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When do peers influence adolescent males' risk-taking? Examining decision-making under conditions of risk and ambiguity

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Abstract

Risk-taking is highly prevalent among adolescent males, and a range of studies have shown that decisions become riskier if a peer is present. However, previous studies have typically provided participants with explicit probabilities of risk in each situation. This does not accurately reflect adolescents' real-world risk taking, where decisions are made in ambiguous situations alongside their peers. Aiming for a more ecologically valid design, the present experiment manipulated situational ambiguity and examined its interplay with group decision-making and developmental factors. Adolescent males (N = 202) aged 12-15 completed a 'Wheel of Fortune' task and then self-reported their score, presenting an opportunity to cheat as a measure of antisocial risk-taking. As predicted, adolescents were more likely to take risks when probabilities were ambiguous rather than explicit. Further, higher levels of gambling choices were made by groups in ambiguous, but not risk situations. Age significantly predicted gambling in ambiguous conditions, while developmental dispositions (risk perception, reward sensitivity, and inhibitory control) did not play a role. Findings provide an insight into the social and situational conditions under which adolescent males engage in reckless behavior.

When Do Peers Influence Adolescent Males' Risk-Taking? Examining Decision-making Under Conditions of Risk and Ambiguity

Adolescence is a developmental stage during which individuals are more likely to engage in behaviors associated with risk (Steinberg, 2008). While adolescence is a period of physical health, teenagers are disproportionally represented in statistics related to hazardous behaviors including dangerous driving, drug misuse and risky sexual practices (Arnett, 1992; Gittes, & Irwin, 1993; Jonah, 1986). Recently, it has been suggested that situational conditions influence adolescents' likelihood of engaging in risky actions (Romer, Reyna & Satterthwaite, 2017). These researchers propose that when the probabilities involved in outcomes of a decision are hidden and thus ambiguous, adolescents are more likely to opt for these choices than when probabilities are known (van den Bos & Hertwig, 2017). While evidence has begun to emerge in support of this phenomenon, adolescents' tolerance for ambiguity has yet to be examined within the context of social and developmental changes that occur during this period.

Risks are encountered across the lifespan and are a distinct type of decision-making. In risk scenarios, the agent is presented with an option that has the potential for either a positive or a negative outcome, which is chosen in favor of an option that is guaranteed against a negative outcome (Defoe et al., 2015). In conditions of risk, the individual has knowledge of the probability distributions involved in both positive and negative outcomes of the risky option, such as evaluating one's chances to win on a roulette table. However, real-world decisions rarely occur in conditions where probability distributions are fully available to the agent. For example, the likelihood of being involved in a road traffic accident by driving above the speed limit involves a myriad of factors that are not available to the individual to evaluate. Rather, these are more appropriately defined as conditions of 'ambiguity', where probability distributions of the decision are unknown (Tversky & Kahnemann, 1992). This distinction is particularly relevant to adolescent decision-making, as their relative inexperience compared to adults means that more scenarios are processed as ambiguous (Romer, 2010).

However, not all adolescents engage in equal amounts of risk taking. Compared to females, males are consistently more likely to engage in real world risky behaviors (Byrnes, Miller & Schafer, 1999). Moreover, adolescent males are more likely than females to engage in acts with the potential for serious injury or mortality (Eaton et al., 2012), making this population particularly vulnerable to negative outcomes. For example, international data on road traffic accidents suggest males are more likely to be involved in accidents associated with reckless behaviors, such as speeding or driving while intoxicated (Swedler, Bowman & Baker, 2012). These behaviors are therefore a public health concern, and it is imperative to understand the factors that contribute to the risk-taking behaviors of this population in order to protect against negative outcomes.

Adolescence is a unique period marked by major social, affective and cognitive developments, which make this population more vulnerable to engaging in reckless behaviors (Casey, Getz & Galvan, 2008). During this time, there significant neurological changes as adolescents develop the mature cognitive architecture of adulthood (Spear, 2013). At the onset of puberty, there is a rapid development of affective regions of the brain, such as the ventral striatum, which has an important role in the dopaminergic reward system (Van Leijenhorst et al., 2009). In contrast, cognitive areas such as the prefrontal cortex and anterior cingulate, which are responsible for complex inhibitory behaviors, develop more gradually and do not reach full maturity until late adolescence (Casey et al., 2008). Therefore, adolescents are predisposed to perceive potential rewards as more salient and subsequently pursue these without the restraint of mature inhibitory control abilities (van Duijvenvoorde, Peters, Braams & Crone, 2016). These observations have led to the development of a ‘dual systems model’ of adolescent decision-making (Steinberg, 2008). This model states that neurobiological changes during puberty create an imbalance between areas responsible for the processing of rewards and those responsible for inhibiting potentially harmful behavior (Steinberg, 2010). Adolescents are thereby predisposed to pursue rewards in conditions of risk, without the ability to inhibit behaviors to avoid negative outcomes.

The dual systems model has seen considerable support from behavioral studies examining decision-making in adolescents (e.g. Braams, van Duijvenvoorde, Peper, & Crone, 2015; O'Brien, Albert, Chein & Steinberg, 2011). In a multinational study of over 5,000 adolescents Duell and colleagues (2016) found a positive relationship between reward sensitivity and risk behavior, whereas they found a negative association between inhibitory control and measures of risk taking. However, these associations were found to be independent of participants' age and therefore require that age be considered as a distinct predictor of risk behavior (Duell et al., 2016). Studies examining age-related differences in risk taking have found that this behavior peaks around the ages of 14-15 (Cauffman et al., 2010), also identified as 'middle adolescence' (Spear, 2013), and declines towards early adulthood (Shulman et al., 2016).

