The Puzzle of Adolescent Risk Taking

An Experimental-Longitudinal Investigation of Individual, Social and Cultural Influences

Ivy Defoe

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An Experimental-Longitudinal Investigation of Individual, Social and Cultural Influences

De Puzzel van Risicogedrag onder Adolescenten
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(met een samenvatting in het Nederlands)

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For my sisters

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Chapter 1
General Introduction

"I wish that there were no age between ten and three and twenty or that youth would simply sleep out the rest; for there is nothing in between but getting wenches with child, wronging the ancestry, stealing and fighting…" Shakespeare (1623; Act III, Scene 3). Although current scholars are currently increasingly considering a more nuanced view on adolescence, for many, this famous historical quote might still be considered as a contemporary illustration of the characterization of adolescence as the stereotypical period of "reckless" (*norm-breaking*) risk behaviors. That is, *the* period of exploration, experimentation and excitation. The current dissertation centers around the *puzzle* of adolescent risk-taking, and aims to identify individual, social and cultural factors related to such risk behaviors which either show a dramatic increase or a peak during adolescence.

1.1 Adolescent Risk Behaviors

Although Shakespeare was perhaps one of the first to popularize risk-taking attributes to the adolescent period via his literary work, it was the psychologist, Stanley Hall who pioneered scientific research dedicated to the understanding of the notorious adolescent period. Over a century ago Hall eloquently made the following statement *"Adolescence is the period when the very worst and best impulses in the human soul struggle against each other.."* (Hall, 1904). Interestingly, this quote sketches a more nuanced and balanced definition of adolescence compared to the quote of Shakespeare. One interpretation of this quote is that adolescence encompasses both *maladaptive* and *adaptive* functioning, in other words challenges/vulnerabilities as well as strengths/opportunities. On the one hand, the very apparent *vulnerabilities* of adolescence in modern times consist of risk-taking behaviors, such as experimentation with drugs and delinquency, as the initiation (Ge, Brody, Conger, Simons, 2006) and peak of many of these behaviors occur in adolescence (Steinberg, 2015). For example, binge drinking, tobacco use, are all more common in adolescence compared to any other developmental phase (Steinberg et al., 2008; Steinberg, 2015). Although such risk behaviors among adolescents have decreased over the last years, adolescents are still overrepresented in these harmful behaviors in the Western part of the world (Eaton et al., 2011; Steinberg, 2015). On the other hand, scholars have begun to point out that most individuals transition to and from adolescence without such storm and stress, and have highlighted some of the positive aspects of adolescents. For example, the adaptive gains in adolescence include greater cognitive control, flexibility, logical reasoning and information processing skills (Crone & Dahl, 2012; Steinberg, 2009).

Moreover, although adolescent risk-taking has always had more of a negative rather than a positive connotation, some theorists (although a minority) have also even emphasized the positive developmental opportunities of risk-taking. For example,

a few decades ago it was the psychologist Diana Baumrind who put forward that "*Willingness to take personal risks for the sake of development is a mark of maturity in adulthood. Some risk-taking activities may be valued by adolescents because they are thought to prepare them to assume adult status.*" (Baumrind, 1987; p. 119). Accordingly, adolescent risk-taking, can be viewed as testing the boundaries, which includes a certain degree of experimental, explorative behavior perhaps as an expression of independence from parents and taking on more adult-like behaviors in this process. Thus in this sense, some types of risk-taking can be viewed as normative and serve an adaptive function within a particular *culture*.

Biology also plays a role in adolescent experiences. During adolescence, the onset of pubertal maturation, which typically begins between ages 9 to 12 (but approximately 1-2 years earlier in girls versus boys) in the Western World (Crone & Dahl, 2012), brings about physical changes that equip adolescents with reproductive capacity (biological maturity), yet they are not allowed to take on most adult roles, reflecting a socially immature status (Moffitt, 1993). This might cause some adolescents to rebel (against their parents and society more generally) and engage in risk behaviors (Moffitt, 1993). More recent research, however, also shows that pubertal maturation (biological factor) triggers increased socioemotional responsiveness, specifically heightened peer presence (social factor) and reward- and sensation-seeking (affective factors) behaviors which could potentially all lead to risk-taking behaviors (despite some of the adaptive consequences of these risk behaviors noted earlier) (Braams, van Duijvenvoorde, Peper, Crone et al., 2015, Dahl & Forbes, 2010; Gardner & Steinberg, 2005). It is further hypothesized that in particularly affectively laden contexts (e.g., during peer presence) such hypersensitivity of the socio-emotional system in the brain (e.g., ventral striatum) might override the functioning of adolescents' less developed cognitive control system of the brain, which is governed by the prefrontal cortex (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Figner & Weber, 2011; Gladwin, Figner, Crone, & Wiers, 2011; Somerville & Casey, 2010; Steinberg, 2007). This neuroscience/biological view of heightened adolescent risk-taking that is typically examined using fMRI methodology is currently also one of the prevailing theoretical perspectives in this branch of research.

Considered together, adolescent risk-taking has both biological and psychosocial roots, and can be viewed as normative and adaptive. However, particularly for adolescents, risk behaviors might come with a host of (long term) detrimental consequences, and as such often interfere with, and override, any potential positive gains of risk-taking. For example, becoming addicted to a substance or being incarcerated for juvenile delinquency are dire consequences of risk behaviors in adolescents. As for addiction, adolescence has been identified as a highly susceptible phase for becoming addicted to substances (Chambers, Taylor & Potenza, 2003; Keshavan & Giedd, 2008). Additionally, risk behaviors can even lead to premature death in adolescents, considering that as a result of such (preventable) reckless risk behaviors, mortality rates show at least a 200% increase from childhood to

adolescence (Dahl, 2004). Moreover, psychological distress of the society (e.g., societal anxiety) and costly expenditures for the juvenile justice system could also be a negative consequence of juvenile delinquency and adolescent drug addiction. Considering these potential long-term, detrimental and diverse effects that risk behaviors can have particularly for adolescents (and sometimes the entire society as a whole), who still have the their entire lives ahead of them, research on identifying risk and protective factors in adolescent risk-taking is crucial. Such research on adolescents is not only crucial because risk behaviors typically debut and peak during the adolescent period, but considering adolescents' psychological gains as described above, could suggest that the adolescent period might also provide an optimal window for effective application of prevention and intervention programs.

1.2 Brief aims

To this end, while paying close attention to individual and developmental differences, the current dissertation aimed to investigate (a) to what extent experimental scientific evidence shows support for risk-taking being a unique feature of adolescence, (b) the role of peers versus parents and siblings in adolescent risk-taking while accounting for individual factors (biological, cognitive, affective, gender, age/adolescent phase), and (c) ethnic and cross-national differences in the links between risk factors and risk behaviors. Furthermore, some chapters open with quotes about the motives of adolescent risk-taking, which were provided by the adolescents who took part in the research project, on which the current dissertation is based.

1.3 Conceptualizations of *Adolescen*ce and *Risk-taking*

For the current dissertation most of the adolescents are between the ages 12-18 , which is the typical period that individuals in the Western world transition in and out of high school. In the current dissertation, adolescence is further divided into two phases, early-adolescence (10-14 years old), mid/late-adolescence (15-18 years old) (Steinberg et al., 2008; Steinberg & Morroris, 2001). A classic and comprehensive review of the development of risk-taking conceptualized risk-taking in the developmental literature as: "*engagement in behaviors that are associated with some probability of undesirable results"* (Boyer, 2006; p. 291). The current dissertation adheres to this definition when investigating real-world risk behaviors. For example, smoking is regarded as a risk behavior because it could potentially lead to cancer, which is considered as an "undesirable outcome". Accordingly, *choosing* to smoke can be viewed as a consequence of risky decision making (Petraitis et al., 1995 Reyna & Rivers, 2008; Reyna & Farley 2006). New methodologies such as experimental risky

decision making tasks are increasingly being used to measure adolescent risk-taking. In these tasks risk taking is typically defined as: *choosing the option with the widest outcome variability* (Figner & Weber, 2011; Weber, 2010). In the current dissertation, the term risk-taking encompasses real-world *risk behaviors*, as well as *risky decision making* as assessed via experimental risky decision making tasks.

1.4 Theoretical framework: Theory of Triadic Influence (TTI)

The TTI is a developmental meta-theory that views adolescent risk behavior as the outcome of decisions/intentions, and it was initially designed to explain onset and change in adolescent substance use (smoking and alcohol use) (Flay, 2009; Flay & Petraitis, 1994; Petraitis et al., 1995). The TTI posits that particularly adolescents have a tendency to underestimate the personal risks that could result from health-compromising behaviors, and that this can be attributed to factors such as under-developed cognitive and affective skills, and deviant peer influences, as these factors make adolescents susceptible to health risk behaviors (e.g., substance use) (Flay, Snyder, & Petraitis, 2009). More recently, the TTI has been used as a framework in research examining other addictive behaviors such as gambling, or other risk behaviors such as delinquency and risky traffic behavior (for an overview see e.g., Snyder & Flay, 2012).

The TTI describes how 3 "streams/domains of influence", the (1) Intrapersonal/individual, (2) Social/normative, and (3) Cultural/environmental, affect the initiation and development of adolescent risky behaviors. These multiple domains of risk-factors are inspired by numerous sociological and psychological theories (e.g., social learning theories, Theories of Planned Action) (Flay, 1999; Flay & Petraitis, 1994; Petraitis et al., 1995). Importantly, the TTI further emphasizes that risk factors from the above-described three domains should simultaneously be taken into account, as risk-factors tend to be interrelated (e.g., Flay, Petraitis, & Hu,1995). In the current dissertation the TTI is used as a broader overarching theoretical framework, and some of the more specific sociological and psychological theories that the TTI is based on are also considered. In the current paragraph, the more general framework of the TTI is described, and some of the more specific theories that the TTI is inspired by will be described when the specific papers in the current dissertation are discussed.

The TTI further suggests that the risk factors in each domain of influence have direct, indirect, and reciprocal (or feedback loops) effects on adolescent risk behaviors. Ultimately, these risk factors influence adolescents' decisions (Gerrard, Gibbons, Houlihan, Stock, & Pomery, 2008; Reyna & Rivers, 2008; Steinberg, 2008) or intentions (Fishbein & Ajzen, 1975 in Flay et al., 2009) and prior experiences with the respective behaviors, which all have direct effects on engagement in risk behaviors (Flay et al., 2009). Moreover, similar to ecological models (e.g., Bronfenbrenner, 1977) , TTI proposes that intrapersonal/individual factors are embedded within social factors, which are in turn embedded within broader cultural-environmental factors that contribute to attitudes about risk-behaviors (Snyder & Flay, 2012). Finally, each domain of influence is explained in further detail below.

Intrapersonal/individual factors

In the current dissertation, the broader term "individual" is used instead of "intra-personal". Individual factors can include factors related to the adolescent's biology (e.g., puberty) and personality (e.g., impulsivity), affective states (e.g., thrill/sensation seeking), and cognitive functions (e.g., inhibition), and many more. Accordingly, the above-mentioned individual factors are some of the risk factors that are considered in the current dissertation. The TTI further postulates that these individual factors influence self-efficacy and internal motivation to engage in risky behavior, and eventually, via decision making processes these individual factors ultimately predict risk behavior (Petraitis et al., 1995). Two individual TTI-based factors that re-occur in the papers included in the current dissertation are gender and age (adolescent phase). The TTI is described as a developmental theory that recognizes that causes or particular paths from risk factors to engagement in risk behaviors, might differ for early versus middle versus late adolescents and for boys versus girls (Flay et al., 1995). For example, many (antisocial) risk-taking behaviors (e.g., delinquency) have been shown to be most prevalent in boys (see e.g., Puzzanchera, Adams & Hockenberry, 2012), and a peak in many risk behaviors is particularly evident in mid-adolescents (Steinberg 2014; 2015), deeming gender and adolescent phase differences fundamental moderators to consider. However, testing for gender and adolescent phase, or gender by adolescent phase moderation effects require large samples, which particularly experimental studies often fail to have. In the current dissertation, in both the longitudinal and experimental studies, gender and age (or adolescent phase) are either controlled for, or investigated as moderators, and when possible and supported by empirical findings or theory, gender by adolescent phase moderation effects are investigated also. Finally, and importantly, the TTI also emphasizes that individual and social factors in adolescents might interact with each other in predicting adolescent risk behaviors. For example, early adolescents (versus middle or late adolescents) might be more susceptible for deviant peer influences (Berndt, 1979; Steinberg & Monahan, 2007). Below more detailed information on the importance of social factors is provided next.

Social factors

According to the TTI, social factors can include peer influences, but also parent influences. Specifically, the TTI postulates that peer influences typically comprise adolescents' perception about the normativeness (i.e., perceived norms) of risky behaviors within their peer group, or pressure to engage in such behavior (Flay et

al., 1995). Thus these are two potential mechanisms through which peers influence adolescents' behaviors. Both of these forms of peer influences are investigated in the current dissertation, as well as affiliation with deviant friends and mere peer presence.

Peers

In the current dissertation, peers can refer to both friends and classmates, and the words peers and friends are used interchangeably. When zooming in on peer influences, particularly for adolescents, social experiences with peers are intertwined with reward-related factors (e.g., Forbes & Dahl, 2010; Steinberg, 2008). In fact, more generally, peers have been considered as "socially rewarding" during adolescence, and thus adolescents are highly motivated to engage in peer socialization (Steinberg, 2008). Peer socialization could suggest that adolescents want to be accepted by their peers (Evans, 2006; Simons-Morton & Farhat, 2010) and this could explain why their peers' opinions and evaluations become increasingly important (Harris, 1995). Hence peer relations are essential for understanding adolescent behavior. The general idea is that adolescents learn deviant behaviors from their deviant friends via modeling, which is facilitated by adopting deviant peer norms or via peer pressure by deviant peers (Brown, Clasen, & Eicher, 1986). According to the TTI, such social influences make adolescents compelled to comply with peers and ultimately affect adolescents' decisions to engage in risk behaviors (Petraitis et al., 1995). Hence in the current dissertation, the effect of friends' behaviors, friend-adolescent relationships, peer/friend norms, peer/friend pressure, as well as mere peer presence are examined in relation to adolescent risk-taking.

Parent influences

Although peer influences become increasingly important during adolescence, adolescents still live at home with their parents, whom thus still form the primary social context for adolescents. Accordingly, the TTI also emphasizes the importance of parents in its social stream of influence. Relevant risk-factors for adolescent risky behaviors that can be derived from the TTI are parents' own behaviors, and the quality of the relationship between adolescents and parents. It should be noted, however, that most studies on parent effects typically only include mothers or examine the combined influence of both. Hence, in the current dissertation both mothers and fathers are of interest. Specifically, in the current dissertation the effects of mothers' and fathers' behaviors, mothers' and fathers' presence, and their relationships with their adolescent offsprings and adolescent risk-taking are investigated.

Sibling influences

Perhaps surprisingly, the TTI does not explicitly consider the effects of siblings, possibly because most theories on adolescent development do not consider the importance of sibling relationships (compared to parent-adolescent and peer-adolescent relationships), and empirical research on this topic is also sorely lacking (Dunn, 2005). However, a recent meta-analysis based on accumulating sibling research, demonstrated that the quality of the sibling relationship was significantly predictive of adolescent externalizing problems (as well as internalizing problems) (Buist, Deković, & Prinzie, 2012). Hence, the current dissertation also considers siblings' behaviors, siblings' presence, and sibling-adolescent relationships in relation to adolescent risk-taking.

Cultural factors

Finally, the TTI posits that cultural factors can be sociological such as local government policies (e.g., about substance use) or general social values that adolescent's adopt from their culture that influence adolescents' beliefs and evaluations of the "goodness" or "badness" of risk behaviors, which ultimately lead adolescents to engage in risky behavior (Petraitis et al., 1995). Hence, in the current dissertation, an ethnically and socio-economically diverse sample of adolescents is used, ethnicity differences are examined, and cross-national comparisons are also made. Although the TTI suggests that the outlined risk-factors are relevant for all ethnic groups, some paths might weigh heavier than other paths for particular ethnic groups, as different groups might react differently to some risk factors (Flay et al., 1995). For example, for Americans with African descent, only direct links were found for smoking of friends on adolescents' initiation of smoking, whereas direct and indirect links (via refusal self-efficacy skills) were found for Americans with European descent and for Hispanic Americans (Flay et al., 1995). Hence, in the current dissertation within-country ethnic differences and cross-national differences are examined. Although more and more studies within the psychological sciences are including ethnic minority youth, still most of such existing research primarily consists of ethnic-majority samples (Ftitache, 2015). This is also the case for psychology studies originating from the Netherlands, despite that 21.7% of its population consists of foreign migrants (Statistics Netherlands, 2016a; Ftitache, 2015). Moreover, with regard to cross-national differences, it could it could be argued that not all of the TTI-based risk factors might be globally relevant for the development of risk behaviors in adolescents. Hence, taken together, the current dissertation includes a large enough sample of ethnic minority adolescents to examine whether the findings can be generalized to the ethnically diverse population in The Netherlands. Moreover, another study included in the current dissertation is a cross-national study comparing European Dutch adolescents living in the Netherlands to Caribbean Dutch adolescents living on the Dutch Caribbean island of St. Maarten.

Interplay among TTI-based risk-factors and risk behaviors

The TTI proposes that the abovementioned risk factors influence adolescents' decisions, intentions, and prior experiences with the respective behaviors, which all have direct effects on engagement in risky behaviors (Snyder & Flay 2012). Empirical research has also provided support for the risk-factors hypothesized by the TTI (see Flay et al., 2009; Snyder & Flay, 2012). Moreover, the TTI further emphasizes that risk factors from the above-described three streams of influence are often interrelated, and should be thus studied simultaneously (e.g., Flay et al., 1995). Finally, the TTI additionally proposes that related behaviors (e.g., alcohol and marijuana/ cannabis use) could also influence each other, the so-called gate-way drug use hypothesis (Flay et al., 1995; Kandel & Yamaguchi, 1999). Such *poly drug-use*, could manifest because engagement in one risky behavior (e.g., alcohol use) might change one's attitudes in a favorable way about other substances (e.g., marijuana use) (Flay et al., 1999). These topics are also investigated in the current dissertation.

1.5 Unanswered Questions

On the one hand, great strides have been made in adolescent risk-taking research (for review see e.g., Boyer, 2006). On the other hand, some further unanswered questions remain. These questions include: Why does real-world risk-taking increase during adolescence? Are the risk and protective factors the same across adolescent phase, and what about the role of gender and pubertal maturation? Additionally, are the above-described peer influences on heightened adolescent risk-taking moderated by such relevant potential moderators? Do adolescents also engage in heightened risk-taking on experimental laboratory risky decision making tasks? Then again, does risky decision making in the lab reflect real-world risk-taking behaviors? Relative to peer influence, to what extent are parents still relevant for predicting risk-taking behaviors when their children enter adolescence? What about the role of siblings? What about the role of fathers? Finally, what about cultural differences? Taken together, research is needed on specific mechanisms (e.g., experimental studies), individual differences (e.g., gender differences), developmental differences (e.g., early versus mid/late adolescence) and still more studies are needed that examine diverse risk-factors simultaneously to account for their interrelatedness as hypothesized by the TTI. Accordingly, the current dissertation aims to fill some of these gaps in the literature, by tackling the above-described research questions (see Figure 1 for the conceptual model of the current dissertation that was inspired by the TTI). This is done by capitalizing on a combination of meta-analytic, longitudinal, and experimental methodologies. Moreover, an ethnically, socioeconomically and educationally diverse longitudinal sample that was large enough to investigate gender, adolescent phase, gender by adolescent phase, and cultural differences is used. This sample was recruited from eight different high schools throughout the Netherlands, and primarily ethnically diverse schools took part.

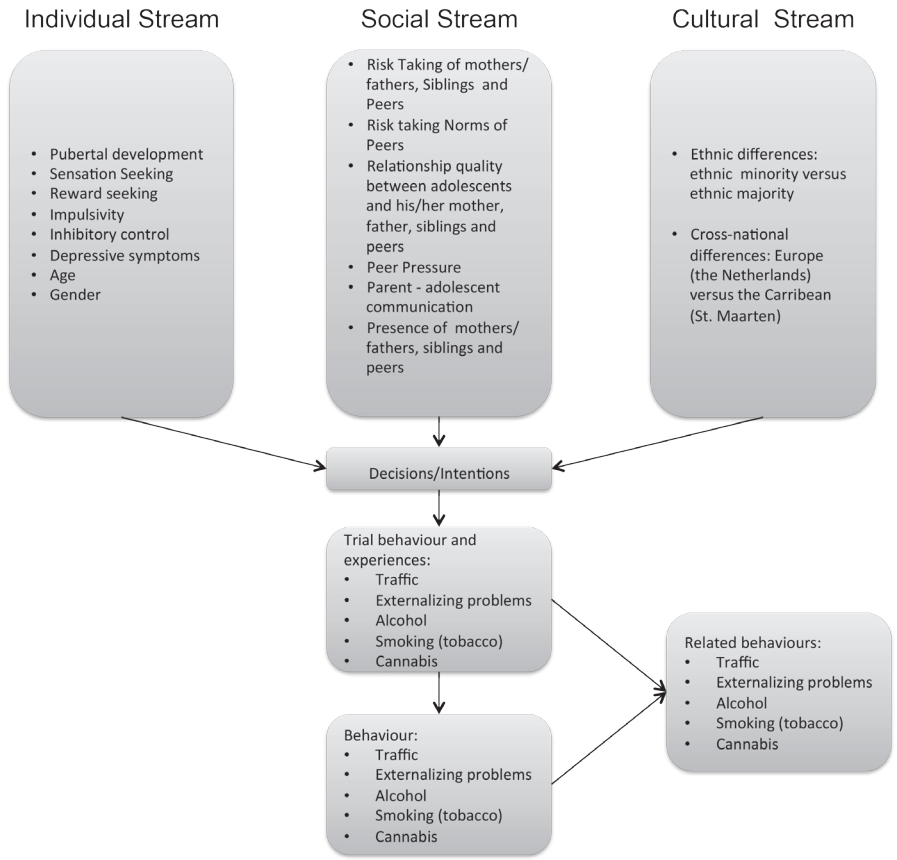

Figure 1. Conceptual model of the current dissertation (inspired by the TTI).

1.6 Study Design

The current dissertation is primarily based on an experimental-longitudinal study (*N*=602 at baseline) in the Netherlands on adolescent risk-taking called that ART project. For three years (2012, 2013 and 2014), adolescents filled out an extensive questionnaire once per year, and a fraction of their mothers and fathers also filled out questionnaires in the 1st and 2nd wave. Furthermore, adolescents additionally completed multiple cognitive tasks, and engaged in experimental sessions wherein they completed risky decision making tasks alone or together with peers. Additionally, some of the adolescents in the above-described longitudinal study participated in extra experimental sessions, wherein they completed cognitive and risky decision making tasks either alone or with their mothers, and/or fathers, and/or siblings. A total of 36 families took part. Additionally, one paper in the current dissertation contains a sample of adolescents who partook in a comparable 2-year longitudinal study on

St. Maarten (*N*=350 at baseline), although family members did not participate. Finally, one paper (chapter 6) consists of a sample (*N*=497) from the project 'Research on Adolescents Development And Relationships' (RADAR; see for instance: Keijsers et al., 2012), a prospective longitudinal study in the Netherlands. Four annual waves of questionnaire data were analyzed from 497 targeted Dutch adolescents, along with their siblings, fathers, mothers, and self-nominated best friends.

Taken together, in the current dissertation, the self-reported real-world risk behaviors, alcohol use, marijuana use, smoking, delinquency and risky traffic behavior are examined. Moreover, risk-decision making is examined via a computerized risky gambling/choice task and a simulated risky driving task.

1.7 Goals of this Dissertation

Part 1: *A Theoretical and Experimental Account of Heightened Adolescent Risky Decision Making*

Part 1 includes *chapter 2: "A meta-analysis on age differences in risky decision making: adolescents versus children and adults".* Thus, chapter 2 is related to *aim (a)* of the current dissertation, that is, "*to what extent does experimental scientific evidence show support for risk-taking being a unique feature of adolescence".* The TTI posits that adolescents in particular are susceptible to engagement in risk behaviors, and that adolescent risk behaviors are directly predicted by intentions/decision making (Flay et al., 2009; Flay & Petraitis, 1994). Thus part 1 addresses the primary hypothesis of the TTI, and in doing so focuses on adolescents' risk-taking via risky decision making tasks. The aim is to answer the following questions. Do adolescents also engage in heightened risk-taking on risky decision making tasks compared to other age groups, and are there differences in risk-taking between early and mid-late adolescents on these tasks? These issues are tackled by giving a review of the literature and meta-analytic methods will be used to draw objective conclusions about age differences in experimental risk-taking.

In **chapter 2** meta-analytic methods are used to investigate whether adolescents also take more risks that children and adults on experimental risky decision making tasks. As explained above, adolescents have increasing independence, whereas this might account for their increased risk-taking in the real-world, this ecological aspect is often neglected in theories and in empirical studies. An experiment, wherein adolescents, children and adults have equal opportunities to engage in risk-taking can provide more conclusive evidence as to whether adolescents engage in more risks than children and adults. A meta-analysis based on such experimental studies on age differences in risky decision making would further be necessary to quantify if such age differences in risk taking generally exist, and how large the differences are. The aims of chapter 2 is to give an extensive review of theories on age differences in risky decision making and accordingly to identify gaps in this area of research. Following this narrative review, four independent but related meta-analyses are conducted to quantify whether there are age differences in risky decision making by contrasting adolescents' risky decision making with children's and adults' risky decision making on experimental risk-taking tasks. Additionally, early adolescents' versus children and mid-late adolescents' risky decision making, are also compared. Next, moderators related to cognitive and affective task characteristics are investigated to establish which underlying factors can account for the hypothesized age differences in risky decision making. These moderators are derived from two contemporary theories on heightened adolescent risk-taking (i.e., *neurodevelopmental imbalance models*; e.g., Somerville et al., 2010; Steinberg, 2007 and *Fuzzy Trace theory*; Reyna & Rivers, 2008). The hypotheses of the TTI are not based on these currently prevailing theories of heightened adolescent risk-taking, perhaps because they emerged at least a decade after the TTI was first put forward. Nevertheless neurodevelopmental imbalance models and Fuzzy Trace Theory, provide excellent theoretical frameworks for the current meta-analysis as some of their hypotheses regarding cognitive and affective factors in age differences in risk-taking can be directly tested with experimental risky decision-making tasks. That is, they provide testable hypotheses as risky decision-making tasks typically vary on the cognitive and affective factors that are hypothesized in these theories. Finally, based on the results of this narrative review and meta-analysis, a new hybrid theory is put forward to bridge the gap between heightened adolescent risk-taking on experimental tasks and heightened adolescent risk-taking in the real-world.

Part 2: *An Experimental Investigation of the Roles of Parents, Peers, and Siblings in Adolescent Risk-Taking*

The papers in **Part 2** (*chapters 3, 4, 5*) tackle *aim (b)* of the current dissertation, that is, to investigate "*the role of peers versus parents and siblings in adolescent risk-taking while accounting for individual factors (biological, cognitive, affective, gender, age/adolescent phase)".* Thus factors related to the intrapersonal and social stream of the TTI are examined. In doing so, experimental risky decision making tasks are employed. The previous section (part 1) investigated whether adolescents engage in more risks than children and adults on experimental risky decision making tasks. However, research on how performance on these tasks are related to real-world adolescent risk-taking is lacking. Therefore, *chapter 3* addresses the question: *does risky decision making in such experimental paradigms (with and without the presence peers) predict self-reported real-world risk behaviors*? Next, using validated risky decision making tasks (which were also included in some of the studies in the above-described meta-analysis in chapter 2), the subsequent chapters 4 and 5 investigate the following questions: Do peers, parents and siblings have the same influences on adolescent risk-taking? Are hypothesized peer influences moderated by gender, age

and pubertal maturation?

Chapter 3: *From the Lab to the Real world: Does Peer Presence Matter in The Link between Adolescent Experimental Risk-taking and Real-world Risk Behaviors?*

In *chapter 3*, the criterion validity of an often used risky decision making task is put to the test. Although studies using laboratory risk-taking paradigms provide the opportunity to investigate risk-taking under more controlled settings, such experimental paradigms might suffer from criterion validity and ecological validity (Dahne, Richards, Ernst, MacPherson, & Lejuez, 2013; Schonberg, Fox, & Poldrack, 2011). Yet, laboratory studies that assess adolescent risk-taking via behavioral risk-taking tasks do not typically include a measure of real-world risk-taking to facilitate the investigation of criterion validity. Moreover, such studies rarely capitalize on affectively laden paradigms which could possibly enhance the ecological validity of a typical lab context. Thus, the current study presented in chapter 3 investigates whether a well-known risk-taking task, predicts multiple real-world risk-taking behaviors. Moreover, the aim is also to examine whether completing such a risky decision making task in a more ecologically valid context (i.e., together with peers) versus alone increases the criterion validity of this task, while controlling for age, gender and sensation seeking.

Chapter 4: *Is the Peer Presence Effect on Heightened Adolescent Risky Decision Making Only Present in Males?*

In *chapter 4*, a two-study paper investigates whether peer presence increases risk-taking in boys and girls on a risky driving task, the "stoplight game" (Gardner & Steinberg, 2005). Adolescents spend more time than children and adults socializing with peers (Brown & Larson, 2009). Hence part of the reason why adolescents typically engage in risks when they are with their peers (Steinberg, 2004), might simply be because they spend more time with them, or perhaps a risk-taking amplification mechanism might be operating when adolescents are in the presence of their peers. Social neurodevelopmental imbalance models suggest that the mere presence of peers activates the reward system in the brain, and leads to heightened risk-taking in adolescents (Steinberg, 2007; Steinberg & Gardner, 2005). An experiment with a risk-taking paradigm wherein peer presence is manipulated can attempt to answer the question as to whether mere peer presence leads to heightened adolescent risk-taking. However, such experimental studies are limited and whether the above-described peer presence effect might differ across gender is rarely investigated (but see e.g., Gardner & Steinberg, 2005; Kretsch & Harden, 2014). Hence the two-study paper in chapter 4 investigates whether adolescents take more risks on a risky decision making task when they completed the task alone (either collectively in a classroom; study 1 *or* individually in a room; study 2) versus when they completed that task together with two same sex peers from their class.

Chapter 5: *Social Presence Effects on Adolescent Risky Decision Making: Peers versus Siblings and Parents*

In *chapter 5,* a two-study paper is presented which serves as a replication and extension of the paper in chapter 4. That is, using another risky decision making task, the Timer Columbia Card Task (timer CCT; for a similar task see: Figner, Mackinlay, Wilkening, & Weber, 2009; Figner & Weber, 2011), the study investigates whether adolescents engage in more risky decision making when they complete this task in groups of three versus when they complete this task alone (study 1). Reasoning from the above-described *social neurodevelopmental imbalance models,* adolescents would be expected to engage in more risks when they complete the risky task in the presence of peers. Moreover, the *Social Re-orientation Theory* further postulates that the pubertal rise in reproductive hormones is responsible for adolescents' tendency to affiliate with their peers, and that pubertal maturation and peer affiliation interact to predict adolescent heightened risk-taking (Forbes & Dahl, 2010). Particularly *pubertal timing*, has consistently been linked to heightened adolescent risk-taking (for reviews see Mendle & Ferrero, 2012; Mendle, Turkheimer, & Emery, 2007). Hence, the first study of chapter 5 investigates whether independent effects exist for pubertal timing, and experimentally manipulated peer presence, while controlling for age and gender, and whether pubertal timing and peer presence interact to exacerbate adolescent risk decision making. Study two in chapter 5 examines whether mother-, father- and sibling- presence affect adolescent risky decision making on the CCT (while controlling for adolescent gender), and thus investigates whether the hypothesized peer presence effect on heightened adolescent risky decision making, also applies to siblings and parents or whether it is specific for peers.

Part 3: *A Longitudinal Investigation of the Roles of Parents, Peers, and Siblings in Adolescent Risk-Taking*

The goal of **part 3** that includes *chapters 6, 7, 8*, is also to address *aim* (*b)* of the current dissertation, that is, "*the role of peers versus parents and siblings in adolescent risk-taking while accounting for individual factors (biological, cognitive, affective, gender and age/adolescent phase)".* However, unlike part 2 that used experimental designs to investigate such research aims, in part 3, *longitudinal* (multi-informant) papers are presented that probe the role of significant others in adolescent-risk-taking, while also taking individual factors into account. Thus part 3 examines the individual and social stream of the TTI within a longitudinal framework. In addition to experimental studies that allow inference of causality, longitudinal studies are also informative as they are the golden standard for studying development (i.e., following subjects over time). Hence, the papers in Part 3 capitalize on such longitudinal methodological designs to investigate social and individual predictors of real-world risk behaviors, that is, adolescent externalizing problems [(aggression

and delinquency) and substance use (smoking), while taking gender, age and adolescent phase into account].

