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The development of risk-taking: A multi-perspective review

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Abstract

The current paper reviews four research perspectives that have been used to investigate the development of risk-taking. Cognitive developmental research has investigated the development of decision-making capacities that potentially underlie risk-taking development, including sensitivity to risk, probability estimation, and perceptions of vulnerability. Emotional development research has found that affective decision-making and emotional regulation skills improve with development through adolescence. Psychobiological research has analyzed the cognitive and affective neurological and biochemical bases of risk-taking, and their development. Social developmental research has explored the effects of parent–child relationship quality, parenting strategies, and peer influences on the emergence of risk-taking tendencies. Although they have remained largely independent, it is argued throughout that factors within each of these perspectives interact to influence the probability that an individual will engage in risky activities, which should be the topic of future research.

Keywords: Risk-taking; Development; Cross-perspective review; Decision-making; Emotional regulation; Psychobiology; Socialization

Introduction

Risk-taking is defined in the developmental literature as engagement in behaviors that are associated with some probability of undesirable results (Beyth-Marom & Fischhoff, 1997; Beyth-Marom, Austin, Fischhoff, Palmgren, & Quadrel, 1993; Byrnes, 1998; Furby & Beyth-Marom, 1992; Irwin, 1993). Many argue that being able to interpret potentially risky

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situations, and the ability to avoid excessive risks, are among the most important skills one develops (Byrnes, 1998; Garon & Moore, 2004; Halpern-Felsher & Cauffman, 2001; Mann, Harmoni, & Power, 1989; Steinberg & Scott, 2003). It is also recognized from a variety of non-empirical perspectives (e.g., federal policy making and naïve parenting) that child and adolescent risk-taking have the potential for significant consequences. Reciprocally, child and adolescent risk-taking research has been implicated in debates of adolescent rights, health care, and criminal culpability (Cauffman & Steinberg, 2000a, 2000b; Fried & Reppucci, 2001; Irwin, Igra, Eyre, & Millstein, 1997; Ozer, MacDonald, & Irwin, 2002; Steinberg & Scott, 2003; Wilcox, 1993).

Given the generality of the definition adopted above, a relatively wide range of behaviors qualifies as risky. Frequently, prototypical, and highly undesirable "real-world" risks, such as alcohol consumption, tobacco use, unsafe sexual activity, dangerous driving, interpersonal aggression, and even more severe delinquent and criminal behaviors are the major foci of researchers interested in the development of risk-taking. It is largely acknowledged that many of these types of risk-taking behaviors emerge, increase, and eventually peak in adolescence (i.e., between 12- and 18-years-of-age; Arnett, 1992, 1999; Donovan & Jessor, 1985; Donovan, Jessor, & Costa, 1988; Gottfredson & Hirschi, 1990; Gullone, Moore, Moss, & Boyd, 2000; Irwin, 1993; Jessor, 1991; Laird, Pettit, Bates, & Dodge, 2003a; Moffitt, 1993; Proimos, DuRant, Pierce, & Goodman, 1998; Rai et al., 2003). For instance, recent national data collection efforts (in the US) have revealed that approximately 28% of sixth-, 43% of seventh-, 54% of eighth-, 65% of ninth-, 76% of tenth-, 79% of eleventh-, and 83% of twelfth-graders (which roughly corresponds with 12-, 13-, 14-, 15-, 16-, 17-, and 18-years), have experimented with alcohol (Centers for Disease Control & Prevention, 2004, 2005), and 20, 27, 32, and 37%, of ninth-, tenth-, eleventh-, and twelfth-graders reported episodic heavy drinking, respectively (i.e., more than five alcoholic drinks in at least one of the preceding 30 days; CDC, 2004). Similarly, approximately 52% of ninth-, 58% of tenth-, 60% of eleventh, and 65% of twelfth-graders have tried cigarette smoking, and 17, 22, 24, and 26 reported that they had recently smoked cigarettes (i.e., one or more cigarettes in the preceding 30 days; CDC, 2004). The fact that more and more adolescents are engaging in these behaviors with each subsequent year suggests development. Furthermore, that these rates of behaviors, which are largely acknowledged as threats to adolescent health, are so high is perhaps the strongest support for the argument that it is imperative that we understand the factors that underlie their development.

Although many have studied the development of risk-taking through analyses of actual risk-taking rates (i.e., using either interview or questionnaire methodologies), many others have adopted the alternative research strategy of assessing performance on more artificial, laboratory based risk-taking tasks. The major goal in this attempt has been to provide analogues to the risks children and adolescents actually engage in, while controlling extraneous variables and assessing the effects of key variables of interest. Certainly actual risks and controlled experimental risks differ, and furthermore, the strengths (e.g., ecological validity and systematic control, for self-report and experimental research, respectively) and weaknesses (e.g., response biases and generalizability, for self-report and experimental research, respectively) of each methodology must be noted. The primary goal of the current paper, however, is to provide a broad account of what is understood of the development of risk-taking, and because both "real-world" and experimental research have informed our understanding, evidence gathered with both methods will be reviewed.

Methodologies aside, the emergence of risk-taking has been examined from a number of theoretical perspectives. Some have focused on the mental processes that underlie risk perception and interpretation, and have considered the possibility that risk-taking during childhood and adolescence is the by-product of cognitive deficit. Some have analyzed the affective characteristics of decisions, as well as the possibility that emotional volatility might predispose younger populations for greater risk engagement. Others have concentrated on the physiological changes (e.g., neural developments and hormonal changes) that unfold with maturation and correlate with risky behaviors. Finally, others have examined the social antecedents of risk-taking, and the interpersonal influence other individuals have on children and adolescents. One issue to note, "risk-taking" behaviors, as they are currently labeled, have been referred to with a variety of other labels (e.g., externalizing behaviors, antisocial behaviors, problem behaviors, delinquency, and normbreaking), even though the end-all goal is understanding of the exact same constellation of behaviors (e.g., alcohol consumption, cigarette smoking, drug use, sexual behaviors, dangerous driving, interpersonal peer aggression, school misconduct, theft, lying, gambling, and criminal acts). This labeling variability is, for the most part, a by-product of the fractures that lie between research perspectives; however, because they describe the same behaviors, the term risk-taking will, from here onward, be applied across perspectives.

Unfortunately, very few theorists have integrated findings and ideas from each of these research perspectives. Jessor and colleagues' Problem Behavior Theory (PBT) is a noteworthy exception to this tendency, that includes components that span developmental research areas, and might be applied to more general risk-taking behaviors (Donovan & Jessor, 1985; Donovan et al., 1988; Jessor & Jessor, 1977; Jessor, 1993, 1991; Jessor, Turbin, & Costa, 1998). According to PBT, adolescent problem behaviors are developmentally anteceded by social structural variables (e.g., parents' education, occupation, religion, ideology, family structure, home climate, and peer and media involvement). These social factors interact and spawn a personality system, which is composed of motivational, belief, and self-control factors, and a perceived-environment system, which is composed of perceptions of parental support, peer support, and parent–peer interactions. These systems are, in turn, conceptualized as risk factors and protective factors for problematic and potentially risky behaviors (Jessor, 1993, 1991). A major developmental assumption of PBT is that risky behaviors increase during adolescence because their engagement is considered a marker for adolescent independence. In this sense, social structural factors not only produce the systems that will determine problem behavior engagement, but also are the trigger for its onset. Another assumption is that, due to rigidity of the proposed systems, certain adolescents will exhibit problem-behavior syndrome, and will regularly engage in unsafe acts (Donovan & Jessor, 1985; Donovan et al., 1988; Jessor & Jessor, 1977). Problem behavior theory, however, is limited by the fact that it rests largely upon social developmental assumptions, and in this sense tends to disregard the role of cognitive and affective decision-making capacities, which, as will be reviewed below, have been major foci of recent risk-taking development research efforts.

Dodge and Pettit's (2003) Biopsychosocial Model of chronic conduct problems also provides an extremely admirable integration of cross-perspective research that is centrally relevant to a discussion of the development of risk-taking. This model proposes that biological risk factors (e.g., gender, a terratogenic prenatal environment, and a predisposition for a difficult temperamental style) and socio-cultural risk factors (e.g., socioeconomic status, parental disciplinary harshness, peer rejection, and institutional influences) underpin cognitive and emotional processes (e.g., knowledge structures, self- and other- representations, and social-information-processing patterns), which determine the probability with which an individual will develop chronic behavioral disorder and hyperaggressive tendencies. Thus, following the model, those who are most likely to experience aggression-provoking situations (i.e., children of aggressive parents, who are rejected by peers) are the least prepared to handle them (i.e., previous experience and biology have shaped impetuous cognitive and affective processes). Although the model's coverage is extensive, it relies primarily upon specification of individual difference factors associated with chronic behavioral disorder. In this regard, although the model specifies numerous features that are relevant to developing children, it has difficulties explaining the developmental trajectory of risk-taking (i.e., why risk-taking emerges, increases, and peaks in adolescence). This set of specified features, however, is potentially causally prognostic for risk-taking likelihood, and therefore, may be ideal for the derivation of preventative intervention strategies (i.e., treatments implemented in childhood to decrease the likelihood of later risk-taking). Furthermore, this issue might be attributed to the fact that the model was explicitly intended to address individuals with extreme and chronic behavioral problems, who make up a relatively small portion of the population (i.e., 6% of developing individuals by the authors' estimation). This base-rate of affliction is markedly inconsistent with above mentioned prevalence estimates of many prototypical risk-taking behaviors, and this difference in scope might account for this inapplicability to risk-taking as a realistically normative developmental phenomenon. Finally, although it implicates social, biological, cognitive, and emotional factors, like Jessor and colleagues' problem behavior theory, the model largely disregards the substantial and growing cognitive- and affective-developmental risk-taking and decision-making literature (although its authors overtly make claims, in line with the Crick & Dodge, 1994; model of social-information-processing, which run parallel to those made in these literatures).

Excluding these noteworthy exceptions, to date there has been minimal cross-perspective integration of developmental studies and theories, and as noted, even with these distinguished models, researchers operating under each developmental perspective primarily neglect findings made under each other perspective. This is not to say that the research conducted within each perspective is exclusive of that conducted within other perspectives; on the contrary, the primary argument of the current paper are that all who are interested in the development of risk-taking could benefit from the findings generated across perspectives, and furthermore, that the component processes within each perspective interact to influence the development of risk-taking. As will be demonstrated, evidence gathered with each perspective is quite convincing, and therefore, the most descriptive and accurate explanation for the development of risk-taking will almost necessarily assume elements of each. Hence, the primary goal of the current paper is to present an extensive review of findings made across perspectives, thus providing a foundation for future cross-perspective integration efforts.

Cognitive development and risk-taking

Traditionally, cognitive developmental research has been conducted with an assumption that children and adolescents are less cognitively proficient than adults. For instance, studies have demonstrated that with age come more sophisticated cognitive representational capacities (Mandler, 1998) improved reasoning skills (DeLoache, Miller, & Pierroutsakos, 1998), more efficient strategies (Siegler, 1996), greater processing speed

(Kail & Salthouse, 1994), superior memory strategies (Ornstein, Haden, & Hedrick, 2004; Schneider & Bjorklund, 1998), and superior metacognitive skills (Flavell, 1999; Flavell & Miller, 1998; Kuhn, Garcia-Mila, Zohar, & Andersen, 1995). Each of these cognitive developments likely influences the probability that an individual will engage in a risky behavior; however, cognitive developmental researchers interested in risk-taking have recently shifted focus towards the development of decision-making skills (Byrnes, 1998; Beyth-Marom & Fischhoff, 1997; Furby & Beyth-Marom, 1992; Jacobs & Klaczynski, 2002; Klaczynski, Byrnes, & Jacobs, 2001; Mann et al., 1989; Tinsley, Holtgrave, Reise, Erdley, & Cupp, 1995). The bases for this approach are largely rooted in behavioral decision research, which, throughout the history of psychological investigation, has been perhaps the most eminent approach to studying risk-taking. As such, a very brief review of adult judgment and decision-making research, as it relates to risk-taking, is in order (for a more extensive review see Baron, 2000; or Mellers, Schwartz, & Cooke, 1998).

Classic judgment and decision-making

Those adopting a cognitive framework traditionally assume that decision-making situations involve estimation of the probable costs and benefits of a given behavior. Locke, Pascal, and other 17th century philosophers are oftentimes credited as the first proponents of such probabilistic theories of choice (Gigerenzer & Selten, 2001; Lopes, 1993, 1994). These early approaches proposed that risks (quite literally monetary gambles) can be modeled as the summed products of probabilities of success and monetary prize outcome values. In a landmark analysis, Bernoulli (1798/1954) suggested that the *utility* of a gamble, which differs from more universally defined financial *value* in the sense that it is relative to current assets, might be used to summarize the gains that one might hope to achieve through risk. Although the specific technical details are beyond the scope of the current discussion, Bernoulli (1798/1954) elegantly demonstrated that utility could be formally mathematically represented. These ideas were incorporated into psychological theory in the midst of the 20th century, when von Neumann and Morgenstern (1944); Savage (1954); and Luce and Raiffa (1957), presented axiomatic theories of expected utility. Generally, the axiom approach stipulated that in order to maximize expected utility people must abide by certain axioms of behavior (e.g., transitivity of preferences, reduction of compound gambles to parts, substitutability, monotonicity of preference, and independence of probabilities and outcomes). Theoretically, individuals who abide by these axioms maximize utility and behave rationally.

A number of subsequent experiments, however, demonstrated that typical human behavior is not entirely consistent with the proposed axioms of rationality (Kahneman & Tversky, 1972, 1973; MacCrimmon & Larsson, 1979; Tversky & Kahneman, 1974; Tversky & Russo, 1969). For instance, Tversky (1969) and Tversky et al. (1990), demonstrated that people do not always abide by the axiom of transitivity (although a person judges $A > B$, and $B > C$, they sometimes violate transitivity and judge $C > A$). Others demonstrated that people are sometimes inconsistent in their choices, and for example, are willing to pay more to play a less preferred gamble (Lichtenstein & Slovic, 1971). Central to the current issue of risk-taking, a number of major works found that participants are inconsistent in their choices, dependent upon how the risks associated with a choice are framed (Allais, 1953; Kahneman & Tversky, 1984; Tversky & Kahneman, 1981). That is, given identical probability and value structures, but variable problem wording, people tend to prefer a certain option when a choice is presented in terms of its potential gains, and prefer a risky option when a choice is presented in terms of its potential losses. In the traditional example, Tversky and Kahneman (1986, 1981) presented participants with choices between flu vaccination strategies. When given a gain-framed choice between vaccines, one of which would save a given number of people with certainty (e.g., 200 people), and a riskier option that would save an equivalent expected value (e.g., 600 people 1/3 of the time), research participants tended to prefer the former, safer option. If, however, participants were given a loss-framed choice between vaccines, one of which would lead to the certain death of a number of people (e.g., 400 people), and a riskier option that would lead to the death of an equivalent expected value (e.g., 600 people 2/3 of the time), they tended to prefer the latter, riskier option. This preference reversal arises despite objective quantitative equivalence between the gain- and loss-framed risks.

