Peers Increase Late Adolescents' Exploratory Behavior and Sensitivity to Positive and Negative Feedback

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Adolescents take more risks with peers than when alone. It is not clear how peer presence affects adolescents' risky decision making, however. We used the Iowa Gambling Task (IGT)—a game used to assess decision making involving risk and reward—to examine how peers affect late adolescents' exploration of relevant environmental cues, ability to learn from the outcomes (positive and negative) of that exploration, and ability to integrate feedback to adjust behavior toward optimal long-term outcomes. One hundred and one 18- to 22-year old males (*M* = 19.8 years) were randomly assigned to play the IGT either alone or observed by peers. Late adolescents tested with observers engaged in more exploratory behavior, learned faster from both positive and negative outcomes, and evinced better task performance than those tested alone.

Most forms of risky behavior, including activities that jeopardize health and well-being, are more common during adolescence than before or after (Steinberg, 2008). Heightened risk taking during adolescence, typically in the pursuit of rewards, has been observed in several mammalian species, leading some writers to speculate that it is an evolutionarily adaptive behavior thought to encourage separation from family in order to facilitate independence, mating, and, ultimately, reproduction (Spear, 2000). Notably, human adolescents are more likely to take risks when they are with friends than when they are alone (Albert & Steinberg, 2011). This peer effect on risk taking may occur in part because peers heighten late adolescents' sensitivity to potential rewards (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Gardner & Steinberg, 2005; Smith, Steinberg, Strang, & Chein, 2015), especially immediate ones (O'Brien, Albert, Chein, & Steinberg, 2011; Weigard, Chein, Albert, Smith, & Steinberg, 2014).

Although adolescents are capable of understanding risk and the possibility of adverse outcomes associated with it (Reyna & Farley, 2006), the extent to which they utilize this information to guide decision making when they are with peers remains unclear. Although behavioral and neural data generally confirm that peers increase late adolescents' sensitivity to the anticipation and receipt of reward, less is known about the influence of peers on late adolescents' sensitivity to negative outcomes. In one relevant study, adolescents played a "Wheel of Fortune" gambling task, either alone or while believing that they were being observed by peers. Each trial involved gambling on a wheel that graphically displayed explicit information about the probabilities of winning and losing (Smith, Chein, & Steinberg, 2014). Adolescents gambled more when they thought they were being observed than when they were alone, and especially so when they were given information indicating that the probability of losing was greater than that of winning. Thus, peers may motivate adolescents to pursue opportunities for reward, even when the chances of positive outcomes are known to be slim.

Although informative, the findings from this gambling study are limited in at least two ways. First, the experimental paradigm always coupled information about the potential for loss with that about the potential for gain on any given trial—thus, it could not be determined whether the peer effect on risk taking arose because peers increased participants' sensitivity to potential rewards or because peers diminished their sensitivity to potential losses.

Second, because every trial represented an independent probabilistic event, there was no reason for the participants to use feedback about the outcomes to inform subsequent decision behavior.

Exploring whether peer contexts influence late adolescents' ability to learn from the outcomes of their decisions is important. Because risk taking is relatively more likely to occur with peers, the rewards and consequences of risky choices are also more likely to be experienced in the presence of others. Peers may not only increase adolescents' reward seeking, but also may influence the extent to which positive and negative outcomes are incorporated into learned representations that inform subsequent decision making. To our knowledge, only one study has examined adolescents' sensitivity to negative feedback as a function of social context (Segalowitz et al., 2012), showing weaker engagement of the medial prefrontal cortex (mPFC) in response to loss when adolescents were in the presence of peers than when alone. In a related study, adolescents exhibited greater activation of the ventral striatum (a reward-processing region) when they were with peers than when they were alone (Smith et al., 2014).