However, findings have been mixed with regard to the age at which risk-taking behavior peaks. In cases of alcohol consumption, cigarette smoking and illicit drug use, the frequency of these behaviors is highest in late adolescence, contrary to predictions of the dual system model (Willoughby, Good, Adachi, Hamza & Tavernier, 2013). Yet, rates of real-world risk taking may be confounded by the increased independence experienced at this age, which provides greater opportunity for adolescents to engage in risk behavior away from the observation of parents and caregivers (Laird, Pettit, Bates & Dodge, 2003). By contrast, in laboratory studies, a significant body of evidence has found risk-taking behaviors to be higher in younger adolescents compared to older adolescents (Burnett, Bault, Coricelli & Blakemore, 2010; Cauffman et al., 2010; Defoe et al., 2015). While the literature is mixed on the age at which risk-taking peaks, most neurobiological accounts agree that rapid developments in reward sensitivity begin around the age of 12 in adolescent males, with inhibitory control developing at a more gradual pace throughout adolescence (Shulman et al., 2016).

Notably, developmental models of risk behavior reflect the lifespan prevalence of criminal activity (Moffitt, 1993), and adolescents are more likely to engage in antisocial behaviors than children or adults (Steinberg, 2013). Correlational measures have found a relationship between reward sensitivity, inhibitory control, and involvement in the criminal justice system (Shulman & Cauffman, 2013), suggesting neurobiological developments are related to delinquent behaviors. Thus, the account given by the dual systems model highlights the importance of reward sensitivity and inhibitory control in predicting a range of risk behaviors in adolescence.

Within adolescent populations, males are particularly at risk of engaging in hazardous behaviors due to the rise in levels of the hormone testosterone, which regulates male puberty (Mehta, Welker, Zilioli, & Carré, 2015). In an experimental study, Hermans and colleagues (2010) found that females who were administered with doses of testosterone exhibited increased activity in the ventral striatum compared to controls. While the authors did not examine the impact of this on risk taking behavior, the ventral striatum is associated with the anticipation of rewards in adolescents, which motivates risk behavior (Galvan, 2010). Furthermore, using a combination of MRI and saliva samples, a number of studies have found a relationship between testosterone and the activation of brain areas related to risk taking (e.g. Braams et al., 2015; de Macks et al., 2011). Peters, Jolles, Van Duijvenvoorde, Crone and Peper (2015) found that testosterone levels mediated the relationship between functional connectivity of the amygdala and the orbitofrontal cortex (OFC), and alcohol use. Yet, this relationship was only found for adolescent boys. These convergent studies indicate that testosterone has a significant role in the areas of the brain related to risk taking during adolescence. Therefore, gender differences in real-world reckless behaviors may reflect adolescent males' hypersensitivity to rewards in the absence of the ability to inhibit their actions (Steinberg, 2008).

Although a number of studies have indicated that adolescents engage in more risk-taking behaviors than adults (Cauffman et al., 2010), it is not the case that they are indiscriminately more risk-seeking than adults (Defoe et al., 2015). Situational influences have a significant role in influencing risk behavior, such as whether there is the presence of affectively 'hot' stimuli (Figner & Weber, 2011). These stimuli are defined by their emotive properties and lead to a decision-making style that is more intuitive and less reliant on information gathering. By contrast, 'cold' decision-making scenarios are those that lack emotive properties and the decision maker utilizes rational, considered thought processes (Figner & Weber, 2011). Within the lifespan, adolescents are more likely to engage in risks in affectively hot scenarios, whilst in the absence of this situational variable, adolescents' risk behavior is similar to that of adults (Figner, Mackinlay, Wilkening & Weber, 2009).

One affectively hot stimulus that is particularly relevant in adolescence is their relationship with their peers. Adolescence is a period of social development and during this period this population is particularly sensitive to feedback from peers (Albert, Chein & Steinberg, 2013). This social sensitivity has an impact on risk behavior, and a robust body of evidence has demonstrated that when adolescents are observed by a same aged peer they are more likely to engage in risky behavior, whereas this effect is not observed in adults (Albert et al., 2013; Gardner & Steinberg, 2005). However, the influence of peers extends beyond merely being present; as active agents, peers exert social influence on risk taking, expressing either support or opposition for these behaviors (Knoll, Magis-Weinberg, Speekenbrink & Blakemore, 2015). When tested experimentally, it has been demonstrated that adolescents are highly sensitive towards peer attitudes and the highest levels of risk taking occurs when adolescents receive positive encouragement from peers to engage in risky behavior (Centifanti, Modecki, MacLellan & Gowling, 2014). This is particularly salient in early adolescence, as this group is more sensitive to the influence of their peers compared to older adolescence (Knoll et al., 2015). Thus, situational variables such as the presence or absence of peers can have a significant influence on the frequency of adolescents' risk behavior.