Several contemporary cognitive decision-making theories have been devised in light of these findings. Kahneman and Tversky proposed prospect theory (1979; Tversky and Kahneman 1992), which assumes that preference in risky situations is largely dependent upon perceptual and attention capacities during editing and evaluating phases of the decision-making process. Formally speaking, the theory describes a weighted utility function that is a remarkably good fit with the previously problematic data mentioned above. Others provide alternative accounts. Luce and colleagues, for example, explain experimental risk-taking findings with a rank- and sign-dependent reinterpretation of axiomatic utility theory, which also assumes weighted outcome utilities (Luce, 1991; Luce & Fishburn, 1991, 1995). Lopes and colleagues (Lopes, 1993, 1996; Lopes and Oden, 1999) propose security-potential/aspiration theory, which assumes that people adjust their attention to the best and worst potential outcomes of a risk as a function of the probability of success. Finally, a number of scholars have proposed that humans are dual-processors. In this sense, people are capable of controlled, analytic, rational processes, but oftentimes rely on more automatic, intuitive, heuristic processes (Brainerd & Reyna, 1990; Epstein, 1998; Evans, 1984; Evans, Venn, & Feeney, 2002; Kirkpatrick & Epstein, 1992; Metcalfe & Mischel, 1999; Reyna, 2004; Sloman, 1996; Stanovich, 2004). This argument extends to risk-taking in that unwise risks might be attributable to the latter, more automatic system. Each of these behavioral decision accounts provides a formalized description of decision-making in risk situations; however, with the lone exception of Brainerd and Reyna's fuzzy-trace theory (e.g., Brainerd & Reyna, 1990; Reyna, 2004), none makes direct developmental predictions, and moreover, each has only been implicated in developmental work minimally (again, with the possible exception of fuzzy-trace theory and other dual-process approaches, as will be discussed). In what follows, research that has analyzed child and adolescent performance on experimental risk-taking tasks, including studies that examine risk framing effects, and investigations of adolescent risk-perception, will be reviewed.

Experimental risk-taking

In perhaps the first study of cognitive risk-taking involving children, Slovic (1966) presented 6- to 16-year-old participants with a series of risky choices. This study has the advantage of a relatively large sample ($N = 1{,}047$, which, of course, is relatively huge for an experimental study); however, as the author notes, the sampling technique is susceptible to the criticism of subject self-selection biases (because participants were volunteers at a public fair, more courageous, less risk-averse individuals may have been over represented). These participants were shown a row of 10 switches, nine of which were "safe," one of which was a risky "disaster" switch (meaning there is an initial .9 probability of success, and .1 probability of failure), and were instructed to pull as many and whichever switches they liked. Pulling a safe switch resulted in a prize, but pulling the disaster switch resulted in a loss of all prizes. Probabilistically, the most adaptive strategy in this task is to pull five of the switches (i.e., expected value = 2.5), pulling fewer is relatively risk-averse, and pulling more is relatively risky. Although few participants elected to cease flipping switches prior to this point of maximum expected value, most elected to stop and collect their prize after reaching this point, which suggests relative appreciation of risk. Furthermore, although the independent effects of age were not reported, the results suggested an age × gender interaction; that is, boys, and particularly older boys, tended to be less risk-averse (i.e., they were less likely to voluntarily cease pulling switches). This might be taken to suggest that there is something of a cognitive basis to the development of risk-taking; recall, prototypical risk-taking is presumed to emerge and increase in adolescence, which this trend matches relatively well.

One very recent study, Hoffrage, Weber, Hertwig, and Chase (2003), used Slovic's classic methodology to differentiate individual difference categories, and classify five- and six-year-olds as risk-seeking or risk-averse. This study is an ingenious rarity, in that the researchers used this relatively artificial risk-taking task (i.e., Slovic's task) to predict safely controlled, but naturalistically observed risk-taking (i.e., participants' street crossing behaviors while wearing a harness that prevented them from wandering into oncoming traffic). The study found that risk-takers (i.e., participants who flipped a high number of switches in the risk-taking task) were more likely to engage in an actual risky behavior than risk-avoiders (i.e., risk-takers were more likely to attempt to cross a street when doing so was not safe). One drawback of the study is that it is not actually developmental, but rather, focuses entirely on individual differences in five- and six-year-olds; therefore, the results cannot inform estimation of developmental trajectory, but rather, is limited to the conclusion that there is variability in risk-taking by five- or six-years. Another contemporary experimental task, Lejuez and colleagues Balloon Analogue Risk Task (BART; Lejuez et al., 2002; Lejuez et al., 2003a, Lejuez, Aklin, Zvolensky, & Pedulla, 2003b), also makes use of a very similar structure as Slovic's risk task (i.e., participants must choose whether or not to proceed through a series of events in which they accumulate prizes, but with some probability of disaster). Studies conducted with the BART have revealed correlations between task performance and prototypical real-world risk behaviors in adolescent and adult samples (e.g., cigarette smoking, alcohol consumption, and interpersonal aggression). These BART studies, however, are limited for current purposes, simply because cognitive development, and its impending effects on the risk-taking, have not been the primary concerns of the authors. Thus, Hoffrage and colleagues (2003) and Lejuez and colleagues (2002, 2003a, 2003b) provide a degree of validation for the structure of Slovic's classic methodology with contemporary populations, identify individual differences categories, and relate experimental risk-taking with real-world risk-taking behavior.

A number of other studies have analyzed an even more specific variety of cognitive risk-taking; namely, preferences for variably framed gambles. Reyna and Ellis (1994), for instance, presented participants (preschoolers, second-graders, and fifth-graders) with a choice between a gamble and a sure thing, framed either in terms of gains or losses. In the gain-framed condition, children were asked to choose between automatically winning a small prize (a sure thing, probability = 1.0), and a gamble that involved the prize's expected value (i.e., a larger prize, with probability = .5, .67, or .75, as determined by the colored portions of a spinner gamble). In the loss-framed condition, children were asked to choose between automatically losing a small prize, and losing its riskier expected value (i.e., a larger prize, with lesser probability). Across frames, participants preferred risk over certainty; however, unlike older children and adults, younger children tended to make choices relatively uniformly across frames, and in this sense, exhibited less susceptibility to framing effects. In line with fuzzy-trace theory (as will be discussed below), Reyna and Ellis (1994) propose that this transition may be representative of development from greater relative verbatim cognition towards increased reliance on intuitive gist-like processing.

Using slightly simpler gambles (i.e., the risk free option = gain/loss of one prize, the risky option = gain/loss of two prizes with .5 probability), and a slightly different gamble mechanism (i.e., the gamble involved drawing prizes, rather than spinning for prizes), Levin and Hart (2003) found that five- and six-year-olds are susceptible to reflection effects, in that they are more likely to choose a probabilistic over a certain option when the situation involves losses than when the situation involves gains (see Fagley, 1993; for a concise description of the defining features of reflection vs. framing effects). Reyna (1996) reported similar findings with preschoolers, second-graders, and fifth-graders. Consistent with Reyna and Ellis (1994), however, Levin and Hart (2003) and Reyna (1996), as well as Harbaugh, Krause, and Vesterlund (2001), found that younger children have greater preference for risky over certain alternatives, independent of how the risks are stated, than older children and adults, which suggests, in the very least, a developmental difference in risk interpretation. Moving upward in development, Chien, Lin, and Worthley (1996) found, using quite a literal adaptation of Tversky and Kahneman's (1981) flu vaccination problem, that adolescents shift preference as a function of problem wording, and therefore are quite susceptible to framing effects. Like adults, adolescents tended to prefer a riskier option when choices were presented with loss frames, and preferred less risky options when choices were presented with gain frames. This line of research is important in that it emphasizes the role of the environment on risk-taking; that is, if problem frame can be generalized as representative of environmental variability, and it influences risk preference, the implicit suggestion is that risk-taking, at least from a purely cognitive standpoint, may be the product of a contextual–developmental interaction. In any case, these studies collectively suggest that younger and older children perceive risk slightly differently, that children tend to prefer risk to certainty, and that by adolescence there is a tendency, as found in the adult literature, to alter preference as a function of the frame with which risks are presented.

Recall from above that classic behavioral decision theory assumes that risks, and choices more generally, are composed of potential outcome probabilities and values. Another cognitive developmental research strategy, which builds directly upon this general assumption, has been to ask, do children and adolescents understand that risky behaviors are associated with some probability of undesirable consequence? There is actually a notable historical debate in the developmental literature regarding when children understand probability, as considered independent of risk-taking (Brainerd, 1981; Kuzmak & Gelman, 1986; Piaget & Inhelder, 1951/1975; Reyna & Brainerd, 1994; Schlottmann, 2001). Piaget and Inhelder (1951/1975) proposed that children do not understand probability, and typically cannot make predictions based upon probabilistic information, until they are capable of formal operational thought, around 12-years. Early empirical tests, using methods similar to those used in cognitive decision-making research (both question the participant as to which of several gamble outcomes are more probable), found support for this theory

(Hoemann & Ross, 1971; Kreitler & Kreitler, 1986; Piaget & Inhelder, 1951/1975). Those adopting a more intensive information processing perspective, however, despite claiming a fairly similar developmental time-frame, criticized the Piagetian perspective as underspecified, and attributed child probability failures to more formally described deficits in working memory and cognitive strategies (Brainerd, 1981; Falk & Wilkening, 1998). More recent studies, on the other hand, have argued that children are able to use probability information to a greater degree than earlier theorists' tasks revealed. Using modified empirical tests, contemporary researchers have demonstrated that even four- to seven-year-olds can differentiate random from certain outcomes, and to some extent, can make intuitive predictions based on odds ratios and expected values (Acredolo, O'Connor, Banks, & Horobin, 1989; Kuzmak & Gelman, 1986; Schlottmann, 2001). These contemporary findings are dependent upon an updated theoretical perspective, which places greater emphasis on intuitive, less-computationally based, cognitive processes; however, they have notable implications for the development of risk-taking behaviors. If it is assumed that an understanding of consequence probability is a basis for avoiding risk (as behavioral decision theories assume), and in some senses that children are able to use probability to make predictions, then this line of research suggests that young children may have at least some appreciation of risk. This, however, represents only very early and basic cognitive abilities.

Building upon the underlying relationship between probability and risk-taking Byrnes and colleagues' have developed an experimental decision-making task, referred to as "the decision game," which has introduced several interesting findings (Byrnes & McClenney, 1994; Byrnes, Miller, & Reynolds, 1999). In the decision game, participants are presented with a simple game board (similar to a traditional board game, as that used in Monopoly or Trivia Pursuit) that has a base area, connected by paths to three intermediate card areas, which are connected to a goal area. At the intermediate areas participants are required to flip a card, revealing a trivia question or a "go back to base" command. The probability of success on each path was systematically varied through manipulation of question difficulty and rate of the "go back to base" command (i.e., one path had relatively more easy questions, making it relatively risk free, another more difficult questions, giving it moderate risk, and the third more "go back to base" commands, making it very risky). Given this design, the real decision, the risk, is which path to choose in pursuit of the goal area. One potential criticism of the design, however, is that probability is not stringently controlled, but rather, is confounded with knowledge (i.e., choosing the difficult path entails no more risk than the easy path if one is able to answer all of the questions from each path). Byrnes and McClenney (1994) found that adolescents and adults use similar strategies in evaluating the path options; however, adults made consistently better choices and were more optimistic in their abilities to succeed through risk (i.e., adults assumed greater confidence at reaching the goal area by answering difficult questions). Byrnes et al. (1999) extended these findings by giving the participants more feedback about each path and the questions that would be asked. Results showed that adolescents do not incorporate decision outcome feedback into their decisions to the extent that adults do. As such, the authors suggest that development of self-regulated cognitive sensitivity to probabilistic outcomes between adolescence and adulthood may impinge upon risk-taking.

Adolescent risk perception

Other researchers have assumed a more applied cognitive developmental perspective, some of whom have argued that children and adolescents analyze risk-taking situations in less than optimal ways. One proposal that adopts this general line of thought, which is principally based on widely read classic theoretical work (Elkind, 1967, 1985), is that adolescents are cognitively egocentric, and therefore have misconceptions of personal invulnerability to undesirable risk outcomes (Arnett, 1990, 1992, 1995; Vartanian, 2000). Current research in support of this view is somewhat limited. Baron, Granato, Spranca, and Teubal (1993) found that seven- through fifteen-year-olds asked to evaluate judgment dilemmas tend not to incorporate precedent, probability, or frequency information into their decision-making processes. The conclusions that can be drawn from this work for current purposes are, however, somewhat limited because its scope was quite narrow (i.e., the study involved single item self reports of several aspects of decision-making), and meaningful comparative analyses were omitted (i.e., the results were largely anecdotal, and what analyses were conducted were only marginally informative). Continuing, Halpern-Felsher and Cauffman (2001) found that adolescents, compared to young adults (early-to-mid twenties), lack the cognitive skills necessary for decision alternative generation and consequence likelihood estimation. This study too is plagued by a noteworthy problem; namely, the risks in question were quite adult-centric (e.g., participants were asked to estimate the risks of a cosmetic medical procedure and granting informed consent). Although even the young adults in the sample may not have much previous experience in these domains, these particular risks may have predisposed superior adult response simply because contemporary social policy prevents adolescents from making these types of decisions, and hence, precludes all previous experience in the domain.

Conversely, a number of contemporary studies have found that adolescents are able to evaluate potentially risky decision options, or in the very least are quite comparable to adults in terms of estimating the likelihood of risk outcomes. Beyth-Marom and colleagues (1993) and Quadrel and colleagues (1993) asked adolescents and adults (sixth- through eleventh-graders and their parents) to estimate the possible consequences of a number of risky behaviors (e.g., alcohol use, drinking and driving, marijuana use, skipping school, unsafe sexual behaviors), the probabilities associated with those consequences, and their own personal vulnerability to negative consequences. Both studies reported that adolescents and adults generated comparable numbers and types of consequences, and furthermore, both adolescents and adults rated themselves as similarly vulnerable to possible negative outcomes (although both populations tended to rate themselves as slightly less vulnerable than other individuals). Taking an individual difference perspective, Benthin, Slovic, and Severson (1993) found that adolescent risk participants perceive risky behaviors as potentially less risky and potentially more beneficial than do non-participants. This study is limited by a relatively small sample size (i.e., $N = 41$), but has the benefit of analyzing a relatively wide range of risk-taking behaviors (i.e., 30 problematic risks, such as alcohol use, drug use, having sex, and more commonplace risks, such as mountain climbing, downhill skiing, and listening to loud music). Even more powerfully, and with a more substantial sample (i.e., $N = 577$), Millstein and Halpern-Felsher (2002) found an *inverse* relationship between age (from earlier adolescence to young adulthood) and notions of invulnerability. Specifically, the study demonstrated that adolescents, in comparison to young adults (in their mid-twenties), have a tendency to vastly *overestimate* their personal vulnerability to the negative consequences of risks (e.g., drinking alcohol, smoking cigarettes, and having sex). In contrast to those reviewed in the preceding paragraph, these studies collectively demonstrate that when presented with risks they may realistically face, and possibly have experience with (i.e., alcohol use, smoking, drug use, sexual behaviors, and academic risks), adolescents evaluate risks similarly to adults, do not view themselves as invulnerable to risk outcomes, and if anything, may overestimate their personal vulnerability. At present, perhaps the most valid conclusion to draw from these studies is that there *may* be cognitive development in the adolescent years, which *may* contribute to adolescent decision-making skills and risk-taking behavior; however, in some regards adolescents are quite similar to adults, and it seems that adolescent risk-taking cannot be attributed to an inability to estimate consequence probability or an attitude of excessive invulnerability.

