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Mind, Brain, and Behavior
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INTRODUCTION

Caffeine is the world's most widely-used psychoactive drug (Nehlig, 1999). Nevertheless, there is a lack of research on caffeine's effects on children and adolescents. In the limited existing data, researchers have found a positive correlation between chronic caffeine use and increased risk taking in adolescents (Arria et al., 2011; Jones and Lejuez, 2005). More recently, Temple et al (2017) studied caffeine's acute impact on adolescent risk taking. While Temple's objectives were strong and timely, the methodology was flawed, resulting in insignificant and unreliable results. In the present study, we aimed to address the same leading question as Temple et al though with improved methodology.

The most salient flaw in Temple et al's methodology is the detrimentally narrow definition of risk taking. The BART, the only task that resulted in useful data, measures a specific type of risk taking that relates to impulsivity and immediate gratification. With the BART, the researchers found a sex-based risk-taking difference in the post-pubertal group. They described that boys tended to increase money earned as caffeine dose increased, while girls tended to decrease money earned as caffeine dose increased. It is remiss and irresponsible to make generalizations about gender and risk taking as they did, when their ways of measuring risk taking focussed on specific and limited types of risk taking.

Our second critique is the unreliable way in which they judged habitual caffeine use. Participants self reported with a survey and were then divided into groups of low, moderate, and high users of caffeine. Accurately dividing the participants into these groups was crucial because the researchers then drew conclusions comparing this habitual usage with BART scores after acute caffeine consumption. This method of gauging habitual caffeine use is particularly unreliable with inherent differences between the two age groups. It is unrealistic to expect pre-pubertal aged children to have the same recall and self observation as post-pubertal aged adolescents (Infante-Rivard, 2000). One way to achieve more reliable data of habitual caffeine use would be to aim for a more polarized group of participants. The researchers could have advertised to extremely frequent daily users and people who claim to never consume caffeine. With a more distinctive binary of users, comparisons drawn between caffeine's acute impact would be more clear. The acute impact of caffeine would be more drastic between reported chronic caffeine users and nonusers, rather than between the vague spectrum of low/medium/high users. Furthermore, the researchers only tested three doses of caffeine on this poorly divided spectrum of users. More variation of caffeine dose is needed to have a more complete view of caffeine's acute effects.

Furthermore, the researchers overlooked the opportunity to observe other factors that were at play in their participant pool. They made the assumption that their population would not have significant caffeine dependency and thus neglected to observe the effects of withdrawal that clearly showed up in their results. With our proposed demographic binary of low/never users versus high users, more attention could be paid to potential signs of withdrawal on performance. The researchers also neglected to collect a baseline for participants' performance on tasks, for fear of task habituation. This is a legitimate concern, but neglecting to collect baselines ended up weakening the results more than task habituation would have.

In this study, we aimed to address the same leading question as Temple et al, examining acutely administered caffeine's effect on risk-taking behavior in pre- and post-pubertal adolescents, though with improved methodology. We sought to have a more streamlined binary

of high/frequent users and low/non users of caffeine for each of the two age groups, and we included double the amount of doses. For a more comprehensive analysis of individuals' risk taking, we distinguished five different categories of risk taking. We modeled our risk taking surveys and tasks after a similar study on adults, which separated risk taking into the following five categories: ethical, financial, health, social, and recreational risks (Lang, 2011). It is crucial to test a broader range of risk taking situations when analyzing gender differences. Prior studies have found nuances within gender based differences in decision making tendencies. Hitchcock (2001) found that even though women showed overall more risk taking aversion than their male counterparts, women seemed to be more willing than males to pay a small cost for the chance of a very positive outcome, while they were far less willing to pay the cost when the cost was potentially high. The context and specifics matter. Risk taking is not a one dimensional, one definition concept.

We hypothesized that boys would have a higher baseline of risk-taking than girls in both age groups and that the pre-pubertal age group would have overall higher risk-taking tendencies than the post-pubertal. We also hypothesized that boys in both age groups would have increased risk taking with increased caffeine doses. We predicted that girls' risk taking in the pre-pubertal group would also increase with increased caffeine dose, whereas we predicted that girls' risk taking in the post-pubertal group would remain stagnant with increased dose. We hypothesized that chronic caffeine users would have a decrease in risk taking when first administered caffeine and then once on the second dose, the risk taking would follow the same correlating increase with increased dose as seen with non users. This study could provide insight into the nuances of gendered decision making, the interaction of socioeconomic status and ethnicity on substance use, and trends of risk taking and substance use through puberty.

