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Feasibility of Functional Neuroimaging to Understand Adolescent Women's Sexual Decision Making

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A B S T R A C T

Purpose: For young women, new sexual experiences normatively increase after puberty and coincide with extensive changes to brain regions governing self-regulation of risk behavior. These neurodevelopmental changes could leave some young women vulnerable for negative sexual outcomes, including sexually transmitted infection and unintended pregnancy. We evaluated the feasibility of using functional neuroimaging to understand the sexual decision making of adolescent women.
Methods: Adolescent women (N = 14; 14–15 years) completed enrollment interviews, a neuroimaging task gauging neural activation to appetitive stimuli, and 30 days of prospective diaries following the scan characterizing daily affect and sexual behaviors. Descriptive and inferential statistics assessed the association between imaging and behavioral data.
Results: Young women were highly compliant with neuroimaging and diary protocol. Neural activity in a cognitive-affective network, including prefrontal and anterior cingulate regions, was significantly greater during low-risk decisions. Compared with other decisions, high-risk sexual decisions elicited greater activity in the anterior cingulate, and low-risk sexual decision elicited greater activity in regions of the visual cortex. Young women's sexual decision ratings were linked to their sexual history characteristics and daily self-reports of sexual emotions and behaviors.
Conclusions: It is feasible to recruit and retain a cohort of female participants to perform a functional magnetic resonance imaging task focused on making decisions about sex, on the basis of varying levels of hypothetical sexual risk, and to complete longitudinal prospective diaries following this task. Preliminary evidence suggests that risk level differentially impacts brain activity related to sexual decision making in these women, which may be related to past and future sexual behaviors.

IMPLICATIONS AND CONTRIBUTION

This investigation demonstrates the feasibility of a neuroimaging paradigm examining sexual decision making in young women. A decision about whether to engage in sex incorporates degree of risk into decision making differently than in nonsexual decisions. Future research can use this paradigm to examine how brain function is related to subsequent sexual behavior.

Learning to express and manage sexuality is a normative developmental task, particularly for young women [1]. During adolescence, young women encounter a variety of new sexuality-related experiences, including managing new romantic/sexual

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relationships [2] and balancing heightened emotions and sexual desire/arousal [3]. These experiences facilitate their decisions about how and when to initiate partnered and nonpartnered sexual activity [4,5]. Although most young women navigate this process without issue, risky sexual behaviors can be associated with adverse outcomes, such as unintended pregnancy and sexually transmitted infections [6].

Although the factors contributing to risk behavior are varied and complex, neurocognitive models of decision making may account for some of the measurable differences in young people's risk behavior. Research suggests that decision making is impacted by timing differences in the maturation of reward- and control-related brain regions after puberty. During adolescence, reward-related brain regions have a heightened sensitivity compared with those during young adulthood, whereas prefrontal, control-related brain regions do not fully mature until the early 20s [7–9]. Some studies have proposed that this imbalance may contribute to an overvaluation of the immediate benefits of risk-taking and an undervaluation of the long-term negative consequences associated with those behaviors [10,11], although recent work has provided evidence of additional complexity in this model [12]. Functional magnetic resonance imaging (fMRI) studies have associated these differences with young people's increased choice of riskier options in laboratory decision-making tasks and with increased participation in a real-world risk-taking behavior, such as substance use [13,14].

Neuroimaging paradigms explicitly examining sexual decision making in adolescents are not yet available, but behavioral studies have demonstrated that perceived benefits of sex (e.g., popularity/social status, physical pleasure, intimacy) influence adolescents' participation in sex [15,16], whereas perceived social, moral, or health risks associated with sex are motivators for their sexual abstention [17,18]. Moreover, neuroimaging studies in adults have demonstrated that sexual decisions recruit a network of reward-sensitive brain regions (striatum, particularly nucleus accumbens) and regions involved in motivation and evaluation of reward and risk, including orbitofrontal cortex, ventromedial prefrontal cortex, and anterior cingulate cortex (ACC) [19–30]. For instance, activity of higher nucleus accumbens and orbitofrontal cortex in response to sexual pictures correlates positively with higher sexual desire and greater sexual frequency [22]. Rupp et al. [29] demonstrated that adult women's ACC activation in response to pictures of high-risk adult men positively correlated with their subjective evaluation of sexual behavior. The ACC has also been implicated in a neural network regulating love and sexual desire [21], with higher activation in response to romantic partners, particularly as relationships progress [19,20], but this has not been studied in adolescent women.

