Under Scrutiny:
Comparing the Effects of Virtual
Peer Ratings on Risk-Taking

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Abstract

Adolescents, compared to other age groups, disproportionately choose to engage in behaviours that endanger them or others, especially in the presence of peers. The dual-systems model attributes this heightened risk-taking to a rapidly developing reward system that overpowers a slower-maturing cognitive control system in situations where excitement is high. The current study uses a new virtual peer paradigm to compare the effects of positive evaluation, negative evaluation, and heightened non-social rewards on risk-taking. Participants (n = 73, ages 12-30, 65.75% women) were randomly assigned to conditions and completed a risk-taking task in two contexts: under low arousal (alone), and under high arousal (watched by a virtual peer). Participants who received a negative evaluation evinced significantly greater risk-taking than those who received a positive evaluation when watched. This effect was not observed when participants completed the task alone. Results suggest, preliminarily, that negative social evaluative contexts may be more likely to lead to increased risk-taking than positive ones.

Keywords: adolescent risk-taking, dual-systems model, social context, BART, peer effect

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TABLE OF CONTENTS

List of Tables

List of Figures

List of Appendices

Under scrutiny: Comparing the effects of virtual peer ratings on risk-taking

More than any other age group, adolescents choose to engage in behaviours that can endanger them and others. Such behaviours include dangerous driving (Statistics Canada, 2019; WHO, 2018), the onset of use and abuse of illicit drugs (Kandel et al., 1992; Wagner & Anthony, 2002), alcohol consumption (Siqueira & Smith, 2015), and engagement in self-harm or assault (Public Health Agency of Canada, 2008; Ray et al., 2020). One social neuroscience theory seeking to explain this adolescent tendency to engage in risky activities is the dual-systems model of adolescent risk-taking (Shulman et al., 2016; Steinberg, 2008). The model posits that, in exciting circumstances, the drive to pursue rewards (despite risks) is more likely to overpower a still developing cognitive control system in adolescents more so than in adults. The current study uses a *virtual peer paradigm* to induce different states of excitement and examines the impact, if any, on adolescent (*vs.* adult) risk-taking in a computer-based task.

The dual-systems model of risk-taking

An early, and still pervasive, theory attempting to explain heightened risk-taking in adolescence attributes the phenomenon to two common biases in adolescents' thinking: their tendency (a) to believe they are under the intense scrutiny of others (i.e., imaginary audience), and (b) to possess the impression they are truly unique and, to some extent, invulnerable (i.e., personal fable; Elkind, 1967). This latter misconception has been especially influential, both in research and society in general. It is still widely believed that adolescents, compared to adults, feel invincible in the face of danger, underestimate the likelihood of negative outcomes when engaging in risky behaviours or, to a certain extent, that they are unaware of the dangers.

However, studies examining this theory fail to find support for the notion that adolescents experience a greater sense of invulnerability than do adults. For instance, Millstein and Halpern-Felsher (2002a) investigated risk perceptions (i.e., participants' beliefs about their likelihood of experiencing specific outcomes), and feelings of invulnerability, (i.e., assigning a likelihood of 0 to any of these outcomes), in three subgroups of adolescents and young adults. Overall, adolescents tended to overestimate the risks to themselves, and had significantly lower rates of feelings of invulnerability compared to adults. Similarly, Fischhoff et al. (2000), using a representative sample of United States youth (mean age of 15.8), found that adolescents reliably overestimate their likelihood of adverse life events, such as being sent to jail or dying. These results portray youth as cognizant of their own vulnerability. Thus, heightened adolescent risk-taking must be due to something else.

More recently, a new theory that draws on evidence from developmental psychology and developmental social neuroscience has been proposed to explain adolescent risk-taking. This "dual-systems model" attributes increased risk-taking during adolescence to the distinct patterns of development in two brain systems that undergo change across the adolescent and young adult periods. The first is the reward system, which consists of dopaminergic pathways linking subcortical regions such as the nucleus accumbens (i.e., ventral striatum) and amygdala (Steinberg, 2008). It undergoes rapid transformation during adolescence (Casey et al., 2011; Mills et al., 2013). Dopaminergic innervations proliferate to the prefrontal cortex as well as within the limbic structures themselves immediately prior to puberty. This sudden growth is followed by pruning during adolescence until dopaminergic density reaches adult levels by young adulthood (Chambers et al., 2003; Montague et al., 1999; Spear, 2000). These structural changes are believed to sensitize adolescents to rewards—especially social rewards—within their environment, which promotes approach behaviors and facilitates learning (Shulman et al., 2016; Steinberg, 2008). Moreover, this neurological maturation has been proposed as the mechanism behind heightened exploratory and reckless behaviors in adolescence (Mills et al., 2013; Shulman et al., 2016; Steinberg, 2008).

The second system highlighted by the dual-systems model is the cognitive control system. This system, comprising the prefrontal cortex and its connections to other regions (Chambers et al., 2003; Mills et al., 2013; Steinberg, 2008), is responsible for the monitoring and selection of stimuli in the environment, and for behaviour to act on or respond to that environment (i.e., executive functions; Shallice, 1982). In contrast to the reward system, the cognitive control system follows a more linear, gradual pattern of development across adolescence and into early adulthood. At the neurological level, development in this system is accomplished through heavy synaptic pruning within the prefrontal cortex. Pruning allows for less diffuse activation during cognitive control tasks, leading to more efficient and refined executive functions, such as working memory, delayed gratification and impulse control (Bunge & Wright, 2007). In addition, myelination of pathways linking the prefrontal cortex to limbic structures and other cortical areas increases linearly during adolescence, and continues into young adulthood (Miller et al., 2012). This increased myelination facilitates synchronization of various brain areas and is implicated in processes such as attention and the ability to remember long term goals (Pajevic et al., 2014). Hence, as adolescents progress toward adulthood, strengthened executive processes such as impulse control, working memory and emotional regulation allow better coordination of individuals' long-term goals and immediate behaviors. This often consists of forgoing an immediate reward in favor of a delayed one. The decline from late adolescence to adulthood in risk-taking is attributed, in part, to the growing ability to resist urges to pursue immediate rewards (e.g., unprotected sex) in favor of long-term goals (e.g., remain free of pregnancies and sexually transmitted infections) thanks to the maturation of the cognitive control system.

In this respect, the dual-systems model offers a nuanced perspective on adolescent risk-taking. The model does not suggest the dopaminergic system always overpowers the cognitive control system in adolescence; positing instead that it more likely to happen under conditions that trigger strong emotional responses and inputs from the reward system (Steinberg, 2008). When reward salience is low, and emotional arousal is low, adolescents have been shown to display adult-like responses to questionnaires and tasks assessing risk perception, risk judgment and risk-taking (Beyth-Marom et al., 1993; Figner et al., 2009; Fishhoff et al., 2000; Gardner & Steinberg, 2005; Millstein & Halpern-Felsher, 2002a, 2002b). However, when salience is high, and emotional arousal is high, adolescents display increased risk-taking compared to adults (Figner et al., 2009; Gardner & Steinberg, 2005).

The dual-systems model provides a plausible account for the apparent discrepancy between adolescents' adult-like responses in calm settings (e.g., when filling out questionnaires; Beyth-Marom et al., 1993; Fishhoff et al., 2000; Millstein & Halpern-Felsher, 2002a, 2002b) and their increased propensity to take risks in emotionally arousing conditions, such as socializing (e.g., unprotected sex, binge drinking, substance abuse; Kandel et al., 1992; Siqueira & Smith, 2015; Steinberg, 2008; Wagner & Anthony, 2002). Indeed, real-world risk-taking takes place in contexts that are drastically different from a laboratory environment. Risky choices are made under exciting circumstances, and with little or no deliberation (Steinberg, 2008). Decision-making in this context is referred to as intuitive, hot (Epstein et al., 1996; Shulman & Cauffman, 2014), implicit (Evans, 2003), or unconscious (Dijksterhuis, 2004). This markedly differs from analytical thinking, or decision-making under "cool" conditions, where one evaluates options under low arousal, and there is enough time for the assessment of different options (Evans, 2003). Research settings using questionnaires likely tap into this latter type of reasoning (i.e., analytical thinking); and do not elicit the kind of decision-making that truly differentiates adolescents from adults.