Although one might conclude from these neuroimaging studies that peers increase adolescents' sensitivity to rewards and decrease sensitivity to costs, and that this contributes to increases in risk taking in the presence of peers, there were no behavioral differences across the alone versus peer contexts in either study. These findings indicate is that adolescents respond differently, at a *neural* level, to positive and negative feedback when they are in social contexts than when they are alone. We do not know whether subsequent decision making changes differentially as a result of the influence of peers on the way rewards and costs are processed.

In the current study, we extend these earlier studies by examining how peers affect late adolescents' decision making in a task in which optimal performance depends on exploring different options early on and learning from positive and negative feedback. We focus on late adolescents (ages 18–22) because there is considerable evidence that the prevalence of certain real-life, high-stakes risk behaviors (e.g., binge drinking, substance use, reckless driving, and unprotected sex) is highest among 18- to 22-year olds (Shulman & Cauffman, 2014; Willoughby, Good, Adachi, Hamza, & Tavernier, 2014). Moreover, previous studies confirm that decision making among 18- to 22-year olds is significantly influenced by social context (Albert & Steinberg, 2011; Gardner & Steinberg, 2005; Mona-

han, Steinberg, & Cauffman, 2009). Although individuals in this age range are adults by legal standards, developmental evidence suggests that they are psychologically less mature than adults aged 25 and older (e.g., Steinberg et al., 2008). At the same time, these late adolescents are subject to much less "adult" supervision than younger adolescents and often reside in situations in which they are in close contact with peers (in college, or in the military), which may contribute to their higher rates of many risky behaviors, despite their relatively greater maturity. The combination of these factors—psychological immaturity, peer-rich environments, and adult freedoms—makes late adolescents an important group in which to investigate risky decision making and the influence of peers. Importantly, the current study is part of a broader program of research, funded by the U.S. Army, designed to inform military decisions about how best to group soldiers into combat teams. Accordingly, the sample is limited to late adolescent males, who disproportionately comprise squads sent into battle.

We use a modified version of the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994) to investigate how the presence of peers affects late adolescents' responses to both positive and negative feedback, as well as their ability to integrate experiences of loss and reward to optimize subsequent performance. The IGT is a widely used measure of affective decision making, which is thought to influence risk behaviors. In the version of the IGT used in this study, participants make play or pass decisions in response to one of four decks (A, B, C, or D) that is pseudorandomly preselected on each trial. As in the original IGT, two of the decks are good and generate long-term gain, while the other two are bad and generate long-term loss. The modified version of the task allowed us to separately quantify the rates at which participants learn to play more from the good decks—an indication of sensitivity to rewarding feedback—and learn to stop playing from the bad decks—an indication of sensitivity to punishing feedback (Cauffman et al., 2010). Moreover, the task allowed us to examine late adolescents' active exploration (via decisions to play rather than pass) of all decks throughout the task. In the study, we investigate whether peer presence affects late adolescent males' (1) tendency to explore relevant environmental cues, (2) ability to learn from the outcomes of that exploration, and (3) ability to integrate positive or negative feedback to adjust behavior toward optimal outcomes.

Although decision making during the IGT is not truly risky—participants are playing with pretend money—the affective and cognitive processes involved in the task are closely related to those involved in real-life risky decision making. The task was initially developed to characterize deficits in decision making in adults with lesions of the mPFC, a brain region implicated in decisions involving the pursuit of reward. People with mPFC lesions perform poorly on the IGT; they persist in pursuing a course that yields large immediate rewards despite suffering larger long-term losses (Bechara, Tranel, & Damasio, 2000). In addition to adults with mPFC damage, people who actually engage in a good deal of risky behavior in life, such as gamblers and substance users, also perform worse on the IGT than other adults (Bechara et al., 1994; Mazas, Finn, & Steinmetz, 2000; Monterosso, Ehrman, Napier, O'Brien, & Childress, 2001; Petry, 2001).