Recently, it has been suggested that ambiguity is a further situational factor that biases adolescents to gamble and therefore expose themselves to potentially negative outcomes (Tymula et al., 2012; Osmont et al., 2017). Using a 'Wheel of Fortune' task (Ernst et al., 2004), several studies have demonstrated that adolescents are more likely than adults to gamble under conditions of ambiguity. However, in conditions of risk where probabilities are explicit, adolescents are equally or more risk averse than adults (Blankenstein, Crone, van den Bos & van Duijenvoorde, 2016; van den Bos & Hertwig, 2017). This economic task is a particularly strong measure of decision-making, as it allows for direct comparison between risk and ambiguity attitudes using identical probability distributions. Further, adolescents' ambiguity tolerance on the task have shown a relationship to real-world risk-taking behavior (van den Bos & Hertwig, 2017). While there are a number of other established tasks that similarly claim to measure ambiguity attitudes (e.g. the Iowa Gambling Task; Bechara, Damasio, Tranel & Damasio, 2005), the extent to which these truly capture this condition of decision-making has been subject to criticism (see Dunn, Dagleish & Lawrence, 2006).

In economic decision-making, the 'expected value' of a gambling decision is calculated by the summed values of the expected gains, weighted against their respective probabilities (Defoe et al., 2015). Adolescents' ability to navigate probability to maximize expected value in risky decision-making tasks has been found to improve linearly with age (Burnett et al., 2010). However, in conditions of ambiguity, the agent does not have information about the probabilities involved in a decision and as such, expected value is incalculable (Huettel, Stowe, Gordon, Warner & Platt, 2006). Decision-making in conditions of ambiguity therefore relies on different psychological mechanisms compared to conditions of risk (Tversky & Kahnemann, 1992). Consistent with this view, research has found no correlation between risk and ambiguity attitudes (van den Bos & Hertwig, 2017) and gambling under these two conditions activates different neural regions (Huettel et al., 2006). Thus, while the ability to understand probability to maximize expected value increases linearly with age, there is still limited understanding about how ambiguity attitudes develop across the lifespan.

The current study aims to build on this line of work by manipulating two situational conditions that can influence adolescents' decision-making: ambiguity and peer presence. Previous studies examining peer influence in conditions of risk and ambiguity have utilized a 'static' peer. It is therefore uncertain whether the influence of peers extends to 'dynamic' contexts, where peers are active in the deliberations that precedes a decision. This consideration is important, as these dynamic interactions are reflective of real-world reckless behaviors, which often occur in group settings (see Diebelius, 2018, for a case example). Unlike adults, adolescents are also more likely to engage in antisocial behaviors in groups rather than alone (Zimring, 1981). Consistent with this, observational studies have found, for example, that discussion with a peer who promotes rule-breaking and substance use has been associated with an immediate rise in adolescents' own substance use (Dishion, Capaldi, Speacklen & Li, 1995). Hence, group contexts are a relevant but as yet understudied variable in adolescents' decision-making.

One of the few studies examining group decision-making in adolescence, by Haller and colleagues (2018), investigated adolescents' decision-making in a perceptual categorization task. Performance on the task was improved when decisions were made after discussion in a group compared to when the task was completed alone. Further, adolescents who completed the task in groups exhibited similar overall accuracy to adult participants who also completed the task in groups. Therefore, group conditions can facilitate optimal decision-making in adolescence. Selecting options with variable outcomes is not necessarily negative. In their 2017 study, McCormick and Telzer found that better performance on the Balloon Analogue Risk Task (BART) was predicted by an interaction of risk taking and learning. As such, selecting options with variable outcomes may be more optimal in conditions of ambiguity.

The present study aims to capture a novel, naturalistic account of adolescents' decision-making. In light of recent developments in the literature, we combine ambiguity and group decision-making with a peer to reflect the conditions under which this population encounters real world scenarios.

Study Overview

The primary aim of this study was to examine the interaction between situational ambiguity, group decision-making and developmental factors. We first predict that adolescents are more likely to gamble in conditions of ambiguity, rather than risk (**Hypothesis 1**, see van den Bos & Hertwig, 2017). Whether the task was completed alone or in a group was manipulated, as peers increase adolescents' risk behavior across a breadth of risk-taking conditions (Albert et al., 2013). It was hypothesized that adolescents making decisions in groups would gamble more in both risk and ambiguous conditions than participants making decisions alone (**Hypothesis 2)**. A further research question was whether groups of adolescents who expressed greater-risk seeking attitudes would exhibit greater gambling behavior than low risk seeking groups (Centifanti et al., 2014).

The current study makes a novel examination of the relationship between variables specified in the dual systems model to behavior under ambiguity. It was predicted that a model consisting of reward sensitivity, risk perception and inhibitory control would display a good fit to choices under these conditions, as had been shown for risk in previous studies (Duell et al., 2016). Specifically, it was predicted that reward sensitivity and risk perception (i.e., the benefit of a choice outweighs the risk) would display a positive relationship to gambling behavior, whereas inhibitory control would display a negative relationship to gambling. Moreover, as age has been found to predict risk-taking independently of neurobiological factors (Duell et al., 2016), this variable was included as a predictor of gambling behavior. As such, **Hypothesis 3** focused on developmental factors and stated that age, reward sensitivity, and risk perception (i.e., benefit of choice outweighs risk) positively predict gambling choices, while inhibitory control negatively predicts gambling choices. We expected this to hold for conditions of a) ambiguity and b) risk.

Models of adolescent risk behavior reflect statistics of antisocial and criminal behavior in youth (Steinberg, 2013). Therefore, it was predicted for **Hypothesis 4** that antisocial risk taking as measured by cheating would be predicted by the same developmental variables of age, reward sensitivity, risk perception and inhibitory control.