A cognitive development—Risk-taking paradox

As reviewed, the relationship between traditional cognitive developmental assumptions and risk-taking is somewhat paradoxical. First, traditional developmental theory presupposes that with age cognitive development proceeds from lesser to greater sophistication, and that increased cognitive skill should decrease the likelihood of participation in risks, which are regarded as maladaptive, to say the least. Second, prevalence data suggest that the frequency of risk-taking behaviors increases with development from childhood into adolescence. These statements are obviously incompatible, in the sense that cognitive developments between childhood and adolescence should produce reductions in risk-taking. That adolescents are believed to take more risks than adults, but have relatively similar cognitive decision-making capacities (i.e., at least in terms of outcome probability estimation), is similarly perplexing. The problem is that *all else being equal*, the increase in cognitive sophistication that is assumed to come with the transition from childhood to adolescence *should* lead towards a decrease in risk-taking tendencies, and similarly, the decrease in risk-taking between adolescence and adulthood *should* concur with an increase in cognitive function.

One noteworthy position addresses these prevalence-cognition issues by building upon the assumptions of the aforementioned dual-processes theories and challenging the traditional cognitive developmental assumption that development *necessarily* proceeds from lesser to greater capacities. Recall, proponents dual-process approaches suppose that cognition involves two processing systems, one of which is automatic, heuristic, and reflexive, the other of which is explicit, logical, and computational (Epstein, 1998; Evans, 1984; Evans et al., 2002; Kirkpatrick & Epstein, 1992; Sloman, 1996; Stanovich, 2004). Generally, whereas the first system is conceptualized as very fast, the second system is conceptualized as slow and more meticulous. Extending this approach to development, some have proposed that in addition to improvements in logical and computational proficiency, development involves more efficient use of automatic cognitive heuristics and fuzzy, intuitive, gist-like representations (Jacobs & Klaczynski, 2002; Klaczynski, 2001; Reyna, 1996; Reyna & Ellis, 1994). More frequent and proficient use of these heuristics with development is assumed to increase overall cognitive efficiency, but is also associated with more frequent cognitive illusions (e.g., the framing effects described above and other decision biases). In this sense, assuming a very general dual-processing approach, adolescents may engage in more risky behaviors than younger children because they have an increased likelihood of heuristically bypassing pertinent factors, in favor of quick and crude strategies that occasionally produce potentially dangerous outcomes. It must be noted, however, that these assumptions are not entirely applicable to fuzzy-trace theory, which, although included in this discussion of developmental dual-process approaches, makes unique predictions. For instance, fuzzy-trace theory predicts that with development comes increased relative use of intuitive, gist-like representations over quantitative, verbatim representations, "Reasoning progresses toward qualitative intuition, rather than away from it" (Reyna, 1996, pp. 107). This is in stark contrast to traditional developmental theories that propose developmental transition from preoperational to formal computational stages of reasoning. Additionally, proponents of fuzzy-trace theory propose that intuitive gist-like processing not only increases with development, but also that extracting the gist from risk situations is critical for rational decision-making (Reyna, 1996, 2004; Reyna & Ellis, 1994).

Another way to address this problematic cognition-age-prevalence paradox is to withdraw the assumption that all else *is* equal when children, adolescents, and adults face decisions regarding participation in risky behaviors. Some have argued that adolescents engage in risky behaviors, despite the increase in cognitive awareness of the risks involved, because they deem the risks as acceptable (Fromme, Katz, & Rivet, 1997; Furby & Beyth-Marom, 1992; Gerrard, Gibbons, Benthin, & Hessling, 1996, 2003; Moore & Gullone, 1996). In support of this general view, multiple studies have found that adolescent risk participation correlates positively with the number of benefits the adolescent perceives and correlates negatively with the number of potential negative outcomes that are perceived, and that adolescents, although similar to adults in probability estimation, rate risky behaviors as less potentially harmful than their parents do (Cohn, Macfarlane, Yanez, & Imai, 1995; Goldberg, Halpern-Felsher, & Millstein, 2002; Lavery, Siegel, Cousins, & Rubovits, 1993). Rather than assume adolescents engage in risks because they fail to realize that there is some probability of negative consequences, this approach assumes that adolescents accept some probability of negative consequences because they desire the potential positive outcomes the risks might bring about. In this sense, although adolescents are capable of superior cognitive processing than younger children, and relatively similar processing to adults (at least in terms of risk outcome likelihood estimation), the information incorporated into their decisions is assumed to differ as a function of age. Keeping with the traditional behavioral decision approach, this might be characterized as an age-based difference in subjective estimations of the potential *outcome values* individuals consider, which will inevitably result in different estimated expected values, and ultimately, variable rates of risk-taking. Furthermore, keeping with the latter sections of this paper, risk-taking may emerge, increase, and peak in adolescence because risks have potential outcomes that are emotionally, biologically, or socially valuable. This is not to assume that cognitive decision-making processes play a diminished role in risk-taking or its development; quite the opposite, decision-making processes might be assumed to bear upon all behaviors one can potentially engage in. Unfortunately, the development of outcome value estimations has been under researched, and as such, although we know a fair amount about adolescents' and adults' outcome probability estimations of realistic risks, we know very little about their corresponding outcome value estimations. Additionally, the potential interaction between cognitive outcome value estimation and emotional, biological, and social factors has been obscured by the tendency towards perspective isolation.

Summary

Cognitive decision-making theorists have addressed human tendencies in risk-taking and gamble situations, traditionally in terms of the perceived desirability and probabilities associated with alternatives and their consequences. Along this line, cognitive developmental researchers have attempted to explain how children and adolescents analyze risks, and how such processes develop, through analyses of decision-making skills. Experimental risk-taking tasks have been used to identify individual and developmental differences. The developmental progression that underlies performance on these tasks, although suggestive of changes in the cognitive bases of risk-taking during the childhood years, is yet somewhat unclear. Recent research does suggest that relatively young children (i.e., four- to seven-year-olds) are capable of intuitively processing probability information, which itself may be an early antecedent of risk appreciation. Several studies suggest that cognitive development in the adolescent years may impinge upon risk-taking behaviors (i.e., deficient adolescent cognition predisposes risk engagement). Numerous other studies, which have more precisely investigated risk consequence probability estimation, with regards to more adolescent-valid risks, however, suggest limited development of risk perception and probability estimation skills between adolescence and adulthood. In this sense, it is quite unclear how cognition and cognitive development relate to the development of risk-taking. One possibility is that with development children increase use of mentally efficient heuristics, with which they systematically bypass computational decision analyses, and thereby engage in risk-taking behaviors. Another possibility is that the content of children's and adolescents' decision analyses change, and due to the emotional, biological, and social factors that will be reviewed below, they come to appreciate the positive possible consequences of risk-taking behaviors, and therefore increase risk participation.

Table 1 summarizes the studies that have been reviewed thus far. This presentation format affords the benefit of a simple summary of the relative strengths and weaknesses of all reviewed studies (i.e., the number of participants, range of ages analyzed, methodological type, and number and types of risks evaluated). Of course, all else being equal, studies with more participants, a relatively disperse range of ages, and a fair number of types of risks are more powerful than those with fewer participants, a more narrow age range, and fewer risks. Also, whereas the above review organized these findings topically (i.e., adult decision-making roots → risk-taking analyzed with basic methods → risk-taking analyzed with more applied methods), Table 1 is organized chronologically (i.e., by participants' ages), which allows a straightforward analysis of the developmental trajectory of cognitive developmental findings. As can be seen in the "Major Findings" column, more of the reported studies have found evidence for cognitive developments that imply decreases in risk-taking [i.e., (↓)], than other potential data patterns [i.e., equivalence across ages, (=), or cognitive developments that imply increases in risk-taking (↑)]. Many of these findings, however, were in studies that have focused on younger populations, and have investigated the most basic underpinnings of risk-taking (e.g., probability judgment). This suggests cognitive development in the childhood years (i.e., between four- and twelve-years) that potentially decreases the likelihood of risk-taking. As discussed above, however, inferences that can be drawn regarding older populations (i.e., 12-year-olds to adults) are less clear. Several studies have generally found cognitive developments that imply decreased risk-taking between adolescence and adulthood (e.g., adults consider more potential consequences to risks, or react more appropriately to feedback). Others have found relative equivalence between adolescent and adult populations (e.g., teens and adults evaluate risk consequence probabilities similarly). Some findings imply a cognitive developmental decrease in risk-taking (e.g., teens see themselves as more vulnerable to risk consequences than adults). Finally, some have had mixed findings (e.g., teens minimize the perceived harm associated with risks, but are less optimistic about their personal invulnerability than adults). As

Table 1
Cognitive developmental studies

Study	N[a]	Ages[b]	Method[c]	Risks analyzed	Major Finding[d]
Kuzmak and Gelman (1986)—2 studies	72	3–8	EXP	NA	(=) and (↓)—4- to 8-year-olds discriminated random and determined events, 3-year-olds did not
Hoemann and Ross (1971)—4 studies	377	4–13	EXP	NA	(↓)—Younger participants failed to choose options with higher probability
Hoffrage et al. (2003)	44	4–6	EXP and OBS	Naturalistic and EXP risk	(ID)—Experimental risk-takers were more likely to take real risks (i.e., unsafely cross-street)
Brainerd (1981)—12 studies	635	4–5 and 7–8	EXP	NA	(↓)—Younger participants failed to retain information in working memory to make probability judgments
Schlottmann (2001)—2 studies	101	4–11 and 17–45	EXP	NA	(=)—Children and adults intuitively understood expected values, and combined probability and value multiplicatively
Reyna and Ellis (1994)	111	Pre-, 2nd-, and 5th-grd	EXP	Exp risk	(↓)—Participants preferred risk, but youngest were consistent across frames and older preferred risk more in loss-frames
Reyna (1996)	146	Pre-, 2nd-, and 5th-grd	Exp	Exp risk	(↓)—Children preferred risk, especially when presented in terms of potential losses, demonstrating reflection effect
Kreitler and Kreitler (1986)	240	5–12	EXP	NA	(↓)—Probability judgment improved with age, most noticeably between 5–6 and 8–9-years
Levin and Hart (2003)—2 studies	102	5–7	EXP	Exp risk	(↓)—Children preferred risky options, especially when presented in terms of potential losses, demonstrating reflection effect
Harbaugh et al. (2001)	234	5–20 and 21–64	EXP	Exp risk	(↓)—Children were more likely than adults to choose risk over certainty
Falk and Wilkening (1998)—2 studies	115	6–14	EXP	NA	(↓)—Youngest used one-dimensional-, older used difference-, oldest used relative proportion-strategies to match probability
Slovic (1966)	1047	6–16	EXP	Exp risk	(↑)—Younger kids were more risk-averse. Boys were more daring than girls by age 11
Acredolo et al. (1989)—2 studies	90	7–11	EXP	NA	(=)—Even the youngest participants attended to changes in probability and accurately estimated expected values
Baron et al. (1993)	103	7–15	INT	Seatbelt use, lying, cigarettes	(=)—Participants generally neglected precedents, probabilities, and frequencies
Millstein and Halpern-Felsher (2002)	577	10–14 and adults	SR	14 Risks (e.g., Sex, risky driving, and alcohol)	(↑)—Adolescents estimated higher personal vulnerability to negative outcomes than college-aged adults
Goldberg et al. (2002)	395	10–16	SR	Alcohol and cigarettes	(ID)—Benefit perceptions predicted risk-taking tendencies
Lavery et al. (1993)	80	11–17	SR	23 Risks (e.g., Alcohol, drugs, sex, and risky driving)	(ID)—Those with conduct disorder took more risks; Perceived benefits increased risk, perceived costs decreased risk

Halpern-Felsher and Cauffman (2001)	223	11–17 and adults	INT	Medical risk, consent risk, familial risk	(↓)—College-aged adults were more likely to consider potential risks and long-term consequences, and seek advice
Quadrel et al. (1993)	181	11–18 and parents	SR	Various (e.g., risky driving, alcohol, sex)	(=)—Adolescents were similar to mid-aged adults, both groups estimated others vulnerability to risk as greater than their own
Byrnes and McClenney (1994)—2 studies	103	12–14 and 19–26	EXP	Exp risk	(=) and (↑)—Adolescents and adults use similar strategies, but adults had tendency to overestimate performance
Beyth-Marom et al. (1993)	398	12–18 and parents	SR	Various (e.g., truancy, marijuana, sex, and alcohol)	(=)—Adolescents were similar to mid-aged adults, both predicted negative consequences assuming risk engagement
Lejuez et al. (2003b)	26	13–17	EXP and SR	10 Risks (e.g., cigarettes, alcohol, drugs, sex, and theft)	(ID)—Experimental risk correlated with self-reported risks, no reported relationship with age
Byrnes et al. (1999)—2 studies	151	13 and Adults	EXP	Exp risk	(=) and (↓)—Limited effects for age, but adults showed greater trial-to-trial decision game improvement
Cohn et al. (1995)	536	13–18 and 28–62	SR	14 Risks (e.g., alcohol, drugs, cigarettes, drunk driving)	(↑) and (↓)—Teens minimized harm associated with risks, but were less optimistic about their own personal invulnerability
Chien et al. (1996)	92	14	EXP	Exp risk	(=)—Young adolescents reacted to problem frame similar to adults, preference shifted with change in problem frame
Benthin et al. (1993)	41	14–18	SR	30 Risks (e.g., alcohol, cigarettes, drugs, and sex)	(ID)—Risk-takers were more aware of potential negative consequences than risk-avoiders. Inter-risk consistency
Lejuez et al. (2003a)	60	18–30	EXP and SR	Exp risk and cigarettes	(ID)—Experimental risk predicted smoking behavior
Lejuez et al. (2002)	86	18-25	EXP and SR	Exp risk and various (e.g., sex, alcohol, drugs, cigarettes)	(ID)—Experimental risk was correlated with self-reported risk-taking behaviors
Tversky and Russo (1969)	161	Adults	EXP	NA	(AF)—Stimulus similarity facilitated judgments, thereby violating the axiom of independence
Tversky (1969)—2 studies	54	Adults	EXP	Exp risk	(AF)—Participants violated transitivity, and varied selections with problem presentation
Tversky et al. (1990)—2 studies	367	Adults	EXP	Exp risk	(AF)—Participants violated procedure invariance and reversed preference
Lichtenstein and Slovic (1971)—3 studies	261	Adults	EXP	Exp risk	(AF)—Participants shifted preference, and agreed to pay more to play a less preferred gamble than a more preferred gamble
Kahneman and Tversky (1984)	997	Adults	EXP	Exp risk	(AF)—Participants varied with differences in problem wording; preferred risk in loss-frames, and certainty in gain-frames

[a] Total number of participants, across studies.
[b] Range of ages analyzed, across studies, rounded to reported year.
[c] SR, self-report; INT, interview; and EXP, experimental task.
[d] (↑), developments that imply increases in risk-taking; (↓), developments that imply decreases in risk-taking; (=), similarity between older and younger participants; (ID), focus on individual differences; (AF), adult findings.

mentioned, these findings are quite difficult to reconcile with risk-taking prevalence data, and as such, beg for future research.

Emotional development and risk-taking

Another developmental perspective has focused on how emotions are experienced, interpreted in the self and others, and regulated by children and adolescents (Gross, 1999; Gross & Levenson, 1997; Larson & Lampman-Petraitis, 1989; Lewis, Sullivan, Stanger, & Weiss, 1989; Rothbart & Bates, 1998; Saarni, Mumme, & Campos, 1998). Researchers have quite recently begun considering the potential role of emotions in risk-taking behaviors and decision-making processes, the timing of which is somewhat surprising, given the sensible relationship between the two. "Quite obviously, the relationship between emotions and decision-making is bi-directional and the positive or negative outcome of a decision can profoundly affect the decider's feelings" (Schwarz, 2000, pp. 435). Some have even proposed that cognitive decision theorists have erred by overemphasizing probabilistic formalism and neglecting the role of emotions in decision processes (Bechara, Damasio, & Damasio, 2003; Dahl, 2003; Damasio, 1994; Loewenstein & Lerner, 2003; Loewenstein, Weber, Hsee, & Welch, 2001; Steinberg, 2004).