HYPOTHESES

We hypothesized that late adolescent males completing the IGT in a peer group would engage in more exploratory behavior and learn to play from the good decks at a faster rate than those completing the task alone. Because less is known about how peer presence affects late adolescents' sensitivity to punishment, we did not have a strong hypothesis about how peer presence would affect the rate at which participants learned to avoid choices that lead to loss. Regarding the extent to which individuals would integrate experience with reward and loss, we hypothesized that greater reward sensitivity among participants in the peer group would contribute to faster improvements in overall task performance (i.e., net score) compared to participants completing the task alone.

METHOD

Participants

Late adolescent males, ranging from 18- to 22-year-olds, were recruited from local colleges and the general community in a large northeastern U.S. city. Participants were also recruited through the subject pool of the home institution's introductory psychology course. In two prior studies of peer influences on late adolescents' decision making (Gardner & Steinberg, 2005; O'Brien et al., 2011), we compared groups of approximately 50 late adolescents tested alone with 50 tested while observed

by peers and found significant group differences with effect sizes of $d = .47$ and $d = .40$, respectively. Although the two prior studies used tasks other than the IGT (a video driving game and a delay discounting task, respectively) and involved two peer observers (rather than three, as is the case in this study), we based our decision in this study to compare two groups of 50 participants each on this prior research. (With an expected effect size of .40, a total sample of 100 provides more than adequate power (.99) to detect a significant effect at $p < .05$.) Analysis for the current study is based on a sample of 101 subjects who completed the IGT either alone ($n = 50$) or in a peer group (i.e., with three late adolescent male peer observers; $n = 51$). Sample recruitment was halted once a predetermined minimum of 50 subjects per experimental group were tested.

Procedure

Manipulation of social context. Flyers advertising a study of decision making invited males between the ages of 18 and 22 to call our research office to learn more about participating in the research. Each caller was told that the study could accommodate up to five people at a time and was asked whether he had any friends (other males between 18 and 22) who might be interested in participating. If a participant referred a friend to the study, our research team communicated directly with that individual to confirm his eligibility. Five participants, some of whom were friends and some strangers, were independently scheduled to participate at a set time, but none was informed that he might participate as a member of a group.

When participants arrived in the laboratory, four of them were randomly assigned to the peer condition and one was randomly assigned to participate alone. Participants in each condition were escorted to separate rooms and instructed about the study. In the peer condition, one participant was randomly selected to take the test battery, which included several tasks, including the IGT, while the other three observed. (Only findings from the IGT are presented in this article.) Study compensation for the player and the observers was $35 per person (or 2.5 research credits for those in the subject pool). In addition to this baseline compensation, all participants were informed that they could win a $15 bonus contingent on the performance of the person completing the task. All participants in the alone condition received the same information regarding compensation. Similar to previous studies,

this strategy was used to increase motivation to perform well (Cauffman et al., 2010). In reality, all participants received both the baseline and bonus compensation.

After verbal consent and random selection of a target participant, all subjects in the peer condition were left in the room for approximately 10 min to permit the group to interact naturally. Within peer groups, 37% ($n = 19$) of the target participants did not know anyone else in the group, while the rest knew at least one person. IGT performance among peer group participants did not differ as a function of how many peers they knew prior to the study. All procedures were approved by the university's institutional review board as well as that of the U.S. Army (the funding agency).

Measures

Demographics. Participants reported their age, race/ethnicity, and education. Educational attainment was used as a proxy for socioeconomic status. Participants in each condition (alone, peer group) did not differ on any demographic variables (Table 1). Ninety-one percent of subjects were current college students. The mean age for the sample was 19.8 years ($SD = 1.25$). Sixty-seven percent of the sample was White, 12% Black/African American, 15% Asian/Pacific Islander, 4% Latino, and 2% other/mixed race.