To summarize, the dual-systems model posits that rapid growth of the brain's dopaminergic system sensitizes adolescents to rewards, while a still developing cognitive control system lacks the maturity to rein in potentially dangerous impulses (Shulman et al., 2016; Steinberg, 2008). Behaviourally, the rapid increased sensitization to rewards actively motivates adolescents to explore and experiment with activities bringing adolescents pleasure, including risky activities (e.g., sex, drugs, alcohol). As the cognitive control system matures, executive functions (e.g., working memory, attention, emotional regulation) are refined. This allows for improved selection and monitoring of emotions and behaviours, ultimately contributing to a reduction in risky behaviour. Newer articulations of the dual-systems model highlight that adolescents are more likely than adults to engage in risky behavior specifically under conditions that excite the reward system, thereby eliciting strong impulses that a still immature cognitive control system might fail to regulate (Shulman et al., 2016).

Context matters: hot vs. cold decision-making

In a test of this model, Figner et al., (2009) designed two versions of a card game meant to modulate the degree to which the reward system was engaged during risky decisions. They then compared the performance of adolescents and adults on both versions of the card game. In the version of the Columbia Card Task meant to engage the reward system—the "hot" version—feedback was immediate. In the cold version, meant to elicit more deliberative decision-making processes, feedback was delayed until the end of all trials. As a manipulation check, participants' arousal state (or excitement) was assessed using galvanic skin conductance (or sweat response). Participants displayed increased physiological arousal in the hot (*vs.* cold) version of the task, but not during baseline. This suggests all participants were sensitive to the manipulation, and that arousal was higher during the hot version of the task. Results for task performance showed that adolescents displayed adult-like decision-making abilities in the cold version of the task (i.e., when excitement was low), but greater risk-taking than adults in the hot version of the task (i.e., when excitement was high). Additionally, adolescent risk-taking was related to lower information use in the high-arousal task, while adults used all the available information in both versions of the task. These results support the dual-system model in that adolescents' (but not adults') risk-taking was heightened in the hot version of the task. Whereas adolescents displayed adult-like capacities in cool environments, they lacked adequate mechanisms to regulate their excitement in situations of heightened arousal.

A particularly salient and arousing context for adolescents is the presence of peers (Chein et al., 2011; Steinberg, 2008). As such, the dual systems model predicts that the presence of peers should induce greater risk-taking among adolescents than among adults. Consistent with this prediction, adolescents are more likely to engage in illegal activities with others than when alone (Reiss & Farrington, 1991). Moreover, many risky activities adolescents engage in cannot be committed alone (e.g., unprotected sex, involvement in physical fights or assault; Public Health Agency of Canada, 2008; Ray et al., 2020) or are tightly associated with peer interactions (e.g., binge drinking, impaired and dangerous driving; Siqueira & Smith, 2015). The tendency for adolescents—but not adults—to engage in more risk-taking when completing tasks with peers (*vs.* alone) has also been observed in laboratory tasks (Breiner et al., 2018; Gardner & Steinberg, 2005; Silva et al., 2015). This phenomenon, coined the "peer effect" (Gardner &

Steinberg, 2005; Silva et al., 2015) is not restricted to human adolescents and may be a particularly adaptive behaviour in social animals (Spear, 2000).

Social context and risk-taking

Evolutionary psychologists (Ellis et al., 2012) have proposed that adolescent risk-taking evolved because it served adaptive functions in the ancestral environment. Sensitization to social status, sexual partners, and resources confers competitive advantages to youth progressing towards adulthood. Indeed, adolescence is a period of experimentation and transition into adult reproductive and societal roles (Schlegel, 1995). Around the time of puberty, adolescents enter a competitive arena where they must learn to navigate peer relationships, negotiate their access to various resources, and attract mates (Ellis et al., 2012). Increased environment exploration outside the family home promotes greater self-reliance, allows the development of social skills, and may decrease the risk of mating with kin. Studies of other animals observe adolescent peaks in risk-taking, and/or novelty-seeking behaviors. In particular, adolescent mice, compared to juveniles and adults, have been observed to spend more time exploring areas of mazes considered more risky due to the lack of walls and height above the ground (e.g., Macrì et al., 2002). Similarly, risk-taking in the presence of peers appears socially or sexually advantageous. For instance, increased male risk-taking provides bold guppies with better access to mating opportunities, as females prefer risk-prone males (Dugatkin, 2013). Risk-taking may also be strategic in times when the competition for single mates tends to be at its highest (i.e., in adolescence; Ellis et al., 2012), especially among those who feel they are at a disadvantage (i.e., those who feel other low risk options are not likely to secure them a mate; Mishra et al., 2014). Given the importance of social life in human cultures around the world, it should not be surprising that these same adaptive behaviours in the presence of peers in other species are also common in human adolescents.

Neuroimaging studies of the peer effect in human adolescents support a heightened salience of social cues in adolescence compared to adulthood, and link peer presence to heightened risk-taking. For instance, Chein et al. (2011) observed brain activation patterns while adolescents, young adults, and adults performed a driving task either alone or while being observed by two same-aged peers. Risk-taking was measured as the percentage of decisions to cross (*vs.* stop) an intersection at a yellow light and the number of car crashes. Adolescents (*vs.* young adults and adults) engaged in greater risk-taking when watched by peers. Moreover, they demonstrated greater ventral striatum activation, a brain region associated with the processing of rewards, when deciding to cross the intersection when their peers were watching (Chein et al., 2011). The heightened activation of reward-related brain regions in adolescents suggests peer presence during a risky behaviour is more arousing and/or rewarding for adolescents than for adults. Furthermore, these results support the idea that adolescents are only more prone to risk-taking than adults under conditions of increased arousal (e.g., when under the scrutiny of their peers).

Research finds that this influence of peers on adolescents' behaviour is observable under a variety of circumstances. For example, heightened risk-taking (in the form of gambling, virtual driving, or drinking) occurred while participants were directly interacting with their peers (Gardner & Steinberg, 2005), were simply observed by peers (Silva et al., 2015), without peers being physically present with participants during laboratory tasks (Chein et al., 2011), and even with a non-existent ("virtual") peer (Breiner et al., 2018). The fact that even a virtual peer can lead adolescents to modulate their behaviour lends considerable credit to the idea that adolescents are particularly attuned to social contexts.

The valence of the social context for risk-taking

To date, the bulk of research examining the peer effect treats the context of peer presence as fun and rewarding. In reality, that is not always the case. Even within a peer group, there is often competition and conflict (Schneider et al., 2005), both of which are likely to increase adolescents' arousal. For instance, in a virtual chatroom interaction paradigm, adolescents' pupil diameters were significantly enlarged (a marker of arousal) when rejected by peers (regardless of gender), as well as when selected by same-gendered peers (Silk et al., 2012). Moreover, a few studies have highlighted increased risk-taking following rejection from peer groups (Buelow & Wirth, 2017; Peake et al., 2013). In particular, when excluded from an online ball-tossing game with same-aged peers, adolescents have engaged in increased risk-taking in some tasks (e.g., stoplight, Iowa gambling task; Buelow & Wirth, 2017; Peake et al., 2013), but not in others (i.e., Balloon analogue risk task; Buelow & Wirth, 2017). Hence, it is unclear whether emotional arousal due to negative experiences with peers also leads to increased risk-taking in adolescence.

Furthermore, negative social interactions are often overlooked in studies comparing social and non-social stimuli, with authors preferring to focus on the similarities between positive social and non-social rewards. In one study that compared responses to social vs. non-social stimuli, researchers examined event-related potentials (ERP), an electrical signal detected on the scalp that occurs in response to specific stimuli, on two tasks involving monetary rewards and social rewards respectively (Ait Oumeziane et al., 2017). The task involved pressing a button when a target appeared. If participants pressed the button before or after the target was presented, they lost money ($0.20) or received negative social feedback (thumbs down) on their performance. If participants pressed the button when the target was displayed on screen, they gained money ($0.40) or received positive social feedback (thumbs up) on their performance. Researchers noted that both the monetary task and the social task elicited similar event-related potentials, at similar latencies and in the same scalp regions, suggesting monetary and social rewards were processed in similar ways (Ait Oumeziane et al., 2017). However, this particular study focused on reward sensitivity in adults only, and did not measure behavioural risk-taking. Other developmental neuroimaging studies suggest that positive social (Chein et al., 2011) and non-social rewards (Braams et al., 2015; Van Leijenhorst, Zanolie, et al., 2010) activate the same reward regions (e.g., ventral striatum, ventral medial frontal cortex), and both, in isolation, have been associated with increased risk-taking, especially in adolescence (Braams et al., 2015; Chein et al., 2011; Van Leijenhorst, Gunther Moor, et al., 2010; Van Leijenhorst, Zanolie, et al., 2010). This would suggest that perhaps peer acceptance is processed in similar ways to monetary rewards, but leaves open the question as to whether negative interactions with peers would lead to the same result.