Method

Design

The present study used an experimental design to measure risk-related choices in adolescent males. Risk taking was measured by the proportion of choices made with the potential for high reward, but significantly greater chance for loss. This was chosen over a safe, non-risky option with a smaller reward in a computer-based task. The first dependent variable was proportion of these risk-related choices chosen in place of the safe option. The second dependent variable, cheating behavior, was measured after the virtual task by the number of unearned points participants awarded themselves from their performance on the computer-based task.

Two independent variables were manipulated which were 1) whether participants were provided with information about the outcome probabilities (explicit vs ambiguous), and 2) whether the task was completed with a peer or alone. The independent variable of risk condition was a within-subject variable, as individuals differ on the level to which they are risk-seeking (Duell et al., 2016). Thus, a within-subject design ensured that differences in behavior between conditions of risk and ambiguity was a result of the experimental manipulation rather than individual-level differences. Further, as adolescents are sensitive towards positive and negative feedback (Cohen et al., 2010; Hauser, Iannaccone, Walitza, Brandeis, & Brem., 2015) we ensured that the order in which adolescents completed the Wheel of Fortune task was counterbalanced. As such, half of participants completed the ambiguity condition first and half completed the explicit condition first to mitigate the effect of past performance on subsequent choices.

Whether decisions were made in groups was a between-subject variable manipulated for the duration of the task. Participants were randomly allocated to one of the two conditions: either groups or alone. In the group condition, adolescents were allowed to discuss their decision with their peer prior to selecting their choice. This design was selected in order to permit naturalistic interactions, where attitudes could be expressed whilst engaging in a common task (Dishion, et al., 1995; Haller et al., 2018). Peers were selected by the participants, as past research examining risk behavior has utilized groups of peers that are familiar to one another (Gardner & Steinberg, 2005).

There were three further independent variables measured alongside the experimental manipulation, which were stable dispositions. These were risk perception and inhibitory control, which are measures of cognitive factors of the dual systems model, and reward sensitivity, which is an affective factor. All variables have previously been used to predict risk behavior in developmental samples (Duell et al., 2016).

Participants

Two hundred and eighteen male participants were recruited in the current study. The data of eight participants were excluded from the analysis due to conditions impeding their understanding of task requirements, namely diagnosed autism, ADHD, or English comprehension issues as reported by the class teacher. Eight further participants did not name a peer whom they wanted to participate with, as required for the study design, and their data was therefore excluded. The final sample was hence composed of two hundred and two male adolescents aged between 12 to 15 years (*M*=13.6, *SD*=0.9) to capture the period of early to mid-adolescence during which the disparity between reward sensitivity and inhibitory control is greatest (Spear, 2013; Steinberg, 2010).

Participants were recruited from two London schools. The schools were average to slightly below average on student attainment in secondary level examinations (OfSTED, 2013). Recruitment took place from mixed ability tutor groups and therefore reflected students of varied academic ability.

Materials

Risk Behavior. The ‘Wheel of Fortune’ task (Ernst et al., 2004) was used to measure risk and ambiguity behavior. Participants are required to select one of two wheels to gain a certain number of points. One wheel represented the ‘safe’ choice, which participants could select for a 100% chance of gaining a modest number of points. In comparison, the risky wheel had a small chance of gaining a high number of points and a larger chance of gaining substantially fewer points. In the explicit risk condition participants could clearly see the probabilities associated with the high reward, which were 10%, 20%, 25% or 30%. The ambiguity condition followed the same design as the explicit risk, using the same series of trials and participants were presented with wheels with the same chance for high reward, either 10%, 20%, 25% or 30%. However, in these trials the wheel associated with risk was obstructed, preventing participants from knowing the probabilities involved in their decision (see Figure 1). Portions of the wheel that were occluded were either 20%, 50%, or 80% as utilized in previous studies (van den Bos & Hertwig, 2017). The number of points participants could score from a risk decision ranged between 0-25, whereas the number of points that could be gained from a 'safe' decision ranged from 5-15. Two average scores were calculated, one for conditions of risk and one for conditions of ambiguity.

Cheating Behavior. Cheating behavior was operationalized as the difference between actual and reported score on the Wheel of Fortune task. As performance was not monitored by the researcher, participants were able to falsify the scores they reported to acquire additional raffle tickets (Gabbiadini, Riva, Andrighetto, Volpato & Bushman, 2014). Following the task, actual scores were calculated from the Qualtrics reports and compared to disclosed scores to determine whether cheating had occurred. As the outcome of interest was whether or not participants had engaged in a rule-infraction, cheating was coded as a dichotomous variable with '1' denoting cheating and '0' denoting no cheating.

Risk Perception. The Benthin Risk Perception Measure (BRPM; Benthin, Slovic, & Severson, 1993) is a measure of risk perception relative to reward. For example, participants are asked whether the benefits or risks of "riding in a car with someone that has been drinking" are greater. Scores are measured on a scale from 1 to 4 with 1 indicating risks being higher than benefits, and 4 being benefits greater than risks. Thus, higher average scores indicate lower risk perception. Risk perception scores were calculated as mean scores of all items belonging to the scale. The measure demonstrated good internal reliability (α = .74).

Reward Sensitivity. Reward sensitivity was assessed using a subscale of 12 items from the Zuckerman Sensation Seeking Scale (SSS; Zuckerman, Eysenck & Eysenck, 1978). The questionnaire offers a series of true or false questions to assess an individual's chance of engaging in acts to experience new and exciting sensations such as "I like doing things for the thrill of it" (Steinberg et al., 2008). Scores were coded as either 0 for 'false' or 1 for 'true'. The scale showed acceptable reliability (α = .62) in line with its use in previous studies (Duell et al., 2016)[1]. Reward sensitivity scores were calculated as mean scores of the items belonging to it.