Modified Iowa Gambling Task. As previously mentioned, we used a modified version of the task, in which participants make play or pass decisions

TABLE 1
Demographic Characteristics of the Study Sample by Social Condition

| | Social Condition | |
	Alone $n = 50$	Peer $n = 51$
Age, M (SD)	19.67 (1.29)	19.94 (1.20)
Race/Ethnicity, %		
White	64.7	70.0
African American	15.7	8.0
Asian	11.8	18.0
Hispanic	3.9	4.0
Other	3.9	0
Socioeconomic status, M (SD)[a]	12.94 (0.24)	12.94 (0.31)

[a]Educational attainment was used as a proxy for socioeconomic status, where 13 = *some college* (including current college students).

on one of the four decks that are pseudorandomly preselected on each trial. As in the original IGT, two of the decks (C and D) are advantageous, generating modest immediate rewards and relatively small losses, and ultimately resulting in long-term monetary gains over repeated play. The other two decks (A and B) are disadvantageous, generating larger immediate rewards but large losses, and resulting in long-term loss over repeated play. In addition, within each type of deck (advantageous vs. disadvantageous), there is one deck in which the losses are infrequent but relatively large (e.g., −$1,150 and −$200 for the disadvantageous and advantageous decks, respectively), and one in which they are consistent and relatively small (e.g., −$250 and −$25 for the disadvantageous and advantageous decks, respectively); see Cauffman et al. (2010) for a complete description of the deck characteristics.

The payoff schedules for each deck reflected the net outcomes of the original IGT. In the original IGT, but not the version used in this study, every card in each of the decks bore an amount indicating a specific gain (e.g., $50 or $100, for good and bad decks, respectively), paired with a varying loss amount (e.g., −$250). In this study, we modified the outcome feedback, such that participants received information on the *net* gain or loss associated with each card, rather than information on both the gain and the loss separately (Bechara et al., 1994). For example, if in the original IGT the choice of Deck A produced a card indicating a simultaneous $100 gain and $250 loss, the outcome shown in our modified version of the task would be a $150 loss. This modification removes a heuristic for distinguishing between the good and bad decks, which makes the task more difficult and may encourage greater reliance on emotional cues (rather than explicit memory) to guide behavior. It also removes any advantage due to greater mathematical skill. Finally, this modification also prevents participants from unequally attending to the rewards or punishments, and instead encourages them to focus on the overall gain or loss for a given card.

Each subject starts the task with $2,000 (of pretend money) and is instructed that his goal is to win as much money as possible. Participants are told that there are good decks and bad decks in the task and that they will earn the most money by learning to play more from the good decks while avoiding the bad ones. On each trial, the computer selects a card from one of the four decks and participants are given 4 s to decide to either *play* the

card (revealing the monetary win or loss) or *pass* (in which case no feedback is provided). Subjects played a total of 120 trials, which were divided into six blocks of 20 trials each.

Iowa Gambling Task performance was operationalized in three ways: (1) percentage of good plays was calculated as the proportion of times a person decided to play (rather than pass) when presented with advantageous decks on a given block; (2) percentage of bad plays was calculated as the proportion of times a person decided to play when presented with disadvantageous decks on each task block; (3) net score was calculated as the difference between percentage of good and bad plays, with the latter being subtracted from the former.

Statistical Analysis

Latent linear growth models were fitted using the maximum likelihood estimation method in Mplus (version 7.0; Muthén & Muthén, 2012) to examine the rates at which participants (1) played, rather than passed, summed across all decks; (2) learned to play from the good decks; (3) learned to avoid the bad decks; and (4) integrated reward and loss experience to optimize net score, as well as (5) to determine whether the presence of peers affected these rates. Time (Blocks 1 through 6) was used as the repeated measure to determine the extent to which participants changed their behavior over the course of the task. Social context (alone, peer group) was specified as a between-subjects variable to explain variation in rates of change for percentage of plays (rather than passes), plays from advantageous decks, plays from disadvantageous decks, and net score.

We conceptualized playing, rather than passing, as an index of exploratory behavior, especially during the early blocks of the task, when participants have not yet learned which decks are good and which are bad. As in Cauffman et al. (2010), the rate of change across the task (i.e., slope) in percentage of good plays served as a measure of reward sensitivity, with more steeply positive slopes indicating increasing attraction to rewarding decks and quicker detection of which decks result in monetary gains over repeated play. The rate of change in percentage of bad plays across the task served as a measure of cost sensitivity, with more steeply negative slopes indicating greater sensitivity to losses produced by the disadvantageous decks. Net score was conceptualized as a measure of overall IGT performance that integrates sensitivity to gains and losses, with steeper positive slopes

indicating faster improvements in task performance.