Chapter 6: *Siblings versus parents and friends: longitudinal linkages to adolescent externalizing problems*

In *chapter 6* the aim is to investigate whether the consistent finding that peer externalizing problems (aggression and delinquency) predict externalizing problems in adolescents (Haynie & Osgood, 2005) also applies for parent and sibling externalizing problems. Thus the current multi-informant 4-year longitudinal study can further help provide an answer to whether peer similarity in externalizing behaviors is unique for the peer-adolescent dyad, or whether siblings and both mothers' and fathers' externalizing problems equally predict future externalizing problems in adolescents. Additionally, it has consistently been shown that parent-adolescent negative relationship quality, particularly in the mother-child dyad predicts adolescent externalizing problems, as hypothesized by Patterson's Coercion Theory (e.g., Patterson, 1992) and substantiated by a comprehensive meta-analysis (Hoeve et al., 2009). Such research with fathers is lacking, however. Hence, the current paper in chapter 6 additionally investigates whether father-adolescent negative relationship quality in addition to mother-adolescent negative relationship quality predicts adolescent externalizing problems. Moreover, whether this parent-adolescent negative relationship quality link with adolescent externalizing problems, is unique for the parent-adolescent dyad is examined, by further investigating whether negative sibling-adolescent relationship quality also predicts externalizing problems in adolescents. This study makes an important contribution to the literature, as scientific papers comparing the roles of peers, siblings, mothers and fathers in adolescent behaviors, all within one study are very rare (but see e.g., Fagan & Najman 2003; Natsuaki et al., 2009). Finally, and importantly, the gender (same sex versus mixed sex) and age (older versus younger and younger versus older) composition of the sibling dyad are taken into account. These research questions are examined with cross-lagged panel models that facilitate the investigation of transactional effects (reversed links). More specifically, not only are the roles of significant others on adolescent externalizing problems investigated, but the potential links from adolescents to their significant others are also simultaneously modelled.

Chapter 7: *On Breaking the Vicious Cycle of Peer Similarity in Adolescent Delinquency: The Moderating Role of Mothers*

The multi-informant longitudinal study in *chapter 7* aims to unpack the potential mechanisms that might be operating in the consistently demonstrated link between delinquent peers and subsequent adolescent delinquency. Whereas parent influences on adolescent behavior begin to diminish during adolescence, peer influences, such as delinquent peer affiliation become one of the strongest and most consistently demonstrated predictors of adolescent delinquent behavior. Although most social learning theories assume that adopting delinquent peer norms and/or submitting to peer pressure to engage in delinquency are some of the prominent mechanisms that link peer delinquency to subsequent adolescent delinquency (Akers, 1998; Brown, Clasen, & Eicher, 1986; Sutherland, 1947), surprisingly, these specific mechanisms are rarely investigated in correlational and/or experimental designs. Instead, studies typically investigate whether adolescents have delinquent friends (or peers) and whether these peer factors predict later externalizing problems in adolescents (thus a similar design to the study presented in chapter 6). However, inspired by social learning theories, the current 2-year longitudinal study goes one step further and investigated whether specifically perceived delinquent peer norms and overt peer pressure to engage in delinquency predict subsequent adolescent delinquency a year later while controlling for prior levels of delinquency. Moreover, as explained earlier, parent-adolescent negative relationship quality is one of the most relevant family predictors of adolescent delinquency (Hoeve et al., 2009). Thus chapter 7 investigates whether mother-adolescent negative relationship quality exacerbates the hypothesized link between delinquent peer norms and peer pressure to engage in delinquency on the one hand and adolescent delinquency on the other hand. In other words, the current chapter also answers the question: Can lower levels of negative mother-adolescent relationship quality minimize engagement in adolescent delinquency that is presumably triggered by delinquent peer norms and peer pressure?

Taken together, building on the above-mentioned previous studies, the current paper in chapter 7 investigates whether lower levels of mother-adolescent negative relationship quality could minimize adolescents being pressured into delinquency and the conformity to delinquent peer norms, which could in turn prevent subsequent adolescent delinquency. Gender by adolescent phase effects are also considered. Finally, using a smaller subsample of adolescents whom had mother reports on negative mother-adolescent relationship quality, an attempt was made to replicate and substantiate the findings that were found when adolescents' reports on mother-adolescent negative relationship quality were used.

Chapter 8: *The Unique Roles of Intrapersonal and Social Factors in Adolescent Smoking Development*

Chapter 8 includes a comprehensive cohort-sequential study, with self-report and a behavioral measure, that (1) investigates the developmental trajectory of smoking from ages 12-17, and (2) investigates whether social, i.e., peer influences (peer pressure and susceptibility to peer influence) are still relevant in the prediction of the growth in smoking when individual (i.e, cognitive and motivational) factors are simultaneously investigated. The individual factors include, impulsivity and inhibitory control (i.e., cognitive factors) and reward seeking and sensation seeking (i.e., motivational factors). Furthermore, putative confounding effects of gender and educational track are taken into account.

Part 4: Ethnic and Cross-national Differences in Adolescent Risk-taking

Finally, **part 4,** which includes *chapters 9 and 10*, addresses *aim* (*c)* of the current dissertation, that is, to investigate *"ethnic and cross-national differences in the links between risk factors and risk behaviors"*. Specifically, part 4 centers around the question: Are the adverse effects of adolescent risk-taking the same across ethnicity and countries? Thus in the last part of the current dissertation, perhaps the least explored stream of influence (i.e., the "cultural stream") of the TTI is examined, first as a moderator (*chapter 9*) and then within a cross-national framework (*chapter 10*). Additionally, in chapter 9, potential moderation roles of gender, adolescent phase, and gender by adolescent phase are also explored.

Chapter 9*: The Longitudinal Link between Delinquency and Depressive Symptoms in Adolescence: Moderation by Adolescent Phase, Gender and Ethnicity*

In *chapter 9*, the link between delinquency and depressive symptoms is examined. Both delinquency and depression show a dramatic increase in adolescents (Angold & Costello, 1993; Loeber & Keenan, 1994; Wolff & Ollendick, 2006), and interestingly, despite their dissimilar symptoms, they tend to co-occur in the same individual at relatively high rates. This co-occurrence of depression and delinquency is an alarming phenomena as such co-occurring externalizing and internalizing problem behaviors have poorer treatment outcomes (for a review see: Wolff & Ollendick, 2006). Despite the well-documented co-occurrence of these problem behaviors, what remains unclear is whether there is a longitudinal link between these two behaviors, as findings that do find longitudinal links show mixed findings for the temporal ordering (i.e., does delinquency precede depressive symptoms, or is the reverse (also) true) (Wolff & Ollendick, 2006). The Failure model (Capaldi, 1992) postulates that externalizing problems such as delinquency predict depressive symptoms, whereas the Acting out model (Carlson & Cantwell, 1980) postulates that depressive symptoms predict delinquency. Likewise, the TTI recognizes that depressed affect (described as a distal affective state in the intrapersonal stream) can contribute to adolescent risk behaviors (Flay et al., 2009), but as the Failure model and most empirical investigations (e.g., Defoe, Farrington, & Loeber, 2013; Van der Giessen, et al., 2014; for a review see: Wolff & Ollendick, 2006) suggest, the reverse might also be true. Hence, capitalizing on a cross-lagged panel model, chapter 9 simultaneously investigates the opposing hypotheses of these two models.

Next, the mixed findings of the temporal order of delinquency and depressive symptoms might be explained by important moderators. First, ethnic differences have been reported in such externalizing problems and internalizing problems (Ftitache, 2015), however results on ethnic differences in particularly adolescent externalizing problems in the Netherlands have been mixed. Hence, might the hypothesized link between delinquency and depressive symptoms differ for ethnic minority and ethnic majority adolescents? This is a pertinent question, particularly for the Netherlands, where 21.7% of the population consists of foreign migrants (Statistics Netherlands, 2016a). Hence, chapter 9 contains a 3-wave cross-lagged panel study and seeks to investigate whether externalizing risk behaviors (i.e., delinquency) can function as both an antecedent and a consequence of internalizing problems (i.e., depressive symptoms). Moreover, ethnicity (i.e., ethnic majority versus ethnic minority youth) is explored as a moderator, and gender, adolescent phase, and gender by adolescent phase moderation effects are also explored.

Chapter 10: *Alcohol and Cannabis Use in Adolescents in the Caribbean and Europe: The Role of Intentions and Substance Use-Specific Parent-Adolescent Communication*

In *chapter 10*, a cross-national study is presented in which the relationship between alcohol use and cannabis use is examined while taking the role of intention to use these substances and parent specific communication about these behaviors into account The TTI hypothesizes that the use of alcohol could trigger the use of similar substances such as cannabis use, and one possible explanation for this link is that the use of alcohol produces favorable attitudes for cannabis (Flay et al., 1999). The TTI further suggests that social factors like parents' behaviors and attitudes towards alcohol and cannabis use, and adolescents' intention to use these substances predict the use of these substances. Hence, the goal of the current two-study longitudinal paper that uses a sample of Dutch-Caribbean adolescents from St. Maarten and a sample of Dutch-European adolescents from The Netherlands is two-fold. First, the temporal order of alcohol and cannabis use in these two samples is investigated. Secondly, bidirectional linkages between (a) intention to use alcohol and cannabis the following year, (b) parent-specific communication about the use of these substances and (c) the use of these substances in adolescents are examined. Moreover, gender and age are controlled in the above-described models.

1.8 Outline of the Current Dissertation

In sum, the current dissertation is divided into 4 parts. Part 1, consists of **chapter 2** *and* aims to answer the following question using meta-analytic methods: Do adolescents also engage in heightened risk-taking on experimental risky decision making tasks? Part 2, which includes **chapters 3, 4,** and **5** seeks to answer the following questions using experimental and self-report methods: Does risky decision making on experimental risky decision making tasks predict self-reported real-world risk behaviors (**chapter 3**)? Do peers/friends, parents and siblings have the same influences on adolescent risky decision making and do age, gender and pubertal maturation moderate the hypothesized peer influences on adolescent risky decision making on experimental risk-taking tasks (**chapter 4 & 5**)? Part 3, consists of three longitudinal papers that investigate social influences on adolescent risk behavior .**Chapters 6 and 7 probe** the roles of friends, mothers, fathers and siblings in adolescent-risk-taking (**chapter 6**) and if parents can moderate the negative effects of deviant peer socialization (i.e., delinquent peer norms and peer pressure) on adolescent delinquency (**chapter 7**). **Chapter 8**, includes a comprehensive study that investigates whether peer influences still hold when relevant TTI-based individual risk factors are simultaneously taken into account. The 4th and final part of the current dissertation, contains **chapter 9 and 10** that focus on within-country ethnic differences and cross-national difference in the links between risk factors and risk behaviors. That is, **chapter 9** investigates whether delinquency predicts depressive symptoms (and the reverse is also investigated) while exploring ethnicity moderation effects, in addition to gender by adolescent phase moderation effects. Additionally, **chapter 10** concerns a cross-national study that examines whether alcohol use predict cannabis use and vice versa in youth from St. Maarten and The Netherlands, while also investigating the roles of the TTI-based risk-factors " intention to use these substances" and "parent-adolescent substance-use specific communication". Finally, the current dissertation ends with **chapter 11**, which includes a Discussion and Conclusion.

Part 1:
A theoretical and experimental account of heightened adolescent risky decision making

Chapter 2

A Meta-analysis on Age Differences in Risky Decision Making: Adolescents versus Childrenand Adults

Author note:
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I.N. Defoe developed the study concept and design, and J.S. Dubas, B. Figner, and M.A.G. van Aken gave advice and feedback. I.N. Defoe did the main literature search. I.N. Defoe coded the studies. I.N. Defoe performed the data-analysis and interpretation. I.N. Defoe drafted the manuscript, and J.S. Dubas, B. Figner, and M.A.G. van Aken provided critical revisions.

Abstract

Despite evident heightened adolescent risk-taking in real-life situations, not all experimental studies demonstrate that adolescents take more risks than children and adults on risky decision-making tasks. Using "neurodevelopmental imbalance models" and "Fuzzy Trace Theory" as conceptual frameworks, the current four independent meta-analyses examined whether adolescents engage in more risk-taking than children and adults, and whether early adolescents take more risks than children and mid-late adolescents on behavioral risk-taking tasks. Studies with at least one of the aforementioned age comparisons met the inclusion criteria. Consistent with imbalance models and Fuzzy Trace Theory, results from a random-effects model showed that adolescents take more risks (g = .37) than adults, and early adolescents take more risks (g = .15) than mid-late adolescents. However, inconsistent with both perspectives, adolescents take equal levels of risks (g = .-00) as children, and *early* adolescents also take equal levels of risks (g = .04) as children. Meta-regression analyses revealed that consistent with imbalance models, (1) adolescents take more risks than adults on "hot" tasks with immediate outcome feedback on rewards and losses; however, contrary to imbalance models but consistent with Fuzzy Trace Theory, (2) adolescents take fewer risks than children on tasks with a sure/safe option. Shortcomings related to studies using behavioral risk-taking tasks are discussed. We suggest a hybrid developmental neuroecological model of risk-taking that includes a "risk opportunity" component to explain why adolescents take more risks than children in the real-world, but equal levels of risks as children in the laboratory.

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

Heightened risk-taking behaviors (e.g., reckless driving, binge drinking) are the leading cause of death for adolescents, as the associated negative outcomes account for about a 200% rise in mortality rates compared to childhood (Dahl, 2004; Spear, 2000). The past decade has witnessed a rapid growth in studies dedicated to the understanding of heightened real-world risk-taking in adolescence, by employing various types of behavioral risk-taking tasks (e.g., description-based vs. experienced-based), in diverse settings (alone vs. peers) (Albert & Steinberg, 2011; Boyer, 2006). Surprisingly, while some of these studies (e.g., Burnett, Bault, Coricelli & Blakemore, 2010) demonstrate an inverted U-shaped curve, denoting a peak in risk-taking in adolescence, other studies (e.g., Paulsen, Carter, Platt, Huettel, & Brannon, 2012) report risk-taking levels that are the highest in childhood with declines thereafter. Yet, still in some studies no age differences are observed (e.g., Van Leijenhorst, Westenberg, & Crone, 2008). Despite existing insightful narrative reviews on heightened adolescent risk-taking (e.g., Boyer, 2006), so far no formal meta-analysis exists that could quantify and perhaps reconcile the seemingly contradictory findings. To date, the only meta-analysis that addressed age differences in risk-taking focused solely on adults, and showed that age differences in young adults' versus older adults' risk-taking varied considerably as a function of task characteristics (Mata, Josef, Samanez-Larkin, & Hertwig, 2011). Hence, the current paper is a meta-analysis that (1) investigates whether adolescents engage in more risk-taking than children and/or adults on behavioral risk-taking tasks, and (2) under which task and contextual circumstances which developmental patterns occur. Moreover, early adolescence and mid-late adolescence are two distinct developmental phases, especially since early adolescence is characterized by pubertal onset. Therefore, we also examine (3) whether early adolescents differ from children and mid-late adolescents in risk-taking.

Adolescent Risk-taking and Defining "Risk"

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

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

Despite the numerous refined risky decision-making tasks that have been designed during the last decade to measure risk-taking, the definition of "risk" has still remained a controversial issue, as no consensus has been reached in defining this term (Schonberg, Fox, & Poldrack, 2011). The lay and clinical definition of the word "risk-taking" is often used in the sense of "engaging in a behavior that could potentially have a *negative* outcome". However, most adolescents engage in normative levels of risk-taking behavior, and risk-taking behavior does not necessarily have to be the "bad" choice, although the term "risk-taking" usually has a negative connotation. Moreover, opinions vary on what should be considered negative, and thus opinions vary on what should be classified "risky" (see Reyna & Farley, 2006 for a more thorough discussion). Hence as an alternative for the subjective definition of risk-taking, in the current meta-analysis we opt for the more objective definition of the term "risk" as used in the judgment and decision making literature, which in essence, encompasses choosing the "option with the highest outcome variability" (Figner & Weber, 2011; Weber, 2010). In other words, this entails choosing the option with the wider range of possible outcomes (see Figner & Weber, 2011). Indeed in most cases, at least one of the possible outcomes

Table 1. Characteristics and Psychometric Properties of the Tasks Employed in the Studies included the Meta-analyses

Task	Description	Psychometric Properties	Number of Studies
Probabilistic Gambling Task	In each trial on this computerized game, participants were presented with 2 wheels of fortunes, and were instructed to choose one of the wheels, with the aim of maximising the number of points won. Positive or negative numbers next to the wheel signified potential wins and losses. The probabilities (0.2/0.8 or 0.5/0.5) of wins and losses (i.e., +200, +50, −50 or −200) for each wheel corresponded with the relative size of the sectors of the wheel. After each trial participants won or lost, depending on where the arrow landed, thereafter participants were asked to indicate how they felt on a linear rating scale at the bottom of the screen: from −50 (extremely negative) to +50 (extremely positive). To maximize winnings the participant should choose gambles with higher EV, however gambles with equal EV may differ in their level of risk. (see Burnett et al., 2010) (see Burnett et al., 2010; p. 184-187) *Risk-taking* is measured as the outcome variability of a gamble (Burnett et al., 2010).	Psychometric properties are unknown.	1
Iowa Gambling Task (IGT)	For each trial, participants are told to choose one card at a time from one of four decks that differ in pay-offs and losses. Selections from the two 'disadvantageous' decks are followed by a higher reward on most trials but also by higher (unpredictable) losses, thus the final result is an "overall net loss" (i.e., negative expected value). The two 'advantageous' decks are followed by lower rewards on most trials but also by lower (unpredictable) losses, thus the final result is an "overall net gain" (i.e., positive expected value). Participants are not told how many card selections they will make, but there are typically 100 selections throughout the entire task. Participants learn the experienced outcomes through trial-and-error. (see Bechara et al., 1994, p. 8-10; Principe et al., 2011, p. 626; Smith et al., 2011, p. 2-3) * In studies using the IGT, risk-taking is typically operationalized as the number of choices from the two advantageous decks minus the two disadvantageous decks. (i.e., net-score). However, in the current meta-analysis, risk-taking was operationalized as the mean number of choices from the deck with the highest outcome variability (i.e., the "risky" deck).	Modest to high reliability has been found for the IGT. With regards to validity, performance on the tasks discriminates between substance abusers and non substance abusers. (see Dahne, Richards, Ernst, MacPherson & Lejuez, 2013)	2
The Hungry Donkey Task (HDT)	The Hungry Donkey Task (HDT) is a modified version of the IGT (see above). On this four choice task, participants lead a donkey to choose one of four doors, all of which are associated with a cost or reward in apples. Like the IGT, two of the doors are "disadvantageous" and the other two are "advantageous". Participants are told that the hungry donkey should be rewarded with as many apples as possible. The relative proportions of wins and losses of the HDT are the same as those used in the IGT (Bechara et al. 1994), however, the absolute magnitude of the wins and losses were reduced by a factor of 25. (see Crone, et al., 2007, p.1291-1292; Crone & Van der Molen, 2004, p. 257-260; Huizenga et al., 2007, p. 3) *In studies using the HDT, risk-taking is typically operationalized as the number of choices from two advantageous doors minus the two disadvantageous doors (i.e., net-score). However, in the current meta-analysis, risk-taking was operationalized as the mean number of choices from the door with the highest outcome variability (i.e., the "risky" door).	Psychometric properties of the HDT is unknown (but see Psychometric properties of the IGT)	2

Table 1. Continued

The Gambling Game (modified version of the Hungry Donkey Task, which is an adaptation of the IGT)	The Gambling Game, is a computerized task with four machines, each characterized by a potential gain amount, and each containing 10 balls, that were either "red" loss balls or "green" gain balls. The amount of loss was indicated on the red balls in numerical format, and "frequency of loss" corresponded with the total number of red balls present in a machine. The idea was to collect as many points as possible. After participants chose a machine, the balls were shuffled, and one ball was (semi-randomly) drawn. Participants began the game with zero points, and each time a machine was chosen, the accumulated won or loss points were updated and were numerically and visually (via a color change) displayed by a horizontal bar. The task consisted of a condition wherein the gain and loss magnitude as well as the frequency of loss per choice option were numerically displayed below the machine (informed condition), and a condition wherein such information was not provided (non-informed condition). (see Van Duijvenvoorde et al., 2012, p. 194-196) * In studies using the Gambling Task, risk-taking is typically operationalized as the number of choices from two advantageous machines minus the two disadvantageous machines (i.e., net-score). However, in the current meta-analysis, risk-taking was operationalized as the mean number of choices from the machine with the highest outcome variability (i.e., the "risky" deck).	Psychometric properties of the The Gambling Game are unknown (But see Psychometric properties of the IGT)	1
Mirror Drawing Risk-Taking Task	This task included a mirror-drawing apparatus, and three drawings of two parallel lines constituting borders that were zigzag-shaped with four irregular peaks. Participants were instructed to draw a line within the border, but to avoid touching either line. There were three stages in this task, and for each stage participants were offered the choice between a less risky task for a smaller reward or a riskier task for a larger reward. Participants who chose the less risky tasks always earned 5 points, and an additional 5 points for each of the four peaks that they traced without touching a line. For the riskier option, the number of points won was double the amount of points that could be won on the less risky task. (see Kreitler & Zigler, 1990, p. 306) *Risk-taking* was operationalized as the number of choices fot the riskier task (see Kreitler & Zigler, 1990).	Psychometric properties of the this task are un known.	1

Table 1. Continued

Chicken Game	Chicken is a computerized driving game, for which participants make decisions concerning whether to stop a car from moving across the screen when a traffic light turns from green to yellow. A yellow traffic light signals an impending red traffic light, and if the car is still moving when the red light appears, a potential crash could occur. Participants are informed that the goal is to allow the car to move as far as possible without crashing into the wall. The further they move the car successfully the more points they earn, but they lose any accumulated points if the car crashes. Participants can stop or move the car, but they have no control over the speed of the car. When the yellow light appears, participants are faced with the decision to either stop the car or to take a risk of running the red traffic light and crashing the car into the wall. The latency between the beginning of the trial and the appearance of the yellow light, and between the appearance of the yellow light and the popping up of the wall, all varied across trials. As a result, participants were unaware of when exactly the wall would appear. (see Garner & Steinberg, 2005, p. 627-628; Steinberg et al., 2008, p. 1768-1769) *Risk-taking* was calculated using a composite score that consisted of the mean scores of the number of car restarts per round, and the percentage of times the car was moving (Garner & Steinberg, 2005). Thus, higher scores for moving times and restarts indicated greater risk-taking (Gardner & Steinberg, 2005).	Psychometric properties of this task are unknown (but see Psychometric properties of the Stoplight game).	1
Stoplight Game	The Stoplight driving game is a modified version of the Chicken game, and it is also played on a computer. On each trial, participants aim to reach the end of a straight driving lane as quickly as possible. Each of the 20 intersections of the lane counted as a separate trial. A yellow traffic light signals an impending red traffic light, and a possible collision with another car if the target car is still moving when the red light appears. When the yellow light appears, participants are faced with the decision to either stop and encounter a short delay, or to take a risk of running the red traffic light and crashing, which resulted in a relatively long(er) delay. However, if risk-taking was successful, there was no delay. (see Chein et al., 2011, p. F2-F3; Steinberg et al., 2008, p. 1768-1769) *Risk-taking* is measured as not braking at the yellow light. The game had an incentivized design, as monetary incentives were paid for completing the course in a timely fashion (which also encouraged risk-taking) (Chein et al., 2011; Steinberg et al., 2008)	This task is correlated with sensation seeking (Chein et al., 2011; Steinberg et al., 2008).	2

Table 1. Continued

Wheel of Fortune	The computerized wheel of fortune (WOF) task is a two-choice decision making task with probabilistic monetary outcomes. On each trial, a wheel (i.e., a circle divided into two slices of different size and of two different colors) was presented to participants. Throughout the task, four types of monetary wheels, differing on probability (corresponding with the size of the slices) and reward magnitude, were presented in random order. Participants were instructed to select one of the slices by its color. If the computer randomly selected the same color as the participant, the designated amount of money was won. However, the participant won nothing, if the computer randomly selected the other color. Smaller slices were always paired with the higher reward magnitude. In a feedback phase, wherein the outcome was displayed participants had to rate how they felt about their outcome. (see Ernst et al., 2004, p. 1586-1588; Eshel et al., 2007, p. 1272) *Risk-taking* was measured using a percent risky selections score, which was computed using the number of times 10 % and 30% probability options were selected relative to the total number of times that the10/90 and 30/70 wheels were presented (Eshel et al., 2007). Thus the risky options had a low(er) probability of a high reward (Eshel et al., 2007).	Reliability data on the WOLF is limited, however regarding validity; greater frequency of low-probability (high-risk) choices on the win–no win version of the WOF is shown to predict substance-related problems. Whereas low probability (low-risk) choice on the lose–no lose version of the task does not predict substance-related problems. (see, Dahne, et al., 2013; Rao et al., 2011)	1
Hot Columbia Card Task (hCCT)	The Hot CCT begins with a presentation of 32 cards and a score of 0 points. Participants decide to turn over cards sequentially with immediate outcome feedback provided after the turning over of each card. A round ends when participants encounter a loss card, or if participants choose to stop turning over cards and collect all gains from that round and move on to the following rounds. Per round, three variables systematically vary, the magnitude of gain, the magnitude of loss, and the gain/loss probability. (see Figner et al., 2009, P. 712; Figner et al., in preparation, p. 9-10; Figner & Weber, 2011, p. 213-214; Gladwin et al., 2011, p. 365) *Risk-taking* is measured by how many cards participants turn over before they decide to stop. The decision to turn over an additional card increases the outcome variability (i.e., risk), because the probability of encountering a loss card increases and the probability of encountering a gain card decreases. (see Figner et al., 2009, P. 712; Figner et al., in preparation , p. 9-10; Figner & Weber, 2011, p. 213-214; Gladwin et al., 2011, p. 365) See below for another variant of the Columbia Card Task.	In the Hot CCT, high sensation seekers (versus low sensation seekers) were shown to turn over more cards (i.e., take more risks (Penolazzi, Gremigni, & Russo, 2012). Chronbach alpha's for this task show high reliability (personal communication with Bernd Figner)	2 articles encompassing 5 studies
Cold Columbia Card Task (cCCT)	The cold CCT is similar to the hot version (see above), the only two differences are: (1) the cold CCT includes a single decision per round and (2) outcome feedback is delayed until all rounds are over (see Figner et al., 2009, p. 712; Figner et al., in preparation, p. 9-10; Figner & Weber, 2011, p. 213-214; Gladwin et al., 2011, p. 365). *Risk-taking* is measured by how many cards participants choose to turn over (Figner et al., 2009; Figner & Weber, 2011).	In the Cold CCT no significant difference was found between high and low sensations seekers (See also the Hot CCT) (Penolazzi, et al., 2012). Chronbach alpha's for this task show high reliability (personal communication with Bernd Figner).	2 articles encompassing 5 studies

Table 1. Continued

Cups Task	On each trial in this computerized cups task, options are presented as a choice of turned-over cups with money hidden under them. Each trial includes either gains or losses, and participants have to choose between a risky and safe option. The sure option always resulted in a gain of $ 2, whereas, the risky option involves the computer randomly selecting two, three or five cups, either containing a gain of $4 , $6, $10, or nothing (i.e., $0). Half the trials framed as a choice between a certain and uncertain gain, and the other half as a choice between a certain and uncertain loss. There were three trial types that differed on expected value (EV). (see Galvan et al., 2011, p. 434-435; Levin & Hart, 2003) *Risk-taking* is operationalized as choosing the uncertain (risky) option (compared to the sure/certain option) (Galvan et al., 2011).	Three-year stability was observed For Equal EV gambles on the Cups Task for both children and adults (Levin, Weller, Hart, & Harshman, 2007). Impulsivity was positively related to overall risk-taking Equal EV choices of the Cups tasks (whereas Thrill seeking was not)	1
Gambling Task	On each trial in this event-related computerized gambling task, participants were presented with a horizontal bar divided into two colored parts representing the probability of an imaginary token being hidden underneath. The proportion of one colored part to the total bar varied from 5%–95% to 50%–50%. Participants could either guess (i.e., gamble) under which part a token was hidden, or pass in order to earn as many points as possible. The points (randomly varying between 10 and 100) that could be won were indicated by a number above the bar, and the points that could be lost were indicated by a number below the bar. The most ambiguous proportions (50%-50%) were linked with the highest losses (80–100 points). Via gambling participants earn the most points possible, but they could also choose to withhold their response (i.e., a pass trial), which resulted in 20 points. Participants began with 100 points and received feedback about the trial and an update of their total score in 67% of all trials. (see Keulers et al., 2011, p. 1444-1445) *Risk-taking* was measured with the ratio gamble/ pass trials (Keulers et al., 2011).	Psychometric properties of the this task are un known.	1
Balloon Analogue Risk Task- Young (BART-Y)	In this computerized game, participants are instructed to pump a balloon. Participants are unaware of the balloons' explosion points, however, they were told that the explosion point vary per balloon trial. Each pump equals one point won, but each pump also increases the chance of an explosion resulting in a loss of all the accumulated points for that balloon. If participants stop pumping the balloon before it explodes, they then earn all of the points accumulated for that balloon. (see Lejeuz et al., 2007, p. 27-28; Macpherson et al., 2010, p. 1402-1403) *Risk-taking* is measured as the average number of pumps on unexploded balloons (i.e., the "adjusted average") (Macpherson et al., 2010).	The BART has been shown to have up to par reliability and performance on the BART is related to numerous real-world risk-taking behaviors (e.g. substance use) in middle adolescents and adults (see e.g., Daphne, et al., 2013).	1

Table 1. Continued

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

Table 1. Continued

The Cake Gambling Task	The Cake gambling task is a two-choice decision making task in which participants are instructed to choose between two flavors of cake; a low risk gamble and a high-risk gamble. The reward magnitude coupled with the high-risk gambles was varied. Three types of cakes with different probability of winning were presented to participants. The amount of credits that could be won or lost was associated with the choices that could be made, with a large amount of credits always being coupled with the smallest probability of winning. (see van Leijenhorst et al., 2008, p. 182-185; 2010, p. 347). *Risk-taking* is measured via the amount of High-Risk choices chosen, since high risk choices were associated with a larger probability of resulting in an undesirable consequence (i.e., not winning) (van Leijenhorst et al., 2008, p. 182-185; 2010, p. 347).	Risk-taking on this task correlates with sensation seeking (see van Leijenhorst et al., 2008)	2
Description/ Experience task	On each trial of this task, participants were presented with a pair of opaque boxes containing cubes varying in point value. Participants had to make a choice between these two boxes, and each choice included an option between a sure thing and a risk, with two possible payout values. Participants were instructed to choose a cube from the box they selected and were told that the idea is to win as many points as possible. The task consisted of two versions. In the description version, the option payoffs are displayed on the front of each box, in frequency format. In the experience condition, participants learn about both options via 10 random draws with replacement, facilitating observation of each option's payoffs. After these 10 observations, participants made their one-shot choice between the two options. (see Rakow & Rahim, 2010, p.70-73) *Risk-taking* is operationalized as the number of risky options chosen (Rakow & Rahim, 2010).	Psychometric properties of this task are unknown	1 article encompassing 3 studies
Incentive-compatible 2 choice Task	Participants performed an incentive-compatible 2 choice computerized task, wherein 1 choice was associated with a sure gain of $5, the other was a gamble with a chance to win more than $5 or with a chance to win $0. In the current meta-analysis the half of the 160 trials (thus 80 trials) for which outcome probability was known to the participant was used (i.e., the "risky" lottery trials). Details about the parameters of the gamble were varied systematically (in random order) to assess how participants' choices were affected by probability of winning (13%, 25%, 38%, 50%, and 75%), the magnitude of the potential win ($5, $8, $20, $50, and $125), and ambiguity about the probability of winning (24%, 50%, and 74% ambiguity around a probability of 50%). Participants also performed loss trials, but the results on those trials were not reported in the paper. (see Tymula et al., 2012, p-5-6) *Risk-taking* is operationalized as choosing the uncertain (risky) option (compared to the sure/certain option) (Tymula et al., 2012).	Risk-taking on this task was not related to self-reported risk-taking behaviors (see Tymula et al., 2012)	1

of a risky choice could (arguably) be considered negative, and riskier options equal more uncertain outcomes (Figner & Weber, 2011). In sum, the core characteristic of the term *risk* as used in the judgment and decision literature is *outcome variability*: the option with the widest range of possible outcomes is considered the riskiest option. Accordingly, risk is often quantified as the variance or standard deviation computed for the possible outcomes an option entails. Importantly, the "riskiest" option is thus also the option associated with the highest uncertainty about what exact outcome one can expect to receive.

