

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

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Implications and Conclusions: 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 non-sexual decisions. Future research can employ this paradigm to examine how brain function is related to subsequent sexual behavior.

Introduction

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 relationships² and balancing heightened emotions and sexual desire/arousal.³ These experiences facilitate their decisions about how and when to initiate partnered and non-partnered sexual activity.^{4,5} While the majority of 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

While 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 following puberty. During adolescence, reward-related brain regions have a heightened sensitivity relative to during young adulthood, while prefrontal, control-related brain regions do not fully mature until the early twenties.⁷⁻⁹ Some studies have proposed that this imbalance may contribute to an over-valuation of the immediate benefits of risk-taking and an under-valuation 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 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 abstinence.^{17,18} Moreover, neuroimaging studies in adults have demonstrated sexual decisions recruit a network of reward-sensitive brain regions (striatum, particularly nucleus accumbens (NAcc)) and regions involved in motivation and evaluation of reward and risk, including orbitofrontal cortex (OFC), ventromedial prefrontal cortex (vmPFC), and anterior cingulate cortex (ACC).¹⁹⁻³⁰ For instance, higher NAcc and OFC activity 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 mid-adolescent women. Specifically, we

investigated how high-risk sex decisions differed from low-risk sex decisions, relative to nonsexual decisions, and whether neural activity was linked to sexual attitudes or behaviors. Based on 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) that 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 STI. 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 were 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 following 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 five 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* (5-point, 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. In order 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; $\alpha=0.86$; e.g., “I felt happy”), *negative mood* (three-items; $\alpha=0.83$; e.g., “I felt unhappy”), *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 non-coital 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*.

fMRI 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 his 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 aged 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: very unlikely [1] to very likely [4]). The current 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 four seconds, followed by a fixation cross for 2-6 seconds (jittered inter-stimulus interval). Trials were presented in seven separate runs of 40 trials each. Before the scan, participants practiced picture ratings on a laptop.

fMRI data acquisition procedure

The MRI device was a 3T 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 3-D 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* EPI scans were conducted with the following parameters: TE = 30 ms, flip angle = 70°, FOV = 240 x 240 mm, matrix 96 x 96, in-plane resolution = 2.5 x 2.5 mm, slice thickness = 3.6 mm, gap thickness = 0 mm. Slices were acquired parallel to the AC-PC 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 anatomical volume, spatially normalized across participants to the stereotaxic space of Talairach and Tournoux (1988). Data underwent pre-image processing including 3D motion correction, spatial smoothing with a Gaussian filter (6 mm full-width at half-maximum), and temporal high-pass filter. A general linear model design matrix was created using predictors generated based on canonical 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 vs. 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) vs. (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 (SD=0.1), 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 *prior to 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 shown in Table 2. At the study level, participants completed 99.7% (419/420) of the 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 to 30).

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

Behavior Ratings and Reaction Times during fMRI tasks

Figure 1 displays the average likelihood each participant gave low- and high-risk decisions in the boy, alcohol, food and household item categories, as well as 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 to 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 (Fig. 1; Panel A: 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 to the low-risk decisions overall ($F(1,13) = 5.84$, $p = .03$), specifically in the boy and household item categories (Fig. 1; Panel B: 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 to 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.

Enrollment characteristics and likelihood ratings.

Reporting a greater number of lifetime sexual partners (Pearson's $R = 0.654$, $p = .011$), a greater number past year sexual partners ($R = 0.713$, $p = .004$) and a greater number of anticipated sexual partners in the next five years ($R = 0.558$, $p = .038$) 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 ($M = 3.98$, $SD = 0.02$ [with experience] vs. $M = 3.70$, $SD = 0.36$ [without experience]; $p = .002$) and the low-risk boy ($M = 3.66$, $SD = 0.58$ [with experience] vs. $M = 2.04$, $SD = 0.82$ [without experience]; $p = .002$) was rated significantly more likely among young women who reported having any sexual fantasies in the 30 days prior to study enrollment ($N = 7$) as compared to young women not reporting such fantasies ($N = 7$). Participants with any solo masturbation prior

to enrollment (N=2) rated sex with the *high risk* boy (M=3.95, SD=0.07 [with experience] vs. M=3.18, SD=0.14 [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) prior to enrollment rated sex with the *low-risk* boy (M=3.68, SD0.63 [with experience] vs. M=2.22, SD=0.92 [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 was 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 *following* the scan (Pearson's $R=-0.654$, $p=.011$).