The current study

Consequently, the current study seeks to better characterize the way in which different types of arousal affect adolescent risk-taking. We designed a novel *virtual peer paradigm* which allows the manipulation of environmental factors thought to promote risk-taking behaviours in adolescence (i.e., presence of a virtual peer and non-social rewards). More specifically, participants could: (a) receive positive feedback from a virtual peer (i.e., the positive social condition), (b) receive negative feedback from a virtual peer (i.e., the negative social condition), or (c) not receive any feedback, but have the opportunity to earn more rewards (i.e., the non-social condition). Following their assignment to conditions, participants completed a risk-taking task twice, once under low arousal, and once under high arousal. We sought to examine how these three different conditions (positive social, negative social, and non-social) and different contexts (high arousal and low arousal) affect risk-taking.

In line with the dual-systems theory, we expected heightened risk-taking in the high arousal context compared to the low arousal context when collapsing across conditions. Moreover, we expect this effect to be more pronounced for adolescents than for adults. Given the especially arousing and rewarding context of peers in adolescence, we expect the effect of arousal on risk-taking to be greater in the positive social condition than in the non-social condition. In contrast, because it is a novel manipulation, we have no hypothesis as to the relative magnitude of the effect of arousal in the negative social condition.

Method

The current study was part of a larger project examining risk-taking in adolescence. The procedure entailed the collection of physiological data, questionnaire data, and the completion of computerized tasks. The methods were reviewed and approved by the Research Ethics Board at the university where the data were collected.

Participants

Participants were recruited in the community through numerous means, including interactions with research assistants at community events and at a local college, flyers posted on community boards, online advertising, and communication with local high school staff. The data set for the current analysis consists of 73 participants, ages 12–29 (M_{age}= 20.52, *SD* = 4.95, 48 women). The majority of our participants identified as White (64.8%). Participants aged 16 and over provided informed consent, and participants younger than 16 provided informed assent. Parents of participants under 16 provided informed consent. Participants under 18 years old were compensated with $15, and participants 18 years old or over were compensated with $25 for participating in the study. University students could choose to forfeit monetary compensation for course credit. In an effort to motivate participants to try their best when performing the tasks, they were told that if their performance was better than the average participant, they could earn a bonus prize at the end of the study. In reality, all participants received a bonus prize. They had the opportunity to either (a) choose a $5 gift card from Bulk Barn, Tim Hortons or Landmark Cinemas, or (b) gamble for a chance to win $100 in gift cards from these same three businesses (1/20 chance of winning).

Procedure

Participants completed a test battery in a laboratory session lasting approximately two hours. The session consisted of a first phase in which preparations were made to record electrophysiology, and a second phase in which the participant completed a series of questionnaires and computer-based tasks while seated at a computer desk. Only the relevant components of the study battery are detailed here.

The Virtual Peer Rating Paradigm. The Virtual Peer Rating Paradigm (VPRP) was designed to investigate the effects of peer approval versus peer non-approval on risk-taking (see Figure 1). Participants were first asked to create a social media profile. A research assistant took a picture of the participant in front of a grey backdrop to upload to the profile. Participants then answered three brief questions about their favourite hobby, ideal vacation and preferred activity. Before moving on to the next task, participants were asked whether they agreed with the profile they had just created, and were given the option to change the information contained in the profile. Once participants were satisfied with their profile, they were asked to rate the social profiles of three other peers (i.e., "On a scale from 1 to 5, how much would like to meet this person?") The peer profile pictures were selected from two databases of portraits taken for use in research. Photographs of adults were selected from the Chicago Face database (Ma et al., 2015); and photographs of minors were selected from the National Institute of Mental Health Child Emotional Faces Picture Set (Egger et al., 2011). A total of 24 peer profiles were created, grouped according to age (three profiles for four age groups: 12 to 14 years old, 15 to 17 years old, 18 to 22 years old, and 23 to 30 years old) and biological sex (man/boy or woman/girl). All profiles provided the same type of information as included in the participant's social profile (i.e., favourite hobby, ideal vacation and preferred activity). Peer profiles were matched on participants' self-reported gender and age group. Of note, one of the three peer profiles presented was specifically designed to be perceived as higher status (i.e., more attractive) and the two other profiles as low status peers (i.e., less attractive). To assess the attractiveness of peer profile pictures, we conducted a small study with 75 MTurk participants. With the exception of the girls aged 12 to 14 years old, the pictures that were rated higher in terms of attractiveness for each age group were retained for the high-status peer profiles, and the two lowest ratings were chosen for the low-status peers. We replaced the lowest ranked girls in the 12 to 14 years old category with the next two lowest because the last two were noticeably overweight, and we did not want this factor to be salient.

Following the rating of the three peer profiles, all participants completed a five-minute rest period during which physiological data were recorded for use as a baseline measure. To standardize participants' experience of the rest period, they were instructed to watch a video of stars slowly fading away.

After the baseline, participants were randomly assigned (by the software program) to one of three conditions: positive social, negative social, or non-social. Importantly, participants' previous rating of the peer profile had no impact on participants' assignment to conditions. This step was only created to increase the believability of our experimental paradigm.

Positive social and negative social conditions. In both the positive and negative social conditions, participants were told that one of the profiles they previously rated was that of an actual participant completing the study "upstairs". Participants were led to believe they would later meet this person to discuss the study tasks. Participants were then shown the profile of the peer, and told the peer had also rated their profile. In the positive social condition, participants received a rating of five out of five stars; in the negative social condition they received a rating of three out of five stars.

Non-social condition. Participants in the non-social condition were not given any feedback about their profile.

Risk-taking in a low vs. high arousal context. All participants then completed a risk-taking task. The risk-taking task (Balloon Analogue Risk Task or BART; Lejuez et al., 2002) used in our paradigm is a widely used and established measure of risk-taking. In the BART participants are presented with a series of balloons (one at a time) which they can inflate gradually by hitting a button to "pump" the balloon. The objective of the BART is to inflate a balloon as much as possible, without bursting it. Every pump earns a small reward. In each trial (each balloon) the participant can cash out and keep the rewards earned if they choose to do so before the balloon explodes. However, if the balloon explodes, they lose all their earnings from that trial. Participants do not know at what point the balloon will burst. Thus, a greater willingness to continue to pump is regarded as reflecting a greater tendency toward risk-taking.

All participants completed the BART twice, once under high arousal, and once under low arousal contexts. The means by which low vs. high arousal was manipulated differed depending on condition (see Figure 1). For those in the social conditions (positive or negative), high arousal was induced by telling the participant that the peer was watching his or her performance remotely. This was indicated by a photograph of the peer appearing in the corner of the screen. Low arousal was induced by having the participant complete the BART unobserved (i.e., the peer in the photograph was crossed out). In the *low arousal context*, the amount of tokens earned per pump (0.05 token per pump) was held constant across all conditions (i.e., positive social, negative social and non-social). For those in the non-social condition, high arousal was induced by increasing the reward amounts on the BART by a factor of three (i.e., participants earned 0.15 tokens per pump). Participants were told before the task whether they would be observed (high arousal) or not (low arousal), or for those in the non-social condition, whether they would earn the base amount (low arousal) or tripled rewards (high arousal). The order of context (high arousal first *vs*. low arousal first) was randomized across participants.