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

Besides "risk," another important concept is expected value (EV). Expected value refers to the expected outcome, i.e., the sum of all outcomes (gains or losses), each multiplied by their probability of occurring. For example, consider that you are offered the choice between either $2 for sure or the chance to toss a fair coin: If the coin lands on heads, you win $4 and if it lands on tails you get $0. The expected value of the gamble (the coin toss) is $4 multiplied by .50 (50% probability) plus $0 multiplied by .50, thus $2. The expected value of the $2 for sure is obviously $2, namely $2 multiplied by 1 (100% probability). Thus, in our example, both choice options have the identical EV ($2), but they differ on risk: The outcome variability is 0 for the sure option (as there is only one possible outcome), while for the coin toss it is non-zero, as there are two different possible outcomes ($4 or $0). The example shows that is important to note that risk (i.e., outcome variability) and expected value (EV) are theoretically independent and need to be distinguished from each other. As described in more detail in later sections, in some tasks, the riskier and the safe(r) option have the identical expected value (which was the case with the previous example of the coin toss); in some tasks, the riskier option has the higher EV, while in other tasks, the safe(r) option has the higher EV. Yet again other tasks (both static and dynamic, see e.g., Figner et al., 2009; Figner & Weber, 2011; Levin, Weller, Hart, & Harshman, 2007; Reyna et al., 2011) systematically vary risk and EV, thus, they might include trials in which the riskier option has the higher EV, trials in which the safe(r) option has the higher EV, and trials in which both options have the same EV.

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

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

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

As this may illustrate, it is often problematic—and may even be misleading—to directly extrapolate from observed risk-taking *levels* to individuals' risk-preferences (i.e., risk-aversion, risk-neutrality, risk-seeking). As argued elsewhere (Figner &

Weber, 2011), it is crucial to make the distinction between observed risk-taking levels and the underlying mechanisms that lead to these observed risk-taking levels. The underlying mechanisms can include, besides other factors, individuals' risk preferences. We return to this issue when we discuss task-related moderators.

Conceptual Framework

Cognitive Processes

Before the mid-90's, the study of risky decision making was dominated by scholars who posited that heightened adolescent risk-taking was the result of cognitive deficits in adolescence, such as a lack of rational (i.e., analytic computational) information processing (for a review, see Furby & Beyth-Marom, 1992). Despite the popularity of such cognitive models, more recent empirical research indicates that even young children can exhibit a firm understanding of probabilities (Schlottmann, 2001), arguing against a more general task and context independent cognitive deficit. Moreover, compelling evidence suggests that logical reasoning and information processing abilities show a linear increase with age and stabilize by mid-adolescence, indicating that such cognitive abilities are for the most part intact by adolescence (Hale, 1990; Kuhn, 2009; Reyna & Farley, 2006). Thus, although rudimentary components of decision-making skills (e.g., the understanding of probabilities) are evident in childhood, these skills undergo significant improvements at least throughout adolescence and only show decline in later adulthood[1].

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

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

Affective Processes

The failure of cognitive theories to explain decision making behavior gave rise to an "emotions revolution" (Weber & Johnson, 2009), which led researchers to first generally investigate how affective processes might play a role in risky decision making (see, e.g., the "risk-as-feelings" hypothesis, Loewenstein, Weber, Hsee & Welch 2001), followed by an interest in the role of affective processes (and cognitive control) specifically in heightened adolescent risk-taking. Within this framework, two primary models[2] of understanding adolescent risk-taking emerged out of a developmental perspective on adolescence: one that focuses primarily on brain development (Developmental Cognitive-Affective Neuroscience Model; Somerville & Casey, 2010; Somerville, Jones, & Casey, 2010) and the other that combines brain development with the role of peers (Developmental Social Neuroscience Model; Steinberg, 2007)[3]. For discussion purposes we label these models collectively as "neurodevelopmental imbalance models"[4].

Neurodevelopmental Imbalance Models

In general, neurodevelopmental imbalance models suggest that there is a potential for an imbalance between cognitive and affective processes in adolescence (Somerville & Casey, 2010; Steinberg, 2007). Specifically, these models postulate that in emotionally charged ("hot") situations, adolescents' hypersensitive motivational-affective system often overrides any cognitive control that adolescents might have, which could explain adolescents' propensity towards risk-taking not only in laboratory conditions, but also in real life (Figner & Weber, 2011; Gladwin, Figner, Crone & Wiers, 2011; Somerville & Casey, 2010; Steinberg, 2007; for a comparable model, the "Triadic Model," see Ernst et al. 2006; Ernst & Fudge, 2009). The term "cognitive control" as used in the contemporary neuroscience literature refers to executive functions more generally, and inhibition in particular (Casey, Getz & Galvan, 2008). Cognitive control encompasses top-down control processes that are executed to organize and coordinate goal-directed behaviors (Luna, Garver,Urban,

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

3 It should be noted that the Developmental Cognitive-Affective Neuroscience Model also incorporates the effect of peer presence on the brain's reward system, however the role of peers in this model is less central compared to the role of peers in the Developmental Social Neuroscience Model.

4 Henceforth, the phrases "neurodevelopmental imbalance models" and "imbalance models" will be used interchangeably.

Lazar & Sweeney, 2004). Unlike cognitive control (governed by the prefrontal cortex) that develops linearly with age, but begins to stabilize by adolescence, subcortical "affective" brain regions develop relatively faster, and are hypothesized to be hyper-responsive in adolescence (Casey et al., 2008; Luna et al., 2004; Somerville, Hare, & Casey, 2011). Accordingly, neurodevelopmental imbalance models posit that the "imbalance" between cognitive control and affective reward-related brain regions causes adolescents to become biased towards arousing appetitive stimuli such as rewards (Somerville et al., 2011; Steinberg, 2007; Ubeda-Bañon et al., 2007), which in turn predicts increased risk-taking in adolescents.

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

Additional Dual Process Models

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

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

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

With regards to risk-taking, Fuzzy Trace Theory argues that verbatim-based decision-making can (perhaps counter-intuitively) induce risk-taking because the negative consequences associated with many real-world risk-taking behaviors have

Table 2. Comparisons between the Neurodevelopmental Imbalance Models and Fuzzy Trace Theory

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

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

A Critical Evaluation of Fuzzy Trace Theory and Neurodevelopmental Imbalance Models

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

Additionally, although gist-based decision making is mature decision making and is assumed to typically reduce or prevent risk-taking, Fuzzy Trace Theory also predicts that gist-based decision making is often linked with emotion. As noted

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

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

Next, neurodevelopmental imbalance models suggest that the affective-motivational system (of which the ventral striatum is assumed to be a central part) is hyper-sensitive during adolescence and that it is activated by emotionally arousing stimuli such as outcome feedback on immediate rewards, or the presence of peers (e.g., Albert & Steinberg, 2011; Somerville et al., 2010). This idea has sparked much interest and debate among researchers (e.g., see Gladwin & Figner, in press; Pfeifer & Allen, 2011), as this is a prediction that has not uniformly been supported. For example, a recent fMRI study showed that activation in the ventral striatum *increases* linearly from childhood to adulthood (Paulsen et al., 2012). Furthermore, two studies (Bjork et al., 2004; Bjork, Smith, Chen & Hommer, 2010) using a reaction time task, the Monetary Incentive Delay (MID) task (Knutson, Westdorp, Kaiser & Hommer, 2000), reported *under*-recruitment (instead of over-recruitment) of adolescents' ventral striatum compared to adults' ventral striatum during the *anticipation* of a gain (versus anticipation of no gain). Moreover, no age differences

in the recruitment of the ventral striatum were present during the *receipt* of a gain on the MID task. Thus, recruitment of the ventral striatum might be different for the anticipation of rewards versus the outcome feedback (receipt) of a reward (cf Braams, Van Leijenhorst, & Crone, in press), which is interesting, but warrants more scientific inquiry. With regards to the role of peers, quite opposite to the findings of Chein et al. (2011) that showed heightened ventral striatum activation when adolescents performed a behavioral risk-taking task in presence of peers, another recent study (Pfeifer et al., 2011) showed that self-reported susceptibility to peer influence and risk-taking were negatively related to ventral striatum activation.

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

Investigated Moderators: Theoretically Relevant Characteristics of Task and Context

Description-Based versus Experience-Based Tasks

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

In the decision-making literature, a distinction is often made between decision-making tasks that are cognitively demanding versus tasks that require decision making

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

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

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

Immediate Outcome Feedback versus Delayed Outcome Feedback

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

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

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

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

Gain Gambles versus Mixed Gambles

An important distinction is made in the risky choice literature, namely whether the possible choice outcomes involve only gains (i.e., rewards), only losses (i.e., punishments), or both. Often these three possibilities are referred to as *gain gambles*, *loss gambles*, and—if both gains and losses are involved—*mixed gambles* (see e.g., Ert & Erev, 2013; Yechiam & Telpaz, 2011). Neurodevelopmental imbalance models suggest that potential gains may have a particularly strong impact on choices and lead to increased risk-taking, particularly in adolescents given their heightened sensitivity to rewards. In contrast, predominant theories of risky choice in the judgment and decision-making literature (which typically focus on general

patterns, not on individual or developmental differences) and in particular Prospect Theory (Tversky & Kahneman, 1981) as the most influential of these models argue that it is not gains, but *losses* (i.e., punishments) that typically have a stronger impact on risky choice. A classic finding is that, compared to a gain of equal size, a loss has about twice the impact than the gain; this phenomenon is often referred to as "loss aversion" ("losses loom larger than gains"). A simple example is that few people would accept to play a game in which a fair coin is tossed and if the results is heads, they win $10, and if the results is tails, they lose $9 (i.e., the gamble has a positive expected value); most people would consider playing this game when the loss is about half as large as the gain (i.e., winning $10 versus losing $5).

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

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

Although risks with a mix of gains and losses are not identical to risks with losses, mixed domain risk-taking paradigms are nevertheless intrinsically different from tasks that include risks with gains alone (Yechiam & Telpaz, 2011), and therefore can serve the function of providing some insight into the role of losses in adolescent risk-taking. At least two studies showed that whereas risk-taking to avoid losses remained stable from childhood to adulthood, risk-taking to obtain gains decreased (Reyna & Ellis, 1994; Weller et al., 2011). However these studies did not include adolescents, and mixed domains were not investigated. One study that did compare gain-domain to mixed-domain gambles found that risk-taking levels of college students were the same in the gain and mixed domains, however risk-taking was associated with more autonomic arousal in the gain condition, whereas risk-taking in the mixed domain condition was associated with less autonomic arousal (Yechiam & Telpaz, 2011). Again, this study was neither developmental nor did it include adolescents, thus no conclusions or predictions can be derived with respect to age differences. Taken together, empirical support is lacking for whether "losses do indeed loom more than gains" for adolescents.

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

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

Incentivized versus Non-incentivized Tasks

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

incentivized paradigms were compared to non-incentivized paradigms, the authors pointed out that methodological improvements need to be made in this regard (Mata et al., 2011).

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

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

Time Pressure versus No Time Pressure

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

Dynamic versus Static Tasks

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

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

Sure Option Tasks Versus No Sure Option Tasks

Another characteristic varying across tasks is whether a "safe" (also called "sure") choice option is available or whether participants are choosing between two (or more) risky choices (i.e., lotteries or gambles). For example, the Cups Task (Levin & Hart, 2002) offers choices between a sure versus a risky option, while for example the IGT offers choices among options that are all risky (the 4 decks) and thus does

not allow for avoiding a risk completely. Furthermore, a distinction can be made between the type of "sure option". In some tasks, the sure option means surely *winning* some (typically small) reward. In other tasks, the sure option means winning nothing but also losing nothing (referred to as "sure neutral" tasks in the current meta-analysis). Although imbalance models do not directly make predictions about how the availability of a sure option might influence heightened adolescent risk-taking, it is interesting to test whether this acts as a moderator since risky decision-making scenarios in the real-world often have a sure/safe way out also.

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

Methodologically Relevant Characteristics

Specific task analyses

In addition to the disparity on the definition of "risk," there is also controversy surrounding the outcome measures for "risk-taking" on several common risky decision-making tasks because many tasks confound differences in options' risk with differences in options' expected value. For this reason, whenever possible we also examine whether age differences are dependent on the specific risk-taking task used. For instance, the IGT has been repeatedly criticized for numerous related reasons (for a recent review see: Schonberg et al.2011), with one important critique being that it is almost impossible to differentiate whether performance on the IGT reflects (reversal) learning, risk preferences, sensitivity to EV, and/or sensitivity to loss and/or gain magnitudes. As a result, the outcome measure (either the net score or the mean of disadvantageous choices, see Table 1) that is derived from the IGT cannot be interpreted as risk-taking without caution (Schonberg et al., 2011). More specifically, in the IGT, the riskier decks (i.e., the decks with the higher outcome variability) are also

the "disadvantageous" decks in terms of expected value. If one's goal is to maximize one's financial earnings in the IGT, one should thus choose the options with the highest EV. As it happens, these options are also the options with the lowest risk. Thus, if an individual makes mostly "advantageous" choices, it is unclear whether the underlying mechanism is that the individual is sensitive to the differences in EV and chooses the option with the highest EV, or is sensitive to risk and avoids the options with the highest outcome variability.

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

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

Putative confounding moderators

Finally, we explore whether putative confounding factors moderate the age effects; these putative confounding factors were (1) Unequal EV versus Equal EV tasks, (2) fMRI versus non-fMRI studies, and (3) studies that include IQ as a covariate versus studies that do not include IQ as a covariate. First, since tasks with equal EV across choice options versus tasks with unequal EV across choice options have been shown to produce different age patterns in risk-taking (Weller et al., 2011), we explore this confound in our moderational analyses (i.e., Equal EV vs. Unequal EV). Secondly, we coded whether a study did or did not use an IQ measure as a covariate. Studies controlling for the effect of age-related IQ differences and reporting these IQ-controlled risk-taking age differences might yield systematically different results because performance on risky decision-making tasks might be associated with differences in intelligence between the age groups. Thus, we investigate whether controlling for IQ (i.e., IQ covariate versus no IQ covariate) moderated the hypothesized age effects in risk-taking. Third and finally, since ecological validity issues might arise from doing a risk-taking task in a fMRI scanner (see e.g., Hasson & Honey, 2012 for a discussion), we also investigated whether data were collected in an fMRI study or not (i.e., fMRI study vs. no fMRI study) moderate the effect sizes related to age differences.

Present Meta-analysis

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

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

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

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

Method

Literature Search

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

Selection Criteria

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

1. Studies had to include at least one distinct adolescent age group and at least one additional distinct age group. Early adolescence was classified as 11-13 years, mid-late adolescence as 14-19, children 5-10, adults 20-65. Thus, children age groups that contained children younger than 5 and adult age groups that contained adults older than 65 did not match the criteria, and were thus not included.
2. The study participants belonged to a non-clinical population. However, clinical studies that included a healthy control sample were eligible for inclusion; in these cases only the healthy control sample was used.
3. The study contained a behavioral measure of risky decision making. Table 1 lists all the risky decision-making tasks used in the included studies.
4. Enough statistics were provided to calculate an effect-size associated with age-differences in risk-taking between "early adolescents and mid-late adolescents" and/or "(early) adolescents and children" and/or "adolescents and adults." If studies had graphical results instead of numerical results, we contacted the authors requesting numerical results. Accordingly we contacted 60% of authors for additional statistical results and 81% of the authors for additional relevant coding information. Of the contacted authors, the response rate was 90.90 %.
5. Only studies that were written in English or Dutch were eligible for inclusion. All studies matching the abovementioned criteria were included in the meta-analysis, independent of whether or not they were published and regardless of publication year. We also had no geographic or cultural restrictions.

Screening for Eligible Studies

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

Coding and Calculation of Effect Sizes

For all of the included studies, we coded reference information, publication status/type, study location, study design (e.g., longitudinal vs. cross-sectional), whether the study was an fMRI study or not, sample characteristics per age group (gender, age, SES, etc.), information on time constraints (time-pressure: yes/no), incentive-compatibility, immediate outcome feedback, availability of a sure option, and risky decision making task used (e.g., IGT: yes/no, Stoplight game: yes/no). In addition, we coded whether the respective study controlled for IQ or not. The first coder (i.e., the first author of the meta-analysis) coded all of the studies, and a second coder, a research assistant with a Master's degree in Developmental Psychology, coded 30% of the studies. The studies that were coded by the second

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

Table 3. Overview of Included Studies

Nr.	Study	Risky Decision Making Task	*n* Early Adolescents	Age Early Adolescents *M* (*SD*) OR Age-range	*n* Mid-Late Adolescents	Age Mid-late Adolescents *M* (*SD*) OR Age-range	*n* Adolescent	Age Adolescent	*n* Children	Age Children *M* (*SD*) OR Age-range	*n* Adults	Age Adults *M* (*SD*) OR Age-range
1	Burnett et al. (2010)	Probabilistic Gambling Task	na	na	na	na	26	13.77 (1.10)	20	10.83 (0.64)	17	30.32 (3.08)
2	Chein et al. (2011)	Stoplight Driving Game	na	na	na	na	14	15.70 (1.50)	na	na	12	25.6 (1.90)
3	Crone et al. 2007	Hungry Donkey Task (HDT; modified IGT)	29	13.3	30	17.3	29	13.3	22	9.5	na	na
4	Crone et al. (2008)	Self-Other Gambling Task	18	10.90 (.68)	17	16.53	17	14.88	20	8.65	na	na
5	Eshel et al. (2007)	Wheel of Fortune	na	na	na	na	16	13.30 (2.10)	na	na	14	20 - 44
6a	Figner et al. (2009)	Hot CCT	na	na	22	18.30 (0.83)	28	15.30 (.27)	na	na	26	24.50 (7.43)
6b	Figner et al. (2009)	Cold CCT	na	na	27	18.20 (0.88)	27	14.90 (.88)	na	na	30	23.60 (5.69)
6c	Figner et al. (2009)	Hot CCT	na	na	na	na	31	14.40 (.75)	na	na	33	24.50 (4.37)
6d	Figner et al. (2009)	Cold CCT	na	na	na	na	41	14.20 (.89)	na	na	33	22.80 (2.75)
7a	Figner et al. in preparation [a]	Hot CCT	na	na	na	na	32	14 - 16	24	8 - 11	25	18 - 23
7b	Figner et al. in preparation[b]	Cold CCT	na	na	na	na	47	14 - 16	36	8 - 11	35	18 - 23
8	Galvan et al. (2011)	Cups Task	na	na	na	na	18	14 - 17	na	na	16	18 - 21
9a	Gardner & Steinberg (2005)	Chicken Game	na	na	na	na	52	14.01	na	na	41	37.24
9b	Gardner & Steinberg (2005)	Chicken Game	na	na	na	na	54	14.01	na	na	54	37. 24
10	Huizenga et al. (2007)	HDT (Modified IGT)	61	11.10	59	13.83	59	13.83	61	7.93	61	20.30
11	Keulers et al. (2011)	Gambling Task	18	12.93 (.34)	21	16.99 (.43)	18	12.93 (.34)	na	na	17	21 (.60)
12	Kreitler et al. (1990)	Mirror Drawing Risk-taking Task	na	na	na	na	60	11.56 (.35)	60	5.45 (.37)	na	na
13	Macpherson et al. (2010)	BART-Y	na	na	na	na	247	13 (.88)	277	11.01 (.81)	na	na
14	Paulsen et al. (2012)	Non symbolic Economic Decision-making Task			na	na	17	14.80	17	6.90	16	23.70
15	Paulsen et al. (2011)	Non symbolic Economic Decision-making Task	na	na	na	na	13	14.90	21	7.10	13	21.60
16	Prencipe et al. (2011)	IGT	21	12.69	27	15.04	21	12.69	26	8.90	na	na
17a	Rakow et al. (2010)	Sure versus Risky Choice task	na	na	na	na	38	17.30 (.25)	37	9-12	na	na
17b	Rakow et al. (2010)	Sure versus Risky Choice task	na	na	na	na	39	17.30 (.25)	38	9-12	na	na
17c	Rakow et al. (2010)	Sure versus Risky Choice task	34	13.30 (.25)	37	17.30 (.25)	17	13.30 (.25)	na	na	na	na
18	Reyna et al. (2011)	The framing Spinner Task	na	na	na	na	51	15.5 (1.10)	na	na	102	19.70 (.90)
19a	Slovic (1966) [c]	Knife Switches task/Devils task	117	12	173	14-16	111	13	89	6-8	na	na
19b	Slovic (1966) [d]	Knife Switches task/Devils task	42	12	49	14-16	89	13	50	6-8	na	na
20	Smith et al. (2011)	IGT	12	12	16	17	7	13	18	8	na	na
21	Steinberg et al. (2008)	Stoplight game	137	12.48 (.50)	141	16.51 (.50)	128	14.48 (.50)	116	10.58 (.50)	136	23.32
22a	Van Duivenvoorde et al. (2012)	The Gambling Game	23	12.30	25	15.70	24	13.70	22	8.15	26	20.30
23b	Van Duijvenvoorde et al. (2012)	The Gambling Game	24	12.30	24	15.70	27	13.70	23	8.15	27	20.30
23	Van Leijenhorst et al. (2008)	The Cake Gambling Task	18	10.90(.68)	17	17.18	20	14.60	19	9.40	19	27.60
24	Van Leijenhorst et al. (2010)	The Cake Gambling Task	15	13.4 (.80)	15	17.10 (.70)	15	13.4 (.80)	12	9.70 (.90)	15	21.60 (2.08)
25	Tymula et al. (2012)	Standard Incentivized task	na	na	na	na	33	14.70 (1.44)	na	na	32	38.41 (7.55)

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

coder were partially randomly selected, and some studies were selected because they were considered to be complex studies. Inter-coder reliability and Cohen's kappa were excellent, 90.18 % and .80, respectively. Whenever there was a discrepancy between coding, both coders discussed this and came to a conclusion concerning how the study should be coded.

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

As suggested by Lipsey and Wilson (2001), we gave preference to computation of the effect-sizes based on means and standard deviations. When these types of statistics were not reported, or if results were presented in a graph, we contacted the authors requesting additional numerical statistical information. This was done for 19 studies. However, (1) if the request for additional numerical statistical information was not successful, (2) if *d* could not be calculated using a *t* score, *F* score, χ^2 value, or (3) if we could not derive numerical results from what was reported, we had to exclude those studies from the meta-analysis; as noted earlier this was the case for six studies.

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

Multiple Results from Single Studies

We opted for a conservative approach to handle non-independent effect sizes. That is, when more than one effect-size could be calculated for a specific age group comparison, we (randomly) selected one of these studies to be included in the meta-analysis (Lipsey & Wilson, 2011). This was the case for Chein et al. (2011)[8] and Figner et al. (in preparation)[9]. In addition, three studies (Gardner & Steinberg, 2005; Smith et al., 2011; Steinberg, 2008) reported results for more than one sub-group within a child and/or adult age group. For such cases we used the results from the sub-group with the mean age closest to the overall mean-age of all the studies in the current meta-analysis. For instance, Steinberg et al. (2008) reported results for two sub-age groups within an adult age group, namely "22-25" and "26-30", which both fit our criteria for the adult age group (i.e., 20-65 years). Considering that the mean-age for the adult-group for all studies with an adult-group in the current meta-analysis was 24.98, we used the sub-age group "22-25" to compute an effect size. However, we adopted a slightly different approach to deal with multiple adolescent age groups. In computing an effect size for "adolescents' versus children's risk-taking" and "adolescents' versus adults' risk-taking," if more than one adolescent age-group was reported, we used the *younger* adolescent age group that had a mean age closest to the mean age of the younger adolescent age-groups in studies including just one younger adolescent age group. We always gave preference to a younger adolescent age-group (compared to an older adolescent age group), considering that most studies included a younger adolescent age group. Furthermore, we tried to avoid computing effect-sizes from samples that included overlapping distinct age groups.

Analyses

We proceeded in the following manner with the analyses. First we estimated the overall effect size per age group comparison by means of a random effects model with a 95% confidence interval. Secondly, we examined the variation in the effect size distribution by inspecting the Q-tests and I^2 (i.e., total variability due to heterogeneity rather than chance alone). Next, to detect and investigate the possible effects of publication bias, we employed the Trim and Fill approach (Duval, 2005; Duval & Tweedie, 2000). The Trim and Fill method is a widely used form of sensitivity analysis, which in effect detects and imputes missing studies and by doing so gives an indication of how sensitive an estimated effect-size is to publication bias (Duval, 2005; Duval & Tweedie, 2000). We also attempted to diminish publication bias by including unpublished studies in the meta-analyses. The current meta-

8 For Chein et al., 2011 a within-subject design was used for the Alone and Peer condition, consequently we chose to include results of the Peer condition in the meta-analysis, as such experimental designs are scarce.

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

analysis includes 1 unpublished study that consisted of 2 independent experiments, thus 2 of the 38 effect sizes (5.26 %) are derived from unpublished studies. Outlier analyses were also conducted using Studentized Deleted Residuals, and we used COVRATIO to diagnose whether outliers were influential and thus problematic (Wolfgang, & Cheung, 2010). There are different views on how to handle outliers in meta-analyses, while most will agree that *influential* outliers should be removed, others also provide valid arguments as to why outliers should not be deleted (see Wolfgang & Cheung, 2010 for a discussion). We took the middle ground for these opposing views; that is, we always report whether removing influential outliers changed the conclusion of the effect sizes, and planned that when this was the case we rerun all subsequent analyses with and without the influential outliers. However, influential outliers did not substantially change the effect sizes.

Finally, we conducted 5 multivariate meta-regression analyses while utilizing a mixed-effects model. First, potential moderators derived from the imbalance framework that were simultaneously tested are: immediate versus delayed outcome feedback on rewards and losses, gain versus mixed (i.e., gains and losses) gamble domains and incentivized versus non-incentivized tasks. Secondly, we tested for the following additional affective moderators simultaneously as they have been shown to trigger emotional arousal which neurodevelopmental imbalance models postulate to be a major determinant of heightened risk-taking in adolescence: experience-based versus descriptive-based tasks, time pressure versus no time pressure and dynamic versus static tasks. Thirdly, moderators related to Fuzzy Trace Theory that were tested simultaneously were: sure win option versus no sure win option tasks, and sure neutral (i.e., no loss or win) option versus no sure neutral option tasks. Fourthly, whenever possible, we tested for moderation by specific tasks simultaneously (i.e., (variants of the) IGT, Cold CCT, Hot CCT and the stoplight game, since these tasks were most often used. Fifth and finally, we tested the following putative confounding moderators simultaneously: whether or not choice options were equal in EV (Unequal EV vs. Equal EV), whether fMRI was used (fMRI study versus non fMRI study), and whether or not IQ was included as a covariate in the studies (IQ covariate vs. IQ no covariate). The above-described procedure was carried out in an identical manner for all four meta-analyses (i.e., the children versus adolescents, children versus early adolescents, early adolescents versus mid-late adolescents and adults versus adolescents models), and we only tested for moderation when there was a minimum of 3 studies per subgroup (see Table 4 for an overview of the moderators tested per model).

Results[10]

Table 3 displays the effect sizes and further relevant sample characteristics for the three meta-analyses we conducted, totaling 58 age group comparisons derived from 28 studies/experiments within 25 articles. In summary, there were 21[11,12] group comparisons (N = 2082) for the adolescents (n = 1074) versus children (n = 1008) model, 12 group comparisons for the early adolescents (n = 516) versus children (n = 478) model (N = 994) 14 group comparisons (N=1220) for the early adolescent (n = 569) versus mid-late adolescent model (n = 651), and 23[13] group comparisons (N = 1587) in the adolescent (n = 791) versus adult model (n = 796). The mean ages were 14.87 (1.25) for adolescents, 8.75 (1.65) for children, and 24.98 (5.83) for adults. In the early adolescents versus mid-late adolescent model, the early adolescents were 12.32 (.78) years, and the mid-late adolescents were 16.16 (1.12) years, and in the early adolescents versus children model, the early adolescents were 12.20 (.74) years and the children were 8.60 (1.25) years. We present the results per age group comparison separately, followed by the meta-regression analyses to test the hypothesized moderators derived from imbalance models and Fuzzy Trace Theory. Lastly, we report results for the putative confounding moderator analyses. An overview of which moderators were tested per model is provided in Table 4.

Meta-analysis 1A and 1B: (Early) Adolescents versus Children Risky Decision Making

Meta-analysis 1A: Early Adolescents versus Children Model

The early adolescents versus children model (k = 12) had a non-significant mean effect-size g = .04, p = .68) indicating no age-related differences between adolescent and children in risky decision making (see Table 5 and Figure 1). The Q-test approached significance: $Q(11)$ = 19.47, p = .05 and I^2 = 43.50% and showed moderate heterogeneity (random-effects model). Sensitivity analyses via the Trim and Fill procedure showed that no studies needed to be imputed, indicating that publication bias is absent in the present meta-analysis. Next, outlier analyses showed that 1 study was both an outlier and an influential case. Thus we re-ran the main analyses without this study, and results showed that the effect size remained non-significant. Thus results reported below include this outlier.

As the Q-test approached significance, and there was a moderate amount of variability due to heterogeneity based on the I^2 statistic, we proceeded to meta-regression to identify potential moderators that could explain the existing

10 The same conclusions can be drawn from the results when Harbaugh et al. (2002) is included in the analyses.
11 Or 22 group comparisons when Harbaugh et al. (2002) is included.
12 The longitudinal study of Macpherson (2010) was included in the children versus adolescent model.
13 Or 24 group comparisons when Harbaugh et al. (2002) is included

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

Moderators	Adolescents versus Children $k = 21; N = 2082$	Early Adolescents versus Children $k = 12; N = 994$	Early adolescents versus Mid-late adolescents $k = 14; N = 1220$	Adolescents versus Adults $k = 23; N = 1587$
Neurodevelopmental imbalance model moderators				
Immediate outcome feedback vs. Delayed outcome feedback	X (3 vs. 18)			X (18 vs. 4)
Incentivized versus non-incentivized tasks	X (11 vs.10)	X (6 vs. 6)	X (6 vs. 8)	X (14 vs. 9)
Gain gambles vs. Mixed gambles	X (5 vs. 16)			X (4 vs. 19)
N	2082	994	1220	1552
Additional Affective Moderators				
Experience- vs. Description based	X (7 vs. 14)	X (5 vs. 7)	X (3 vs. 11)	
Dynamic vs. Static	X (5 vs. 16)	X (3 vs. 9)	X (3 vs. 11)	X (7 vs. 16)
Time pressure vs. No time pressure	X (3 vs. 18)	X (3 vs. 9)	X (3 vs. 11)	X (8 vs. 15)
N	2082	994	1220	1587
Fuzzy Trace Theory				
Sure win option vs. No sure win option	X (6 vs. 14)		X (4 vs. 10)	X (10 vs. 13)
Sure neutral option vs. No sure neutral option	X (3 vs. 17)			X (6 vs. 17)
N	1962	994	1220	1587
Task Moderators				
IGT vs. No IGT	X (6 vs. 15)	X (6 vs. 6)	X (6 vs. 8)	X (3 vs. 20)
Cold CCT vs. No Cold CCT				X (3 vs. 20)
Hot CCT vs. No Hot CCT				X (3 vs., 20)
Stoplight game vs. No stoplight game				X (4 vs. 19)
N	2082	994	1220	1587
Putative Confounding Factors				
Unequal EV vs. equal EV	X (9 vs. 4)			X (11 vs. 4)
IQ covariate vs. IQ no covariate	X (7 vs. 14)	X (7 vs. 5)	X (7 vs. 7)	X (6 vs. 17)
fMRI study vs. no fMRI study	X (3 vs. 18)			X (5 vs. 18)
N	836	994	1220	721

* The values in parentheses represent the number of studies per subgroup.