The brain's reward network also interacts with visual and attention regions tasked with perceiving stimuli (i.e., potential mates), as reflected by greater visual cortex activity for salient, rewarding stimuli in adults [31,32]. Other visual regions, such as the fusiform gyrus, could also play a role during sexual decision making, as they are influential in recognition of facial identity and facial expression [33].

Accordingly, we conducted a pilot study to evaluate the feasibility of an fMRI and behavior study of sexual decision making in midadolescent women. Specifically, we investigated how high-risk sexual decisions differed from low-risk sexual decisions, compared with nonsexual decisions, and whether neural activity was linked to sexual attitudes or behaviors. On the basis of the strong association between reward value and sexual cues in existing literature, we expected that (1) sexual decision making would be more closely tied with activation in visual and striatal regions than during other types of decisions and (2) high-risk sexual decisions would more strongly engage anterior cingulate and orbitofrontal regions.

Methods

Participants and study design

Participants (N = 14; 14–15 years) were adolescent women recruited from three primary care adolescent health clinics in Indianapolis, IN. These clinics serve primarily lower- and middle-income families in areas with high rates of early childbearing and sexually transmitted infection. Exclusion criteria included non-English speaking, acute intoxication at scan time, pregnancy (confirmed via urine test), known psychiatric illness (except mild/moderate anxiety or depression), not having started menstruating, and MRI contraindications. Neither sexual experience nor sexual orientation was a criterion for entry; all young women reported male partners during the diaries.

Young women completed three arms of data collection: (1) an enrollment interview; (2) an fMRI procedure; and (3) 30 daily prospective diaries after the scan. This research was approved by the Institutional Review Board of Indiana University/Purdue University Indianapolis. Informed consent was obtained from each participant, and permission was obtained from a parent or legal guardian.

Measures

Enrollment interview. Enrollment interviews assessed demographic, medical history, sexual beliefs, sexual behavior history, and psychological attributes. Sexual behavior history included number of lifetime sexual partners, number of sexual partners anticipated in the next 5 years, and sexual behavior past 30 days (kissing, sexual dreams, solo masturbation, mutual masturbation, petting, oral sex, vaginal sex, and anal sex). For comparison purposes, we dichotomized all behaviors (reported/not reported). Psychological attributes included body satisfaction (five-point scale, single item, very dissatisfied to very satisfied) and *impulsivity* (additive index, 24 semantic differential type items; e.g., "When faced with a potentially dangerous event… [I take my time…I instantly react]," "I like to take risks [not at all to a lot]," "A menacing dog approaches [I confront it–I run away]").

Daily diaries. Each diary consisted of a single bar-coded sheet, on which participants identified (using initials, first names, or nicknames) up to five "partners," including boyfriends, dating partners, friends, and sexual partners. To represent both ongoing and potential sexual relationships, prior sexual activity was not a criterion for naming partners.

Individual affect included positive mood (three items; $\alpha = .86$; e.g., "I felt happy"), negative mood (three items; $\alpha = .83$; e.g., "I felt unhappy"), and feeling in love and sexual interest (both one item). Partner-specific affect was partner support (four items; $\alpha = .95$; e.g., "He let me know he cared about me") and partner negativity (five items; $\alpha = .83$; e.g., "He made me feel bad about myself"). Partner-specific coital and noncoital sexual behaviors included (all no/yes) touched partner's genitals, partner touched [my] genitals, received oral sex, gave oral sex, vaginal sex, and *anal sex*.

Functional magnetic resonance imaging paradigm. Participants were instructed to make decisions regarding color pictures of appetitive stimuli: male adolescent faces, alcoholic beverages, restaurant food, and household items (e.g., frying pan). Stimuli included information indicating the item's "low" or "high" risk level. Alcoholic beverage pictures included the number of alcohol units and whether there was a designated driver (yes/no). Adolescent male faces (with neutral expressions; selected to have above-average attractiveness/desirability from pilot testing) presented their number of previous sexual partners and typical condom use (yes/no). This task was adapted from a similar task conducted in a study of adult women [34]. Food pictures suggested caloric content and whether the restaurant serving the food had been cited in the past year for health code violations (yes/no). Household items contained information about whether the object could be returned to the store (yes/no). For each picture, participants rated, on a finger-press button response pad, how likely they were to drink the alcohol beverage, have sex with the man, eat the food, or purchase the household product (four-point Likert scale: 1, very unlikely to 4, very likely). The present study focused on the legal behaviors (e.g., sexual behavior, buying item, and eating food) in which adolescents could participate.