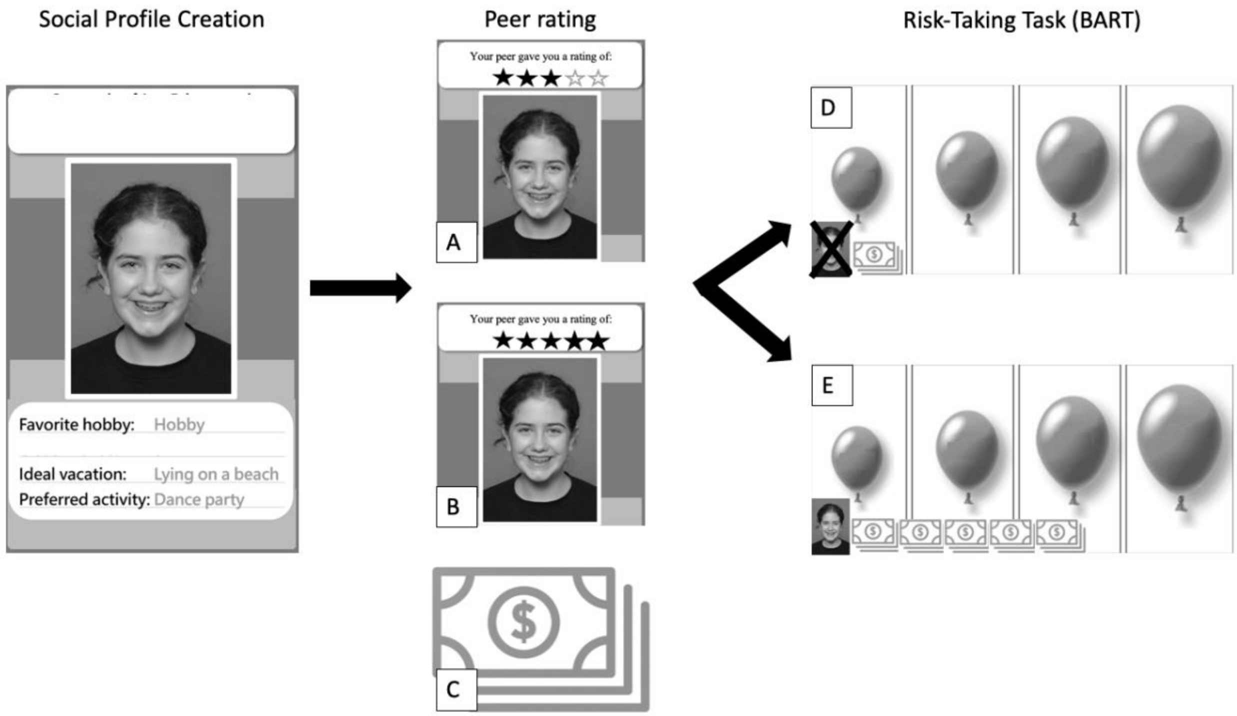

Figure 1. Procedure outlining the manipulation of context and arousal used in the virtual peer paradigm. Participants were first prompted to complete a social media profile, then were randomly assigned to one of three conditions: (A) negative feedback from a virtual peer (3 stars), (B) positive feedback from a virtual peer (5 stars) or (c) non-social condition (no feedback). Every participant then completed two rounds of a risk-taking task, once under low arousal (D; not watched or low rewards), and once under high arousal (E; watched or high rewards).

At the end of the study, participants were debriefed about the purpose of the study. Participants in the social conditions were informed that, in reality, the "other participant" did not exist, and that the social profile and pictures taken in the laboratory would be deleted immediately. To ensure the social manipulation was effective, participants were also asked whether they believed they were being watched by a peer when completing the tasks.

Measures

Virtual Peer Rating Paradigm Condition. The three experimental "reward conditions" for the VPRP—positive social, negative social, and non-social—were dummy coded. The positive social condition was used as the reference category. The arousal context for each run of the BART was coded as 0 (high arousal) or 1 (low arousal). Though this coding seems counterintuitive, it aided in interpretation of the model parameters.

Risk-taking. A computerized version of the BART (Lejuez et al., 2003), a widely used measure of risk-taking (Schmitz et al., 2016), assessed participants' propensity to take risks. The goal of the task is to accumulate as many tokens as possible by pumping air into balloons (30 trials/balloons). Each time the participant pumps air into the balloon, they earn 0.05 tokens (0.15 if they are in the non-social, high arousal condition). After each pump, the participant can choose to cash in the number of tokens accumulated in their bank, or pump more air into the balloon. If the balloon explodes, they lose all the tokens accumulated for that balloon. The point at which a given balloon exploded was semi-random and unknown to the participant. However, the average number of pumps for balloons to burst for all 30 trials was set to 20. All participants had the same series of balloons. Consistent with other studies using this measure, risk-taking was calculated using the average number of pumps on unexploded balloons (Lauriola et al., 2014), because it is impossible to know when a participant would have stopped pumping on balloons that exploded. This is referred to as the adjusted mean pumps.

Age. Age was entered as a continuous variable. Additionally, to permit for specialized analyses (described later), an age-squared term was calculated by squaring the age of participants.

Gender. Gender (self-reported) was coded as 1 for females and 0 for males.

Race/Ethnicity. Race/ethnicity was collected via self report. For analysis it was coded as white (1) and not white (0). This choice was necessary given the smaller number of participants recruited.

Socio-economic status (SES). SES was inferred from the highest level of education achieved by parents, which was coded from 1 (some grade school) through 10 (professional or graduate degree). Parents' level of education has been related to later SES outcome and is often used as a proxy for SES (Aarø et al., 2009).

Plan of analysis

Descriptive analyses for the characteristics of our sample, as well as the relationship between risk-taking and relevant demographic variables (age, gender, ethnicity, and socio-economic status) are included. Two correlational analyses are provided (under low and high arousal, respectively). Because the dual-systems model posits that risk-taking peaks in adolescence and decreases into early adulthood (i.e., there is a curvilinear relationship with age), an age-*squared* term is also included in our analyses.

The primary analyses will examine whether the effect of arousal on risk-taking differs by VPRP condition. To allow for the simultaneous inclusion of both risk-taking scores for each participant (high arousal run and low arousal contexts) without loss of information (e.g., using a difference score), we used a multilevel modeling approach (Peugh, 2010). Each participant completed the risk-taking task twice, once under low arousal, and once under high arousal. Therefore, the high and low arousal data were entered as within-individual variables (level 1). In contrast, each participant was only assigned to one of three possible condition (positive social, negative social, and non-social). Hence, condition was entered as the between-individual variable (level 2). The outcome variable was risk-taking (adjusted mean pumps on the BART).

Results

Descriptive analyses

Our first analysis describes the demographic characteristics of participants in our current sample. The number of participants recruited in each age group, along with their self-reported sex and race are reported in Table 1. Means, standard deviation, skewness and kurtosis of variables of interest within each of the three experimental conditions (non-social, positive social, and negative social) are reported in Table 2. The composition of all three conditions were comparable in terms of participants' age, sex, ethnicity, and socioeconomic status. The original goal was to recruit equal numbers of participants across four age groups. However, because of the interruption in data collection, our sample includes more adults than adolescents (see Table 1). There was no missing data, and no outliers (i.e., number of pumps for a given balloon that was three standard deviations above or below the mean in the high, or the low arousal condition). Hence, data from all 73 participants were used in the analyses herein.

Table 1.
Demographic Characteristics of Participants per Condition.

		Conditions						
		Non-Social		Positive Social		Negative-Social		Total
		N	*(%)*	*N*	*%*	*N*	*%*	
Age ranges								
	12 to 14 years old	5	20.0	3	11.5	3	13.6	11
	15 to 17 years old	4	16.0	6	23.1	1	4.6	11
	18 to 22 years old	7	28.0	8	30.8	9	40.9	24
	23 to 30 years old	9	36.0	9	34.6	9	40.9	27
Sex	Men	9	36.0	9	34.6	7	31.8	25
	Women	16	64.0	17	65.4	15	68.2	48
Race	White	19	76.0	14	53.9	16	72.7	46
	Other than White	9	36.0	11	42.3	5	22.7	25

Note: Non-social condition N = 25, positive social N = 26, negative social N = 22; Total N = 73.

Table 2.

Means, Standard Deviations, Skewness and Kurtosis of Variables of Interest.

