thinking (Hypothesis 2a) and temporal discounting (Hypothesis 2b). Furthermore, working memory ability is expected to be negatively associated with acting-without-thinking (Hypothesis 3a) and temporal discounting (Hypothesis 3b), but positively related to sensation seeking (Hypothesis 3c). Given the conflicting associations that sensation seeking shares with potentially protective (working memory) and risk-enhancing (acting-without-thinking) influences, we hypothesize that after controlling for acting-without-thinking, sensation seeking will be either negatively related or unrelated to early sexual onset (Hypothesis 4a). In contrast, acting-without-thinking (Hypothesis 4b) and temporal discounting (Hypothesis 4c) are expected to be positively associated with early sexual onset.

We expect that the exogenous predictors in our model (i.e., racial identity, socioeconomic background, and pubertal maturation) will have effects that are largely mediated by working memory and its associations with sensation seeking and two forms of impulsivity. Age is hypothesized to be positively related to working memory (Bunge & Wright, 2007; Luciana, Conklin, Hooper, & Yarger, 2005), sensation seeking (Romer & Hennessy, 2007; Steinberg et al., 2008), and acting-without-thinking (Romer et al., 2011; Steinberg et al., 2008). Temporal discounting, however, is not expected to be related to age, as it tends to remain relatively stable during adolescence (Green, Fry, & Myerson, 1994; Romer et al., 2010).

Method

Participants

Panel data were used in the present study from a longitudinal survey of a community sample of preadolescents residing in the Philadelphia, Pennsylvania, area, aged 10–12 years at the time of the study's inception. Details about sample recruitment have been described

previously (Romer et al., 2009). The study was approved by the Institutional Review Board of the Children's Hospital of Philadelphia. Participants were surveyed annually for 4 consecutive years with a minimal (<6%) attrition rate. For purposes of the present study, data from only the two most recent annual assessments (i.e., Waves 3 and 4) were analyzed ($N = 351$). Loss to follow-up for these two waves was only 1%. The sample had a mean age of 13.4 years (± 0.87) at baseline (Wave 3 in the study), was balanced in terms of sex (48% males), and comprised primarily of non-Hispanic White adolescents (55%), followed by non-Hispanic Black youth (28%) and Hispanic youth (9%). Majority (92%) of adolescents had at least one parent who had graduated from high school, and only 33% had a parent who had a college degree. The most common occupation of the primary caregiver was reported as unskilled/unemployed (30%) followed by clerical/sales (22%). Less than 18% of our sample had a parent employed in a managerial or higher executive position.

Assessments

Assessments were conducted in schools, research center testing rooms, and community libraries by examiners who were trained to collect data in a standardized manner. Tasks were administered using pencil and paper or on touch screen laptops with either e-Prime (Schneider, Eschman, & Zuccolotto, 2002; Stahl, 2006) or Medialab software (Jarvis, 2004) using audio-computer-assisted self-interviewing (ACASI). Use of the ACASI method of interviewing allows the participant to listen to the interview questions privately by the use of earphones, while the text is displayed on a computer screen, and to respond to them by touching the appropriate response option that appears on the computer monitor. As such, the use of ACASI serves to maximize participants' comfort in answering truthfully about their behavior as they are not responding face-to-face to an interviewer, while also reducing comprehension differences that might result from reading a self-administered survey (Metzger et al., 2000; Romer et al., 1997).

Measures

Sexual initiation—Respondents were asked at baseline and at 1-year follow-up if they had ever engaged in vaginal intercourse during their lifetime (yes/no). There were four participants who reported having engaged in vaginal intercourse at baseline but did not report having ever had vaginal intercourse at follow-up. These four cases were deleted from the analyses to ensure response consistency, resulting in a final sample size of 347 participants. Twenty-five adolescents (7.2% of the sample) had initiated sexual intercourse at baseline, and a total of 55 adolescents (15.9%) reported being sexually experienced by follow-up.

Working memory—Adolescents' working memory ability was assessed using five separate tasks (described below), the scores on which were found to load significantly on a single latent factor, labeled as working memory. The factor loadings ranged from 0.40 to 0.60, and the reliability coefficient (ρ) for these items was estimated to be 0.70 (Raykov, 2009).

