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A Meta-Analysis on Age Differences in Risky Decision Making: Adolescents Versus Children and Adults

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Despite evident heightened adolescent risk-taking in real-life situations, not all experimental studies demonstrate that adolescents take more risks than children and adults on risky decision-making tasks. In the current 4 independent meta-analyses, neurodevelopmental imbalance models and fuzzy trace theory were used as conceptual frameworks to examine whether adolescents engage in more risk-taking than children and adults and whether early adolescents take more risks than children and mid-late adolescents on behavioral risk-taking tasks. Studies with at least 1 of the aforementioned age comparisons met the inclusion criteria. Consistent with imbalance models and fuzzy trace theory, results from a random-effects model showed that adolescents take more risks (g = .37) than adults, and early adolescents take more risks (g = .15) than mid-late adolescents. However, inconsistent with both perspectives, adolescents and children take equal levels of risk (g = −.00), and early adolescents and children also take equal levels of risk (g = .04). Meta-regression analyses revealed that, consistent with imbalance models, (a) adolescents take more risks than adults on hot tasks with immediate outcome feedback on rewards and losses; however, contrary to imbalance models but consistent with fuzzy trace theory, (b) adolescents take fewer risks than children on tasks with a sure/safe option. Shortcomings related to studies using behavioral risk-taking tasks are discussed. We suggest a hybrid developmental neuroecological model of risk-taking that includes a risk opportunity component to explain why adolescents take more risks than children in the real world but equal levels of risks as children in the laboratory.

Keywords: risky decision making, risk-taking, age differences, meta-analysis, adolescence

Heightened risk-taking behaviors (e.g., reckless driving, binge drinking) are the leading cause of death for adolescents, as the associated negative outcomes account for about a 200% rise in mortality rates compared to childhood (Dahl, 2004). The past decade has witnessed a rapid growth in studies dedicated to the understanding of heightened real-world risk-taking in adolescence, by employing various types of behavioral risk-taking tasks (e.g., description-based vs. experienced-based), in diverse settings (alone vs. peers; Albert & Steinberg, 2011; Boyer, 2006). Surprisingly, although some of these studies (e.g., Burnett, Bault, Coricelli, & Blakemore, 2010) demonstrated an inverted *U*-shaped curve, denoting a peak in risk-taking in adolescence, other studies (e.g., Paulsen, Carter, Platt, Huettel, & Brannon, 2012) reported risk-taking levels that are the highest in childhood with declines thereafter. Yet, in some studies no age differences were observed (e.g., Van Leijenhorst, Westenberg, & Crone, 2008). Despite existing insightful narrative reviews on heightened adolescent risk-taking (e.g., Boyer, 2006), so far no formal meta-analysis exists that could quantify and perhaps reconcile the seemingly contradictory findings. To date, the only meta-analysis that addressed age differences in risk-taking focused solely on adults and showed that age differences in young adults' versus older adults' risk-taking varied considerably as a function of task characteristics (Mata, Josef, Samanez-Larkin, & Hertwig, 2011). Hence, the current paper is a meta-analysis that investigates (a) whether adolescents engage in more risk-taking than children and/or adults on behavioral risk-taking tasks and (b) under which task and contextual circumstances specific developmental patterns occur. Moreover, early adolescence and mid-late adolescence are two distinct developmental phases, especially because early adolescence is

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characterized by pubertal onset. Therefore, we also examine (c) whether early adolescents differ from children and mid-late adolescents in risk-taking.

Adolescent Risk-Taking and Defining Risk

For ages, adolescents have been labeled as the stereotypical risk-takers, but only recently has science become concerned with unraveling why adolescents disproportionately engage in risk-taking compared to children and adults. Complicating this matter further is the fact that, although pubertal onset is conceptually acknowledged as the beginning of adolescence, there is no consensus on the span of the adolescent period. For example, recent reviews (e.g., Crone & Dahl, 2012) indicate that some studies have referred to 9- to 12-year-olds as early adolescents but other (recent and older) studies have referred to 9- to 12-year-olds as children (for a review and overview of these studies, see Boyer, 2006; Richard, Plate, & Ernst, 2013). Similarly, some reviews have referred to youths between ages 19 and 24 as late adolescents (because it is now believed that the prefrontal cortex continues to mature until mid-adulthood; Giedd, 2010), but the vast majority of existing studies have referred to youths within that age range (i.e., 19–24 years) as emerging or young adults (for a review and overview of these studies, see Boyer, 2006; Richards et al., 2013).

In the current meta-analysis we use the traditional definition of adolescence (11–19 years), as used most commonly in past studies, which describes adolescence as beginning at the age of 11/12 and ending at the age of 18/19. Thus, adolescence (as defined in the current meta-analysis) is the period in life in which most youths make a transition into and out of high school. Of importance, this period is also the hallmark in which opportunities to engage in many health-threatening risky behaviors show accelerated growth (e.g., alcohol access, driving). Consequently, adolescents are repeatedly faced with decisions that they are compelled to make, often including competing choice options of whether or not to engage in risk-taking behaviors. Accordingly, a *decision-making framework* is deemed a promising approach for studying heightened adolescent risk-taking, because engaging in risk-taking can be considered a decision that someone makes (for a critical evaluation, see Furby & Beyth-Marom, 1992; Reyna & Farley, 2006). Indeed, there is substantial growth in the number of experimental studies employing diverse risky decision-making tasks aimed at inducing naturalistic heightened adolescent risk-taking, in hope of capturing the underlying mechanisms of this phenomenon. However, laboratory risky decision-making tasks have often been questioned on their validity, primarily their ecological validity; yet, such criticism is unjustified for many risky decision-making tasks, because these tasks have been shown to be related to sensation seeking and real-world risk-taking behaviors alike (e.g., Defoe, Dubas, & van Aken, 2014; Lejuez, Aklin, Zvolensky, & Pedulla, 2003; Reyna et al., 2011; Steinberg et al., 2008). This is also the case with many tasks included in the current meta-analysis (see Table 1 for a description of the tasks and their psychometric properties). An ongoing related unresolved issue, however, is the debate of what the phenomenon “risk-taking” essentially entails, which we will try to clarify next.

Despite the numerous refined risky decision-making tasks that have been designed during the last decade to measure risk-taking, the definition of *risk* has remained a controversial issue. No consensus has been reached in defining this term (Schonberg, Fox, & Poldrack, 2011). The lay and clinical definition of the word *risk-taking* is often used in the sense of “engaging in a behavior that could potentially have a negative outcome.” However, most adolescents engage in normative levels of risk-taking behavior, and risk-taking behavior does not necessarily have to be the “bad” choice, although the term risk-taking usually has a negative connotation. Moreover, opinions vary on what should be considered negative, and thus opinions vary on what should be classified as risky (see Reyna & Farley, 2006, for a more thorough discussion). Hence, as an alternative for the subjective definition of risk-taking, in the current meta-analysis we opt for the more objective definition of the term risk as used in the judgment and decision making literature, which in essence encompasses choosing the “option with the highest outcome variability” (Figner & Weber, 2011; Weber, 2010). In other words, this entails choosing the option with the wider range of possible outcomes (see Figner & Weber, 2011). Indeed, in most cases, at least one of the possible outcomes of a risky choice could (arguably) be considered negative, and riskier options equal more uncertain outcomes (Figner & Weber, 2011). In sum, the core characteristic of the term risk as used in the judgment and decision literature is *outcome variability*: The option with the widest range of possible outcomes is considered the riskiest option. Accordingly, risk is often quantified as the variance or standard deviation computed for the possible outcomes an option entails. Of importance, the riskiest option is thus also the option associated with the highest uncertainty about what exact outcome one can expect to receive.

There is a somewhat related confusion about the terms risk-taking, risk preference, risk-aversion, and risk-seeking. Also in this case, we adhere to the nomenclature used in the decision-making literature, as this field developed objective meanings and operationalizations for these concepts. Risk-taking is choosing the riskiest of the available choice options (i.e., the option with the highest outcome variability). Many risky decision-making tasks offer choices between two options. At least one of the two is a risky option (i.e., the outcomes do not have a 100% probability of occurring); the other option is sometimes a safe option (i.e., a “sure” option; the participant knows exactly which outcome he/she will receive when he/she chooses that option), and sometimes it is also a risky option (but might be an option with a lower outcome variability and thus a less risky option). Risk preference is related to an individual’s preference (or tendency) to choose riskier or less risky (or safe) options in a decision-making task.

Besides risk, another important concept is expected value (EV). Expected value refers to the expected outcome; that is, the sum of all outcomes (gains or losses), each multiplied by their probability of occurring. For example, consider that you are offered the choice between either $2 for sure or the chance to toss a fair coin: If the coin lands on heads, you win $4, and if it lands on tails, you get $0. The expected value of the gamble (the coin toss) is $4 multiplied by .50 (50% probability) plus $0 multiplied by .50; thus, $2. The expected value of the $2 for sure is obviously $2; namely, $2 multiplied by 1 (100% probability). Thus, in our example, both choice options have the identical EV ($2), but they differ on risk: The outcome variability is 0 for the sure option (as there is only one possible outcome) but is non-zero for the coin toss, as there are two different possible outcomes ($4 or $0). The example shows that is important to note that risk (i.e., outcome variability) and

Table 1
Characteristics and Psychometric Properties of the Tasks Employed in the Studies Included in the Meta-Analyses

Task	Description	Psychometric properties	No. studies
Probabilistic Gambling Task	In each trial on this computerized game, participants were presented with 2 wheels of fortune. They were instructed to choose 1 of the wheels, with the aim of maximizing the number of points won. Positive or negative numbers next to the wheel signified potential wins and losses. The probabilities (0.2/0.8 or 0.5/0.5) of wins and losses (i.e., 200, 50, −50, or −200) for each wheel corresponded with the relative size of the sectors of the wheel. After each trial participants won or lost, depending on where the arrow landed; thereafter, participants were asked to indicate how they felt on a linear rating scale at the bottom of the screen: from −50 (extremely negative) to 50 (extremely positive). To maximize winnings, the participant should choose gambles with higher expected value (EV); however, gambles with equal EV may differ in their level of risk (see Burnett et al., 2010, pp. 184–187). *Risk-taking* is measured as the outcome variability of a gamble (Burnett et al., 2010).	Psychometric properties are unknown.	1
Iowa Gambling Task (IGT)	For each trial, participants are told to choose 1 card at a time from 1 of 4 decks that differ in payoffs and losses. Selections from the 2 "disadvantageous" decks are followed by a higher reward on most trials but also by higher (unpredictable) losses; thus, the final result is an "overall net loss" (i.e., negative expected value). The 2 "advantageous" decks are followed by lower rewards on most trials but also by lower (unpredictable) losses; thus, the final result is an "overall net gain" (i.e., positive expected value). Participants are not told how many card selections they will make, but there are typically 100 selections throughout the entire task. Participants learn the experienced outcomes through trial and error (see Bechara et al., 1994, pp. 8–10; Prencipe et al., 2011, p. 626; Smith et al., 2012, pp. 181–182). In studies using the IGT, risk-taking is typically operationalized as the number of choices from the 2 advantageous decks minus the 2 disadvantageous decks (i.e., net score). However, in the current meta-analysis, risk-taking was operationalized as the mean number of choices from the deck with the highest outcome variability (i.e., the "risky" deck).	Modest to high reliability has been found for the IGT. With regard to validity, performance on the tasks discriminates between substance abusers and non-substance abusers (see Dahne et al., 2013).	2
The Hungry Donkey Task (HDT)	The Hungry Donkey Task (HDT) is a modified version of the IGT (see above). On this 4-choice task, participants lead a donkey to choose 1 of 4 doors, all of which are associated with a cost or reward in apples. As in the IGT, 2 of the doors are "disadvantageous," and the other 2 are "advantageous." Participants are told that the hungry donkey should be rewarded with as many apples as possible. The relative proportions of wins and losses of the HDT are the same as those used in the IGT (Bechara et al., 1994); however, the absolute magnitude of the wins and losses was reduced by a factor of 25 (see Crone & van der Molen, 2004, pp. 257–260; Crone & van der Molen, 2007, pp. 1291–1292; Huizenga et al., 2007, p. 816). In studies using the HDT, risk-taking is typically operationalized as the number of choices from 2 advantageous doors minus the 2 disadvantageous doors (i.e., net score). However, in the current meta-analysis, risk-taking was operationalized as the mean number of choices from the door with the highest outcome variability (i.e., the "risky" door).	Psychometric properties of the HDT are unknown (but see psychometric properties of the IGT).	2

Table 1 (*continued*)

Task	Description	Psychometric properties	No. studies
The Gambling Game (modified version of the Hungry Donkey Task, which is an adaptation of the IGT)	The Gambling Game is a computerized task with 4 machines, each characterized by a potential gain amount. Each machine contains 10 balls that are either "red" loss balls or "green" gain balls. The amount of loss is indicated on the red balls in numerical format, and frequency of loss corresponds with the total number of red balls present in a machine. The idea is to collect as many points as possible. After participants chose a machine, the balls were shuffled, and 1 ball was (semi-randomly) drawn. Participants began the game with zero points, and each time a machine was chosen, the accumulated won or lost points were updated and were numerically and visually (via a color change) displayed by a horizontal bar. The task consisted of a condition wherein the gain and loss magnitude and the frequency of loss per choice option were numerically displayed below the machine (informed condition) and a condition wherein such information was not provided (noninformed condition; see Van Duijvenvoorde et al., 2012, pp. 194–196). In studies using the Gambling Task, risk-taking is typically operationalized as the number of choices from 2 advantageous machines minus the 2 disadvantageous machines (i.e., net score). However, in the current meta-analysis, risk-taking was operationalized as the mean number of choices from the machine with the highest outcome variability (i.e., the "risky" deck).	Psychometric properties of the the Gambling Game are unknown (but see psychometric properties of the IGT).	1
Mirror Drawing Risk-Taking Task	This task included a mirror-drawing apparatus and 3 drawings of 2 parallel lines constituting borders that were zigzag-shaped with 4 irregular peaks. Participants were instructed to draw a line within the border but to avoid touching either line. There were 3 stages in this task, and for each stage participants were offered the choice between a less risky task for a smaller reward or a riskier task for a larger reward. Participants who chose the less risky tasks always earned 5 points, and they earned an additional 5 points for each of the 4 peaks that they traced without touching a line. For the riskier option, the number of points won was double the amount of points that could be won on the less risky task (see Kreitler & Zigler, 1990, p. 306). *Risk-taking* was operationalized as the number of choices for the riskier task (see Kreitler & Zigler, 1990).	Psychometric properties of this task are unknown.	1
Chicken Game	Chicken is a computerized driving game, for which participants make decisions concerning whether to stop a car from moving across the screen when a traffic light turns from green to yellow. A yellow traffic light signals an impending red traffic light, and if the car is still moving when the red light appears, a crash could occur. Participants are informed that the goal is to allow the car to move as far as possible without crashing into the wall. The farther they move the car successfully the more points they earn, but they lose any accumulated points if the car crashes. Participants can stop or move the car, but they have no control over the speed of the car. When the yellow light appears, participants are faced with the decision to either stop the car or take a risk of running the red traffic light and crashing the car into the wall. The latency between the beginning of the trial and the appearance of the yellow light, and between the appearance of the yellow light and the popping up of the wall, varied across trials. As a result, participants were unaware of when exactly the wall would appear (see Gardner & Steinberg, 2005, pp. 627–628; Steinberg et al., 2008, pp. 1768–1769). *Risk-taking* was calculated with a composite score that consisted of the mean scores of the number of car restarts per round and the percentage of times the car was moving (Gardner & Steinberg, 2005). Thus, higher scores for moving times and restarts indicated greater risk-taking (Gardner & Steinberg, 2005).	Psychometric properties of this task are unknown (but see psychometric properties of the Stoplight Game).	1

(*table continues*)

Table 1 (*continued*)

Task	Description	Psychometric properties	No. studies
Stoplight Game	The Stoplight driving game is a modified version of the Chicken Game, and it is also played on a computer. On each trial, participants aim to reach the end of a straight driving lane as quickly as possible. Each of the 20 intersections of the lane counted as a separate trial. A yellow traffic light signals an impending red traffic light and a possible collision with another car if the target car is still moving when the red light appears. When the yellow light appears, participants are faced with the decision either to stop and encounter a short delay or to take a risk of running the red traffic light and crashing, which resulted in a relatively long delay. However, if risk-taking was successful, there was no delay (see Chein et al., 2011, pp. F2–F3; Steinberg et al., 2008, pp. 1768–1769). *Risk-taking* was measured as not braking at the yellow light. The game had an incentivized design, as monetary incentives were paid for completing the course in a timely fashion (which also encouraged risk-taking; Chein et al., 2011; Steinberg et al., 2008).	This task is correlated with sensation seeking (Chein et al., 2011; Steinberg et al., 2008).	2
Wheel of Fortune	The computerized wheel of fortune (WOF) task is a 2-choice decision-making task with probabilistic monetary outcomes. On each trial, a wheel (i.e., a circle divided into 2 slices of different size and of 2 different colors) was presented to participants. Throughout the task, 4 types of monetary wheels, differing on probability (corresponding with the size of the slices) and reward magnitude, were presented in random order. Participants were instructed to select 1 of the slices by its color. If the computer randomly selected the same color as the participant did, the designated amount of money was won. However, the participant won nothing if the computer randomly selected the other color. Smaller slices were always paired with the higher reward magnitude. In a feedback phase, wherein the outcome was displayed, participants had to rate how they felt about their outcome (see Ernst et al., 2004, pp. 1586–1588; Eshel et al., 2007, p. 1272). *Risk-taking* was measured with a percent risky selections score, which was computed using the number of times 10% and 30% probability options were selected relative to the total number of times that the 10/90 and 30/70 wheels were presented (Eshel et al., 2007). Thus, the risky options had a lower probability of a high reward (Eshel et al., 2007).	Reliability data on the WOF is limited; however, regarding validity, greater frequency of low-probability (high-risk) choices on the win–no win version of the WOF has been shown to predict substance-related problems. Low-probability (low-risk) choice on the lose–no lose version of the task does not predict substance-related problems (see Dahne et al., 2013; Rao et al., 2011).	1
Hot Columbia Card Task (hCCT)	The hCCT begins with a presentation of 32 cards and a score of 0 points. Participants decide to turn over cards sequentially, with immediate outcome feedback provided after the turning over of each card. A round ends when participants encounter a loss card, or if participants choose to stop turning over cards and collect all gains from that round and move on to the following rounds. Per round, three variables vary systematically: the magnitude of gain, the magnitude of loss, and the gain/loss probability (see Figner et al., 2009, p. 712; Figner et al., 2014, pp. 9–10; Figner & Weber, 2011, pp. 213–214; Gladwin et al., 2011, p. 365). *Risk-taking* was measured by how many cards participants turn over before they decide to stop. The decision to turn over an additional card increases the outcome variability (i.e., risk), because the probability of encountering a loss card increases and the probability of encountering a gain card decreases (see Figner et al., 2009, p. 712; Figner et al., 2014, pp. 9–10; Figner & Weber, 2011, pp. 213–214; Gladwin et al., 2011, p. 365). See below for another variant of the Columbia Card Task.	In the hCCT, high sensation seekers (vs. low sensation seekers) were shown to turn over more cards (i.e., take more risks (Penolazzi et al., 2012). Cronbach's alphas for this task show high reliability (personal communication with Bernd Figner).	Two articles encompassing 5 studies.