METHODS

Participant and recruitment

Participants included 500 children, male and female, who fit into either the 7-8 year old pre-pubertal group or the 16-17 year old post-pubertal group. Additionally, 20 gender non-binary participants were welcomed. Participants were recruited via flyers, direct mailings, and Instagram ads. In an effort for an ethnically and socioeconomically diverse participant pool, we reached out to organizations in working class, middle class, and upper class communities across the Bay Area. Some of the organizations that provided the most participants include West Oakland Boys and Girls Club, El Cerrito Boys and Girls Club, Albany JCC, Berkeley Recreation Center, and the Hills Country Club. At these organizations, flyers were strategically placed next to vending machines that sold caffeinated beverages in order to capture the attention of youth who were purchasing these beverages. Eligibility criteria included: identifying as a high or very low/non user of caffeine and not taking any medications known to have significant interactions with caffeine. This study was approved by the Committee for the Protection of Human Subjects at UC Berkeley.

Experimental procedures

Participants attended laboratory sessions at the Center for Behavioral Studies on the UC Berkeley campus on four separate occasions. There were at least two months between each visit

to minimize the likelihood of task familiarity. Leading up to each visit, participants were asked to abstain from anything other than water for 4 hours before scheduled arrival. In addition, participants were asked to abstain from any caffeine consumption for 48 hours prior to arrival and to keep a log of food and beverages consumed within these 48 hours prior to each visit.

This was a double-blind placebo-controlled experiment. In order to collect baselines, half of the participants received no caffeine on their first visit, and the other half received no caffeine on the fourth visit. Excluding the participants who would receive no caffeine (placebo), participants were randomized to receive 1 mg/kg, 2 mg/kg, 3 mg/kg, or 4 mg/kg of caffeine in the beverage of their choice. Upon arrival for the first visit, participants were all given consent and assent forms to look over and sign with their legal guardians. The consent form included an option to opt out of a physical examination. Participants who opted out of the physical examination would then complete the Tanner stage and Pubertal Development Scale assessments to be classified as pre- or post-pubertal. Next, guardians filled out a demographic questionnaire while participants were measured for height and weight and went over their 48-h dietary logs with a research assistant. Participants were then offered a choice of three beverages, Lemon Fanta, grape juice, and Sprite. They were informed on the consent sheet that the beverage of their choice may have two or more of the following: Splenda, sugar, caffeine, or artificial coloring. Parents were also offered these beverages as a courtesy. To make sure the risk taking tasks were performed at peak plasma caffeine levels, participants were given the next 30 minutes to complete the risk taking questionnaires that are described in the following section. After the 30 minutes, participants completed the BART. The second, third, and fourth visits followed these same procedures, though logically excluding intake procedures (height, weight, pubertal assessments, consent forms).

Questionnaires

Intake questionnaires included the *Tanner Stage* and *Pubertal development scale*, *Caffeine usage questionnaire*, *Demographic questionnaire*, as used by Temple et al (2017).

Risk taking questionnaire: We crafted a modified version from the questionnaire used in a study on gender differences in risk assessment (Harris et al, 2006). The questionnaire included scenarios that fell into four domains of risk behavior: gambling, social decisions, health (e.g., the decision to wear or not wear sunblock), and recreation (e.g., extreme sports). Participants rated their likelihood to engage in the given activity, the probability of negative consequences, the severity of negative consequences if any should occur, and how enjoyable they might find the activity, given no negative consequences. Participants responded with a 10 point scale (1 = very unlikely; 10= very likely). The questionnaire also included questions that dealt with risky past behaviors. These few questions were adapted from a questionnaire by Gibbons and Gerrard (1995). In these questions, subjects reported the frequency in which they had actually performed behaviors that fit into the four aforementioned negative domains (gambling, recreation, health, and social).

Texas Christian University (TCU) Self-Rating Form: This final questionnaire contains many sub-categories, including decision making confidence, social conformity, anxiety, and self-esteem. It has been used in prior studies to complement measures of risk taking (Lang, 2011).

Measures

BART: This is one of the most common computer-based tasks used to measure risk-taking, and has been used previously in studies with children (Temple et al., 2017; Lejuez et al., 2003a, 2003b). Participants must decide when to stop inflating the balloon on the screen in order to save the earnings before the balloon explodes.