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=0.92 [with experience] vs. M=1.27, SD=0.02 [without experience]; $p=.022$) in the 30 days *following* the scan as compared to young women reporting no genital touching. The difference in likelihood rating for the high-risk vs. low-risk boy was also significantly greater among those who reported having their genitals touched by a partner (M=2.61, SD=0.81 [with experience] vs. M=0.72, SD=0.92 [without experience]; $p=.022$) in the 30 days *following* 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; Fig. 2 Panel A) were significantly more active during low-risk decisions than high-risk. 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 relative to 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 (Fig. 2 Panel B). In the anterior cingulate, high-risk decisions induced a relatively greater response for sexual decisions, compared to 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 to other conditions (Fig. 2 Panel B). On the other hand, visual area differences were due to the opposite reason: while control decisions were similarly active for low- and high-risk decisions, sexual decisions had greater activity for low-risk, compared to high-risk decisions.

Enrollment, diary data and sexual decisions.

Exploratory tests were performed with mean activity during high- vs. 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 prior to 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 ($R=-.66$, $p=.01$), as well as 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 utility 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 current study is the first to utilize this approach with mid-adolescent aged 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, based on varying levels of hypothetical sexual risk, and to complete longitudinal prospective diaries. We demonstrated neural activity differences between high- and low-risk decisions, as well as 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, as well as to their daily self-reports of sexual emotions and behaviors following the scan.

Participants were highly compliant with both the fMRI paradigm and diary entry protocols. Allowing participants to practice decision ratings on a laptop prior to commencing the scan alleviated anxiety, minimized movement during the task and 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 over 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, PFC, and ACC) as compared to 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 to 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 to 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, while 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/arousal³⁹ 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 non-coital behaviors, or condom use) recruit brain networks in the context of young women's actual relationships.

Past demographic or sexual characteristics or sexual behavior following 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 prior to 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, as well as reports of any genital touching, in the 30 days following 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 well as 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 and "low risk" conditions. Expanded studies may benefit from including a greater variety of risk categories on which participants can assess risk.

Moreover, since 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 non-coital 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 non-penetrative, solo and partnered, and genital and non-genital sexual behavior 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 upon 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 (for example, emotional control), and invoke prospective diaries over a longer period of time.

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Table 1. Enrollment Characteristics (N=14)

Age (M, SD)	14.7 (0.1)
Race/ethnicity	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 (M, SD)	0.79 (1.4)
Number of sexual partners, past year (M, SD)	0.43 (0.9)
Number of predicted sexual partners, next five years (M, SD)	0.57 (0.93)
Sexual behavior history (30 days prior to 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 (0.0)
Impulsivity (M, SD)	313.5 (43.7)

Table 2. Post-Scan 30-day partnered behavior reports.