Table 1 (*continued*)

Task	Description	Psychometric properties	No. studies
Cold Columbia Card Task (cCCT)	The cCCT is similar to the hot version (see above). There are only 2 differences: (a) the cCCT includes a single decision per round and (b) outcome feedback is delayed until all rounds are over (see Figner et al., 2009, p. 712; Figner et al., 2014, p. 9–10; Figner & Weber, 2011, pp. 213–214; Gladwin et al., 2011, p. 365). *Risk-taking* was measured by how many cards participants choose to turn over (Figner et al., 2009; Figner & Weber, 2011).	In the cCCT, no significant difference was found between high and low sensation seekers (see also the hCCT; Penolazzi et al., 2012). Cronbach's alphas for this task show high reliability (personal communication with Bernd Figner).	Two articles encompassing 5 studies
Cups Task	On each trial in this computerized cups task, options are presented as a choice of turned-over cups with money hidden under them. Each trial includes either gains or losses, and participants had to choose between a risky and a safe option. The sure option always resulted in a gain of $2; the risky option involved the computer randomly selecting 2, 3, or 5 cups, containing either a gain of $4, $6, or $10 or nothing (i.e., $0). Half the trials were framed as a choice between a certain and uncertain gain, and the other half were framed as a choice between a certain and uncertain loss. There were 3 trial types that differed on EV (see Galván & McGlennen, 2012, pp. 434–435; Levin & Hart, 2003). *Risk-taking* was operationalized as choosing the uncertain (risky) option (compared to the sure/certain option; Galván & McGlennen, 2012).	Three-year stability was observed for equal EV gambles on the Cups Task for both children and adults (Levin et al., 2007). Impulsivity was positively related to overall risk-taking equal EV choices of the Cups Task (whereas thrill seeking was not).	1
Gambling Task	On each trial in this event-related computerized gambling task, participants were presented with a horizontal bar divided into 2 colored parts representing the probability of an imaginary token being hidden underneath. The proportion of 1 colored part to the total bar varied from 5–95% to 50–50%. Participants could guess (i.e., gamble) under which part a token was hidden, or they could pass in order to earn as many points as possible. The points (randomly varying between 10 and 100) that could be won were indicated by a number above the bar, and the points that could be lost were indicated by a number below the bar. The most ambiguous proportions (50–50%) were linked with the highest losses (80–100 points). Participants earned the most points possible via gambling, but they could also choose to withhold their response (i.e., a pass trial), which resulted in 20 points. Participants began with 100 points and received feedback about the trial and an update of their total score in 67% of all trials (see Keulers et al., 2011, pp. 1444–1445). *Risk-taking* was measured with the ratio gamble/pass trials (Keulers et al., 2011).	Psychometric properties of this task are unknown.	1
Balloon Analogue Risk Task–Youth (BART-Y)	In this computerized game, participants are instructed to pump a balloon. Participants are unaware of the balloon's explosion point; however, they are told that the explosion point varies per balloon trial. Each pump equals 1 point won, but each pump also increases the chance of an explosion resulting in a loss of all the accumulated points for that balloon. If participants stop pumping the balloon before it explodes, they then earn all of the points accumulated for that balloon (see Lejuez et al., 2007, pp. 27–28; Macpherson et al., 2010, pp. 1402–1403). *Risk-taking* was measured as the average number of pumps on unexploded balloons (i.e., the "adjusted average"; Macpherson et al., 2010).	The BART has been shown to have up-to-par reliability, and performance on the BART is related to numerous real-world risk-taking behaviors (e.g., substance use) in middle adolescents and adults (see, e.g., Dahne et al., 2013).	1

(*table continues*)

Table 1 (*continued*)

Task	Description	Psychometric properties	No. studies
Nonsymbolic Economic Decision-Making Task	On each trial, participants were presented with a choice between 2 certain options (safe–safe trials), between a certain and a gamble option (risk–safe trials), or between 2 gamble options (risk–risk trials). On safe–safe trials participants made a decision between 2 certain options; on risk–safe trials they made a decision between a gamble and a safe option with equal EV. On risk–risk trials participants had to make a decision between 2 gambles of different EV and coefficient of variation. Two levels of EV (and 2 levels of risk) were used (see Paulsen et al., 2011, pp. 2–3; Paulsen et al., 2012, pp. 2–3). In the current meta-analysis, results based on the risk–safe trials were used. *Risk-taking* was operationalized as choosing the gamble (risky) option (see Paulsen et al., 2011, 2012).	Psychometric properties of this task are unknown.	2
The Framing Spinner Task	In the Framing Spinner Task, participants made a choice between 2 spinners with an arrow in the middle: One spinner was completely red representing a sure option, and the other spinner had varying proportions of blue and red representing a gamble. Risk levels varied as follows: one-half, two-thirds, and three-fourths chance of winning nothing (i.e., gain frame) and one-half, two-thirds, and three-fourths chance of losing something (i.e., loss frame). Reward levels varied between low ($5), medium ($20), and high ($150). There was money on the spinners, which represented hypothetical wins or losses. In loss problems, participants began with an endowment, from which subsequent losses were deducted, whereas participants began with no money for the gain frames. The displayed net outcomes were the same for both frames. On each trial, after participants selected their choice, they rated their degree of preference (see Reyna et al., 2011, pp. 1129–1130). *Risk-taking* was operationalized as the proportion of gamble choices (Reyna et al., 2011).	This tasks predicts real-world risk-taking behaviors, such as sexual risk-taking (see Reyna et al., 2011).	1
Knife Switches Task (also known as the Devil's Task)	The participant was seated before a panel of 10 small knife switches and was told that 9 of these switches were "safe" and 1 was a "disaster" switch. The participant was told in simple terms that the disaster switch was assigned in a random and equiprobable manner to each of the switch positions. The participant was instructed to pull 1 of the switches. If the participant pulled a safe switch, he (or she) was allowed to put 1 spoonful of M&M's candies into a glass bowl. The participant then had to decide whether to pull another switch in an attempt to win another spoonful of candy or to stop and keep the accumulated candy. In the event that a participant pulled the disaster switch, a buzzer went off, and he lost all the accumulated candy. The game ended when the participant either stopped and collected his candy or pulled the disaster switch and lost all of his accumulated candy. If the participant pulled 9 safe switches, he was told that the game is over and was then given his 9 spoonfuls of candy. Each participant was allowed to play the game only once except if the first switch pulled was the disaster switch. Hence, all participants had the chance to pull at least 1 safe switch (see Slovic, 1966, pp. 171–172). *Risk-taking* was operationalized as the number of pulled switched, because the probability and magnitude of the participant's potential loss increase with the number of switches pulled (Slovic, 1966, pp. 171–172).	This task has obvious face validity (Dahne et al., 2013), and it predicts whether children will or will not cross a street safely or dangerously (Hoffrage et al., 2003).	1

Table 1 (*continued*)

Task	Description	Psychometric properties	No. studies
The Cake Gambling Task	The Cake Gambling Task is a 2-choice decision making task in which participants are instructed to choose between 2 flavors of cake; a low-risk gamble and a high-risk gamble. The reward magnitude coupled with the high-risk gambles was varied. Three types of cakes with different probability of winning were presented to participants. The amount of credits that could be won or lost was associated with the choices that could be made, with a large amount of credits always being coupled with the smallest probability of winning (see Van Leijenhorst et al., 2008, pp. 182–185; Van Leijenhorst et al., 2010, p. 347). *Risk-taking* was measured via the amount of high-risk choices chosen, because high-risk choices were associated with a larger probability of resulting in an undesirable consequence (i.e., not winning; Van Leijenhorst et al., 2008, pp. 182–185; Van Leijenhorst et al., 2010, p. 347).	Risk-taking on this task correlates with sensation seeking (see Van Leijenhorst et al., 2008).	2
Description/ Experience Task	On each trial of this task, participants were presented with a pair of opaque boxes containing cubes varying in point value. Participants had to make a choice between the 2 boxes, and each choice included an option between a sure thing and a risk, with 2 possible payout values. Participants were instructed to choose a cube from the box they selected and were told that the idea was to win as many points as possible. The task consists of 2 versions. In the description version, the option payoffs are displayed on the front of each box, in frequency format. In the experience condition, participants learn about both options via 10 random draws with replacement, facilitating observation of each option's payoffs. After these 10 observations, participants make their one-shot choice between the 2 options (see Rakow & Rahim, 2010, pp. 70–73). *Risk-taking* was operationalized as the number of risky options chosen (Rakow & Rahim, 2010).	Psychometric properties of this task are unknown.	One article encompassing 3 studies
Incentive-Compatible Two-Choice Task	Participants performed an incentive-compatible 2-choice computerized task, wherein 1 choice was associated with a sure gain of $5, and the other was a gamble with a chance to win more than $5 or with a chance to win $0. In the current meta-analysis the half of the 160 trials (thus, 80 trials) for which outcome probability was known to the participant was used (i.e., the "risky" lottery trials). Details about the parameters of the gamble were varied systematically (in random order) to assess how participants' choices were affected by probability of winning (13%, 25%, 38%, 50%, and 75%), the magnitude of the potential win ($5, $8, $20, $50, and $125), and ambiguity about the probability of winning (24%, 50%, and 74% ambiguity around a probability of 50%). Participants also performed loss trials, but the results on those trials were not reported in the paper (see Tymula et al., 2012, pp. 17139–17140). *Risk-taking* was operationalized as choosing the uncertain (risky) option (compared to the sure/certain option; Tymula et al., 2012).	Risk-taking on this task was not related to self-reported risk-taking behaviors (see Tymula et al., 2012).	1

expected value are theoretically independent and have to be distinguished from each other. As described in more detail in later sections, in some tasks, the riskier and the safer options have the identical expected value (which was the case with the previous example of the coin toss); in some tasks, the riskier option has the higher EV, but in other tasks, the safer option has the higher EV. Yet other tasks (both static and dynamic; see, e.g., Figner, Mackinlay, Wilkening, & Weber, 2009; Figner & Weber, 2011; Levin, Hart, Weller, & Harshman, 2007; Reyna et al., 2011) systematically vary risk and EV. Thus, they might include trials in which the riskier option has the higher EV, trials in which the safer option has the higher EV, and trials in which both options have the same EV.

Many experimental risk-taking tasks involve making choices about monetary outcomes and include receiving actual money based on the participant's choices. In these tasks, the EV (as well as risk) therefore is calculated in terms of money. From a normative viewpoint, if one's only goal is to maximize long-term financial outcomes, one should choose only according to EV and ignore risk. It should be noted as well, however, that choosing according to EV is a special case, in which one assumes that the individual has linear subjective representations of outcomes and probabilities and that gains and losses are equally weighted (in the literature, this is sometimes referred to as *risk* and *loss neutrality*). A large body of evidence—starting with the earliest theorizing about risky decision making (e.g., Bernoulli (1738/1954) and the concept of expected utility instead of expected value and more recently within the framework of prospect theory (Kahneman & Tversky, 1979)—has shown that maximization of EV is typically not the case. Rather, humans and other animals deviate from this strategy due to nonlinear representation of the underlying "primitives," such as probabilities, gains, and losses, from which expected value or expected utility are computed (for a brief introduction including a historical overview, see Weber & Johnson, 2008; see also the section Gain Gambles Versus Mixed Gambles, below).

However, instead of finding risk neutrality, the vast majority of the risky decision-making literature (using most often adult participants, probably often undergraduate students) finds patterns of risk-aversion. That means, everything else being equal, as risk increases, a choice option becomes less attractive and will less likely be chosen. As we have just explained, risk-aversion also means that individuals choose suboptimally, if the goal is to maximize financial earnings, as long-term maximization of financial earnings typically implies risk-neutrality (i.e., to always choose the option with the highest EV).

Keeping these points in mind can be important when interpreting empirically observed risk-taking levels: In some risky decision-making tasks, the majority of participants exhibits risk-aversion, meaning that they stay below the level of risk-taking that would maximize EV. For example, studies that find that one group (e.g., substance users) exhibits higher levels of risk-taking than another group (e.g., healthy controls) actually observe that the "problematic" group (e.g., substance abusers) might make the more ideal choices (again, at least from the perspective of long-term maximization of financial outcomes). That is, both groups may be risk-averse (and thus below the optimal risk-taking levels that EV maximization would suggest) but the problematic group less so than the control group. As a consequence, the problematic group might actually earn more money than the control group, and thus caution should be used when labeling such decisions negatively, such as calling them excessive risk-taking.

As this may illustrate, it is often problematic—and may even be misleading—to directly extrapolate from observed risk-taking levels to individuals' risk-preferences (i.e., risk-aversion, risk-neutrality, risk-seeking). As argued elsewhere (Figner & Weber, 2011), it is crucial to make the distinction between observed risk-taking levels and the underlying mechanisms that lead to these observed risk-taking levels. The underlying mechanisms can include, besides other factors, individuals' risk preferences. We return to this issue when we discuss task-related moderators.

Conceptual Framework

Cognitive Processes

Before the mid-1990s, the study of risky decision making was dominated by scholars who posited that heightened adolescent risk-taking was the result of cognitive deficits in adolescence, such as a lack of rational (i.e., analytic computational) information processing (for a review, see Furby & Beyth-Marom, 1992). Despite the popularity of such cognitive models, more recent empirical research indicates that even young children can exhibit a firm understanding of probabilities (Schlottmann, 2001), arguing against a more general task and context independent cognitive deficit. Moreover, compelling evidence suggests that logical reasoning and information processing abilities show a linear increase with age and stabilize by mid-adolescence, indicating that such cognitive abilities are for the most part intact by adolescence (Hale, 1990; Kuhn, 2009; Reyna & Farley, 2006). Thus, although rudimentary components of decision-making skills (e.g., the understanding of probabilities) are evident in childhood, these skills undergo significant improvements at least throughout adolescence and show decline only in later adulthood.[1]

Accordingly, given that such developmental differences in cognitive maturity exist (Hale, 1990; Kuhn, 2009) and that risk-taking is highly dependent on cognitive maturity, this would imply monotonic, not nonlinear quadratic, developmental differences (e.g., that adolescents take fewer risks than children and more risks than adults on risky decision-making tasks). This hypothesis does not mirror the disproportionate adolescent risk-taking evident in the real world, however. Hence, there should be more to age differences in risk-taking than just disparities in deliberative, analytic cognitive abilities. Building upon this notion, developmental differences in risk-taking are increasingly being studied within several frameworks; namely, cognitive dual-process models, cognitive-affective dual-process models, and cognitive-affective-social frameworks. These frameworks are not mutually exclusive, however, and all have been linked in varying degrees to pubertal and neurological changes occurring during adolescence. Hence, in the current meta-analysis we take an integrative approach in studying the underpinnings of age differences in adolescents' risk-taking compared to children's and adults' risk-taking, which we describe in detail below.

Affective Processes

The failure of cognitive theories to explain decision-making behavior gave rise to an "emotions revolution" (Weber & Johnson, 2009), which led researchers to generally investigate how affective processes might play a role in risky decision making (see, e.g., the risk-as-feelings hypothesis; Loewenstein, Weber, Hsee, & Welch 2001). Interest in the role of affective processes (and cognitive control) specifically in heightened adolescent risk-taking followed. Within this framework, two primary models of understanding adolescent risk-taking emerged out of a developmental perspective on adolescence:[2] one that focuses on brain development (developmental cognitive-affective neuroscience model; Somerville & Casey, 2010; Somerville, Jones, & Casey, 2010) and one that combines brain development with the role of peers (developmental

[1] Mata et al. (2011) conducted a meta-analysis on 31 comparisons between young (18–35 years) and old (65–88 years) adults. It was observed that on the majority of the description-based tasks (i.e., tasks wherein information about the probability of the outcomes is provided), no significant age differences were found; however, older adults compared to younger adults made more risky choices on experience-based tasks (i.e., tasks wherein information about the probability of the outcomes is not provided) in which learning should have resulted in risk-avoidant behavior (Mata et al., 2011). Yet, in one task (i.e., the Balloon Analogue Risk Task; Lejuez et al., 2002), when learning should have resulted in risk-seeking behavior, older adults made less risky choices than did young adults (Mata et al., 2011). Thus, Mata et al. (2011) underscored that cognitive-related task characteristics may play a decisive role in age differences in risky decision making, at least in adults.

[2] It is noteworthy that other, related models exist (e.g., the triadic model; Ernst & Fudge, 2009; Ernst et al., 2006).

social neuroscience model; Steinberg, 2007).[3] For discussion purposes we label these models collectively as neurodevelopmental imbalance models.[4]

Neurodevelopmental Imbalance Models

In general, neurodevelopmental imbalance models suggest that there is a potential for an imbalance between cognitive and affective processes in adolescence (Somerville & Casey, 2010; Steinberg, 2007). These models postulate in particular that in emotionally charged ("hot") situations, adolescents' hypersensitive motivational-affective system often overrides any cognitive control that adolescents might have, which could explain adolescents' propensity toward risk-taking not only in laboratory conditions but also in real life (Figner & Weber, 2011; Gladwin, Figner, Crone, & Wiers, 2011; Somerville & Casey, 2010; Steinberg, 2007; for a comparable model, the triadic model, see Ernst & Fudge, 2009; Ernst, Pine, & Hardin, 2006). The term *cognitive control* as used in the contemporary neuroscience literature refers to executive functions more generally and inhibition in particular (Casey, Getz, & Galván, 2008). Cognitive control encompasses top-down control processes that are executed to organize and coordinate goal-directed behaviors (Luna, Garver, Urban, Lazar, & Sweeney, 2004). Unlike cognitive control (governed by the prefrontal cortex), which develops linearly with age but begins to stabilize by adolescence, subcortical "affective" brain regions develop relatively faster and are hypothesized to be hyperresponsive in adolescence (Casey, Jones, & Hare, 2008; Luna et al., 2004; Somerville, Hare, & Casey, 2011). Accordingly, neurodevelopmental imbalance models posit that the "imbalance" between cognitive control and affective reward-related brain regions causes adolescents to become biased toward arousing appetitive stimuli such as rewards, which in turn predicts increased risk-taking in adolescents (Somerville et al., 2011; Steinberg, 2007; Ubeda-Bañon et al., 2007).

Although several similar imbalance models (or dual-process models) exist, it is beyond the scope of the current meta-analysis to fully review all of these imbalance models and other models in detail. However, we do briefly discuss and compare two additional models (the prototype-willingness model and fuzzy trace theory), given that these models are often referred to in contemporary research on adolescent risk-taking (for an extensive review, see Albert & Steinberg, 2011; Reyna & Rivers, 2008). We also go in further detail about fuzzy trace theory, as it is more dissimilar to the neurodevelopmental imbalance models, compared to most other dual-process or imbalance models, which share a close family resemblance (for a more general and thorough discussion as well as a critical evaluation of dual-process models in adolescent risk-taking and other domains, see Gladwin et al., 2011; Gladwin & Figner, 2014; see also Pfeifer & Allen, 2012).

Additional Dual-Process Models

Building on theories of reasoned action and of planned behavior, prototype-willingness theory is a dual-process model that postulates that overreliance on an experiential social reactivity pathway (as opposed to a deliberative reasoned pathway) leads to unplanned risk-taking in adolescence, due to heuristic processing that includes social prototypes (i.e., social images of typical risk-takers) and behavioral willingness (i.e., openness to take risks if the opportunity arises; Gerrard, Gibbons, Houlihan, Stock, & Pomery, 2008; Gibbons, Gerrard, Blanton, & Russell, 1998). However, the prototype-willingness model differs particularly from the cognitive-affective variant of the neurodevelopmental imbalance models by additionally stressing the role of social factors in encouraging and/or allowing risk behavior, such as exposure to media that portray risk behavior positively or living in areas where access to alcohol, drugs, or even guns is relatively easy (i.e., "risky opportunity"; Gerrard et al., 2008). The social variant of the neurodevelopmental imbalance models centrally implicates social processes but mostly in the form of peer presence (see Steinberg, 2007), rather than factors such as media. In any case, neurodevelopmental imbalance models and the prototype-willingness model have in common that they acknowledge that adolescent risk-taking is a result of an imbalance between a top-down cognitive control system and reactive or hypersensitive affective system. Research that is driven by the prototype-willingness model usually does not employ the types of behavioral decision-making tasks that are reviewed here. Therefore, this model is not considered further in the current meta-analysis.

An alternative dual-process model is fuzzy trace theory (Reyna & Rivers, 2008). This theory gives cognitive control a more subordinate role in adolescent risky decision making than do the previously discussed imbalance models (see Table 2 for a comparison of neurodevelopmental imbalance models and fuzzy trace theory). Traditional dual-process models and fuzzy trace theory concur that cognitive control or inhibition increases from childhood to adulthood; however, in fuzzy trace theory, cognitive control is not considered a reasoning mode but serves the function of inhibiting thoughts and actions (Reyna & Rivers, 2008).

Fuzzy trace theory further makes a distinction between two different decision-making processes (or "reasoning modes"); namely, the verbatim-based/quantitative decision-making reasoning mode, more predominant in earlier developmental phases, and the gist-based/qualitative decision making reasoning mode, more predominant in later developmental phases. Of importance, although engaging in either mode shows opposite developmental patterns, the quality of both types of processing is assumed to improve with development. Verbatim-based decision making is more computational and can involve (quasi)mathematical reasoning about costs, benefits, and probabilities. In contrast, gist-based decision making is more categorical (some–none, sure–risky), relies on intuition and heuristics, and can have an affective component (Reyna, 2012; Reyna & Rivers, 2008). Fuzzy trace theory posits that gist-based decision making develops with age, incorporating acquired experiences over time. Fuzzy trace theory thus generally predicts that adolescents will engage in more gist-based decision making than children but will engage in less gist-based decision making than adults.

With regard to risk-taking, fuzzy trace theory argues that verbatim-based decision making can (perhaps counterintuitively)

[3] It should be noted that the developmental cognitive-affective neuroscience model also incorporates the effect of peer presence on the brain's reward system. However, the role of peers is less central in this model than it is in the developmental social neuroscience model.

[4] Henceforth, the phrases *neurodevelopmental imbalance models* and *imbalance models* will be used interchangeably.