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

Study Nr.	Study Author	Task	Effect-size g	Variance
16	Prencipe et al. (2011)	IGT	.23	.09
20	Smith et al. (2011) [a]	IGT	1.10	.16
3	Crone et al. (2007) [a]	Hungry Donkey task (Modified IGT)	.25	.08
10	Huizenga et al. (2007) [a]	Hungry Donkey task (Modified IGT)	-.21	.03
23a	Van Duijvenvoorde et al. (2012) [a]	Gambling Task (modified IGT; non-informed version)	.04	.09
23b	Van Duijvenvoorde et al. (2012) [a]	Gambling Task (modified IGT; informed version)	-.20	.09
19a	Slovic et al. (1966)	Knife Switches task/Devils task	.40	.03
19b	Slovic et al. (1966)	Knife Switches task/Devils task	.07	.06
23	Van Leijenhorst et al. (2008) [a]	The Cake Gambling Task	-.19	.11
24	Van Leijenhorst et al. (2010) [a]	The Cake Gambling Task	-.19	.11
4	Crone et al. (2008) [a]	Self-Other Gambling Task	.42	.11
18	Steinberg et al. (2008)	Stoplight Game	-.16	.02

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

heterogeneity. In the current model, we tested Incentivized vs. Non-incentivized designs as an imbalance model moderator, but this moderator was not significant (Immediate outcome feedback vs. delayed outcome feedback and Mixed gambles vs. Gain gambles could not be tested in this moderational analysis as to few studies included these characteristics). Secondly, we simultaneously tested the additional affective moderators, namely: Time pressure versus No time pressure, Dynamic versus Static and Experience-based vs. Description-based tasks. However, none of these potential affective moderators were significant. Thirdly, we only tested IGT versus no IGT as a task moderator (as only 1 study employed the CCT and no studies employed the Stoplight game). The IGT did not moderate the results. Finally, we tested IQ covariate vs. no IQ covariate as a putative confounding factor, but this moderational analysis also yielded non-significant results (Equal EV vs. Unequal EV, fMRI vs. no fMRI study could not be tested as putative confounding moderators in this model). Noteworthy is that in this model, we were unable to test for the Fuzzy

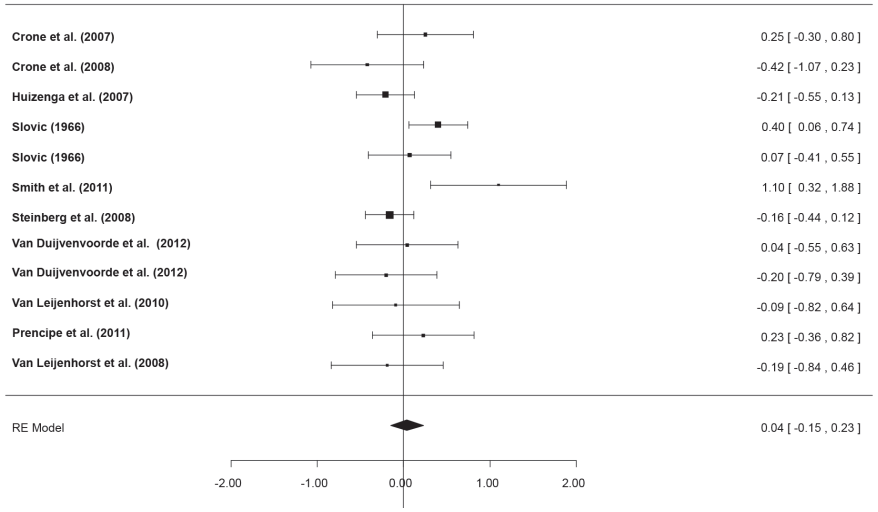

Figure 1. Forest plot with the distribution of effect sizes for studies containing *early* adolescents versus children comparisons on behavioral risky decision making tasks. Effect sizes per study are depicted by the positioning of the filled squares on the x-axis, the sizes of these squares represent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

Trace Theory moderators "Sure win option versus no Sure win option" and "Sure neutral option versus No sure neutral option". Taken together, these results indicate that early adolescents and children take equal levels of risks on a wide range of risky decision making tasks, with varying task characteristics and contexts.

Meta-analysis 1B: Adolescents versus Children Model

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

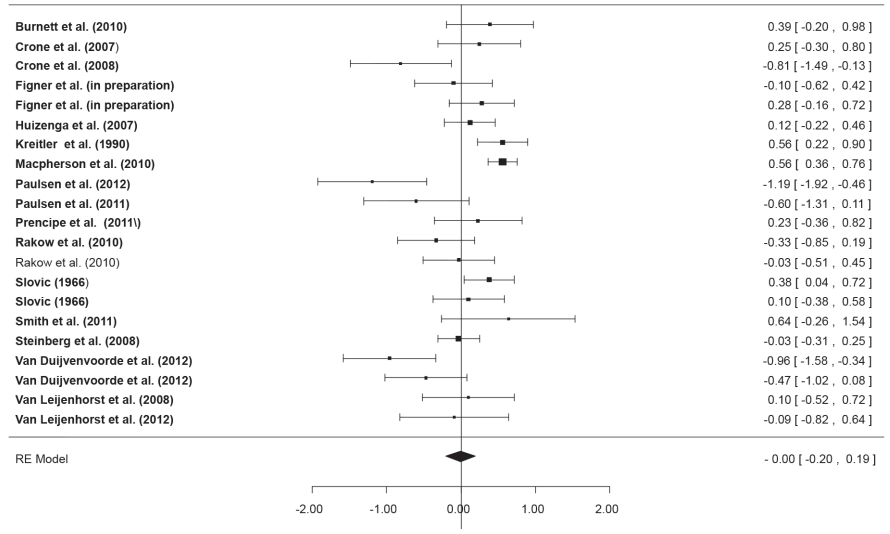

Figure 2. Forest plot with the distribution of effect sizes for studies containing children versus adolescents comparisons on behavioral risky decision making tasks. Effect sizes per study are depicted by the positioning of the filled squares on the x-axis, the sizes of these squares represent the weight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

Considering a significant Q-test and a substantial amount of variability due to heterogeneity based on the I^2 statistic, we proceeded to meta-regression to explain possible underlying factors of the existing heterogeneity. In the current model, we simultaneously tested the following 3 moderators derived from the Imbalance model theory: Immediate outcome feedback vs. delayed outcome feedback[14], Gain gambles vs. Mixed gambles and Incentivized vs. Non incentivized designs, but the moderator analysis was not significant. Secondly, we tested the additional affective moderators simultaneously, namely: Time pressure versus No time pressure, Dynamic versus Static and Experience-based vs. Description-based tasks. This moderator analyses also did not yield significant results. Thirdly, we simultaneously tested the following moderators which we derived from the Fuzzy Trace Theory: Sure win option versus No sure win option, and Sure neutral versus No sure neutral option. Moderation effects ($QM(2) = 8.20$, p = .02) were observed for the tasks that had a Sure win option (versus No sure win option) (b = -.46, p = .02), denoting that the effect size decreases on average by .46 points when a task includes a "sure win option". This suggests that adolescents take fewer risks than children when a "sure win option" is present. Fourthly, we only tested IGT versus No

14 Keulers et al. (2011) was not included in the moderation analyses for immediate outcome feedback, since this study did not consistently provide immediate outcome feedback on all trials.

Table 6. Effect sizes for the Adolescents versus Children Model, Sorted by Type of Task (k= 21)

Study Nr.	Study Author	Task	Effect-size *g*	Variance
16	Prencipe et al. (2011)	IGT	.23	.09
20	Smith et al. (2011)[a]	IGT	.64	.21
22a	Van Duijvenvoorde (2012)[a]	Gambling Task (modified IGT; non-informed version)	-.96	.10
23b	Van Duijvenvoorde (2012)[a]	Gambling Task (modified IGT; informed version)	-.47	.08
3	Crone et al. (2007)[a]	Hungry Donkey task (Modified IGT)	.25	.08
10	Huizenga et al. (2007)[a]	Hungry Donkey task (Modified IGT)	.12	.03
4	Crone et al. (2008)[a]	Self Other Task	-.69	.12
7a	Figner et al. (in preparation)	Cold CCT	-.10	.07
7b	Figner et al. (in preparation)	Hot CCT	.28	.05
14	Paulsen et al. (2012)[a,b]	Non symbolic Economic Decision-making Task	-1.19	.14
15	Paulsen et al. (2011)[a,b]	Non symbolic Economic Decision-making Task	-.60	.13
17a	Rakow et al. (2010)[a]	Sure versus Risky Choice Task (Description version)	-.33	.07
17b	Rakow et al. (2010)[a]	Sure versus Risky Choice Task (Experience version)	-.03	.06
19a	Slovic (1966)	Knife Switches task/Devils task	.38	.03
19b	Slovic (1966)	Knife Switches task/Devils task	.10	.06
23	Van Leijenhorst et al. (2008)[a]	The Cake Gambling Task	.10	.10
24	Van Leijenhorst et al. (2010)[a]	The Cake Gambling Task	-.09	.14
1	Burnett et al. (2010)[a]	Probabilistic Gambling Task	.39	.09
13	Macpherson et al. (2010)	BART	.56	.01
12	Kreitler et al. (1990)	Mirror Drawing Risk-Taking Task	.56	.03
21	Steinberg et al. (2008)	Stoplight Game	-.03	.02

Note. Positive effect sizes indicate that adolescents took more risks than children, whereas negative effect-sizes indicate that adolescents took fewer risks. [a] = The authors of the corresponding studies were contacted for additional numerical statistical information, to facilitate the computation of the effect-sizes. [b] = Results based on the Risk Safe Trials were used to compute the effect sizes.

IGT as a task moderator (as only 1 study employed the CCT and no studies employed the Stoplight game). The IGT did not moderate the results. Finally, we tested the following putative confounding factors simultaneously, Equal EV vs. Unequal EV, fMRI vs. no fMRI study, and IQ covariate vs. no IQ covariate. The overall moderator was significant ($QM(3) = 10.39$, $p = .02$), and inspection of the individual moderators showed that adolescents take more risks than children on tasks with unequal EV ($b = .78$; $p<.01$), however adolescents take fewer risks than children when IQ is

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

Study Nr.	Study Author	Task	Effect-size *g*	Variance
16	Prencipe et al. (2011)	IGT	.52	.09
20	Smith et al. (2011)[a]	IGT	1.00	.17
22a	Van Duijvenvoorde (2012)[a]	Gambling Task (modified IGT; non-informed version)	.51	.09
23b	Van Duijvenvoorde (2012)[a]	Gambling Task (modified IGT; informed version)	.08	.08
3	Crone et al. (2007)[a]	Hungry Donkey task (Modified IGT)	.42	.07
10	Huizenga et al. (2007)[a]	Hungry Donkey task (Modified IGT)	-.05	.03
4	Crone et al. (2008)[a]	Self Other Task	-.17	.11
17c	Rakow et al. (2010)[a]	Sure versus Risky Choice Task (Experience version)	.05	.07
19a	Slovic (1966)	Knife Switches task/Devils task	.06	.02
19b	Slovic (1966)	Knife Switches task/Devils task	.17	.06
23	Van Leijenhorst et al. (2008)[a]	The Cake Gambling Task	-.14	.11
24	Van Leijenhorst et al. (2010)[a]	The Cake Gambling Task	.15	.14
11	Keulers et al. (2014)	Gambling Task	.15	.01
21	Steinberg et al. (2008)	Stoplight game	.32	.10

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

controlled for ($b = -.65$; $p=.02$). A follow-up moderational analysis with only Unequal EV tasks showed that whether the sure option (or less riskier option) vs. the risky (or riskier) option had the highest EV did not moderate the results.

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

Meta-analysis 2: Early Adolescent versus Mid-late Adolescent Risky Decision Making

The early adolescent versus mid-late adolescent model ($k = 14$) resulted in a significant but small standardized mean difference of $g = .15$ ($p = .01$), and a non-significant Q-test ($Q(13) = 12.19$, $p = .51$; $I^2 = 0$ %; random effects model). These findings (see Table 7 and Figure 3) suggest greater risk-taking levels by early adolescents compared to mid-late adolescents on risky decision making tasks,

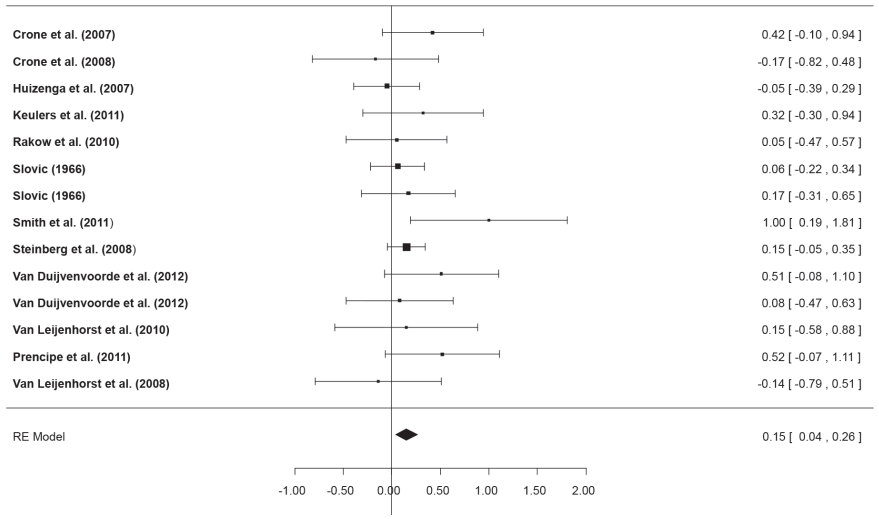

Figure 3. Forest plot with the distribution of effect sizes for studies containing early adolescents versus mid-late adolescents comparisons on behavioral risky decision making tasks. Effect sizes per study are denoted by the location of the squares (i.e., weight of the studies). The diamond portrays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

with an absence of heterogeneity. Sensitivity analysis results from the Trim and Fill procedure revealed that 2 studies had to be imputed. When these potential studies were imputed, the effect size dropped slightly and the resulting effect-size was marginally significant g = .12; p =.08. Finally, outlier analyses did not reveal any influential outliers. Although heterogeneity was not detected, we still progressed to moderation analyses, as the Q-test sometimes fails to detect heterogeneity due to limited statistical power (Lipsey & Wilson, 2001). Incentive compatibility vs. Incentive incompatibility which was tested as an Imbalance model moderator was not significant (Gain vs. Mixed gambles, peer presence vs. alone, and immediate vs. Delayed outcome feedback could not be tested as moderators). The additional affective moderators that were simultaneously tested were Time pressure vs. No time pressure, Dynamic vs. Static, Experienced-based vs. Descriptive-based tasks, but they were all non-significant. Sure win option vs. No sure win that was tested as a Fuzzy Trace Theory moderator was also not significant. IGT vs. no IGT was investigated as a task moderator but no moderational effect was found (in this model we could not test for moderation by the Stoplight game or the CCT). Finally, results showed that the putative confounding moderator IQ covariate vs. no IQ covariate was not significant (the Equal EV vs. unequal EV and fMRI vs. No fMRI moderators

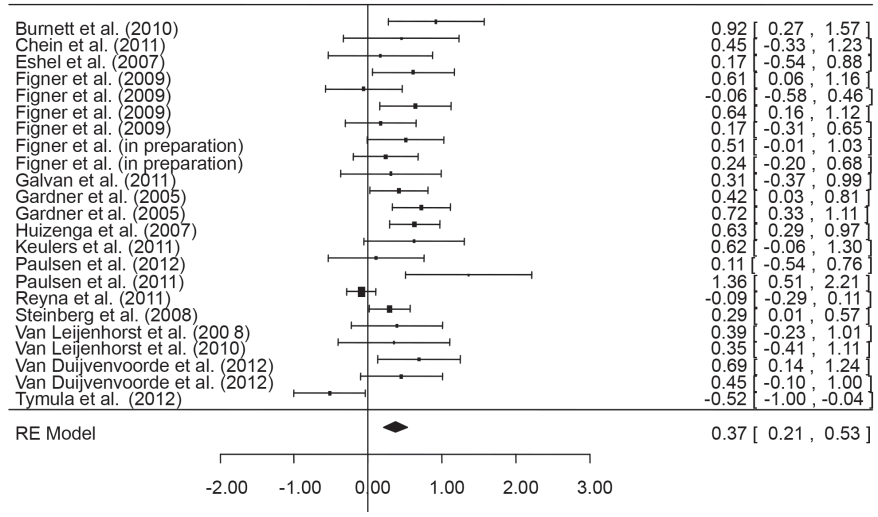

Figure 4. Forest plot with the distribution of effect sizes for studies containing adults versus adolescents comparisons on behavioral risky decision making tasks. Effect sizes per study are denoted by the positioning of the filled squares (i.e. weight of the studies). The vertical line with the value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

could not be tested in this analysis). Taken together, none of the moderators were significant, thus, collectively, it can be concluded that early adolescents engage in more risky decision making relative to mid-late adolescents, on a range of tasks, although when controlling for publication bias, this effect becomes marginally significant.

Meta-analysis 3: Adolescent versus Adult Risky Decision Making

The final model (k = 23) which compared adolescents' risky choice to adults' risky choice yielded a medium effect size g = .37 (p < .01) and the Q-test was significant $Q(22)$ = 53.88, p < .01, I^2 = 59.17% (random-effects model). These results (Table 8 and Figure 4) indicate that adolescents engage in more risk-taking relative to adults on risky decision-making tasks and that there was substantial heterogeneity in the distribution of effect-sizes. Regarding publication bias, sensitivity analyses via the Trim and Fill method suggested that 7 studies had to be imputed. However, despite the suggested imputations, the mean effect size remained significant and of medium magnitude (g = .37 to g = .21) and the Q-test remained significant. Thus, these tests confirm that despite a slight decline in effect-size, age differences in risk-taking between adults and adolescents remained, suggesting that results reported in the current meta-analysis are relatively robust to any potentially missing studies.

Table 8. Effect sizes for the Adolescent versus Adult Model, Sorted by Type of Task (k = 23)

Study Nr.	Study Author	Task	Effect-size g	Variance
2	Chein et al. (2011)	Stoplight game (modified Chicken Game)	.45	.16
9a	Gardner et al. (2005)	Chicken game	.42	.04
9b	Gardner et al. (2005)	Chicken game	.72	.04
21	Steinberg et al. (2008)	Stoplight game (modified Chicken Game)	.29	.02
5	Eshel et al. (2007)	Wheel of Fortune	.17	.13
6b	Figner et al. (2009)	Cold CCT	-.06	.07
6d	Figner et al. (2009)	Cold CCT	.17	.06
6b	Figner (in preparation)	Cold CCT	.24	.05
7a	Figner et al. (2009)	Hot CCT	.61	.08
7c	Figner et al. (2009)	Hot CCT	.64	.06
7a	Figner (in preparation)	Hot CCT	.51	.07
14	Paulsen et al. (2012) [a, c]	Non symbolic Economic Decision-making Task	.11	.11
15	Paulsen et al. (2011) [a, c]	Non symbolic Economic Decision-making Task	1.36	.19
23	Van Leijenhorst et al. (2008) [a]	The Cake Gambling Task	.39	.10
24	Van Leijenhorst et al. (2010) [a]	The Cake Gambling Task	.35	.15
10	Huizenga et al. (2007) [a]	Hungry Donkey Task (modified IGT)	.63	.03
22a	Van Duijvenvoorde (2012) [a]	The Gambling Task (modified IGT)	.69	.08
22b	Van Duijvenvoorde (2012) [a]	The Gambling Task (modified IGT)	.45	.08
25	Tymula et al. (2011)	a standard incentive-compatible technique	-.52	.06
1	Burnett et al. (2010) [a]	Probabilistic Gambling Task	.92	.11
8	Galvan et al. (2011) [ab]	Cups Task	.31	.12
11	Keulers et al. (2011)	Gambling Task	.62	.12
18	Reyna et al. (2011)	The Framing Task	-.09	.01

Note. Positive effect sizes indicate that adolescents took more risks than adults, whereas negative effect-sizes indicate that adolescents took fewer risks. [a] = The authors of the corresponding studies were contacted for additional numerical statistical information, in order to the calculate the effect-sizes. [b] = The Equal EV (EQEV) condition and the Low Stress Condition were used to compute the effect sizes. [c] = Results based on the Risk Safe Trials were used to compute the effect sizes.

Moreover, when 2 influential outliers were removed, the effect size increased slightly and remained significant. Since there was no substantial change in the mean effect-size when the outliers were removed, below we report moderational analyses including the outliers.

The following Imbalance Model moderators were tested simultaneously, Immediate vs. Delayed outcome feedback, Gain gambles versus Mixed gambles and Incentivized designs vs. Non-incentivized designs. The overall moderational test was significant $QM(3) = 9.40$, $p = .02$. However Immediate outcome feedback versus Delayed outcome feedback did not fully reach significance ($b = .37$ $p = .059$), whereas the remaining two imbalance moderators were clearly not significant as their p-values were larger than $p=.10$[15]. Thus, for every task including immediate outcome feedback on gains and losses, the effect size increases on average with .37 points, although this seemingly substantial increase is only marginally significant. The following additional affective moderators were simultaneously tested: Time pressure vs. no Time pressure and Dynamic vs. Static tasks (the Descriptive-based vs. Experienced-based moderator could not be tested since a subgroup only included 2 studies); however, none of the moderators was significant. Next, we simultaneously tested the outcome moderators: Sure win option vs. No sure win option and Sure neutral vs. No sure neutral (i.e., Fuzzy Trace Theory moderators); results showed no significant effects. The task moderator analysis including IGT vs. No IGT, Stoplight vs. No Stoplight, Cold CCT vs. No Cold CCT, and Hot CCT vs. no hot CCT moderators was also not significant. Finally, the confounding moderators that were tested simultaneously, i.e., Unequal EV versus Equal EV, fMRI vs. no fMRI and IQ covariate vs. no IQ covariate, were all not significant. Taken together, results imply that adolescents generally take more risks than adults, but that this is especially the case on tasks with immediate outcome feedback on rewards and losses.

Discussion[16]

Survey data as well as real-life accounts concur that adolescence is a period for both the initiation and peak of many health-threatening risk-taking behaviors (Albert &

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

16 For the 4 excluded studies (due to failed attempts to retrieve necessary statistical information from the respective authors) that matched the inclusion criteria, the reported results were based on net-scores and disadvantageous choices, and thus do not reflect "risk-taking" as defined in the field of Judgment and Decision Making (Weber, 2010), which defines "risk" behavior as "choosing the outcome with the highest variance." For this reason we cannot give a summary of the risk-taking results of these studies, nor is it valid to refer to them in the discussion section.

Steinberg, 2011; Reyna & Farley, 2006; Steinberg, 2004). However, despite evident disproportionate adolescent risk-taking in real life situations, only some--but not all--experimental studies have found that adolescents indeed engage in more risk-taking than children and adults (Gladwin et al., 2011). In view of such conflicting findings on age-differences in risk-taking, we conducted four rigorous independent meta-analyses, comparing children's versus early adolescents' , children's versus adolescents', early adolescents' versus mid-late adolescents', and adolescents' versus adults' risk-taking on behavioral risky decision making tasks.

As our primary theoretically guiding framework, we used the neurodevelopmental imbalance perspective, which postulates a transient potential during adolescence for an imbalance between relatively strong "hot" affective-motivational versus relatively immature "cold" deliberative-cognitive control processes (Figner & Weber, 2011; Somerville et al., 2010; Steinberg, 2007). Further, we also used Fuzzy Trace Theory, as an additional theoretical guiding framework. Fuzzy Trace Theory generally distinguishes between two different types of processing (here explained in the context of risk decision making), a *verbatim-based quantitative* reasoning mode and a *gist-based qualitative* reasoning mode (Reyna & Brainerd, 2011). Fuzzy Trace Theory posits that reliance on gist-based qualitative decisions increases with age, and, as a result, adults are more likely than adolescents to use a gist-based mode when making a risky choice. Thus, while neurodevelopmental imbalance models predict that adolescents should take *more* risks compared to children and adults especially in highly arousing (e.g., "hot" affect-charged) situations, for example, when salient rewards (gains) are involved, Fuzzy Trace Theory predicts that adolescents should take *fewer risks* than children, but *more* risks than adults, as gist-based decision making increases with age and thus leads to decreasing risk-taking with increasing age (holding all other things equal). The first question motivating the current meta-analyses was: "How do (early) adolescents' risk-taking levels differ from children's and adults' and how strong are these differences?". Secondly, since imbalance models postulate that the imbalance between more cognitive top-down control processes versus more affective-motivational bottom-up processes is especially driven by puberty-specific maturational changes in the brain that begin during *early* adolescence (Somerville et al., 2010), we also investigated whether there are age differences in early versus mid-late adolescents' risk-taking and whether early adolescents differ from children. Finally, again inspired by imbalance models, we investigated whether cold versus hot affective task and setting features moderated the results. Additionally, inspired by Fuzzy Trace Theory, we investigated if the availability of a sure option (in contrast to both available choice options being risky) moderated the results.

Contrary to the predictions of Imbalance models and abundant evidence of heightened real-world adolescent risk-taking alike, two meta-analyses (i.e., (1) a children-versus-adolescents meta-analysis and (2) a children-versus-early-adolescents meta-analysis) consistently revealed that adolescents generally engage in equal levels of risk-taking as children on risky decision-making tasks. A modest but significant age-difference (g = .15) was present between early and mid-late adolescence, with early adolescents taking more risks than mid-late adolescents. Additionally, consistent with imbalance models, results showed that adolescents engage in more risk-taking than adults, denoted by a medium mean effect-size (g = .37). Next, a series of moderation analyses revealed that adolescents take fewer risks than children when IQ is controlled for, and particularly on tasks that include a choice between a sure option to *win* something and a gamble (compared to tasks wherein engaging in a gamble is unavoidable as both options are risky). Finally, adolescents engage in more risk-taking than children on tasks with unequal Expected Values (EVs). As for the adult-adolescent model, moderation analyses revealed that the moderator "immediate versus delayed outcome feedback" approached significance, (b = .37; p = .059), indicating that compared to adults, adolescents engage in more risk-taking particularly on tasks that provide immediate feedback on potential outcomes (versus tasks with delayed feedback on potential outcomes)[17]. No other significant moderator was found, more specifically, the remaining hot affective and cold cognitive task and contextual characteristics derived from the Imbalance framework, the sure option moderator derived from Fuzzy Trace Theory, and the confounding factors all did not moderate the variability in the effect-sizes.

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

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

Contrary to popular belief, the present results revealed that when (early) adolescents and children are presented with the same risk-taking task under similar conditions (i.e., identical risk-taking opportunities), they generally end up taking equal levels of risks. These results challenge imbalance models, because these theories posit that adolescents are more inclined to take risks than both children and adults. The results are generally, also not consistent with Fuzzy Trace Theory, since this theory predicts that adolescents should take fewer risks than children due to adolescents' stronger reliance on more gist-based decision making, compared

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

to children. However, it is worth noting that substantial heterogeneity in age differences across studies was present. Whereas, no significant moderators were present in the children versus *early* adolescents models[18], moderation analyses in the children versus adolescent model, revealed that adolescents take fewer risks than children when a sure win option is available (it was not possible to test for moderation for Sure neutral option, as too few studies included such a task characteristic). Additionally, adolescents also take fewer risks than children when IQ is controlled for. On the other hand, adolescents take more risks than children on tasks with unequal EV choice options[19].

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

First, is it possible that gender effects might explain the current results? A meta-analysis on gender differences in self-reported risk-taking more or less supports this notion, as this meta-analysis documented that females were more risk-averse than males; however, the effect sizes were small and domain-specific (Byrnes et al., 1999). Unfortunately, the vast majority of studies included in our meta-analyses (with the exception of 2 studies: Kreitler & Zigler 1990; Slovic, 1966) did not provide results for males and females separately, making it impossible for us to investigate gender as a moderator in age effects. Nonetheless, the few studies in the current meta-analyses that investigated gender differences in age effects in risk-taking (but did not report results for males and females separately), reported that gender did not moderate these effects (e.g., Figner et al., 2009; Steinberg et al., 2008). Thus, there are reasons to believe that moderation by gender of the current age effects is absent in the present findings.

A second potential explanation of the lack of age differences in the adolescents-versus-children model, could be the presence of individual differences. More specifically, when a risk-taking opportunity arises, adolescents' inclination to take risks might be predicted by hypersensitive affective personality traits (e.g.,

18 Please note that for the children versus early adolescent model, it was not possible to test for moderation by the following factors, as there were not enough studies available per subgroup: Imbalance model moderators: (i) immediate versus delayed outcome feedback, (ii) mixed versus gain gambles tasks, Putative confounding moderators: (iii) fMRI study versus no fMRI study, (iv) controlling for IQ versus not controlling for IQ, Fuzzy Trace moderator: (v) Sure win versus no Sure win, (vi) Sure neutral versus No Sure neutral and Task moderators: (vii) Cold CCT versus no Cold CCT, (viii) Hot CCT versus no Hot CCT, and (ix) Stoplight game versus no Stoplight game)

19 Please note that it was not possible to test for moderation in age differences in risk-taking for the following tasks; (i) Cold CCT, (ii) Hot CCT, and (iii) the Stoplight game, as too few studies included these tasks.

individual differences in sensation seeking or anxiety) (Casey, Jones, & Hare, 2008; Harden & Tucker-Drob, 2011). Accordingly, individual differences in baseline activity of the affective motivational system could potentially exacerbate the imbalance between cognitive top-down control processes and affective-motivational bottom-up processes in adolescence (Casey et al., 2008). The role of individual differences in age-differences in risk-taking between children and adolescents was not directly measured in the current meta-analysis, but it is supported by substantial empirical evidence (e.g., Crone et al., 2008; Hare et al., 2008; Lejuez et al., 2003; Rao et al., 2011; Reyna et al., 2011; Romer & Hennessy, 2007; Steinberg, 2008). Thus, the neglect of individual differences in the current meta-analysis could perhaps--at least partially--account for the lack of age differences found between children and adolescents' risk-taking in the present meta-analysis. It is imperative to mention that although there is evidence showing that individual differences might be a predictor of the "affective-cognitive imbalance" only few studies consider individual differences in risk-taking (cf Somerville et al., 2010; but see Figner et al., 2009; Reyna et al., 2011; Steinberg et al., 2008); thus, conducting a meta-analysis on this topic--up until now--might be quite challenging and unfeasible due to a dearth of available studies.

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

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

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

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

The two remaining significant moderators were putative confounding factors, namely whether a study used unequal (or equal) EV choice options, and whether the study controlled for IQ (or not). The effect size increases significantly (i.e., approaches a positive value indicating that adolescents take more risks than children) when the EV for the choice options differ (i.e., unequal EV). Such unequal EV choice options might require more computational abilities, implying that in such cases, older persons should outperform (i.e., take less risk) younger persons, by choosing the option with the highest EV. However, follow-up moderational analyses including only Unequal EV tasks showed that "higher EV for the risky option versus higher EV for the sure option" did not moderate the effect size. Interestingly, this finding indicates that unequal EVs seem to be more relevant than *which* option has the higher EV[20]. In any case, the current results reveal that task characteristics such as unequal EV vs. equal EV should be considered, particularly when the aim is to identify age differences in risk-taking.

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

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

help choose closer to the financial optimum in such tasks. Taken together these results coupled with our moderation effects highlight the need for future studies to include assessments of IQ in research on adolescent risk-taking. This might be of particular importance for studies testing neurodevelopmental imbalance models, since cognitive control, which is a centerpiece of these models, is related to IQ.

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

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

In sum, while over the entire investigated age range we found partial support for both of the theoretical frameworks used (the decline in risk-taking from adolescence to adulthood, discussed further below), and the children vs. adolescents model discussed here, the present results are in quite sharp contrast with neurodevelopmental imbalance models, which predict that adolescents engage in more risk-taking than children (and adults) in hot affective situations. The main result of no age difference in risk-taking between children and adolescents also does not fully support Fuzzy Trace Theory. While Fuzzy Trace Theory predicts varying developmental patterns based on task characteristics, averaging across all tasks, we would expect as a main pattern that children take more risks than adolescents. However, consistent with Fuzzy Trace Theory that gist-based sound decision making increases with age, we found that adolescents took fewer risks than children on tasks that provide a sure win option. In an attempt to reconcile the current mixed findings, we suggest a hybrid "developmental neuroecological model of risk-taking", as it appears to be most parsimonious to posit that the mere availability of risk-opportunities might be an important factor accounting for more risk-taking in adolescents than children in the real world, and that equal levels of risk-taking by these two age groups will emerge when they perform identical risky decision-making tasks under similar situations (i.e., situational component).

Meta-Analysis 2: Early Adolescents versus Mid-late Adolescents Risk-taking

Considering that puberty begins in early adolescence, and that imbalance models consider puberty-related changes as the main source of the affective-cognitive imbalance (Somerville et al., 2010), imbalance models would predict that early adolescents should engage in more risk-taking than mid-late adolescents. The current results confirmed these expectations as early adolescents compared to mid-late adolescents took significantly more risks. Thus, consistent with the Imbalance framework, it seems plausible to conclude that the onset of puberty in early adolescence might be driving the direction of the age-differences in risk-taking between early and mid-late adolescents. However, it should be recognized that there are too few studies examining the link between pubertal development and adolescent risky decision making on behavioral tasks directly. Among the studies included in our meta-analyses, only one study (i.e., Steinberg et al., 2008) examined self-reported pubertal status as a predictor of risky decision making on the Stoplight Game (see Table 1). In their cross-sectional sample of 12-16 year olds, pubertal status was not related to safe stopping, risky driving, or crashing. However, it was related to the number of intersections adolescents crossed through successfully. Specifically, those who just entered puberty crossed more intersections than either pre-pubertal, mid-pubertal or post-pubertal adolescents. Thus, although it is perhaps likely that the onset of puberty may be linked to the age differences we found, clearly the link between pubertal development and risky decision making

needs to be investigated among additional (longitudinal) samples. The current results are also in line with Fuzzy Trace Theory, as this theory postulates that early adolescents should be more susceptible to risk-taking than older adolescents, considering that older adolescents rely less on verbatim-based decision making (Reyna & Farley, 2006; Rivers et al., 2008). Furthermore, heterogeneity was not detected in this model, and moderation analyses confirmed that no moderators were present.

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

Meta-Analysis 3: Adolescents versus Adults Risk-Taking

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

Interestingly, whereas the availability of a sure option moderated the age differences in the adolescent versus children model, this was not the case in the adolescent versus adult model. This latter finding could perhaps be again explained by Fuzzy Trace Theory. Although Fuzzy Trace Theory predicts that gist decision-making (linked to risk-aversion) increases with age (Reyna & Ellis, 1994), unlike the transition from childhood to adolescence, the transition from adolescence to adulthood is not marked by dramatic increases in gist-based decision making (Reyna et al., 2005; Reyna et al., 2011; Rivers et al., 2008). This could perhaps explain why the moderator sure option was not significant in the adolescents vs. adults model. Next, it is also noteworthy that whether or not IQ was controlled for in a given study did not moderate the effect sizes in the adolescents versus adults model, whereas this was the case for the adolescents versus children model. This result might be due to the fact that IQ, and, thus, cognitive control begin to stabilize during adolescence (Luna et al., 2004).