There are two basic ways in which emotions have been implicated in risk-taking research. With the first, researchers have analyzed how people react to emotion provoking experiences, and how these reactions influence decision-making in potentially risky situations (Bechara, Damasio, & Damasio, 2000; Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Damasio, Tranel, & Damasio, 2005; Caffray & Schneider, 2000; Catanzaro & Laurent, 2004; Cooper, Frone, Russell, & Mudar, 1995; Damasio, 1994; Damasio, Tranel, & Damasio, 1991; Loewenstein et al., 2001; Mellers, Schwartz, Ho, & Ritov, 1997). Generally, those that adopt this approach, for most intents and purposes, substitute emotional costs and benefits for utility estimates, in otherwise standard decision-making models (although specific accounts vary slightly). In effect, anticipated increases in positive emotions and decreases in negative emotions are expected to increase the likelihood of risk engagement, and anticipated increases in negative emotions and decreases in positive emotions are expected to deter risk behaviors. The second basic way emotions have been implicated in risk-taking research considers the role of emotional regulation, and the possibility that inherently emotionally dysregulated populations, particularly impulsive or anger prone populations, are inclined towards externalizing and risk-taking behaviors (Cauffman & Steinberg, 2000a, 2000b; Colder & Stice, 1998; Cooper, Wood, Orcutt, & Albino, 2003; Eisenberg et al., 2001, 2005; Lemery, Essex, & Smider, 2002; Silk, Steinberg, & Morris, 2003; Steinberg & Scott, 2003). Each of these approaches will be reviewed in turn.

Affective decision-making

Perhaps the most prominent affective decision-making account is Damasio, Bechara, and colleagues' somatic marker hypothesis (SMH). The SMH posits that emotional responses to positive and negative consequences guide decision-making in risky and uncertainty situations (Bechara et al., 1999, 2000; Damasio, 1994). "Those emotions and feelings have been connected, by learning to predicted future outcomes of certain scenarios. When a negative somatic marker is juxtaposed to a particular future outcome the combination functions as an alarm bell. When a positive somatic marker is juxtaposed instead, it becomes a beacon of incentive" (Damasio, 1994, p. 174). Thus, according to the SMH, emotions are necessary for decision-making, and the inability to generate, attend to, and recall emotional responses in potentially risky situations is marked by an inability to make rational decisions, which in and of itself, is related to an increased preponderance of risk-taking.

Much of the evidence for the SMH has been gathered with an experimental task, commonly referred to as the "Iowa Gambling Task" (IGT; Bechara et al., 2003; Bechara, Damasio, Damasio, & Anderson, 1994; Bechara et al., 1999, 2000, 2005). In this task participants make a series of card selections from one of four decks. The decks are manipulated so that two are risky (i.e., with larger relative payoffs, but even larger losses, resulting in net losses), and two are safe (i.e., with smaller relative payoffs, and even smaller losses, resulting in net gains). Normal adult participants learn this underlying structure, theoretically due to the emotionally arousing nature of the large losses associated with the risky decks, and after a number of trials (e.g., 30 or so), tend to gravitate towards the safer decks. Participants with emotional disability (the biological source of which will be reviewed below in a discussion of affective neuroscience research), on the other hand, choose the risky options much more often than is sensible (Damasio, 1994; Bechara et al., 1999, 2000, 2005). These participants, however, are cognitively indistinguishable from normal controls (i.e., in terms of memory and reasoning capacities). The fact that these participants are emotionally impaired, yet are cognitively adept, is the foundation for the affective decision-making position described by the SMH. As is apparent, however, the IGT is not radically different from experimental risk-taking tasks that have been presented in the cognitive and cognitive developmental literature (e.g., Slovic's risk task or Byrnes and colleagues "decision game"). Moreover, some challenge the assumption that unconscious somatic markers guide decisions in the IGT, and propose that more parsimonious cognitive processes may actually guide choice (Maia & McClelland, 2004, 2005). Launching a methodological criticism, others have even found that slight manipulations of the IGT produce dramatically different results (i.e., if the large losses associated with the disadvantageous decks occur early in the sequence of draws, emotionally impaired participants are similar to normal controls; Fellows & Farah, 2005). These objections notwithstanding, that emotionally impaired but otherwise normal individuals have dramatic inabilities on the IGT suggests, even if all other specific assumptions are unmet, that affect plays at least some role in risk-taking.

Very recently, adaptations of the gambling task have been given to children and adolescents to assess the developmental patterns of affective decision-making capacities. Kerr and Zelazo (2004), for example, gave three- and four-year-olds a simplified version of the gambling task (i.e., using two instead of four selection decks), and found an age $\times$ trial block interaction; that is, four-year-olds were more likely than chance, and more likely than three-year-olds, to gravitate towards the advantageous option in latter trials. Garon and Moore (2004) presented three-, four-, and six-year-olds with a fairly standard version of the gambling task (i.e., using four selection decks). Somewhat inconsistent with Kerr and Zelazo (2004), the results suggested that participants did not demonstrate a preference for any of the decks through the total 40 trials; however, six-year-olds were more conceptually aware of the game structure than three- and four-year-olds. Perhaps the 40-trial sessions used by Garon and Moore (2004) were simply insufficient to produce preference (recall, adults tend not to alter their selection strategies until around trial 30). Crone and colleagues have administered an adaptation of the gambling task (referred to as the "hungry donkey task" because, rather than flip cards in a deck, the participant is asked to sequentially choose four doors on a computer screen to reveal food that a donkey character might eat), to slightly older children (six- through nine-year-olds), adolescents (12 to 13-year-olds and 15 to 16-year-olds), and young adults (Crone & van der Molen, 2004; Crone, Vendel, & van der Molen, 2003). These studies' findings suggest development of affective decision-making abilities between childhood, adolescence, and young adulthood; specifically, with age came increased and more consistent gravitation towards advantageous doors. Further, like Garon and Moore (2004), older participants were more likely than younger participants to derive an explicit "hunch" or conceptual understanding about the task. Overman and colleagues (2004) also found improvement on the standard IGT during the adolescent years (e.g., between sixth- and twelfth-grade). In total, these studies demonstrate that the gambling task can be used with children, and that development of affective decision-making skills begins early (i.e., as early as between 3- and 4-years), proceeds throughout childhood and adolescence, and becomes more explicit with age.

Another approach has been to focus on individual differences in affective decision-making tendencies. Ernst and colleagues (2003), for instance, presented adolescent and adult participants, some of whom had been diagnosed with behavioral disorders, with the standard IGT. Although healthy adolescents and adults did not significantly differ in task performance, adolescents with behavioral disorders improved less between administrations conducted a week apart. Quite similarly, Stanovich, Grunewald, and West (2003) found that adolescents who had been suspended from school multiple times (i.e., as punishment for various behavioral offenses) were more likely to choose disadvantageously on the IGT than those that had never been suspended or had been suspended once. Although neither of these studies reported developmental differences, individual difference findings are themselves quite interesting, and lend support to the argument that affective decision-making capacities are related to risk-taking.

Emotional regulation and impulsivity

As mentioned, the affective decision-making approach is but one of two ways that emotional development has been associated with risk-taking. The other, rather than appeal to the potential emotional costs and benefits of certain behaviors, proposes that risk-taking behaviors are the product of impulsivity. Classically defined, impulsivity is the tendency to make decisions hastily rather than reflectively (Eysenck & Eysenck, 1977). Contemporary approaches more emphatically stress the relationship between impulsivity and emotional regulation, proposing that impulsivity might be construed as an inability to inhibit prepotent responses while attempting to enact secondary responses (Rothbart & Bates, 1998). The logic of the approach is that individuals who lack regulation skills hastily engage in more goal-defeating risky behaviors, especially in frustrating or anger provoking situations. Along these lines, Eisenberg and colleagues (Eisenberg et al., 2000, 2001, 2005) have found relationships between children's emotionality, effortful control capacities, and externalizing problem behaviors. For instance, Eisenberg and colleagues (2001) found that five- to eight-year-olds who were identified as high in emotionality, and particularly anger prone children, tended to have less inhibitory control skills (as assessed observationally and through parent and teacher reports), and were more likely to have general externalizing problems. Eisenberg et al. (2005) followed-up this sample, and found that these relations had remained relatively stable two-years later. Others have even more directly demonstrated, in both adolescent and adult populations, that increased impulsivity is related to increases in a variety of prototypical risky behaviors, such as alcohol use, cigarette smoking, gambling, and unsafe sex (Donohew et al., 2000; Robbins & Bryan, 2004; Stanford & Barratt, 1992; Stanford, Greve, Boudreaux, Mathias, & Brumbelow, 1996). These studies cumulatively demonstrate a relationship between impulsive and risk-taking tendencies.

Turning more directly towards development, a substantial body of well-known research has found that younger individuals are less able to self-regulate than older individuals, and furthermore, that there are significant longitudinal relationships between early self-regulatory tendencies and later cognitive and social competencies (Metcalfe & Mischel, 1999; Mischel & Ayduk, 2002; Mischel & Mischel, 1983; Mischel, Shoda, & Peake, 1988; Mischel, Shoda, & Rodriguez, 1989; Sethi, Mischel, Aber, Shoda, & Rodriguez, 2000). For instance, Sethi and colleagues (2000) found stability in impulsivity and self-regulation strategies between toddlerhood (i.e., one-year-six-months) and early childhood (i.e., four-years-ten-months); specifically, toddlers who were observed more able to regulate and avoid the frustration associated with maternal separation, were also more able to delay gratification in a goal-directed task three-and-a-half years later. Similarly, numerous studies have demonstrated relative stability in self-regulatory capacities and susceptibility to impulsivity between early childhood and early adolescence (Mischel & Mischel, 1983; Mischel et al., 1988, 1989); that is, preschoolers who are able delay gratification for longer periods tend to be more socially and academically competent in early adolescence. Building even more directly upon the relationships between development, impulsivity, and risk-taking, Stanford and colleagues (1996) demonstrated, with a reasonably large sample of adolescents and young adults ($N = 1{,}100$), that high school students are more likely to be highly impulsive than are college students, and furthermore, that psychometrically identified highly impulsive individuals were more likely than less impulsive individuals to engage in a number of risk-taking behaviors (e.g., peer aggression, drunk driving, and drug use).

Theoretically, Byrnes and colleagues (e.g., Byrnes, 1998, 2003; Byrnes et al., 1999; Byrnes, Miller, & Schafer, 1999; Miller & Byrnes, 1997) have captured many of these elements in a self-regulation model (SRM) of decision-making development. Although not an emotional developmental theory, per se, the SRM hypothesizes that individuals may engage in risky behaviors because they fail to regulate, and thereby bypass crucial decision-making processes (e.g., attending to incoming information, analyzing pertinent probability and outcome variables, and consolidating outcomes for future use). The model further proposes that these regulation capacities continue to develop through adolescence. In this manner, excessively emotional individuals, who are over-represented in adolescent populations, have a tendency to bypass rational decision-making processes and irrationally engage in potentially dangerous risk-taking behaviors. Commendably, this approach emphasizes the interactive effects of cognition and affect for risk-taking tendencies, in the sense that emotional reactivity is assumed to bear upon the likelihood of cognitive evaluation of the decision-making situation.

Similarly, Steinberg and colleagues have proposed a psychosocial maturity theory of criminal and antisocial behaviors (Cauffman & Steinberg, 2000a, 2000b; Steinberg, 2004; Steinberg & Cauffman, 1996; Steinberg & Scott, 2003). One of the key propositions of this theory is that temperance, which is defined as the ability to limit impulsiveness and evaluate situations prior to acting, is critical to behaving adaptively. In support of this claim Cauffman and Steinberg (2000a) found relationships between psychosocial maturity, age (adults and eighth-, tenth-, and twelfth-grade adolescents), and hypothetical antisocial decisions; basically, adults were found more psychosocially mature, and tend to make more socially responsible decisions than adolescents. Summarized elsewhere, “To the extent that adolescents are less psychosocially mature than adults, they are likely to be deficient in their decision-making capacity, even if their cognitive processes are mature” (Steinberg & Scott, 2003). This approach, and the studies that have been conducted in its support, however, is somewhat open to a criticism of circularity; that is, adolescents are assumed to take risks because they are psychosocially immature, and conversely, they are considered less psychosocially mature because they take risks.

Cooper and colleagues have also developed a line of work that, to some degree, has bridged the gap between the affective decision-making view and the roles of emotional regulation and impulsivity in risk-taking behaviors (Cooper, Agocha, & Sheldon, 2000; Cooper et al., 1995, 2003; Cooper, Russell, Skinner, & Windle, 1992). Using self-report methodologies, Cooper and colleagues have demonstrated that affective motives, such as desire for positive affect, avoidance of negative affect, and emotional coping strategies, underlie risk-taking behaviors (Cooper et al., 1992, 1995). This line of research has also replicated the relations between emotional regulation, impulsivity, and engagement in risky behaviors (Cooper et al., 2000, 2003). A series of sophisticated path analysis models, which take into account the relative contributions of affective expectancies, emotional regulation, impulsivity, emotional coping strategies, and various personality constructs (i.e., neuroticism and extroversion), have accounted for a substantial portion of explained variance in risk-taking behaviors (e.g., an approximate average of 40% of the variance in alcohol use in Cooper et al., 2003; and an estimated 32% of variance in alcohol use in Cooper et al., 2000). How these factors develop is yet to be determined; however, that these researchers have mapped the relative influence of these factors on risk-taking is encouraging, and should contribute to the derivation of developmental models.

An emotional development—Risk-taking paradox

As was the case with the cognitive developmental approach, if affective decision-making and emotional regulation are associated with decreases in risk-taking, and each increases with age, there is something of a paradox between emotional development and risk-taking prevalence data. Some who adopt an emotional development approach sidestep this issue by focusing primarily on the transition from adolescence to adulthood, noting the increase in emotional capacities and corresponding decrease in risk-taking that occurs with this transition (Cauffman & Steinberg, 2000a, 2000b; Steinberg, 2004). Although this stance does alleviate one facet of the paradox (the adolescence → adulthood component), and thereby moves towards an explanation for why risk-taking peaks in adolescence, it fails to provide a truly satisfactory solution, because developments that occur between childhood and adolescence and the discordant emergence and increase in risk-taking behaviors are disregarded. Perhaps a superior solution is to again suggest that risk-taking is a product of the interaction of cognitive, affective, biological, and social factors, and that there is age-based variability in the subjective outcome values individuals associate with certain behaviors. It might even be argued that the factors within each perspective are in some ways negligible when isolated from factors that are traditionally analyzed within other perspectives. For instance, emotional self-regulatory capacities are interdependent with cognitive risk assessment capacities, in at least two ways: (1) one must cognitively assess emotionally loaded behaviors as potentially dangerous in order to self-regulate and temper them, and conversely, (2) heightened emotional states presumably influence the likelihood that one will enact cognitive risk assessment processes. This interaction is bi-directional, and it therefore may not be possible to parse apart the degree to which cognitions influence emotions, or vice versa; however, as reviewed, available developmental data suggest that aspects of cognitive decision-making are "adult-like" somewhat earlier than aspects of affective decision-making and regulation. These issues further stress the need for future integrative efforts, and studies that breech the boundaries between theoretical perspectives.