There were 35 stimuli for each category, each presented twice, once with low-risk and once with high-risk information, with presentation order randomized. Each picture was shown for 4 seconds, followed by a fixation cross for 2–6 seconds (jittered interstimulus interval). Trials were presented in seven separate runs of 40 trials each. Before the scan, participants practiced picture ratings on a laptop.

Functional magnetic resonance imaging data acquisition procedure

The MRI device was a 3-T Siemens Magnetom TIM TRIO equipped with a 32-channel head coil. Stimuli projected onto a screen mounted behind the participant's head and viewed via a mirror. Functional scans followed a T1 three-dimensional (3D) turbo-flash structural scan of the entire brain at high resolution (1-mm isotropic voxels). Each functional run began with 12 seconds of rest to ensure a stable baseline signal. We used parallel imaging to decrease voxel size to partially compensate for susceptibility gradients and improve signal in orbital frontal cortex and amygdala. Gradient-echo $T2^*$ echo-planar imaging scans were conducted with the following parameters: echo time, 30 milliseconds; flip angle, 70°; field of view, 240 × 240 mm; matrix, 96 × 96, in-plane resolution, 2.5 × 2.5 mm; slice thickness, 3.6 mm; and gap thickness, 0 mm. Slices were acquired parallel to the anterior commissure - posterior commissure plane to efficiently cover the entire cortex and subcortical areas, including the amygdala and hypothalamus.

Data analyses

Descriptive and inferential statistics were used (parametric or nonparametric two-sample tests as appropriate) to summarize enrollment data and diary completion, including behavior reports at the diary and participant levels. Analyses were conducted using SPSS 21.0 (IBM, Armonk, NY).

MRI data were analyzed using BrainVoyager QX (www.brainvoyager.com). Functional data were registered to each participant's 3D anatomic volume, spatially normalized across participants to the stereotaxic space of Talairach and Tournoux (1988). Data underwent preimage processing including 3D motion correction, spatial smoothing with a Guassian filter (6 mm full width at half maximum), and temporal high-pass filter. A general linear model design matrix was created using predictors generated on the basis of canonic two-gamma hemodynamic response functions mimicking the timing sequence of each experimental condition, along with motion regressors of no interest. High- and low-risk choices were treated as separate conditions for each stimulus category (boys, food, and item). Group comparisons were performed with beta coefficients from each condition.

To measure overall effects of risk level on the decision-making process, the first contrast examined all high-risk versus low-risk conditions. Next, to examine whether sexual risks were processed differently, we contrasted the difference between high- and low-risk sexual decisions with those between the two control conditions (food and item), boys (high risk–low risk) versus (Item [high risk vs. low risk] + food [high risk vs. low risk]). Beta coefficients were extracted from significant clusters ($p < .001$ and 108 voxel cluster extent determined by Monte Carlo simulation) for direct contrasts between conditions.

Results

Participant characteristics

The mean age of the sample was 14.7 (standard deviation [SD] = .1), and the majority (85.7%) of participants were African-American. The average maternal education level was 12th grade. Very few reported ever using drugs (n = 2) or alcohol (n=3), and three young women were currently using hormonal contraception. Women averaged less than one lifetime, past year, or anticipated future sexual partners. The most common sexual behaviors reported in the 30 days before enrollment were kissing (42.9% of women) and having sexual fantasies (50.0%) or sexual dreams (57.1%); very few reported any mutual masturbation, oral sex, vaginal sex, or anal sex. Other participant data are reported in Table 1.