Caffeine preparation

For our double-blind design, a third party was outsourced to prepare and code the caffeine and placebo additives.

Analytic Plan

Once all questionnaires and the BART were completed, we used Pearson's Correlation to generate and compare risk taking scores.

RESULTS

Participant characteristics

Participants were female (n=251) and male (249), pre- (n=230) and post-pubertal (n=270). Additionally there were 20 gender non binary participants, all post-pubertal. In the end it was more effective to exclude the gender non binary participants from analyses. Participants were predominantly Hispanic (55%), with a significant percentage of African Americans (43%) and a small percentage of Caucasians (1%) and other (1%). On average, the participants were lean and from middle class families with annual income around \$45,000. See Table 1 for participant characteristics.

Table 1. Characteristics of the study population.	Pre-pubertal (n=230)	Post-pubertal (n=270)
M/F	114/116	130/140
	Mean (SEM)	Mean (SEM)
BMI Percentile	68.2(5.3)	64.3(4.8)
Age	7.5 (0.1)	16.7 (0.1)
	N (%)	N (%)
Education level of primary caregiver		
Completed high school	100 (42.4)	118 (43.7)
Some college	25 (10.8)	17 (6.2)
Completed college	88 (38.2)	100 (37)
Completed grad degree	17 (7.3)	25 (9.2)
Family income		
\$10k-49,999	140 (60)	130 (48.1)
\$50k-69,999	20 (8.6)	80 (39)
\$70k-89,999	50 (21.7)	10 (3.7)
\$90k-109,999	10 (4.3)	20 (7.4)
\$110k-139,999	4 (1.7)	15 (5.5)
\$140k+	6 (2.6)	15 (5.5)
Race		
White	2 (0.8)	4 (1.5)
Black/African American	98 (42.6)	116 (43)
Hispanic	126 (54.7)	148 (54.8)
Other	2 (0.8)	2 (.8)