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

Strengths, Limitations and Direction for Future Research

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

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

The third limitation of the current meta-analysis also reflects a major gap in the (adolescent) risk-taking literature, that is, the absence of risky decision making studies that manipulate peer presence and risk-taking studies including pubertal maturation are also lacking. Two central features of Imbalance models (especially the Developmental *Social* Neuroscience model) is the focus on the relationship between peers and perceived rewards in adolescence and how pubertal onset might play a significant role in the hyper-sensitization of reward-related regions in the brain (Dahl, 2004; Nelson, 2005; Spear, 2004). Imbalance models predict that adolescents' hyper-sensitivity to rewards becomes even stronger when adolescents are among peers, which might, in turn, cause adolescents to pay more attention to the potential rewards of risk-taking behaviors, leading to risk-taking (Chein et al., 2011; Somerville et al., 2013; Steinberg, 2010). Unfortunately, the current meta-analysis could not include peer presence/awareness as a moderator, as there are only two existing experimental studies on age differences between adolescents and another age-group (in both studies adults) that manipulated peer presence. Nevertheless, we briefly report the intriguing results of these two studies below.

The first empirical study to demonstrate the significant effect of peers in a laboratory setting reported that when adolescents performed a risky driving task in the presence of peers (versus on their own), their risky choices increased more strongly in comparison to when adults performed the same task with peers (Gardner & Steinberg, 2005). Likewise, fMRI evidence revealed that risky choices as well as activation in the ventral striatum concurrently and significantly increased when adolescents (compared to adults) completed a risky driving game in the presence of peers versus on their own (Chein et al., 2011). Moreover, recent empirical evidence shows that when adolescents believed that they were being observed by a peer, they experienced heightened self-conscious emotions and activation in socio-affective brain circuits (Somerville et al., 2013)[21].

A notable methodological difference between the "peer presence" paradigms used in Gardner and Steinberg (2005) and Chein et al. (2011), is that in the former study, peers were in the same room and were allowed to communicate with the participants while they performed the risky driving game, whereas in the latter fMRI study, peers were in a separate room, but the participants were aware that their peers were observing their performance on the risky driving game from a distance. Despite the methodological difference in the abovementioned studies, in both studies, the peer condition induced significantly more risk-taking by adolescents compared to the condition wherein participants performed the risky driving game alone and compared to the adults. Beyond the link of heightened reward sensitivity (Albert, Chein, & Steinberg, 2013), imbalance models do not investigate the exact social mechanisms or characteristic of peer interactions that trigger adolescent risk-taking (e.g., do non-supportive peer reactions still produce heightened adolescent risk-taking?). However, from the above-discussed findings it appears that the mere "awareness" of peer presence might influence risky decision-making in an upward fashion, and that this is especially the case for adolescents, but not for adults. The finding that adolescents' risky choice is dependent on peer presence/awareness in the laboratory is also consistent with real life risk-taking scenarios, as most risk-

21 No comparisons to other age groups were made.

taking behaviors in adolescence occur when they are among their peers, while this phenomenon generally does not hold true for adults (for an overview, see Steinberg, 2004). Hereby, we thus urge scholars to manipulate social context in their experimental risk-taking paradigms, and, in addition to investigating possible neurobiological pathways, such as pubertal processes, for potential peer effects, the actual behaviors of peers should be examined, as this might prove to be a promising factor for gaining a better understanding of the mechanisms underlying age differences in risk-taking. Moreover, it is recommended that puberty researchers consider more objective measures of puberty (e.g., direct measures of pubertal hormones) instead of the traditional self-report measures.

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

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

Conclusions

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

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

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

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

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

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

Collectively, the current 4 independent but related meta-analyses raise some interesting questions, but at the same time the current results reveal that the reasons why in the real-world adolescents take more risks than children, on one the hand, and why adolescents take more risks than adults, on the other hand, might not solely be a product of neurodevelopmental changes in the adolescent brain, or reliance on different reasoning modes. Thus, while neurodevelopmental imbalance models and Fuzzy Trace Theory can contribute to explaining half of the puzzle (why adolescents take more risks than adults in the real-world), perhaps a situational theory is necessary to help explain the other half of the puzzle (why adolescents take more risks than children in the real-world). Hence, our advocacy of a more integrative "developmental neuroecological" model of risk-taking. As emphasized in the beginning of the current meta-analysis, heightened risky decision making in adolescence is a serious problem, as its negative consequences (e.g., depression; Defoe, Farrington & Loeber, 2013) account for a dramatic increase in mortality rates (e.g., as a result of suicidality) in adolescence (Dahl, 2004; Spear, 2000). Rigorous experimental studies to identify task and contextual characteristics that contribute to heightened adolescent-risk-taking could improve our understanding of when and under which circumstances adolescents are more or less inclined to take dangerous risks in the real-world. The current meta-analysis provides a promising starting point in this direction.

PART 2:

An experimental investigation of the roles of parents, peers, and siblings in adolescent risk-taking

3

Chapter 3

From the Lab to the Real world: Does Peer Presence Matter in The Link between Adolescent Experimental Risk-taking and Real-world Risk Behaviors?

Author note:
This chapter is based on a manuscript in preparation to be submitted.

I.N. Defoe developed the study concept and design, and J.S. Dubas and M.A.G. van Aken gave advice and feedback. I.N. Defoe oversaw the data-collection. I.N. Defoe performed the data-analysis and interpretation. I.N. Defoe drafted the manuscript, and J.S. Dubas, and M.A.G. van Aken provided critical revisions.

Abstract

Despite methodological advantages of using laboratory risky decision making tasks to investigate risk-taking, such tasks are often questioned on their criterion and ecological validity, as such tasks and contexts are typically *not* emotionally arousing (i.e., cold). However, it is likely emotionally arousing "affective" (i.e., hot) paradigms that will more accurately capture the nature of heightened adolescent real-world risk-taking and the contexts in which this behavior typically occurs. Yet, laboratory studies that assess adolescent risk-taking via behavioral risk-taking tasks do not typically assess participants' real-world risk-taking to facilitate the investigation of criterion validity. Moreover, such studies rarely capitalize on affectively laden paradigms which could possibly enhance the ecological validity of a typical lab context. Hence, the current study investigated whether a well-known risky driving task (the stoplight game), predicts multiple real-world risk-taking behaviors in adolescents (*N*= 331; 50% female). Moreover, the aim is also to examine whether completing such a risky decision making task in a more ecologically valid context (i.e., together with peers) versus alone increases the criterion validity of this task, while controlling for age, gender and sensation seeking. Results showed that risk-taking on the stoplight game predicted risky traffic behavior, alcohol use and delinquency (but not smoking (p = .06) and marijuana use (p=.11)). However, peer presence during completion of the stoplight game did not moderate these links. Hence, these findings provide support for using experimental risk-taking tasks to understand risk-taking behaviors in the real-world, whether completed individually or with a peer.

Can you think of some reasons why you or other youth engage in risky traffic behavior? "They don't know exactly that it's extremely dangerous and all they think is 'As long as I get home as soon as possible' and they often don't think of the risks that they can encounter." adolescent participant[22]

Currently, there is a rapid ongoing increase in experimental studies aimed at understanding disproportionate real-world risk-taking in adolescence. In these studies, various behavioral risk-taking tasks (e.g., simulated driving and gambling tasks) are being used in diverse settings (alone vs. peers) (Defoe, Dubas, Figner, & van Aken, 2015). Despite methodological advantages of such experimental studies, laboratory risk-taking tasks are often questioned on their criterion and ecological validity, as such tasks and contexts are typically *not* emotionally arousing (i.e., cold). However, it is likely emotionally arousing "affective" (i.e., hot) paradigms that will more accurately capture the nature of heightened adolescent real-world risk-taking and the contexts in which this behavior typically occurs. Surprisingly, experimental studies utilizing behavioral risk-taking tasks rarely include measures of real-world risk-taking behaviors (but see e.g., Kim-Spoon et al., 2016) to account for criterion validity (Defoe et al., 2015). An example of an increasingly widely used risky driving task in adolescent research is the "the stoplight game". Until recently, only one study has investigated the criterion validity of the stoplight game and found that performance on this task was related to a composite score of alcohol, marijuana and smoking in late adolescents (17-20 years; *N*=24; 25% female) but not in adults (31-60 year olds; Kim-Spoon et al., 2016). Hence, the authors concluded that the stoplight game might be a promising tool for studying underlying behavioral and neurobiological mechanisms of adolescent health risk behaviors.

Furthermore, interestingly, some studies that have employed the stoplight game show that during an alone (i.e., "cold") condition, adolescents show comparable levels of risk-taking as adults, however, adolescents show more risk-taking than adults in the presence of peers (i.e., "hot" condition) (e.g., Gardner & Steinberg, 2005). Unfortunately, whether hot and/or cold risky decision-making on the stoplight game was related to adolescent risk-taking in the real-world was not examined in these studies. However, social neurodevelopmental imbalance models posit that high affective paradigms (e.g., including peer presence), as opposed to low affective paradigms (e.g., excluding peer presence) mirror the affectively-laden contexts in which heightened adolescent risk-taking typically occurs in the real-world (Gardner & Steinberg, 2005). Accordingly, perhaps the validity of

22 The original quote as it appeared in the Dutch language: "Ze weten niet precies dat het heel erg gevaarlijk is en ze denken alleen maar '' als ik maar snel thuis ben" en ze denken vaak niet naar de risico's die ze kunnen opnemen."

experimental risk-taking tasks might be stronger in affective paradigms with peer presence. Hence, the current study investigates this pertinent question.

The current study builds upon, and extends, Kim-Spoon et al. (2016) in distinctive ways. First, unlike Kim-Spoon et al. (2016) that used late adolescents, we use a sample of younger adolescents (i.e., early- and mid-adolescents), because experimental risk-taking is higher in early adolescents (versus mid-adolescents; Defoe et al., 2015), and many risk-taking behaviors peak during mid-adolescence (e.g., Eaton et al., 2008). Secondly, in addition to alcohol use, marijuana and smoking, we investigate whether experimental risk-taking is related to self-reported risky traffic behavior and delinquency, while controlling for possible confounding effects of age and gender. Additionally, we control for sensation seeking, which has consistently been shown to be related to real-world risk-taking (Schonberg, Fox & Poldrack, 2011). Finally, we investigate whether a possible relation between adolescent experimental risky decision-making and self-reported risk-taking is moderated by peer presence versus no peer presence paradigms. That is, extrapolating from social neurodevelopmental imbalance models, we hypothesize that adding an affective component (i.e., peer presence) to a risk-taking paradigm will increase its criterion validity of predicting self-reported real-world risk-taking. That is, individual differences in risk-taking might be exacerbated in the peer condition, strengthening the association between risky decision making on the stoplight game and self-reported real-world risk-taking.

Method

Participants

Participants were drawn from the first wave of a prospective 3-year longitudinal study in the Netherlands (for detailed information see Defoe, Dubas, Somerville, Lugtig, & van Aken, in press). A total of 602 adolescents who were either in the first or third year of middle level secondary educational tracks (advanced vocational and technical tracks) filled out questionnaires during school hours at their schools. In addition, adolescents also engaged in experimental sessions, which consisted of completing cognitive tasks and the stoplight game. The majority of adolescents (93.2%) indicated that they were born in the Netherlands with 61.6% identifying as Dutch, and the rest (identified with various other ethnicities (e.g., Dutch-Turkish). Nearly half of the adolescents (44.90% fathers; 46.5% mothers) did not know their parents' highest level of completed education partially because parents (11.0% fathers; 11.8% mothers) were born abroad, in countries that did not have educational systems that were similar to the Dutch educational system. For the the education levels that were reported, 6.7% of mothers and 6.4% of fathers did not complete high school, whereas 35.8% of mothers and 28% of fathers completed a lower or middle level vocational training and 3.8% mothers and 10.5% of the fathers completed a university degree.

Procedure

Participants were recruited from high-schools in six different regions in the Netherlands. After the schools gave permission, parents could still refuse to let their children participate via passive consent forms. Participants received written and verbal instructions by trained research assistants during the data collections. The participants were randomly assigned to perform the stoplight game either in an alone condition (i.e., they completed the task in the same classroom, behind their own computer) or they were assigned to the peer condition in a separate room, where they completed the stoplight game in groups of three. Research assistants ensured that participants in the alone condition (*n*=252; 49.2% female) did not communicate with each other during the stoplight game. Participants wore headphones during the alone condition to prevent the other participants in the classroom (who were also busy with their own experimental tasks) from hearing the sound effects of the stoplight game. In the Peer condition participants were placed in groups of three same-sex peers from their class (*n*=120; 40 groups; 52.5% female). In this condition, participants played the stoplight game, one after the other, and were allowed to communicate with each other about the game.

Schools varied in how much time was allowed to be used for data-collection (90-120 minutes). In some schools there was insufficient time for the stoplight game and in the group condition we primarily had complete data for the first or second participant. We reported the effects of peer presence on adolescent risk-taking elsewhere, and in the current study we focus on the validity of the risk-taking paradigm.

Measures

Risky decision-making was assessed with a two-dimensional version of the stoplight game, which was programmed in OpenSesame (Mathôt, Schreij, & Theeuwes, 2012). For this task, participants viewed the roads with a birds-eye view, with their car driving upwards on their computer screen. At each intersection approach, the traffic light changed from green to yellow. Participants could then decide to either brake by pressing the space bar, or to continue driving by not responding. If they decided not to stop, a crash could occur in which another car (not visible during the approach) would crash into the participant's car. Risky decision making was operationalized as the proportion of yellow stoplights for which the participant did not brake, using the same parameters as Chein, Albert, O'Brien, Uckert, & Steinberg (2011). The delay of waiting at the traffic light was 3 seconds, and the penalty for crashing was 6 seconds. Finally, at the start of the stoplight game, participants were informed that a prize would be awarded to the person in their school who finished the game the fastest.

Risky traffic behavior was assessed with three questions that were adapted from previous studies (Feenstra, Hazevoet, & Van der Houwen, 2002; Nieuwenhuijzen et al., 2009). An example item is: How often in the past four weeks, have you crossed a red light on your bike? Answer categories ranged from 0=never to 4 = very often. A

mean score was computed with higher scores indicating more risky traffic behavior. Cronbach's alpha was .65 denoting adequate reliability.

Smoking was measured with the question "*Do you smoke tobacco? (cigarette, cigar, shag, (water-)pipe)?"* that was derived from previous studies (e.g., Monshouwer, 2008; Monshouwer et al., 2004; Nieuwenhuijzen et al., 2009; Reijneveld et al., 2003). Answer categories ranged from 0 = No, I have never smoked to 5 = Yes, every day.

Alcohol use was measured with a question that was adapted from previous studies (e.g., Monshouwer, 2008, Nieuwenhuijzen, 2009), namely *"Do you drink alcohol?".* Answer categories ranged from 0 = No, I have never drunken alcohol to 5 = Yes, every day.

Marihuana use was assessed with a question that was similar to marijuana questions used in previous studies (e.g., Monshouwer (2008). Reijneveld, 2002; Nieuwenhuijzen et al., 2009), namely: *Have you ever used marihuana (cannabis weed, hash, ganga).* The answer categories ranged from 0= No, I have never used marihuana to 5= Yes, every day.

Delinquency was measured with 7 items, of which most were derived from the International Self-Reported Delinquency questionnaire (ISRD; Junger-Tas, Terlouw, & Klein (1994); Junger-Tas, Haen Marshall, & Ribeaud, 2003). From this questionnaire, one item tapped vandalism (*Have you ever damaged something on purpose, such as a bus shelter, a window, a car or a seat in the bus or train?)* and four items tapped property crime related to theft. Additionally, one vandalism item from another questionnaire was also used, in addition to the item "*Have you ever done something for which you were arrested by the police?*" (Baerveldt, Rossem & van Vermande, 2003). Thus in total, 2 vandalism items were used. The answer-categories for each of the seven items were: 0 = Never *or* Yes, but that was longer than 12 months ago; 1=Yes, once in the past 12 months; 2=Yes, twice in the past 12 months; 3= Yes, three times or more during the past 12 months. We computed a mean score, with higher means reflecting higher levels of delinquency. The Cronbach alpha of.78, indicated adequate reliability.

Sensation seeking, which was used as a control variable, was assessed with four items of the *fun seeking* sub-scale of the Behavioral Approach System questionnaire (BAS; Carver & White, 1994). This Fun seeking sub-scale is often used to measure sensation seeking tendencies (Zuckerman, 2012; Franken & Muris, 2006, Ko et al., 2008). An example item is *"I crave excitement and new sensations*". Answers categories ranged from 1 = "Very false for me" to 4="Very true for me". Cronbach's alpha was .56, which is on the lower side, and this could perhaps be attributed to the small number of items on that scale.

Strategy of Analyses

We conducted descriptive analyses in SPSS and the main analyses were conducted in Mplus 7.11 (Muthén & Muthén, 1998-2012). In Mplus, we accounted for dependency within the group triads, by using the "Type=COMPLEX" feature to adjust for standard error biases caused by our clustered data (participants clustered in groups of 3) (Korendijk, Maas, Hox, & Moerbeek, 2012). A Full Information Robust Maximum Likelihood Estimator (MLR) was used (Satorra & Bentler 1994) in order to adjust for any non- normality and to allow the inclusion of incomplete data.

A path model was specified per risk-taking behavior in Mplus, while controlling for gender, age and sensation-seeking. We first estimated an overall model (i.e., non multi-group model), per self-reported risk-taking behavior . Specifically, in these individual models, we combined adolescents who completed the stoplight game alone and in the peer conditions, in order to test the overall criterion validity of the stoplight game. That is, we regressed risky decision making on the stoplight game on the self-reported risk-taking behaviors. Next, in order to test for a possible moderation effect by peer presence, per self-reported risk-taking behavior, we specified a multi-group model with two subgroups that represented the alone condition versus the peer condition. We tested for significant moderation effects by using a Wald test. All models had a perfect fit to the data (just identified).

Results

Bivariate correlations (Table 1) showed that the risky decision making on the stoplight game was significantly correlated with all of the self-reported risk-taking behaviors, with correlations ranging from .12 to .22. The means and SD's of risky decision making , alcohol, smoking, marijuana, delinquency, sensation seeking, were: 33.43 (21.93), .56(1.11), .64(1.24), .14(.60), .10 (.28), 2.78(.53), respectively. In the overall models, risky decision making on the stoplight game predicted risky traffic behavior (β=.11; p=.045), risky alcohol use (β=.15; p=.01), and delinquency (β=.12; p=.02). However, no links were found from risky decision making to smoking (p=.06) and/or marijuana use (p=.11). As for the multi-group models, although risky decision making on the stoplight game only predicted risky traffic behavior in the Peer

Table 1. Correlations of variables of interest

	1	2	3	4	5	6
Stoplight	-					
Alcohol	.217**	-				
Smoking	.164**	.554**	-			
Marijuana	.117*	.423**	.531**	-		
Delinquency	.143**	.286**	.381**	.586**	-	
SS	.090	.192**	.229**	.203**	.199**	-

Note. **p<.01; *p<.05; SS= Sensation seeking

condition (β=.19; *p*=04), and not in the Alone condition (*β*=.10; *p*=.13), there were no significant peer presence X risky decision making effects (Wald $\chi 2$ (1) = .39, *p*=.53). As for substance use, risky decision making on the stoplight game only predicted higher levels of risky alcohol use in the peer condition (*β=.31; p*<.01) and not in the alone condition (*β=.11; p*=.08), but there was no interaction (Wald $\chi 2$ (1) = 1.56, *p*=.21).

As for the control variables, higher levels of sensation seeking significantly predicted higher levels of all the self-reported risk-taking behaviors, older adolescents reported more risk taking behaviors except for delinquency, and boys reported higher levels of risk-taking in traffic.

Discussion

Stringent structural equation models showed that risky decision making on the stoplight game was predictive of risky traffic behavior, alcohol use and delinquency in adolescents, and these linkages were found above and beyond significant effects of sensation seeking. Contrary to our predictions, peer presence during completion of the stoplight game did not moderate these links.

The stoplight game is a simulated risky driving task, thus it is natural that performance on this task predicted self-reported real-world risky traffic behavior, and this speaks to its criterion validity. Similarly, performance on the stoplight game was predictive of delinquency and alcohol use. With regard to alcohol, our findings are more or less consistent with Kim-Spoon et al. (2016). However, that study included older adolescents, and our results further suggest that the significant link found in that study from performance on the stoplight game to a composite score of smoking, alcohol and marijuana, might be primarily driven by alcohol use.

Next, although no moderation effect of peer presence was found, of note is that for alcohol and delinquency, risky decision making on the stoplight game predicted these self-reported risk-taking behaviors in the peer condition (and overall), but not in the alone condition. Thus perhaps these findings indicate that individual differences in risk-taking are still somewhat exacerbated in the peer condition, but not significantly. All things considered, the current findings suggest that perhaps the decision making processes that are at play during completion of the stoplight game, whether completed alone or in the presence of peers, are the same underlying processes that contribute to risky traffic behavior, alcohol use and delinquency in adolescents.

Strengths and Limitations

The current study provides some new insights into the predictive power of a laboratory task on multiple self-reported real-world risk-taking behaviors in adolescents. However, when interpreting the results readers should keep in mind that the effect sizes were modest.

Conclusion

We did not find that the affective "peer presence" component increased the criterion validity of the stoplight game. Instead the current results suggest that the stoplight game in itself is a sufficient affectively laden task with adequate criterion validity, which predicts heightened adolescent real-world risk-taking behaviors such as risky traffic behavior, alcohol use and delinquency. The finding that performance on a laboratory risky decision-making task can perhaps help identify adolescents at risk for risky traffic behavior, alcohol use and delinquency, is an important finding, for science as well as prevention and intervention efforts.

Chapter 4

Is the peer presence effect on heightened adolescent risky decision making only present in males?

Author note:
This chapter is based on a manuscript in preparation to be submitted.

I.N. Defoe., J.S. Dubas and M.A.G van Aken developed the study concept and design. E.S. Dalmaijer programmed the stoplight game task. I.N. Defoe oversaw the data-collection. I.N. Defoe performed the data-analysis and interpretation. I.N. Defoe drafted the manuscript, and J.S. Dubas, E.S. Dalmaijer and M.A.G. van Aken provided critical revisions.

Abstract

Social neurodevelopmental imbalance models posit that the mere presence of peers causes heightened adolescent risk-taking. The current two-study paper adds to the small amount (*N*=4) of experimental studies that have investigated this theory. Study one (*N*=327) and study two (*N*=148) consistently showed no general peer presence effect on risk-taking in 12-16 year old adolescents. However, in study one, a gender by peer presence interaction effect showed that whereas boys and girls engaged in equal levels of risks when they completed the risky task alone, boys engaged in more risk-taking than girls when they completed this task together with two same-sex peers. Taken together, both studies question a pure peer presence effect, however, peer presence might only increase risk-taking in boys.

Keywords: risky decision making, adolescence, peer influences, gender differences, development

Most risk-taking behaviors that peak in adolescence occur when adolescents are with their peers (Steinberg, 2008). However, the majority of studies on peer influences on adolescent risk-taking do not investigate the direct effect of presence of peers on heightened adolescent risk-taking. Instead, past studies have often focused on similarity in risk-taking behaviors among peers, with the assumed mechanism being *social learning* (e.g., Haynie & Osgood, 2005). However, current advances in adolescent brain research suggest that mere "peer presence" as opposed to "social-learning" mechanisms, may lead to heightened adolescent risk-taking (Albert & Steinberg 2011). Specifically, neurodevelopmental imbalance models postulate that heightened adolescent risk-taking occurs, particularly when adolescents are in emotionally arousing situations. It is hypothesized that in such emotionally arousing contexts, adolescent's hyper-responsive motivational-reward system in the brain gets triggered, resulting in a pronounced imbalance with their relatively immature cognitive control system (Somerville, Hare, & Casey, 2011; Steinberg, 2008). Distinctively, social variants of neurodevelopmental imbalance models (i.e., social neurodevelopmental imbalance models) postulate that peers increase risk-taking particularly in adolescence, because the mere presence of peers activates the same brain regions as rewards do, and in that sense, peers can be considered as socially rewarding (Steinberg, 2008).

To date, only four experimental studies have attempted to investigate whether, indeed, peer presence causes heightened adolescent risk-taking. Results from these studies (Table 1) did not yield consistent results, however. Furthermore, although gender differences exist in risk-taking (e.g., Byrnes, Miller, & Schafer, 1999), the majority of the studies on peer presence in adolescent risky decision making did not take gender into account. Hence, the current paper includes two experimental studies that aim to add to the empirical literature of what is known on peer presence effects in heightened adolescent risk-taking, by investigating if adolescents engage in more risky decision making on a simulated risky driving task in the presence of peers compared to when alone, and if gender moderates this effect.

As evident from Table 1, three (i.e., Chein et al., 2011; Gardner & Steinberg, 2005; Smith et al., 2014) of the four studies that manipulated peer presence in an adolescent risk-taking paradigm, found that peer presence (whether physical or imagined), was associated with heightened risk-taking in adolescents. However, one (i.e., Kretsch & Harden, 2014) of the four studies wherein peers were physically present, failed to find an effect of peer presence on percentage risky decisions made by adolescents on a risky driving task (i.e., the stoplight game; Chein et al., 2011; Gardner & Steinberg, 2005). It is also noteworthy that three out of the four studies on peer presence effects on risky decision making have employed (versions of) the stoplight game and two of these studies have found support for a peer presence effect. Thus, findings on peer presence effects in risky decision making on the stoplight game are mixed.

Table 1. An Overview of All Studies that have Experimentally Manipulated Peer Presence in an Adolescent Risky Decision Making Paradigm

		N Adolescents (alone/peer condition)	Adolescent Age	Peer presence	Task	Effect of Peer presence
1a.	Gardner & Steinberg (2005)	52 / 54	13-16 yrs. (*m* age = 14)	2 peers physically present in the same room	Chicken Game	$F(1, 284) = 4.801$, $p < .05$, $d = .67$
1b.	Gardner & Steinberg (2005)	51/50	18-22 yrs. (*m* age = 18.78)	2 peers physically present in the same room	Chicken Game	$F(1, 284) = 4.801$, $p < .05$ $d = .47$
2.	Chein, Albert, O'Brien, Uckert, and Steinberg (2011)	14/14 (within-subjects design)	14-18 yrs. (*m* age = 15.7)	Observation by 2 peers from an adjacent room	Stoplight game	$t(13) = 2.16$, $p = .025$, *one-tailed* $d = 1.20$
3.	Kretsch & Harden (2014)	58/58 (within-subjects design)	11-16 yrs. (*m* age = 13.6)	2 peers physically present in the same room	Stoplight game	$t(49) = 1.61$, $p = .11$ $d = .46$
4.	Smith, Chein, & Steinberg (2014)	26/26	15-17 yrs. (*m* age = 16.17)	Simulated observation by 1 peer	Probabilistic gambling task (PGT)	$F(1,44) = 7.19$, $p = .01$ $d = .79$

Gender effects

The social neurodevelopmental imbalance model (Steinberg, 2008) does not make any explicit predictions about gender differences in peer presence effects on heightened adolescent risk-taking, perhaps because males and females presumably undergo similar neurological development. Yet, correlational and observational data show that many (antisocial) risk-taking behaviors are gender specific, with boys taking more risks than girls on average (Byrnes et al., 1999; Moffitt et al., 2001). As for gender differences in experimental risk-taking, only one (i.e., Kretsch & Harden, 2013) of the four previously described studies on peer presence effects on adolescent risk-taking examined such effects, but no gender differences existed. However, considering that gender differences have been neglected in experimental adolescent risk-taking research (Defoe et al., 2015), it is worthwhile to explore such potential gender differences. Moreover, when it comes to gender-moderated peer influences on risk-taking, even fewer studies investigate such influences (Weerman & Hoeve, 2012). The limited (correlational) studies that do, show mixed results pertaining to whether males or females are more susceptible to peer influence leading to risk-taking (e.g., Mears et al., 1998; Piquero et al., 2005; Weerman & Hoeve, 2012). The only experimental study (i.e., Gardner & Steinberg, 2005) to test whether gender moderated peer effects in adolescents' risk-taking did not find gender effects. However, an absence of gender moderation in the peer presence effects in Gardner and Steinberg (2005) could be due to power issues as a result of the relatively small sample of adolescent participants (see Table 1).

Overview of the Present Studies

The current paper investigates whether peer presence and gender predict experimental risk-taking in adolescents, and if the hypothesized peer effect is moderated by gender. We rigorously test the peer presence effect by including two studies that differ in the type of alone conditions used. The "*collective*" alone condition of study one consists of adolescents who completed the stoplight game alone behind their own computer, while they were in a classroom with other classmates (peers) who were also working alone behind their own computer on experimental tasks. Furthermore, the adolescents were not allowed to communicate or observe each other's performance on the tasks. The peer condition consisted of a triad of same-sex adolescents who completed the stoplight game together (i.e., one adolescent played the task while the two same-sex adolescents observed the player). Thus in study one we investigated whether adolescents engage in more risks when they completed the stoplight game together with two same-sex peers (i.e., peer condition) versus when they completed the stoplight game on their own in a *collective* alone condition.

We realize that although participants completed the tasks alone in the collective alone condition, there are other peers in the room. Thus some might argue that comparing our collective alone condition to the peer presence condition is not a strict investigation of the peer presence effect. Hence, in study two we introduced an even stricter alone condition, namely an "*individual* alone condition" wherein adolescents completed the stoplight game alone in a room without the presence of anyone, and we investigated whether adolescents engaged in more risk-taking on the stoplight game in the peer condition compared to this "*individual*" alone condition.

Study 1

Method

Participants

Participants in study one were drawn from the first wave of a prospective 3-year longitudinal study in the Netherlands that began in 2012. For this multi-informant study, questionnaire data were annually (years 2012, 2013, 2014) collected from adolescents at schools, and a subsample of their parents and siblings. During the first wave of the data-collections, 602 adolescents took part during school hours at their schools, and they were either in the first or third year of middle level secondary educational tracks (advanced vocational and technical tracks). In addition, adolescents also engaged in experimental sessions. In the first wave, the majority of the adolescents (93.2%) indicated that they were born in the Netherlands with 61.6% identifying as Dutch, 9.3% as Turkish or Turkish Dutch, 7.4% as Surinamese or

Surinamese Dutch and 5.5% as Moroccan or Moroccan Dutch, and the rest (16.2%) identified with various other ethnicities. Most of their parents (68.4%) were either married or living together and 24.8% were either divorced or separated. Roughly half of the adolescents (44.90% fathers; 46.5% mothers) were unaware of their parents' highest level of completed education, in part because parents (11.0% fathers; 11.8% mothers) were born abroad, in countries where the educational tracks were not comparable to the Dutch system. Of the reported education levels, 6.7% of mothers and 6.4% of fathers did not complete a high school education, 35.8% of mothers and 28% of fathers completed a lower or middle level vocational training and 3.8% mothers and 10.5% of the fathers completed a university degree.

For the first study that compared the "collective alone vs. peer presence" conditions, a subsample of 331 participants (49.80% female) who completed the stoplight game were used, and analyses were based on 327 valid cases. Adolescents were 12-16 years old (Mage = 13.61; *SD*=1.19), and they were either in the 1st (*n*=139; 47.50% female) or 3rd (*n*=192; 51.60% female) year of middle level secondary educational tracks (advanced vocational and technical tracks).

Procedure

Participants were recruited from high-schools in six different regions in the Netherlands. After approaching the schools via telephone calls and emails, eight schools agreed to participate. Parents received information letters about the research project as well as dissent letters that could be returned to the schools if parents did not want their children to participate (i.e., passive consent forms were used). During the data-collections, participants received both written and verbal instructions by trained research assistants. The first part of a data-collection session consisted of a digital questionnaire and one cognitive task. A break followed and in the second part adolescents then completed the stoplight-game and two cognitive tasks.

Adolescents were randomly assigned to perform the stoplight game either simultaneously in a *collective* alone condition (i.e., they completed the task in the same classroom, behind their own computer) or a peer condition in a separate room. Research assistants ensured that participants in the alone condition (*n*=252; 49.2% female) sat as far away from each other as possible, and that they did not communicate with each other during the stoplight game. Participants wore headphones during the collective alone condition in order to prevent the other participants in the room from hearing the sound effects of the stoplight game, as those participants were also busy with their own experimental tasks. In the Peer condition participants were placed in groups of three same-sex peers from their class (*n*=120; 40 groups; 52.5% female). In this condition, participants played the stoplight game, one after the other, and were allowed to communicate with each other about the game.