Inhibitory control. Inhibitory control describes behaviors that demonstrate the ability for forethought and control of one's actions. This measure was reverse coded from a subset of four items in the SSS, with higher scores denoted more inhibitory behaviors. An example of the items included in this scale include "I tend to begin a new job without much advance planning on how I will do it". The scale has shown acceptable internal reliability ($\alpha = .58$)[2], consistent with its use in previous studies (Duell et al., 2016). Planning scores were calculated as mean scores of the items belonging to it.

Procedure

After ethical approval was obtained and consent received from schools, parents and participants, data was collected within schools by a single male researcher. Upon arrival into the classroom participants were given a participant number and were asked to form pairs with a peer. It was decided beforehand that 3/7 participants would be allocated to the alone condition while 4/7 participants would be allocated to the group condition as the latter condition required less time to set up. This was to ensure that all participants in a class completed the task within the time allocated to the researcher. One-hundred and eighteen participants thus completed the task with a peer and 84 completed the task alone.

One pair of participants were invited into the research area at a time, where they were randomly allocated to complete the task either alone or in their group. In the alone condition participants were led to computers in separate locations that prevented participants from seeing or hearing one another. In the group condition, participants shared a single computer and were

[1, 2] Reliability analyses showed that Cronbach's alpha could not be significantly increased through deleting items.

informed that they were allowed to discuss their decisions for as long as they wanted before choosing an option (Haller et al., 2018). For participants who completed the task in pairs, they were informed that they would each receive the total number of points accrued during the study. For example, if the total score was 80, both individuals in the pair would receive this number of points. Participants then completed five rounds of both the risk and ambiguity conditions of the Wheel of Fortune task.

Participants were asked to add their points throughout the task which would be exchanged for raffle tickets. They were told that the host software (Qualtrics; Qualtrics, 2017) could not calculate their score and they would have to do so themselves. At the end of the trial the researcher re-entered the room where participants reported their score, presenting the opportunity for them to falsify their score.

Participants were then asked to complete a questionnaire alone, which was comprised of demographic information, the BRPM and the SSS. At the end of the session participants were debriefed and thanked for their participation. In order to not unduly reward cheating behavior, all participants were entered into the raffle equally to award the prize at the conclusion of the study.

Data Analysis Plan

We first inspected the decisions being made, under risk and ambiguity conditions, and by pairs of adolescents (group condition) and alone; we also inspected cheating behavior under the various experimental conditions.

To investigate the interplay of developmental factors on the individual level (age, risk perception, reward sensitivity, and inhibitory control) with the experimental manipulation of group decision-making, we employed Hierarchical Linear Modelling (HLM, Raudenbush & Bryk, 2002): All 202 participants were initially paired with a peer, meaning that there were 101 groups. As the two members of these dyads were not simply two independent individuals, and there is dependency of the data points they provided, HLM was the method of choice (see Kenny, Kashy, & Cook, 2006 for statistical background, Centifanti et al., 2014, for an example of application in a similar experimental design, and Maas & Hox, 2005 for sample size requirements). We included two levels: 1) individual, 2) group.

As we considered three types of behavior as outcomes – gambling under risk, gambling under ambiguity, and cheating – we performed HLM analyses separately for each of these behaviors. We employed the Maximum Likelihood Estimation algorithm, so that we could compare the fit of different models (Boedeker, 2017). We first estimated the null model (no predictors) as: $Y_{ij}=\beta_0+u_{0j}+e_{ij}$. In the second step, the full level 1 model (on individual level) was developed. As predictors we entered age (X_1), risk perception (X_2), reward sensitivity(X_3), and inhibitory control(X_4): $Y_{ij}=\beta_{0j}+ \beta_1X_{1ij}+ \beta_2X_{2ij}+ \beta_3X_{3ij}+ \beta_4X_{4ij}+e_{ij}$. In the third step, we entered the variable 'group membership' as a predictor (whether the task was completed alone or in a group, Z_1): $\beta_{0j}= \beta_0+ \beta_5Z_1+ u_{0j}$. Finally, we entered risk perception within the dyad as level 2 predictor. We performed grand mean centering for the four predictors on individual level and group mean centering for risk perception on dyad level before entering these variables into the models. The Mixed Procedure in SPSS (see Peugh & Enders, 2005, Ringdal, 2018) was used for data analysis.

Results

Adolescents chose a peer who was similar to themselves in age (r=.84, p<.001), risk perception (r=.59, p<.001) and reward sensitivity (r=.42, p<.001), but did not share similar levels of inhibitory control (r=.03, p=.787).

The descriptive data indicated that overall adolescents gambled more on wheels when probabilities were unknown rather than explicit (see Table 1, which also shows correlations between variables). Gambling decisions were more frequent in the ambiguous condition (M=0.58, SD=0.25) than the explicit condition (M=0.52, SD=0.28), as shown by a paired-samples t-test: $t(142)=2.10$, $p=.038$ (see Figure 2). In the risk condition, gambling decisions made in groups ($M=0.54$, $SD=0.28$) were not significantly higher than gambling decisions made alone ($M=0.54$, $SD=0.28$): $t(141)=0.94$, $p=.350$, two-tailed. However, under ambiguity, gambling decisions made in groups ($M=0.61$, $SD=0.23$) were significantly higher than gambling decisions made alone ($M=0.52$, $SD=0.26$): $t(141)=2.15$, $p=.033$, two-tailed. Regarding cheating, 69 (59.5%) of the reported scores were correct, and 47 (40.5%) were reported as higher than they actually were (i.e., cheating).[3] Participants who completed the task in groups did not cheat more often than those who completed the task alone: $\chi^2(1)=0.13$, $p=.723$.