Diary completion and sexual behaviors

Prevalence of sexual behaviors is summarized in Table 2. At the study level, participants completed 99.7% (419 of 420) of the

Table 1
Enrollment characteristics of adolescent women (N = 14)

Age, mean (standard deviation [SD])	14.7 (.1)
Race/ethnicity, African-American: yes; n (%)	12 (85.7)
Currently using hormonal contraception: yes; n (%)	3 (21.4)
Ever used alcohol: yes; n (%)	3 (21.4)
Ever used drugs: yes; n (%)	2 (14.2)
Sexual partner history	
Number of partners, lifetime; mean (SD)	.79 (1.4)
Number of sexual partners, past year, mean (SD)	.43 (.9)
Number of predicted sexual partners, next 5 years; mean (SD)	.57 (.93)
Sexual behavior history (30 days before enrollment: yes; n (%)	
Sexual dreams	8 (57.1)
Sexual fantasies	7 (50.0)
Solo masturbation	2 (14.3)
Kissing	6 (42.9)
Mutual masturbation	2 (14.3)
Oral sex	2 (14.3)
Touching partner's genitals	1 (7.1)
Vaginal sex	2 (14.3)
Anal sex	0 (.0)
Impulsivity; mean (SD)	313.5 (43.7)

Table 2
Postscan 30-day partnered behavior reports

	Diary level; n (%)	Participant level		
		Any reported; n (%)	Frequency, mean (standard deviation); median	Maximum count
Touching partner's genital	7 (.9)	3 (23.1)	.53 (1.39); 0	5
Having one's genitals touched	4 (.5)	2 (15.4)	.31 (.76); 0	2
Giving oral sex	1 (.1)	1 (7.7)	.07 (.77); 0	1
Receiving oral sex	4 (.5)	2 (15.4)	.31 (.85); 0	3
Vaginal sex	19 (2.5)	2 (15.4)	1.46 (3.61); 0	11
Anal sex	7 (.9)	1 (7.7)	.53 (1.94); 0	7

expected subject-focused diaries; 13 of the 14 young women completed all 30 days, with the remaining young woman completing 29 of the 30 expected days. Participants submitted 762 partner-specific diary entries, covering a total of 71 uniquely identified partners. The average number of entries per specific partner was 10.7 (SD = 11.1; median = 6.0; range = 1–30).

Of all partner-diary entries, less than 1% were associated with giving (3 of 762) or receiving (3 of 762) oral sex; 2% (19 of 762) were associated with vaginal sex; and about 1% with touching a partner's genitals (6 of 762), having one's genitals touched (6 of 762), or having anal sex (7 of 762). Behavior prevalence was generally similar to other studies using this population [35].

Behavior ratings and reaction times during functional magnetic resonance imaging tasks

Figure 1 displays the average likelihood each participant gave low- and high-risk decisions in the boy, alcohol, food, and household item categories and the average time it took participants to make low- and high-risk decisions in each stimulus category. As expected, participants indicated they were significantly less likely to partake in the high-risk stimuli as compared with the low-risk stimuli [main effect of risk: $F(1,13) = 40.44$; $p < .001$], with differences in the boy, food, and household item categories (Figure 1A: all $p < .05$). In addition, likelihood ratings differed by stimulus type, independent of risk level (main effect of stimulus type: $F(3,39) = 4.62$, $p < .001$). Also, a significant risk condition-by-stimulus interaction was present [$F(3,39) = 3.39$, $p = .027$], with follow-up analyses for each risk type separately revealing significant between-stimulus category differences in the mean likelihood ratings for the low-risk condition ($F(3) = 8.51$; $p < .01$) but not for the high-risk condition. Post hoc tests (all $p < .05$) suggest that mean low-risk boy stimuli were rated significantly more unlikely than the food or household item control conditions.

Across all stimulus categories, young women took significantly less time to make the high-risk decisions as compared with the low-risk decisions overall [$F(1,13) = 5.84$, $p = .03$], specifically in the boy and household item categories (Figure 1B, all $p < .05$). In addition, there was a significant risk-by-stimulus interaction on reaction times [$F(3,39) = 5.10$, $p = .005$]. Young women took significantly less time to make decisions regarding sex with a high-risk boy condition as compared with the food and household item control conditions, and there were no significant differences between the low-risk boy condition reaction time and other low-risk conditions.