Digit span—This task tests auditory-verbal working memory by having participants immediately repeat back in reverse order sequences of digits to the experimenter. It was administered in standard form according to procedures listed in the Wechsler Intelligence Scale for Children-fourth edition (WISC-IV) manual (Wechsler, 2003).

Corsi block tapping—This task is a nonverbal variant of the digit span task (Milner, 1971). The participant views a set of identical blocks that are spatially dispersed on the screen and are individually lit up in a random sequence. The participant is asked to tap each box in the *reverse* order of the sequence of lit boxes. This task is considered a task of spatial

working memory as the visual sequence must be maintained and reversed in working memory in order to guide the response.

Letter two-back—This task involves monitoring a series of letters for a repeat “two-back.” Letters are presented for 500 ms each, separated by a 1-s interval. Participants must continually update their working memory in order to compare the current letter with the letter shape presented two trials back. This task was adapted for children by Casey et al. (1995).

Object two-back—This task is similar to the letter two-back with the exception that objects in the form of irregular polygons are presented at each trial instead of letters, and participants have to continually update their working memory to compare the current object with the object presented two trials back (D'Esposito, Postle, Ballard, & Lease, 1999; Postle, D'Esposito, & Corkin, 2005).

Spatial working memory—This self-directed computerized task requires the participant to search for hidden tokens one at a time within sets of four to eight randomly positioned boxes. Tokens are hidden only once in each box per trial. Working memory skills are tapped as the participant while searching must hold in working memory the locations already checked and as tokens are found must remember and update information about the locations of those tokens (Owen, Downes, Sahakian, Polkey, & Robbins, 1990). *Between-search* errors on this task are made if the participant returns to a box where a token had already been found during a *previous* search sequence. In comparison, a *within-search* error is made when a participant returns to a box that has already been checked during the *same* search sequence. Working memory performance was indexed using the between-search errors score, because it places more demands on working memory of participants as they have to remember where the token was found in the last search when beginning a new search for the next token.

Sensation seeking—The tendency to seek novel and exciting experiences was assessed using respondents' level of agreement with four items (e.g., “I like to do frightening things”), each on a Likert-type scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*). These items were taken from the Brief Sensation Seeking Scale (Hoyle, Stephenson, Palmgreen, Lorch, & Donohew, 2002) and represented each of the four dimensions (i.e., experience seeking, boredom susceptibility, thrill/adventure seeking, and dis-inhibition) of the original sensation-seeking scale (Zuckerman, 1971). Scores on these items loaded on a single latent factor, with loadings ranging from 0.53 to 0.73, and a rho of 0.77.

Acting-without-thinking—This dimension of impulsivity was assessed using a self-report measure including 13 yes/no questions (e.g., “Do you usually do and say things without stopping to think?”), derived from the Junior Eysenck Impulsivity Scale (Eysenck et al., 1984; Kuo, Chih, Soong, Yang, & Chen, 2004). Exploratory factor analyses conducted using scores on these 13 items suggested a single-factor solution. Four items that did not load well (e.g., “Do you often change your interests?”) were removed. The remaining nine items loaded significantly on a single latent factor with loadings ranging from 0.37 to 0.71, and rho of 0.80.

Temporal discounting—A monetary choice procedure adapted from Green et al. (1994) was used to assess adolescents' preference for immediate reward. Similar monetary choice procedures have been shown to be valid with youth in this age group (Duckworth & Seligman, 2005; Scheres et al., 2006) and to be valid indicators of the ability to delay gratification (Reynolds & Schiffbauer, 2005). Respondents are asked in the context of

payment for a job to identify an amount of money between \$10 and \$90 that, if received immediately, would be equivalent to receiving \$100, 6 months later. Respondents are initially asked if they would accept a payment of \$50 immediately in lieu of being paid \$100 in 6 months. Those who accept the \$50 offer are then asked if they would accept an amount lower than \$50 in \$10 decrements. The lowest amount they accepted was taken as their equivalent value. A comparable procedure with successively increasing values was used for those who did not accept \$50. Scores on this variable ranged from 10 to 100, which were reverse scored such that higher scores were indicative of greater temporal discounting. Research comparing hypothetical with real rewards and delays indicates that the procedure produces comparable estimates of individual differences (Johnson & Bickel, 2002). The test–retest reliability of this measure in our sample was $r = .43$ ($p < .001$), which is quite robust considering that the test was readministered after a gap of 1 year.