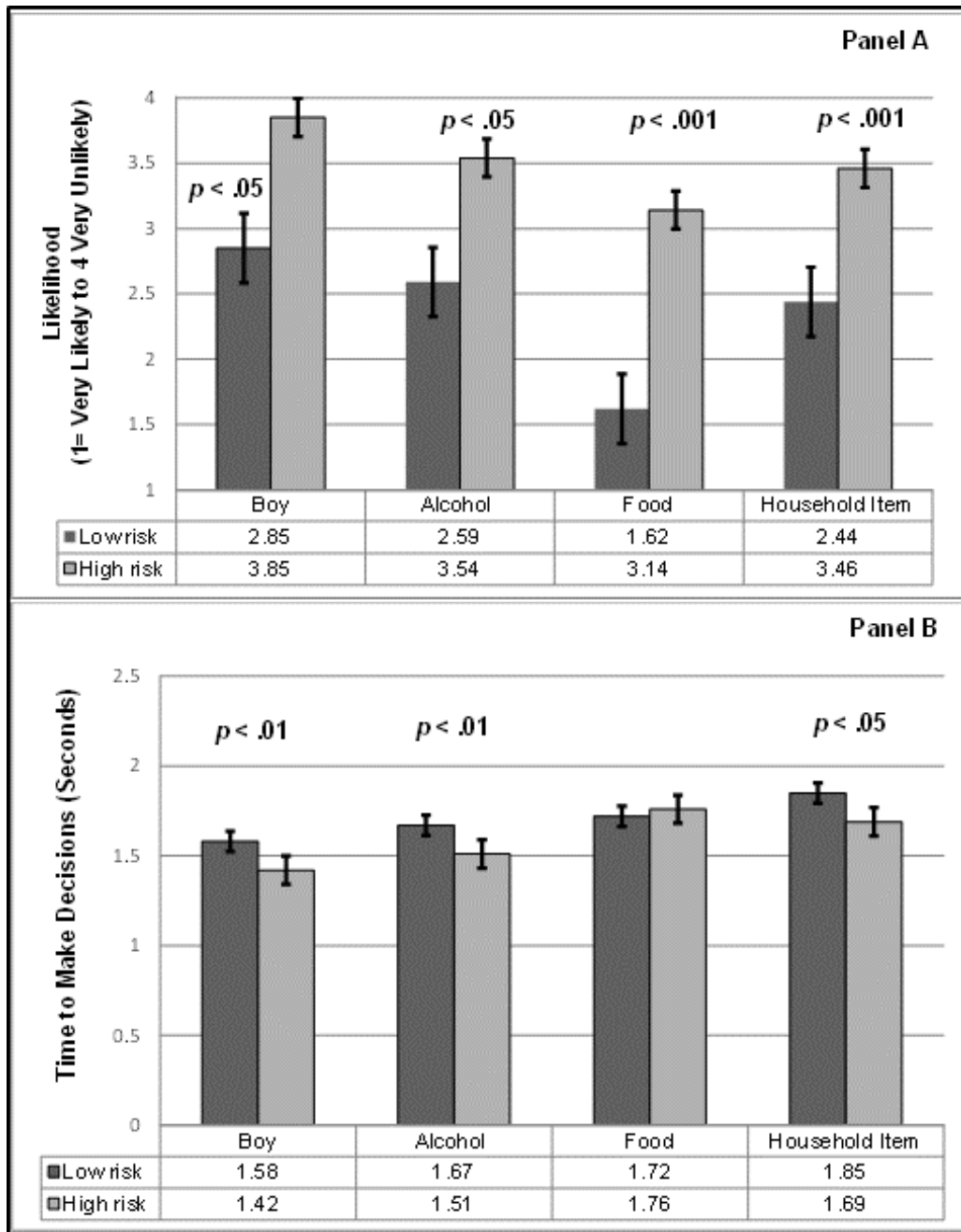
	Diary Level	Participant Level		
	(N, %)	Any Reported N (%)	Frequency (Mean, SD; Median)	Maximum Count
Touching partner's genital	7 (0.9)	3 (23.1)	0.53 (1.39); 0	5
Having one's genitals touched	4 (0.5)	2 (15.4)	0.31 (0.76); 0	2
Giving oral sex	1 (0.1)	1 (7.7)	0.07 (0.77); 0	1
Receiving oral sex	4 (0.5)	2 (15.4)	0.31 (0.85); 0	3
Vaginal sex	19 (2.5)	2 (15.4)	1.46 (3.61); 0	11
Anal sex	7 (0.9)	1 (7.7)	0.53 (1.94); 0	7

Table 3. Regions sensitive to risk during decision making.