RESULTS

Exploratory Behavior

We first examined participants' overall tendency to play (rather than pass) during each task block, summing across deck types. A repeated measures analysis of variance was conducted with social context as a between-subjects variable and time as a within-subject variable. There was a main effect of time on overall decisions to play, $F (5, 495) = 11.36$, $p < .001$; as the task progressed, the percentage of decisions to play (rather than pass) decreased, with a linear trend, $F (1, 99) = 20.71$, $p < .001$. There was no main effect of social context, $F (1, 99) = 2.68$, $p > .05$. The interaction between social context and time was marginally significant, $F (1, 99) = 3.84$, $p = .053$. We conducted independent samples t-tests to assess the influence of social context on decisions to play at each block. Overall percentage of decisions to play (rather than pass) was significantly greater in the peer condition during Blocks 1 and 2, $t (99) = −2.41$, $p < .05$ and $t (99) = −2.30$, $p < .05$, respectively (Figure 1).

Learning From Experience

Because we were interested in individual differences in performance at the end rather than at the beginning of the task, time was centered on Block 6 in the initial latent linear growth model. As a consequence, the estimated intercepts in the models correspond to predicted level of performance (in terms of good plays, bad plays, and net score) during the last task block.

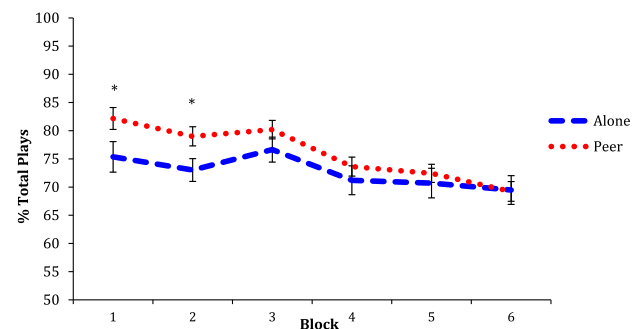*Reward sensitivity.*   With respect to plays from good decks, the model indicated that social context

FIGURE 1   Total percentage of plays across time by social condition.   *$p < .05$.

had a significant effect on the intercept (β = 9.97, SE = 3.32, p < .01); at Block 6, participants in the peer condition made a greater percentage of good plays compared to those in the alone condition. The average slope for both groups combined was positive and marginally significant (β = 1.14, SE = 0.59, p = .05), indicating that participants learned to increase their percentage of plays from good decks over time. The rate of learning to play from rewarding decks did not differ by social context, however (β = 0.64, SE = 0.83, p = .437).

Because, as noted above, individuals in the peer condition were playing at an especially high rate from the beginning of the task, we further sought to examine whether there was a potential ceiling effect with respect to sensitivity to rewarding decks for participants in the peer condition. Accordingly, we reran the model with the intercept set at Block 1 and found that participants in the peer group were indeed more likely than solo participants to play from advantageous decks in the first task block (β = 6.77, SE = 3.38, p < .05). Moreover, this model also revealed a negative and significant correlation between the initial percentage of good plays and rate of change. Thus, the heightened inclination to play from the advantageous cards during Block 1 may have created a ceiling effect for peer group participants, potentially limiting the rate of learning these participants could demonstrate by increasingly playing from rewarding decks as the task progressed.

To address this limitation, we reran the model to estimate the rate of change in advantageous plays from Block 2 through Block 6, controlling for the percentage of good plays on Block 1. Doing so improved overall model fit, and showed that, with initial play rate held constant, participants in the peer condition learned to shift behavior toward the advantageous decks at a faster rate than participants completing the task alone (β = 1.69, SE = 2.91, p < .05; Figure 2). The percentage of good plays during Block 1 had an independent effect on the reward-learning slope, indicating that making more good plays at the beginning of the task reduced the rate of learning from advantageous decks (β = −0.07, SE = 0.02, p < .001). There was no significant interaction between social context and good plays during Block 1 in the prediction of rate of learning.