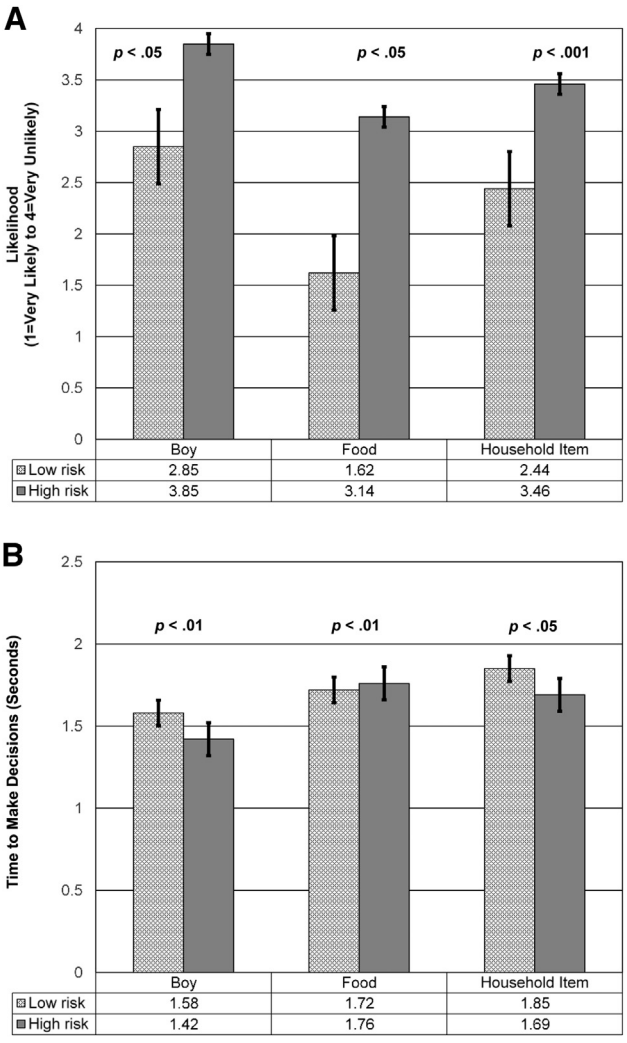

Figure 1. Average low- and high-risk decision likelihood and reaction times, by stimulus category. Panel (A) provides the average likelihood of young women's endorsing low- and high-risk decisions in the boy, alcohol, food, and household item (control) stimulus categories. In each stimulus category, young women rated the low-risk condition as significantly less likely as the high-risk condition. Panel (B) displays the average reaction time participants took to make decisions about each low- and high-risk decision in the boy, alcohol, food, and household item (control) stimulus categories. Participants took significantly more time to make decisions about low-risk decisions than high-risk decisions in the boy, alcohol, and household item categories. The alcohol condition is provided for comparison but was excluded from any functional magnetic resonance imaging contrasts.

Enrollment characteristics and likelihood ratings. Reporting a greater number of lifetime sexual partners (Pearson $R = .654$; $p = .011$), a greater number of past-year sexual partners ($R = .713$; $p = .004$) and a greater number of anticipated sexual partners in the next 5 years ($R = .558$; $p = .038$) significantly correlated with the difference between the likelihood rating of sex with the high-risk boy and sex with the low-risk boy.

Nonparametric two-sample mean difference tests indicated that sex with both the high-risk (*M*, 3.98; SD, .02 [with experience] vs. *M*, 3.70; SD, .36 [without experience]; $p = .002$) and the low-risk boy (*M*, 3.66; SD, .58 [with experience] vs. *M*, 2.04; SD, .82 [without experience]; $p = .002$) was rated significantly more likely among young women who reported having any sexual

fantasies in the 30 days before study enrollment (N = 7) as compared with young women not reporting such fantasies (N = 7). Participants with any solo masturbation before enrollment (N = 2) rated sex with the high-risk boy (*M*, 3.95; SD, .07 [with experience] vs. *M*, 3.18; SD, .14 [without experience]; $p = .022$) as significantly more likely ($p = .022$) than those without masturbation before enrollment (N = 12), and young women reporting any sexual dreams (N = 8) before enrollment rated sex with the low-risk boy (*M*, 3.68; SD, .63 [with experience] vs. *M*, 2.22; SD, .92 [without experience]; $p = .022$) as significantly more likely than young women without sexual dreams (N = 6). No psychological attributes were associated with differences in likelihood ratings or reaction times.