Table 2
Comparisons Between the Neurodevelopmental Imbalance Models and Fuzzy Trace Theory

Hypothesis	Fuzzy trace theory	Neurodevelopmental imbalance models
1. Heightened reward seeking in adolescence	Yes (but see reversed framing effect)	Yes
2. Susceptibility to peer influence in adolescence	No	Yes
3. Adolescents take more risks than children	No (but depends on framing)	Yes
4. Adolescents take more risks than adults	Yes	Yes
5. Puberty-related effects on risk-taking	No	Yes
6. Effects of gains versus losses on risk-taking	Yes	No

induce risk-taking because the negative consequences associated with many real-world risk-taking behaviors have a relatively low probability of occurring, compared to the rewards associated with risk-taking (Reyna et al., 2011). For example, the probability of an HIV infection on a single occasion of unprotected vaginal intercourse is very small. Thus, if one weighs the nearly surely occurring advantages of unprotected sex and the more unlikely disadvantages of unprotected sex each with their probabilities, a "cold" computational cost–benefit analysis might indeed come to the conclusion that unprotected sex is the better option, in the sense that the expected benefits outweigh the expected costs. In short, quantitative weighing of the positive and negative consequences by their respective probabilities might foster the conclusion that it is worthwhile to take the risk (Reyna et al., 2011; Reyna & Farley, 2006). In contrast, gist-based reasoning may suggest that incurring any (i.e., even the smallest) chance of infecting oneself with HIV does not outweigh even the surest and most positive advantages that unsafe sex might bring about (Reyna et al., 2011). Additionally, as reliance on gist-based decision making is assumed to increase with age (with a steady increase in adolescence; Rivers, Reyna, & Mills, 2008), holding all other factors equal, fuzzy trace theory predicts that adolescents engage in less risk-taking than children but more risk-taking than adults.[5]

A Critical Evaluation of Fuzzy Trace Theory and Neurodevelopmental Imbalance Models

Neurodevelopmental imbalance models and fuzzy trace theory are currently prominent theoretical models of adolescent risk-taking that are supported by empirical research. However, just like every theory, both of these models have some shortcomings, which we discuss next. First, neurodevelopmental imbalance models explicitly give an estimation of when risk-taking will decline; namely, when the prefrontal cortex is fully developed and thus mature enough to effectively regulate the affective circuit in the brain (Somerville et al., 2010). In contrast, fuzzy trace theory posits that gist-based decision making emerges in early adolescence and gradually improves with age (e.g., Reyna & Ellis, 1994; Reyna et al., 2011), but does not make any specific predictions concerning at what age or during which developmental phase gist-based decision making gets the upper hand. Thus, deriving developmental predictions might be more complex, and less clear for fuzzy trace theory than for neurodevelopmental imbalance models.

Additionally, although gist-based decision making is mature decision making and is assumed to typically reduce or prevent risk-taking, fuzzy trace theory also predicts that gist-based decision making is often linked with emotion. As noted in Rivers et al. (2008), gist-based decision making incorporates emotional valence; that is, whether potential outcomes are viewed as positive or negative. Valence can bias risk and benefit perceptions of outcomes associated with risky situations (Reyna & Rivers, 2008). With experience (and age), risky situations are more likely to be quickly recognized as negatively valenced, which is one factor in protecting adults from taking risks. However, viewing a risky situation as fun or rewarding (which is typically the case when adolescents are with their peers; Albert & Steinberg, 2011) may serve to enhance risk taking among younger (less experienced) adolescents. Fuzzy trace theory attributes risk taking to greater emphasis on verbatim processing of details about risks and benefits, including social benefits associated with peers (i.e., how adolescents are perceived by their peers; Wilhelms & Reyna, 2013). However, research is lacking about how perceptions of positive and negative valences of risky situations develop and how those perceptions influence verbatim and gist processing. Furthermore, the role of affective states in relation to risk taking and risky decision making is not always clear. Positive affective states (as distinct from positive valence of potential outcomes) are assumed to also trigger gist-based decision making (Rivers et al., 2008), resulting in a complex pattern of mutual influences. Fuzzy trace theory also describes that gist-based decision making allows adolescents to better resist emotional impulses than does interference-sensitive verbatim processing (Reyna et al., 2011), predicting that adolescents should engage in less risk-taking when decision making is gist based. If gist-based decision making is more likely to be triggered in positive feeling states (Rivers et al., 2008), why are social situations (e.g., when peers are present) that presumably evoke positive feelings associated with increased risk-taking in adolescents (e.g., Figner et al., 2009; Figner & Weber, 2011; Somerville & Casey, 2010; Steinberg, 2007)? Therefore, the integration of these different factors and situational characteristics appears to be a promising but challenging next step in advancing understanding of the development of risky decision making.

[5] Noteworthy, fuzzy trace theory predicts reverse framing (or less standard framing). That is, in cases when the differences in rewards between the gamble and sure option is large, the gamble option is preferred in the gain frame, whereas the sure option is preferred in the loss frame (Reyna & Ellis, 1994; Reyna et al., 2011; Reyna & Farley, 2006). This reverse framing phenomenon is typically seen in children and adolescents but is hardly ever seen in adults, perhaps because adults are less sensitive to quantitative differences between the outcomes of choice options (e.g., Reyna, 2012; Reyna et al., 2011). We return to the reverse framing effect in the Discussion section.

Next, neurodevelopmental imbalance models suggest that the affective-motivational system (of which the ventral striatum is assumed to be a central part) is hypersensitive during adolescence and that it is activated by emotionally arousing stimuli, such as outcome feedback on immediate rewards or the presence of peers (e.g., Albert & Steinberg, 2011; Somerville et al., 2010). This idea has sparked much interest and debate among researchers (see, e.g., Gladwin & Figner, 2014; Pfeifer & Allen, 2012), as this is a prediction that has not uniformly been supported. For example, a recent fMRI study showed that activation in the ventral striatum increases linearly from childhood to adulthood (Paulsen et al., 2012). Furthermore, two studies (Bjork et al., 2004; Bjork, Smith, Chen, & Hommer, 2010) using a reaction time task, the Monetary Incentive Delay (MID) task (Knutson, Westdorp, Kaiser, & Hommer, 2000), reported under-recruitment (instead of over-recruitment) of adolescents' ventral striatum compared to adults' ventral striatum during the anticipation of a gain (vs. anticipation of no gain). Moreover, no age differences in the recruitment of the ventral striatum were present during the receipt of a gain on the MID task. Thus, recruitment of the ventral striatum might be different for the anticipation of rewards versus the outcome feedback (receipt) of a reward (cf. Braams, Van Leijenhorst, & Crone, 2014), which is interesting but warrants more scientific inquiry. With regard to the role of peers, quite opposite to the findings of Chein, Albert, O'Brien, Uckert, and Steinberg (2011) that showed heightened ventral striatum activation when adolescents performed a behavioral risk-taking task in presence of peers, another recent study (Pfeifer et al., 2011) showed that self-reported susceptibility to peer influence and risk-taking were negatively related to ventral striatum activation.

Although findings across studies might not be directly comparable because of differing methodologies, these inconsistencies indicate that there is still much work to be done on clarifying the neurological mechanisms involved in risky decision making. Despite these shortcomings, both neurodevelopmental imbalance models and fuzzy trace theory provide a useful framework for investigating age differences in risky decision making. Of the predictions of all of the above-described imbalance models, those of the neurodevelopmental imbalance models of heightened adolescent risk-taking can be readily assessed because of their focus on (social) rewards and other affective components, on which contemporary risky decision-making tasks typically vary. Hence we primarily use neurodevelopmental imbalance models as a theoretical guiding framework (a) to investigate (early) adolescents' versus children's, early adolescents' versus mid-late adolescents', and adolescents' versus adults' risky decision making and (b) to investigate (cold vs. hot) moderators relevant for neurodevelopmental imbalance models. However, because fuzzy trace theory addresses certain aspects that neurodevelopmental imbalance models do not take into consideration, we based our hypotheses in these cases on the equally well-established fuzzy trace theory (cf. Tymula et al., 2012). Accordingly, where possible, moderators relevant for fuzzy trace theory were also examined. We next discuss the moderators investigated in the current meta-analysis, as potential candidates to explain differing developmental patterns in risk-taking occurring from childhood to adolescence and from adolescence to adulthood.

Investigated Moderators: Theoretically Relevant Characteristics of Task and Context Description-Based Versus Experience-Based Tasks

Although neurodevelopmental imbalance models emphasize the role of affective processes, these models do not totally disregard cognitive processes. However, they do question the decisive role of cognitive skills in the decision-making process. A reliable way to test just how much cognitive capacity plays a role in age differences in risky decision making is to manipulate the cognitive demands of risky decision-making tasks in an experiment using a developmental sample.

In the decision-making literature, a distinction is often made between decision-making tasks that are cognitively demanding versus tasks that require decision making based on feelings (e.g., Epstein, 1994; Evans, 2008). A pertinent illustration is the categorization of tasks wherein explicit verbal, numerical, or graphical information on probabilities concerning the outcomes is provided (i.e., description-based tasks) versus tasks that require probability learning (e.g., Strub & Erickson, 1968), for which participants have to "learn" the probabilities of the outcomes via feedback (i.e., experience-based tasks; Appelt, Milch, & Weber, 2011). Although learning undeniably includes cognitive processes, experience-based tasks might force participants to rely more on their feelings (Wagar & Dixon, 2006), because computational information on these tasks has to be acquired via experience (i.e., learning), rather than via description. As such, experience-based tasks might be considered to be more emotionally arousing than description-based tasks, and in this sense, affective processes might be more strongly involved in experience-based tasks than in description-based tasks. In fact, the somatic markers hypothesis (Bechara & Damasio 2005; Damasio, Tranel, & Damasio, 1991) introduced the term *emotion-based learning*, which is assumed to be especially salient in ambiguous/uncertain situations (e.g., experience-based tasks without descriptive information; Bechara, Damasio, Damasio, & Anderson, 1994). This, in effect, suggests that when people repeatedly experience rewards or losses, they consequently begin to rely more on affective reactions toward different anticipated outcomes (Bechara et al., 1994). Hence the inclusion of the word *emotion* in emotion-based learning, to signify the influence of emotions in a cognitive process such as learning.

Although on theoretical grounds affective processes might be more strongly involved in experience-based tasks than in description-based tasks, it would be expected that, if adolescents show heightened affective reactivity, they would take more risks than children on such tasks. However, empirical studies employing experience-based risky decision-making tasks do not consistently confirm that adolescents take more risks than children and adults on such tasks. A methodological shortcoming that should be noted in this regard is that only a few experimental studies with developmental samples including children, adolescents, and adults have employed paradigms that actually manipulate availability of explicit information on outcome probabilities (i.e., description-based vs. experience-based tasks). Two exceptions are the recent study of Van Duijvenvoorde, Jansen, Bredman, and Huizenga (2012), which implemented both a description-based (informed) and experience-based (noninformed) condition of a modified version of the popular Iowa Gambling Task (IGT; Bechara et al., 1994), and the study of Rakow and Rahim (2010), which also manipulated the availability of explicit information on probabilities in a risky decision-making task. The former study observed that adolescents took fewer risks than children but more risks than adults in both the description-based (informed) task and the experience-based (noninformed) task (Van Duijvenvoorde et al., 2012). In contrast, Rakow and Rahim's (2010) study, which compared adolescents to children, reported that in the description condition, children took more risks than adolescents, but in the experience-based condition, children and adolescents took equal levels of risks.

These results indicate that the empirical evidence is inconclusive pertaining to the direction of age-related effects on experience-based risky decision-making tasks. Hence, the current meta-analysis aims to quantify if hypothesized age differences in risk-taking among adolescents, on the one hand, and children and adults, on the other hand, vary as a function of task characteristics (i.e., description-based vs. experience-based tasks). If the predictions of neurodevelopmental imbalance models are valid, adolescents are expected to engage in more risk-taking than will children and adults on emotionally laden tasks (i.e., experience-based tasks) but not on primarily cognitive tasks, wherein probability-related information on outcomes is available. However, characteristics of outcome feedback (i.e., feedback on rewards and losses) of choices might also play a decisive role in the decision-making process, and thus this should be taken into account when studying contextual factors of risky decision making.

Immediate Outcome Feedback Versus Delayed Outcome Feedback

Outcome feedback on tasks is usually in the form of feedback on rewards/gains and/or punishments/losses. Imbalance models elucidate that the "imbalance" between cognitive control and reward-related brain regions is the product of puberty-specific maturational changes in reward-related brain regions (e.g., ventral striatum/nucleus accumbens), which cause adolescents to become biased toward arousing motivational stimuli, in particular rewards (Somerville et al., 2010; Ubeda-Bañon et al., 2007). On a side note, it is important to point out that adults' affective-reward system can override their cognitive control system in hot contexts also. However, this overriding will be more pronounced in adolescents, because their affective system is assumed to be hyperresponsive (as a result of puberty) and their cognitive control system is still developing, whereas for adults, the former is not hyperresponsive and the latter is fully developed (thus, any potential imbalance is less pronounced in adults than adolescents; Somerville & Casey, 2010; Somerville et al., 2010). However, fMRI studies show mixed findings with regard to hyperactivation of the ventral striatum in adolescents (vs. adults) in reward versus loss paradigms (Bjork et al., 2004; Blakemore & Robbins, 2012; Crone & Dahl, 2012; Ernst et al., 2005; May et al., 2004). Nonetheless, some evidence for reward salience in adolescence comes from studies that demonstrate that perceived benefits associated with risk-taking behaviors are better predictors of adolescent risk-taking behaviors than perceived costs associated with risk-taking behaviors (Reyna & Farley, 2006; see also Steinberg, 2007).

Taken together, the abovementioned findings in light of the imbalance framework imply that adolescents are sensitive to outcome feedback, perhaps to feedback on rewards in particular, and as a consequence their decisions are driven by the availability of such outcome feedback on tasks. Therefore, it is worthwhile to investigate the importance of immediate outcome feedback on rewards and losses for age differences in risky decision making. The effect of immediate feedback on rewards and losses versus delayed feedback on rewards and losses on adolescents' risk-taking tendencies can be investigated in the current meta-analysis, because risky decision-making tasks differ on whether they provide immediate or delayed feedback.

Although most studies employ either an immediate feedback task or a delayed feedback task, to the best of our knowledge, the influence of immediate versus delayed outcome feedback on risky choice has been tested in only one experimental study in conjunction with a developmental sample (i.e., Figner et al., 2009). To illustrate, Figner et al. (2009) employed the "hot" affective (with immediate feedback on rewards/losses) and the "cold" cognitive-deliberative version (with delayed feedback on rewards/losses) of the Columbia Card Task (CCT; Figner et al., 2009) in a sample of early adolescents, late adolescents, and adults. Of interest, whereas risk-taking levels on the cold CCT were equal across age groups, the risk-taking levels across the age groups on the hot CCT showed that adolescents took more risks than adults (with no significant difference between early and late adolescents; Figner et al., 2009).

Considered together, the increased risk-taking by adolescents in the studies just reviewed might be the result of the affective and motivational aspect of immediate outcome feedback. The current meta-analysis puts these assumptions to the test by investigating if immediate versus delayed outcome feedback moderates age differences in risky choice between adolescents and adults, between early adolescents and mid-late adolescents, and between early adolescents and children. Unfortunately, in the current meta-analysis, we cannot specifically test if the hypothesized moderation effects can exclusively be attributed to immediate outcome feedback on rewards (vs. immediate outcome feedback on losses), as these two outcome feedback options are typically confounded on tasks (i.e., tasks typically include a mix of immediate feedback on both rewards and losses). Nevertheless, neurodevelomental imbalance models suggest that rewards are highly salient in the decision-making process of adolescents, and therefore adolescents would take more risks on tasks with immediate feedback than on tasks with delayed feedback, all else being equal (Somerville et al., 2010).

Gain Gambles Versus Mixed Gambles

An important distinction is made in the risky choice literature; namely, whether the possible choice outcomes involve only gains (i.e., rewards), only losses (i.e., punishments), or both. Often, these three possibilities are referred to as *gain gambles, loss gambles,* and—if both gains and losses are involved—*mixed gambles* (see, e.g., Ert & Erev, 2013; Yechiam & Telpaz, 2011). Neurodevelopmental imbalance models suggest that potential gains may have a particularly strong impact on choices and lead to increased risk-taking, particularly in adolescents, given their heightened sensitivity to rewards. In contrast, predominant theories of risky choice in the judgment and decision-making literature (which typically focus on general patterns, not on individual or developmental differences) and in particular prospect theory (Tversky & Kahneman, 1981), as the most influential of these models, argue that it is not gains but losses (i.e., punishments) that typically have a stronger impact on risky choice. A classic finding is that, compared to a gain of equal size, a loss has about twice the impact of the gain; this phenomenon is often referred to as loss aversion (losses loom larger than gains). A simple example is that few people would accept to play a game in which a fair coin is tossed and if the results is heads, they win $10, and if the results is tails, they lose $9 (i.e., the gamble has a positive expected value); most people would consider playing this game when the loss is about half as large as the gain (i.e., winning $10 versus losing $5).

Additionally, the probabilities of the possible gains and losses also matter: The so-called fourfold pattern (Tversky & Kahneman, 1992) describes that for moderate to high outcome probabilities, individuals are typically risk-averse in the gain domain but risk-seeking in the loss domain; this pattern reverses for low-probability outcomes. Thus, individuals are typically risk-averse in the presence of low probability losses (consistent with the buying of insurance) but risk-seeking in the presence of low-probability gains (consistent with the buying of lottery tickets). One important factor for this pattern is the overweighting of small probabilities and the underweighting of moderate to large probabilities (see, e.g., Kahneman & Tversky, 1979; Tversky & Kahneman, 1992). Thus, in short, these important risky choice models predict that it matters whether the presented choice options involve gains, losses, or both. Accordingly, an important factor potentially moderating observed choice pattern in our meta-analysis might be the domain (i.e., gain vs. loss vs. mixed gambles).

Distinctively, neurodevelopmental imbalance models focus in their explanation of increased adolescent risk-taking only on the gain (i.e., reward) aspect. They argue that adolescents have a hypersensitivity to rewards, which can increase adolescents' affective state, which in turn makes them particularly vulnerable to engage in heightened risk-taking. In short, it is assumed that the possibility of a reward is a crucial driving force underlying increased risk-taking. However, empirical support for whether gains or losses are more predictive of adolescent risk-taking is scarce, as results for risks with gains and risks with losses are rarely reported separately, perhaps simply because most risk-taking tasks used in adolescent studies do not facilitate this possibility. In fact, most developmental studies use either only gain gambles or mixed gambles (cf. Weller, Levin, & Denburg, 2011), but studies do not use pure loss-domain gambles. Accordingly, our moderator analyses can investigate differences only between gain gambles versus mixed gambles.

Although risks with a mix of gains and losses are not identical to risks with losses, mixed-domain risk-taking paradigms are nevertheless intrinsically different from tasks that include risks with gains alone (Yechiam & Telpaz, 2011) and therefore can serve the function of providing some insight into the role of losses in adolescent risk-taking. At least two studies showed that whereas risk-taking to avoid losses remained stable from childhood to adulthood, risk-taking to obtain gains decreased (Reyna & Ellis, 1994; Weller et al., 2011). However, these studies did not include adolescents, and mixed domains were not investigated. One study that did compare gain-domain to mixed-domain gambles found that risk-taking levels of college students were the same in the gain and mixed domains; however, risk-taking was associated with more autonomic arousal in the gain condition, whereas risk-taking in the mixed-domain condition was associated with less autonomic arousal (Yechiam & Telpaz, 2011). Again, this study was not developmental, and it did not include adolescents; thus, no conclusions or predictions can be derived with respect to age differences. Taken together, empirical support is lacking for whether losses do indeed loom more than gains for adolescents.

Neurodevelopmental imbalance models do not make direct predictions about the effect of losses on adolescent risk-taking, and neither do these imbalance models or fuzzy trace theory make predictions about the effects of mixed gambles on adolescent risk-taking. Nonetheless, with regard to mixed gambles, fuzzy trace theory predicts that gist-based decisions to avoid risky situations that involve a possible loss (or other dangers; i.e., loss aversion) should increase with age, indicating that adolescents will take fewer risks than children but more risks than adults on mixed-domain gamble tasks versus pure gain-domain gamble tasks. The assumption of an adolescent hypersensitivity for rewards in neurodevelopmental imbalance models may suggest quite the opposite: that adolescents should take more risks than children and adults in gain-domain tasks versus mixed-domain tasks, because gains are more salient in pure gain-domain tasks.

Taken together, although fuzzy trace theory and neurodevelopmental imbalance models do not explicitly make predictions about the role of gain versus mixed gambles in risky decision making, it seems plausible to infer that these theories would suggest opposite patterns for age differences in risk-taking, particularly for children's versus adolescents' risk-taking. In the current meta-analysis we therefore explore gain gambles versus mixed gambles as a moderator.