Exogenous risk factors—Adolescents' were asked to report their age, sex, and racial-ethnic background in a demographics questionnaire. Age was included in the model as a continuous variable, whereas sex was dummy coded with females scored as 1. Given higher rates of early sexual initiation among Black and Hispanic adolescents, two separate dummy variables were included for youth who identified as Black or Hispanic, with Whites and others combined as the reference group. The decision to include Whites along with other groups (comprising Asian Americans and American Indians) as the reference category was made because of the low representation of participants in the “other” category and because the rates of sexual initiation did not differ significantly between these groups.

Information about socioeconomic background was gathered from the primary caregivers, using two items that assessed their “current occupation” on a 7-point scale ranging from 1 (*unskilled/unemployed*) to 7 (*higher executive*) and “years of education completed” ranging from fewer than 7 years (coded 1) to greater than 16 years (coded 7) (Hollingshead, 1975; Miller & Salkind, 2002). Scores on these two measures were found to be highly correlated ($r = .54$, $p < .001$), and therefore an average of the two measures was used as an indicator of the adolescents socioeconomic background.

Pubertal development was measured by adolescents' self-reports using sketches of the Tanner stages of pubertal development (Tanner, Whitehouse, Marubini, & Resele, 1976). For boys, the development of genitals and body hair growth was assessed; for girls, the development of breasts and pubic hair growth was assessed. This method generates scores that bear strong correspondence with physician assessments of pubertal development (Morris & Udry, 1980). The two sex-specific scores were averaged to get an index of pubertal maturation separate for each sex, with higher scores signifying greater pubertal development.

Analytic Procedure

Descriptive analyses were conducted using STATA 11.0. Exploratory and confirmatory factor analyses for indicators of working memory, sensation seeking, and acting-without-thinking were conducted using Mplus v6 with robust estimation procedures. The measurement model including the latent factors of working memory, sensation seeking, and acting-without-thinking had a good model fit, $\chi^2(129, N = 347) = 165.29$, $p = .02$, root-mean-square error of approximation (RMSEA) = .03, 90% CI [.01, .04], comparative fit index (CFI) = .98, Tucker-Lewis index (TLI) = .97. Structural equation modeling procedures for model specification and evaluation were conducted next. Given the dichotomous nature of our outcome variable, we analyzed the models using the robust mean and variance adjusted weighted least-squares estimator. The model specification proceeded in two steps. In the first step, the effect of sensation seeking, acting-without-thinking, and temporal

discounting was tested on the likelihood of sexual initiation at follow-up among adolescents who were virgins at baseline. As part of the second step of the model-building process, the latent factor of working memory was introduced as well as the other exogenous covariates, including age, sex, pubertal development, Black racial identity, Hispanic ethnicity, and socioeconomic background. In a supplemental analysis, the hypothesized model was tested using the full sample, including adolescents who were sexually experienced at baseline. Model fit was assessed using global fit indices as well as an examination of residual diagnostics. The criteria for a good model fit included a low chi-square test statistic, an RMSEA value less than 0.05, and CFI and TLI values greater than 0.90.

Results

Nearly 16% ($n = 55$) of our full sample of 347 adolescents reported having initiated vaginal intercourse by follow-up, of which 25 adolescents reported being sexually experienced at baseline. Sample descriptives based on sexual initiation status by follow-up are presented in Table 1. Statistically significant differences in the rates of sexual initiation were observed on the basis of adolescents' age ($OR = 2.78$, 95% CI [1.93, 4.06], $p < .001$) and Black racial identity, $\chi^2(1, N = 347) = 10.34$, $p < .001$, but not based on sex or Hispanic ethnicity, with older adolescents and those from Black racial backgrounds reporting higher rates of sexual initiation at follow-up. As seen in Table 2, most of the predictors in our model were correlated with sexual initiation at baseline and at follow-up. Statistically significant correlations were observed between sexual initiation and sensation seeking, acting-without-thinking, and temporal discounting, but correlations between measures of working memory and sexual initiation tended to be weaker.