Schools varied in how much time was allowed to be used for data-collection (90-120 minutes). In some schools there was insufficient time for the stoplight game and in the group condition we primarily had complete data for the first or second participant. Consequently, a total of 79 (51.9% female) of the 120 participants in the peer condition fully completed the stoplight game. The remaining participants in the peer condition did not (fully) complete the stoplight game because of the time constraints mentioned above, but also due to random causes, which included technical difficulties (e.g., computer crashed).

Measures

Risky decision-making was measured with a two-dimensional version of the stoplight game), which was programmed in OpenSesame (Mathôt, Schreij, & Theeuwes, 2012). The game was constructed such that participants viewed the roads with a birds-eye view, with their car driving upwards on the screen. During each intersection approach, the traffic light jumped from green to yellow. Participants could decide to either brake by pressing the space bar, or to continue driving by not responding. If they chose not to stop, a crash could occur in which another car (not visible during the approach) would drive into the participant's car. Risk-taking was operationalized as the proportion of yellow stoplights for which the participant did not brake, i.e., "percentage risky decisions" (Chein et al., 2011). The parameters spaces we employed were identical to those reported by Chein et al. (2011, supporting information): temporal distance between intersections varied randomly between 10 and 16 seconds, the car's braking duration was set to 0.5 seconds, the time between onset of the yellow light and the car reaching the intersection varied between 2 and 4.5 seconds in five evenly spaced steps (2000, 2625, 3250, 3875, 4500 milliseconds), the delay of waiting at the traffic light set to 3 seconds, and the penalty for crashing was set to 6 seconds. In four practice runs, the probability of crashing was set to 0%, and to 50% in the successive 20 experimental trials, resulting in an overall crash probability of 40%. The task variably induces risky decision making in participants and that participants fail to determine an optimal strategy, thus the degree of risky or cautious behavior is determined by individual differences rather than task characteristics (Chein et al., 2011). Finally, before participants began the stoplight game, they were informed that a prize would be given to the person in their school who finishes the game the fastest.

Strategy of Analyses

We conducted descriptive analyses in SPSS. Main analyses were conducted in Mplus 7.11 (Muthén & Muthén, 1998-2012), wherein we accounted for dependency within the group triads. Specifically, we used the "Type=COMPLEX" feature to adjust for standard error biases as a result of our clustered data (participants clustered in groups of 3) (Korendijk, Maas, Hox, & Moerbeek, 2012). A Full Information Robust Maximum Likelihood Estimator was used for all models (Satorra & Bentler

1994) to adjust for possible deviation from normality and to allow the inclusion of incomplete data. The analyses in Mplus were carried out using (ANOVA-analogue) path models; that is, we specified a regression wherein we used dummy-coded variables (Pehazur, 1997). For the main effects model, we investigated whether peer presence and gender showed main effects on risky decision making. That is, we investigated whether adolescents took more risks in the peer condition (vs. alone condition), and whether there were gender differences in risky-decision making, while controlling for age effects. In our interaction models, we tested whether there was a two-way interaction effect for peer presence and gender, while controlling for age effects. For the interaction term the dummy variables were multiplied and added to the model simultaneously with the main effects. All models were just-identified with a perfect fit.

Results and Discussion

Main Effects Model

The mean percentage risky decision making was 33.87 (*SD*=23.18) for the peer condition and 33.45 (*SD*=21.60) for the collective alone condition, with a Cohen's *d* of .02. Structural equation models accounting for dependency within the peer condition showed that peer presence did not predict risky decision making (β = -.01; *p*= .84). We found no main effect of gender (β =-.10; *p* =.10). Finally, age was a significant control variable (β =.20; *p* <.01) indicating that older adolescents take more risks than younger adolescents.

Peer Presence by Gender Interaction Model

We found a significant interaction effect for peer presence and gender on risky decision making (β = -.20; *p* = .04; Figure 1). Follow-up post-hoc analyses showed that whereas boys and girls engage in equal levels of risk-taking (β = -.02; *p* =.74) in the alone condition, boys significantly engage in more risk-taking than girls (β = -.31; *p* = .02) in the peer condition. Although peers did not increase risk-taking in boys (β = .12; *p* = .14) or girls (β = -.14; *p* = .14), the significant interaction effect shows that peer presence has an opposite effect on male versus female risk-taking. That is, peers have an increasing effect on boys' risk-taking, but a diminishing effect on girls' risk-taking.

Taken together, the results of study one suggest that adolescents who perform the stoplight game together with two-same sex peers do not significantly engage in more risk-taking compared to when adolescents complete the stoplight game alone. Furthermore, gender moderated the peer presence effects on risk-taking, namely, whereas boys and girls engaged in equal levels of risks in the collective alone condition, boys engaged in more risk-taking than girls in the peer condition.

Although study one can serve as a conceptual replication of studies on peer presence effects on adolescent risky decision making, one might argue that the

results from study one cannot completely rule out that peer presence does *not* increase adolescent risky decision making, since the adolescents in the alone condition were not completely alone. Hence, we conducted study two, for which we collected an additional sample of participants for an alone condition wherein in adolescents were completely alone in a room when they completed the stoplight game (i.e., *individual* alone condition).

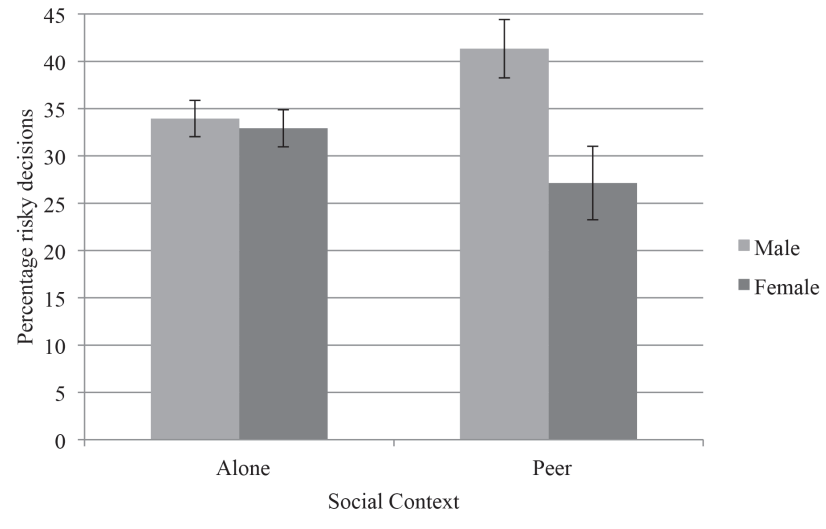

Figure 1. Graph of the peer presence by gender interaction. Error bars indicate standard errors of the mean.

Study 2 (Replication Study)

Method

In study two, we aimed to replicate the results of study one, and to rule out the possibility that we did not find peer effects in study one because peers were in the room during the collective alone condition of study one. Specifically, in study two we compared adolescent risk-taking in the peer condition to a condition wherein adolescents completed the stoplight game completely alone in a room (i.e., *individual* alone condition), and we tested whether gender moderated the peer presence effects.

Participants

For study two we additionally collected more data for an *individual* alone condition (*N*=70), and used the peer condition from study one (*N*=79). Participants in the

individual alone condition were recruited from two schools that participated in the larger 3-wave longitudinal study (see study one for details), and one additional new school. For the individual alone condition, a total of 70 (54.3% female) participants fully completed the stoplight game. The final sample size for study two included 148 valid cases. Similar to study one, the adolescents in study two were 12-16 years old (*M*age = 13.66; *SD*=1.15), and they were either in the 1st (*n*=57; 54.4% female) or 3rd (*n*=92; 52.2% female) year of middle level secondary educational tracks (advanced vocational and technical tracks).

Procedure

Parents received information letters about the research project as well as dissent letters that could be returned to the schools if parents did not want their children to participate (i.e., passive consent forms were used). During the data-collections, participants received both written and verbal instructions by trained research assistants. The adolescents that participated in the individual alone condition completed the task in a room completely alone. For the peer condition the same participants were used as for study one, thus the same procedure was also used.

Measures and Strategy of Analyses

The stoplight game was also employed in study two (see study one for details). We also performed identical analyses as in study one.

Results and Discussion

Preliminary Analyses

We ran two sets of control analyses. First, we tested whether the new additional school differed in risk-taking compared to the two old schools. We found that this was not the case ($t(50)=0.75$, $p = .46$). Secondly, we tested whether the old alone condition and new alone condition are indeed unique conditions, thus we tested whether risky decision making differed across the two different alone conditions. We found that adolescents in the individual alone condition took more risks than adolescents in the collective alone condition ($\beta = .10$; $p = .04$).

Main Effects Model

The mean percentage risky decision making was 33.87 (*SD*=21.72) for the peer condition and 38.15 (*SD*=19.07) for the individual alone condition, with a Cohen's *d* of -.20. Structural equation models accounting for dependency within the peer condition showed that a peer presence effect was absent in study two ($\beta = -.13$; $p = .15$). However, we did find a main effect of gender ($\beta = -.23$; $p = .01$), indicating that boys engage in more risk-taking than girls. The control variable age showed no effect on risk-taking ($\beta = .12$; $p = .18$).

Peer Presence by Gender Interaction Model

We found no interaction effect between peer presence and gender on risky decision making ($\beta = -.20$; $p = .19$). Thus a peer presence effect was absent for both boys and girls in study two.

Taken together, peer presence did not influence adolescent risk-taking in study two, which replicates the main findings we found in study one. Additionally, in study two we found that boys engaged in more risk-taking than girls, however there was no gender by peer presence interaction effect on adolescent risk-taking. Considering that the magnitude of the interaction term between peer presence and gender was virtually the exact magnitude as in study one, could suggest that the peer presence by gender moderation effect in study two did not reach the conventional level of statistical significance perhaps because the sample size was not large enough.

General Discussion

Results across the current two studies consistently showed that peer presence generally did not lead to an increase in adolescent risky decision making, which contradicts what is predicted by social neurodevelopmental imbalance models. Additionally, in the first study with the collective alone condition, there was no main effect of gender, however there was an interaction effect between gender and peer presence on risky decision making. Follow-up post hoc analyses showed that whereas boys' and girls' risk-taking in the alone condition did not significantly differ, in the peer condition boys significantly took more risks than girls. Moreover, whereas same-sex peers have an increasing effect on boys' risk-taking, same-sex peers have a diminishing effect on girls' risk-taking. Interestingly, this interaction effect between peer presence and gender did not exist for study two wherein we contrasted an individual alone condition with a peer presence condition. Since the effect size of the interaction effect for both studies were of virtually the same magnitudes, perhaps the sample size of the second study was not large enough to detect moderation effects.

In accordance with our findings, one of the three existing studies that also employed the stoplight game also did not find a peer presence effect for risky decision making when boys and girls were combined (Kretsch & Harden, 2013). Unlike the current study, Kretsch and Harden (2013) did not investigate a moderating role of gender in peer effects, however. As for our theoretical framework, considering that we found no general peer presence effect in both studies, our results could imply that the social neurodevelopmental imbalance model might be most meaningful for adolescent boys' heightened risk-taking in the presence of peers, but not for girls. Although this framework does not predict such gender differences, we further speculate that boys were perhaps more pressured than girls to engage in deviant behaviors by their same-sex peers. Equally possible is that both boys and girls

encourage risk-taking, however girls are more capable of suppressing or resisting peer pressure than boys are. Consistent with this interpretation, adolescent girls report more resistance to peer influence than do adolescent boys on self-report measures of peer resistance (Steinberg & Monahan, 2007). Further support for why this interaction effect should not be ignored, comes from correlational studies showing that peers have more negative peer influences on boys' risk-taking compared to girls' risk-taking (Mears et al., 1998; Piquero et al., 2005). Thus our results could suggest that whether peer presence sensitizes adolescents to rewards leading to risk-taking and/or whether this sensitization to respond to the rewarding aspect of risk-taking behaviors further undermines self-regulation capacities (e.g., resistance to peer influence) (Albert, Chein, & Steinberg, 2013), might be modulated by gender and other social mechanisms (e.g., peer pressure) as discussed here.

Strengths, Limitations, Implications and Future Directions

In addition to the methodological strengths inherent in a true experimental design used in the current study, the current study is also unique as it investigated if individual (gender) and social (peer presence) factors interact to predict heightened adolescent risk-taking. Another distinct feature of the current study is that we used two samples that differed in their alone conditions to thoroughly test the mere peer presence effect hypothesis and we used rigorous structural equation modeling techniques to account for dependency within the peer condition. However, the present experimental paper also has its limitations.

First, considering that the sample for the alone condition of study one and study two were collected three years apart, we cannot completely rule out a cohort effect. For example, video games that are similar to the stoplight game might have become more graphically sophisticated during that period, which might have affected the appeal of the stoplight game during study two. However, it is unlikely that such cohort effects would have an effect on whether a participant chooses to brake for a yellow stoplight on the stoplight game. A more plausible critique is that the stoplight game might be considered gender-stereotyped and thereby more meaningful for understanding boys', but not girls' heightened risk-taking. Future studies should thus also consider that the gender role specificity of risky behaviors as driving may be viewed as more masculine. For example, gambling tasks could perhaps serve as gender-neutral tasks. Thus future studies could implement diverse (gender-neutral) tasks, in order to capture under which circumstances peers might potentially also increase girls' risk-taking. Such potential gender and task moderation effects could provide us a more thorough understanding of the hypothesized peer presence effect on adolescent heightened risk-taking. Finally, as studies that manipulate peer presence in adolescent risky decision making paradigms are sorely lacking, we encourage future studies to investigate the peer presence effect, and to consider using diverse alone and peer paradigms when doing so.

Conclusion

Unexpectedly, the current two-study paper consistently found no general peer presence effect on heightened adolescent risk-taking, which sharply contradicts social neurodevelopmental imbalance models. Instead, the current study suggests that heightened adolescent risk-taking in the presence of peers might be gender specific. Thus, is the peer presence effect on heightened adolescent risk-taking not generally potent, or is it only potent for males? If the latter is the case, why is the peer presence effect only present in males? In the real-world, boys evidently engage in more (antisocial) risk-taking behaviors than girls (e.g., Moffitt et al., 2001), however the current experimental study raises an interesting observation that this gender difference might particularly arise when boys are in company of peers. Taken together, the present findings show how individual differences (i.e., gender) determine how the social environment (i.e., peer presence) could affect adolescent risk-taking.

Chapter 5

Social Presence Effects on Adolescent Risky Decision Making: Peers versus Siblings versus Parents

Author note:
This chapter is based on a manuscript in preparation to be submitted.

I.N. Defoe., J.S. Dubas, and B. Figner developed the study concept and design. I.N. Defoe oversaw the data-collection. J. Fenneman performed the main data-analysis. I.N. Defoe ran additional analyses. J. Fenneman, B. Figner, and I.N. Defoe interpreted the results. I.N. Defoe drafted the manuscript, and J.S. Dubas, J. Fenneman, and B. Figner provided critical revisions.

Abstract

The current two-study experimental paper investigated social presence (peers, mothers, fathers, siblings) effects on adolescent risk-taking. Study 1 investigated whether adolescents take more risks when they complete a risky choice task in the presence of peers versus when alone and whether there were interactions between peer presence, pubertal timing, and gender. The results did not show a main effect of peer presence on risk taking in adolescents. However, a significant three-way interaction was found for social context, pubertal timing, and gender for one of the risk-taking outcome measures, showing that pubertal timing was more strongly associated with risk-taking in the peer condition for girls versus boys. No association between pubertal timing and risk taking was found in the alone condition. These findings are partly consistent with the Social Re-orientation Theory of adolescent risk-taking (Forbes & Dahl, 2010). Using the same task as in study 1, study 2 investigated whether the presence of siblings and parents influenced adolescent risk-taking and examined potential gender moderation effects. A social presence effect was found on one of the risk-taking outcome measures, showing that adolescents engaged in more risk-taking when they completed the task alone versus when they completed the task with their mother, father, or sibling. Theories on the effects of the presence of parents and siblings on adolescent risk-taking are lacking and further research is needed to examine whether mechanisms behind the demonstrated risk-taking reduction effect is the same for parents and siblings. Possible mechanisms are discussed.

Key-words: social presence, risky decision making, adolescence, family, peers

Adolescence is a developmental milestone that is marked by significant changes in the biological, social, and psychological domains. Parallel to pubertal maturation and changes in social dynamics, adolescents begin to show elevated dangerous risk-taking behaviors (e.g., binge drinking, unsafe driving, delinquency) especially when they are in the company of peers (e.g., Steinberg, 2008). Besides parent influences and increasing peer influences, adolescents also spend a substantial amount of time with their siblings, and thus it is to be expected that sibling influences are also relevant for adolescents' behavior and development (Jenkins & Dunn, 2009). Although much less is known about sibling influences on adolescent risk-taking, there is some evidence that sibling and peer influences might be similar (e.g., Defoe et al., 2013). It should be noted, however, that all known studies (e.g., Defoe et al., 2013; Fagan & Najman 2003; Natsuaki, Ge, Reiss & Neiderhiser, 2009) on differential roles of parents and/or peers and/or siblings on adolescent risk-taking are non-experimental, which limits causal interpretations. That is, despite the gradual rise in experimental studies on peer presence (e.g., Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Kretsch & Harden, 2014), and parent (mother) presence effects (Telzer, Ichien, & Qu, 2015), to the best of our knowledge no study has investigated effects of *sibling* or *father* presence on adolescent risky decision making or has compared these effects to other social effects (e.g., peers or mothers) within the same study. To this end, the goal of the current two experimental studies is to build on recent advances in experimental research on social contextual effects on adolescent risky decision making and to compare the effect of the presence of peers, siblings, mothers, and fathers on adolescent risky decision making in a risky choice task (i.e., Columbia Card Task; Figner et al., 2009; Figner & Weber, 2011).

In the first study, we investigate whether there is a peer presence effect on adolescent risky decision making and what possible mechanisms might explain such a peer presence effect. Specifically, the first study investigates whether the role of timing of pubertal maturation and gender moderate a hypothesized peer presence effect on adolescent risky decision making. In the second study, we investigated whether adolescents' risky decision making differs when they completed the task alone versus when they completed the task in the presence of siblings, mothers, and fathers (i.e, 4 social presence conditions).

Study 1: The moderating role of puberty in peer presence effects on adolescent risky decision making.

Peers are prominent social influences, particularly for adolescents as during adolescence individuals spend increasingly more time with their peers. However, in the real world it is difficult to tease apart whether adolescents engage in more risk-taking when they are with their peers versus alone, or if they take more risks when they are with their peers simply because they spend more time with their peers

versus time spent alone. In other words, many (typical) behaviors of adolescents are more likely to occur when they are with their peers, that is, not just specifically behaviors characterized by high risk taking, but likely also behaviors characterized by medium or low levels of risk taking are more likely to be observed in the presence of peers versus alone. Social neuro-developmental imbalance models posit that pubertal maturational changes in the brain cause heightened reward sensitivity, and that this hyper-sensitivity to rewards becomes even stronger in the presence of their peers (Chein et al., 2011; Somerville et al., 2013; Steinberg, 2010). As a result, adolescents might pay more attention to the potential rewards of risk-taking behaviors, leading to heightened risk-taking (Chein et al., 2011; Somerville et al., 2013; Steinberg, 2010). Although there is substantial variability in effect sizes, three studies concluded that the mere presence of peers increases risky decision making in adolescents (Chein et al., 2011; Gardener & Steinberg, 2005; Smith et al., 2014). However, other studies have not found a peer presence effect on risky decision making in adolescents (Harden & Krestch, 2014) or college students (ages 19-24; Nawa, Nelson, Pine, & Ernst, 2008). Another study found that peer presence only increases adolescent risky decision making when adolescents are *encouraged* to take risks (Reynolds, MacPherson, Schwartz, Fox & Lejuez, 2014). And finally, Boer et al. (2016) found that the peer presence effect is moderated by gender, such that males engage in more risky decision making than girls when they complete a risky task with peers, but not when they complete the task alone. These mixed findings on peer presence effects might be due to relevant moderators. In the current study we therefore consider gender, age, and puberty as potential moderators of potential peer presence effects on adolescent risk-taking.

Puberty was chosen as a moderator based on *The Social Re-orientation Theory* (Forbes & Dahl, 2010), which is explicit about the role of pubertal maturation in peer effects in adolescent risk-taking. This theory postulates that the pubertal rise in reproductive hormones activates the tendency for adolescents to want to affiliate with their peers, and that pubertal development and peer affiliation interact to predict heightened risk-taking in adolescents (Forbes & Dahl, 2010). Indeed, in addition to peer influence, pubertal development and in particular *pubertal timing* has consistently been shown to be linked with heightened adolescent risk-taking (for reviews see Mendle & Ferrero, 2012; Mendle, Turkheimer, & Emery, 2007). This suggests that although changes in pubertal hormonal secretion that provoke the above-described re-organization occur regardless of whether puberty is early, on time, or late (Ge & Natsuaki, 2009), it might be that the earlier an adolescent experiences such hormonal alterations, the greater the impact on behavior because the less likely adolescents might be capable of adaptively managing the potentially negative emotional and behavioral consequences (Ge & Natsuaki, 2009; Mendle & Ferrero, 2012; Schultz, Molenda-Figueira, & Sisk, 2009). In other words, adolescents whose pubertal timing is earlier than their same-sex and same-age peers (i.e., early maturers) (Ge & Natsuaki, 2009) might be most vulnerable to the amplifying effects that peers could have on adolescent risk-taking. Accordingly, pubertal timing might moderate the hypothesized link between peer presence and heightened risky decision making in adolescence; particularly early maturers (versus on time- and late-maturers) might show heightened risk-taking during peer presence. Importantly, gender differences in the age of onset of puberty exist, and that the timing of puberty has different effects for boys and girls (Graber, Seeley, Brooks-Gunn, & Lewinsohn, 2004, Mendel & Ferrero 2012; Mendle,Turkheimer, & Emery, 2007). Thus gender and age effects should also be taken into account when investigating moderation effects of pubertal timing on the association between peer presence and heightened adolescent risk-taking .

Thus far, to the best of our knowledge, only one study (i.e., Kretsch & Harden, 2014) investigated the role of pubertal development and peer presence on adolescent risky decision making on a risky driving task. Findings showed that peers did not influence the percentage risky decisions that participants took (Kretsch & Harden, 2014), instead peer presence increased latency to break, suggesting that peer presence increased the deliberation time of the decision making process (Kretsch & Harden, 2014). Moreover, the effect of puberty was only significant in the alone condition, and an interaction between advanced pubertal development and risky decision making emerged, but again, only for the "latency to break" outcome measure and not for "percentage risky decisions" (Kretsch & Harden, 2014). However whether gender differences existed is unknown as a peer presence by pubertal timing by gender moderation effect was not investigated. Thus, building on Kretsch and Harden (2014), we investigate whether peer presence effects on adolescent risk-taking are moderated by pubertal timing, and we additionally explore gender and age moderation effects. That is, in study 1, we examine possible moderation effects involving social context pubertal timing, age, and gender.

Study 2: Parent and sibling presence effects on adolescent risky decision making

In the second study, we examine whether mother, father, and/or sibling presence differentially influence adolescent risky decision making on the CCT and compare it with a control condition in which adolescents complete the task alone. The second study is primarily exploratory, as it is the first empirical study of its kind and theories on sibling versus parent presence effects on adolescent risky decision making are lacking. However, we speculated that adolescents might be more cautious about taking risks when they are in the company of their parents versus when they are alone or with siblings. The effects that siblings will have on adolescent risky decision making are expected to be more similar to the effects of peers compared to the effects of parents. As for parent-presence effects, one recent study found that adolescents engage in less risky decision making when they thought their mother

was observing their performance on a risky driving task (stoplight game) compared to when they completed the task alone (Telzer, et al., 2015). Those findings are novel, as they perhaps provide the first causal evidence that "parental supervision" has an effect on adolescent risk-taking (Telzer, et al., 2015). The current study differs from Telzer et al. (2015) as we additionally compare the effect of the presence of parents with the presence of other significant family members (i.e., siblings) on adolescent risk-taking. The current study is also distinct as it includes not only mothers but also fathers in order to further determine whether the reported "reduced risk-taking" effect of mother presence that was found in Telzer, Ichien and Qu (2015) is unique for mothers, or if this effect is also generalizable to fathers.

Overview of studies

The current two-study experimental paper aims to add to the limited empirical literature on social presence effects on adolescent risk-taking on lab-based risky decision-making tasks. Hence, the current paper investigates the generalizability and robustness of social presence effects on adolescent risk-taking. Study 1 investigates the effects of the presence of peers on adolescent risky decision making and possible moderation effects by age, gender, and pubertal timing. Study 2 investigates and compares the effects of the presence of parents (separately for mothers and fathers) and siblings on adolescent risky decision making. To assess risky decision making, we used the timer version of the CCT. The CCT is a risky decision making task that has previously been shown to be sensitive to age differences and correlates with self-reported "need-for-arousal" (a construct closely related to sensation seeking) and other personality characteristics (e.g., Buelow, 2015; Figner et al., 2009; Panno, Figner, & Lauriola, 2013; van Duijvenvoorde et al., 2015).

Study 1

Methods

Participants

Participants in the current study took part in the second wave of a three-year longitudinal research project called the *Adolescent Risk-Taking* (ART) project (for details see: Defoe, Dubas, Somerville, Lugtig, & van Aken, in press). Only participants who completed all of the 24 rounds of the CCT (N = 420) were used for the current study. Most adolescents were either in year 2 or year 4 of middle level and lower level secondary educational tracks (advanced vocational and technical tracks). The adolescents (46.4% female) were between 13 and 17 years old (M_{age}: 14.63 years, SD = 1.30).

Procedure

Participants were recruited via high-schools in 6 different regions in the Netherlands; after approaching the schools via telephone calls and emails, 8 schools agreed to participate. Data collection took place during school hours. During data collection, students received both written and verbal instructions by trained research assistants. The first part of a data-collection session consisted of a digital questionnaire, which lasted approximately 30 minutes and a cognitive task in the middle of the questionnaire, which lasted roughly 10 minutes. A break of maximum 10 minutes followed hereafter. After the break, for each class, adolescents were assigned to perform the CCT alone in a large classroom with their peers (i.e., classmates) or with 2 randomly chosen same-sex peers in a separate small room. In the peer condition, 26 participants (42% females; M_{age} = 15.08; SD_{age} = 1.08) divided over 16 groups completed the 24 rounds of the CCT, one after the other, and they were allowed to communicate with each other while completing the task. There were always groups of three individuals in the peer conditions, but in the majority of these groups, we have complete data only for the first and second participant. The alone condition consisted of 394 participants (46% female; M_{age} = 14.63; SD_{age} = 1.30). Research assistants ensured that participants in the Alone condition sat as far away from each other as possible, and that they did not communicate with each other during the CCT. Voice recordings of the adolescents were made during the CCT sessions but this data is not used in the current study.

Participants received a prize worth EUR 2 (a candy with a miniature toy) for participation, but they could choose to exchange this small prize to enter a raffle for a chance to win a 50 euro gift voucher. In addition, participants were informed that one person in their school would be randomly selected to receive a gift voucher worth the amount of money they accumulated on the CCT.

Measures

Risky decision making in both studies was assessed with the Timer version of the Columbia Card Task (Timer CCT). The Timer CCT is identical to the short hot CCT version (described in Figner & Weber, 2011); see also Figner et al., 2009), with the exception that on top of the screen a timer is shown that is set to 16 seconds per game round. Thus identical to the hot CCT, in the Timer CCT the participants are presented with a deck of 32 cards face-down on a computer screen at the beginning of each of 24 game rounds. Across game rounds, 3 variables are varied systematically according to a full factorial design: (a) the gain magnitude (i.e., 10 or 30 points per gain card), (b) the loss magnitude (i.e., if a loss card is turned over, the current game round stops and -250 or -750 points are subtracted from the number of points accumulated in the current game round), and (c) the gain/loss probability (i.e., 1 or 3 loss cards out of 32 cards total). Each round begins with 0 points, which increases whenever a participant turns over a gain card but decreases when a participant turns over a loss card (which also stops the current game round, i.e., no

more cards can then be turned over in this round and the next game round starts). Participants turn over the cards sequentially (i.e., they make incremental decisions) and receive immediate outcome feedback (whether the turned card was a gain or loss card). In the Timer CCT, a game round can stop for three different reasons: (1) When the participant decides to stop turning over cards (and clicks on the respective button to end the game round) and thus collects the points gained in this round; (2) when the participant turns over a loss card; (3) when the 16 seconds allotted for each game round are over. When this happens, participants are presented with a screen stating that the time is up and they have to hit the space bar to continue with the following round. Participants can also choose not to turn over any card in the game round (e.g., if they think the round is too risky), in such a case no points will be earned and participants will automatically start the next round (see Figner et al.2009; Figner & Weber, 2011). The main indicator for risk taking was the number of cards turned over in each of the game rounds. Turning over more cards is a riskier strategy both in the decision-sciences and the lay definition of risk: Turning over more cards is associated with a larger range of possible outcomes (risk as outcome variability) and is also associated with an increased probability of encountering a negative event (risk in the lay sense). As an exploratory secondary measure, we used the proportion of game rounds in which a loss card was encountered as an indicator for risk taking (see more explanations below).

Pubertal timing was measured by first ascertaining pubertal status via the Pubertal Development Scale (PDS; Petersen, Crockett, Richards, & Boxer, 1988). The validity of this scale has been established in previous studies (e.g., Robertson, Skinner, Love, Elder, Conger, Dubas, & Petersen, 1992). The scale contained 5 items related to physical maturation, and answer categories ranged from 1 (has not yet started) to 4 (has completed.) Cronbach alphas were .76 and for boys and .58 for girls, thus pubertal development had adequate reliability for boys, but it was on the lower side for girls. To minimize the confounding effects of age on pubertal status, we used a pubertal timing measure for which we standardized the PDS scores within sex and age category (12-, 13-, 14- 15-, and 16 year olds) (for details see Ge, Conger, & Elder, 2001b). Higher scores reflected earlier pubertal maturation relative to peers within each age group and within each sex.

Strategy of analyses

We analyzed the CCT data mainly with a linear mixed-effects model approach using the lmer and glmer functions of the lme4 package (version 1.1.12; Bates, Maechler, Bolker, & Walker, 2015) in R (version 3.2.5; R Core Team, 2015). We followed Barr, Levy, Scheepers, and Tily's (2013) advice to use a maximal random-effects structure whenever possible, that is, we strived to use maximal models with respect to the random effects as this has been shown to avoid inflated Type 1 errors. The repeated-measures nature of the data (each participant provides multiple observations) was modeled by including random intercepts and random slopes as well as covariance estimates between the random effects where appropriate and possible (for more details see below in the results section). Unless explicitly mentioned below, categorical predictors (such as gender) were coded using sum-to-zero contrasts and continuous predictors (such as age) were centered and scaled. *P* values were determined using Type 3 Likelihood Ratio Tests (LRT) as implemented in the function mixed of the package afex (version 0.16-1; Singmann, Bolker, Westfall & Aust, 2016). Models were fitted using the *optimx* optimizer (version 2013.8.7; Nash & Varadhan, 2011).

Results

The main model used the number of cards turned over in each game round as the dependent variable. The fixed effects included the following variables of interest: social context, pubertal timing, gender, age, gain amount, loss amount, number of loss cards. Additionally, we added a numeric predictor representing whether a game round was stopped voluntarily ("uncensored" = 0) or was stopped involuntarily when the participant turned over a loss card ("censored" = 1). Interactions between social context and all of the above described predictors (except the "censoring" predictor) were also included as fixed effects, in addition to a three-way interaction between social context x pubertal timing x gender. We used a per-participant random adjustment to the fixed intercept ("random intercept"), and per-participant random adjustments to the slopes ("random slopes") for the variables loss cards, gain amount, and loss amount. Finally, all possible random correlation terms among the random effects were included as well.

The mean number of cards turned over per game round in the alone condition was 17.72, and in the peer condition it was 15.85. These are both comparatively high levels of risk taking, reflected also in the fact that 73% of the game rounds ended with participants turning over a loss card. Accordingly, we observed only two significant effects: The significant effect of the number of loss cards (b = -2.40(.17), $\chi^2(1) = 159.71$, p <.01) indicates that participants turned over fewer cards in game rounds with 3 compared to game rounds with 1 loss card. As was expected, and not of much interest in this specific analysis (but see below), the "censoring" effect was also significant (b = 5.24(.15), $\chi^2(1) = 1077.22$, p <.01), indicating that fewer cards were turned over in game rounds that ended with a loss card than in game rounds that were stopped voluntarily. The effects of gain amount and loss amount were not significant (p = .79; p = .99, respectively).

Importantly, the effects of interest were all non-significant: i.e., social context, pubertal timing, gender, age, three sets of two-way interaction effects between social context and the previously mentioned variables, as well as a three-way interaction between social context x pubertal timing x gender). The overall high levels of risk taking and the high proportion of game rounds ending with a loss card

may have made it difficult to detect any effects of interest. Therefore, we decided to conduct an additional initially unplanned exploratory analysis that used *the number of game rounds that ended with a loss card* as the dependent variable: In the hot 24-trial CCT version with unrigged feedback that we used in the current study, participants typically start off with turning over many cards but then learn to reduce risk-taking based on the negative feedback (i.e., the game rounds that end with a loss card), and thus end up with only some game rounds ending in a loss. In contrast, in the current study, participants seem to be relatively immune to this negative feedback, as they otherwise would not end up with over 70% of game rounds ending with a loss card. Therefore we were interested to see whether this risk taking in the form of an absence of risk-reduction in the face of negative feedback might differ as a function of social context, as it might be a more sensitive measure in the current study, due to the high proportion of "censored" game rounds.