Incentivized Versus Nonincentivized Tasks

In the previous sections, the discussed studies differed in whether the rewards/losses were hypothetical or real. Nonetheless, participants are routinely compensated with monetary or tangible rewards for participation in laboratory risk-taking paradigms, and some studies (though rather a minority) also compensate participants' actual performance on decision-making tasks. In technical terms, only a few studies include "incentivized" paradigms (also referred to as incentive-compatible reimbursement schemes; in contrast to nonincentivized paradigms, wherein compensation is not contingent on the performance of individual participants). For example, in a recent meta-analysis on age differences in adult risky decision making based on 31 studies, participation was compensated in 51% of the studies, but only 28% of the studies compensated participants' actual performance (Mata et al., 2011). Although there were no observed effects when incentivized paradigms were compared to nonincentivized paradigms, Mata et al. pointed out that methodological improvements should be made in this regard.

Neither fuzzy trace theory nor neurodevelopmental imbalance models consider how age differences in risk-taking between adolescents and other age groups might be exaggerated for incentivized paradigms (vs. nonincentivized paradigms). However, building upon the neurodevelopmental imbalance framework concerning reward salience in adolescence, more specifically considering the hypothesized hypersensitive motivational system, it is to be expected that the adolescent's brain is more likely to be triggered by incentivized paradigms, leading to heightened adolescent risk-taking specifically on such tasks. Hence, we investigate if age-related differences in risk-taking depend on whether or not performance on a task is incentivized. It is noteworthy that although some studies compensate all participants for their performance, others notify participants that, based on their performance, they will win (e.g., via a raffle) tangible (monetary) prizes. In the present meta-analysis both of these compensation types are classified as incentivized and are compared with nonincentivized studies, in which reimbursement is unrelated to participants' choices in the decision-making task.

In the previous paragraphs, different aspects of rewards in risk-taking paradigms have been addressed, and we examine whether the presence of these reward factors moderate age differences in risk-taking between adolescents versus children and adults. However, although ample focus has been given to the role of reward processing in heightened adolescent risk-taking, less emphasis has been given to how other relevant affective task components might equally contribute to increased risk-taking in adolescence. Therefore, in the following paragraphs, we discuss other potential influential task characteristics that have received relatively little attention, such as time pressure, dynamic or static nature, and the presence of safe/sure options in risk-taking paradigms.

Time Pressure Versus No Time Pressure

An emotionally arousing factor that varies across risky decision-making studies is whether there is a time limit wherein choices have to be made. Despite this potential ecological relevance, the effects of time pressure on risky decision making in adolescence have been neglected. This is surprising, as the circumstances surrounding typical risk-taking behaviors in adolescence (e.g., shoplifting) obviously include time pressure (Steinberg, Cauffman, Woolard, Graham, & Banich, 2009). In fact, there is evidence from the adult decision making literature showing that the perception that time is limited can make a decision-making situation emotionally arousing, as it increases the arousal state of the decision maker (Finucane, Alhakami, Slovic, & Johnson, 2000; Maule & Svenson, 1993). Moreover, time pressure might suppress cognitive analytic and deliberative processes (Finucane et al., 2000; Maule & Svenson, 1993), thus potentially giving even more weight to affective-motivational processes. Hence, the current meta-analysis investigates whether time pressure in risky decision-making tasks moderates adolescents' heightened risk-taking relative to children's and adults' risk-taking. Extrapolating from imbalance models, it is to be expected that adolescents will engage in more risk-taking than children and adults, especially on emotionally arousing time-pressured decision-making tasks.

Dynamic Versus Static Tasks

Although contextual aspects of risk-taking in reality often may be dynamic in nature (e.g., binge drinking involves accumulative decisions linked to escalating risk-taking levels; Weber & Johnson, 2009), most risky decision-making tasks use static risk situations. The most common static paradigm is the choice between two static options, at least one of them risky (but such paradigms can also involve more than 2 choice options; e.g., the IGT offers 4 options from which to choose). In such a task, all relevant characteristics (probabilities, gain and loss magnitude; or higher level descriptives such as expected value and risk) do not change but are static. In contrast, in dynamic paradigms, at least one of the relevant characteristics changes dynamically, typically as a function of a previous action in the same trial of the task. In the hot CCT (Figner et al., 2009), for example, turning over a first card means that the probability of encountering a negative outcome (the loss probability) increases for the following decision of whether or not to turn over another card (at the level of the higher order descriptives, both the risk increases and the expected value decreases). Other common dynamic paradigms are the Devil's Task/Knife Switches Task (Slovic, 1966) and the Balloon Analogue Risk Task (BART; Lejuez et al., 2002).

Considering that it has been argued that dynamic tasks may more accurately reflect many prototypical situations of risky behaviors in the real world (for a discussion on this topic, see Weber & Johnson, 2009, as well as Schonberg et al., 2011), we explore if age-related differences in risk-taking on dynamic risk-taking tasks (e.g., the hot CCT, which includes incremental decisions coupled with increasing risks) or on static risk-taking tasks (e.g., the cold CCT) better mirror the pattern of age differences in risk-taking evident in the real world. Considering that dynamic tasks are more affectively engaging than static tasks (Figner et al., 2009), neurodevelopmental imbalance models would predict that adolescents should take more risks than children and adults on dynamic tasks.

Sure Option Tasks Versus No Sure Option Tasks

Another characteristic varying across tasks is whether a "safe" (also called sure) choice option is available or whether participants are choosing between two (or more) risky choices (i.e., lotteries or gambles). For example, the Cups Task (Levin & Hart, 2003) offers choices between a sure versus a risky option, while the IGT offers choices among options that are all risky (the 4 decks) and thus does not allow for avoiding a risk completely. Furthermore, a distinction can be made between the type of sure option. In some tasks, the sure option means surely winning some (typically small) reward. In other tasks, the sure option means winning nothing but also losing nothing (referred to as sure neutral tasks in the current meta-analysis). Although imbalance models do not directly make predictions about how the availability of a sure option might influence heightened adolescent risk-taking, it is interesting to test whether this acts as a moderator because risky decision-making scenarios in the real world often have a sure/safe way out also.

Of importance, fuzzy trace theory does make predictions about whether the used task is a pure gamble paradigm (e.g., choice between two risky options) or whether the task offers a sure option. Fuzzy trace theory postulates that the availability of a sure option induces mature gist-based decision making, which is accompanied by (adaptive) emotional arousal (to avoid risk; Reyna & Rivers, 2008). Empirical support for fuzzy trace theory shows that gist-based decision making increases with age, and sound gist-based decision making could promote risk-aversion (Reyna & Ellis, 1994; Reyna & Farley, 2006); however, these studies did not include teenagers. Nevertheless, it can be extrapolated from fuzzy trace theory that adolescents should take fewer risks than children but more risks than adults if a sure option is present. In contrast, neurodevelopmental imbalance models do not make any specific predictions about whether or not a task includes a sure option, but these models generally suggest that adolescents exhibit greater risk-taking in affective situations, thus regardless of whether or not a sure option is available. The current meta-analyses pit the contradictory hypotheses of fuzzy trace theory and neurodevelopmental imbalance models against each other, as we explore sure win option tasks versus no sure win option tasks and sure neutral tasks versus no sure neutral option tasks as moderators for age differences in risky decision making.

Methodologically Relevant Characteristics

Specific task analyses. In addition to the disparity on the definition of risk, there is controversy surrounding the outcome measures for risk-taking on several common risky decision-making tasks because many tasks confound differences in options' risk with differences in options' expected value. For this reason, whenever possible we also examine whether age differences are dependent on the specific risk-taking task used. For instance, the IGT has been repeatedly criticized for numerous related reasons (for a recent review, see Schonberg et al. 2011), with one important critique being that it is almost impossible to differentiate whether performance on the IGT reflects (reversal) learning, risk preferences, sensitivity to EV, and/or sensitivity to loss and/or gain magnitudes. As a result, the outcome measure (either the net score or the mean of disadvantageous choices; see Table 1) that is derived from the IGT cannot be interpreted as risk-taking without caution (Schonberg et al., 2011). More specifically, in the IGT, the riskier decks (i.e., the decks with the higher outcome variability) are also the disadvantageous decks in terms of expected value. If one's goal is to maximize one's financial earnings in the IGT, one should thus choose the options with the highest EV. As it happens, these options are also the options with the lowest risk. Thus, if an individual makes mostly advantageous choices, it is unclear whether the underlying mechanism is that the individual is sensitive to the differences in EV and chooses the option with the highest EV or is sensitive to risk and avoids the options with the highest outcome variability.

To address these issues related to the IGT (and its child-friendly variants, such as the Hungry Donkey Task; Crone & Van der Molen, 2004) in the current meta-analysis, whenever possible, we use *outcome variability* as indicator for choice options' riskiness (Weber, 2010). Thus, for the IGT, instead of using the net score or the mean of disadvantageous choices (as it is commonly done in IGT studies), we operationalized risk-taking in the IGT as choosing from the deck with the highest outcome variability (i.e., highest variance) and thus used the mean number of choices from this "risky" deck to compute the effect sizes for the current meta-analysis (for further details, see the Method section).

Although other static tasks may suffer from the above-described confound between EV and risk to varying degree, some tasks are particularly laudable as they systematically and independently vary risk and EV, allowing for a precise assessment of these factors' influence on risky choice. Among these tasks are the Framing Spinner Task (Reyna & Ellis, 1994) and the more recent versions of the Cups Task (Levin et al., 2007). Among the dynamic tasks (e.g., the Devil's Task, Slovic, 1966; the BART, Lejuez et al., 2002; and the CCT, Figner et al., 2009) some correlation of EV and risk within trials is virtually unavoidable, due to their dynamic nature, but as long as the confound is not too strong, one can at least disentangle the two influences (EV and risk) statistically. However, in contrast to the CCT, both the Devil's Task and the BART suffer from another confound, which the CCT specifically was designed to avoid: In the Devil's Task and the BART, each risk-taking step (pulling the next lever; pumping the balloon by one more puff) at the same time increases the potential loss amount (i.e., the current score, as all the money accrued in the current trial is lost in case a negative outcome is encountered) and the probability of encountering a negative event. In addition, and again in contrast to the CCT, gain amounts and base-rate probabilities are not varied across trials, thus allowing no inferences about these important factors in risky decision making. In short, neither the Devil's Task nor the BART lends itself well to decomposition, whereas the CCT was designed with the explicit goal to decompose risky choices both (a) into the so-called economic primitives of probability, gain magnitude, and loss magnitude and (b) into the higher order moments of risks (outcome variability) and returns (expected value; see Schonberg et al., 2011, for a thorough critical evaluation of these and other tasks). To summarize, given that risk-taking tasks vary considerably on important (methodological) characteristics, we examined whether age differences are dependent on the specific risk-taking task used, whenever the number of studies was sufficient to do so.

Putative confounding moderators. Finally, we explore whether putative confounding factors moderate the age effects; these putative confounding factors were (a) unequal EV versus equal EV tasks, (b) fMRI versus non-fMRI studies, and (c) studies that include IQ as a covariate versus studies that do not include IQ as a covariate. First, because tasks with equal EV across choice options versus tasks with unequal EV across choice options have been shown to produce different age patterns in risk-taking (Weller et al., 2011), we explore this confound in our moderational analyses (i.e., equal EV vs. unequal EV). Second, we coded whether a study did or did not use an IQ measure as a covariate. Studies controlling for the effect of age-related IQ differences and reporting these IQ-controlled risk-taking age differences might yield systematically different results, because performance on risky decision-making tasks might be associated with differences in intelligence between the age groups. Thus, we investigate whether controlling for IQ (i.e., IQ covariate vs. no IQ covariate) moderated the hypothesized age effects in risk-taking. Third, because ecological validity issues might arise from doing a risk-taking task in a fMRI scanner (see, e.g., Hasson & Honey, 2012, for a discussion), we also investigated whether or not data were collected in an fMRI study (i.e., fMRI study vs. no fMRI study) moderates the effect sizes related to age differences.

Present Meta-Analysis

The present meta-analysis focuses on the transitions from childhood to adolescence and from adolescence to adulthood and thus compares adolescents' risky choice to both children's and adults' risky choice. Furthermore, because early/peripubertal adolescence (11–13 years) is characterized by the onset of puberty, and puberty plays a significant role in the hypothesized hypersensitization of reward-related regions in the brain (Dahl, 2004; Nelson, Leibenluft, McClure, & Pine, 2005; Spear, 2004), we compared early adolescent to mid-late adolescent (14–19 years) risk-taking in an additional analysis. It would be more informative to include a direct measure of pubertal maturation as a moderator, instead of using the 11–13 years age group as a proxy for pubertal status; however, risk-taking studies rarely assess information related to the pubertal status of their adolescent participants (Crone & Dahl, 2012). Of the current studies included in the meta-analysis, only one study investigated pubertal effects on heightened adolescent risk-taking (we shall return to this issue in the Discussion section). Moreover, we also contrast early adolescents (11–13 years) with children (5–10 years), as a proxy for comparing peripubertal adolescents to prepubertal children.[6] Accordingly, we conducted four separate meta-analyses: one for each age group comparison (i.e., early adolescents vs. children, adolescents vs. children, early adolescents vs. mid-late adolescents, and adolescents vs. adults).

As we discussed previously, there is substantial evidence showing that task characteristics and the type of involved decision-making processes contribute to age-related differences in risky decision making (e.g., Figner et al., 2009; Mata et al., 2011; Rakow & Rahim 2010; Van Duijvenvoorde et al., 2012). Hence, we examine whether age-related differences in risky decision making vary as a function of task characteristics. Moreover, the current meta-analyses draw from neurodevelopmental imbalance models and investigate whether cognitive versus affective factors inherent in the paradigms used in the studies moderate age-related differences in risky choice; namely, description-based versus experience-based tasks; immediate versus delayed outcome feedback on rewards and losses; gain versus mixed gambles; no time pressure versus time pressure; static versus dynamic task characteristics; sure win option versus no sure win option; sure neutral option versus no sure neutral option. If the predictions of neurodevelopmental imbalance models are accurate, adolescents should take more risks than both children and adults on tasks that contain hot affective components (e.g., dynamic tasks). The predictions of the imbalance models pertaining to the level of adolescent risk-taking on cold, emotionally neutral tasks are less straightforward, however. Nonetheless, it is likely that adolescents will take fewer risks than children and more risks than adults, and that they and adults will engage in equal levels of risks on tasks including cold cognitive components (e.g., descriptive tasks; Blakemore & Robbins, 2012).

Additionally, the current meta-analyses investigate if early adolescents take more or fewer risks than children and adults on tasks with a sure option (vs. tasks with no sure option). In general, fuzzy trace theory predicts that adolescents should take fewer risks than children but more risks than adults on tasks with a sure option. Besides exploring moderation by such specific task characteristics, whenever possible, we explore whether the observed age differences are moderated by the risky decision-making task employed, as we have shown that risk-taking tasks vary to a large extent on important methodological features. Finally, we explore whether putative confounding moderators are present.

Method

Literature Search

Multiple methods were used to locate relevant articles. First, the literature was extensively searched, primarily with the electronic search engines PsycINFO, Scopus, Medline, ERIC, and Google Scholar. A psychology undergraduate assisted the first author with the literature search. The following keywords related to "risk" were used: *risk**, *risk-taking, risky choice, risk seeking, decision making.* Considering that the studies should include at least one adolescent age group, we also included the following keywords in the search: *adolescen*, teen, teenager,* and *youth.* In addition, searches were carried out by using the names of popular risky decision-making tasks (e.g., IGT, BART, Cambridge Gambling Task [CGT], CCT) and the names of well-established adolescent decision-making researchers. Next, bibliographies of previous reviews on adolescent risk-taking (e.g., Boyer, 2006), a prior meta-analysis on age differences in adult risk-taking (i.e., Mata et al., 2011), and a meta-analysis on gender differences in risk-taking (i.e., Byrnes, Miller, & Schafer, 1999) were manually inspected. Furthermore, we posted a message requesting related published and unpublished studies to all members of two relevant e-mail lists; namely, the Society for Judgment and Decision Making and the Social Affective Neuroscience Society. Finally, several experts in the field of adolescent risk-taking were contacted directly via e-mail and were asked to provide us with information on any published or unpublished studies we might have missed.

Selection Criteria

We used the following five criteria to select studies for inclusion in the current meta-analysis.

1. Studies had to include at least one distinct adolescent age group and at least one additional distinct age group. Early adolescence was classified as 11–13 years, mid-late adolescence as 14–19 years, children as 5–10 years, and adults as 20–65 years. Children's age groups that contained children younger than 5 and adults' age groups that contained adults older than 65 did not match the criteria and were thus not included.

2. The study participants belonged to a nonclinical population. However, clinical studies that included a healthy control sample were eligible for inclusion; in these cases only the healthy control sample was used.

3. The study contained a behavioral measure of risky decision making. Table 1 lists all the risky decision-making tasks used in the included studies.

4. Enough statistics were provided to calculate an effect size associated with age differences in risk-taking between early adolescents and mid-late adolescents and/or (early) adolescents and children and/or adolescents and adults. If studies had graphical results instead of numerical results, we contacted the authors requesting numerical results. Accordingly, we contacted 60% of authors for additional statistical results and 81% of the authors for additional relevant coding information. Of the contacted authors, the response rate was 90.90%.

5. Only studies that were written in English or Dutch were eligible for inclusion.

[6] We realize that there will be some peripubertal early maturers in the 5- to 10-year-olds; nonetheless, on average the groups will differ in pubertal status.

All studies matching the above-mentioned criteria were included in the meta-analysis, independent of whether or not they were published and regardless of publication year. We also had no geographic or cultural restrictions.

Screening for Eligible Studies

On the basis of our searches and inclusion criteria, we initially identified 71 articles that included nonclinical adolescent participants and a behavioral measure of risk-taking. Of these 71 articles, 32 articles including 38 studies/experiments met all of the above-mentioned criteria and were thus coded for the meta-analysis. However, for 6 articles an effect size could not be derived from the reported results or retrieved from the authors (i.e., Cauffman et al., 2010; Crone, Bunge, Latenstein, & van der Molen 2005; Crone, Vendel, & van der Molen, 2003; Ernst et al., 2003; Hooper, Luciana, Conklin, & Yarger 2004; and Overman et al., 2004). Exclusion of the above-mentioned studies brought the amount of included papers in the final meta-analysis to 25 articles, encompassing 28 studies/experiments.[7] There were 12 group comparisons between early adolescents and children, 21 group comparisons between children and adolescents, 14 group comparisons between early and mid-late adolescents and 23 group comparisons between adolescents and adults. Table 3 summarizes the relevant sample characteristics of the included studies.

Coding and Calculation of Effect Sizes

For all of the included studies, we coded reference information, publication status/type, study location, study design (e.g., longitudinal vs. cross-sectional), whether or not the study was an fMRI study, sample characteristics per age group (gender, age, socioeconomic status, etc.), information on time constraints (time pressure: yes/no), incentive compatibility, immediate outcome feedback, availability of a sure option, and risky decision-making task used (e.g., IGT: yes/no, Stoplight Game: yes/no). In addition, we coded whether or not the respective study controlled for IQ. The first coder (i.e., the first author of the meta-analysis) coded all of the studies, and a second coder, a research assistant with a master's degree in developmental psychology, coded 30% of the studies. The studies that were coded by the second coder were partially randomly selected, and some studies were selected because they were considered to be complex studies. Intercoder reliability and Cohen's kappa were excellent (90.18% and .80, respectively). Whenever there was a discrepancy between coding, both coders discussed this and came to a conclusion concerning how the study should be coded.

As effect size, Cohen's d was calculated for each pair of age group comparisons (early adolescent vs. mid-late adolescent, early adolescent vs. children, adolescent vs. children, and adolescent vs. adult) separately, by computing the difference in risk-taking levels between the (early) adolescent age group minus the other age group and dividing this difference by the pooled standard deviation (Cohen, 1988). The effect sizes were coded so that positive values represented higher risk-taking levels by (early) adolescents, whereas negative values represented higher risk-taking levels by the other age group. To compensate for upward bias in effect size estimates as a result of small sample sizes, we transformed Cohen's d to Hedges's g (Hedges & Olkin, 1985). We performed all effect size calculations via the website http://mason.gmu.edu/~dwilsonb/ma.html, using syntax written by Lipsey and Wilson (2001). We conducted the meta-regression analyses with the meta-analysis package Metafor (version 1.7-0) in the statistical software R (version 3.0.0).

As suggested by Lipsey and Wilson (2001), we gave preference to computation of the effect sizes based on means and standard deviations. When these types of statistics were not reported or if results were presented in a graph, we contacted the authors requesting additional numerical statistical information. This was done for 19 studies. However, (a) if the request for additional numerical statistical information was not successful, (b) if d could not be calculated with a t score, F score, χ^2 value, or (c) if we could not derive numerical results from what was reported, we had to exclude those studies from the meta-analysis; as noted, this was the case for six studies.