Intraclass correlations (ICCs) for the null models predicting risk behavior were $\rho=.633$ (ambiguity), $\rho=.612$ (risk) and $\rho=.592$ (cheating). These indicate that a large proportion of the variance in risk behavior stems from variation between dyads (i.e., level 2 units) and hence supported the need for HLM to be used in the data analysis. Table 2 presents the HLM models. For all outcome variables – gambling in the ambiguous condition (Table 2a), gambling in the risk condition (Table 2b), and cheating (Table 2c) – we first entered the level 1 predictors (age, risk perception, reward sensitivity, and inhibitory control) in Model 1, and then added the level 2 predictor group membership in Model 2.

Gambling in the ambiguous condition (Table 2a, Model 1) was significantly predicted by participants' age: The older the adolescents, hence approaching mid-adolescence, the more often they gambled. None of the developmental dispositions significantly predicted gambling under ambiguity. As group membership was added as predictor in Model 2, the model fit (-2LL) improved ($p < .01$): Gambling was more frequent when decisions were made in groups compared to those made alone. A third model which included only age and group membership

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[3] 27 participants (16.8%) did not calculate their scores manually due to misunderstanding the task requirements; hence there was no cheating score for those participants.

as predictors had the best fit, which was significantly better than Model 1 ($p < .05$). Finally, risk perception on the group level was entered into a fourth model alongside age and group membership. This did not improve the model fit ($p > .05$), nor was this variable a significant predictor ($p = .855$).

Gambling under risk (Table 2b) was not significantly predicted by any of the proposed predictors. Cheating (Table 2c) was significantly predicted only by age: The older the participants, the less they cheated.

It is also noteworthy that the intercept in all models differs significantly from zero. For all outcomes, zero marks no gambling. This underlines that adolescents significantly engaged in gambling behavior.

Discussion

The current study investigated early-adolescent males' responses in an economic decision-making task which varied whether probabilities were made explicit or ambiguous. Participants demonstrated higher levels of gambling behavior when probability distributions involved in the option with the variable outcome were unknown to them than when these were available, supporting Hypothesis 1. This finding is consistent with previous literature which has examined differences in developmental decision-making between conditions of risk and ambiguity (Osmont et al., 2017; van den Bos & Hertwig, 2017). The present study also manipulated whether participants completed the task within a group, to examine whether this influenced decision-making. Hypothesis 2 was supported as group decision-making did increase gambling behaviors under conditions of ambiguity and this significantly improved the model fit.

The current study also examined the relationship between factors identified in the dual systems model and choices under ambiguity. These dispositions did not make a significant contribution to a model predicting decisions under ambiguity, and thus Hypothesis 3a was rejected. However, a model comprised of age and group membership displayed a significantly better fit to choices under ambiguity, thus providing a novel insight into key factors in this context of decision-making. None of the variables in the model predicted choices under risk, and thus Hypothesis 3b was rejected.

A further goal of this investigation was to examine the variables that contribute towards an additional measure of risk-related behavior: cheating. Age was a significant negative predictor of cheating behavior, whereas group membership was not significant in this model, hence Hypothesis 4 was rejected. Together, these findings provide an insight into the relationship between situational, social and developmental factors in adolescent males' decision-making.

Ambiguity and Risk in Adolescence

Adolescence is a period of increased risk behavior both within and outside of laboratory conditions (Arnett, 1992; Defoe et al., 2015). That adolescent males are more likely to gamble in conditions of ambiguity suggests that reckless behavior in this population may not be a maladaptive behavior as traditionally suggested (Romer et al., 2017). Pursuing ambiguous outcomes allows adolescents to collect information about the probabilities involved in novel scenarios, contributing to their experiential knowledge (Crone & Dahl, 2012). The 'Lifespan Wisdom Model' argues that by engaging in behaviors when the likelihood of a negative outcome is unknown, adolescents are able to develop an understanding of their environment and the probability of scenarios yielding positive or negative outcomes (Romer et al., 2017). Indeed, neuroimaging research has found that areas responsible for monitoring performance feedback exhibit higher levels of activation in conditions of ambiguity compared to risk (Blankenstein et al., 2018). The present study makes a novel addition to the literature by suggesting that tolerance to ambiguity increases towards 'middle adolescence'. This finding is consistent with trends of exploration in the Lifespan Wisdom Model and reflects the age at which the greatest levels of real-world reckless behaviors are observed (Arnett, 1992; Gittes, & Irwin, 1993; Jonah, 1986; Romer et al., 2017). While this study did not measure exploration, the trend to gamble more under ambiguity as individuals mature may serve the need for adolescents to develop a reliable experiential framework to guide future decisions in later life (Blankenstein et al., 2018). Hence, in unfamiliar situations where the probabilities of a decision leading to either a positive or negative outcome are unknown, older adolescents are increasingly likely to gamble in order to establish this novel understanding.