Summary

Some argue that traditional decision-making research has focused too narrowly on cognitive operations, and that increased attention should be paid to the role of emotions in decision-making. Generally, affective decision-making positions assert that emotional costs and benefits guide decisions, and related to this, emotionally disabled individuals take unwise risks. Developmental studies have demonstrated relative improvements in affective decision capacities from early childhood into adolescence, and from adolescence into adulthood. A separate line of research has demonstrated that risk-taking is related to emotional regulation and its converse, impulsivity. Studies have shown that impulsivity is associated with increased risk-taking, and that inhibitory capacities improve with development. Both Byrnes and colleagues' self-regulation model and Steinberg and colleagues' psychosocial maturity approach, generally propose that emotional volatility and impulsivity, which are heightened in adolescence, may contribute to adolescent risk-taking behaviors. Finally, Cooper and colleagues have crossed these subareas, and have emphasized the importance of affective decision-making, emotional regulation, and impulsivity in risk-taking behaviors. Taking these findings into account, a paradox exists between emotional development and risk-taking prevalence data, which makes explaining the emergence and increase of risk-taking in adolescence difficult; however, research does suggest that risk-taking is higher in adolescence than later developmental periods because adolescents attend to the emotional consequences of risks less effectively than older populations, and because they are more likely to impulsively neglect important decision information.

Table 2 summarizes the emotional developmental studies reviewed above. Like Table 1, Table 2 provides a description of the sample sizes, age ranges, methodology, and types of risks evaluated by each study. Also, whereas the above discussion was topically organized (i.e., affective decision-making → emotional regulation and impulsivity), Table 2 is organized chronologically (i.e., again, by participants' ages), which, again, allows relatively straightforward analysis of the developmental trajectory of findings. In contrast to those summarized in Table 1, the emotional developmental studies summarized in Table 2 are relatively consistent, and uniformly indicate emotional developments that imply decreases in risk-taking [i.e., (↓)]. Furthermore, these findings are applicable to developments that occur relatively early (i.e., in childhood) and later (i.e., between adolescence and adulthood). This suggests that emotional developments in childhood and adolescence bear upon risk-taking; however, as discussed above, exactly how to interpret these findings in the face of risk-taking prevalence data is somewhat unclear. This, of course, is something future studies and theories must address, optimally with an approach that utilizes elements from across the traditional research perspectives.

Table 2
Emotional developmental studies

Study	N[a]	Ages[b]	Method[c]	Risks analyzed	Major Finding[d]
Sethi et al. (2000)	97	LONG, 1 → 4–5	OBS and EXP	NA	(ID)—Self-regulating toddlers were more likely to later use effective self-regulating strategies in delay of gratification task
Kerr and Zelazo (2004)	48	3–4	EXP–IGT	Exp risk	(↓)—Four-year-olds were more likely than three-year-olds to select advantageously on the simplified gambling task
Garon and Moore (2004)	69	3–4 and 6	EXP–IGT	Exp risk	(=) and (↓)—No age differences in selection on the gambling task, older had more conceptual understanding
Mischel and Mischel (1983)—2 studies	297	3–5, 8, 10–11	EXP—DoG	NA	(↓)—Older children were more likely to use distraction strategies on delay of gratification task, and able to verbalize those strategies
Mischel et al. (1988)	95	LONG, 4 → 15	EXP—DoG and PR	NA	(ID)—those able to delay gratification for longer in preschool were more socially and cognitively competent in adolescence
Eisenberg et al. (2001)	214	4–8	OBS, PR, and TR	General externalizing, delinquency, and aggression	(ID)—Strong correlation between effortful control and externalizing problems
Eisenberg et al. (2005)	185	LONG, follow-up, Eisenberg et al., 2001	OBS, PR, and TR	General externalizing, delinquency, and aggression	(ID)—Externalizers were higher in anger-emotionality, lower in effortful control, and higher in impulsivity, suggesting stability at 2-year follow-up
Eisenberg et al. (2000)	146	LONG, K-3rd → 2nd- 5th-grd	OBS, PR, and TR	General externalizing	(ID)—Structural equation model demonstrated that behavioral regulation and attention regulation were predictive of externalizing, but latter was moderated by emotionality
Crone and van der Molen (2004)—2 studies	231	6–15 and 18–25	EXP–IGT	Exp risk	(↓)—Teens were more likely than children, and adults more likely than teens, to select advantageously on latter gambling task trials
Overman et al. (2004)	451	11–18 and 17–23	EXP–IGT and SR	Exp risk	(↓)—Improvement on gambling task with age

Crone et al. (2003)	436	12–13, 15–16, and 18–25	EXP–IGT and SR	Exp risk	(↓) and (ID)—Adults made better selections in latter gambling task trials, and disinhibited individuals performed worse
Ernst et al. (2003)	116	12–14 and 21–44	EXP–IGT	Exp risk	(=) and (ID)—healthy adolescents were similar to healthy adults, but those with behavioral disorders did not improve across test sessions
Cauffman and Steinberg (2000)	1015	13, 15, 17, 19, and 25	SR	Marijuana, theft, school misconduct	(↓)—Younger participants were less psychosocially mature, and more likely to make socially irresponsible decisions
Donohew et al., 2000	2949	14-16	SR	Sex, and risks associated with sex	(ID)—Sensation-seeking and impulsivity correlated with risk-taking, those high on both measures were most likely to take risks
Robbins and Bryan (2000)	300	15	SR	Alcohol, and risks associated with alcohol	(ID)—Impulsivity was positively related with risk-taking in sample of adjudicated adolescents
Stanford et al. (1996)	1100	13–65	SR	Aggression, drugs, drinking and driving, seatbelt use	(↓) and (ID)—Teens were more impulsive than older participants, and more impulsive participants were more likely to take risks
Stanovich et al. (2003)	90	16	EXP–IGT	Exp risk	(ID)—Participants with more school suspensions selected less advantageously on gambling task
Cooper et al. (2003)	1978	LONG, 16 → 21	INT	Various (e.g., sex, alcohol, cigarettes, and crimes)	(ID)—Avoidant emotional coping strategies and poor impulse control lead to general vulnerability to risk-taking
Cooper et al. (2000)	1,666	17–26	INT	Alcohol and sex	(ID)—Neuroticism interacted with impulsivity and predicted coping motives, and surgency predicted enhancement motives for risks
Stanford and Barratt (1992)	72	Adults	SR and criminal records	Major Crimes, alcohol, and drug use	(ID)—Impulsivity was significantly related to the number of criminal and risky acts convicted participants committed

[a] Total number of participants, across studies.
[b] Range of ages analyzed, across studies, rounded to reported year. LONG, longitudinal assessment.
[c] SR, self-report; INT, interview; EXP, experimental task; IGT, Iowa Gambling Task; DoG, delay of gratification task; PR, parent report; and TR, teacher report.
[d] (↑), developments that imply increases in risk-taking; (↓), developments that imply decreases in risk-taking; (=), similarity between older and younger participants; (ID), focus on individual differences; and (AF), adult findings.

Biological bases of risk-taking development

Researchers began considering the physiological bases of psychological and developmental processes relatively recently (Nelson et al., 2002). There are three biologically oriented approaches that are directly relevant to the current discussion of the development of risk-taking: (1) the neuro-cognitive bases of risk-taking, (2) the neuro-affective bases of risk-taking, and (3) physiological developments that correlate with the emergence of risk-taking. Many of the studies that will be discussed, particularly in regards to approaches 1 and 2, are aimed at localizing the neural regions that become active during risk. The findings made across approaches are significant by virtue of the fact that they elucidate what psychological processes conspire when an individual is presented with any particular situation (e.g., if specific neural regions, that are known to become active during specific cognitive processes become activated in response to a risk, it might be inferred that the specific cognitive process is associated with risk-taking). In this sense, biological processes intrinsically interact with the cognitive and affective research discussed thus far, and psychobiological research provides the essential mechanics that underlie psychological processes and their development. This relationship, however, is reciprocal, and whether research is categorized as cognitive or affective neuroscience is largely dependent upon the behavioral manifestations associated with the neural region of interest. In this sense, certain cognitive and affective processes might be inferred relevant to risk-taking by virtue of associated activation of specific neural areas, which themselves have been inferred relevant to the cognitive and affective processes through associated behavioral correlates. So, in a roundabout way, neuroscience provides a means to identify the core psychological processes at work in risk-taking situations. Another noteworthy contribution of this branch of research is that describing the underlying biological mechanisms affords the possibility of drawing inferences to specific samples (i.e., adolescents or extreme risk-takers). This is particularly important for a developmental perspective, in that biological differences between developmentally heterogeneous populations are bound to implicate behavioral differences. In addition, identification of biological bases can conceivably lend itself to biologically oriented intervention strategies (e.g., pharmacological treatment). In what follows, the cognitive neuroscience approach to risk-taking, the affective neuroscience approach to risk-taking, and the psychobiological developments that impinge upon risk-taking development are discussed.

Cognitive neuroscience

Early neuroscientific studies found that the frontal- and fronto-temporal lobes are vital for cognitive analysis of risk (Miller, 1985; Miller & Milner, 1985). In a series of experiments participants were asked to identify pictures or words with only partial information to earn rewards that varied inversely with the amount of information given, and as such, the risk in question was when to venture an identity guess. The results demonstrated that participants with localized frontal lobe damage were impaired on this task, and regularly ventured guesses with insufficient information (Miller & Milner, 1985). The initial assumption, therefore, was that the frontal lobes are imperative for cognitive function, which in turn affects risk-taking. More recent investigations, however, revealed that patients with frontal-lobe lesions are less able to inhibit maladaptive impulses (Miller, 1992), thus leading to the conclusion that the frontal-lobes impinge upon risk-taking, as mediated by impulsivity, which, as already discussed, is primarily classified as an affective contributor to risk-taking. As such, the role of the frontal lobes in risk-taking, which has blossomed in more recent research, will be analyzed more thoroughly below, in a discussion of affective neuroscience studies.

Other recent work has suggested that cognitive decision-making in risk-taking situations is neurologically distributed, rather than localized, in the sense that decisions require multiple cognitive processes that are associated with multiple neural structures. The general proposal is that through the course of a decision, one proceeds through a series of processes (sensing and identifying possible alternatives, evaluating alternatives, selection of one of the alternatives, anticipation of outcomes, and situational learning), which sequentially activates various neural regions (Ernst et al., 2003, 2004). Neuro-imaging studies have demonstrated that the first areas activated in decision situations are the sensory-motor pathways, including the occipito-parietal pathway (i.e., visual pathways), which detect incoming stimuli, and identify the possible decision alternatives (Ernst et al., 2003, 2004). Activation then spreads to the amygdala and hippocampus, which are hot spots for emotion and memory processes, and have been associated with processing rewards and punishments in learning and decision-making frameworks (Buchel, Dolan, Armony, & Friston, 1999; Elliott, Friston, & Dolan, 2000). Next, activation spreads to the higher cortical regions, including the orbital-frontal cortex, the dorsolateral prefrontal cortex, the ventromedial prefrontal cortex, the anterior cingulate gyrus, and the parietal cortex, which are inferred associated with weighting alternatives, choosing an alternative, and storing the information for future use (Bechara et al., 1994; Elliott, Rees, & Dolan, 1999; Elliott et al., 2000). Using positron emission tomography imaging (PET), (Ernst and colleagues, 2002) found evidence for this sequence of activation when participants were presented with experimental risk-taking tasks. Functional magnetic resonance imaging (*f*MRI) data further suggest that activation of the above specified neural regions follow a pattern that corresponds with selection and anticipation phases of a risk-taking task. Furthermore, relative activation of the subcortical ventral striatum has been found to vary as a function of the degree of risk and reward (Ernst et al., 2004), which is significant in that it suggests localized processing of outcome value information. Recall, this holds importance, following the cognitive decision-making tradition, because outcome value (along with outcome probability) is an elementary component of any decision or risk, and moreover, insensitivity to outcome values, which might be inferred a function of insufficient ventral striatum activation, would likely be associated with increased risk-taking tendencies.

Another relevant neuro-cognitive risk-taking study focused on localized activation with gain and loss framed decisions (Smith, Dickhaut, McCabe, & Pardo, 2002). Recall from above, major behavioral decision-making research efforts have found that individuals alter risk preference as a function of how the risk is presented, and whether terms that stress potential gains or losses are used. Smith and colleagues (2002) asked participants, while subjected to PET, for their preference between two gambles, with outcomes framed in terms of gains (with gamble A you may win $v, with gamble B you may win $x) or losses (with gamble A you may lose $y, with gamble B you may lose $z). Consistent with the above reviewed cognitive decision-making studies, participants altered their choices based on the situational frames. Perhaps more interesting, however, was that neural region activation varied with problem frames. In loss situations, the neo-cortical dorsomedial system, which is typically implicated in cognitive tasks that demand calculation, became activated. In gain situations, however, primary relative activation was in the ventromedial system, which is usually implicated in automatic and visceral processes. This intriguing finding thus provides a neurological basis for the variability in reactions to gain and loss framed risks, and emphasizes the utility of analyzing neurological substrates in that the results suggest greater cognitive processing for some types of risks (e.g., loss framed), and greater emotional processing for others (e.g., gain framed).

Affective neuroscience

A substantial amount of research has isolated the neural regions that are central to processing emotions. Numerous studies have demonstrated that fear, conditioned startle responses, and observationally learned aversion are associated with activation of the amygdala, which are bilateral subcortical structures within the limbic system (Amaral, 2002; Anderson & Phelps, 2001; Bechara et al., 1999; Blair, Schafe, Bauer, Rodrigues, & LeDoux, 2001; Davidson, 2002; Larson, Ruffalo, Nietert, & Davidson, 2000; LeDoux, 1995; Phelps et al., 2001; Thomas, Drevets, & Dahl, 2001). Such findings are relevant to a discussion of the development of risk-taking for two reasons: (1) fear of consequences can greatly influence the options entertained in a risk situation, and (2) fear moderates exploratory and withdrawal behaviors, which themselves are central to risk-taking. The amygdala are also important because their activation spreads to other structures, which effectively triggers increases in attention and vigilance, theoretically to resolve environmental ambiguity (Davis & Whalen, 2001; Whalen, 1998). Perhaps the emergence of risk-taking behaviors, which by definition have some possibility of harmful and perhaps fearful outcomes that are oftentimes probabilistically ambiguous, is related to inhibition or decreased activation of the amygdala structures that would otherwise curb the behavior.

Much of the affective neuroscience research that is most relevant to risk-taking and decision-making focuses more directly on the role of the prefrontal cortices. Many studies have noted the psychological processes associated with the prefrontal cortices (i.e., personality, emotion, drive, affect, and mood), as well as the pathologies that are associated with prefrontal cortex impairment (i.e., schizophrenia, mood disorder, bipolar disorder, and obsessive compulsive disorder; see Stuss, Gow, & Hetherington, 1992; for a further review). Damasio, Bechara, and colleagues somatic marker hypothesis, as reviewed above, draws supporting evidence from affective neuroscience. The majority of this evidence is based upon differences between individuals with brain damage, particularly localized to the ventromedial prefrontal cortex (VMF), and normal controls. Damasio and colleagues have demonstrated that individuals with VMF lesions typically perform poorly in risk-taking tasks, such as the "Iowa gambling task." As discussed above, that these patients show no cognitive impairment, yet are impaired emotionally and on the IGT, is taken as the primary evidence for the affective stance of the SMH. In further support of this proposal, although largely anecdotal and based upon just two individuals, an extensive case study illustrates that early prefrontal cortex damage is related to behavioral problems, poor executive functioning, poor decision-making skills, but normal working memory and attention capacities (Anderson, Damasio, Tranel, & Damasio, 2000). Bechara and colleagues have quite recently extended the hypothesis, suggesting that the amygdala process primary inducers (i.e., intuitive and automatic emotional response generators), and the VMF process secondary inducers (i.e., explicit and recalled emotional response elicitors; Bechara et al., 2003).