In the first step of the model-building process, using the virgin-only sample ($n = 322$), we found that acting-without-thinking ($B = 0.47$, $SE = 0.22$, $p < .05$) and temporal discounting ($B = 0.01$, $SE = .004$, $p < .05$) were significantly associated with sexual initiation at follow-up, but sensation seeking was not ($B = 0.22$, $SE = 0.23$, $p = .35$). This pattern held true even after the effects of all exogenous variables were taken into account.

We then introduced the latent working memory factor as an additional predictor of sexual initiation, testing for its influence both directly and indirectly, as mediated by sensation seeking, acting-without-thinking, and temporal discounting. Consistent with our hypothesis, working memory did have a protective effect on sexual initiation (Hypothesis 1), and this effect was entirely mediated by acting-without-thinking (Hypothesis 2a) and temporal discounting (Hypothesis 2b), both of which were inversely related to working memory (Hypothesis 3a and 3b). Even though sensation seeking was significantly and positively associated with working memory ($B = 0.08$, $SE = 0.3$, $p < .05$) (Hypothesis 3c), it continued to have no effect on the likelihood of sexual initiation (Hypothesis 4a). The influence of acting-without-thinking on sexual initiation at follow-up was significant ($B = 0.46$, $SE = .17$, $p < .01$) (Hypothesis 4b), as was the effect of temporal discounting ($B = .01$, $SE = .004$, $p < .01$) (Hypothesis 4c).

In a separate model, we also tested the effect of sensation seeking as a *predictor* of working memory rather than a *consequence* of it. Here again, we found sensation seeking to be positively related to working memory (Hypothesis 3c), but its net effect on sexual initiation as mediated by working memory was still not significant ($B = -0.05$, $SE = 0.04$, $p = .13$). At this point, sensation seeking was removed from the model. Acting-without-thinking and temporal discounting were retained as significant mediators of the influence of working memory on sexual initiation.

Working memory had a significant protective influence on acting-without-thinking ($B = -.13$, $SE = .05$, $p < .01$) and temporal discounting ($B = -4.72$, $SE = 1.48$, $p = .001$). The total indirect effect of working memory on likelihood of sexual initiation was significant ($B = -.11$, $SE = .04$, $p < .01$), as were the independent indirect effects mediated through acting-without-thinking ($B = -.06$, $SE = .03$, $p < .05$) and temporal discounting ($B = -.05$, $SE = .02$, $p < .05$). Accounting for the influence of working memory, there was no residual covariance between acting-without-thinking and temporal discounting ($r = .03$, $p = 0.57$).

All the exogenous variables (age, sex, pubertal development, Black racial identity, and socioeconomic background), except Hispanic ethnicity, were found to have a direct influence on working memory or on sexual initiation. Adolescents from higher socioeconomic backgrounds displayed better working memory performance ($B = .18$, $SE = .08$, $p < .05$), whereas the mean working memory performance of Black adolescents in our sample was significantly lower than that of the reference group (i.e., Whites and other ethnicities) ($B = -.88$, $SE = .27$, $p = .001$). Black adolescents reported higher levels of acting-without-thinking ($B = .37$, $SE = .14$, $p = .01$) and displayed marginally higher levels of temporal discounting ($B = 6.44$, $SE = 3.94$, $p = .10$) than the reference group. Adolescents from higher socioeconomic backgrounds had marginally lower rates of temporal discounting ($B = -2.06$, $SE = 1.16$, $p < .08$) than those from lower socioeconomic backgrounds.

The net indirect effect of Black racial identity ($B = .34$, $SE = .1$, $p < .01$) and socioeconomic background ($B = -.04$, $SE = .02$, $p < .05$) on sexual initiation was significant and entirely channeled through the mediators in our model, namely working memory and the two dimensions of impulsivity. Closer examination of these indirect paths revealed that in the case of Black racial identity, 50% of its effect on sexual initiation was channeled through acting-without-thinking, 29% through working memory, and 21% uniquely through temporal discounting. For socioeconomic background, slightly over half of the effect on sexual initiation was transmitted through temporal discounting (53%), whereas the remaining 47% was channeled through working memory.