Diary data and likelihood ratings. A greater number of sexual thoughts and behaviors in 30-day diaries were closely associated with increased sex likelihood ratings, although only with low-risk boy stimuli. For instance, higher likelihood ratings of sex with the low-risk boy significantly correlated with higher average sexual interest in the 30 days after the scan (Pearson $R = -.654$; $p = .011$).

Nonparametric tests revealed that likelihood ratings for sex with the low risk boy were significantly greater among those who reported having their genitals touched by a partner (*M*, 3.11; SD, .92 [with experience] vs. *M*, 1.27; SD, .02 [without experience]; $p = .022$) in the 30 days after the scan as compared with young women reporting no genital touching. The difference in likelihood rating for the high-risk versus low-risk boy was also significantly greater among those who reported having their genitals touched by a partner (*M*, 2.61; SD, .81 [with experience] vs. *M*, .72; SD, .92 [without experience]; $p = .022$) in the 30 days after the scan.

Imaging results

Comparing high- and low-risk decisions. Overall, low-risk decisions elicited greater activity in several regions involved in cognitive, emotional, and sensory aspects of the decision-making process. Most notably, bilateral dorsolateral prefrontal cortex and anterior cingulate cortex (Table 3; Figure 2A) were significantly more active during low-risk than high-risk decisions. Clusters in the midbrain/substantia nigra and visual cortex were also significantly more active for low-risk decisions. No clusters were significantly more active during high-risk decisions.

Comparing sexual decisions and other decisions. Comparing the effect of risk on sexual decisions with the effect of risk on the two control decisions (food and item stimuli), differences were seen in left anterior cingulate cortex and in two regions of visual cortex, the left fusiform gyrus, and right superior occipital cortex (Figure 2B). In the anterior cingulate, high-risk decisions induced a relatively greater response for sexual decisions, compared with control conditions. On the other hand, low-risk sexual decisions were associated with relatively higher activity in the two visual clusters. Differences in ACC were evidently due to a smaller difference between low- and high-risk sexual decisions, compared with other conditions (Figure 2B). On the other hand, visual area differences were due to the opposite reason: control decisions were similarly active for low- and high-risk decisions, whereas sexual decisions had greater activity for low- compared with high-risk decisions.

Table 3
Brain regions sensitive to risk during decision making

Region	*x*	*y*	*z*	Cluster size (voxels)	Peak, *t*-stat
All low > all high					
Substantia nigra/midbrain	−14	−18	−6	398	4.71
Ventromedial ACC	−3	30	−5	244	4.73
R Middle frontal gyrus	36	42	23	455	5.32
R IFG, pars triangularis	38	37	11	418	4.96
L Middle frontal gyrus	−37	35	18	410	4.73
L Middle frontal sulcus	−32	25	17	205	4.53
Boys (high–low) > control (high–low)					
Ventromedial ACC	−4	23	−7	231	4.49
Boys (high–low) > control (high–low)					
L Fusiform gyrus	−30	−70	−15	351	4.76
R Superior occipital gyrus	16	−91	−3	903	4.89

Table depicts clusters with significantly different activity during high- and low-risk stimuli (top; no significant clusters for high > low) or clusters with significantly different activity to high- versus low-risk sexual decisions compared with high- versus low-risk control stimuli (bottom; boys [high risk–low risk] versus [food {high risk–low risk} + item {high risk–low risk}]). Significance was designated as $p < .001$ (voxel level) and clusters >108 voxels.
ACC = anterior cingulate cortex; IFG = inferior frontal gyrus; L = left; R = right.

Enrollment, diary data, and sexual decisions. Exploratory tests were performed with mean activity during high versus low sexual decision making in anterior cingulate, left fusiform gyrus, and right occipital cortex clusters and sexual behavior history, psychological characteristics, and diary reports of sexual behavior. There were no significant differences in neural activity during sexual decision making between young women reporting any sexual behavior and those reporting no sexual behavior, either in the 30 days before the study (enrollment data) or in the daily diaries. However, impulsivity scores at enrollment were significantly correlated to activity in regions showing a differential response to sexual decision making. Impulsivity was associated with relatively lower activity to high-risk sex-related decisions in fusiform gyrus ($R = -.58$, $p = .03$) and occipital cortex ($R = -.66$, $p = 01$) and overall risk-dependent activity (i.e., during all high-risk vs. all low-risk decisions) in the occipital cortex cluster ($R = -.63$, $p = .02$).