Physiological development

The studies of the neural bases of cognitive and affective decision-making reviewed thus far are not actually developmental in nature, but rather, have been conducted with developmentally homogenous populations. As such, it cannot be concluded with absolute certainty whether the processes and patterns of neural activation outlined above are present in the brain of a child or teenager, or rather, are the culmination of development. To more precisely address developmental questions, a number of studies have drawn associations between the timing of biological maturation and the emergence of risk-taking and delinquent behaviors, typically reporting that early maturation is related to increased risk participation (Caspi, Lynam, Moffitt, & Silva, 1993; Duncan, Ritter, Dornbusch, Gross, & Carlsmith, 1985; Williams & Dunlop, 1999). These studies, however, emphasize that maturation interacts with social factors to influence risk-taking tendencies. For instance, Caspi and colleagues (1993) found that early maturing females were more likely to engage in delinquent behaviors at 15-years than those who matured later; however, this interacted with the social environment, and the maturation effect was limited to those who attended coeducational schools, who therefore were assumed to have greater social demand for, and greater social facilitation of, delinquency.

The limited neurological evidence on this topic, gathered with *f*MRI imaging techniques, suggests that children and adolescents experience activation patterns in reward situations similar to those outlined above (May et al., 2004). This, of course, is not to say that neuro-physiology does not change with development; on the contrary, the structures implicated above are believed to develop throughout childhood and adolescence (Giedd et al., 1999; Segalowitz & Davies, 2004). Along these lines, Spear (2000a, 2000b) presents a comprehensive account of adolescent neurological development, and details the implications of said development for the emergence of risk-taking behaviors. This neuro-developmental model, similar to the above reviewed findings of Ernst and colleagues (Ernst, 2003; Ernst et al., 2002, 2004), supposes that numerous neural areas, including the amygdala, the prefrontal cortices, the hippocampus, the ventral tegmental area, and the accumbens (a substructure within the ventral striatum), are sequentially activated when an adolescent faces a risk. Spear's model developmentally proposes that synaptic pruning, which continues through adolescence, and an adolescent shift from relatively more glutamate and gamma-amino-butyric acid (GABA) neurotransmitters, towards relatively more dopaminergic neurotransmitters, influence the development of decision-making skills, and are central to adolescent risk-taking (Spear, 2000a, 2000b). These neural changes are largely thought to affect the adolescent's evaluation of reward and punishment outcomes, and may contribute to the emergence of adolescent onset psychopathologies, such as schizophrenia and depression (Lewis, 1997; Spear, 2000a, 2000b). Yet another notable potential contributor to adolescent neural development is an age-based shift in localized activation. Bauer and Hesselbrock (1999), for example, demonstrated that with development in adolescence there is a shift from greater relative posterior cortical activation in response to unusual sudden stimuli, towards greater relative frontal cortical activation, which parallels the proposal of frontal cortex development in adolescence. Further, this work has found that adult substance abusers and adolescents diagnosed with conduct disorder (both of which are related to risk-taking) tend to have decreased frontal and pareietotemporal activation.

Connections have also been drawn in the developmental literature between the biological bases of sensation seeking, typical adolescent biological development, and the emergence of reckless and risky behaviors (Arnett, 1992, 1995, 1996). Zuckerman (1983, 1984) proposed that biochemistry, specifically, decreased neural inhibitory monoamine oxidase (MAO) and increased sex hormones (i.e., testosterone), are related to increases in risk-taking behaviors, via a sensation seeking personality construct. Sensation seeking is defined as, "the need for varied, novel, and complex sensations and experiences and the willingness to take physical and social risks for the sake of such experience" (Zuckerman, 1979). A number of studies have found significant correlations between self-reported levels of sensation seeking tendencies and various risky behaviors, including criminal acts, financial risks, risky sexual behavior, social violations, and cigarette smoking (e.g., Arnett, 1996; Donohew et al., 2000; Horvath & Zuckerman, 1993; Rolison & Scherman, 2002, 2003; Zuckerman, 1994; Zuckerman, Black, & Ball, 1990). For instance, Arnett (1996) reported moderate correlations between adolescent sensation seeking tendencies and risky driving tendencies, risky sexual behaviors, alcohol, cigarette, and drug use, and theft and vandalism. Although no theorists have attempted to do so, these data might be reinterpreted with the cognitive decision approach introduced above, and sensation seeking may be characterized as a consistent preference for stimulating outcome values.

Sensation-seeking tendencies aside, many others have appealed to the effects of androgenic hormones, which increase dramatically in adolescence (i.e., androgenic hormone levels double in females, and increase 10- to 20-fold in males), as contributing to the emergence of risk-taking behaviors, and particularly risky sexual behaviors (Collaer & Hines, 1995). Udry (1988), for instance, very comprehensively parsed the contribution of sociological factors (family characteristics) and biological factors (relative testosterone levels, obtained through blood sample analysis), to sexual behaviors. The results demonstrate that inclusion of hormonal data dramatically increase the portion of explained variance in sexual behaviors, especially for males (a biosocial model accounts for upwards of 61% of the explained variance in male sexual behaviors, and 47% of that in females, which substantially exceeds the social model alone).

Summary

Cognitive-, affective-, and developmental-neuroscience each hold implications for the emergence of risk-taking behaviors. Across these perspectives, the brain regions that are believed key to decision-making include the sensory cortices, amygdala, hippocampus, ventral striatum, and various cortical regions (i.e., the orbital-frontal, prefrontal, dorsomedial, and ventromedial cortices). Although neuroscience has isolated these structures in the adult brain as important to processing risks, how, and the degree to which, the structures change with age to influence the emergence of risk-taking is yet somewhat unclear. Nonetheless, the reviewed data suggest that the emergence, increase, and peak of risk-taking behaviors in adolescence may be associated with psychobiological developments, including synaptic pruning, a shift from greater relative posterior to frontal activation, decreased relative inhibitory MAO and GABA, increased relative excitatory dopamine, increased androgenic and growth hormone levels, and general physical maturation. Cumulatively, these developments are associated with developmental increases in risk-taking behaviors, which is in contrast to the reviewed cognitive- and affective-developmental data, which, all else being equal, are generally assumed inversely related to risk-taking. It must be stressed, however, that physical and neurological maturation are confounded with cognitive, affective, and social developments. For instance, individuals' biological developments (e.g., increases in synaptic transmission) influence their cognitive and affective processes (e.g., probability estimations and emotional reactions), which in turn affect how they interact with others (e.g., how they interpret others' actions). Conversely, how children and adolescents are treated is influenced by their biological, cognitive, and affective developments (e.g., adolescents are treated differently by parents and peers before and after puberty).

Table 3 summarizes the reviewed studies. As discussed, the major contribution of these studies has been isolation of the neural, hormonal, and maturational bases of risk-taking [indicated within the table as (PB)], as opposed to a direct analysis of development, per se. In this sense, psychobiological research has identified neural structures that become activated in situations of risk, which have in turn been used to draw inferences about the cognitive and affective processes involved with risk-taking. The developmental implications of the findings summarized in Table 3, however, are relatively consistent, and are in concert with general prevalence data, implying developmental increases in risk-taking [i.e., symbolized by (↑)].

Social development and risk-taking

Many address the development of risk-taking with a social developmental perspective. Proponents of this general position emphasize that child development occurs within a social and cultural context, which itself develops, and furthermore, perpetually interacts with the developing child (Bronfenbrenner & Morris, 1998; Magnusson & Stattin, 1998; Rogoff, 1998). Whereas research reviewed in the preceding psychobiological section was significant because it provided the underlying bases of psychological capacities, social developmental research is significant because the socio-cultural environment envelops development. Also like psychobiological research, the social developmental approach provides explanatory mechanisms that are inferred to underlie psychological development, which are reciprocal with psychological processes. That is, the social environment influences the child's developing cognitive and affective processes, which in turn feedback to influence how the child interacts with and interprets the environment. Additionally, these patterns of influence are both direct and indirect. For instance, as will be discussed, many researchers have drawn associations between peer relationships and risk-taking tendencies, which are direct, in that an individual's peers may instigate risk-taking behaviors (e.g., by providing alcohol or cigarettes), but are also indirect, in that peers contribute to the development of cognitive, affective, and psychobiological factors (e.g., risk evaluation, emotional regulation, and sensation-seeking). Further emphasizing reciprocity, these factors influence later peer relationships. Recent research in this area has provided a number of very powerful longitudinal and large sample studies, which have greatly contributed to what is understood of the development of risk-taking.

Jessor and colleagues' Problem Behavior Theory and Dodge and Pettit's Biopsychosocial Model, both of which were reviewed above, are seated primarily within the social developmental perspective. Another influential proposal, Arnett's (1992) theory of broad and narrow socialization (BNS), also draws very direct links between social developmental and risk-taking research. The major claim of the BNS model is that adolescents' abilities to engage in reckless behaviors are bound by the socio-cultural context in which they develop. A broad socio-cultural context is characterized by greater emphases on adolescent autonomy, less clearly articulated rules of behavior, and greater leniency for rule violations. Conversely, narrow socialization is characterized by insistence on group allegiance and clear

Table 3
Psychobiological developmental studies

Study	N[a]	Ages[b]	Method[c]	Risks analyzed	Major finding[d]
Anderson et al. (2000)	2	LONG, 3 months → adult	Case study and PHYS	Theft, lying, alcohol, marijuana, cigarettes	(PB) and (ID)—Although cognitively normal, prefrontal brain-damaged patients showed consistently poor executive control and decision-making in their everyday lives
Giedd et al. (1999)	145	LONG, 4 → 21	PHYS	NA	(PB)—MRI revealed white matter volume increased linearly with age, but gray matter increase was nonlinear and region specific
Caspi et al. (1993)	297	LONG, 9 → 13 → 15	SR	29 risk items (e.g., alcohol, drugs, theft, and crimes)	(↑)—Females who matured early, who attended coed schools were more likely to interact with delinquent peers and were more likely to engage in delinquent behaviors at age 15
May et al. (2004)	12	9–16	EXP and PHYS	NA	(PB) and (=)—*f*MRI revealed sensory and motor pathway activation during risk task, and dorsal and ventral striatum activation while processing reward information, which did not differ with age
Duncan et al. (1985)	5735	12–17	PHYS, INT, and TR	Crimes, runaway, truancy, cigarettes, school trouble	(↑)—Early-maturing males were more likely to engage in deviant behaviors than average- or late-maturing males
Udry (1988)	201	13–16	SR and PHYS	Sex	(PB) and (↑)—Blood sample hormone measures were significantly predictive of risky sexual behaviors
Williams and Dunlop (1999)	99	13–15	SR	31 Items (e.g., crimes, alcohol, cigarettes, and drugs)	(↑)—Those that report maturing early or late also reported more delinquent acts than those who matured on-time
Donohew et al., 2000	2949	14–16	SR	Sex, and risks associated with sex	(ID)—Sensation-seeking and impulsivity correlated with risk-taking, those high on both measures were most likely to take risks
Bauer and Hesselbrock (1999)	257	15–20	INT, EXP, and PHYS	Family history of drug and alcohol use, conduct disorder	(PB) and (ID) and (↑)—Participants with conduct disorder showed decreased P300 EEG activation, related to attention control, and around 16.5-years activation shifted from posterior to frontal
Arnett (1996)—2 studies	479	17–23	SR	16 items (e.g., alcohol, risky driving, sex, and drugs)	(ID)—Sensation seeking, which is theoretically higher in adolescence, was predictive of all types of reckless behaviors
Larson et al. (2000)	49	17–20	EXP and PHYS	NA	(PB)—Test–retest eye-blink conditioned startle response reliability was greater with unfamiliar than familiar stimuli
Zuckerman et al. (1990)	1071	17–21	SR	Cigarettes	(ID)—Sensation seeking was related to cigarette smoking, and high sensation seekers were found more likely to inhale

Miller and Milner (1985)	67	17–49	EXP	Exp risk	(PB) and (ID)—Right frontal-lobe patients were more likely than control subjects to respond with insufficient information, particularly those with right temporal brain-damage
Rolison and Scherman (2002)	171	18–21	SR	19 Risks (NR)	(ID) and (AF)—Sensation seeking predicted risk-taking, but locus of control was not related to risk-taking
Rolison and Scherman (2003)	196	18–21	SR	23 Risks (e.g., drinking and driving, sex)	(ID) and (AF)—Sensation-seeking predicted risk-taking tendency. Benefit perception was positively associated with risk-taking
Bechara et al. (1999)	23	19–58	EXP and PHYS	Exp risk	(PB) and (ID)—Patients with amygdala or ventromedial prefrontal damage were impaired on, the gambling task, and did not generate SCR, suggesting emotional bases
Miller (1985)	92	17–54	EXP	Exp risk	(PB) and (ID)—Patients with right fronto-temporal damage were more likely than controls to take risks with limited information
Miller (1992)	59	26–34	EXP	Exp risk	(PB) and (ID) and (AF)—Frontal lobe damage patients were more impulsive than controls, and took risks with limited information
Smith et al. (2002)	9	Adults (M = 27)	EXP and PHYS	Exp risk	(PB) and (AF)—Participants committed framing effects. PET revealed neocortical dorsomedial activation with loss-frames, and ventromedial activation with gain-frames
Ernst et al. (2004)	17	20–40	EXP and PHYS	Exp risk	(PB) and (AF)—*f*MRI revealed activation of visuo-spatial, conflict monitoring, quantitative, and action pathways during selection (occipito-parietal, dorsal anterior cingulate, parietal cortex, and pre-motor cortex), but cognitive reward processing regions during anticipation (ventral striatum)
Elliott et al. (1999)	5	29–41	EXP and PHYS	NA	(PB) and (AF)—*f*MRI revealed dorsolateral prefrontal cortex activation during simple guesses, and medial orbitofrontal cortex activation during more complex guessing, suggesting links to working memory
Elliott et al. (2000)	9	Adults	EXP and PHYS	Exp risk	(PB) and (AF)—*f*MRI revealed dopaminergic midbrain and ventral striatal activation with rewards, and hippocampus activation with penalties, the role of the amygdala was unclear

(*continued on next page*)

Table 3 (*continued*)

Study	*N*[a]	Ages[b]	Method[c]	Risks analyzed	Major finding[d]
Anderson and Phelps (2001)	31	Adults	EXP	NA	(PB) and (ID) and (AF)—Normal controls and patients with right amygdala damage identified negative words more accurately than neutral words, but left amygdala patients showed no negative bias
Phelps et al. (2001)	12	Adults	EXP and PHYS	NA	(PB) and (AF)—*f*MRI and SCR revealed heightened left amygdala activation to stimuli they were told would be aversive
Horvath and Zuckerman (1993)	447	Adults	SR	Sex, crimes, sports, financial risks	(ID) and (AF)—Sensation seeking predicted sexual and criminal risks, but not necessarily financial or sports risks

[a] Total number of participants, collapsed across reported studies.

[b] Range of ages analyzed, across reported studies, rounded to reported year, LONG = longitudinal assessment.

[c] SR, self-report; TR, teacher report; INT, interview; EXP, experimental task; PHYS, physiological assessment; *f*MRI, functional magnetic resonance imaging, PET, possitron emissions tomography; SCR, skin conductance response.