On the knife-switches task used in Slovic (1966) and in Tymula et al. (2012), higher scores reflected less risk-taking behavior, whereas in all of the other tasks higher scores reflected more risk-taking behavior. Thus, for consistency, we reversed the sign of the effect sizes for these studies, to ensure that positive values continued to indicate that early adolescents took more risks than the other age groups. It is important to note that we used an alternative statistic to measure risk-taking on the IGT. That is, instead of the traditional statistics used in IGT studies (i.e., net score or the mean of the disadvantageous choices), which reflect expected value more than risk-taking, we computed a statistic that measures outcome variability (Figner & Weber, 2011; Weber, 2010). To achieve this, we contacted the respective authors requesting statistics per deck, as this information is not generally reported in studies employing the IGT. Because Deck B is the deck with the highest variance, here we report only results based on this deck.

Multiple Results From Single Studies

We opted for a conservative approach in handling nonindependent effect sizes. That is, when more than one effect size could be calculated for a specific age group comparison, we (randomly) selected one of these studies to be included in the meta-analysis (Lipsey & Wilson, 2001). This was the case for Chein et al. (2011)[8] and Figner, Duijvenvoorde, and Huizenga (2014).[9] In addition, three studies (Gardner & Steinberg, 2005; Smith, Xiao, & Bechara, 2012; Steinberg et al., 2008) reported results for more than one subgroup within a child and/or adult age group. For such cases we used the results from the subgroup with the mean age closest to the overall mean age of all the

[7] Harbaugh, Krause, and Vesterlund (2002) did not fully match the inclusion criteria for the eligible age groups. Unlike other excluded studies, this study did compare an adolescent age group with other age groups. However, there were overlapping age groups of children, adolescents, and adults (the age groups in that study were ages 5–8; 9–13; 14–20; 21–64); moreover, the mean of none of the age groups (7.40; 10.10; 19.60; 37.8, respectively) of this study falls within the adolescent age range we used (11 and 19 years). Nevertheless, we conducted the analyses including and excluding this study in the adolescents versus children and adolescents versus adults models. We report the results excluding this study in the body of the paper and note report relevant findings with this study included.

[8] For Chein et al. (2011), a within-subject design was used for the alone and peer conditions. We consequently chose to include results of the peer condition in the meta-analysis, as such experimental designs are scarce.

[9] As a within-subject design was used by Figner et al. (2014), we computed an effect size for only the first task administration per condition, in order to avoid (task) dependency complications.

Table 3
Overview of Included Studies

No.	Study	Risky Decision-Making Task	*n* early adolescents	Age early adolescents *M* (*SD*) or age range	*n* mid-late adolescents	Age mid-late adolescents *M* (*SD*) or age range	*n* adolescent	Age adolescent	*n* children	Age children *M* (*SD*) or age range	*n* adults	Age adults *M* (*SD*) or age range
1	Burnett et al. (2010)	Probabilistic Gambling Task	na	na	na	na	26	13.77 (1.10)	20	10.83 (0.64)	17	30.32 (3.08)
2	Chein et al. (2011)	Stoplight Driving Game	na	na	na	na	14	15.70 (1.50)	na	na	12	25.6 (1.90)
3	Crone & van der Molen (2007)	Hungry Donkey Task (HDT; modified IGT)	29	13.3	30	17.3	29	13.3	22	9.5	na	na
4	Crone et al. (2008)	Self–Other Gambling Task	18	10.90 (.68)	17	16.53	17	14.88	20	8.65	na	na
5	Eshel et al. (2007)	Wheel of Fortune	na	na	na	na	16	13.30 (2.10)	na	na	14	20–44
6a	Figner et al. (2009)	Hot CCT	na	na	22	18.30 (0.83)	28	15.30 (.27)	na	na	26	24.50 (7.43)
6b	Figner et al. (2009)	Cold CCT	na	na	27	18.20 (0.88)	27	14.90 (.88)	na	na	30	23.60 (5.69)
6c	Figner et al. (2009)	Hot CCT	na	na	na	na	31	14.40 (.75)	na	na	33	24.50 (4.37)
6d	Figner et al. (2009)	Cold CCT	na	na	na	na	41	14.20 (.89)	na	na	33	22.80 (2.75)
7a	Figner et al. (2014)[a]	Hot CCT	na	na	na	na	32	14–16	24	8–11	25	18–23
7b	Figner et al. (2014)[b]	Cold CCT	na	na	na	na	47	14–16	36	8–11	35	18–23
8	Galván & McGlennen (2012)	Cups Task	na	na	na	na	18	14–17	na	na	16	18–21
9a	Gardner & Steinberg (2005)	Chicken Game	na	na	na	na	52	14.01	na	na	41	37.24
9b	Gardner & Steinberg (2005)	Chicken Game	na	na	na	na	54	14.01	na	na	54	37. 24
10	Huizenga et al. (2007)	HDT (modified IGT)	61	11.10	59	13.83	59	13.83	61	7.93	61	20.30
11	Keulers et al. (2011)	Gambling Task	18	12.93 (.34)	21	16.99 (.43)	18	12.93 (.34)	na	na	17	21 (.60)
12	Kreitler & Zigler (1990)	Mirror Drawing Risk-Taking Task	na	na	na	na	60	11.56 (.35)	60	5.45 (.37)	na	na
13	Macpherson et al. (2010)	BART-Y	na	na	na	na	247	13 (.88)	277	11.01 (.81)	na	na
14	Paulsen et al. (2012)	Nonsymbolic Economic Decision-Making Task			na	na	17	14.80	17	6.90	16	23.70
15	Paulsen et al. (2011)	Nonsymbolic Economic Decision-Making Task	na	na	na	na	13	14.90	21	7.10	13	21.60
16	Prencipe et al. (2011)	IGT	21	12.69	27	15.04	21	12.69	26	8.90	na	na
17a	Rakow & Rahim (2010)	Sure versus Risky Choice Task	na	na	na	na	38	17.30 (.25)	37	9–12	na	na
17b	Rakow & Rahim (2010)	Sure versus Risky Choice Task	na	na	na	na	39	17.30 (.25)	38	9–12	na	na
17c	Rakow & Rahim (2010)	Sure versus Risky Choice Task	34	13.30 (.25)	37	17.30 (.25)	17	13.30 (.25)	na	na	na	na
18	Reyna et al. (2011)	Framing Spinner Task	na	na	na	na	51	15.5 (1.10)	na	na	102	19.70 (.90)
19a	Slovic (1966)[c]	Knife Switches Task/ Devil's Task	117	12	173	14–16	111	13	89	6–8	na	na
19b	Slovic (1966)[d]	Knife Switches Task/ Devil's Task	42	12	49	14–16	89	13	50	6–8	na	na
20	Smith et al. (2012)	IGT	12	12	16	17	7	13	18	8	na	na
21	Steinberg et al. (2008)	Stoplight Game	137	12.48 (.50)	141	16.51 (.50)	128	14.48 (.50)	116	10.58 (.50)	136	23.32
22a	Van Duijvenvoorde et al. (2012)	The Gambling Game	23	12.30	25	15.70	24	13.70	22	8.15	26	20.30
22b	Van Duijvenvoorde et al. (2012)	The Gambling Game	24	12.30	24	15.70	27	13.70	23	8.15	27	20.30
23	Van Leijenhorst et al. (2008)	Cake Gambling Task	18	10.90 (.68)	17	17.18	20	14.60	19	9.40	19	27.60
24	Van Leijenhorst et al. (2010)	Cake Gambling Task	15	13.4 (.80)	15	17.10 (.70)	15	13.4 (.80)	12	9.70 (.90)	15	21.60 (2.08)
25	Tymula et al. (2012)	Standard Incentivized Task	na	na	na	na	33	14.70 (1.44)	na	na	32	38.41 (7.55)

Note. Articles designated with letters described multiple experiments/studies and age group comparisons, yielding multiple effect sizes per article. For Chein et al. (2011), effect sizes are computed only for the peer condition, to avoid dependency complications, considering that the alone and peer conditions contained the same participants. na = not applicable (i.e., when a study did not include the corresponding age group comparison); IGT = Iowa Gambling Task; CCT = Columbia Card Task; BART-Y = Balloon Analogue Risk Task–Youth.
[a,b] Effect-sizes are computed only for the first task administration per condition, in order to avoid (task) dependency complications. [c] Information for male participants in Slovic (1966). [d] Information for female participants in Slovic (1966).

studies in the current meta-analysis. For instance, Steinberg et al. (2008) reported results for two age subgroups within an adult age group (i.e., 22–25 and 26–30), which both fit our criteria for the adult age group (i.e., 20–65 years). Considering that the mean age for the adult group for all studies with an adult group in the current meta-analysis was 24.98, we used the age subgroup 22–25 to compute an effect size. However, we adopted a slightly different approach to deal with multiple adolescent age groups. In computing an effect size for adolescents' versus children's risk-taking and adolescents' versus adults' risk-taking, if more than one adolescent age group was reported, we used the younger adolescent age group that had a mean age closest to the mean age of the younger adolescent age groups in studies including just one younger adolescent age group. We always gave preference to a younger adolescent age group (compared to an older adolescent age group), considering that most studies included a younger adolescent age group. Furthermore, we tried to avoid computing effect sizes from samples that included overlapping distinct age groups.

Analyses

We proceeded in the following manner with the analyses. First, we estimated the overall effect size per age group comparison by means of a random effects model with a 95% confidence interval. Second, we examined the variation in the effect size distribution by inspecting the Q tests and I^2 (i.e., total variability due to heterogeneity rather than chance alone). Next, to detect and investigate the possible effects of publication bias, we employed the trim and fill approach (Duval, 2005; Duval & Tweedie, 2000a, 2000b). The trim and fill method is a widely used form of sensitivity analysis, which in effect detects and imputes missing studies and by doing so gives an indication of how sensitive an estimated effect size is to publication bias (Duval, 2005; Duval & Tweedie, 2000a, 2000b). We also attempted to diminish publication bias by including unpublished studies in the meta-analyses. The current meta-analysis includes one unpublished study that consisted of two independent experiments; thus, 2 of the 38 effect sizes (5.26%) are derived from unpublished studies. Outlier analyses were also conducted using studentized deleted residuals, and we used COVRATIO to diagnose whether outliers were influential and thus problematic (Viechtbauer & Cheung, 2010). There are different views on how to handle outliers in meta-analyses. Although most will agree that influential outliers should be removed, others also provide valid arguments as to why outliers should not be deleted (see Viechtbauer & Cheung, 2010, for a discussion). We took the middle ground for these opposing views; that is, we always report whether removing influential outliers changed the conclusion of the effect sizes and planned that when this was the case we would rerun all subsequent analyses with and without the influential outliers. However, influential outliers did not substantially change the effect sizes.

Finally, we conducted five multivariate meta-regression analyses while utilizing a mixed-effects model. First, potential moderators derived from the imbalance framework that were simultaneously tested are immediate versus delayed outcome feedback on rewards and losses, gain versus mixed (i.e., gains and losses) gamble domains, and incentivized versus nonincentivized tasks. Second, we tested for additional affective moderators simultaneously, as they have been shown to trigger emotional arousal that neurodevelopmental imbalance models postulate to be a major determinant of heightened risk-taking in adolescence. These moderators are experience-based versus descriptive-based tasks, time pressure versus no time pressure, and dynamic versus static tasks. Third, moderators related to fuzzy trace theory that were tested simultaneously were sure win option versus no sure win option tasks and sure neutral (i.e., no loss or win) option versus no sure neutral option tasks. Fourth, whenever possible, we tested for moderation by specific tasks simultaneously (i.e., variants of the IGT, cold CCT, hot CCT, and the Stoplight Game), because these tasks were most often used. Fifth, we tested the following putative confounding moderators simultaneously: whether or not choice options were equal in EV (unequal EV vs. equal EV), whether fMRI was used (fMRI study versus non fMRI study), and whether or not IQ was included as a covariate in the studies (IQ covariate vs. IQ no covariate). The above-described procedure was carried out in an identical manner for all four meta-analyses (i.e., the children vs. adolescents, children vs. early adolescents, early adolescents vs. mid-late adolescents, and adults vs. adolescents models), and we tested for moderation only when there was a minimum of 3 studies per subgroup (see Table 4 for an overview of the moderators tested per model).

Results

Table 3 displays the effect sizes and further relevant sample characteristics for the four meta-analyses we conducted, totaling 70 age group comparisons derived from 28 studies/experiments within 25 articles. (The same conclusions can be drawn from the results when Harbaugh et al., 2002, is included in the analyses.) In summary, there were 21[10,11] group comparisons ($N = 2{,}082$) for the adolescents ($n = 1{,}074$) versus children ($n = 1{,}008$) model, 12 group comparisons ($N = 994$) for the early adolescents ($n = 516$) versus children ($n = 478$) model, 14 group comparisons ($N = 1{,}220$) for the early adolescent ($n = 569$) versus mid-late adolescent ($n = 651$) model, and 23[12] group comparisons ($N = 1{,}587$) in the adolescent ($n = 791$) versus adult ($n = 796$) model. The mean ages were 14.87 (1.25) years for adolescents, 8.75 (1.65) years for children, and 24.98 (5.83) years for adults. In the early adolescents versus mid-late adolescents model, the early adolescents were 12.32 (.78) years, and the mid-late adolescents were 16.16 (1.12) years, and in the early adolescents versus children model, the early adolescents were 12.20 (.74) years and the children were 8.60 (1.25) years. We present the results per age group comparison separately, followed by the meta-regression analyses to test the hypothesized moderators derived from imbalance models and fuzzy trace theory. Last, we report results for the putative confounding moderator analyses. An overview of which moderators were tested per model is provided in Table 4.

Meta-Analysis 1A and 1B: (Early) Adolescents Versus Children Risky Decision Making

Meta-Analysis 1A: Early adolescents versus children model. The early adolescents versus children model ($k = 12$) had a nonsignificant mean effect size ($g = .04$; $p = .68$), indicating no age-related differences between adolescent and children in risky decision making (see Table 5 and Figure 1). The Q test approached significance, $Q(11) = 19.47$, $p = .05$ and $I^2 = 43.50\%$, and

[10] Or 22 group comparisons when Harbaugh et al. (2002) is included.

[11] The longitudinal study of Macpherson et al. (2010) was included in the children versus adolescent model.

[12] Or 24 group comparisons when Harbaugh et al. (2002) is included.

Table 4
An Overview of the Moderators Tested Per Model by Age Group Comparisons

Moderator	Adolescents vs. children $k = 21$; $N = 2{,}082$	Early adolescents vs. children $k = 12$; $N = 994$	Early adolescents vs. mid-late adolescents $k = 14$; $N = 1{,}220$	Adolescents vs. adults $k = 23$; $N = 1{,}587$
Neurodevelopmental imbalance model moderators				
Immediate outcome feedback vs. delayed outcome feedback	X (3 vs. 18)			X (18 vs. 4)
Incentivized vs. nonincentivized tasks	X (11 vs. 10)	X (6 vs. 6)	X (6 vs. 8)	X (14 vs. 9)
Gain gambles vs. mixed gambles	X (5 vs. 16)			X (4 vs. 19)
N	2,082	994	1,220	1,552
Additional affective moderators				
Experience- vs. description-based	X (7 vs. 14)	X (5 vs. 7)	X (3 vs. 11)	
Dynamic vs. static	X (5 vs. 16)	X (3 vs. 9)	X (3 vs. 11)	X (7 vs. 16)
Time pressure vs. no time pressure	X (3 vs. 18)	X (3 vs. 9)	X (3 vs. 11)	X (8 vs. 15)
N	2,082	994	1,220	1,587
Fuzzy trace theory				
Sure win option vs. no sure win option	X (6 vs. 14)		X (4 vs. 10)	X (10 vs. 13)
Sure neutral option vs. no sure neutral option	X (3 vs. 17)			X (6 vs. 17)
N	1,962	994	1,220	1,587
Task moderators				
IGT vs. no IGT	X (6 vs. 15)	X (6 vs. 6)	X (6 vs. 8)	X (3 vs. 20)
Cold CCT vs. no Cold CCT				X (3 vs. 20)
Hot CCT vs. no Hot CCT				X (3 vs. 20)
Stoplight game vs. no stoplight game				X (4 vs. 19)
N	2,082	994	1,220	1,587
Putative confounding factors				
Unequal EV vs. equal EV	X (9 vs. 4)			X (11 vs. 4)
IQ covariate vs. IQ no covariate	X (7 vs. 14)	X (7 vs. 5)	X (7 vs. 7)	X (6 vs. 17)
fMRI study vs. no fMRI study	X (3 vs. 18)			X (5 vs. 18)
N	836	994	1220	721

Note. The values in parentheses represent the number of studies per subgroup. IGT = Iowa Gambling Task; CCT = Columbia Card Task; EV = expected value; fMRI = functional magnetic resonance imaging.

showed moderate heterogeneity (random-effects model). Sensitivity analyses via the trim and fill procedure showed that no studies needed to be imputed, indicating that publication bias is absent in the present meta-analysis. Next, outlier analyses showed that one study was both an outlier and an influential case. Thus, we reran the main analyses without this study, and results showed that the effect size remained nonsignificant. The results reported below include this outlier.

As the *Q* test approached significance and there was a moderate amount of variability due to heterogeneity based on the I^2 statistic, we proceeded to meta-regression to identify potential moderators that could explain the existing heterogeneity. In the current model, we tested incentivized versus nonincentivized designs as an imbalance model moderator, but this moderator was not significant (immediate outcome feedback vs. delayed outcome feedback and mixed gambles vs. gain gambles could not be tested in this

Table 5
Effect Sizes for the Early Adolescent Versus Children Model, Sorted by Type of Task (k = 12)

No.	Study	Task	Effect size *g*	Variance
16	Prencipe et al. (2011)	IGT	.23	.09
20	Smith et al. (2012)[a]	IGT	1.10	.16
3	Crone & van der Molen (2007)[a]	Hungry Donkey Task (modified IGT)	.25	.08
10	Huizenga et al. (2007)[a]	Hungry Donkey Task (modified IGT)	−.21	.03
22a	Van Duijvenvoorde et al. (2012)[a]	Gambling Task (modified IGT; noninformed version)	.04	.09
22b	Van Duijvenvoorde et al. (2012)[a]	Gambling Task (modified IGT; informed version)	−.20	.09
19a	Slovic (1966)	Knife Switches Task/Devil's Task	.40	.03
19b	Slovic (1966)	Knife Switches Task/Devil's Task	.07	.06
23	Van Leijenhorst et al. (2008)[a]	Cake Gambling Task	−.19	.11
24	Van Leijenhorst et al. (2010)[a]	Cake Gambling Task	−.19	.11
4	Crone et al. (2008)[a]	Self–Other Gambling Task	.42	.11
18	Steinberg et al. (2008)	Stoplight Game	−.16	.02

Note. Positive effect sizes indicate that early adolescents took more risks than mid-late adolescents, whereas negative effect sizes indicate that early adolescents took fewer risks. IGT = Iowa Gambling Task.
[a] We contacted the authors of the corresponding studies for additional numerical statistical information, in order to calculate the effect sizes.

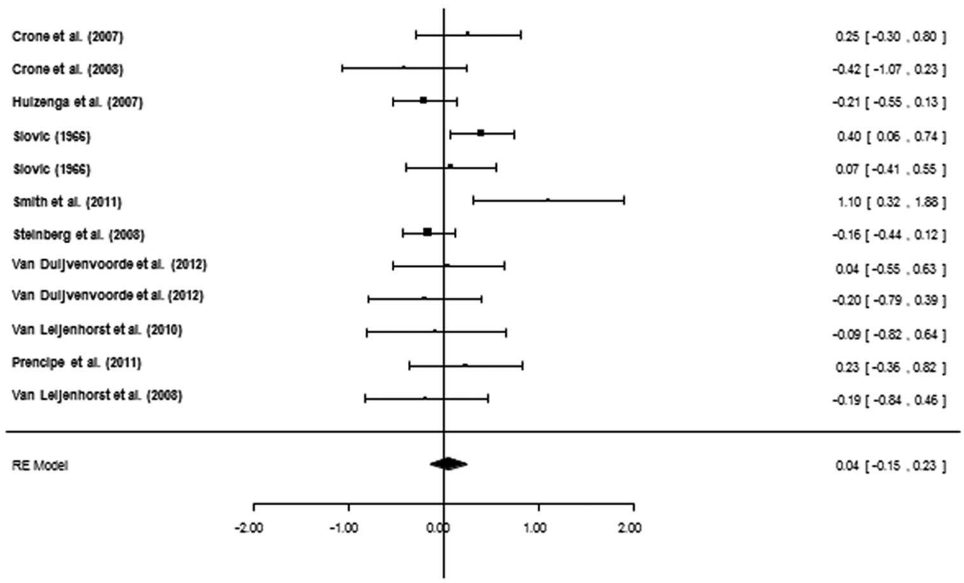

Figure 1. Forest plot with the distribution of effect sizes for studies containing early adolescents versus children comparisons on behavioral risky decision-making tasks. Effect sizes per study are depicted by the positioning of the filled squares on the *x*-axis; the sizes of these squares represent the weight of the studies. The vertical line with the value 0 is the line of no effect. The bars correspond with a 95% CI of the effect sizes (outer edges of the polygon indicating limits of the CI). CI = confidence interval; RE Model = random-effects model.

moderational analysis, as too few studies included these characteristics). Second, we simultaneously tested the additional affective moderators; namely, time pressure versus no time pressure, dynamic versus static, and experience-based versus description-based tasks. However, none of these potential affective moderators were significant. Third, we tested only IGT versus no IGT as a task moderator (as only one study employed the CCT and no studies employed the Stoplight Game). The IGT did not moderate the results. Finally, we tested IQ covariate versus no IQ covariate as a putative confounding factor, but this moderational analysis also yielded nonsignificant results (equal EV vs. unequal EV and fMRI vs. no fMRI study could not be tested as putative confounding moderators in this model). It is noteworthy that, in this model, we were unable to test for the fuzzy trace theory moderators sure win option versus no sure win option and sure neutral option versus no sure neutral option. Taken together, these results indicate that early adolescents and children take equal levels of risks on a wide range of risky decision-making tasks, with varying task characteristics and contexts.