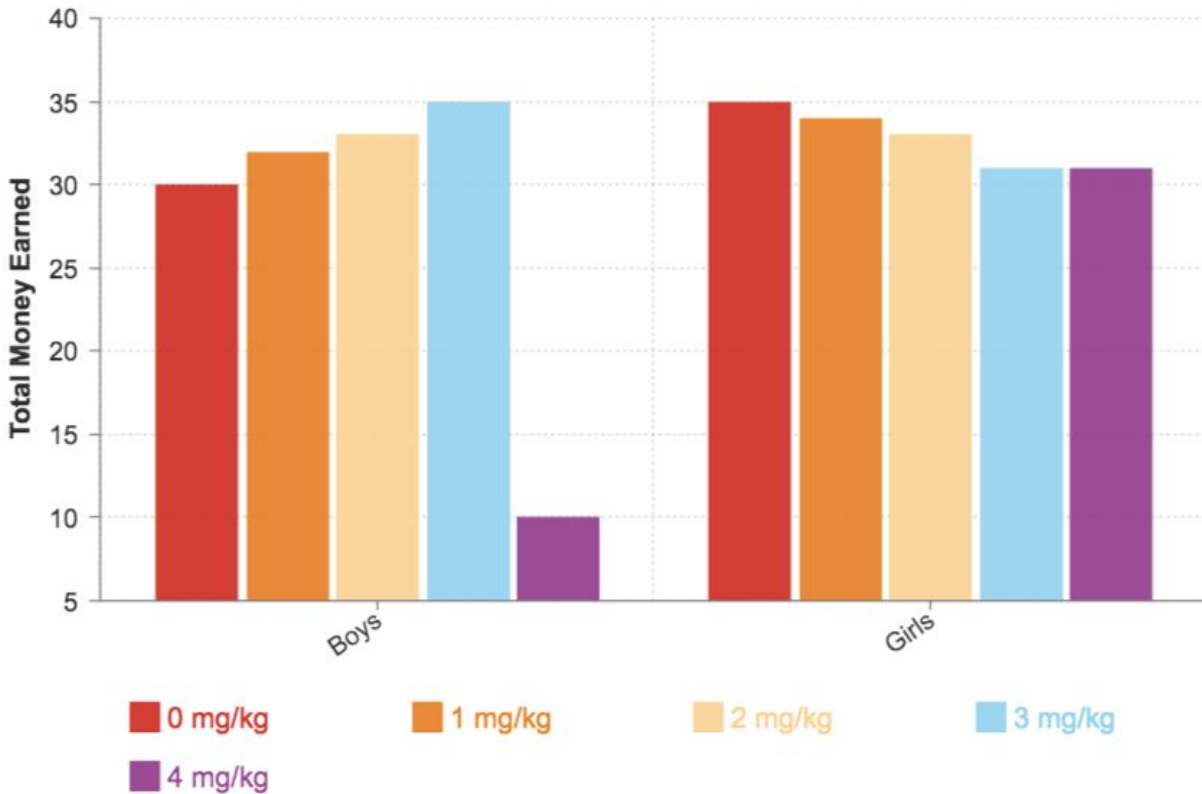


Figure 1. Mean + SEM post-pubertal participants' total earnings in BART task 30 min post consuming 0 mg/kg, 1 mg/kg, 2 mg/kg, 3 mg/kg, or 4 mg/kg of caffeine. Boys tended to increase money with increased dose but then had a sharp decrease at 4 mg/kg. Girls tended to decrease money earned with increasing caffeine dose and plateaued between 3 and 4 mg/kg.

Effects of acute caffeine and gender

As seen in Figure 1, boys tended to increase money earned with increased dose but then had a sharp decrease at 4 mg/kg. Girls tended to decrease money earned with increasing caffeine dose and plateaued between 3 and 4 mg/kg. Interestingly, the post-pubertal girls had a higher baseline performance for total money earned with 0mg/kg of caffeine than boys did.