<i>Region</i>	<i>x</i>	<i>y</i>	<i>z</i>	<i>Cluster Size (voxels)</i>	<i>Peak t-stat</i>
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- vs. low-risk sexual decisions compared to high- vs. low-risk control stimuli (bottom) [Boys (High-risk – Low-risk) vs. (Food (High-risk – Low-risk) + Item (High-risk – Low-risk))]. Significance was designated as $p < .001$ (voxel-level) and clusters > 108 voxels. Abbreviations: *R* Right; *L* Left; *ACC* anterior cingulate cortex; *IFG* Inferior frontal gyrus.

Figure 1. Average Low and High Likelihood and Reaction Times, by Stimulus Category

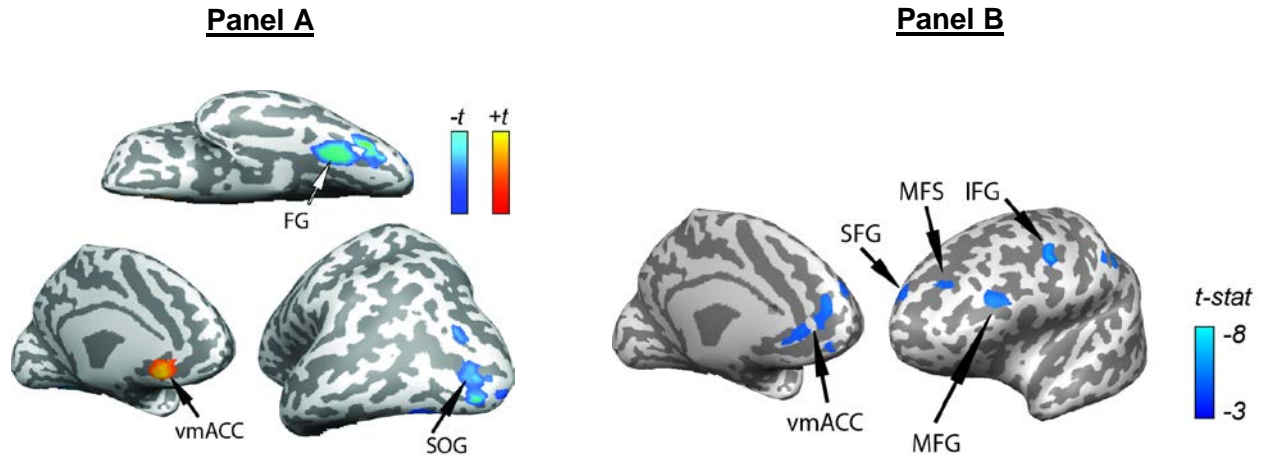


Panel A provides the average likelihood of young women's endorsing low- and high-risk decisions in the boy, alcohol, food and household item (control) stimulus categories. In each stimulus category, young women the low-risk condition as significantly less likely as the high risk condition. Panel B displays 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 and alcohol categories, and took more time to make low-risk decisions than high-risk decisions in the household item category. The alcohol condition is provided for comparison, but was excluded from any contrasts.

Figure 2. Functional neuroimaging results during sexual decision making task.

Panel A. Risk-dependent activity during adolescent decision making. Significant clusters (voxel $p < .001$; clusters > 108 voxels) depicted for all high-risk – all low-risk. Negative t-values indicate low-risk activity is higher). Abbreviations: *MFG* middle frontal gyrus; *IFG* inferior frontal gyrus; *MFS* middle frontal sulcus; *vmACC* ventral medial anterior cingulate cortex; *subNigra* substantia nigra/mid-brain.



Panel B. Differences in sexual risk-dependent decision making. Significant clusters depicted that show risk-dependent differences in activity during sexual decisions compared to control decisions [Boys (High-risk – Low-risk) vs. (Food (High-risk – Low-risk) + Item (High-risk – Lowrisk))]. Cluster means are depicted at bottom. All clusters are voxel-level $p < .001$ and cluster size > 108 voxels. Abbreviations: *vmACC* ventral medial anterior cingulate cortex; *SOG* superior occipital gyrus; *FG* fusiform gyrus.