Condition		*M* (*SD*)	Skewness	Kurtosis
Non-social (N = 25)	Risk-Taking			
	High arousal	10.82 (4.68)	0.09	-0.76
	Low arousal	10.22 (3.66)	-0.18	-0.68
	Age	19.92 (5.04)	-0.17	-1.30
	SES	6.80 (2.16)	0.01	-0.25
Positive social (N = 26)	Risk-Taking			
	High arousal	10.31 (3.35)	0.62	0.90
	Low arousal	10.51 (3.59)	0.26	-0.05
	Age	19.92 (4.93)	0.09	-0.96
	SES	6.27 (2.29)	0.25	-1.00
Negative social (N = 22)	Risk-Taking			
	High arousal	12.66 (4.12)	-0.01	-1.10
	Low arousal	11.79 (3.71)	0.48	-0.35
	Age	21.91 (4.81)	-0.36	-0.54
	SES	6.00 (2.45)	0.22	-1.41

Note: Total $N = 73$. Risk-Taking = mean number of pumps for unexploded balloons on the Balloon analogue risk task. SES based on parents' level of education (1 = some grade school to 10 = professional or graduate degree).

The relationship between key demographic variables and risk-taking were also examined via correlations for both the low and high arousal conditions and are illustrated in Tables 3 and Table 4, respectively.

Table 3.

Correlations Between Risk-Taking and Demographic Variables in the Low Arousal Context.

Measures	1	2		3		4	5	6
1. Risk-Taking	–							
2. Age	0.20	–						
3. Age squared	0.18	0.99	**	–				
4. Sex	0.11	-0.02		-0.03		–		
5. Race	0.03	-0.21		-0.20		-0.03	–	
6. SES	-0.20	-0.28	*	-0.27	*	0.08	0.15	–

Note: *n* = 73. Risk-Taking = mean number of pumps for unexploded balloons on the Balloon Analogue Risk Task. Sex (0 = men, 1 = women); Race (0 = not White, 1 = White); SES based on parents' level of education (1 = some grade school to 10 = professional or graduate degree).
* $p < .05$. **$p < .01$.

Table 4.

Correlations Between Risk-Taking and Demographic Variables in the High Arousal Context.

Measures	1	2		3		4	5	6
1. Risk-Taking	–							
2. Age	0.15	–						
3. Age squared	0.13	0.99	**	–				
4. Sex	0.20	-0.02		-0.03		–		
5. Race	0.09	-0.21		-0.20		-0.03	–	
6. SES	-0.18	-0.28	*	-0.27	*	0.08	0.15	–

Note: *n* = 73. Risk-Taking = mean number of pumps for unexploded balloons on the Balloon Analogue Risk Task. Sex (0 = men, 1 = women); Race (0 = not White, 1 = White); SES based on parents' level of education (1 = some grade school to 10 = professional or graduate degree).
* $p < .05$. **$p < .01$.

Primary analyses

To evaluate whether risk-taking differs depending on the arousal context and the condition, a multilevel model analysis was specified (see Table 5). The model was constructed in steps, starting with a model without predictors (i.e., the unconditional model), followed by a model with predictors (i.e., a main effects model, our first conditional model) and finally, a model that included interaction terms between arousal context and condition (i.e., a second conditional model). Considering the dual-systems model's emphasis on rewards—especially social rewards—both conditional models used the positive social condition as the reference category. Additionally, because we hypothesized heightened risk-taking in a 'hot' context, comparisons were made in the high-arousal condition (i.e., when participants were being watched by the virtual peer or had the opportunity to earn more rewards).

Table 5.
Fixed Effects Predicting Risk-Taking in the High Arousal Context.

	Parameter	*b*		*SE*	*p*
Model Without Predictors (Unconditional Model)					
Fixed effects					
	Intercept	11.00		0.42	.000
Covariance Parameters					
	Residual	4.32		0.72	
	Intercept	10.96		2.22	
Model with Predictors (Conditional Model without Interactions)					
Fixed effects					
	Intercept	10.61		0.72	.000
	Low arousal	-0.39		0.34	.255
	Non-social Condition	0.11		1.00	.914
	Negative social Condition	1.81		1.04	.085
Covariance Parameters					
	Residual	4.30		0.72	
	Intercept	10.66		2.20	
Model with Predictors and Interactions (Conditional Model with Interactions)					
Fixed effects					
	Intercept	10.31		0.76	.000
	Low arousal	0.21		0.58	.721
	Non-social Condition	0.51		1.08	.640
	Negative social Condition	2.36	*	1.12	.038
	Low arousal x Non-social	-0.80		0.82	.335
	Low arousal x Negative social	-1.09		0.85	.206
Covariance Parameters					
	Residual	4.31		0.73	
	Intercept	10.66		2.20	

Note: n = 73. Risk-Taking = mean number of pumps for unexploded balloons on the Balloon Analogue Risk Task. The positive social condition served as the reference category; arousal was coded as 0 (high arousal) or 1 (low arousal).
*p < .05.

The unconditional model showed that 71.73% of the variance in the data was between subjects, and can be explained by clustering variables such as the condition to which participants were assigned (i.e., positive social, negative social, or non-social). According to a chi-square difference test, which is the standard for comparing nested models, adding predictors to the unconditional model led to significant improvement in model fit ($\Delta\chi^2$ (3) = -8.23, p = .041). This indicates that arousal context and condition, together, were useful in predicting participants' risk-taking. Adding interactions terms did not significantly improve model fit ($\Delta\chi^2$ (2) = -4.511, p = .105). This is consistent with the interaction coefficients outlined in Table 5, which did not reach significance. Results for the model including interaction terms are interpreted below because they permit the interpretation of simple slopes. Overall, results suggest participants in the negative social condition evinced greater risk-taking than those in the positive social condition when watched by a peer (see Figure 2).

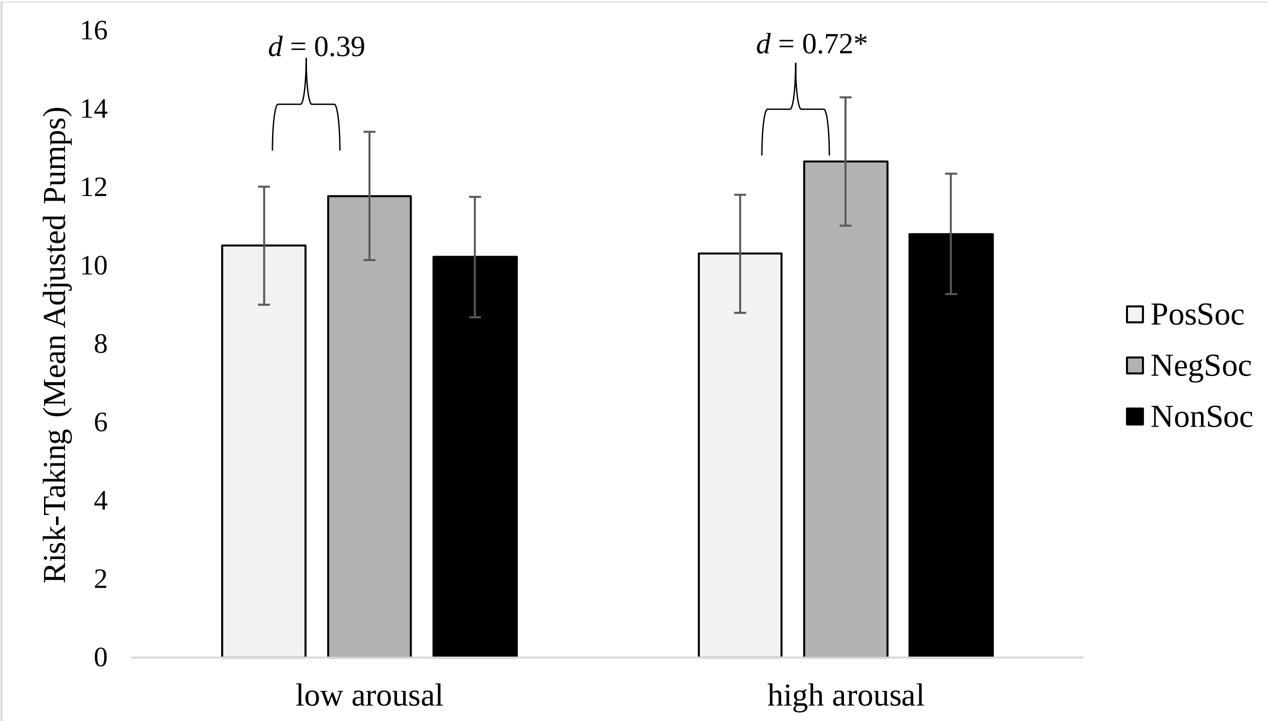

Figure 2. Risk-taking by arousal and condition. Error bars represent 95% confidence intervals. Effect sizes (i.e., Cohen's d) are provided for the difference in the mean number of pumps between the negative and positive social condition, in both low arousal and high arousal contexts.
$^*p < .05$.