In contrast to Black identity and low socioeconomic background, which had consistent risk-enhancing effects, the *indirect* effects of pubertal development were mediated through pathways that both increased and decreased the likelihood of sexual initiation at follow-up. More specifically, its indirect effect mediated by its relationship with acting-without-thinking was marginally significant and associated with increased likelihood of sexual initiation ($B = .09$, $SE = .05$, $p < .08$). However, pubertal development had a protective influence through the mediated pathway involving working memory. Supplemental analyses testing for interactions revealed that the influence of pubertal development on working memory was moderated by sex ($B[SE]_{\text{interaction}} = .86[.27]$, $p = .001$). More specifically, the conditional effect of pubertal development on working memory was significant only for females ($B = .74$, $SE = .21$, $p < .001$) and not for males ($B = -.09$, $SE = .18$, $p = .61$). Controlling for age, females in our sample were on average pubertally more developed than males ($B = .35$, $SE = .09$, $p < .001$), which may explain why the effect of pubertal development on working memory was stronger in females. The net protective effect of pubertal development on sexual initiation for females as mediated through working memory was significant ($B = -.10$, $SE = 0.04$, $p < .05$). Of the total effect of pubertal development on sexual initiation, 47% was mediated through acting-without-thinking and was risk enhancing, whereas 53% was mediated through working memory and was protective, although only for females.

Age, by itself, had a direct influence on sexual initiation, such that adolescents who were older at baseline were more likely to have initiated sexual intercourse at follow-up ($B = .46$, $SE = .15$, $p < .01$). Older adolescents also reported slightly more acting-without-thinking (B

$= .13$, $SE = .08$, $p = .08$). Of the total effect of age on sexual initiation, only 14% was mediated through acting-without-thinking, the remaining 86% was direct.

Because adolescents with attention-deficit/hyperactivity disorder (ADHD) may have higher rates of impulsivity and associated working memory weaknesses, we reanalyzed our final model after removing those participants from the sample whose parents reported that their child had been diagnosed with ADHD ($n = 24$). The significance of findings reported above was replicated, which indicates that our results do not depend on the preexisting attentional problems of adolescents in our sample.

Figure 2 presents the path diagram for the final model showing only the significant paths along with the standardized path coefficients and variance explained (adjusted R^2). In terms of an underlying continuum of risk, the model explained 31% of the variance in sexual initiation at 1-year follow-up among a sample of virgin adolescents. Thus, our model was able to explain a sizable portion of sexual initiation risk observed at these early ages. The global model fit indices suggested an excellent fit for the final model (CFI = 0.96; TLI = 0.95; RMSEA = 0.03, 90% CI [.01, .04]), despite a significant chi-square test, $\chi^2(198, N = 322) = 246.45$, $p < .05$. An assessment of the residual diagnostics and modification indices also suggested a good model fit.

We reanalyzed the model using the full sample, that is, including both virgin and nonvirgin adolescents at baseline ($n = 347$). The outcome variable for this model was sexual initiation *by follow-up*. The pattern of findings observed using the virgin-only sample was replicated. This suggests that the predictor and mediator variables in our model had a similar influence on the likelihood of sexual initiation, both contemporaneously and prospectively. Because the focus of this research was to examine the prospective relationships between these variables and sexual initiation, we only present findings from the sample of adolescents who were virgins at baseline.

Discussion

Early sexual debut is a behavior that is fraught with risk for adolescents. Although previous research has identified a number of demographic, developmental, and personality characteristics associated with this risk behavior, less is known about potential mediating mechanisms for these factors. In the present study, we examined the role of working memory ability—an important predictor of suboptimal decision making as well as the unique roles of sensation seeking and two forms of impulsive tendencies (acting-without-thinking and temporal discounting) as mediators of the effects of exogenous risk factors (low socioeconomic background, Black racial identity, and early pubertal maturation) on early sexual initiation. We hypothesized that weak working memory would underlie the risk-enhancing effects of impulsive tendencies and that the effects of exogenous risk factors would be mediated by working memory ability and the two forms of impulsivity. In contrast, because sensation seeking was not related to weakness in working memory, we did not expect it to be positively related to early debut apart from its overlap with acting-without-thinking.

The findings from a panel study of nearly 350 adolescents supported the study hypotheses. As expected, working memory ability was found to have a significant influence on likelihood of sexual initiation that was entirely mediated by measures of impulsive tendencies. More specifically, only temporal discounting and acting-without-thinking emerged as significant mediators of this effect. Sensation seeking, although associated positively with working memory, failed to have a significant effect on likelihood of sexual

initiation either as an exogenous risk factor or as a mediator of working memory's influence on sexual initiation.