For the above-mentioned reasons and since the majority of previous studies have reported an effect of peers on risk-taking, we thus ran secondary exploratory analyses with the *proportion of game rounds that ended with a loss cards turned* as an alternative risk-taking outcome measure for our main predictors of interest, that is, social context, gender, pubertal timing, age, an interaction between social context and all of these variables, as well as a three-way interaction between social context, pubertal timing and gender. Since each participant contributed only 1 data point to the dependent variable (the proportion of the 24 game rounds ending with a loss card), we ran a binomial model with R's glm function. Results showed that there was no main effect of peer condition (b = -1.29(1.35); p = .34), however there were significant interaction effects. Namely, a two-way interaction effect between social context and pubertal timing (b = .44 (.19); p = .03) showed that adolescents with earlier pubertal timing engaged in more risks in the peer condition than peers with later pubertal timing, whereas there were no differences in the alone condition. Additionally, we observed a significant three-way interaction between social context, pubertal timing, and gender (b = -.50(.22); p = .02). Both females and males in the peer condition (but not in the alone condition) showed a relationship between pubertal timing and risky decision making, with earlier pubertal timing being associated with more risk taking (i.e., more game rounds that end with a loss card), however, with this relationship being steeper for females than males. In contrast, in the alone condition, there was no evidence for a relationship between pubertal timing and risk-taking for females or males (see (Figure 1 and 2). Finally, there was also a main effect of gender, showing that boys take more risks than girls (b = .30(.05); p < .01).

Readers should bear in mind, however, that the *proportion of game rounds that ended with a loss card* as a risk-taking outcome measure is more difficult to interpret than the *number of cards turned over*, as the former is likely not only capturing risk-taking propensities but also capturing participants' inability (or unwillingness) to learn from negative feedback (i.e., turning over a loss card). However, given that the traditional measure of risk taking in the CCT (the number of cards turned over) showed such a high proportion of censoring (akin to a ceiling effect), this novel indicator seemed worth exploring and the results indeed suggest that it seems to be able to capture relevant individual and group differences.

Study 2

Method

Participants

Participants of study 2 took part in additional family experimental sessions as part of the ART Project (for details: see study 1). A total of 36 families in total participated in study 2, resulting in data of 40 target adolescents (we obtained 40 target adolescents from 36 families because 8 of the 40 target adolescents belonged to the same family, i.e., 4 of the families had 2 adolescent siblings each). Of the 40 adolescents, 39 completed the CCT in the alone condition (M_{age} = 14.53, SD_{age} = 1.70), 26 completed it with their mothers (M_{age}= 14.54, SD_{age} = 1.66), 18 with their fathers (M_{age}= 14.53, SD_{age} = 1.76), and 14 with their adolescent siblings.

Procedure

Roughly half of the adolescent participants in the families took part in the larger 3-wave longitudinal study, the rest were recruited via multiple strategies by University students who had to recruit families as an assignment for their bachelor and master theses. Data collection took place at schools (after school hours), at the University of Utrecht, and at community centers throughout The Netherlands. The families were told that they could win a voucher worth EUR 50, and each family member received 1 book voucher that worth EUR 10. The target adolescent completed the CCT a maximum of three times, once alone[23], and the 2nd or third time with a family member (either mother, father, or sibling) and the order of session was counterbalanced, and we also controlled for "order of session" in the analyses. Thus each target adolescent contributed 2-3 CCT data-sets.

Measures

The timer CCT was also used for study 2 (see study 1 for the description of the timer CCT).

Strategy of analyses

The same analysis strategies were used in studies 1 and 2 (see study 1 for details).

23 However one adolescent did not complete the CCT in the Alone condition.

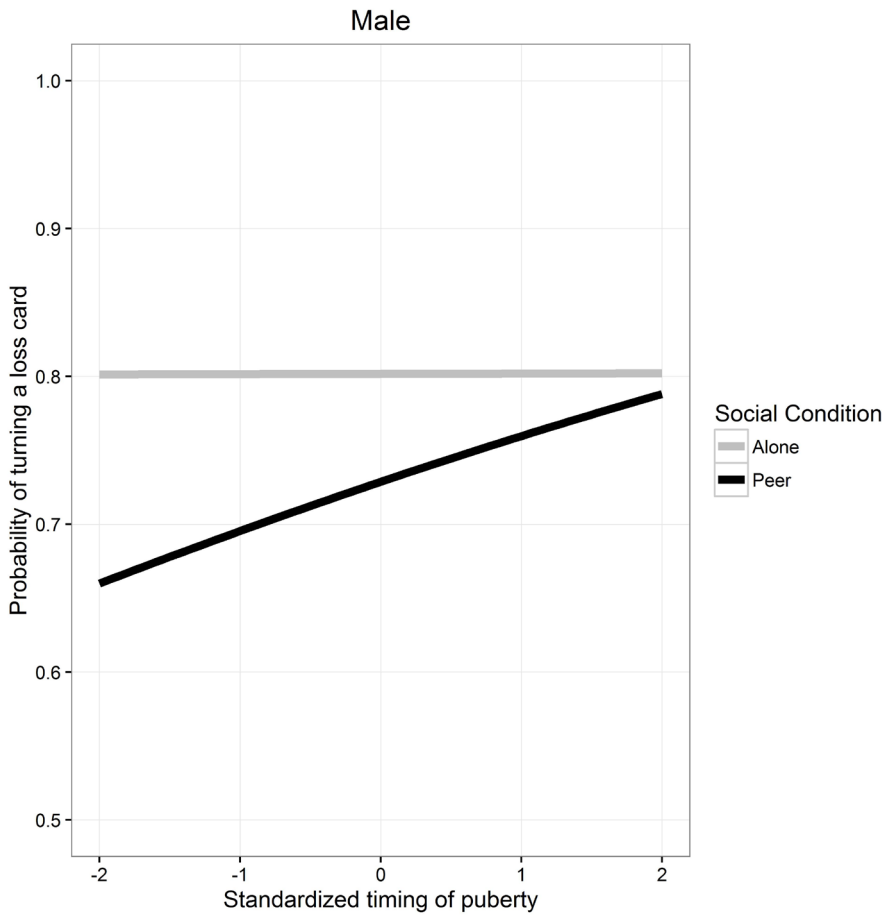

Figure 1. Social context x pubertal timing for females.

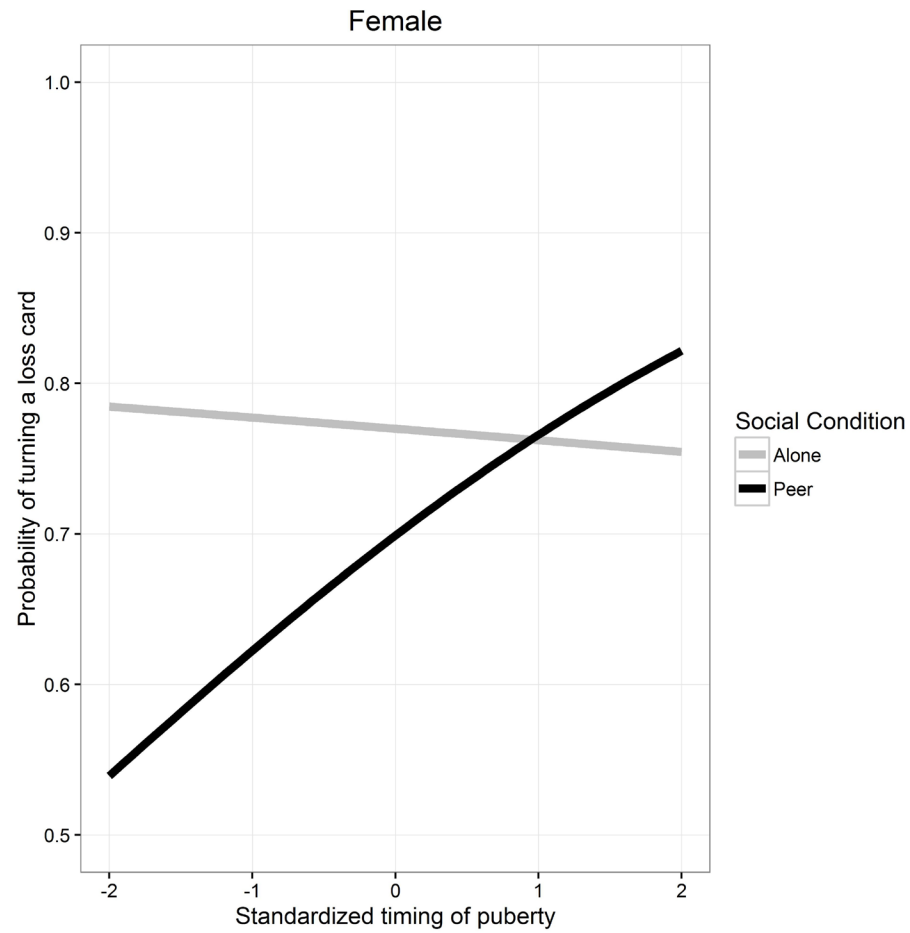

Figure 2. Social context x pubertal timing for males.

Results

The mean number of cards turned over in the alone, sibling, mother, and father conditions were as follows: 7.56, 5.98, 6.84, 6.89, respectively. In this data set, 56% of the game rounds ended with a loss card turned over. While still rather high, this is substantially lower than in study 1. For our main analysis, with the number of cards turned over as the dependent variable, we first attempted to fit a model maximal with respect to the random effects: The fixed effects included social context, gender, gain amount, loss amount, loss cards, order of session (i.e., whether the adolescent played the CCT for the first time, second time, or third time), a social context x gender interaction effect. Similar to study 1, we additionally added a numeric predictor representing whether a game round was stopped voluntarily ("uncensored" = 0) or was stopped involuntarily when the participant turned over a loss card ("censored" = 1). We used a per-participant random adjustment to the fixed intercept ("random intercept") as well as a per-family random adjustment to the fixed intercept, and per-participant and per-family random adjustments to the slopes "random slopes" for social context, loss cards, gain amount, and loss amount. Finally, all possible random correlation terms among the random effects were included as well.

This maximal model did not converge and several attempts such as increasing the number of iterations or trying different optimizers failed. Therefore, we split the analysis up in two segments: In model 1, we first tested whether loss cards, loss amount, gain amount, and the "censoring" predictor of no interest had significant

effects (akin to a sanity check, i.e., to investigate whether participants seemed to have understood the task and exhibited reasonable choice behavior). In this model we included a random intercept percepts per family and per participant, as well as random slopes for loss cards, gain amount, and loss amount. Results for model 1 showed that the number of cards turned over was lower in game rounds with 3 loss cards compared to game rounds with 1 loss card (b = -1.99(.17), $\chi^2(1) = 57.30$, p <.01). The effect of loss amount was significant (b = -.28(.13), $\chi^2(1) = 4.15$, p = .04) indicating that participants turned over fewer cards for a higher loss amount, but the effect of gain amount was not significant (p= .61). Additionally, we found again a significant "censoring" effect (b= 4.30(.20), $\chi^2(1) = 398.38$, p <.01). Thus, this pattern of results looks very similar to what we observed in study 1, possibly suggesting that as in study 1, effects of interest might be hard to detect in this data set. Nevertheless, we ran a second model to focus on the variables of interest (plus order session) to investigate whether gender, social context, and the interaction between these two variables predicted risky decision making (i.e., number of cards turned over). In this model we included random intercepts per family and per participant, as well as a random slope for social context. There were no significant effects for these variables of interest, however there was an effect of session order, indicating that participants engaged in more risky decision making the first time they played the CCT.

Taken together, similar to study 1, participants exhibited overall a large proportion of game rounds ending with a loss card, suggesting that they were relatively immune to negative feedback. Accordingly, we conducted follow-up analyses to investigate whether this non-responsiveness to negative feedback might differ as a function of social context, as in study 1. That is, we ran secondary exploratory analyses with *proportion of game rounds ending with a loss cards* as an alternative risk-taking outcome measure. As participants could contribute more than 1 data point and to appropriately take into account the non-independence in the data, in contrast to study 1, we here used a generalized linear mixed model (as in study 1 with a binomial link function). We included fixed effects for social context, gender, and the interaction between these two variables, as well as a random intercept per participant. This analysis was done using the lme4 package (version 1.1.12; Bates, Maechler, Bolker, & Walker, 2014) in R (version 3.2.5; R Core Team, 2014). Results showed that in all the social presence conditions, adolescents engaged in fewer risks (i.e., turned over fewer loss cards) compared to the alone condition (b= .23(.07); p = <.01).

General Discussion

The current paper included two studies that together investigated peer, sibling, mother, and father presence effects in adolescent risky decision making on a risky decision making task, namely the Timer CCT. Extrapolating from social

neurodevelopmental imbalance models and the Social Re-orientation Theory, in study 1 we investigated whether gender, age, and pubertal timing moderated a hypothesized effect of peer presence on adolescent risk-taking, in addition to investigating a *social context by gender by pubertal timing* interaction effect on adolescent risky decision making. Overall the results did not show that peer presence increased risk-taking in adolescents for any of the two risk-taking measures that we used (that is, the number of cards turned over, and the proportion of game rounds ending with a loss card), which is inconsistent with social neuro-developmental imbalance models. Next, for our second (initially unplanned) risk-taking outcome measure, a main effect was found for gender, showing that boys take more risks than girls. However, *social context by gender* and a *social context by pubertal timing by gender* moderation effects were present showing that earlier pubertal timing predicted higher levels of risk-taking in the peer condition, but not in the alone condition. Moreover, earlier pubertal timing increased risk-taking in both boys and girls, but to a greater extent in girls.

Taken together, these results indicate that although mere peer presence did not have an effect on adolescent's risky decision making, when pubertal timing in combination with gender was additionally taken into account, girls with earlier pubertal timing showed increases in risk-taking in the peer condition, to a higher extent than boys. In study 2, we found no main effect of social presence when number of cards turned over was used as the risk-taking outcome measure, and the results were the same for boys and girls. However, when the number of loss cards turned over was used as the risk-taking outcome measure, adolescents engaged in more risks when they completed the CCT alone versus when they completed the CCT with siblings, mothers or fathers, and regardless of whether the target adolescent was male or female. We further discuss these results below.

In general, we did not observe any evidence for peer presence increasing risk taking. This is inconsistent with social neurodevelopmental imbalance models, but it is consistent with accumulating studies that do not find such an effect of mere peer presence (see e.g., Reynolds et al., 2014).The findings that pubertal timing and pubertal timing by gender moderate peer presence effects are consistent with the Social Re-orientation Theory of adolescent risk-taking (Forbes & Dahl, 2010). However this theory is particularly concerned with how pubertal status interacts with peer effects to predict heightened adolescent risk taking, but it is not explicit about pubertal timing effects and gender moderation effects.

Our significant results of a risk increasing effect in the peer condition for early matureres (especially girls) are inconsistent with Kretsch and Harden (2014), which is, as far as we know, the only other experimental study that investigated a social context by pubertal maturation moderation effect on adolescent risk-taking. On the one hand, Kretsch and Harden 2014 found that advanced pubertal development attenuated adolescent risk-taking in the presence of peers on one of the risk-taking outcome measures that was used (i.e., latency to break) for the stoplight

game. On the other hand, neither pubertal development nor peer presence had an effect on risk-taking when "percentage risky decision making" was used as an outcome measure. However, the current results might not be directly comparable with Kretsch and Harden (2014), as gender x puberty moderation effects were additionally investigated in the current study, whereas this was not the case in Kretsch and Harden (2014).

Considered together, when it comes to real-world risk-taking, the current results might suggest that the earlier adolescents experience puberty, the greater the impact that peers will have on increasing their risk taking, and this association is stronger in girls versus boys. This is perhaps because puberty may trigger heightened reward sensitivity, and peer presence amplifies that effect (Gardner & Steinberg, 2005), however early maturers are not yet cognitively and/or socio-emotionally mature to regulate such effects on risk-taking. However, in other words, the current results could also suggest that later pubertal timing is related to fewer levels of risk-taking, whereas early pubertal timing is related to slightly more risk-taking, particularly in girls. Why a stronger effect is found for girls' risk-taking needs additional research attention, but studies do show that mainly early maturing girls engage in higher levels of risk behavior (Baams, Dubas, Overbeek, & Van Aken, 2015; Harden & Mendel, 2012).

Theories on the effects of siblings', mothers', and fathers' presence on adolescent risk-taking are lacking. In any case, the results that emerged for parents are to be expected, as assumingly, most parents would typically discourage risk-taking in their children. Our results are also consistent with earlier work using the stoplight game in a study that compared adolescent risk taking when alone versus when completing the stoplight game with their mothers (Telzer et al., 2015).

Interestingly, the current results add to the literature by additionally demonstrating that this risk-reducing effect can be generalized to both father and sibling presence. Although we found that parents and siblings reduce risk-taking in adolescents, different mechanisms might be producing the same effects. For example, it is possible that adolescents engage in fewer risks when their parents are around because they become more cautions and/or because parents typically discourage risks, but that they engage in fewer risks when their siblings are around to set a positive example, especially if their siblings are younger. These findings await to be replicated in future studies, especially because as far as we know, the current study is the first to investigate sibling and father presence effects on adolescent risky decision making, and only one other study investigated mother presence effects (i.e., Telzer et al., 2015).

Strengths, Limitations, and Future Directions

The current two-study experimental paper is novel as it is, as far as we know, the first paper to investigate the robustness of the mere peer presence effect on adolescent risk-taking by investigating whether such an effect is moderated by pubertal timing, gender, and age. Moreover, it is also the first attempt to investigate and ascertain whether differential effects exist for the presence of mothers, fathers, and siblings on adolescent risky decision making. However, there are some limitations that should be mentioned.

First, the sample size for the peer condition in study 1 was relatively small. We found significant interaction effects but a replication with a larger sample is desirable. Secondly, although our alternative measure of risk-taking (i.e., porportion of turned loss cards) can be interpreted as risk-taking, it is a less "pure" risk-taking measure than the original risk-taking outcome measure that we used (i.e., *number of cards turned over).* Specifically, on the one hand, *porportion of game rounds ending with a loss card*, might not only reflect risk preferences but also other processes, such as insensitivity to negative feedback, as participants seemingly did not learn to reduce risk-taking after receiving repeated negative feedback. On the other hand, insensitivity to negative feedback might be perhaps also an important aspect of real-world risk behaviors. We further speculate that participants particularly in the alone condition might have been too pre-occupied with the timer and were primarily concerned with turning over as many cards as possible before the timer ran out, and this strategy may have caused them to ignore everything else. In contrast, in the social conditions, participants maybe significantly turned over fewer loss cards in the presence of their significant others because they perhaps took the time to discuss the task characteristics (i.e., loss probability, gain amount, etc.) of each round, and thus were less concerned about turning over as many cards as possible before the timer ran out. Reasoning along these lines, it would be worthwhile for future studies to examine whether adolescents' risk-taking differs for the timer CCT versus the regular cold and/or hot CCT (as these CCT versions do not have a timer), in order to further investigate the effect of the timer on adolescent risk-taking.

Also, the social context by pubertal timing by gender moderation effect should be interpreted with caution as the reliability for the pubertal development scale for girls was relatively low. Next, due to our relatively small number of siblings in the current study, we could not investigate whether gender composition and birth-order composition of the sibling dyads moderated sibling presence effects on adolescent risk-taking. It would be of added value for future studies to consider such moderation effects, as longitudinal studies have shown that particularly older siblings tend to influence younger siblings, rather than the other way around (see e.g., Defoe et al., 2013; Buist, 2010).

Additionally, future studies could consider other moderators that might affect peer presence effects, such as peer pressure. It would also be worthwhile to investigate whether "sibling pressure" (or so-called "sibling power") could potentially moderate sibling presence effects, as tangential evidence with children suggest that this might indeed be the case (see: Morrongiello & Bradley, 1997). Finally, considering that longitudinal studies show that peers and (older) siblings tend to have the same influences (i.e., risk increasing) on adolescent risk behaviors

(Defoe et al., 2013; Buist, 2010), provokes the speculation that similar to what we found for peers, pubertal timing by gender effects might also moderate sibling presence effects on adolescent risk-taking. Hence, it would be of added value for future studies to take gender and pubertal timing of the target adolescent into account when investigating sibling effects on adolescent risk-taking.

Conclusion

In the real-world, it appears that adolescents engage in deviant behaviors (e.g., delinquency) particularly when they are in company of their peers (Steinberg, 2004). However the present results revealed that it is perhaps not just mere peer presence that triggers adolescent risk behavior. Specifically, in the presence of peers, early pubertal timing increases risk-taking, however this relationship is greater for females compared to males. These results are partly in line with the *social re-orientation theory,* which hypothesizes a pubertal development and peer influence interaction on heightened adolescent risk-taking. Furthermore, the current study was unique in that it showed for the first time that the mere presence of siblings and fathers reduce risk-taking in adolescents. In addition, the findings of a previous study (Telzer et al., 2015) that showed such an effect for the presence of mothers was replicated. However, although siblings' and parents' presence appear to have the same effect on adolescent risk-taking, future studies should test the robustness and generalizability of these effects. Also, different mechanisms for mother versus father versus siblings might be at play. Taken together, the current study has provided some answers but also demonstrated that there is still a need for more research in order to fully understand the mechanisms of social presence effects on adolescent risk-taking.

Part 3:
A longitudinal investigation of the roles of parents, peers, and siblings in adolescent risk-taking

Chapter 6

Siblings versus parents and friends: Longitudinal linkages to adolescent externalizing problems

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I.N. Defoe., L. Keijsers and S.T. Hawk developed the study concept and design. I. N. Defoe performed the data-analysis. I.N. Defoe, L. Keijsers and S.T. Hawk interpreted the results.
I.N. Defoe drafted the manuscript, and L. Keijsers, S.T. Hawk, S. Branje, J.S. Dubas, K. Buist, T. Frijns, M.A. G. van Aken, H.M. Koot, Pol A. C. van Lier, and W.Meeus provided critical revisions.

Abstract

Background: It is well-documented that friends' externalizing problems and negative parent-child interactions predict externalizing problems in adolescence, but relatively little is known about the role of siblings. This four-wave, multi-informant study investigated linkages of siblings' externalizing problems and sibling-adolescent negative interactions on adolescents' externalizing problems, while examining and controlling for similar linkages with friends and parents.

Methods: Questionnaire data on externalizing problems and negative interactions were annually collected from 497 Dutch adolescents (*M* = 13.03 years, *SD* = .52, at baseline), as well as their siblings, mothers, fathers, and friends.

Results: Cross-lagged panel analyses revealed modest unique longitudinal paths from sibling externalizing problems to adolescent externalizing problems, for male and female adolescents, and for same-sex and mixed-sex sibling dyads, but only from older to younger siblings. Moreover, these paths were above and beyond significant paths from mother-adolescent negative interaction and friend externalizing problems to adolescent externalizing problems, one year later. No cross-lagged paths existed between sibling-adolescent negative interaction and adolescent externalizing problems.

Conclusions: Taken together, it appears that especially older sibling externalizing problems may be a unique social risk factor for adolescent externalizing problems, equal in strength to significant parents' and friends' risk factors.

Key words: externalizing problems, siblings, longitudinal, negative interaction, adolescents, friends, parents

Youths' externalizing problems, such as delinquency and aggression, negatively and directly affect the external environment, and can result in great societal economic costs and social distress. A notable increase in delinquency is evident in adolescence (Farrington, 1986) primarily entailing minor delinquent acts (i.e., vandalism and shoplifting) (Moffitt, 1993). Several variants of social learning theory (Bandura, 1977) suggest that adolescents' externalizing problems occur via modeling of such behaviors from their social environment (e.g., deviancy training; Dishion, Spracklen, Andrews, & Patterson, 1996). In addition, coercion theory posits that the *quality* of adolescent relationships with significant others may increase adolescents' likelihood of externalizing problems (Patterson, 1982). Both of these theories are prominent "social learning" explanations for friend and parent influences on adolescent externalizing problems. Remarkably, although most families consist of multiple children (e.g., Statistics Netherlands, 2003), evidence for sibling influences on adolescent externalizing problems is relatively scarce (Dunn, 2005), even though they are theoretically just as likely as friend and parent influences. Furthermore, the sibling-adolescent, friend-adolescent, and parent-adolescent subsystems are interrelated (Bronfenbrenner, 1979), implying that sibling associations should also be considered when studying friends' or parents' associations with adolescents' externalizing problems. The current multi-informant, four-year study draws upon social learning theories of friend and parental influences to examine the unique and relative roles of siblings' externalizing problems and/or negative interactions with target youths in predicting externalizing problems in adolescence.

Sibling Externalizing Problems Versus Friend and Parent Externalizing Problems

Social learning theory (Bandura, 1977) postulates that people learn each other's behaviors through observation and imitation. Variants of such modeling theories are usually applied to the friend context, in order to explain the development and maintenance of similarity in externalizing problems among friends. For example, *deviancy training* theory posits that mutual social processes (e.g., laughing at antisocial acts) among individuals engaged in externalizing problem behaviors may reinforce adolescents' deviant behaviors, and proposes that such behaviors can be learned (Dishion et al., 1996). Likewise, similarity between parents' and adolescents' externalizing problems could be the result of youths learning these behaviors from parents (e.g.,Thornberry, Freeman-Gallant, Lizotte, Krohn, & Smith, 2003). Considering the aforementioned accounts of behavioral modeling in friend-adolescent and parent-adolescent relationships, it is likely that similar processes also occur between adolescents and siblings who exhibit externalizing problems.

Numerous cross-sectional studies demonstrate significant associations between siblings' externalizing problems (e.g.,Craine, Tanaka, Nishina, & Conger, 2009; Lauritsen, 1993). One of the few longitudinal studies among early adolescents

showed that older siblings' externalizing problems were related to a faster increase in younger siblings' externalizing problems two years later within same-sex sibling dyads (Buist, 2010). Similarly, another study showed that older siblings' antisocial behavior at ages 10 and 12 predicted younger siblings' antisocial behavior at age 16 (Compton, Snyder, Schrepferman, Bank, & Shortt, 2003). Hence, these findings suggest that modeling and imitation of externalizing problem behaviors may also occur between siblings.

Negative Interactions with Sibling versus Negative Interactions with Parents and Friends

Close relationships characterized by negative interactions can also be a predictor of adolescent externalizing problems. Patterson's (1982) *coercion theory* posits that coercive processes between parents and children provide a training ground for adolescents' externalizing problem development. In support of coercion theory, one recent longitudinal study reported a bidirectional relationship between parent-adolescent negative interaction and youths' externalizing problems (Burt, McGue, Krueger, & Iacono, 2005). Moreover, these processes may also be evident in the friend context, at least in childhood. For example, one study documented that coercive friend interactions were related to more externalizing problems (Snyder et al., 2008).

Similar processes may also occur in the sibling dyad. Patterson's coercion theory postulates that "sibling training in coercion" can emerge when parent-child negative interactions spill over to the sibling dyad, resulting in siblings' externalizing problems (Patterson, 1984, 1986). Empirical research on sibling negative interactions shows that they are typical and frequent (Kim, McHale, Wayne Osgood, & Crouter, 2006), but decline after early adolescence (Kim, McHale, Wayne Osgood, & Crouter, 2006) and may predict adolescent externalizing problems. For instance, a study demonstrated that sibling negative interactions at ages 10 to 12 predicted adolescent externalizing problems over 4 years (Bank, Burraston, & Snyder, 2004; see also, Criss & Shaw, 2005; Natsuaki, Ge, Reiss, & Neiderhiser, 2009; Slomkowski, Rende, Conger, Simons, Conger, 2001).

Collectively, empirical literature shows that the social learning perspective (Bandura, 1977) and coercion theory (Patterson, 1984) describe meaningful social processes with parents and friends that contribute to adolescent externalizing problems. In contrast, sibling relationships have been relatively understudied. The present research aims to extend the current literature by establishing whether these theories are also relevant for sibling relationships. We also address several of the methodological limitations in previous research.

Addressing Methodological Issues

First, the sibling dyad should not be studied in isolation, because that would ignore previously established interrelations between the sibling, parent, and friend subsystems (Bronfenbrenner, 1979; for a review: Steinberg & Morris, 2001). For instance, although parental differential treatment is possible, parents' behaviors might still have identical consequences for all siblings as a group since they share the same parents (e.g., Boyle et al., 2004). Accordingly, sharing the same antisocial parents, might cause siblings to overlap in externalizing problems; this may reflect both genetic and social learning processes (Boyle et al., 2004; Thornberry, et al., 2003). Siblings' similarity in externalizing problems may also stem from their communal antisocial friends (Rowe & Gulley, 1992). Thus it is necessary to disentangle unique sibling associations from those of friends and parents.

Second, some studies have accounted for parent-child negative interactions (i.e., Bank, et al., 2004; Criss & Shaw, 2005; Natsuaki, et al., 2009). However, none to our knowledge have longitudinally examined whether sibling negative interactions contribute to adolescent externalizing problems, independent of the *simultaneous* influences of both parent-adolescent and friend-adolescent negative interactions.
Third, the gender and birth-order composition of sibling dyads may moderate sibling associations. It is a commonly-held notion that same-sex pairs exert stronger influence on each other, although mixed-sex sibling pairs may also overlap in their externalizing problems (e.g., Buist, 2010). Further, although social learning theory (Bandura, 1977) suggests reciprocal relationships between persons involved, older siblings may have stronger effects, because they are more likely already involved in delinquency (Farrington, 1984) and may thus serve as role models for antisocial behavior (Moffitt, 1993). Indeed, the majority of research on birth-order in sibling dyads reports a unidirectional relationship, from older siblings' externalizing problems to younger siblings' externalizing problems (e.g., Buist, 2010; Craine et al., 2009).

Fourth, generally speaking, past research has rarely controlled for transactional processes (Granic & Patterson, 2006) in which parents, friends, and siblings not only affect adolescents, but are also affected *by* adolescents. For instance, reciprocal links have been established between friends' and adolescents' externalizing problems (e.g., Haynie & Osgood, 2005), and between poorer quality parent-child relationships and adolescent externalizing problems (e.g., Lytton, 1990; Keijsers, Loeber, Branje, Meeus, 2011). Thus, to disentangle whether siblings predict externalizing problems, it is necessary to control for reverse associations.

The present study

In sum, the primary goal of this multi-informant, four-year study was to establish the roles of siblings' externalizing problems and negative interaction in the prediction of adolescent externalizing problems, while estimating and controlling for similar links with parents and friends. In addition, reverse links from adolescents' externalizing problems to the relationships with and externalizing problems of siblings, friends, and parents were also assessed and controlled for. Based on our dual theoretical approach, we hypothesized that both sibling externalizing problems and negative interactions would uniquely predict adolescent externalizing problems, beyond

the hypothesized similar linkages from parents and friends. Finally, we explored moderation by adolescent's gender, and by gender and birth-order composition in the sibling dyad.

Method

Participants

Participants were recruited from the project "Research on Adolescents Development And Relationships" (RADAR; see for instance: Keijsers et al., 2012), a prospective longitudinal study in the Netherlands. Four annual waves of questionnaire data were analyzed from 497 targeted Dutch adolescents (57% male and 43% female), along with their siblings, fathers, mothers, and self-nominated best friends. These youths predominantly (89%) came from families with a medium or high socioeconomic status (SES), with a remaining 11% from families with low SES (Statistics-Netherlands, 1993).

At baseline (T1), target adolescents were 13.03 years (*SD* = .52), siblings were 14.92 years (*SD* = 3.33), fathers were 46.76 years (*SD* = 5.12), and mothers were 44.46 (*SD* = 4.50) years, on average. A total of 408 sibling dyads were present: 111 brother-brother pairs, 100 sister-sister pairs, 122 brother-sister pairs, and 75 sister-brother pairs. In addition, 288 target adolescents were younger than their siblings, and 115 adolescents were older.

Approximately 92% of target adolescents had a participating best friend (M_{Age} = 13.17, *SD* = .84) at T1, and 79% had a best friend participating each year. Friendships were quite stable: From T1 to T2, 69% of the adolescents nominated the same person as their best friend (79% from T2 to T3 and 66 % from T3 to T4).

Procedure

Families received a description of the RADAR project and a written informed consent document. In addition, the target adolescent was asked to invite and to provide contact information of his/her best friend. Once informed consent was granted by target adolescents, best friends, and parents of these adolescents, a trained research assistant arranged home-visits to administer the questionnaires to the respondents. Families received a total equivalent to US $100 per home visit. Friends were paid US $35.