Does the effect of arousal on risk-taking differ by VPRP condition? The conditional model with predictors and interactions (the last model in Table 5) uses the mean level of risk-taking in the positive social condition in the high arousal context (in Figure 2, the light column on the right half of the graph) as a reference point. Therefore, the intercept coefficient of our model represents that reference point; it is equal to the average number of adjusted pumps for participants in the positive social condition *when watched by their peer*. This mean level of risk-taking is compared to: (i) the level of risk-taking in the other two conditions (i.e., the conditional effects for the non-social and the negative social conditions), and (ii) its own change in risk-taking from the low-arousal context to the high arousal context (i.e., the conditional effect of arousal). Moreover, our model tests whether changes in risk-taking from the low arousal context to the high arousal context are different for the positive social condition compared to the other two conditions (i.e., the two interaction terms in our model).

Given our current sample, only the conditional effect for the negative social condition reached significance. Participants who received a mediocre rating took significantly more risks than those who received a positive rating when they were watched by the virtual peer (p = .038; see Table 5). On average, participants in the negative social condition had 2.36 more pumps than those in the positive social condition when completing the risk-taking task under the scrutiny of their peer (see Figure 2). The difference in the number of pumps did not reach significance when participants in both social conditions completed the risk-taking task alone (b = 1.27, SE = 1.12, p = .260). To better compare the behaviour of participants who were evaluated positively to those who were evaluated negatively when completing the tasks alone (*vs.* watched), effect sizes were added in Figure 2. Of note, the effect size in the high arousal context was nearly double the size of the corresponding effect in the low arousal context. In other words, participants took more risks, on average, in the negative social condition than in the positive social condition, and this effect was bigger when participants were watched by the virtual peer (see Figure 2). Despite this difference in effect size, the interaction testing whether the effect of arousal was different in the positive social condition compared to the negative social condition was not (p = 206).

While the other conditional effects and interactions in the model did not reach significance (see Table 5), they are relevant to our hypotheses and a short description of each follows. The conditional effect of the non-social condition compares the risk-taking of participants watched by the peer who positively evaluated them to the risk-taking of participants who earned more rewards. This effect was positive, but not significant (p = .640), and suggests that risk-taking behaviours in the high arousal context were similar in the non-social and the positive social conditions. The arousal by non-social condition interaction term, which investigates whether the effect of arousal differed between the positive social and the non-social condition, was also not significant (p = .335). Finally, the conditional effect of arousal investigated whether risk-taking behaviours changed when participants who were evaluated positively were watched by the peer (i.e., high arousal) compared to completing the task alone (i.e., low arousal). The effect did not reach significance (p = .721), suggesting that the change in participants' risk-taking behaviour, if it occurred, was not large enough to be detected.

To better visualize the effect of arousal, we compared individuals' risk-taking in the high arousal condition to their own performance in the low arousal condition (see Figure 3). The change in risk-taking behaviour in each condition (i.e., non-social, positive social and negative social conditions) is shown in standard deviation units. We obtained the average risk-taking in the three conditions and for each arousal run by rotating the reference category. The high arousal condition appears to have elicited greater risk-taking behaviour in the negative social condition and, to a smaller extent, in the non-social condition.

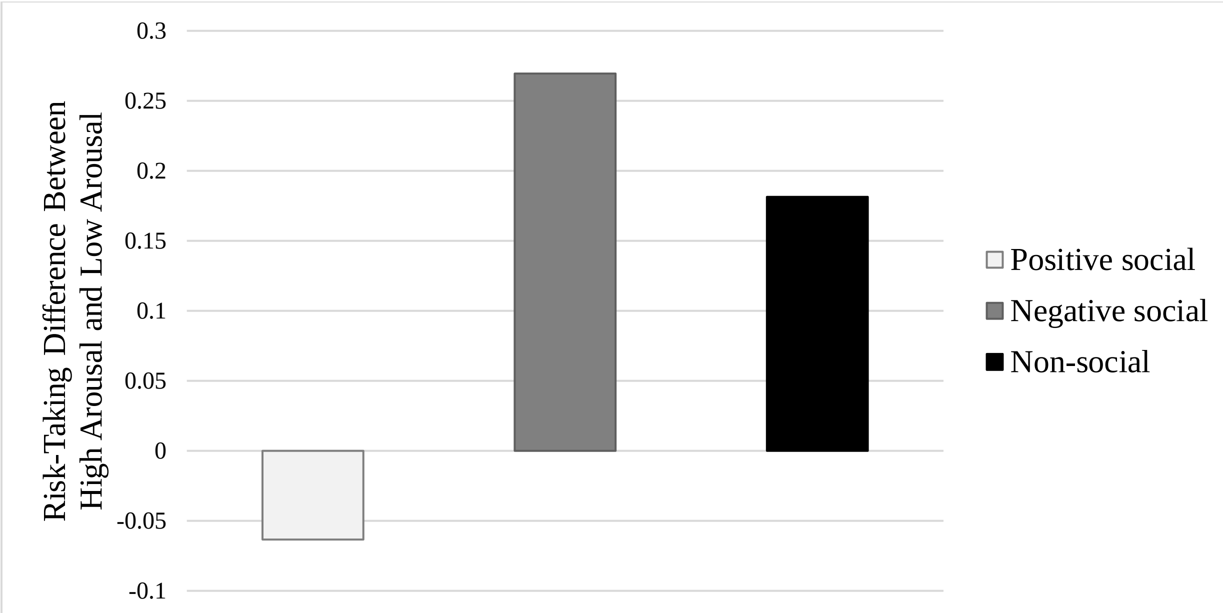

Figure 3. Difference in risk-taking between the high and low arousal contexts for each condition. The difference in risk-taking is expressed in standard deviation units.

Planned future analyses

Once data collection can be completed, we plan to conduct additional analyses. The first will explore the relationship between age and risk-taking in adolescence. In line with the dual-systems model, we expect risk-taking will be higher for adolescents than for young adults and adults. Therefore, we predict a curvilinear relationship between age and risk-taking will best describe the data. This will entail testing whether the age-squared term (the curvilinear component) is significantly related to risk-taking, over an above the age term (the linear component). Next, we will seek to determine whether the effect of age moderates the effect of arousal and/or conditions on risk-taking. We will investigate whether these effects remain when controlling for covariates (e.g., ethnicity, SES, sex, order of presentation of the tasks, and the difference between participants' own ratings and the peer's rating), and whether any of these covariates moderate effects in our model. For example, participants who were highly interested in interacting with the peer (*vs.* not interested) may have perceived the stakes were higher when performing a task in front of that peer. If that was the case, the difference in the psychological experience of 'being watched' could result in different risk-taking behaviours, even within a condition.

Furthermore, we will be analyzing physiological data (electrocardiography and electrodermal activity) to assess the extent to which physiological arousal differed across conditions and context. These analyses will compare changes from baseline to low and to high arousal for both tonic skin conductance levels (i.e., sweat response) and heart rate across conditions. The multilevel model would be specified as follows. Level 1 (within-subjects) variables would comprise two measurements: change from baseline to high arousal (reference) and change from baseline to low arousal. Condition (positive social, negative social, and non-social) would be added as a Level 2 (between-subjects) variable. We will examine main effects as well as interactions. Higher skin conductance in high arousal contexts (i.e., when watched or earning higher rewards) would confirm that our arousal manipulation worked. Therefore, we predict a main effect of context such that individuals exhibit greater elevation in skin conductance and heart rate in the high arousal contexts compared to low arousal contexts. Moreover, because we suspect the non-social manipulation was quite weak in comparison to both social conditions, we predict this effect will be greater for the two social conditions than for the non-social condition.