Meta-Analysis 1B: Adolescents versus children model. The adolescents–children model ($k = 21$) yielded a nonsignificant mean effect size ($g = -.00$; $p = .97$), indicating no age-related differences between adolescents and children in risky decision making (see Table 6 and Figure 2). However, there was a large degree of heterogeneity, $Q(20) = 75.28$, $p < .01$, and $I^2 = 73.43\%$ (random-effects model). Sensitivity analyses via the trim and fill procedure confirmed that no studies had to be imputed. Thus, publication bias appears to be absent in the present meta-analysis. Next, outlier analyses showed that two studies were both outliers and influential cases. Thus, we reran the main analyses without these two studies, but the conclusion did not change (i.e., the effect size remained nonsignificant). Thus, results reported below include these outliers.

Considering a significant Q test and a substantial amount of variability due to heterogeneity based on the I^2 statistic, we proceeded to meta-regression to explain possible underlying factors of the existing heterogeneity. In the current model, we simultaneously tested the following three moderators derived from the imbalance model theory: immediate outcome feedback versus delayed outcome feedback,[13] gain gambles versus mixed gambles, and incentivized versus nonincentivized designs; the moderator analysis was not significant. Second, we tested the additional affective moderators simultaneously; namely, time pressure versus no time pressure, dynamic versus static, and experience-based versus description-based tasks. This moderator analyses also did not yield significant results. Third, we simultaneously tested the following moderators, which we derived from the fuzzy trace theory: sure win option versus no sure win option and sure neutral versus no sure neutral option. Moderation effects, $QM(2) = 8.20$, $p = .02$, were observed for the tasks that had a sure win option (vs. no sure win option, $b = -.46$; $p = .02$), denoting that the effect size decreases on average by .46 points when a task includes a sure win option. This suggests that adolescents take fewer risks than children when a sure win option is present. Fourth, we tested IGT versus no IGT only as a task moderator (as only one study employed the CCT and no studies employed the Stoplight Game). The IGT did not moderate the results. Finally, we tested the

[13] Keulers, Stiers, and Jolles (2011) was not included in the moderation analyses for immediate outcome feedback, because this study did not consistently provide immediate outcome feedback on all trials.

Table 6
Effect Sizes for the Adolescents Versus Children Model, Sorted by Type of Task (k = 21)

No.	Study	Task	Effect size *g*	Variance
16	Prencipe et al. (2011)	IGT	.23	.09
20	Smith et al. (2012)[a]	IGT	.64	.21
22a	Van Duijvenvoorde (2012)[a]	Gambling Task (modified IGT; noninformed version)	−.96	.10
22b	Van Duijvenvoorde (2012)[a]	Gambling Task (modified IGT; informed version)	−.47	.08
3	Crone & van der Molen (2007)[a]	Hungry Donkey task (modified IGT)	.25	.08
10	Huizenga et al. (2007)[a]	Hungry Donkey task (modified IGT)	.12	.03
4	Crone et al. (2008)[a]	Self–Other Task	−.69	.12
7a	Figner et al. (2014)	Cold CCT	−.10	.07
7b	Figner et al. (2014)	Hot CCT	.28	.05
14	Paulsen et al. (2012)[a,b]	Nonsymbolic Economic Decision-Making Task	−1.19	.14
15	Paulsen et al. (2011)[a,b]	Nonsymbolic Economic Decision-Making Task	−.60	.13
17a	Rakow et al. (2010)[a]	Sure vs. Risky Choice Task (description version)	−.33	.07
17b	Rakow et al. (2010)[a]	Sure vs. Risky Choice Task (experience version)	−.03	.06
19a	Slovic (1966)	Knife Switches Task/Devil's Task	.38	.03
19b	Slovic (1966)	Knife Switches Task/Devil's Task	.10	.06
23	Van Leijenhorst et al. (2008)[a]	Cake Gambling Task	.10	.10
24	Van Leijenhorst et al. (2010)[a]	Cake Gambling Task	−.09	.14
1	Burnett et al. (2010)[a]	Probabilistic Gambling Task	.39	.09
13	Macpherson et al. (2010)	BART	.56	.01
12	Kreitler et al. (1990)	Mirror Drawing Risk-Taking Task	.56	.03
21	Steinberg et al. (2008)	Stoplight Game	−.03	.02

Note. Positive effect sizes indicate that adolescents took more risks than children, whereas negative effect sizes indicate that adolescents took fewer risks. IGT = Iowa Gambling Task; CCT = Columbia Card Task; BART = Balloon Analogue Risk Task.
[a] We contacted the authors of the corresponding studies for additional numerical statistical information, to facilitate the computation of the effect sizes. [b] Results based on the risk–safe trials were used to compute the effect sizes.

following putative confounding factors simultaneously: equal EV versus unequal EV, fMRI versus no fMRI study, and IQ covariate versus no IQ covariate. The overall moderator was significant, $QM(3) = 10.39$, $p = .02$, and inspection of the individual moderators showed that adolescents take more risks than children on tasks with unequal EV ($b = .78$; $p < .01$); however, adolescents take fewer risks than children when IQ is controlled for ($b = -.65$; $p = .02$). A follow-up moderational analysis with only unequal EV

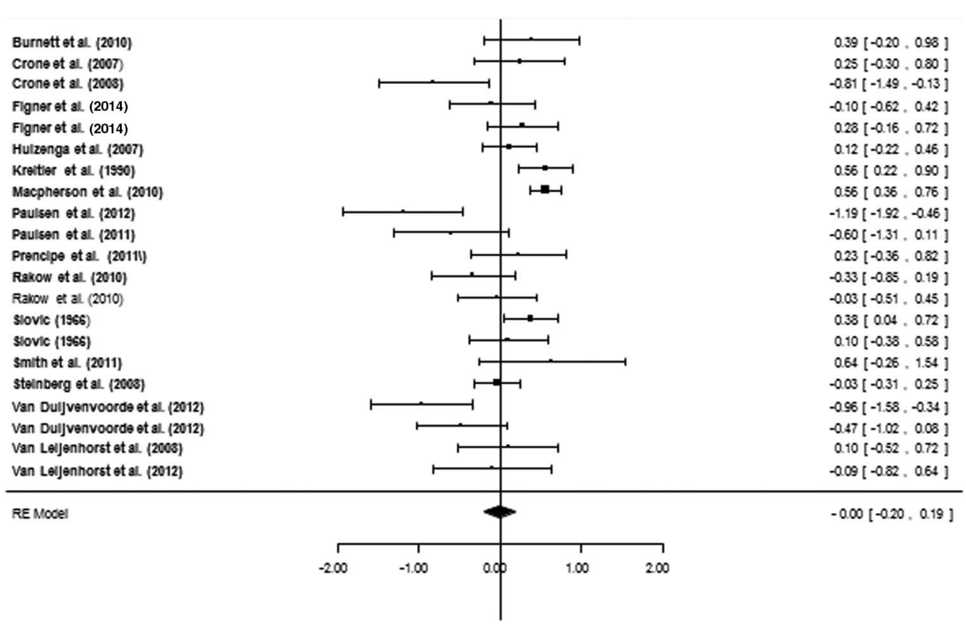

Figure 2. Forest plot with the distribution of effect sizes for studies containing children versus adolescents comparisons on behavioral risky decision-making tasks. Effect sizes per study are depicted by the positioning of the filled squares on the *x*-axis; the sizes of these squares represent the weight of the studies. The vertical line with the value 0 is the line of no effect. The bars correspond with a 95% CI of the effect sizes (outer edges of the polygon indicating limits of the CI). CI = confidence interval; RE Model = random-effects model.

tasks showed that whether the sure option (or less riskier option) versus the risky (or riskier) option had the highest EV did not moderate the results.

Collectively, results suggest that adolescents and children generally take equal levels of risks but that the context matters. When a risky decision-making task includes unequal EV for its choice options, adolescents engage in more risk-taking than children. However, on risky decision-making tasks with a sure win option or when IQ is controlled, adolescents actually take fewer risks than children.

Meta-Analysis 2: Early Adolescent Versus Mid-Late Adolescent Risky Decision Making

The early adolescent versus mid-late adolescent model ($k = 14$) resulted in a significant but small standardized mean difference ($g = .15$; $p = .01$) and a nonsignificant Q test, $Q(13) = 12.19$, $p = .51$, $I^2 = 0\%$ (random effects model). These findings (see Table 7 and Figure 3) suggest greater risk-taking levels by early adolescents than mid-late adolescents on risky decision-making tasks, with an absence of heterogeneity. Sensitivity analysis results from the trim and fill procedure revealed that two studies had to be imputed. When these potential studies were imputed, the effect size dropped slightly and the resulting effect size was marginally significant ($g = .12$; $p = .08$). Finally, outlier analyses did not reveal any influential outliers. Although heterogeneity was not detected, we still progressed to moderation analyses, as the Q test sometimes fails to detect heterogeneity due to limited statistical power (Lipsey & Wilson, 2001). Incentive compatibility versus incentive incompatibility, which was tested as an imbalance model moderator, was not significant (gain vs. mixed gambles and immediate vs. delayed outcome feedback could not be tested as moderators). The additional affective moderators that were simultaneously tested were time pressure versus no time pressure, dynamic versus static, and experience-based versus descriptive-based tasks. All of them were nonsignificant. Sure win option versus no sure win, which was tested as a fuzzy trace theory moderator, also was not significant. IGT versus no IGT was investigated as a task moderator, but no moderational effect was found. (In this model we could not test for moderation by the Stoplight Game or the CCT.) Finally, results showed that the putative confounding moderator IQ covariate versus no IQ covariate was not significant (the equal EV vs. unequal EV and fMRI vs. no fMRI moderators could not be tested in this analysis). Taken together, none of the moderators were significant. Thus, collectively, it can be concluded that early adolescents engage in more risky decision making relative to mid-late adolescents, on a range of tasks, although when controlling for publication bias, this effect becomes marginally significant.

Meta-Analysis 3: Adolescent Versus Adult Risky Decision Making

The final model ($k = 23$), which compared adolescents' risky choice to adults' risky choice, yielded a medium effect size ($g = .37$; $p < .01$), and the Q test was significant, $Q(22) = 53.88$, $p < .01$, $I^2 = 59.17\%$ (random-effects model). These results (see Table 8 and Figure 4) indicate that adolescents engage in more risk-taking than did adults on risky decision-making tasks and that there was substantial heterogeneity in the distribution of effect sizes. Regarding publication bias, sensitivity analyses via the trim and fill method suggested that seven studies had to be imputed. However, despite the suggested imputations, the mean effect size remained significant and of medium magnitude ($g = .37$ to $g = .21$) and the Q test remained significant. Thus, these tests confirm that despite a slight decline in effect size, age differences in risk-taking between adults and adolescents remained, suggesting that results reported in the current meta-analysis are relatively robust to any potentially missing studies. Moreover, when two influential outliers were removed, the effect size increased slightly and remained significant. Because there was no substantial change in the mean effect size when the outliers were removed, below we report moderational analyses including the outliers.

The following imbalance model moderators were tested simultaneously: immediate versus delayed outcome feedback, gain gambles versus mixed gambles, and incentivized designs versus nonincentivized designs. The overall moderational test was significant, $QM(3) = 9.40$, $p = .02$. However, immediate outcome feedback versus delayed outcome feedback did not fully

Table 7
Effect Sizes for the Early Adolescent Versus Mid-Late Adolescent Model, Sorted by Type of Task (k = 14)

No.	Study	Task	Effect size *g*	Variance
16	Prencipe et al. (2011)	IGT	.52	.09
20	Smith et al. (2012)[a]	IGT	1.00	.17
22a	Van Duijvenvoorde (2012)[a]	Gambling Task (modified IGT; noninformed version)	.51	.09
22b	Van Duijvenvoorde (2012)[a]	Gambling Task (modified IGT; informed version)	.08	.08
3	Crone & van der Molen (2007)[a]	Hungry Donkey Task (modified IGT)	.42	.07
10	Huizenga et al. (2007)[a]	Hungry Donkey Task (modified IGT)	−.05	.03
4	Crone et al. (2008)[a]	Self–Other Task	−.17	.11
17c	Rakow & Rahim (2010)[a]	Sure vs. Risky Choice Task (experience version)	.05	.07
19a	Slovic (1966)	Knife Switches Task/Devil's Task	.06	.02
19b	Slovic (1966)	Knife Switches Task/Devil's Task	.17	.06
23	Van Leijenhorst et al. (2008)[a]	Cake Gambling Task	−.14	.11
24	Van Leijenhorst et al. (2010)[a]	Cake Gambling Task	.15	.14
11	Keulers et al. (2014)	Gambling Task	.15	.01
21	Steinberg et al. (2008)	Stoplight Game	.32	.10

Note. Positive effect sizes indicate that early adolescents took more risks than mid-late adolescents, whereas negative effect sizes indicate that early adolescents took fewer risks. IGT = Iowa Gambling Task.
[a] We contacted the authors of the corresponding studies for additional numerical statistical information, in order to calculate the effect sizes.

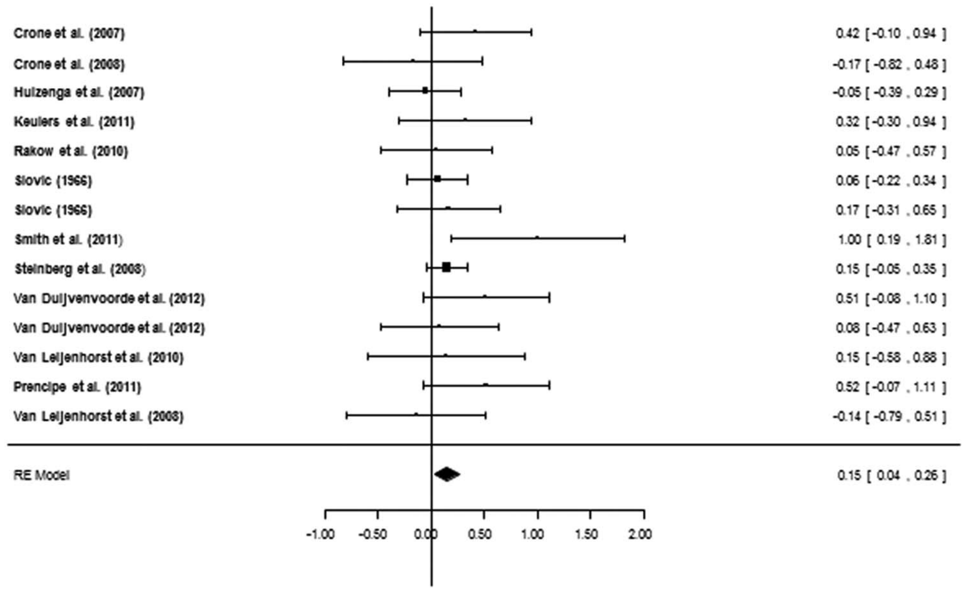

Figure 3. Forest plot with the distribution of effect sizes for studies containing early adolescents versus mid-late adolescents comparisons on behavioral risky decision-making tasks. Effect sizes per study are denoted by the location of the squares (i.e., weight of the studies). The diamond portrays the overall effect estimate, and the width of the diamond shows the CI for this effect. The vertical line with the value 0 is the line of no effect. The bars represent the 95% CI of the effect sizes (outer edges of the polygon indicating limits of the CI). CI = confidence interval; RE Model = random-effects model.

reach significance ($b = .37$; $p = .059$), whereas the remaining two imbalance moderators were clearly not significant as their p values were larger than .10.[14] Thus, for every task including immediate outcome feedback on gains and losses, the effect size increases on average with .37 points, although this seemingly substantial increase is only marginally significant. The following additional affective moderators were simultaneously tested: time pressure versus no time pressure and dynamic versus static tasks (the descriptive-based vs. experience-based moderator could not be tested because a subgroup included only two studies); however, none of the moderators was significant. Next, we simultaneously tested the outcome moderators: sure win option versus no sure win option and sure neutral versus no sure neutral (i.e., fuzzy trace theory moderators); results showed no significant effects. The task moderator analysis including IGT versus no IGT, Stoplight versus no Stoplight, cold CCT versus no cold CCT, and hot CCT versus no hot CCT moderators also was not significant. Finally, all of the confounding moderators that were tested simultaneously (i.e., unequal EV vs. equal EV, fMRI vs. no fMRI, and IQ covariate vs. no IQ covariate) were not significant. Taken together, results imply that adolescents generally take more risks than adults but that this is especially the case on tasks with immediate outcome feedback on rewards and losses.

Discussion

Survey data as well as real-life accounts concur that adolescence is a period for both the initiation and peak of many health-threatening risk-taking behaviors (Albert & Steinberg, 2011; Reyna & Farley, 2006; Steinberg, 2004). However, despite evident disproportionate adolescent risk-taking in real life situations, only some—but not all—experimental studies have found that adolescents indeed engage in more risk-taking than children and adults (Gladwin et al., 2011). In view of such conflicting findings on age differences in risk-taking, we conducted four rigorous independent meta-analyses, comparing children's versus early adolescents', children's versus adolescents', early adolescents' versus mid-late adolescents', and adolescents' versus adults' risk-taking on behavioral risky decision-making tasks.

We used the neurodevelopmental imbalance perspective as our primary theoretically guiding framework. Neurodevelopmental imbalance models postulate a transient potential during adolescence for an imbalance between relatively strong "hot" affective-motivational versus relatively immature "cold" deliberative-cognitive control processes (Figner & Weber, 2011; Somerville et al., 2010; Steinberg, 2007). Further, we used fuzzy trace theory as an additional theoretical guiding framework. Fuzzy trace theory generally distinguishes between two different types of processing (here explained in the context of risky decision making), a *verbatim-based quantitative* reasoning mode and a *gist-based qualitative* reasoning mode (Reyna & Brainerd, 2011). Fuzzy trace theory posits that reliance on gist-based qualitative decisions increases with age, and, as a result, adults are more likely than adolescents to use a gist-based mode when making a risky choice. Thus, although neurodevelopmental imbalance models predict that

[14] When the moderator immediate versus delayed outcome feedback was tested in an univariate meta-regression (as a result of a backward elimination approach, selecting only moderators with a $p < .10$), it was significant ($b = .50$; $p = .01$). Thus, the inclusion of other related moderators in the multivariate meta-regression analysis leads to suppression of the moderator immediate outcome feedback versus delayed outcome feedback.