[d] (↑), Developments that imply increases in risk-taking; (=), similarity between older and younger participants; (PB), physiological basis of risk-taking; (ID), focus on individual differences; and (AF), adult findings.

standards of conduct, violations of which invoke clear and forceful punishments (Arnett, 1992). The breadth of socialization is argued to be culturally and historically variable, and therefore is an effective way to describe cultural, historical, and individual differences. Arnett (1992) further argues that the breadth of the child's socialization interacts with egocentrically biased cognition and biologically based sensation-seeking tendencies, resulting in an increased preponderance of risk-taking in adolescence. There are, however, several limitations of the model. Most specifically, the model's cognitive assumptions have been challenged (i.e., as reviewed, studies have challenged the assumption that adolescents are cognitively egocentric, which the BNS model relies heavily upon). Also, the model largely disregards the role of emotional reactivity and regulation in risk-taking, which, however, might be attributed to the chronology the theory's development (i.e., as reviewed, the emphasis on emotionality and affective decision-making has come since the initial development of the BNS model). These issues aside, the model is a reasonable attempt at cross-perspective integration of risk-taking findings, with strong socio-cultural underpinnings.

Parents

Most researchers interested in social development and risk-taking have analyzed the effects of specific social relationships on risk-taking behaviors. In this tradition, no relationship has been studied more intensively than that between the parent and child. One parenting approach, based primarily on the tenets of Bowlby's, 1969/1982 theory of attachment, has examined the association between parent–child relationship quality, which permeates the parent–child relationship from birth, and adolescent risk-taking tendencies (Allen, Hauser, & Borman-Spurrell, 1996; Allen, Moore, Kuperminc, & Bell, 1998; Berger, Jodl, Allen, McElhaney, & Kuperminc, 2005; Marsh, McFarland, Allen, McElhaney, & Land, 2003). Specifically, insecurely attached adolescents, and particularly those with preoccupied-attachment percepts, who are more prone to extreme relational dysfunction and socially manifested anger, tend to have decreased social competence, and, as a result, are more likely to engage in risky behaviors (Allen et al., 1996; Allen et al., 2002). This preponderance for risk-taking is theoretically due to the individual's cumulative social-representational system; whereas securely attached individuals are capable of successfully negotiating the challenges of adolescence, insecure-preoccupied adolescents have a marked inability to manage the increase in autonomy that inevitably coincides with adolescence. The general findings from a number of studies, which primarily use interview and questionnaire methodologies, are that children with a secure attachment organization engage in fewer risky behaviors than those classified as having insecure-preoccupied attachment organizations (Allen et al., 1996, 1998, 2002). This effect, however, is mediated by maternal autonomy; specifically, Allen and colleagues have also found that insecurely-preoccupied attached adolescents, whose mothers are highly autonomous (who use reasoned arguments in conflictual parent-teen interactions) are more likely to engage in risks, but those whose mothers are less autonomous are actually less likely to take risks (e.g., Allen et al., 2002; Marsh et al., 2003). In this sense, the sheer quality of the parent-adolescent relationship, which was being defined when the initial attachment relationship was forged in the first year of life, impacts the likelihood that an adolescent will take risks.

A fair amount of research has analyzed slightly more specific parenting practices and strategies as antecedents and correlates of risky behaviors (Baumrind, 1971; Darling & Steinberg, 1993; Maccoby & Martin, 1983). Loeber and Dishion (1983) found, using a correlative meta-analytic procedure, that parental family management technique, out of several child behavioral and social factors, was the most powerful and consistent predictor of male adolescent delinquency. Elsewhere, it has been consistently demonstrated that an authoritative parenting style, which is characterized by moderate amounts of both warmth and discipline, is associated with lower levels of prototypical risk-taking behaviors than other parenting styles (Goldstein & Heaven, 2000; Lamborn, Mounts, Steinberg, & Dornbusch, 1991; Steinberg, 1987; Steinberg, Lamborn, Darling, Mounts, & Dornbusch, 1994). For instance, using an extremely large sample of adolescents ($N = 4{,}081$), Steinberg and colleagues have found that authoritative (high warmth, high discipline) and authoritarian (low warmth, high discipline) parented adolescents typically engage in fewer self-reported risk-taking behaviors than indulgent (high warmth, low discipline) or neglectful (low warmth, low discipline) parented adolescents (Lamborn et al., 1991). Longitudinal follow-up further revealed that authoritative and authoritarian parenting tends to lead to decreases in risk-taking, whereas indulgent and neglectful parenting tends to lead to increases in risk-taking (Steinberg et al., 1994).

Slightly more current views propose that this effect might be attributed to authoritative parents use of superior monitoring strategies (e.g., surveillance techniques used to obtain information regarding where their child is, who their child is with, and what their child is doing; Laird et al., 2003a, Laird, Pettit, Dodge, & Bates, 2003b; Patterson & Stouthamer-Loeber, 1984; Dishion & McMahon, 1998; Pettit, Laird, Dodge, Bates, & Criss, 2001). A number of studies suggest that increased parental monitoring, independent of other factors, such as self-esteem and locus of control, is related to decreased adolescent delinquency (Peiser & Heaven, 1996; Rai et al., 2003; Vazsonyi & Flannery, 1997). For example, Pettit, Laird, and colleagues longitudinally demonstrated that children whose parents use psychological control strategies are more likely to exhibit a range of negative outcomes in adolescence (including more risky, delinquent, and anti-social behaviors) than children whose parents use more monitoring strategies (Pettit et al., 2001). Recent research, however, has contested, and subsequently recharacterized, the source of the "parental monitoring" effects (Kerr & Stattin, 2000; Stattin & Kerr, 2000). Stattin and Kerr make the basic argument that the information parents attain regarding their child's behavior may not necessarily derive from active monitoring techniques, but rather, is also the product of a more open parent–child relationship, in which the child is able to self-disclose behaviors more freely.

Taking this into account, Laird, Petit, and colleagues have presented several studies that reveal an inverse relationship between the knowledge parents have regarding their adolescents' activities (obtained generally, as opposed to through active monitoring techniques), and the frequency with which the adolescents engage in risky behaviors (Laird et al., 2003a, 2003b). Specifically, Laird and colleagues (2003a) found that longitudinal decreases in parental knowledge of adolescent behaviors corresponded with increases in delinquency, and vice versa. As Dodge and Pettit (2003) discuss, these findings might be interpreted with a number of directional-effects explanations. For example, assuming a parent-effects model, adolescents may curtail risky behaviors in response to parental knowledge of their behaviors, or parents who monitor may effectively regulate the opportunities their teens have to partake in risks. Reciprocally, assuming a child-effects model, and building upon Stattin and Kerr's (2000; Kerr and Stattin, 2000) argument, increased delinquency may hedge adolescent disclosure of behavior, which may in turn limit parents' knowledge. Assuming a transactional model, adolescent delinquency may harvest negative feelings, which in turn decrease the frequency and quality of parent–child interactions, thereby decreasing parental knowledge of adolescent behaviors. Further bringing these concepts together, Fletcher, Steinberg, and Williams-Wheeler (2004) reanalyzed data from earlier large-scale collection efforts (Lamborn et al., 1991; Steinberg et al., 1994) and tested several potential models of the parent–child-risk-taking relationship. The model of best fit assumed relationships between parental warmth, parental monitoring strategies, parental control strategies, and child engagement in risky acts; however, whereas parental monitoring and control had both direct and indirect effects on child behaviors, the relationship between parental warmth and delinquency was entirely mediated by parents' knowledge of their child's acts. In total, parenting practices generally, and parental warmth, monitoring, and knowledge specifically, affect adolescent engagement in risky or antisocial behaviors.

Peers

Another sub-area of social developmental research has addressed the influence of peers on child and adolescent risk-taking. Classic developmental research demonstrates that there is a developmental trade-off in the amount of time children spend with adults and peers; that is, with development, children spend less time with adults, and more time with similar-age peers (Ellis, Rogoff, & Cromer, 1981). Furthermore, it is popularly acknowledged that peers may pressure one another into risk-taking behaviors, and many self-report studies have consistently demonstrated that children and adolescents that associate with peers that engage in risky behaviors are themselves more likely to engage in risky behaviors (Benthin et al., 1993; Blanton, Gibbons, Gerrard, Conger, & Smith, 1997; Dishion, Patterson, Stoolmiller, & Skinner, 1991; Gerrard et al., 1996; La Greca, Prinstein, & Fetter, 2001; Prinstein, Boergers, & Spirito, 2001; Rubin, Bukowski, & Parker, 1998; Santor, Messervey, & Kusumaker, 2000). For instance, Prinstein et al. (2001) demonstrated, with a moderately sized sample of adolescents ($N=527$, in 9th- to 12th-grade), that those who engage in prototypical risk-taking behaviors (e.g., drinking alcohol, smoking cigarettes, interpersonal aggression, and drug use) are more likely to have friends that engage in similar behaviors. Adopting an even more general approach, Gardner and Steinberg (2005) had adolescent (13–16-years), young adult (18–22-years), and adult (24+ years) participants play a computerized risk-taking game with or without same-age peers present. The data revealed that participants, and particularly the adolescent participants, who played the game with peers present were far more risky in the experiment than those who played the game alone. This and the above studies substantiate the argument that peers facilitate risk-taking behaviors.

This general peers-influence approach, however, has been criticized because the relationship between one child's risk-taking behaviors and his peers' risk-taking behaviors is correlational, and therefore cannot be interpreted as diagnostic of peer influence. The major argument is that peers not only influence one another's behaviors, but children and adolescents select the peers they associate with as a function of personal similarities, and as such, children inclined towards risks tend to identify and associate with others who are similarly inclined towards risks (Bauman & Ennett, 1996). Another related argument suggests that children and adolescents tend not to be exceptionally accurate in their recollection of their peers' behaviors. Kandel (1996) used an algebraic model of interpersonal influence to demonstrate that traditional research has over attributed the influence of peers, and controlling for selection effects and distortion of recollection, the power of peer influence on risk-taking behaviors decreases significantly. Similarly, Jaccard, Blanton, and Dodge (2005) reported a short-term longitudinal study (i.e., one-year) that teased apart peer influence and selection effects, and found that previous correlational studies overestimate peer influence effects. This general criticism does not entirely debase the argument that peers play a role in risk-taking behaviors; however, it does reestablish the peer–risk-taking relationship as bi-directional.

Another relevant peer-oriented approach has considered the effects of sociometric status on risk-taking and delinquent behaviors. Generally, this research has found that children who are classified as "rejected by peers" engage in significantly more risky, externalizing, and aggressive behaviors (Dishion et al., 1991; Laird, Jordan, Dodge, Pettit, & Bates, 2001; Miller-Johnson, Coie, Maumary-Gremaud, Lochman, & Terry, 1999). Laird et al. (2001), for instance, demonstrated that externalizing behaviors in early childhood, peer rejection in childhood, and associating with antisocial peers in adolescence are related to increased externalizing behaviors in adolescence; however, controlling for the stability of externalizing behaviors revealed that peer rejection is a unique predictor of adolescent externalizing behaviors, but that associating with antisocial peers is not.

Parent–peer interactions

The influences parents and peers have on child and adolescent risk-taking are not entirely as discrete as characterized thus far. In fact, many note the interactive effects of parents, peers, and other socializing agents on the development of risk-taking tendencies (Ary, Duncan, Duncan, & Hops, 1999; Dishion, Nelson, & Bullock, 2004; Dishion et al., 1991; Flannery, Williams, & Vazsonyi, 1999; Kim, Hetherington, & Reiss, 1999; Lansford, Criss, Pettit, Dodge, & Bates, 2003; Rai et al., 2003). Lansford and colleagues (2003), for example, found that parenting tactics, peer affiliation, and peer antisocial behaviors interact. That is, the effects of negative parenting skills on risk-taking behaviors seem to attenuate with positive peer relationships; however, the effects of negative parenting skills are intensified by affiliation with antisocial peers. Similarly, Flannery and colleagues (1999) found an integral relationship between peer interaction in after-school hours, parental monitoring, and delinquency; specifically, adolescents that spent more after-school time with friends, and were parentally monitored less, had increased rates of engagement in risky and delinquent behaviors. Finally, in a remarkably comprehensive study, Dishion and colleagues (1991) found that parental monitoring and disciplinary strategies at 10-years were related to associations with antisocial peers at 12-years, which in turn, were predictive of engagement in a relatively wide range of antisocial behaviors. In this sense, there seems to be a directional social developmental effect; parenting tendencies seem to predict peer interactions, which themselves seem to predict adolescent risk-taking, which coincides with increased autonomy with development. In total, these studies maintain the general idea that parenting techniques and peer pressures influence risk-taking behaviors; however, they further note their interactive nature.

Individual differences and development

The social developmental data discussed actually impinge far more directly on individual than developmental differences. That is, most of these studies describe the individuals that are most likely to develop risk-taking tendencies, rather than describe the development of those tendencies, per se. Many of these studies have utilized very powerful longitudinal designs, which afford the prediction of latter categories (i.e., greater or lesser risk-taking) with earlier categories (i.e., authoritative vs. neglectful parented children, more vs. less parental monitoring, peer rejection vs. peer acceptance); however, even these approaches are dependent upon correlative designs and individual difference categorizations, and therefore are unable to explain the actual developmental mechanisms of risk-taking. This limitation might be attributed to the tendency towards perspective isolation mentioned in the introduction, and may be alleviated by an approach that emphasizes the interaction of cognitive, affective, and social processes. In this sense, future work must investigate the degree to which individuals with different social histories (e.g., a more vs. less secure relationship tendency, more vs. less parental monitoring, or peer acceptance vs. rejection) vary in their assessments of potentially risky situations (e.g., their estimates of risk probabilities and values, and reactions to emotional ramifications). Doing so will disentangle the degree to which the development of risk-taking behaviors may be attributed to the development of cognitive and affective decision capacities, and the degree to which these might be attributed to social developmental influences. Furthermore, social factors themselves might be characterized as potential risk-taking outcomes with distinct subjective value. As a conceptual example, adolescents who believe that their parents will discover (i.e., through monitoring, control, or self-disclosure) and will disapprove of a risk, likely factor that information into their decision of whether or not to take the risk, assuming parental discovery and disapproval matters to the adolescents. Therefore, children's social interactions, and particularly interactions with parents and peers as indicated by the reviewed research, influence the development of cognitive and affective processes and preferences; however, precisely how these developmental constructs and processes interact to predict risk-taking is yet unclear.

Assuming a strict social developmental perspective, with all else held equal, as children progress from childhood to adolescence they are granted increased autonomy. As Darling and Steinberg (1993) argued, the adolescent's social environment is different from the child's, in the sense that social roles are renegotiated and the adolescent's willingness to be socialized must be taken into account. Perhaps it is not inappropriate to think of children's immediate social atmosphere as lying upon risk-taking "constraining → facilitating" continuum. That is, at some point in development, social constraints loosen, through a conjoined developmental decrease in parental restriction and increase in peer facilitation, and *all else being equal*, with age, the likelihood that the child will take a risk, given *purely* social circumstances, increases. In this sense, relatively young children likely have the necessary physical abilities, cognitive fallibility, and impulsivity that would predispose risk-taking, but a more restrictive social environment that inhibits risk-taking. An adolescent, on the other hand, despite greater cognitive and affective decision-making skills and emotional regulation strategies, is more likely to have a social environment more conducive to risky behaviors. This, of course, is not to assume that all children will engage in risks once they are given enough free reign from parents or pressure from peers to do so; rather, as has been argued throughout, all else can rarely, if ever, be held entirely equal, and risk-taking is the potential product of the correct interaction of cognitive, emotional, biological, and social factors (e.g., cognitive fallibility, emotional impulsivity, biological pleasure seeking, and social facilitation). These factors, furthermore, are to some degree interdependent. For instance, how parents monitor their children, and how peers pressure one another, is likely a function of the parents' and peers' estimations of the child's decision-making competencies; yet, those very competencies are to some extent attributable to the strategies parents have used, and the acceptance peers have shown, throughout the child's development.