We will also conduct more nuanced analyses of how our experimental paradigm affected cardiac activity. These analyses will operationalize physiological arousal in different ways, including heart rate variability, pre-ejection period, total peripheral resistance, and cardiac output. Prior research using these methods suggests that these measures, either alone or combined, reliably differentiate between different types of arousal (Seery, 2013). When experiencing a challenge (i.e., a task demanding mental/physical resources that are readily available), an individual's heart pumps more blood faster, providing better oxygenation. In contrast, when under threat (i.e., a task demanding more resources than what the individual can provide), the heart pumps faster, but without a change in cardiac output (i.e., liters of blood per minute). Thus, analysis of these variables could help us assess whether the negative and positive social conditions were perceived as threatening or challenging.

Discussion

Adolescent risk-taking is context dependent: they display adult-like decision-making when excitement is low (e.g., when completing questionnaires; Beyth-Marom et al., 1993; Fischhoff et al., 2000), but not when excitement is high (e.g., when receiving monetary rewards, or when with friends; Chein et al., 2011; Gardner & Steinberg, 2005; Steinberg, 2008). The current research sought to better understand how a positive rating from a virtual peer (i.e., positive social condition), a somewhat mediocre rating from a virtual peer (i.e., negative social condition), and an opportunity to earn more rewards (i.e., non-social condition) affect risk-taking in a laboratory task performed twice under different arousal contexts. Although we expected participants to evince greater risk-taking in all three conditions under high arousal (vs. low arousal), our results suggest otherwise. While the effect of arousal did not reach significance, effect sizes suggest that participants in the non-social condition and the negative social condition took more risks under arousal contexts. In contrast, those in the positive social condition either evinced less risk-taking or did not alter their behaviour (see Figure 2). When comparing the three groups, the only significant difference was between the positive and negative social conditions. When under the scrutiny of a virtual peer, participants who were rated somewhat negatively took significantly more risks on the BART than did participants who were rated positively. Under low arousal contexts, the effect did not reach significance.

At first glance, lower risk-taking when watched by a peer who evaluated participants positively (*vs.* negatively) appears contradictory to most of the literature, which emphasizes rewards (especially social rewards) as a primary driver of risk-taking in adolescence (e.g., Albert et al., 2013). More specifically, it has been argued that peers increase the salience of rewards in adolescence, thus leading to heightened risky behaviours (Chein et al., 2011; Logue et al., 2014). Indeed, adolescent mice have been shown to drink more alcohol in the presence of known peers, while not displaying increased exploratory behaviours (Logue et al., 2014). This led researchers to conclude it was the heightened salience of rewards that drove the increased consumption in alcohol and not stress or arousal due to the presence of peers. Additionally, neuroimaging results suggest that, when observed by friends, adolescents displayed greater neural activity in the ventral striatum when taking risks in a driving game, again suggesting that peers increase the salience of rewards (Chein, et al., 2011). This premise would suggest increased risk-taking in participants assigned to the positive social condition, the complete opposite of our current findings. Although we currently do not have enough adolescents in our sample to make firm conclusions, our results hint that the peer effect may not occur with all peers. Risk-taking behaviours may differ when individuals are in the presence of well-known peers or strangers.

Increased risk-taking in front of friends in laboratory games or other fun group activities (e.g., partying, playing sports) might serve to strengthen bonds with other well-known peers. One's acceptance among peer groups is especially important in adolescence, a period during which group structures are becoming increasingly complex (Spadafora et al., 2019). Moreover, the formation of strong bonds before adulthood is linked to a range of mental and physical health benefits that extend to adulthood (Allen & Loeb, 2015). In this regard, increased activity in reward regions of the brain during risk-taking when in the presence of friends would be evolutionarily beneficial. It would be associated with the collective experience of pleasure by group members, and incentivize more frequent contact with these known peers. Conversely, when engaging with new peers, the context may become more evaluative in nature, and adolescents may be more concerned about "fitting in".

In particular, individuals may engage in more risk-taking when evaluated negatively, but avoid engaging in risky behaviours or changing their behaviours when evaluated positively by a new peer. This perspective would be in line with literature that examines risk-taking as a motivated approach to negotiate one’s status among peers, and to gain social acceptance. Indeed, concerns about reputation are well documented across the lifespan (Huberman et al., 2004), and suggest that individuals are willing to take personal risks to increase their social status (e.g., bullying; Reijntjes et al., 2013). Yet, the relationship between risk-taking and social status is not straightforward. While some studies report a linear relationship, in which peer acceptance has been linked to lower risk-taking over time, and peer conflict, to heightened risk-taking over time (Telzer et al., 2015), others report a curvilinear relationship. For instance, Rebellon et al.'s (2019) longitudinal study has shown that risk-taking predicts greater popularity within peer groups over time, but only to a certain extent. This relationship was curvilinear, such that too much engagement in risk-taking behaviours was associated with lower popularity over time. These results suggest that risk-taking may be a double edge sword—one that adolescents must wield carefully. In the context of the current study, a negative rating from a peer, even virtual, may have heightened the stakes, and in this way, contributed to increased risk-taking for this group. In contrast, for participants who already had the full approval of their peer, there may not have been a need to negotiate this status, and a less risky approach may have been preferred. Another interpretation would be that participants did not feel the need to adjust their behaviour to impress the peer, especially because the peer already expressed a desire to interact with the participant. Therefore, participants may have opted to behave the way they were naturally inclined to behave. This would suggest that a particularly influential context in which increased risk-taking occurs involves an opportunity to improve one's reputation among new peers.

Heightened risk-taking when watched by the peer in the negative (*vs.* positive) social condition would not necessarily be contrary to the dual-systems model. In fact, if the stakes were higher for those who received a negative rating from the virtual peer (*vs.* positive), we would expect this negative peer rating to be more arousing for participants in our paradigm than the positive peer rating. This should elicit a stronger response from the socio-emotional system, which in turn, is more likely to lead to increases in risk-taking. Whether our data supports a generalized effect of arousal cannot be confirmed yet. This question will be addressed once data collection is complete. Additional details on this topic are provided in the limitations section.

The size and representativeness of our sample also constrains my ability to interpret results about a generalized peer effect. However, our results thus far fail to support a systematic increase in risk-taking in the presence of peers. Rather, the effect of peer presence differs depending on how the peer rated the participant's profile. This suggests that there may only be a weak or perhaps no, generalized peer effect; rather, the nature of the social context matters (Berndt, 1979; Chein et al., 2011; Foulkes & Blakemore, 2016): individuals may behave differently depending on whether their motivations are affiliative (i.e., friendly competition and/or banter with friends) or integrative (i.e., seeking acceptance from new peers).

The lack of support for a generalized peer effect may be explained by the novel methodology used in this study. Indeed, there are no prior studies, to my knowledge, in which participants received direct feedback as to whether a virtual peer would like to interact with them or not. This paradigm makes it possible to differentiate risk-taking in response to a positive rating, and a mediocre rating. If participants continue to take more risks in the negative social condition when watched, but not in the positive social condition, this study would help qualify conditions under which peers likely promote individuals' engagement in risky behaviours. More specifically, it would suggest that heightened risk-taking does not only occur in rewarding contexts, as suggested by the dual-systems model (Shulman et al., 2016; Steinberg, 2008), but also when the context is evaluative in nature. This prediction can be examined once the data collection is more complete.

At this point in time, my analyses are underpowered and should be interpreted with caution. It is quite possible that a generalized peer effect could not be detected because of the small sample size and the relatively low number of adolescent participants within the sample. Notably, the peer effect, when it has been observed in prior studies, is more pronounced among adolescents than among young adults (Chein et al., 2011; Gardner & Steinberg, 2005), and young adults were overrepresented in our study. Moreover, young adults may have been drawn from a different population than our adults.

Exploring the Effect of the Non-Social Condition

Although we expected the non-social condition to heighten risk-taking when participants could earn greater rewards, how this effect would compare to the positive social and the negative social condition remained an open question. The comparison of the high and low arousal contexts suggests that participants took more risks in the high arousal than the low arousal condition (see Figure 3), but the effect was small and not significant. It should be noted, however, that my analyses had low power and the effect size was positive and greater in magnitude than that of the positive social condition. In this sense, the positive social arousal condition produced little to no behavioural change, whereas the negative social and non-social (although to a lesser extent) conditions produced some change.