Overall, our findings point to the important role of two distinct forms of impulsivity and their relationship with working memory ability as precursors of early sexual debut. The association between impulsivity and early sexual debut reported in previous research has largely overlooked the distinctions between different dimensions of impulsivity. Our results show that although acting-without-thinking and temporal discounting are interrelated due to their shared underlying weakness in working memory, they predict sexual debut independently of each other.

Previous research has also documented associations between early sexual debut and IQ (Halpern et al., 2000; House, Bates, Markham, & Lesesne, 2010; Paul, Fitzjohn, Herbison, & Dickson, 2000; Shearer et al., 2002). Although we did not assess IQ, our findings suggest that at least some of IQ's association with early sexual onset may be mediated by weakness in working memory. Besides being a critical cognitive construct that is fundamental to higher order cognitive functions, recent research indicates that working memory is malleable and can be improved with training (Jaeggi, Buschkuhl, Jonides, & Perring, 2008; Klingberg, 2010; for a review, see Diamond & Lee, 2011). Working memory training has also been found to be helpful in reducing impulsive behaviors among children (Mezzacappa & Buckner, 2010; Klingberg et al., 2005). Interventions to improve working memory ability may therefore have promise for reducing the effects of low IQ on early sexual debut as well as other risk behaviors that are associated with the acting-without-thinking and temporal discounting dimensions of impulsivity.

Our findings regarding sensation seeking are consistent with other research that suggests that this personality trait is less predictive of early risk-taking behaviors (Romer et al., 2011) than impulsive tendencies (Magid et al., 2007; Smith et al., 2007). One explanation for this divergence of effects is that sensation seekers do not suffer from deficits in executive cognitive abilities, and therefore their proneness to engage in risky behaviors is tempered by their ability to evaluate the consequences of their behavior (Romer et al., 2011). Previous research documenting effects of sensation seeking on early adolescent risk taking may have been confounded by the overlap with acting-without-thinking, resulting from shared variation in the underlying mesolimbic dopaminergic activation that characterizes both traits (Buckholtz et al., 2010; Pattij & Vanderschuren, 2008; Zald et al., 2008).

Despite our null finding regarding the influence of sensation seeking on early sexual initiation, a previous study of ninth graders reported a positive link between sensation seeking and early sexual debut controlling for impulsive decision making (Donohew et al., 2000). This inconsistency may be due to at least two reasons. First, our sample was younger in age, with the vast majority (70%) being 14 years old or younger at follow-up, as compared with the participants of Donohew et al.'s study. Considering the inverted U-shaped trajectory of sensation-seeking tendencies during adolescence, it may still be too early to detect effects of sensation seeking (if present) in our sample. It is possible that sensation seeking may become a significant predictor of sexual initiation during later adolescence, when sexual involvement becomes more normative. Another reason for our divergent result may be that we used more sensitive measures to assess the unique effect of sensation seeking and acting-without-thinking on early sexual initiation. In comparison, Donohew and colleagues used dichotomized scores of sensation seeking and impulsive decision making as correlated predictors of early sexual debut that might have resulted in less than complete control for the effects of impulsive decision making and spurious effects due to the inflated probability of Type I errors (Maxwell & Delaney, 1993).

Effects of Exogenous Predictors

A plethora of research has documented links between race (O'Donnell et al., 2001), low socioeconomic background (Brewster, 1994a; Cubbin et al., 2005), and early sexual debut. In comparison, very little is known about the pathways through which these structural risk factors exert their influence. Therefore, another important goal of this study was to identify mediational pathways of influence for these risk factors. Our analyses revealed that the effects of Black racial identity and socioeconomic background on early sexual initiation were indirect and entirely mediated by working memory ability and the two forms of impulsivity.