Cost sensitivity. Next, we estimated the rates at which participants learned to avoid the bad decks. Being in a peer group was associated with a lower percentage of bad plays during Block 6
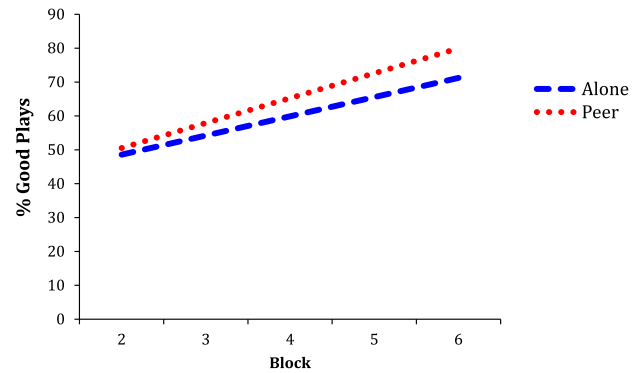

FIGURE 2   Percentage of plays from good decks across time by social condition.
Note. Results control for percentage of plays from good decks during Block 1.

(β = −10.80, SE = 5.21, p < .05). Social context also had a significant effect on the slope, (β = −3.39, SE = 1.23, p < .01), with peer group participants quicker to respond to experiences of loss and reducing their percentage of plays from disadvantageous decks at a faster rate than solo participants (Figure 3).

To examine whether social context had a significant effect on the initial percentage of plays from the disadvantageous decks, we reran the model with the intercept set at Block 1, as we did in our analysis of plays from good decks. The model showed that during the initial task block participants in the peer groups also made a greater percentage of bad plays than participants who were alone (β = 6.26, SE = 2.67, p < .05), consistent with the higher overall level of exploratory behavior evinced by participants in the peer condition. However, the overall correlation between intercept and slope, across both social contexts, was nonsignificant, meaning that participants' initial level of attraction to the disadvantageous decks (at the start
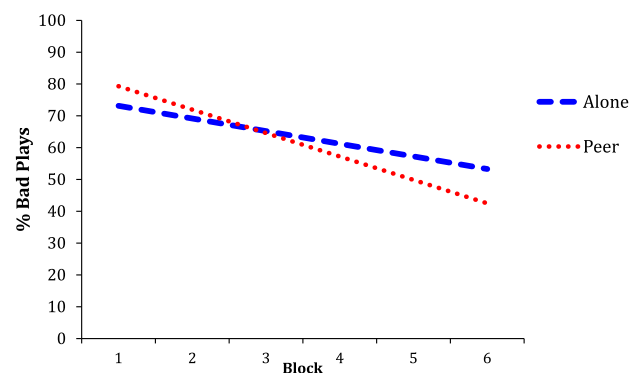

FIGURE 3   Percentage of plays from bad decks across time by social condition.

of the game) was unrelated to the rate at which they adjusted their choices in response to negative feedback over the course of the task.

Net score. Finally, overall IGT performance was examined in terms of participants' net score, which is a measure of performance that integrates sensitivity to gains and losses. For this measure, the intercept reflects the overall performance during Block 6, whereas the slope reflects the rate of improvement in overall performance over the course of the task. The model indicated a positive and significant rate of change in net score ($\beta = 5.96$, $SE = 1.00$, $p < .001$), indicating that all participants improved performance as the task progressed. However, social context had a significant effect on the rate of change ($\beta = 3.67$, $SE = 1.39$, $p < .01$), with participants in peer groups evincing faster rates of improvement in task performance over time (Figure 4). As a consequence, by the end of the task, participants in the peer condition had a higher net score than those in the alone condition ($\beta = 20.53$, $SE = 6.29$, $p < .001$).