Discussion

Recent literature underscores the use of fMRI to understand how differences in reward- and control-related brain regions link to young people's decisions to participate in risk-taking behavior [13,14,36,37]. The present study is the first to use this approach with midadolescent women's sexual decision making. Our data demonstrate that it is feasible to recruit and retain a cohort of female participants to perform an fMRI task focused on making decisions about sex, on the basis of varying levels of hypothetical sexual risk, and to complete longitudinal prospective diaries. We demonstrated neural activity differences between high- and low-risk decisions and between sex-related decisions and other types of decisions. Finally, young women's likelihood ratings to sexual decisions were linked to their demographic and sexual history characteristics and their daily self-reports of sexual emotions and behaviors after the scan.

Participants were highly compliant with both the fMRI paradigm and diary entry protocols. Allowing participants to practice decision ratings on a laptop before commencing the scan alleviated anxiety, minimized movement during the task, and

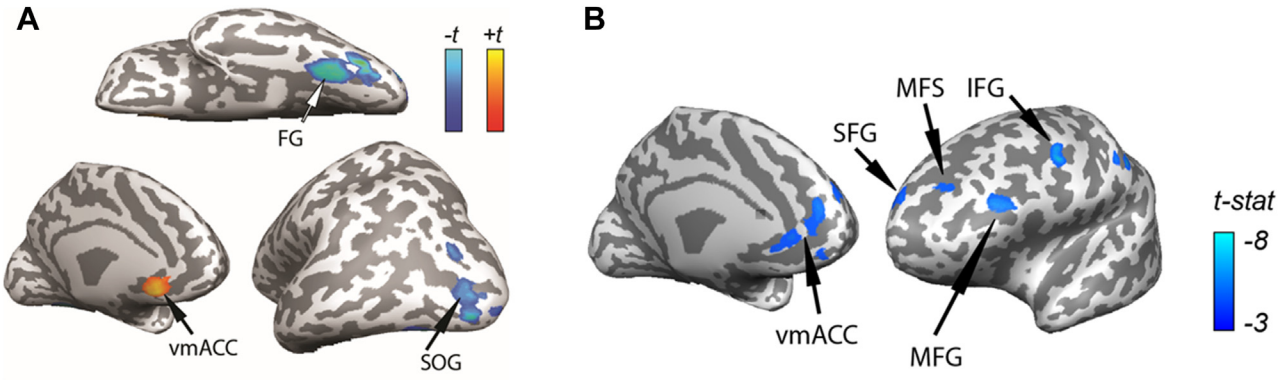

Figure 2. Functional neuroimaging results during sexual decision-making task. (A) Risk-dependent activity during adolescent decision making. Significant clusters (voxel $p < .001$; clusters >108 voxels) depicted for all high risk and all low risk. Negative t values indicate that low-risk activity is higher. (B) Differences in sexual risk-dependent decision making. Significant clusters show risk-dependent differences in activity during sexual decisions compared with control decisions (boys [high risk–low risk] versus [food {high risk–low risk} + item {high risk–low risk}]). Cluster means are depicted at the bottom. All clusters are voxel level $p < .001$ and cluster size >108 voxels. FG = fusiform gyrus; IFG = inferior frontal gyrus; MFG = middle frontal gyrus; MFS = middle frontal sulcus; SOG = superior occipital gyrus; vmACC = ventral medial anterior cingulate cortex.

provided usable imaging data. Participants submitted virtually all (99.7%) of the expected individual diaries, and we were able to capture emotional and behavioral information specific to more than 70 individual romantic/sexual partners, consistent with other longitudinal, sexual behavior diary work with similar adolescent samples [35].

We observed that low-risk decisions were associated with significantly more activity in brain regions associated with cognitive, emotional, and sensory aspects of the decision-making process (e.g., visual cortex, pre-frontal cortex, and ACC) as compared with high-risk decisions. Thus, like previous work in older samples [22–24,29], the widespread recruitment of neural substrates underlying social, cognitive, and affective systems underscores that appetitive cue-driven decision making in high- versus low-risk contexts is a multifaceted process for young women.