There are several possible explanations for failing to find a significant effect of arousal in the non-social condition compared to the positive social condition. First, it may be that the non-social arousal manipulation (i.e., earning greater rewards in the risk-taking task) may not have been enough to elicit arousal in our participants. Our use of tokens may have had an especially dampening effect, as participants could not convert the number of tokens earned to societally meaningful units (e.g., dollars). Second, given that half of the participants performed the risk-taking task with high rewards first, an order effect may have reduced the size of any effect. Future analyses based on the full sample will consider order (i.e., low vs. high arousal first) as a moderating variable.

Limitations

While the present study advances our understanding of individuals' risk-taking when watched by a virtual peer, it is important to consider some limitations when interpreting the results. First, the sample used in this study was not representative of the general population. White, middle-class Canadians were over-represented in our sample and limit our ability to generalize results to a more diverse population.

Second, the virtual peer paradigm probably elicits a small response compared to feedback received from peers in a real-world setting. Similarly, the Balloon Analogue Risk-Task was much less exciting than real-world risk-taking behaviours. Although the BART has been associated with measures of real-world risk-taking (Lejuez et al., 2003), the stakes of real-world consequences tend to be much higher outside a laboratory environment (Shulman et al., 2016). Consequently, the effects observed in this study may have been attenuated.

Third, although our results to date do not appear to support an overall effect of arousal, we are unable to draw conclusions until the examination of physiological data. Our data would support a generalized effect of arousal on risk-taking if heightened risk-taking was observed in conditions where the arousal context actually increased physiological arousal, and not in conditions where physiological arousal was not increased. Given our current dataset, we would observe heightened physiological arousal in the negative social condition, but not in the positive social and the non-social conditions. On the other hand, if participants who were being watched by peers in the positive social condition displayed increased physiological arousal, but did not engage in increased risk-taking, our results would not support a generalized effect of arousal (i.e., high arousal did not systematically lead to increased risk-taking). This particular pattern of results would be contradictory to the dual-systems model's predictions which notably relies on the assumption that heightened arousal undergirds engagement in intuitive processing rather than deliberative processes (Shulman et al., 2016; Steinberg, 2008).

Fourth, our peer manipulation (i.e., providing feedback on a social media profile) might be weaker than other paradigms used to investigate the peer effect. For instance, some paradigms allow participants, during breaks, to have conversations with the peers who are watching their performance (Chein et al., 2011), or even ask the peers to comment on the participants' performance while they are engaging in the risk-taking task (Gardner & Steinberg, 2005). Still, the virtual peer paradigm does have the benefit of a standardization of the interactions between participants and the virtual peer.

Future research

The next steps for this study involve completing data collection, and conducting planned analyses as described in the methods. Beyond this, the results of the current study underscore the need for further exploration of how differently valanced social contexts affect adolescents and young adults in a laboratory and in a natural environment. First, it would be important to determine whether the reported results reflect actual differences in the effect of the positive and negative social condition on risk-taking. In addition, future studies should seek to replicate current findings using similar social paradigms, and examine additional social elements (e.g., whether peers are close friends or strangers, or possible moderators of the effect of peers) that may influence adolescents' and young adults' risk-taking. An approach that may yield especially rich details about the kinds of context that promotes engagement in risky behaviours is data collection in real-world settings. For instance, ecological momentary assessments paradigms take advantage of new mobile technology to ask participants to periodically report information about their behaviours, surrounding environment, and psychological states in real-time. Because these measurements are taken in real-life circumstances, they circumvent much of the problems inherent with assessing risk-taking in the laboratory (e.g., lower stakes and excitement).

Moreover, more attention should be given to the methodology used to increase risk-taking in the presence of peers. Such an approach may help us better understand some of the variations in the literature, especially relating to the effects of peer exclusion on risk-taking. For instance, some studies have found that following social exclusion from a cyberball game, adolescents did not evince greater risk-taking in the BART task (Buelow & Wirth, 2017). However, in this particular paradigm, adolescents completed the BART alone—the new peers that ostracized them previously were not watching. It was therefore impossible for participants to attempt to change the opinion of those peers—something that may have influenced whether or not they would take more risks in the task.

Implications

Broadly speaking, results suggest that increased risk-taking may be a response to negatively or ambiguously valenced social-evaluative contexts. Participants who received a mediocre rating (i.e., three stars out of five) from a virtual peer took more risks than those rated positively by the virtual peer (i.e., five stars out of five) when they were watched (*vs.* not watched) by that peer. This finding challenges the notion, proposed by the dual systems model, that increased risk-taking in adolescence in the presence of peers is attributable to increased reward salience or to general positive emotional arousal (Shulman et al., 2016; Steinberg, 2008). This, in turn, raises the possibility that heightened risk-taking may not only be due to sensitivity to rewards, but also to other elements of social interactions. A key social element that may drive engagement in risk-taking is the receipt of an ambiguous or negative feedback from peers with whom individuals interact.

Of note, there was an over-representation of young adults and adults in my current sample, which suggest this effect might not be specific to adolescence. In this regard, risk-taking in response to socially evaluative contexts may represent a normative behavioural pattern in adults—one that adolescents may simply be more responsive to given the importance of social interactions during this period.

Although implications are limited at this point, further exploring the key elements in social interactions that lead to increases in risk-taking would be beneficial. These results could be used to inform policies and procedures to reduce unnecessary risk-taking.

Conclusion

Ultimately, our results suggest that participants may take more risks in socially threatening or evaluative contexts. This furthers our understanding of the possible role that risk-taking may serve in social interactions with peers. More importantly, our findings highlight that adolescents, whose sensitivity to social cues are heightened (Foulkes & Blakemore, 2016), may be especially prone to risk-taking in a context where they are motivated to gain the acceptance of their peers, or when they perceive an opportunity to improve their reputation. Depending on the peer group, this could lead to engagement in potentially harmful behaviour (e.g., binge drinking, drug use).

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Appendices

Brock University
Research Ethics Office
Tel: 905-688-5550 ext. 3035
Email: reb@brocku.ca

Bioscience Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE:	8/22/2018	
PRINCIPAL INVESTIGATOR:	SHULMAN, Elizabeth - Psychology	
FILE:	17-422 - SHULMAN	
TYPE:	Faculty Research	STUDENT: SUPERVISOR:

TITLE: The Mind and Body Study

ETHICS CLEARANCE GRANTED

Type of Clearance: NEW Expiry Date: 8/1/2019

The Brock University Bioscience Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from **8/22/2018** to **8/1/2019**.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 8/1/2019. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at http://www.brocku.ca/research/policies-and-forms/research-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

Craig Tokuno, Chair
Bioscience Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.

Brock University
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Bioscience Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE:	October 22, 2018	
PRINCIPAL INVESTIGATOR:	SHULMAN, Elizabeth - Psychology	
FILE:	17-422 - SHULMAN	
TYPE:	Faculty Research	STUDENT: SUPERVISOR:

TITLE: The Mind and Body Study

ETHICS CLEARANCE GRANTED

Type of Clearance: MODIFICATION　　Expiry Date: 8/1/2019

The Brock University Bioscience Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement.

Modification: Option for social media accounts as a means of contacting participants who consent/assent to be contacted for follow up; added questions about smoking, menstrual timing, and birth control; replaced the IQ test (Shipley-2) with a digit span assessment of working memory; record pre-measurement questions on paper; include details about debriefing.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before **8/1/2019**. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at http://www.brocku.ca/research/policies-and-forms/research-forms.

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c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

Craig Tokuno, Chair
Bioscience Research Ethics Board

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Brock University
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Bioscience Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE:	April 16, 2019		
PRINCIPAL INVESTIGATOR:	SHULMAN, Elizabeth - Psychology		
FILE:	17-422 - SHULMAN		
TYPE:	Faculty Research	STUDENT: SUPERVISOR:	

TITLE: The Mind and Body Study

ETHICS CLEARANCE GRANTED

Type of Clearance: MODIFICATION Expiry Date: 8/1/2019

The Brock University Bioscience Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement.

Modifications:

1)Addition of a new questionnaire.
2)Introduction for new guidelines to aid data collection.
3)Minor adjustments to flyers and consent/assent forms.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before **8/1/2019**. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at http://www.brocku.ca/research/policies-and-forms/research-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

Craig Tokuno, Chair
Bioscience Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

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