In support of this view, there were significant differences between the predictors for decisions under ambiguity and cheating behavior. This suggests that factors associated with heightened recklessness in adolescents do not promote negative behaviors, and that antisocial actions are not merely an excess of typical risk behavior in adolescence. Rather, persistently antisocial behavior in adolescents reflects only a subsample of this population (Moffitt, 1993). As such, the present study is consistent with the growing body of literature that suggests risk behavior in adolescence can have a beneficial role within the lifespan (Romer et al. 2017).

Risk-Taking Under Ambiguity and Peer Influence

This is the first study to demonstrate that peers accentuate risk behavior when adolescents encounter conditions of ambiguous risk. Unlike previous experimental paradigms (e.g. O'Brien et al., 2011) participants were encouraged to complete the task together, rather than have one participant observe neutrally. This design was chosen to capture an ecologically valid account of adolescent decision-making, where peers are active in the decision process (Haller et al., 2018; Knoll et al., 2015).

Notably, risk attitudes within groups did not interact with the number of ambiguous choices made, meaning pairs that scored higher on dispositions related to risk taking performed no differently to groups scoring low on these measures. This is noteworthy as it suggests that making decisions in groups increased gambling behavior under conditions of ambiguity regardless of risk attitudes. Consistent with this, Blankenstein et al. (2016) found that providing adolescents with information about an anonymous peer's prior decision (thereby indicating their risk attitude) did not increase gambling behavior under conditions of ambiguity. The present study builds on this work by suggesting that peers do increase the likelihood adolescents will gamble in conditions of ambiguity, but this is independent from the risk attitudes that peers express.

The current study is the first to examine the impact of group contexts on adolescents' decision-making. Previous studies have utilized 'static' peers who either observe (Smith et al., 2014) or express a fixed view (Centifanti et al., 2014; Knoll et al., 2015) in risk scenarios. However, this is limited in capturing the full dynamic of peer influence, where there is often discussion that precede the decision to engage in or avoid an action. In a study where interactions between peers were recorded, Dishion and colleagues (1995) found that discussions with a peer who endorsed rule-breaking and substance misuse were associated with a subsequent increase in the participants' reporting of those behaviors. Group decision-making is not necessarily a negative feature, though, as adolescents' performance can be improved by consulting with a peer (Haller et al., 2018). As it has been suggested that ambiguity tolerance may have adaptive properties in adolescence (Romer et al., 2017), the increased rate of gambling when encountering ambiguous scenarios with a peer may be optimal at this point of the lifespan. Future research should seek to explicitly examine whether ambiguity tolerance can lead to adaptive outcomes in adolescence and whether peers can facilitate more optimal decision-making under conditions of ambiguity.

Risk Taking Under Ambiguity and The Dual Systems Model

The present study contributes to the recent debates surrounding the utility of the dual systems model in accounting for risk behavior in adolescence (Pfeifer & Allen, 2012). We did not find evidence for the link between dispositions highlighted by this model (risk perception, reward sensitivity and inhibitory control) and decision-making under ambiguity. Critics hold that the predictions of the dual systems model are too broad to adequately capture the complexities of risk behavior (Pfeifer & Allen, 2012). Indeed, in rich decision-making scenarios such as that utilized in the present study, relying only on the imbalance between reward sensitivity and inhibitory control neglects the range of situational factors that can either promote or discourage risky behaviors (Defoe et al., 2015; Figner & Weber, 2011).

Limitations, Future Research and Implications

There are important limitations that must be considered with the present study. One criticism is that the measures of inhibitory control and reward sensitivity were imperfect due to the low level of the Cronbach's alpha (Peterson, 1994). It is important to note that the sample recruited were of the lower age boundary utilized in previous studies using these scales (Defoe et al., 2015). Therefore, the scales may not capture these dispositions in a younger cohort. Nevertheless, both scales demonstrated the expected pattern of relationships to risk-related behavior, and reliability was consistent with previous studies (Duell et al., 2016), which made their inclusion in the current study informative. As peer interactions were unscripted, this introduced a certain amount of noise into the data. However, this method was consistent with previous research (Haller et al., 2018) and was selected to allow for naturalistic interactions reflective of the real conditions with which adolescents encounter risk and ambiguous scenarios. Nevertheless, future research could code interactions within groups for a more precise understanding of how these decisions were made (Dishion et al., 1995).

A further limitation is that the order with which the Wheel of Fortune task and questionnaire measures were administered was not counterbalanced. As a number of the questionnaire measures made reference to scenarios related to risk, we did not want participants' performance to be affected by prior consideration of their own risk attitudes. Nevertheless, future research should seek to improve on this design. Moreover, future research should also seek to incorporate a sample of female adolescents and older adolescents, to further elucidate how risk and ambiguity tolerance develop at this point in the lifespan.

This study adds to the growing body of literature suggesting that adolescents gamble in ambiguous situations, but this behavior is reduced when risks are explicit. This research has implications for real-world settings, as it suggests the conditions under which this population are more likely to engage in reckless behavior. In order to minimize the risk of hazardous behaviors, youth programs should seek to develop adolescents' understanding of the likelihood of risks occurring, thereby reducing the ambiguity associated with these situations. For example, education programs that highlight the risks associated with privacy on social networking sites have been associated with a reduction in the frequency of unsafe online behaviors (Vanderhoven, Schellens & Valcke, 2013).

These findings can be applied to interventions aimed at reducing specific risk behaviors, such as gambling. By informing adolescents about the probabilities involved in these potentially negative behaviors, the present research suggests that the likelihood of adolescents engaging in these behaviors will be reduced. Consistent with this, educational interventions that inform adolescents about the probabilities involved in gambling have been found to be an effective strategy at reducing gambling behaviors in this population (Donati, Primi & Chiesi, 2014).