Another objective was to identify how risk level affected neural activity with sex-related decisions differently than other risk-related decisions. First, we observed that young women showed greater activation in brain regions associated in ACC for decisions about *high-risk sex* as compared with high-risk food or item decisions. This finding aligns with work demonstrating ACC activation in adult women while viewing similar pictures [29] and could speak to the role of sexual arousal/desire in young women's sexual decision-making process.

We additionally noted greater activity in visual clusters (left fusiform gyrus and right visual cortex) for low-risk sex decisions as compared with the other low-risk decisions. Commensurate with existing work showing visual and attention region activation in reward perception [31,32] and the role of fusiform gyrus in facial processing [38], these findings could suggest that young women's visual processing of attractiveness was more important during the low-risk decisions, whereas attractiveness was less influential in the high-risk context. Indeed, participants took less time to make decisions about the high-risk boy, which indicates that low-risk sexual decisions were actually more difficult for young women to make. Altered risk-dependent activation during sexual decisions could reflect a young woman's emerging ability to weigh growing sexual desire/arousal [39] with a larger awareness of the potential risks [17,40] and benefits of sexual participation. Sex with high-risk boys was rated as less likely than sex with low-risk boys, upholding the validity of this paradigm and supporting its use in future research. In addition to expanding the current investigation, future research could also more explicitly examine how specific types of sexual decisions (e.g., different coital and noncoital behaviors or condom use) recruit brain networks in the context of young women's actual relationships.

Past demographic or sexual characteristics or sexual behavior after the scan did not significantly predict differences in neural activation between high- and low-risk sexual decisions. However, impulsivity was negatively associated with neural activation in fusiform gyrus and visual cortex during high-risk sexual decisions. Less visual engagement of high-risk boy stimuli with increasing impulsivity may reflect that less attention was paid to attractiveness for quicker decision makers. In addition, we found that individual and partnered behavior experiences before enrollment were associated with higher likelihood ratings of sex with the high-risk boy. In addition, higher likelihood ratings of sex with the low-risk boy significantly correlated with higher average sexual interest and reports of any genital touching, in the 30 days after the scan. Combined, these data suggest a tight relationship between past/ongoing sexual experiences and evaluative components of young women's sexual decisions.

Findings are considered preliminary because of several limitations that should be addressed in future investigations. First, our small sample size precluded more detailed between-subject analyses with variables of interest. In addition, greater racial/ethnic and geographic participant diversity will be needed to extend these findings to broader community-based samples of young women as and to young men. Likewise, stimuli in future work can be altered to acknowledge greater diversity of sexuality among people of all genders. For example, the exploratory focus of the study precluded parallel assessment of young women's sexual decision making with female faces. It is possible that participants with sexual attraction to both men and women, participants with sexual attraction to only women, participants without sexual attraction, or those who question their attraction may have altered their evaluation around our inclusion of only male faces. In addition, the pilot nature of the study also rendered us unable to assess variation in levels of risk between "high-risk" and "low-risk" conditions. Expanded studies may benefit from including a greater variety of risk categories on which participants can assess risk.

Moreover, because neural activity was only assessed at one point in time, it is unclear how activation may change over time within each woman. Additionally, young women only reported sexual behaviors for 30 days, so associations with longer term developmental patterns in sexual emotions and sexual behavior could not be examined. Finally, we did not query young women on other noncoital behaviors such as kissing, holding hands, other types of genital-to-genital contact, or the use of sex toys or other sexual aids. Future studies will benefit from incorporating a more diverse array of penetrative and nonpenetrative, solo and partnered, and genital and nongenital sexual behavior that young people incorporate into their sexual repertoire.

Despite these limitations, this pilot study does suggest the feasibility and value of examining neurocognitive aspects of sexual decision making and sexual behavior in young women. Future longitudinal work can expand on this study and include hormonal and environmental measures, to determine how laboratory-measured neural data can be integrated with external and other biological factors to influence sexual decision making. An ideal investigation would include repeated fMRI measurements of sexual decision making, consider tasks to examine other aspects of sexuality (e.g., emotional control), and invoke prospective diaries over a longer period.

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