Results of the relevant statistical analyses are summarized in Table 2.

DISCUSSION

If some level of risk taking in adolescence is inevitable, as has been argued (e.g., Steinberg, 2008), it is presumably through a process of exploration and learning, via trial and error, that late adolescents are able to eventually shift their behavior toward more prudent choices. The ability to learn from the consequences of past actions is particularly vital for young people, who, in search of novelty and opportunities for reward, often find themselves in new and unpredictable situations, often in group settings. The present study shows
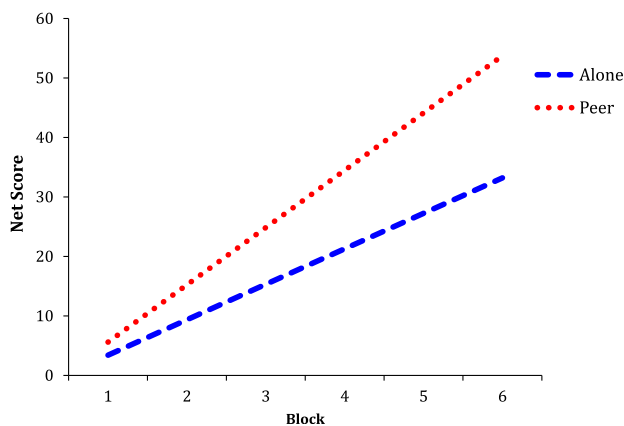

FIGURE 4   Net score across time by social condition.

that the presence of peers increases the extent to which late adolescents learn from both positive and negative experience.

Prior behavioral and neuroimaging studies have indicated that the presence of peers increases adolescents' sensitivity to the potential rewards of risky decisions (Chein et al., 2011; Gardner & Steinberg, 2005; Smith, Chein, & Steinberg, 2014; Smith, Steinberg, et al., 2015). The current study was designed to extend this previous research by examining whether the presence of peers specifically affects late adolescents' sensitivity to rewards or whether it enhances late adolescents' sensitivity to feedback more generally (both rewards and punishments). We also aimed to investigate whether social context affects the rate at which late adolescents learn to integrate experiences of reward and loss to guide decision making.

The modified version of the IGT employed in the present study afforded us the opportunity to examine exploratory behavior, by seeing how often participants sought to obtain information about the potential rewards and costs of alternative choices, by choosing to play rather than pass when given the opportunity to draw a card. Being in a peer group was associated with late adolescents' greater tendency to explore the environment, such that they made decisions to play much more frequently than solo participants during the initial blocks of the task, when they lacked information about each deck's payoff schedule. Participants in peer groups were not only more inclined than solo participants to explore the opportunities before them, but were also more responsive to feedback, even in the earliest stages of the task. It is important that the presence of peers increased both the rate at which participants shifted behavior toward making more plays from advantageous decks and the rate at which they came to avoid the disadvantageous ones. Thus, when in a peer group, late adolescents are quicker to learn which choices lead to rewards and which ones have costs. Notably, optimal decision making in the IGT requires individuals to rely on emotional cues (Bechara, Tranel, Damasio, & Damasio, 1996). Also, subjects have been found to display a preference for good decks over bad decks before they are consciously aware of which decks are good or bad (Bechara, Damasio, Tranel, & Damasio, 1997). The fact that, in our study, subjects in the peer condition performed better on the IGT therefore suggests that peer presence can affect decision making processes of which the subject is not even aware.