Conclusion

In sum, the current study has suggested that adolescent risk taking may be more appropriately defined by a likelihood to gamble under conditions of ambiguity. This is a challenge to previous work suggesting risk behaviors in this population occur despite an awareness of the likelihood of a negative outcome occurring. These choices are linked to social influence during decision-making and adolescents were more likely to gamble under ambiguity when decisions were made in groups. Moreover, this investigation has suggested that there is an important distinction between normative decision-making and antisocial decision-making. Differentiating between conditions under which adolescents are more likely to gamble with variable outcomes can provide insight into the adaptive properties of these decisions, whilst recognizing the potential for these behaviors to lead to negative outcomes.

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Table 1. Descriptive Statistics and Correlations Between Variables.

	Dispositions			Behavioral Outcomes		
	Risk Perception	Reward Sensitivity	Inhibitory Control	Gambling – Risk	Gambling – Ambiguity	Cheating
Correlations						
Risk Perception		.10	-.01	.07	.03	.12
Reward Sensitivity			-.35***	.11	.08	.16*
Inhibitory Control				-.01	-.06	-.12
Gambling – Risk					.43***	.04
Gambling – Ambiguity						-.02
Range	1-4	0-1	0-1	0-1	0-1	0-45
M (*SD*)	1.77 (0.75)	0.57 (0.21)	0.71 (0.31)	0.52 (0.28)	0.58 (0.25)	7.92 (12.24)

Note. * p<.05, *** p<.001

Table 2 a. Multilevel Models to Predict Gambling Under Ambiguity.

	B	*SE*	CI_{Low}	CI_{High}	*Fit Indices*
Model 1					-2LL=-39.44
					AIC=-25.44; BIC=-3.09
Intercept	0.58***	0.02	0.53	0.62	
Age	0.06**	0.02	0.02	0.10	
Risk Perception	0.01	0.02	-0.03	0.06	
Reward Sensitivity	0.09	0.09	-0.08	0.27	
Inhibitory Control	0.01	0.05	-0.10	0.11	
Model 2					-2LL=-42.51, Δ-2LL=3.07^{+}
					AIC=-26.51; BIC=-0.97
Intercept	0.53***	0.03	0.46	0.60	
Age	0.57*	0.02	0.01	0.10	
Risk Perception	0.01	0.02	-0.04	0.06	
Reward Sensitivity	0.10	0.09	-0.07	0.28	
Inhibitory Control	0.01	0.05	-0.09	0.12	
Group Membership	0.08^{+}	0.05	-0.01	0.17	
Model 3					-2LL=-46.21 , Δ-2LL=6.77*
					AIC=-36.21; BIC=-20.02
Intercept	0.53***	0.03	0.45	0.59	
Age	0.05*	0.02	0.01	0.09	
Group Membership	0.09^{+}	0.04	0.00	0.17	

Note. CI = 95% Confidence Interval. $^{+}$ *p*<.10, **p*<.05, ** *p*<.01, *** *p*<.001

Table 2 b. Multilevel Models to Predict Gambling Under Risk.

	B	*SE*	CI_{Low}	CI_{High}	*Fit Indices*
Model 1					-2LL=9.81
					AIC=23.81; BIC=46.16
Intercept	0.52***	0.03	0.47	0.57	
Age	0.02	0.03	-0.03	0.07	
Risk Perception	0.01	0.03	-0.05	0.06	
Reward Sensitivity	0.14	0.10	-0.07	0.34	
Inhibitory Control	0.04	0.06	-0.08	0.16	
Model 2					-2LL=9.44, Δ-2LL=0.37
					AIC=25.44; BIC=50.98
Intercept	0.50***	0.04	0.42	0.58	
Age	0.02	0.03	-0.03	0.07	
Risk Perception	0.01	0.03	-0.05	0.06	
Reward Sensitivity	0.14	0.10	-0.06	0.34	
Inhibitory Control	0.05	0.06	-0.08	0.17	
Group Membership	0.03	0.05	-0.07	0.14	

Note. CI = 95% Confidence Interval. $^{+}$ p<.10, *p<.05, ** p<.01, *** p<.001

Table 2 c. Multilevel Models to Predict Cheating.

	B	*SE*	CI_{Low}	CI_{High}	*Fit Indices*
Model 1					-2LL=1,134.47
					AIC=1,148.47; BIC=1,169.73
Intercept	7.95***	1.11	5.75	10.16	
Age	-2.97**	1.07	-5.10	-0.85	
Risk Perception	0.79	1.09	-1.36	2.95	
Reward Sensitivity	4.05	4.11	-4.08	12.18	
Inhibitory Control	-3.16	2.48	-8.08	1.75	
Model 2					-2LL=1,134.46, Δ-2LL=0.01
					AIC=1,150.46; BIC=1,174.76
Intercept	8.11***	1.74	4.65	11.58	
Age	-2.96**	1.08	-5.10	-0.82	
Risk Perception	0.81	1.10	-1.37	2.98	
Reward Sensitivity	4.02	4.12	-4.12	12.16	
Inhibitory Control	-3.18	2.48	-8.11	1.74	
Group Membership	-0.28	2.29	-4.83	4.27	

Note. CI = 95% Confidence Interval. $^{+}$ p<.10, *p<.05, ** p<.01, *** p<.001