Summary

Those that adopt a social developmental perspective emphasize the importance of the all-encompassing socio-cultural context in which development occurs. Research has demonstrated that active parental monitoring, and more generally, authoritative parenting, parental knowledge of child behaviors, and a secure parent–child relationship, are related to decreased adolescent risk-taking behaviors. A long line of research has also demonstrated that adolescents are more likely to engage in a risky behavior if the peers they associate with do (although research has also demonstrated that some of the variance attributed to peer influence is likely due to peer selection effects and distortion of recollections of peers' behaviors), and that children rejected by their peers are more likely to take risks. Moreover, with development children are granted increased autonomy, and with time are allowed to make more decisions, and consequently take more risks, than was possible earlier in development.

Table 4 summarizes the social developmental studies that have been reviewed. As mentioned, many of these studies have benefited from longitudinal analyses and large sample sizes. As can be seen in the "Major Findings" column of Table 4, however, the vast majority of these studies have described individual differences in development, rather than actual developmental processes or mechanisms. In this sense, these studies can be used to estimate whether a given individual, with a specific social developmental history, will engage in a risk-taking behavior; however, they are unable to explain the emergence, increase, and peak of risk-taking in adolescence. The general principles of parental monitoring and peer risk facilitation, though, can be combined with the general principle that with development the former decreases and the latter increases, as an explanation for why risk-taking behaviors increase in adolescence.

General conclusion

The current paper reviewed research that has examined the development of risk-taking from four perspectives. Historically, adult risk-taking has been analyzed within a cognitive framework, which makes use of probabilistic models of thought, and characterizes risks as the product of decision analyses. This perspective has influenced cognitive developmentalists, who have investigated the decision-making capacities of children and adolescents. The most general findings from this line of work have been that cognitive development, including development of cognitive risk appreciation, improves in some senses through childhood and into adolescence. Others have considered the role of emotions in risk situations. The general findings from this perspective have been that affective decision-making capacities and emotional regulation skills increase with age through adolescence, and that impulsivity, which is largely considered the undesirable by-product of insufficient emotional regulation, decreases through childhood, adolescence, and into adulthood. Recent psychobiological research has considered the neurological, biochemical, and hormonal bases of decision-making tendencies and risky behaviors. The general findings from this perspective suggest that neurological and physical maturation, generally, and shifts in relative inhibitory and excitatory neurotransmission and increased growth and sex hormone levels,

Table 4
Social developmental studies

Study	N[a]	Ages[b]	Method[c]	Risks analyzed	Major finding[d]
Ellis et al. (1981)	436	1–12	OBS	NA	(↑)—Percent of observations with adult companions decreased with age, while percent of observations with child companions increased
Laird et al. (2001)	585 (families and peers)	LONG, 5 → 14	SOCIO, SR, and PR	General externalizing problems	(ID)—Early externalizing, peer rejection, and involvement with antisocial peers contributed to later externalizing problems. Peer rejection was an especially stable predictor beyond other factors
Pettit et al. (2001)	440 (families)	LONG, 5 → 14	PR and TR	General delinquency	(ID)—Proactive parenting anteceded parental monitoring, and harsh parenting anteceded parental psychological control. High monitoring was associated with decreased delinquency
Miller-Johnson et al. (1999)	327 (African-American)	LONG, 3rd → 6th → 8th → 10th-grd	SOCIO and SR	Crimes	(ID)—Peer rejection and aggression in childhood interacted to significantly predict adolescent delinquency, and “early-starter” delinquency
Dishion et al. (1991)	206 (males, families)	LONG, 9–10 → 11–12	OBS, INT, PR, TR, SOCIO, and school records	General antisocial behaviors (e.g., lying, theft, and disobedience)	(ID)—Early antisocial behaviors were positively related with later antisocial behaviors, which were inversely related to academic skills and social adjustment. Increased early parental monitoring and discipline predicted decreased associations with antisocial peers, which predicted increased engagement in antisocial behaviors
Dishion et al. (2004)	206	LONG, 9–10 → 13–14 → 15–16 → 17–18	INT and OBS	Marijuana use, antisocial behaviors	(ID)—Interactions with deviant peers were reciprocally associated with degraded parental family management, and both predicted risk-taking

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Table 4 (*continued*)

Study	N[a]	Ages[b]	Method[c]	Risks analyzed	Major finding[d]
Kim et al. (1999)	654 (families)	10–18	SR, PR, OBS and sibling report	6 items (General externalizing)	(ID)—Family process variables predicted externalizing behaviors directly, and indirectly through delinquent peers associations. Maternal negativity and parental monitoring were significant predictors of externalizing
Patterson and Stouthamer-Loeber (1984)	206 (families)	4th-, 7th-, and 10th-grd	SR, INT, and OBS, Court records	General delinquency	(ID) and (↑)—Decreased parental monitoring (which concurs with age) was associated with greater adolescent delinquency
Lansford et al. (2003)	362 (families)	LONG, 5th → 6th → 7th-grd	PR, INT, and TR	General externalizing behaviors	(ID)—Effects of negative parenting on externalizing behaviors were attenuated by positive peer relationships, and were exacerbated by antisocial peer relationships
Flannery et al. (1999)	1170	6th- and 7th-grd	SR	18 Delinquency items (e.g., Drug use, aggression)	(ID)—Those that spend after-school time with peers reported less parental monitoring, and more delinquency
Vazsonyi and Flannery (1997)	1,170	6th- and 7th-grd	SR	13 Delinquency items (e.g., lying, cheating, and theft)	(ID)—Family process variables and school variables were associated with delinquency
Jaccard et al. (2005)	1692 (peer dyads)	LONG, 7th–11th → 8th–12th grd	SOCIO and INT	Alcohol, Sex	(ID)—Participants were more likely to engage in risky behaviors if their friends had, but the effect was weak, and therefore peer influence effects might be attributed to selection or other confound
Rai et al. (2003)	1279 (African-Americans)	13–16	SR	Various (e.g., Sex, aggression, cigarettes, alcohol, and drugs)	(ID) and (↑)—Parental monitoring and peer involvement in risk-taking both predicted participants' risk-taking, which increased with age
Gardner and Steinberg (2005)	306	13–16, 18–22, and adult	EXP and SR	Experimental risk	(↑)—Participants that played an experimental risk game with same-age peers present, particularly teens, were more likely to take risks than those who played the game alone

Goldstein and Heaven (2000)	92	13–18	SR	Various (e.g., theft, aggression, and vandalism)	(ID)—Parental bond predicted delinquency; perceptions of parental love withdrawal were associated with increased delinquency
Stattin and Kerr (2000)	703	14	SR and PR	Alcohol, drugs, vandalism, theft, and aggression	(ID)—Child self-disclosure of behaviors was found more predictive of risk-taking tendencies than parental monitoring
Kerr and Stattin (2000)	1186	14	SR and PR and TR	15 items (e.g., theft, drugs, vandalism)	(ID)—Parental monitoring was related to teen delinquency and school problems, but the source of the effect was better attributed to teens self-disclosure of behaviors
Laird et al. (2003a)	426	LONG, 14 → 19	INT or SR	General antisocial tendencies	(ID)—Higher parental knowledge predicted lesser adolescent antisocial behavior, but greater relationship enjoyment and involvement
Laird et al. (2003b)	396	LONG, 14 → 18	INT and SR	General delinquency	(ID) and (↑)—Delinquent behavior increased with age and was negatively correlated with parental knowledge. Those with the most decreases in parental knowledge had most increases in delinquency
Allen et al. (1996)	142	LONG, 14 → 25	INT and SR	Crimes, drug use	(ID)—Adolescents hospitalized for psychopathology were more likely to have insecure attachment organization, and both were associated with later criminal and antisocial behaviors
Allen et al. (2002)	125	LONG, 15 → 18	INT and SR	Crimes	(ID)—Insecure preoccupied attachment at 16-years interacted with maternal autonomy to predict delinquency at 18-years

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Table 4 (*continued*)

Study	*N*[a]	Ages[b]	Method[c]	Risks analyzed	Major finding[d]
Marsh et al. (2003)	123 (teens and mothers)	9th- to 10th-grd	INT, OBS, and SR	Early sexual behavior, drugs	(ID)—Adolescents with preoccupied attachment were more likely to take risks if maternal autonomy was high, but were more likely to have internalizing symptoms if maternal autonomy was low
Berger et al. (2005)	146, 52 (fathers), and 120 (peers)	14–17	INT, SR, PR, and peer report	General externalizing	(ID)—Those with insecure attachment organization had greater discrepancy between self- and other-reports of problems
Fletcher et al. (2004)	2568	14–18	SR	Alcohol, cigarettes, soft drug use, and crimes	(ID)—Parental warmth predicted adolescent behavior problems only through parental knowledge, but parental control and monitoring affected problem behaviors directly and indirectly
Allen et al. (1998)	131	14–18	INT, PR, and peer report	Crimes, aggression	(ID)—Those with a preoccupied attachment organization were found more likely to have internalizing problems and deviant behavior
Blanton et al. (1997)	463 (families)	LONG, 14 → 15 → 16	SR and PR	Alcohol, cigarettes	(ID)—Immersion in a peer group that takes risks leads to increased risk-taking. Teens with positive parental relationships were more likely to associate with peer groups that take risks
Prinstein et al. (2001)	527	9th- to 12th-grd	SR	7 risks (e.g., drugs, cigarettes, alcohol)	(ID)—Participants who engaged in risky behaviors tended to have friends that did as well
Lamborn et al. (1991)	4081	9th- to 12th-grd	SR	Various (e.g., Alcohol, cigarettes, drugs, and crimes school misconduct)	(ID)—Authoritatively parented adolescents are more likely to be psychosocially competent, and are less likely to engage in problem behaviors than those classified as parentally neglected

Steinberg et al. (1994)	2353	LONG, Follow-up Lamborn et al., 1991	SR	Various (e.g., Alcohol, cigarettes, school misconduct, drugs, and crimes)	(=) and (ID) and (↑)—Parenting tendencies were relatively stable, and parentally neglected adolescents were even more likely to engage in delinquent acts at 1-year follow-up
Peiser and Heaven (1996)	177	15–16	SR	Aggression, vandalism, theft	(ID)—Inductive parenting predicted reduced delinquency; Punitive parenting predicted increased delinquency. Locus of control and self-esteem did not mediate effects
La Greca et al. (2001)	250	15–19	SR	Cigarettes, alcohol, sex, and drugs	(ID)—Participants identified as "burnouts" and "nonconformists" tended to take more risks and had more friends who took the risks, "brains" tended not to take health risks, nor had friends who did
Ary et al. (1999)	196 (families)	LONG, 15 → 16 → 17	SR and PR	Various (e.g., vandalism, theft, alcohol, cigarettes, marijuana, and sex)	(ID)—Model that assumes family conflict influences family involvement, which influences parental monitoring, which directly and through peer deviance influence problem behaviors
Santor et al. (2000)	145	16–18	SR	Various (e.g., alcohol, cigarettes, drugs, and sex)	(ID)—Participants susceptible to peer pressure and peer conformity were more likely to take risks, popularity was less predictive

[a] Total number of participants, collapsed across reported studies.

[b] Range of ages analyzed, across reported studies, rounded to reported year, LONG, longitudinal assessment.

[c] SR, self-report; PR, parental report; TR, teacher report; INT, interview; EXP, experimental task; SOCIO, sociometric peer acceptance ratings or nominations; OBS, and observational.

[d] (↑), social developments that imply increases in risk-taking; (ID), focus on individual differences.

specifically, may contribute to risk-taking development. Social developmental research has considered the socio-cultural antecedents and correlates of risky and delinquent behaviors. The general findings from this perspective indicate that individual differences in the general parent–child relationship (e.g., parent–child attachment and parental knowledge of child behaviors), parenting strategies (e.g., parental warmth and discipline), the peers a child associates with (e.g., whether they engage in antisocial behaviors), and sociometric status (e.g., whether the child is rejected), are all related to risky behaviors.

In total, the reviewed studies demonstrate that the cumulative probability that a developing individual will engage in a risk is influenced by cognitive skills, affective tendencies, biological underpinnings, and the socio-cultural surroundings. All else being equal, the probability of risk-taking behaviors is proposed to increase as an individual enters adolescence as a function of psycho-physiological development and changes in the socio-cultural environment. Likewise, all else being equal, the probability of risk-taking behaviors decreases as cognitive capacities and emotional regulation skills improve. In this sense, risk-taking is particularly probable if social and biological developments occur before cognitive and emotional skills have matured.

This interactive stance lends itself to consideration of individual differences. As the above reviewed literature suggests, risk-taking behaviors will be more prevalent, and will emerge earlier, if cognitive capacities and emotional regulation skills are deficient, if physiological developments occur earlier, and if the social atmosphere is relatively conducive to risk-taking. A useful conceptual exercise is to consider the development of individuals at opposite ends of the spectrum on each of the reviewed developmental constructs. Imagine, for instance, an adolescent with superior cognitive and affective decision-making capacities and emotional regulation skills, healthy and on-time physical and neurological development, vigilant and warm parents who have knowledge of his behaviors, social acceptance, and a peer-group that does not engage in antisocial behaviors. Conversely, imagine an adolescent with less efficient cognitive decision-making capacities, inferior emotional regulation skills, high impulsivity, early physical maturation or damaged neural structures, an insecure relationship with parents, limited parental monitoring, peer rejection, and association with antisocial peers. Research from each of the perspectives suggests the developmental progressions for each of these individuals will differ radically, and all of the research reviewed suggests that the latter child is far more likely to engage in risk-taking behaviors, and is more likely to do so earlier, than the former. Of course, this exercise represents potential outliers, a teen very much at risk for risk-taking, and another that has limited susceptibility. The general proposal, however, is flexible in the sense that deviations from the norm in any of the perspectives (i.e., cognitive risk-appreciation, emotionality, affective decision skill, psychobiology, parent–child relationship, parental monitoring, and peer interaction) will result in an altered developmental path.

Each of these developments likely contributes to the emergence, increase, and peak in risk-taking seen in adolescence; however, the current state of the research, and relatively strict perspective isolation that has permeated the field, constricts identification of precisely how these factors *interact* to result in risk-taking. That is not to say that these factors, and how they interact cannot be specified; in fact, future data, if collected with an integrative approach in mind, could inform a model that makes precise predictions of the probability that a given individual will engage in a risk-taking behavior, given factors from each perspective, and their interactions. What the field truly needs is an extremely ambitious study, or set of studies, which monitors the environment and biology of a sample of developing children, notes the influence of that environment and biology on developing cognitive and affective processes, and analyzes how frequently particulars within the sample engage in risk-taking behaviors.

It must also be kept in mind, as discussed in the cognitive developmental section, that risk-taking behaviors are not entirely foolhardy, and although by definition associated with some probability of undesirable consequences, may be the most rational course of action given one's priorities. That is, although by definition potentially harmful, prototypical risk-taking behaviors might be engaged because they are also associated with some probability of desirable results. Future studies could dramatically benefit from a conceptualization that characterizes the potential social, biological, emotional, and cognitive consequences of risks, as potential *outcome values* to decision-making and risk-taking behaviors. Analysis of how those multi-perspective outcome values, along with outcome probabilities, are addressed by children, adolescents and adults, would certainly inform our understanding of risk-taking development.

Conclusion

Much of the reviewed research is quite recent, and more is continually emerging. A trend that may be forecasted is progress within, as well as a greater integration of, each perspective. Future studies and theories designed to address the development of risk-taking should make greater use of findings across the research areas. Although a substantial amount of research has considered the emergence of risk-taking, precisely how social, psychophysiological, affective, and cognitive factors interact to contribute to the development of risk-taking is a problem future studies should strive to solve.

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