High rates of early sexual onset among Black adolescents are likely to be confounded by the high rates of poverty experienced in Black households (Hofferth, 1987; Santelli, Lowry, Brener, & Robin, 2000). Because of the limited variation in the socioeconomic backgrounds of the adolescents in our sample, there was less of an inverse relation observed between this variable and Black racial identity. Previously, researchers have argued that the dearth of resources in low-income families may reduce parents' ability to successfully monitor their adolescent, thereby providing contexts more conducive to early sexual onset (Mott, Fondell, Hu, Kowaleski-Jones, & Menaghan, 1996). Still others have suggested that lack of future aspirations, scarcity of good role models, and low collective efficacy in poor neighborhoods may serve as pathways through which low socioeconomic background can influence adolescent early sexual behaviors (Brewster, 1994a, 1994b; Browning, Leventhal, & Brooks-Gunn, 2004; Cubbin et al., 2005). Our study adds to these findings by indicating the common underlying link of weakness in working memory and inability to delay gratification for both Black adolescents and those from low socioeconomic households, which places them at greater risk for early sexual debut. In case of Black adolescents only, there also was a direct pathway of influence through acting-without-thinking.

The detrimental effects of poverty on children's working memory performance and ability to delay gratification has been documented previously (Evans & Rosenbaum, 2008; Hackman & Farah, 2009; Mezzacappa, 2004). By identifying weakness in working memory and impulsivity dimensions as mediators of the influence of Black racial identity and low socioeconomic background, our findings help in better understanding the ways in which these distal risk factors can exert their impact on adolescent early sexual debut. They also help identify promising channels for intervention, such as self-control/impulsivity-focused interventions (Botvin & Griffin, 2004; Diamond, Barnett, Thomas, & Munro, 2007; Domitrovich, Cortes, & Greenberg, 2007) and working memory training programs (Klingberg et al., 2005; Morrison & Chein, 2011).

The effect of pubertal maturation on executive cognitive ability and impulsivity has also been examined previously (Farber & Ignat'eva, 2006; Forbes & Dahl, 2010; Sisk & Zehr, 2005). Nevertheless, we find that pubertal maturation can have a *protective effect* on early sexual onset by improving working memory ability (although this held true only for girls in our sample), apart from its risk-enhancing effect channeled through acting-without-thinking (Forbes & Dahl, 2010). Thus, by improving the working memory abilities of adolescents, it may be possible to reduce their risk for early sexual onset, even if they exhibit early pubertal maturation.

The fact that girls mature earlier than boys (which was also the case in our sample) may explain why the effect of pubertal maturation on working memory performance was only significant for girls. Future research is needed to verify whether these sex differences remain significant in relatively older adolescent samples, when pubertal maturation levels become more balanced across sex. Given that differences in pubertal maturation based on race and socioeconomic background have also been previously reported (Obeidallah, Brennan,

Brooks-Gunn, Kindlon, & Earls, 2000; Wu, Mendola, & Buck, 2002), we explored the moderating effect of these two variables on the influence of pubertal development in our models but failed to detect a statistically significant effect.

Despite the novel and relevant contributions of the present research, our findings are limited by the moderate size of our sample and its predominant urbanicity, which preclude generalization to other adolescent populations. In addition, our sample was recruited in the community and thus was less likely to have as large a proportion of high-risk youth as samples drawn to purposely represent them. Our findings also are limited by the self-reported nature of our measure of sexual initiation, although assessment using ACASI probably served to enhance the validity of these reports by increasing perceived confidentiality. The cross-sectional nature of our data on working memory and personality measures also precludes us from conclusively establishing a temporal order for these variables in our analyses. Finally, we did not assess parental income and thus could not account for its unique effect as an indicator of the adolescents' socioeconomic background besides parental education and occupation.

In summary, by highlighting the role of working memory and the two dimensions of impulsivity as the proximal predictors of early sexual initiation and as mediators of the effect of structural variables, our findings underscore the potential impact that self-control/impulsivity-focused interventions (e.g., Botvin & Griffin, 2004; Diamond et al., 2007; Domitrovich et al., 2007; Durlak, 1995) as well as working memory training programs (e.g., Diamond & Lee, 2001; Jaeggi et al., 2008, 2011; Klingberg, 2010; Morrison & Chein, 2011) can have in reducing the risk of early sexual initiation. These interventions also seem promising because working memory ability and lack of self-control can be detected at a young age and therefore can be targeted much before the onset of sexual activity. Interventions that can be delivered at a young age and more universally, without any risk of stigmatizing the recipients, may have greater chances of success.

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Figure 1.