Our decision to make the peer observers' compensation contingent on the target adolescent's performance stemmed both from a desire to increase

TABLE 2
Unstandardized Coefficient Estimates for Models Predicting Change in Good Plays, Plays, and Net Score as a Function of Social Condition

	Good Plays		Bad Plays		Net Score	
	β	SE	β	SE	β	SE
Intercept (Block 6)	71.06***	6.37	53.28***	3.71	33.21***	4.49
Peer condition	8.72**	3.36	−10.80*	5.21	20.53***	6.29
Good plays on BL1	0.19*	0.08	—	—	—	—
Rate of change	5.74***	1.58	−3.97***	0.88	5.96***	1.00
Peer condition	1.69*	2.91	−3.39**	1.23	3.67**	1.39
Good plays on BL1	−0.07***	0.02	—	—	—	—
Variance components						
In intercept	234.49***	37.65	553.70***	97.09	841.37***	141.74
In rate of change	7.91**	2.75	25.74***	5.67	33.54***	7.12
Covariance	37.31***	8.56	110.86***	22.01	158.25***	29.91
Model fit statistics						
BIC	4004.50		5302.539		5540.58	
Chi-square (df)	41.51*** (16)		38.10** (20)		42.19** (20)	
RMSEA (90% CI)	0.13** (0.08, 0.17)		0.10 (0.05, 0.14)		0.11* (0.06, 0.15)	
CFI	0.93		0.88		0.88	
R^2 intercept	0.15		0.05		0.11	
R^2 rate of change	0.23		0.10		0.09	

Note. BL1 = Block 1; BIC = Bayesian information criterion; RMSEA = root mean square error of approximation; CI = confidence interval; CFI = comparative fit index. $N = 101$.
*$p < .05$; **$p < .01$; ***$p < .001$.

the salience of the peer context and to better mimic experiences in the real world, where adolescents' choices in groups often affect the welfare of their peers (e.g., when driving with passengers). We cannot rule out the possibility that the presence of peers increased late adolescents' rate of learning in the present study simply because their choices affected the amount of money that both they and their observers would earn—that is, adolescents' learning was faster in the group context because the stakes were in fact higher. (We note, however, that studies of adolescents in group settings using rodent models have found that peers have a greater influence on the behavior of juvenile than adult animals (Spear, 2009).) This may have motivated participants in peer groups to be more sensitive to both negative as well as positive cues in the IGT. Future studies using this paradigm might vary the extent to which participants' performance affects their observers' compensation in order to examine this issue further.

One limitation of the present study is that results are based on males and may not be generalizable to females, especially in light of evidence suggesting that males may be relatively more susceptible to peer influence (Gardner & Steinberg, 2005; Steinberg & Monahan, 2007; Sumter, Bokhorst, Steinberg, & Westenberg, 2009). Another limitation of our findings is that they are based on older adolescents,

between 18 and 22 years old. It is possible that the presence of peers would evoke different patterns of outcome sensitivity, and overall IGT performance, at different ages, although previous studies have found an even stronger peer effect on risk taking in middle adolescence (e.g., Gardner & Steinberg, 2005). Lastly, relative to national race estimates in the United States, our study sample included a high percentage of Asian Americans and low percentage of Hispanics. This demographic profile is likely because the majority of our sample were college students, and U.S. college enrollment rates are highest for Asians and lowest for Hispanics. Thus, our findings may only be generalizable to college students (who comprise approximately two-thirds of all late adolescents in the United States).

Identifying the mechanisms through which peer presence heightens late adolescents' sensitivity to feedback is beyond the scope of this study, and a limitation that should be the subject of future work in this area. One possibility consistent with our results is that the presence of peers may enhance late adolescents' ability to learn from both rewarding and punishing events in a way that shifts behavior toward the most desirable long-term outcome. One way to interpret these findings is through an evolutionary lens; it would be adaptive for individuals to be as responsive to threatening events as they are to

rewarding ones in order to increase their chances of survival. An important implication of this study is that behavior in peer groups that we and others have interpreted as reflecting a peer effect on reward sensitivity may be more properly characterized as an effect on "outcome sensitivity." Although late adolescents may engage in relatively more risky behavior when they are with their peers, they also may learn more about the environment in group settings than when they are alone. In this regard, our findings suggest that spending time with peers during adolescence may be a double-edged sword, increasing the odds that adolescents will behave recklessly, but also that they will learn from the consequences of their actions.

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