Table 8
Effect Sizes for the Adolescent Versus Adult Model, Sorted by Type of Task (k = 23)

No.	Study	Task	Effect size *g*	Variance
2	Chein et al. (2011)	Stoplight Game (modified Chicken Game)	.45	.16
9a	Gardner et al. (2005)	Chicken Game	.42	.04
9b	Gardner & Steinberg (2005)	Chicken Game	.72	.04
21	Steinberg et al. (2008)	Stoplight Game (modified Chicken Game)	.29	.02
5	Eshel et al. (2007)	Wheel of Fortune	.17	.13
6b	Figner et al. (2009)	Cold CCT	−.06	.07
6d	Figner et al. (2009)	Cold CCT	.17	.06
6b	Figner (2014)	Cold CCT	.24	.05
7a	Figner et al. (2009)	Hot CCT	.61	.08
7c	Figner et al. (2009)	Hot CCT	.64	.06
7a	Figner (2014)	Hot CCT	.51	.07
14	Paulsen et al. (2012)[a,c]	Nonsymbolic Economic Decision-Making Task	.11	.11
15	Paulsen et al. (2011)[a,c]	Nonsymbolic Economic Decision-Making Task	1.36	.19
23	Van Leijenhorst et al. (2008)[a]	Cake Gambling Task	.39	.10
24	Van Leijenhorst et al. (2010)[a]	Cake Gambling Task	.35	.15
10	Huizenga et al. (2007)[a]	Hungry Donkey Task (modified IGT)	.63	.03
22a	Van Duijvenvoorde et al. (2012)[a]	Gambling Task (modified IGT)	.69	.08
22b	Van Duijvenvoorde et al. (2012)[a]	Gambling Task (modified IGT)	.45	.08
25	Tymula et al. (2012)	Standard incentive-compatible technique	−.52	.06
1	Burnett et al. (2010)[a]	Probabilistic Gambling Task	.92	.11
8	Galván & McGlennen (2012)[a,b]	Cups Task	.31	.12
11	Keulers et al. (2011)	Gambling Task	.62	.12
18	Reyna et al. (2011)	Framing Task	−.09	.01

Note. Positive effect sizes indicate that adolescents took more risks than adults, whereas negative effect sizes indicate that adolescents took fewer risks. CCT = Columbia Card Task; IGT = Iowa Gambling Task.
[a] We contacted the authors of the corresponding studies for additional numerical statistical information, in order to calculate the effect sizes. [b] The equal expected value (EQEV) condition and the low-stress condition were used to compute the effect sizes. [c] Results based on the risk-safe trials were used to compute the effect sizes.

adolescents should take more risks than children and adults, especially in highly arousing (e.g., hot affect-charged) situations (e.g., when salient rewards [gains] are involved), fuzzy trace theory predicts that adolescents should take fewer risks than children but more risks than adults, as gist-based decision making increases with age and thus leads to decreasing risk-taking with increasing age (holding all other things equal). The first question motivating the current meta-analyses was "How do (early) adolescents' risk-

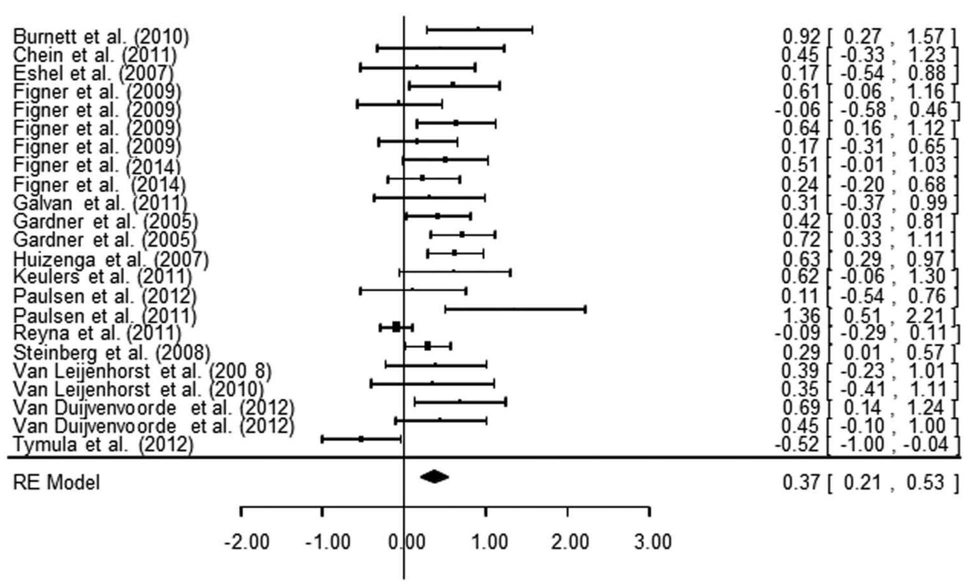

Figure 4. Forest plot with the distribution of effect sizes for studies containing adults versus adolescents comparisons on behavioral risky decision-making tasks. Effect sizes per study are denoted by the positioning of the filled squares (i.e., weight of the studies). The vertical line with the value 0 is the line of no effect. The diamond represents the overall effect size, and the bars represent the 95% CI of the effect sizes (outer edges of the polygon indicating limits of the CI). CI = confidence interval; RE Model = random-effects model.

taking levels differ from children's and adults' and how strong are these differences?" Second, because imbalance models postulate that the imbalance between more cognitive top-down control processes versus more affective-motivational bottom-up processes is especially driven by puberty-specific maturational changes in the brain that begin during early adolescence (Somerville et al., 2010), we also investigated whether there are age differences in early versus mid-late adolescents' risk-taking and whether early adolescents differ from children. Finally, again inspired by imbalance models, we investigated whether cold versus hot affective task and setting features moderated the results. Additionally, inspired by fuzzy trace theory, we investigated if the availability of a sure option (in contrast to both available choice options being risky) moderated the results.

For the four excluded studies (due to failed attempts to retrieve necessary statistical information from the respective authors) that matched the inclusion criteria, the reported results were based on net scores and disadvantageous choices. Thus, they do not reflect risk-taking as defined in the field of judgment and decision making (Weber, 2010), which defines risk behavior as "choosing the outcome with the highest variance." For this reason we cannot give a summary of the risk-taking results of these studies, nor is it valid to refer to them in the Discussion section.

Contrary to the predictions of imbalance models and abundant evidence of heightened real-world adolescent risk-taking alike, two meta-analyses (i.e., a children vs. adolescents meta-analysis and a children vs. early-adolescents meta-analysis) consistently revealed that adolescents generally engage in levels of risk-taking equal to those of children on risky decision-making tasks. A modest but significant age difference ($g = .15$) was present between early and mid-late adolescence, with early adolescents taking more risks than mid-late adolescents. Additionally, consistent with imbalance models, results showed that adolescents engage in more risk-taking than adults, denoted by a medium mean effect size ($g = .37$). Next, a series of moderation analyses revealed that adolescents take fewer risks than children when IQ is controlled for, particularly on tasks that include a choice between a sure option to win something and a gamble (compared to tasks wherein engaging in a gamble is unavoidable as both options are risky). Finally, adolescents engage in more risk-taking than children on tasks with unequal expected values (EVs). As for the adult-adolescent model, moderation analyses revealed that the moderator immediate versus delayed outcome feedback approached significance ($b = .37$; $p = .059$), indicating that compared to adults, adolescents engage in more risk-taking, particularly on tasks that provide immediate feedback on potential outcomes (versus tasks with delayed feedback on potential outcomes).[15] No other significant moderator was found. More specifically, the remaining hot affective and cold cognitive task and contextual characteristics derived from the imbalance framework, the sure option moderator derived from fuzzy trace theory, and the confounding factors all did not moderate the variability in the effect sizes.

Below, we discuss the interpretations and implications of the age differences effects and the moderation effects that we found, separately per age group comparison. Additionally, we discuss how the current results contribute to understanding age differences in real-world risk-taking and to guiding future directions in experimental research on risk-taking.

Meta-Analysis 1A and 1B: (Early) Adolescents Versus Children Risk Taking

Contrary to popular belief, the present results revealed that when (early) adolescents and children are presented with the same risk-taking task under similar conditions (i.e., identical risk-taking opportunities), they generally end up taking equal levels of risks. These results challenge imbalance models, because these theories posit that adolescents are more inclined to take risks than both children and adults. The results are generally also not consistent with fuzzy trace theory, because this theory predicts that adolescents should take fewer risks than children due to adolescents' stronger reliance on more gist-based decision making. However, it is worth noting that substantial heterogeneity in age differences across studies was present. Whereas, no significant moderators were present in the children versus early adolescents models,[16] moderation analyses in the children versus adolescent model revealed that adolescents take fewer risks than children when a sure win option is available (it was not possible to test for moderation for sure neutral option, as too few studies included such a task characteristic). Additionally, adolescents also take fewer risks than children when IQ is controlled for. On the other hand, adolescents take more risks than children on tasks with unequal EV choice options.[17]

The overall lack of significant age differences between children and adolescent risk-taking and the result that adolescents take fewer risks than children on tasks with a sure win option raise a burning question: Why does the current synthesis of studies point toward adolescents generally taking the same or even fewer risks than children on risky decision-making tasks, while adolescents evidently engage in more risk-taking in the real world? Three potential explanations could clarify this unanticipated finding.

First, is it possible that gender effects might explain the current results? A meta-analysis on gender differences in self-reported risk-taking more or less supports this notion, as this meta-analysis documented that females were more risk-averse than males; however, the effect sizes were small and domain specific (Byrnes et al., 1999). Unfortunately, the vast majority of studies included in our meta-analyses (with the exception of two studies: Kreitler & Zigler 1990; Slovic, 1966) did not provide results for males and females separately, making it impossible for us to investigate gender as a

[15] It should be emphasized that despite the apparently substantial moderational effect ($b = .37$), this trend effect missed significance ($p = .059$); thus, it should be interpreted with caution. However, when this moderator was tested in a univariate meta-regression, it was significant ($b = .50$; $p = .01$). Thus, the inclusion of other related moderators in the multivariate meta-regression analysis leads to suppression of the moderator immediate outcome feedback versus delayed outcome feedback.

[16] Please note that for the children versus early adolescent model, it was not possible to test for moderation by the following factors, as there were not enough studies available per subgroup: Imbalance model moderators: (a) immediate versus delayed outcome feedback, (b) mixed versus gain gambles tasks. Putative confounding moderators: (c) fMRI study versus no fMRI study, (d) controlling for IQ versus not controlling for IQ. Fuzzy trace moderators: (e) sure win versus no sure win, (f) sure neutral versus no sure neutral. Task moderators: (g) cold CCT versus no cold CCT, (h) hot CCT versus no hot CCT, and (i) Stoplight Game versus no Stoplight Game.

[17] Please note that it was not possible to test for moderation in age differences in risk-taking for (a) cold CCT, (b) hot CCT, and (c) the Stoplight Game, as too few studies included these tasks.

moderator in age effects. Nonetheless, the few studies in the current meta-analyses that investigated gender differences in age effects in risk-taking (but did not report results for males and females separately) reported that gender did not moderate these effects (e.g., Figner et al., 2009; Steinberg et al., 2008). Thus, there are reasons to believe that moderation by gender of the current age effects is absent in the present findings.

A second potential explanation of the lack of age differences in the adolescents-versus-children model could be the presence of individual differences. More specifically, when a risk-taking opportunity arises, adolescents' inclination to take risks might be predicted by hypersensitive affective personality traits (e.g., individual differences in sensation seeking or anxiety; Casey et al., 2008; Harden & Tucker-Drob, 2011). Accordingly, individual differences in baseline activity of the affective motivational system could potentially exacerbate the imbalance between cognitive top-down control processes and affective-motivational bottom-up processes in adolescence (Casey et al., 2008). The role of individual differences in age differences in risk-taking between children and adolescents was not directly measured in the current meta-analysis, but it is supported by substantial empirical evidence (e.g., Crone, Bullens, van der Plas, Kijkuit, & Zelazo, 2008; Hare, O'Doherty, Camerer, Schultz, & Rangel, 2008; Lejuez et al., 2003; Rao et al., 2011; Reyna et al., 2011; Romer & Hennessy, 2007; Steinberg et al., 2008). Thus, the neglect of individual differences in the current meta-analysis could perhaps—at least partially—account for the lack of age differences found between children and adolescents' risk-taking in the present meta-analysis. It is imperative to mention that although there is evidence showing that individual differences might be a predictor of the affective-cognitive imbalance, only a few studies have considered individual differences in risk-taking (cf. Somerville et al., 2010; but see Figner et al., 2009; Reyna et al., 2011; Steinberg et al., 2008); thus, until now, conducting a meta-analysis on this topic might have been quite challenging and unfeasible due to a dearth of available studies.

The third possible explanation that could account for the absence of an adolescent peak in risk-taking is a methodological one. The fact that all the included studies except one were cross-sectional could mean that actual age differences might have been obscured because longitudinal studies are better at detecting developmental changes in behaviors across the life span. The single longitudinal study (Macpherson, Magidson, Reynolds, Kahler, & Lejuez, 2010) included in the current meta-analysis supports this notion, given that risk-taking significantly increased from age 11 to age 13. However, it would clearly be premature to make such a conclusion based on the findings from just one study employing one specific assessment method (i.e., the BART). Thus, studies that include multiple tasks and multiple age groups, as well as longitudinal designs, are clearly needed. Moreover, when interpreting age-related changes in risk-taking, one has to be careful not to conflate overt risk-taking levels with risk preferences. For example, A might exhibit higher risk-taking levels than B, but both might still be risk-averse (just A less so than B); thus, from a pure outcome-maximization viewpoint (assuming risk and loss neutrality, as discussed in the introduction), both A and B might be undershooting in their risk-taking. In the case of the Macpherson et al. (2010) study, participants stayed below the optimal level of risk-taking on the BART even in the third assessment wave, which exhibited the highest risk-taking levels. Therefore, the increasing number of pumps in the task might not necessarily reflect risk preferences but might equally well reflect an increase in EV sensitivity, leading to task performance that comes closer and closer to the risk-neutral strategy that maximizes long-term outcomes risk-taking. Thus, although the results of this longitudinal study are intriguing, it is important to verify these results by using tasks and methods that unconfound risk-taking from EV. The CCT is one such task that does not suffer from interpretational ambiguity (see also Schonberg et al., 2011).

We are confident that, taken together, the present results reflect the actual nature of age differences in risk-taking between adolescents and children. Moreover, our sensitivity analyses indicated an absence of publication bias, as no studies were missing in the adolescent–children model, which further supports the robustness of the current results. Thus, whereas in the real world, apparent differences in risk–opportunity are large between children and adolescents (which makes their risk-taking propensity difficult to compare in the real world), children and adolescents are presented with equal opportunities to take risks in the lab setting; therefore, their behaviors in the lab might reflect their actual risk-taking propensities better than real-world behaviors. Hence, we conclude that age differences in risk-taking between children and adolescents generally become negligible when children and adolescents are presented with identical risk-taking opportunities. However, despite the apparently current robust findings, the substantial heterogeneity that was detected in the distribution of the age effects in risk-taking between children and adolescents has to be taken into account when interpreting the current results. Thus, we address the significant moderators below.

No moderators were present in the early-adolescent-versus-children meta-analysis; however, three moderators were found to be present in the children-versus-adolescent meta-analysis: the sure win versus no sure win option, controlling for IQ, and unequal EV versus equal EV. The first significant moderator contradicts imbalance models, as our results suggest that adolescents actually take fewer risks than children on tasks that provide a sure win option. In contrast, this result is consistent with fuzzy trace theory, which describes that tasks including a sure option (in addition to a risky option) facilitate the possibility to engage in simple categorical thinking (i.e., gist decision making; Reyna et al., 2011; "no loss is better than some loss"). Moreover, empirical support for fuzzy trace theory has shown that gist-based decision making increases with age, and sound gist decision making can promote risk-aversion (Reyna & Ellis, 1994; Reyna & Farley, 2006). In other words, as adolescents are expected to engage in more gist-based decision making than children, adolescents are expected to choose the sure option over the risky option in sure versus gamble tasks. However, it is important to note here that we did not take the reverse framing effect of the fuzzy trace theory into account. The reverse framing effect—which implies sensitivity to quantitative differences between the outcomes of choice options—could have implications for the current results on age effects, because this phenomenon is common in children and adolescents but hardly ever occurs in adults (e.g., Levin, Gaeth, Schreiber, & Lauriola, 2002; Reyna, 2012; Reyna et al., 2011). Future studies should consider including risk-taking paradigms with both gain and loss gambles, as well as variations of risks, in order to test the reversed framing effect further.

In addition to there being age differences in the use of gist, it is likely that children may take more risks simply because they are less efficient in their deliberative analytic processing of risks and benefits, perhaps underestimating risks. (Although this is not in line with fuzzy trace theory's predictions; the theory predicts parallel development of verbatim analytic processing.) Another alternative explanation is that impulsivity might also play a role; specifically, considering the typical impulsive nature of children (Steinberg et al., 2008) compared to adolescents, children might impulsively choose the risky option (vs. sure option) with the seemingly larger reward, independent of the respective probabilities of winning that reward.

The two remaining significant moderators were putative confounding factors; namely, whether a study used unequal (or equal) EV choice options and whether (or not) the study controlled for IQ. The effect size increases significantly (i.e., approaches a positive value indicating that adolescents take more risks than children) when the EV for the choice options differ (i.e., unequal EV). Such unequal EV choice options might require more computational abilities, implying that in such cases, older persons should outperform (i.e., take less risk) younger persons, by choosing the option with the highest EV. However, follow-up moderational analyses including only unequal EV tasks showed that higher EV for the risky option versus higher EV for the sure option did not moderate the effect size. Of interest, this finding indicates that unequal EVs seem to be more relevant than which option has the higher EV.[18] In any case, the current results reveal that task characteristics such as unequal EV versus equal EV should be considered, particularly when the aim is to identify age differences in risk-taking.

Next, in studies that control for the IQ of the participants, the meta-analytic finding is that adolescents take fewer risks than children. This is an interesting finding that could have implications especially for neurodevelopmental imbalance models, as cognitive control (or executive functioning) is fundamental to intelligence (Cole, Yarkoni, Repovs, Anticevic, & Braver, 2002). Immature levels of cognitive control appear to predict more risk-taking but only in the presence of heightened reward reactivity (e.g., Luna, Paulsen, Padmanabhan, & Geier, 2013), which is especially the case in adolescence, according to neurodevelopmental imbalance models. Similar to overall intelligence, cognitive control increases with age but begins to stabilize during adolescence (Luna et al., 2004). There is a lack of research on the direct link between components of intelligence and risky decision making (for a discussion, see Frederick, 2005), but intelligence has been shown to predict more risk-taking behavior, particularly on tasks related to financial choices among adults (e.g., Benjamin & Shapiro 2005; Donkers, Melenberg, & van Soest, 2001). At first sight, this might seem counterintuitive; however, as adults are typically risk-averse in many of the used paradigms, greater risk-taking in these paradigms is actually less risk-aversion (rather than more risk-seeking) and thus closer to the optimal choice behavior that maximizes financial outcomes. Thus, intelligence appears to help choose closer to the financial optimum in such tasks. Taken together, these results coupled with our moderation effects highlight the need for future studies to include assessments of IQ in research on adolescent risk-taking. This might be of particular importance for studies testing neurodevelopmental imbalance models, because cognitive control, which is a centerpiece of these models, is related to IQ.

Revisiting the burning question posed earlier in this section, it appears that neither a neurodevelopmental perspective (e.g., neurodevelopmental imbalance models) nor a cognitive perspective (e.g., fuzzy trace theory) can fully explain the current results of adolescents generally taking equal levels risks as children (and even fewer risks than children on sure win option tasks). However, although it is unquestionable that neurodevelopmental and cognitive changes differentiate adolescence from childhood, the transition to adolescence is obviously also associated with significant environmental changes, which should not be ignored either. For example, an increase in autonomy, later curfews, and an increase in time spent away from home indicate that adolescents have many more opportunities than children to engage in risky behaviors. Thus, opportunity factors clearly play a role in the (risky) choices adolescents make, but both neurodevelopmental imbalance models and fuzzy trace theory do not take these changes into account explicitly (which is to be expected, as they focus mainly on processes occurring within the person). Accordingly, we propose a convergence of neural and psychological models with a situational model (i.e., a developmental neuroecological model) to reconcile the results of the current meta-analysis, on the one hand, and the predictions of neurodevelopmental (e.g., imbalance) models, cognitive (e.g., fuzzy trace theory) models, and real-world findings, on the other hand.

Developmental neuroscience models (e.g., imbalance models) suggest that children have relatively immature affective-motivational brain-systems (e.g., ventral striatum) in addition to relatively immature cognitive and impulse control systems (e.g., prefrontal cortex), whereas in adolescents the former system is mature but the latter system is immature (Somerville et al., 2010). Although the developmental social model proposed by Steinberg and colleagues (Albert & Steinberg, 2011; Steinberg, 2007) recognizes the added importance of peers in activating the affective-motivational brain systems, the situational (or ecological) model underscores that risk-taking behaviors are more prevalent when situational circumstances (e.g., the accessibility of alcohol at a party) facilitate the opportunity to engage in such behaviors (Boyer & Byrnes, 2009; Gerrard et al., 2008). There are variants of well-established situational models of risk-taking (Gottfredson & Hirschi, 1990) that are supported by extant empirical research (e.g., Boyer & Byrnes, 2009). Further, as discussed, for example, by Gladwin et al. (2011), it is quite possible that an individual's control system first needs to "learn" and gain experience about when and how to control prepotent affective-motivational urges that are novel, particularly when a child transitions to adolescence and comes in contact for the first time with such risky real-world situations as being offered alcohol or other substances.