Hypothesized model testing direct and mediational pathways of influence on early adolescent sexual debut. All variables except sexual initiation were assessed at baseline. The direct effects of exogenous risk factors on endogenous personality variables in the model (i.e., sensation seeking, acting-without-thinking, and temporal discounting) were tested. Similarly, the direct effect of working memory on sexual initiation was examined. All exogenous variables were correlated. These paths are not shown in the figure for the sake of clarity.

Figure 2.

Final structural equation modeling (SEM) showing the significant paths ($p < .05$) with standardized coefficients, unless noted otherwise. Model fit: comparative fit index = 0.95; Tucker-Lewis index = 0.94; root-mean-square error of approximation = 0.03, 90% CI [.02, .04]. WM = working memory; AWT = acting-without-thinking; TD = temporal discounting; SEB = socioeconomic background. Dashed lines represent effects significant at $p < .10$ level. ^uIn case of dichotomous predictors, the unstandardized coefficients are reported for ease of interpretation. ^fPubertal development's effect on working memory was significant only for females, and the female-specific coefficient is reported here. All exogenous variables were assessed at baseline and are correlated. These paths are not shown for reasons of clarity.

Table 1

Sample Descriptives: Mean (Standard Deviation) and Frequencies

Variable	Sexual initiation by follow-up		<i>p</i>
	Sexually experienced (<i>n</i> = 55)	Not experienced (<i>n</i> = 292)	
Working memory (Factor score)	−0.23 (0.95)	0.04 (0.81)	<.05
Sensation seeking (Factor score)	0.40 (0.92)	−0.08 (0.85)	<.001
Acting without thinking (Factor score)	0.60 (0.87)	−0.11 (0.87)	<.001
Temporal discounting (range = 10–100)	62.18 (30.65)	48.28 (28.49)	=.001
Age (range = 11.9–15.1)	14.01 (0.82)	13.28 (0.82)	<.001
Pubertal development (range = 1–5)	4.41 (0.64)	3.76 (0.90)	<.001
Parental education (range = 1–7)	4.67 (1.19)	5.04 (1.27)	<.05
Parental occupation (range = 1–7)	2.62 (1.85)	3.34 (1.90)	<.05
Black racial identity	45.5%	24.3%	=.001
Hispanic ethnicity	14.6%	7.5%	=.09

Table 2

Correlation Matrix of Key Study Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Sex_In T2	—														
2. Sex_In T1	.64***	—													
3. Corsi (WM)	-.10	-.04	—												
4. L2bc (WM)	-.12*	-.07	.23***	—											
5. Ob2bc (WM)	-.01	.09	.29***	.52***	—										
6. Dgtsp (WM)	-.16**	-.13*	.19***	.22***	.16**	—									
7. Swm (WM)	-.07	.02	.34***	.33***	.31***	.26***	—								
8. SS	.20***	.17**	.08	.01	.08	.14*	.14*	—							
9. AWT	.29***	.23***	-.17**	-.14**	-.09	-.07	-.05	.35***	—						
10. TD	.17**	.12*	-.08	-.13*	-.10	-.07	-.09	.03	.16**	—					
11. Pubertal dev.	.26***	.26***	.07	.05	.12*	.06	.05	.12*	.21***	.12*	—				
12. Female	-.04	-.05	-.08	-.01	-.09	.04	-.01	-.13*	-.05	-.04	.19***	—			
13. Age	.31***	.24***	.12*	.03	.10	-.01	.03	.08	.20***	.05	.42***	-.05	—		
14. SEB	-.12*	-.09	.07	.14*	.15**	.16**	.004	.02	-.18***	-.18***	-.12*	.03	-.04	—	
15. Black identity	.17***	.20***	-.23***	-.07	-.05	-.04	-.15**	.02	.22***	.17**	.20***	.15***	.03	-.06	—

Note. Sex_In T2 = Sexual initiation at follow-up; Sex_In T1 = Sexual initiation at baseline; Corsi (WM) = Corsi block tapping score, working memory item; L2bc (WM) = Letter two-back score, working memory item; Ob2bc (WM) = Object two-back score, working memory item; Dgtsp (WM) = Digit span score, working memory item; Swm (WM) = Spatial working memory score, working memory item; SS = Sensation-seeking score, average of four items; AWT = Acting-without-thinking score, average of nine items; Pubertal dev. = Pubertal development; TD = Temporal discounting score; SEB = Socioeconomic background.

* $p < .05$.

** $p < .01$.

*** $p < .001$.