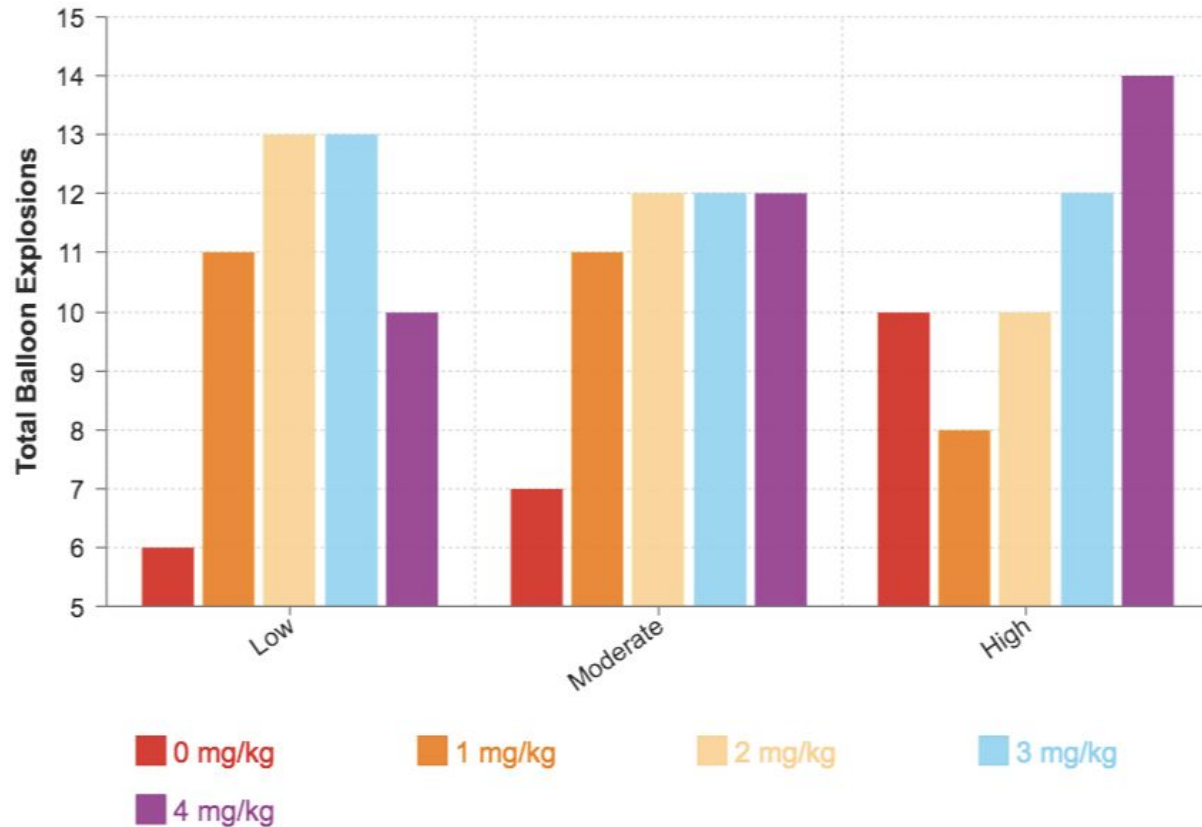


Figure 2. Mean + SEM total amount of balloon explosions on the BART task 30 minutes post consuming 0 mg/kg, 1 mg/kg, 2 mg/kg, 3 mg/kg, or 4 mg/kg of all participants, organized into non/low users, medium/moderate, or high/frequent users. Low/non users had the most immediate, extreme impact from caffeine administration and then risk taking increased with increased dose. Moderate users similarly, though less extremely, had a spike after the first administration of caffeine. High users had an inverse effect initially. Risk taking decreased with the first administration of caffeine.

Effects of acute caffeine on responses in the BART

The Pearson's Correlation showed a significant interaction between acute caffeine administration and risk taking in the BART task. As shown in Figure 2 low users of caffeine had the most dramatic impact from the first milligram of caffeine administered. The number of balloons exploded jumped from 6 to 11. Moderate users also showed this same trend though not as extreme, only jumping from 7 to 11 balloon explosions. High users had the inverse effect, as was found in Temple et al's study (2017). Balloon explosions lowered, meaning risk taking diminished, with the administration of 1 mg/kg of caffeine. Afterward, risk taking positively correlated with increased dose like it did for the moderate and low users (excluding the curious effect low users had with the drop in risk taking at 4 mg/kg). This effect on high users could indicate caffeine withdrawal. It is possible the high users wouldn't reach their peak performance level until the caffeine dependency was met.

DISCUSSION

Only recently have researchers begun to collect data on caffeine's impact on minors. The goal of this study was to further this research, picking up where Temple et al (2017) left off. Temple found a correlation between increased risk taking and increased caffeine dose in minors. We also found this to be the case. Our results furthered Temple's findings since we tested on more of a binary of low and high users. Temple had a brief mention of withdrawal, though did not dive deeply into it, making the assumption that the child and adolescent population would not yet have a caffeine dependency. This was an oversight we sought to negate. Interestingly, the results of Temple's study clearly showed caffeine withdrawal, though they neglected to read it that way. We found the same phenomenon. Frequent chronic users of caffeine had an initial drop in total balloon explosions on the BART, unlike the low and moderate groups that had increased risk taking beginning with the first administration of caffeine. This result points to the fact that the chronic users, who had abstained from caffeine for the 48 hours prior to participation, needed to have some caffeine to return to their sober level performance. This pattern, that has now been shown in two studies, speaks strongly to the nature of caffeine dependency. Adults, as well as children, can become dependent on caffeine, evident in the way that optimal, or even normal, function shifts, as the body and mind adapt to having daily caffeine.

We also aimed to add to the conversation of sex based differences in risktaking. Hitchcock (2001) previously explored nuances of women and decision making, finding exceptions to the pattern of women having less risk taking tendencies than men. Context and specifics matter. We were curious to see how our post-pubertal group of young women would compare to their male counterparts. We had the same result as Temple et al (2017) in that the female post-pubertal group's performance on the BART decreased with increased caffeine intake. However, our results also show that the female post-pubertal group had a higher initial performance rate than the male group. Also, the female group did not have the crash with 4 mg/kg as the male group did, resulting in an overall higher average of money earned across the 5 rounds for the female group. While men may be more likely to take risks, women seem to have a different way of weighing benefit/loss in situations that when added together cumulatively can result in overall higher gains. This phenomenon was seen in this study with the cumulative earnings in BART rounds, though could be mirrored on a larger scale in business earnings over a multi year period, for example. We felt it important to add to the information bank on this topic of young women and decision making under the influence of caffeine. Misinformation, or incomplete information, on this topic could be harmful to progress for women's equality in the workforce.

This study was not without weaknesses. We made an effort to include a gender non binary population, though unfortunately we were not able to work them into our results. Future studies should investigate how to best include non binary people in traditionally binary topics like gender and decision making. Another limitation we had was the hesitation of strict non consumers of caffeine. We were unable to recruit children who had never consumed caffeine. Future studies should work to define an incentive for parents to allow their children to have the controlled doses of caffeine in studies of this nature.

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