In sum, although over the entire investigated age range we found partial support for both of the theoretical frameworks used (the decline in risk-taking from adolescence to adulthood, discussed further below) and the children versus adolescents model discussed here, the present results are in quite sharp contrast with neurodevelopmental imbalance models, which predict that adolescents engage in more risk-taking than children (and adults) in hot affective situations. The main result of no age difference in risk-taking between children and adolescents also does not fully support fuzzy trace theory. Although fuzzy trace theory predicts

[18] We also realize that this is probably also a question of how much the EVs differ: If there is a huge difference in EV, this surely will have an influence on choice such that people choose the higher EV option more often; this might be particularly true for adolescents, as the reverse framing effect suggests.

varying developmental patterns based on task characteristics, averaging across all tasks, we would expect as a main pattern that children take more risks than adolescents. However, consistent with fuzzy trace theory that gist-based sound decision making increases with age, we found that adolescents took fewer risks than children on tasks that provide a sure win option. In an attempt to reconcile the current mixed findings, we suggest a hybrid developmental neuroecological model of risk-taking, as it appears to be most parsimonious to posit that the mere availability of risk-opportunities might be an important factor accounting for more risk-taking in adolescents than children in the real world, and that equal levels of risk-taking by these two age groups will emerge when they perform identical risky decision-making tasks under similar situations (i.e., situational component).

Meta-Analysis 2: Early Adolescents Versus Mid-Late Adolescents Risk Taking

Considering that puberty begins in early adolescence and that imbalance models consider puberty-related changes as the main source of the affective-cognitive imbalance (Somerville et al., 2010), imbalance models would predict that early adolescents should engage in more risk-taking than mid-late adolescents. The current results confirmed these expectations, as early adolescents compared to mid-late adolescents took significantly more risks. Thus, consistent with the imbalance framework, it seems plausible to conclude that the onset of puberty in early adolescence might be driving the direction of the age differences in risk-taking between early and mid-late adolescents. However, it should be recognized that there are too few studies examining the link between pubertal development and adolescent risky decision making on behavioral tasks directly. Among the studies included in our meta-analyses, only one study (i.e., Steinberg et al., 2008) examined self-reported pubertal status as a predictor of risky decision making on the Stoplight Game (see Table 1). In their cross-sectional sample of 12- to 16-year-olds, pubertal status was not related to safe stopping, risky driving, or crashing. However, it was related to the number of intersections adolescents crossed through successfully. Specifically, those who just entered puberty crossed more intersections than prepubertal, midpubertal, or postpubertal adolescents. Thus, although it is perhaps likely that the onset of puberty may be linked to the age differences we found, the link between pubertal development and risky decision making clearly has to be investigated among additional (longitudinal) samples. The current results are also in line with fuzzy trace theory, as this theory postulates that early adolescents should be more susceptible to risk-taking than older adolescents, considering that older adolescents rely less on verbatim-based decision making (Reyna & Farley, 2006; Rivers et al., 2008). Furthermore, heterogeneity was not detected in this model, and moderation analyses confirmed that no moderators were present.

Finally, it should be noted that albeit the direction of the significant age effects in the early adolescent versus mid-late adolescent model could be explained from a neurodevelopmental imbalance framework as well as a fuzzy trace theory framework, these findings do not perfectly mirror real-world risk-taking. That is, although the majority of risk-taking behaviors have their debut in early adolescence (Reyna & Farley, 2006; Steinberg, 2004), the peak in risk-taking actually occurs in mid adolescence (Albert & Steinberg, 2011). Again, we posit that regarding the peak in risk-taking in mid-adolescents, situational factors might account for the contradicting findings between survey and real-life accounts on one hand and experimental findings on the other hand. In essence, mid-late adolescents might simply take more risks than early adolescents in the real world, because they have more access to different potential risk-taking domains (e.g., recklessly riding a scooter in traffic) and, possibly, because they are more familiar with these risky situations, potentially reducing perceived risk and thus increasing risk-taking levels (e.g., Figner & Weber, 2011). Yet, as the current results imply, providing early adolescents with identical risk-taking opportunities as mid-late adolescents in the form of risky decision-making tasks, their more pronounced imbalance might lead to greater risk-taking than in mid-late adolescents. Thus, once again these results support a more integrative developmental neuroecological model of risk-taking.

Meta-Analysis 3: Adolescents Versus Adults Risk Taking

Consistent with Imbalance models, the results of the fourth and final meta-analysis demonstrated that adolescents engage in more risk-taking than adults, which is also consistent with real-world statistics of age differences in risk-taking. Whereas the overall moderational model for moderators derived from neurodevelopmental imbalance models was significant, the only imbalance model moderator that approached significance was immediate outcome feedback on rewards and losses (the other imbalance model related moderators that were tested simultaneously were clearly not significant, with *p* values greater than .10). Indeed, when immediate outcome feedback was tested in a univiarate model, this moderator fully reached significance. This (trend) effect of immediate outcome feedback on rewards and losses perhaps supports neurodevelopmental imbalance models, as moderation by immediate outcome feedback was observed: Adolescents engaged in more risk-taking than adults on tasks with immediate outcome feedback but not on tasks with delayed outcome feedback, consistent with the notion that the presence of outcome feedback (perhaps particularly on rewards) might trigger the hyperactivation of the ventral striatum especially in adolescence, possibly resulting in heightened risk-taking behavior (Albert & Steinberg, 2011; Somerville et al., 2010; but see Bjork et al., 2004, 2010; Paulsen et al., 2012). However, again it is important to note that outcome feedback in these tasks was not always positive. Thus, it is unclear whether the observed effects are due mainly to the experience of positive outcomes (monetary gains or rewards), negative outcomes (monetary losses or punishments), both, or whether the mere immediacy of the outcome feedback is the crucial characteristic. Hence, risky decision-making tasks are clearly needed that allow direct decomposition of these factors. Of interest, the moderator of immediate versus delayed outcome feedback was not significant in the children versus (early) adolescent models, suggesting that children might be equally sensitive to immediate outcome feedback on rewards and losses. This finding is a challenge for neurodevelopmental imbalance models, as they suggest that adolescents are more sensitive to rewards ultimately leading to heightened risk-taking.

Whereas the availability of a sure option moderated the age differences in the adolescent versus children model, this was not the case in the adolescent versus adult model. This latter finding could perhaps be again explained by fuzzy trace theory. Although fuzzy trace theory predicts that gist decision making (linked to risk-aversion) increases with age (Reyna & Ellis, 1994), unlike the transition from childhood to adolescence, the transition from adolescence to adulthood is not marked by dramatic increases in gist-based decision making (Reyna et al., 2011; Rivers et al., 2008). This could perhaps explain why the moderator sure option was not significant in the adolescents versus adults model. Next, it is also noteworthy that whether or not IQ was controlled for in a given study did not moderate the effect sizes in the adolescents versus adults model, whereas this was the case for the adolescents versus children model. This result might be due to the fact that IQ and, thus, cognitive control begin to stabilize during adolescence (Luna et al., 2004).

Considered together, the results of the adolescent versus adult model partially support neurodevelopmental imbalance models, as adolescents overall take more risks than adults, and moderation analyses further revealed that this is especially the case on tasks that provide immediate outcome feedback on rewards and losses. Note, however, that this last result was only a trend-level effect when tested in a multivariate model and thus should be interpreted with caution. The main result that adolescents take more risks than adults equally supports fuzzy trace theory. Thus, the result showing that adolescents take more risks than adults is in line with both neurodevelopmental imbalance models and fuzzy trace theory.

Strengths, Limitations, and Direction for Future Research

The current meta-analysis (technically, meta-analyses) is the first to study age differences in risk-taking from childhood up until adulthood, with a special focus on adolescence, and as such our results provide new insights that are meaningful for diverse fields (e.g., psychology, psychiatry, health and medical sciences, law, policy making, economy, and the decision sciences). Whereas several more “qualitative” overview and review papers exist (Albert & Steinberg, 2011; Blakemore & Robbins, 2012; Crone & Dahl, 2012; Ernst et al., 2006; Gladwin et al., 2011; Pfeifer & Allen, 2012; Reyna & Farley, 2006; Somerville et al., 2010), showing the strong interest in gaining an overview of the existing studies, to date no formal integration of the existing studies has been published. Crucially, the advanced meta-regression statistical techniques that were employed in the current paper are a strength of this meta-analysis, thus supporting even more trust in the reported findings, compared to qualitative narrative overviews. Further, the rigorous design of the current meta-analysis should be noted, as it included experimental studies employing behavioral measures of risk-taking, unlike the vast majority of self-report studies that have dominated the field of adolescent risk-taking, at least until the last decade or so. However, despite these overarching strengths, there are some limitations that should be considered when interpreting the present results.

Unfortunately, most of the limitations in the current meta-analysis reflect the underdeveloped (but growing) field of experimental investigations of adolescent risk-taking, which only recently have begun capitalizing on more objective behavioral measures of risky decision making. First, although the amount of studies in each age comparison model was clearly sufficiently large to conduct a meta-analysis, the number of studies included in the meta-analysis was relatively small. Thus, besides giving a much needed formal integration and overview of the current state of empirical findings, the current meta-analysis highlights the need for more studies with developmental samples that compare age differences in risk-taking on behavioral risky decision-making tasks. Second, another related issue in the field is the absence of longitudinal studies that span several distinct developmental stages (with the one noted exception Macpherson et al., 2010, spanning at least both childhood and adolescence, though unfortunately not adulthood). As a result, the current meta-analysis included only one longitudinal study. However, longitudinal studies are essential because they can foster a better understanding of age differences than can cross-sectional studies, which are more sensitive to confounding cohort effects or to random sampling differences, particularly when small sample sizes are used.

The third limitation of the current meta-analysis also reflects a major gap in the (adolescent) risk-taking literature; that is, the absence of risky decision-making studies that manipulate peer presence and the lack of risk-taking studies including pubertal maturation. Two central features of imbalance models (especially the developmental social neuroscience model) are the focus on the relationship between peers and perceived rewards in adolescence and that on how pubertal onset might play a significant role in the hypersensitization of reward-related regions in the brain (Dahl, 2004; Nelson et al., 2005; Spear, 2004). Imbalance models predict that adolescents’ hypersensitivity to rewards becomes even stronger when adolescents are among peers, which might, in turn, cause adolescents to pay more attention to the potential rewards of risk-taking behaviors, leading to risk-taking (Chein et al., 2011; Steinberg, 2010). Unfortunately, the current meta-analysis could not include peer presence/awareness as a moderator, as there are only two existing experimental studies on age differences between adolescents and another age group (in both studies adults) that manipulated peer presence. Nevertheless, we briefly report the intriguing results of these two studies below.

The first empirical study to demonstrate the significant effect of peers in a laboratory setting reported that when adolescents performed a risky driving task in the presence of peers (versus on their own), their risky choices increased more strongly in comparison to when adults performed the same task with peers (Gardner & Steinberg, 2005). Likewise, fMRI evidence revealed that risky choices as well as activation in the ventral striatum concurrently and significantly increased when adolescents (compared to adults) completed a risky driving game in the presence of peers versus on their own (Chein et al., 2011). Moreover, recent empirical evidence shows that when adolescents believed that they were being observed by a peer, they experienced heightened self-conscious emotions and activation in socioaffective brain circuits (Somerville et al., 2013).[19]

A notable methodological difference between the “peer presence” paradigms used in Gardner and Steinberg (2005) and Chein et al. (2011) is that, in the former study, peers were in the same room and were allowed to communicate with the participants while they performed the risky driving game, whereas in the latter fMRI study, peers were in a separate room, but the participants were aware that their peers were observing their performance on the risky driving game from a distance. Despite the methodological difference in the abovementioned studies, in both studies, the peer

[19] No comparisons to other age groups were made.

condition induced significantly more risk-taking by adolescents than did the condition wherein participants performed the risky driving game alone and compared to the adults. Beyond the link of heightened reward sensitivity (Albert, Chein, & Steinberg, 2013), imbalance models do not investigate the exact social mechanisms or characteristics of peer interactions that trigger adolescent risk-taking (e.g., do nonsupportive peer reactions still produce heightened adolescent risk-taking?). However, from the above-discussed findings it appears that the mere awareness of peer presence might influence risky decision making in an upward fashion, and that this is especially the case for adolescents but not for adults. The finding that adolescents' risky choice is dependent on peer presence/awareness in the laboratory is also consistent with real-life risk-taking scenarios: Most risk-taking behaviors in adolescents occur when they are among their peers, but this phenomenon generally does not hold true for adults (for an overview, see Steinberg, 2004). Hereby, we thus urge scholars to manipulate social context in their experimental risk-taking paradigms. In addition to investigating possible neurobiological pathways, such as pubertal processes, for potential peer effects, they should examine the actual behavior of peers, as this might prove to be a promising factor for gaining a better understanding of the mechanisms underlying age differences in risk-taking. Moreover, it is recommended that puberty researchers consider more objective measures of puberty (e.g., direct measures of pubertal hormones) instead of the traditional self-report measures.

Next, we address two potential limitations related to how we conceptualized the moderators in the present meta-analysis. First, we tested immediate feedback on potential outcomes as a moderator (which was significant in the adult vs. adolescent model), and, based on imbalance models, we expected that specifically immediate outcome feedback on *rewards* might determine whether or not this moderator would be significant. However, tasks that included immediate feedback on rewards also included immediate feedback on losses. Consequently, given the existing studies, our analysis could not separately test the role of feedback on rewards and on losses. Looking into the original literature, no clear picture emerges: One self-report study showed that benefits (rewards) predict adolescent behaviors more strongly than do costs (Reyna et al., 2011), while another experimental study showed that it was the neglect of explicit loss (not gains/rewards) information that increased risk-taking (Figner et al., 2009). More research is clearly needed to disentangle whether adolescents are more reactive to rewards than to losses and whether they weigh rewards more relative to losses in their decision making. Nonetheless, the current results suggest that immediate feedback on a combination of rewards and losses moderates age differences in risk-taking between adolescents and adults.

Another related issue concerns our incentive compatibility moderator. It is in principle possible that there might be a difference in the subjective utility of task earnings between the different age groups, and that these differences, rather than the objective availability of an incentive (as we investigated), might account for the age differences in risk-taking between age groups. In most studies the average (monetary) incentive that can be earned on a task is not likely to be more than a value of 20 dollars. Although this might be a large value for adolescents and especially for children, adults might regard this as a trivial value. However, even if this were the case, this likely would imply that risk-taking should increase with age, not decrease, as larger stakes typically lead to greater risk aversion (e.g., Kahneman & Tversky, 1979). In any case, if subjective utility was indeed a relevant confounding factor in the current meta-analysis, we would have most likely observed incentive compatibility as a moderating factor, especially in the children versus adolescent model, as children might attach greater value to the (relatively small) rewards that are typically used in research. However, large incentives may have more meaning for adolescents than children, as they have more expenses.

Conclusions

Although adolescents are considered as the stereotypical risk-takers for quite obvious reasons, the current meta-analysis reveals that adolescents do not always engage in more risk-taking than children and adults. These findings lend support to a recent review that concluded that adolescents have a flexible control system that is highly dependent on the motivational salience of the context (Crone & Dahl, 2012). Moreover, the results of the present meta-analyses have demonstrated that the sometimes symbolic imbalance models' characterization of adolescent risk-taking as a neurodevelopmental tug-of-war cannot account for all observed developmental patterns in risky decision making. Particularly, we did not find evidence for an increase in risk-taking from childhood to adolescence, thus challenging the idea that earlier developing or hyperactive affective-motivational bottom-up processes are not being offset by cognitive control systems. Moreover, this null finding also suggests that developmentally increasing reliance on gist-based (vs. verbatim-based) decision making does not tell the full story either, as we then would have expected a decrease in risk-taking from childhood to adolescence. It is also important to note that fuzzy trace theory does not simply reduce to gist-based versus verbatim-based decision making. It is a complex model that makes differing and often complex predictions for different contextual and task-related characteristics.

One likely but more recently perhaps overlooked factor in age differences in risk-taking might be situational; namely, the age-dependent access and general exposure to risky situations, which is similar to the risk opportunity concept as discussed in Gerrard et al. (2008). Hence, we suggest that future models not only should take neurodevelopmental or psychological processes into account but also should consider more strongly situational factors, resulting in what one could call a developmental neuroecological model of risk-taking. Accordingly, we propose that one of the primary reasons adolescents take more risks than children in the real world, but not in experimental studies, is due to the fact that adolescents are faced with many more opportunities to engage in risk-taking behaviors than children are (e.g., children are more closely monitored than adolescents, they have less access to substances such as alcohol and nicotine, they are not allowed to drive a car). When children are confronted with a risk-taking opportunity, their underdeveloped brain regions, which are vital for optimal decision-making skills, could make them equally vulnerable to engage in similar levels of risks as adolescents. This is a tantalizing idea, as it perhaps implies that not only should measures be taken to protect (early) adolescents from tempting but dangerous risk-taking opportunities but that the same (or even more) efforts should be continued to protect children from such situations.

Thus, taken together, considering the current novel findings, it is important to realize that children might not necessarily be less vulnerable than adolescents to engaging in risk-taking behaviors. It is important to note that important nonsituational (e.g., motivational) changes are occurring as well during the transitions from childhood to adolescence, such as increasing novelty and sensation seeking, growing importance of peers, and growing sexual interest and motivation. Nevertheless, given the opportunity to exhibit risk-taking, both the overall suboptimal immaturity of control-related brain regions in children and the disadvantageous imbalance of top-down control processes being too weak to counteract the affective-motivational processes triggered in adolescence might increase not only adolescents' but also children's risk-taking propensity. In other words, although adolescents and children are equally susceptible to engaging in similar levels of risk-taking, the processes leading up to this behavior might be different. Furthermore, there might be an interplay between these neurodevelopmental processes and ecological factors, making a hybrid developmental neuroecological model of risk-taking convincing.

As for the finding of early adolescents engaging in more risk-taking than mid-late adolescents, in addition to neurodevelopmental changes that distinguish early adolescents from mid-late adolescents, differing opportunities might also explain why risk-taking is more prevalent among late adolescents than early adolescents in the real world, whereas, in the current meta-analysis (where opportunity was equal for all participants), an opposite pattern emerged. In the real world, early adolescents clearly have less freedom in creating their environments (e.g., as a result of more parental monitoring) and therefore might encounter fewer tempting risk-taking opportunities than do their late adolescent counterparts; after all, it is opportunity that makes a thief, not just, but perhaps particularly so, during adolescence.

The obvious importance of opportunity in age differences in risk-taking highlights that the challenge for future research is to create a risk-taking paradigm in which risk-taking opportunity can be manipulated in an ecologically valid and meaningful manner. One step in this direction is to make a sure/certain option always available in risky decision-making tasks. That way, participants also have the option of choosing to turn down the risk-taking opportunity. As our results show, although in general adolescents and children take equal levels of risks, the mere availability of a sure win option resulted in adolescents actually taking fewer risks than children. Thus, crucially, the current results demonstrate that the availability of a risk-taking possibility versus a safe possibility is influential in determining whether age differences are found. Taken together, risk-taking paradigms that also incorporate sure options could be considered a more reliable way of testing someone's true risk preference, as in the real world there is typically always a safe (i.e., sure) option. New theories on age differences in risk-taking are also likely to benefit from incorporating such situational and opportunity factors.

As for the adolescent versus adult model, although our results showed that adolescents generally engage in more risk-taking than adults, this appears to be the case, particularly when immediate outcome feedback is available. This finding implies that when adolescents are presented with immediate consequences of their actions, this can increase risk-taking. At least theoretically, both positive and negative outcomes may increase risk-taking (the former via reinforcement of risk-taking behavior, the latter via the so-called break-even effect; Thaler & Johnson, 1990). These thought-provoking findings might further imply that prevention and intervention programs that target risk-taking could perhaps suggest that when adolescents do engage in nonrisky behaviors they should also immediately be acknowledged for that, perhaps in the form of compliments or other reinforcements (e.g., gifts). As mentioned earlier, readers should keep in mind though that although the overall multivariate moderational test was significant, the immediate versus delayed outcome feedback moderator was only marginally significant when tested in a multivariate model, although it did fully reach significance when tested in a univariate model.

Collectively, the current four independent but related meta-analyses raise some interesting questions. At the same time, the current results reveal that the reasons why in the real-world adolescents take more risks than children, on one the hand, and why adolescents take more risks than adults, on the other hand, might not solely be a product of neurodevelopmental changes in the adolescent brain or reliance on different reasoning modes. Thus, although neurodevelopmental imbalance models and fuzzy trace theory can contribute to explaining half of the puzzle (why adolescents take more risks than adults in the real world), perhaps a situational theory is necessary to help explain the other half of the puzzle (why adolescents take more risks than children in the real world). Hence, our advocacy of a more integrative developmental neuroecological model of risk-taking. As emphasized in the beginning of the current meta-analysis, heightened risky decision making in adolescence is a serious problem, as its negative consequences (e.g., depression; Defoe, Farrington, & Loeber, 2013) account for a dramatic increase in mortality rates (e.g., as a result of suicidality) in adolescence (Dahl, 2004). Rigorous experimental studies to identify task and contextual characteristics that contribute to heightened adolescent risk-taking could improve our understanding of when and under which circumstances adolescents are more or less inclined to take dangerous risks in the real world. The current meta-analysis provides a promising starting point in this direction.

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