Measures

Externalizing problems during the previous six months were assessed via self-reports. Adolescents, siblings and friends reported on 30 items of the Youth Self Report (YSR: Achenbach, 1991b). Mothers and fathers filled in the 35-item Adult Self Report (ASR: Achenbach & Rescorla, 2003). Both questionnaires contain items such as: "I use drugs or alcohol" and "I fight a lot". Answers were given on 3-point Likert scales ranging from (0) *not true*, to (2) *very true or often true*. Mean scores were calculated. For each wave, the externalizing problems scales of the YSR and ASR showed good reliability (see Table 1).

Negative interactions with the adolescent were reported by mothers, fathers siblings, and friends, using the "Negative Interaction" subscale of the Network of Relationships Inventory (NRI; Furman & Buhrmester, 1985). Negative interactions were assessed with a 5-point Likert scale ranging from 1 (*little to none*) to 5 (*could not be more*), and comprises measures of conflict (3 items; e.g., 'How much do you and your sibling disagree and quarrel?) and antagonism (3 items; e.g., 'How much do you and your sibling hassle or nag one another?). Thus, higher scores indicate greater quantity (not intensity) of negative interactions. Mean scores across items were used. Reliabilities were acceptable across waves (Table 1).

Strategy of Analyses

To investigate the hypothesized longitudinal links from siblings' externalizing problems and sibling-adolescent negative interactions to adolescent externalizing problems, we constructed a series of multi-informant cross-lagged panel models in M*plus* 6.1 (Muthén & Muthén, 1998-2010). In step 1, we tested a model per significant other, resulting in four models. Each model contained four repeated measures of externalizing problems of the adolescent, externalizing problems of the significant other (i.e., either sibling, friend, mother or father), and of negative interactions between adolescents and that significant other. Hypothesized longitudinal links were examined from externalizing problems of- and negative interactions with- the significant other, at a given time point to adolescent externalizing problems one year later. We controlled for one-year stability paths of each variable, all possible T1 associations, and all possible concurrent error covariance between variables at each measurement wave, and reverse longitudinal links (i.e., links from adolescent externalizing problems to externalizing problems of and negative interactions with the significant other, one year later).

Each model was time-invariant, meaning that hypothesized cross-lagged paths and reverse cross-lagged paths could be constrained to be equal over time without worsening the model-fit (sibling: Wald $\chi 2$ (4) = 6.99, p = .14; mother: Wald $\chi 2$ (4) = 2.61, p = .63, father: Wald $\chi 2$ (4)= .51, p = .97; friend: Wald $\chi 2$ (4) = .15, p > .99). Additionally, we examined whether members of the sibling-adolescent and friend-adolescent dyads were distinguishable (Kenny, Kashy, & Cook, 2006), by testing whether the cross-lagged paths from siblings and friends to adolescents could be constrained to be equal to the reverse paths, from adolescents to siblings and friends. These constraints did not worsen the model-fit (sibling: Wald $\chi 2$ (3) = 1.12, p = .77; friend: Wald $\chi 2$ (3) = 2.72, p = .44), and were thus added.

We tested for moderation of adolescent gender, by constraining parameters to be equal for males versus females in these preliminary models. In the sibling model,

we additionally tested for moderation of gender composition (i.e., same-sex versus mixed-sex sibling dyads), and birth order composition (i.e., older-younger sibling versus younger-older sibling dyads).

In step 2, we examined the relative strength of links of siblings, from parents and friends to adolescent's externalizing problems. Therefore, we combined only the significant links in one final combined model.

Attrition in this study was low. Of the 497 families at T1, 466, 474, and 440 participated at the three follow-up measurements, respectively. Per variable, a maximum of 27% of the cases were missing. Missing data analyses suggested a random pattern of missingness. A Full Information Robust Maximum Likelihood Estimator was used for all models (Satorra & Bentler 1994), because the data for our externalizing problems measure were somewhat skewed (Skewness was between .65 and 2.47). All models had a good fit to our data (See Online Supplementary Information concerning details about the fit of the preliminary models).

Results

Descriptive statistics are provided in Table 1. Notably, the frequency of negative interaction was highest among siblings (compared to mothers, fathers, and friends). Moreover, mean levels for sibling-adolescent negative interactions decreased significantly over time (F (3,332) = 12.26, p < .01, η^2= .10). Bivariate concurrent correlations amongst the study variables within each measurement wave[24] are presented in Table 2 and Table 3.

Preliminary Models per Significant Other

In line with our hypothesis, siblings' externalizing problems modestly predicted adolescent externalizing problems (βs between .04 and .05) in the sibling model, and the same was found for friends (βs between .04 and .05). In contrast, mothers' and fathers' externalizing problems did not predict adolescents' externalizing problems in the parent models.

Contrary to our expectations, sibling negative interactions did not predict adolescent externalizing problems, nor were there reversed effects. However, adolescent negative interactions with mothers (βs between .06 and .07) and friends (βs between .04 and .05) significantly predicted adolescent externalizing problems. Father-adolescent negative interactions predicted adolescent externalizing problems at a trend level (βs between .04 and .05, p = .06). (See Online Supplementary Information for details concerning the preliminary analyses.)

24 A complete correlation table is available from the first author upon request.

Table 1. Descriptive Statistics, Reliabilities, and One Year Stability (Correlation Coefficients)

	T1			T2			T3			T4			Relative Stability		
Variable	*M*	*SD*	*a*	*M*	*SD*	*a*	*M*	*SD*	*a*	*M*	*SD*	*a*	T1-T2	T2-T3	T3-T4
Externalizing Adolescent	.35	.24	.87	.32	.27	.91	.35	.32	.89	.35	.26	.89	.64**	.58**	.77**
Externalizing Sibling	.37	.23	.87	.34	.20	.83	.31	.22	.85	.29	.21	.85	.66**	.73**	.70**
Externalizing Mother	.12	.13	.83	.10	.11	.83	.09	.11	.84	.08	.09	.77	.72**	.76**	.73**
Externalizing Father	.13	.12	.80	.13	.14	.86	.11	.13	.85	.10	.12	.83	.63**	.70**	.77**
Externalizing Friend	.38	.22	.85	.36	.25	.88	.36	.27	.88	.35	.25	.88	.60**	.58**	.57**
Negative Interaction Sibling	2.39	.79	.93	2.36	.81	.94	2.23	.81	.95	2.14	.82	.95	.63**	.66**	.72**
Negative Interaction Mother	1.52	.53	.92	1.55	.54	.92	1.52	.50	.90	1.55	.56	.92	.69**	.69**	.71**
Negative Interaction Father	1.51	.50	.90	1.52	.53	.92	1.51	.52	.91	1.53	.51	.92	.70**	.67**	.70**
Negative Interaction Friend	1.25	.34	.80	1.26	.37	.83	1.27	.40	.85	1.28	.42	.85	.39**	.36**	.41**

Note. Externalizing = Externalizing Problems
** p < .01.

Table 2. Bivariate Concurrent Correlations at Time 1 and Time 2

		1	2	3	4	5	6	7	8	9
1.	Externalizing problems Adolescent	-	.09	.21**	.05	.20**	.09	.33**	.22**	.16**
2.	Externalizing Problems Sibling	.15**	-	.17**	.21**	.05	.30**	.11**	.17**	-.01
3.	Externalizing Problems Mother	.24**	.07	-	.06	.07	.19**	.34**	.14**	.01
4.	Externalizing Problems Father	.08	.20**	.07	-	.06	.04	.01	.28**	-.01
5.	Externalizing Problems Friend	.23**	.06	.14**	-.01	-	-.01	.17**	.10*	.34**
6.	Negative interaction Adolescent-Sibling	.16**	.31**	.07	.09	.07	-	.21**	.20**	.08
7.	Negative interaction Adolescent-Mother	.34**	.05	.34**	-.03	.12**	.20**	-	.41**	.17**
8.	Negative interaction Adolescent-Father	.28**	.04	.15**	.16**	.08	.14**	.39**	-	.16**
9.	Negative interaction Adolescent-Friend	.22**	.02	-.00	.01	.24	.12*	.16**	.15**	-

Note. The concurrent-correlations of the first year are presented below the diagonal and concurrent correlations of the second year are displayed above the diagonal.
*p < .05. ** p < .01.

Table 3. Bivariate Concurrent Correlations at Time 3 and 4

		1	2	3	4	5	6	7	8	9
1.	Externalizing problems Adolescent	-	.17**	.17**	.10*	.20**	.09	.28**	.27**	.15*
2.	Externalizing Problems Sibling	.22**	-	.11**	.12*	.11*	.25**	.13**	.12*	.07
3.	Externalizing Problems Mother	.24**	.18**	-	.04	.06	.08	.37*	.12*	.02
4.	Externalizing Problems Father	.10*	.15**	-.00	-	.09	.00	.02	.16**	-.03
5.	Externalizing Problems Friend	.23**	.06	.06	.03	-	-.02	.07	.05	.23**
6.	Negative interaction Sibling	.14**	.18**	.07	.11*	-.02	-	.20**	.23**	.03
7.	Negative interaction Mother	.24**	.04	.31**	.05	.06	.25**	-	.41**	-.01
8.	Negative interaction Father	.23**	.11*	.08	.19**	.09	.31**	.43**	-	.10*
9.	Negative interaction Friend	.16**	-.01	-.00	-.04	.19**	.09	.10*	.02*	-

Note. The concurrent-correlations of the third year are presented below the diagonal and concurrent correlations of the fourth year are displayed above the diagonal.
*$p < .05$. ** $p < .01$.

Multi-group Comparisons

Multi-group analyses for adolescent gender revealed few gender differences. T1 associations in the sibling, mother and father model were not moderated by gender (sibling: Wald $\chi 2$ (3) = 1.49, p=.68; mother: Wald $\chi 2$ (3) = .82, p =.85; father: Wald $\chi 2$ (3) = 1.51, p =.68), but T1 associations of friend externalizing problems with friend-adolescent negative interactions existed only in the model for males (Males: β = .34, p <.01. Females: β= .09 p = .21. Wald $\chi 2$ (3) = 12.78, p =.21). Cross-lagged paths of each model, per significant other, did not differ for males and females (sibling: Wald $\chi 2$ (4) = 8.48, p=.08, mother: Wald $\chi 2$ (4) = 2.19, p =.70; father: Wald $\chi 2$ (4) = 3.64, p =.46; friend: Wald $\chi 2$ (4) = 3.08, p =.54).

For the sibling model, we also examined whether gender and birth-order composition in the sibling dyad moderated the hypothesized paths. No differences for gender composition of the sibling dyad for T1 associations (Wald $\chi 2$ (3) = 2.98, p =.40), or cross-lagged paths (Wald $\chi 2$ (4) = 1.64, p = .80) were found. As for birth-order moderation, T1 associations were equal across groups (Wald $\chi 2$ (3) = 2.80, p = .42) but the cross-paths were moderated (Wald $\chi 2$ (4)= 10.50, p = .03).Siblings' externalizing problems predicted adolescents' externalizing problems only when siblings were older than adolescents (β's between .04 and .05)

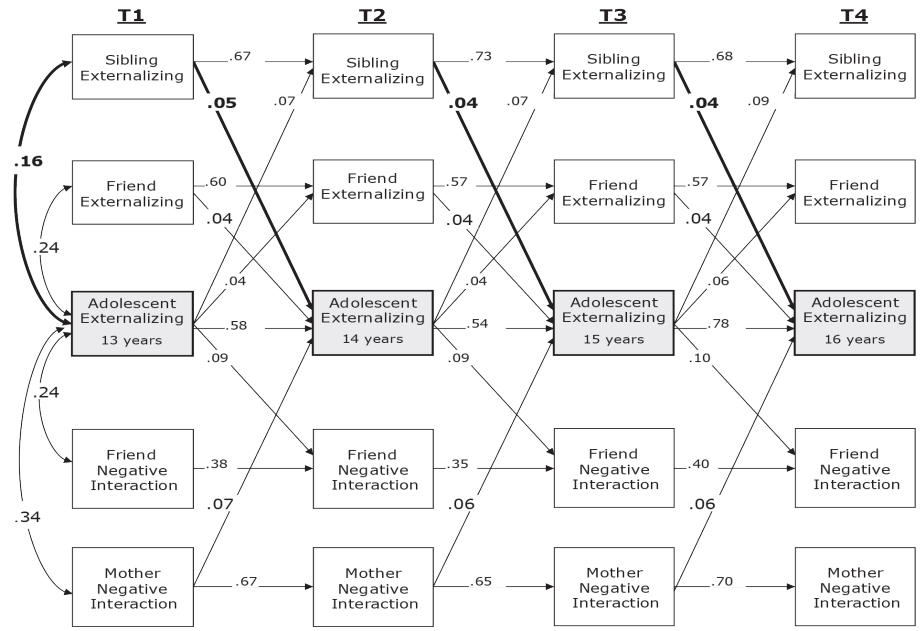

Figure 1. Significant standardized paths for combined model. Externalizing = externalizing problems. Bold arrows indicate hypothesized sibling paths. Concurrent error covariance at T_2, T_3, and T_4 are estimated, but not depicted.

The Combined Model: Relative and Unique Sibling Associations

Finally, we investigated unique links of sibling externalizing problems compared to the significant links of friends, mothers, and fathers[25] in one combined model (see Figure 1). Results of the combined model showed significant T1 associations (β = .16) between siblings' externalizing problems and adolescents' externalizing problems and significant cross-lagged effects of sibling externalizing problems upon adolescent externalizing problems (β = .04 to .05). Reverse associations from adolescent externalizing problems to sibling externalizing problems were also present (βs between .07 and .09).

Pertaining to friends and mothers, we found significant T1 associations of adolescent externalizing problems with friends' externalizing problems (β = .24), friend-adolescent negative interactions (β = .24), and mother-adolescent negative

25 Because the paths from father-adolescent negative interactions to adolescent externalizing problems was a trend at p = .06, we ran two different combined models, in one of which we also included this trend, and in one of which we left it out. Both models yielded similar results. That is, the magnitudes of the paths were equal. We decided to report the model without the trend effect.

interactions (β = .34). Friends' externalizing problems (βs between .04 and .06) and mother-adolescent negative interactions (βs between .06 and .07) also remained significant predictors of adolescent externalizing problems in the combined model, but friend negative interaction was no longer a significant predictor. Reversed links were found from adolescent externalizing problems to friend externalizing problems (βs between .07 and .09), and from adolescent externalizing problems to friend negative interaction (βs between .09 and .10). Taken together, results showed that externalizing problem behaviors of siblings and friends and negative interaction with mothers were significant longitudinal predictors of adolescent externalizing problems.

Discussion

Sibling relationships are one of the most constant social companionships, providing a proximal context for youth's developmental opportunities (Jenkins & Dunn, 2009). Accordingly, siblings might influence adolescent behaviors in ways similar to both parents and friends. Moreover, prominent developmental theories (Bronfenbrenner, 1979) and previous empirical investigations (review: Steinberg & Morris, 2001) suggest that the sibling subsystem is interrelated with the parent-adolescent and friend-adolescent subsystems. Hence, sibling influences on adolescent externalizing problems may be partly explained by other social influences. To our knowledge, this study is the first to longitudinally examine the unique and relative role of siblings' externalizing problems and sibling-adolescent negative interactions in the prediction of adolescent externalizing problems. Strict cross-lagged panel models revealed modest but unique cross-sectional and bidirectional longitudinal links between sibling externalizing problems and adolescent externalizing problems. Moreover, longitudinal links were similar in magnitude to links from friend externalizing problems and mothers-adolescent negative interactions to adolescent externalizing problems, both of which have more frequently been addressed in prior studies. Although T1 associations between sibling-adolescent negative interactions and adolescent's externalizing problems were found, no longitudinal paths from sibling-adolescent negative interactions to adolescent externalizing problems were present. We address the implications of these findings below.

Sibling Externalizing Problems

Modeling and imitation of behaviors are core components of social learning theory (Bandura, 1977). Considering that sibling relationships are among the most prominent social factors in adolescence (Jenkins & Dunn, 2009), we hypothesized that one sibling's externalizing problems would predict those of the other sibling. Indeed, the primary finding of the current study is that sibling externalizing problems

(but not sibling negative interaction) could be a unique risk factor for subsequent adolescent externalizing problems, and vice-versa, even when controlling for established roles of parents and friends. The current longitudinal study is the first to demonstrate robust links between siblings' externalizing problems. That is, although a few studies have considered parent-adolescent or friend-adolescent associations when studying sibling similarity in externalizing problems (e.g., Fagan & Najman 2003; Natsuaki et al., 2009), we could find no other study accounting for *simultaneous* influences of parents *and* friends on adolescents. In addition, this study extends the relevance of social learning theory to the sibling dyad.

In line with a social learning perspective, we found reciprocal, positive linkages between siblings' externalizing problems. This suggests that siblings may mimic each others' externalizing problem behavior, fueling a downward spiral in which siblings mutually maintain and reinforce each other's problematic behavior. This illustration corresponds to deviancy training among antisocial friends (Bandura 1977; Dishion et al., 1996). However, unlike friends who often have the same age, siblings are almost always of a different age. Accordingly, findings revealed that older siblings' externalizing problems predicted younger siblings' externalizing problems but not the reverse. These results concur with the majority of sibling studies that report a typical direction of influence from older sibling to younger sibling (e.g., Buist 2010, Craine et al., 2009). Hence, although deviancy training may also occur in sibling dyads, the direction of modeling is predominantly from the older to the younger sibling.

Interestingly, associations between siblings' externalizing problems were comparable for male and female adolescents and for same-sex and mixed-sex sibling pairs. Thus, the present findings support the suggestion by Snyder, Bank, and Buraston (2005) that modeling behaviors - while perhaps more likely for same-sex siblings (e.g., Buist, 2010) - can also occur within mixed-sex sibling pairs. These moderation results should be interpreted with caution, however, because we may not have had enough power to detect small moderation effects.

Sibling Negative Interactions

Coercion theory posits that parent-child negative interactions may trigger negative interactions in the sibling dyad, which may predict externalizing problems in childhood and adolescence (Patterson, 1984, 1986). In the present research, sibling-adolescent negative interactions were associated, but not longitudinally. This contradicts previous empirical studies with at-risk samples, showing that sibling negative interactions predict adolescent externalizing problems (e.g., Bank et al., 2004; Criss & Shaw 2005).

Several explanations can be given for this discrepancy. First, sibling negative interactions may be a normative process that declines after early adolescence (e.g., Kim, et al., 2006; Kramer, 2010), and could be either destructive or constructive (Kramer, 2010). This study possibly tapped into the more constructive and normative

patterns of negative interaction, including small disagreements. Secondly, our study used a very stringent methodological approach, including a longitudinal design controlling for reverse paths and temporal stability, and using multiple informants for different measures. Bivariate associations that did not take all of these possible confounds into account indeed showed the (small) positive correlations that we predicted. Future studies with a stringent longitudinal design are needed to test this hypothesis further.

Limitations and Implications

Despite the multi-informant longitudinal design of the present study, there are also some limitations. Firstly, the magnitudes of the cross-lagged paths were small. We believe this is caused by our rigorous cross-lagged panel design with different reporters for different variables. Effect sizes were comparable to a similar recent study (i.e., Natsuaki et al., 2009) on "Nonshared Environment in Adolescent Development" data (Hetherington et al., 1999). This suggests the cross-lagged paths are small but meaningful (e.g., McCartney & Rosenthal, 2000). Second, although our sample size was adequate for this type of modeling, statistical power was perhaps limited for finding moderation effects. Third, our measurement for negative interaction did not make a distinction between constructive and destructive negative interaction. A conflict resolution measure might have better assessed whether constructive or destructive negative interaction was being tapped. Fourth, we relied purely on longitudinal questionnaire data, and did not directly study underlying mechanisms. Hence, no causal inferences can be made from the present, non-experimental results. Finally, we postulated social learning as the mechanism underlying our findings, but other explanations for the sibling linkages may also be plausible, such as those derived from "identity based theories" (see e.g., Heilbron & Prinstein, 2008), as well as shared genes or gene-environment interactions.

Conclusion

Despite the aforementioned limitations, this study overcame several methodological challenges unaddressed in prior research. It demonstrated the unique relation of older sibling's externalizing problems with subsequent adolescent externalizing problems, independent of the interrelatedness between the sibling-adolescent, parent-adolescent, and friend-adolescent subsystems. Results suggest moreover that siblings and friends (i.e., peers) play a similar role in adolescent externalizing problems, as their problem behaviors are linked with adolescent externalizing problems to a similar extent. For parents, however, it was the relationship quality with adolescents - particularly mother-adolescent negative interaction - that predicted adolescent externalizing problems. Taken together, it appears that especially older sibling externalizing problems may be a unique social risk factor for adolescent externalizing problems, equal in strength to significant parents' and friends' risk factors.

Chapter 7

On Breaking the Vicious Cycle of Peer Similarity in Adolescent Delinquency: The Moderating Role of Mothers

Author note:
This chapter is based on a manuscript that is currently under review.

I.N. Defoe developed the study concept and design, and J.S. Dubas and M.A.G van Aken. gave advice and feedback. I.N. Defoe oversaw the data-collection. I.N. Defoe performed the data-analysis and interpretation. I.N. Defoe drafted the manuscript, and J.S. Dubas and M.A.G. van Aken provided critical revisions.

Abstract

Although most social learning theories assume that delinquent peer norms and/or peer pressure are the mechanisms that link peer delinquency to subsequent adolescent delinquency, surprisingly, these specific mechanisms are rarely investigated. Another important understudied question is whether parenting behaviors can moderate these linkages. Hence, the current two-year multi-informant longitudinal study investigated these questions among 12-16 year old ethnically-diverse Dutch adolescents (*N*=602 at baseline), and tested whether gender and adolescent phase further moderated these links. We found independent links from delinquent peer norms and negative mother-adolescent relationship quality to early and middle adolescent girls' delinquency one year later, respectively. As for boys, higher levels of mother-adolescent relationship quality exacerbated the link between peer pressure and subsequent early adolescent boys' delinquency. This finding was replicated when mother reports on negative mother-adolescent relationship quality was used. Implications for theory and prevention/intervention efforts are discussed.

Delinquency (theft, vandalism) concerns a variety of externalizing behaviors that violate legal and social rules at a high personal and societal cost. Besides the offender, far too often the society suffers as well, as delinquency is responsible for considerable societal psychological distress (e.g., societal anxiety) as well as societal economic distress (e.g., expenditures on the justice system). It has been consistently documented that an array of delinquent behaviors shows accelerated growth and peaks during adolescence (e.g., Farrington, 1986), and that delinquent peer affiliation is one of the strongest predictors of juvenile delinquency (Haynie & Osgood, 2005). Criminological variants of social learning theories (e.g., Akers, 1998; Sutherland, 1947) that posit that *modeling* links delinquent peer affiliation to subsequent adolescent delinquency are among the leading theories of peer similarity in delinquency. Although rarely tested directly, it is often assumed that modeling is facilitated via conformity to perceived delinquent peer norms (i.e., indirect peer pressure) or via direct/overt peer pressure (Brown, Clasen, & Eicher, 1986).

Hence, instead of investigating whether mere delinquent peer affiliation predicts adolescent delinquency, we specifically investigate whether delinquent peer norms and/or peer pressure to engage in delinquency predict subsequent adolescent delinquency. Although such peer influences become increasingly strong during adolescence (Steinberg & Morris, 2001), a meta-analysis showed that parent-adolescent relationship quality is also a significant predictor of adolescent delinquency (Hoeve et al., 2009). Thus a critically valid –yet understudied— follow-up question is whether such poor parent-adolescent relationship quality make adolescents more susceptible to adverse peer effects on adolescent delinquency. Accordingly, the primary goal of the current multi-informant study is to investigate whether negative mother-adolescent relationship quality (reported by mothers and adolescents) exacerbates the hypothesized link between delinquent peer norms and peer pressure to engage in delinquency and subsequent delinquency in adolescent boys and girls.

Many prominent developmental theories (e.g., Moffitt, 1993; Patterson & Yoerger, 2002) concur that youth delinquency development typically begins at home, as the home environment is the first socializing context for children. For example, coercion theory postulates that parent-child negative interactions provide a breeding ground for children to learn to act out, which can trigger subsequent youth externalizing problems, such as delinquency (Patterson, 1982). However, during adolescence, deviant peer affiliations become a stronger predictor of adolescent delinquency (e.g., Haynie & Osgood, 2005), which is perhaps not surprising, as individuals tend to gravitate more towards their peers (compared to their parents) during adolescence. Nevertheless, there is some empirical evidence showing that parents can still exert influence on adolescents' behavior even when accounting for similar peer (and sibling) influences. For example, a recent 4-year longitudinal cross-lagged panel study (*N*=497) demonstrated that parent-adolescent negative interactions (but not parent externalizing problems) predicted adolescent externalizing problems (i.e.,

delinquency and aggression) above and beyond significant effects of friends' (and siblings') externalizing problem behavior (Defoe et al., 2013). Defoe et al. (2013) concluded that parents and friends might play a differential role in adolescent delinquency, that is, whereas the delinquent behavior of friends determines adolescent delinquent behaviors, it is the relationship quality between parents (particularly mothers) and their adolescent offsprings that predict whether the adolescent gets involved in delinquency.

Although the independent and unique effects of negative mother-adolescent relationship quality and peer delinquency on subsequent adolescent delinquency have been established, what is less clear is a potential interplay between these differential social factors in predicting adolescent delinquency. Particularly, does poor parent-child relationship quality, such as parent-adolescent negative interactions make adolescents more susceptible to delinquent peer norms and peer pressure leading to heightened adolescent delinquency? In other words, can fewer mother-adolescent negative interactions minimize such hypothesized adverse peer effects on adolescent delinquency? This is a pivotal question for interventions catered to equipping parents to help their adolescents resist deviant peer influence.

To the best of our knowledge, there are no existing studies that have examined whether perceived delinquent peer norms and overt peer pressure predict adolescent delinquency and whether this link is moderated by parent-adolescent relationship quality within the same study. Nevertheless, there are a handful of studies that have investigated whether parent-adolescent relationship quality can serve as a moderator between delinquent peer affiliation more generally, and subsequent adolescent delinquency. Conflicting results have been reported however, as some studies have found support for this hypothesis (Mason, Cauce, Gonzales & Hiraga, 1994; Poole & Regoli,1979; Vitaro, Brendgen, Tremblay, 2000), whereas others have not (Kemp, Scholte, Overbeek, & Engels, 2006; Henneberger, Tolan, Hipwell & Keenan, 2014; Warr 1993b). Perhaps the general *delinquent peer affiliation* measure that was used in these studies could at least partially explain the contradicting findings, as these studies investigated the effect of affiliation with delinquent peers on subsequent adolescent delinquency, but neglected whether perceived delinquent peer norms and/or overt peer pressure were present. Thus, the mechanism behind why delinquent peer affiliation might predict adolescent delinquency in the first place, is less clear (for a critical review on this issue see: Brown, Bakken, Ameringer, & Mahon, 2008). Furthermore, presumably, parent-adolescent relationship quality might influence the link between peer delinquency and adolescent delinquency, only in the presence of heightened delinquent peer norms and/or peer pressure. Accordingly, building on the above-mentioned previous studies, the current study investigates whether mother-adolescent relationship quality (i.e., mother-adolescent negative interactions) moderates the hypothesized longitudinal link from delinquent peer norms and peer pressure to adolescent delinquency. We also examine whether gender and adolescent phase moderate these effects.

Gender and Developmental Moderation Effects

Gender effects are important to consider, as males outnumber females in delinquency prevalence rates (e.g., Puzzanchera, Adams & Hockenberry, 2012) -and perhaps not surprisingly- most research on delinquency is conducted with male participants (cf Hennebergeret al. 2014). As for adolescent phase effects, there is evidence that peer influence might have stronger effects for early compared to middle adolescence, as resistance to peer influence increases throughout middle adolescence, but there is negligible growth from early to middle adolescence (Steinberg & Monahan, 2007). Similarly, other studies show that peer approval and conformity decrease during middle and late adolescence (Berndt, 1979). Thus in the current study we take both gender and adolescent phase moderation effects into account.

Adolescent versus Mother Reports on Negative Interactions

The link between parent-adolescent relationship quality and adolescent delinquency is stronger when adolescents (versus parents) reports are used (Hoeve et al., 2009). On the one hand adolescents (perhaps particularly delinquent adolescents), might perceive more and/or over-report negative interactions with parents in order to demonstrate their uniqueness and independence (Noller & Callan, 1988). On the other hand, parents might perceive fewer and/or under-report adolescent-mother negative interactions (Steinberg, 2001), possibly, because they do not want to be stigmatized as "bad" parents. Although both parents' and adolescents' reports on adolescent-parent relationship quality are important to consider, for the above-mentioned reasons, studies with parent reports on parent-adolescent relationship quality in relation to adolescent delinquency are lacking, as the vast majority of such studies use adolescents as the informant (Hoeve et al., 2009). Hence, all things considered, we test the robustness of our results, by investigating whether our primary findings based on adolescent reports on negative mother-adolescent relationship quality are replicated in a smaller sample when mother reports on this behavior are used.

Present study

Extrapolating from social learning theories and Coercion Theory, the current 2-year longitudinal study including adolescents between ages 12-17 (*N*=602) at time point one, was designed to test whether higher levels of (adolescent and mother reported) negative mother-adolescent relationship quality[26] exacerbates the hypothesized links between delinquent peer norms and/or peer pressure to engage

26 While positive aspects of parenting could also be important to consider, we chose to focus on the negative aspects of parent support, as such parenting indices were shown to be the strongest predictors of adolescent delinquency in a meta-analysis on the relationship between parenting and adolescent delinquency (Hoeve et al., 2009). This meta-analytic finding is also in line with the Coercion theory, which is one of the theoretical frameworks of the current paper.

in delinquency and subsequent adolescent delinquency one year later. Additionally, we explore gender and adolescent phase (early versus middle adolescence) moderation effects. Finally, using a smaller sample (*N* = 66 mothers), we investigate whether the findings can be replicated when mother reports on negative mother-adolescent relationship quality are used.

Method

Participants

Adolescents in the current study were from the first two waves of a larger longitudinal study in the Netherlands on adolescent risk-taking. Data-collections began in 2012, and were conducted one year apart. At baseline, most adolescents (93.2%) reported that they were born in the Netherlands. A total of 61.6% identified as Dutch while the remaining 30.9% identified with other ethnic minority groups in the Netherlands: 9.3% Turkish or Turkish-Dutch, 7.4% Surinamese or Surinamese-Dutch, 5.5% as Moroccan or Moroccan-Dutch, and 16.2% identified with various other ethnicities. In wave 1 and 2 the sample consisted of 602 (46.50% female) and 582 (45.40% female) adolescents respectively. The parents of the adolescents also filled out questionnaires, and for the current study data from the mothers (*N*=170) that took part and reported on mother-adolescent relationship quality in wave 1 are used. Thus approximately 28% of the adolescents in wave 1 had mothers who also participated in the study. At baseline (year one) adolescents were 13.50 years (*SD* = 1.23)[27] and were in their 1st or 3rd year of high school, and mothers were 43.54 (*SD* = 4.88) years.

We ran bias checks on the variables of interest and found that adolescents with mother reports and without mother reports did not differ in their levels on the predictor variables (i.e., the peer influence variables and negative mother-adolescent relationship quality). However, adolescents with mother reports versus adolescents without mother reports differed on the outcome variable, namely the latter had higher levels of delinquency in year two ((*F*(1, 573)=5.09, *p* = .02)). Similarly, adolescents without mother reports (compared to adolescents with mother reports) also had higher levels on delinquency in year one (i.e., control variable) ((*F*(1, 599)=3.96, *p* = .047)). A description of the questionnaires used to assess these variables of interest is provided below.

Furthermore, nearly half (47.7%) of the 602 adolescents were unaware of their mothers' highest level of completed education. This was partly because their mothers (12.1 %) were born abroad, in countries where the educational system was not comparable to the Dutch educational-system. Based on mothers for whom adolescents did report this information, 6.8% did not complete secondary education, 36.8% completed a lower-middle level vocational training and 3.9% completed university. When comparing the adolescents with mother reports (*N*=170) versus the adolescents without mother reports (*N*=432), 46.4 % versus 48.3% were unaware of their mother's highest level of education. Of the rest, 3 % versus 8.3 % did not complete secondary education, 40.9% versus 35.3% completed a lower-middle level vocational training and 6.1% versus 3.1% completed university.

27 For one adolescent we did not have information on age.

Procedure

The data-collections took place at schools during regular school hours, and were led by trained research assistants, who were all bachelor and master psychology students. Parents of adolescents from 8 high-schools in 6 different regions in the Netherlands received information letters about the research project as well as dissent letters that could be returned to the schools if they wished to not let their adolescents participate. Adolescents with parental permission who were absent from school in wave 1 or who did not partake in the research for another reason, could still take partake in subsequent waves. Mplus, the statistical structural Equation Modeling (SEM) program that is used for the current analyses adequately handles such unbalanced data due to missings, which is further explained in the Statistical Approach section. Participants could choose to receive a chocolate candy worth 2 euros as a participation prize, or have their name entered in a raffle for a chance to win a 50 euro gift voucher.

Measures

Delinquency was measured with 7 items, that tapped vandalism (1 item*; Have you ever damaged something on purpose, such as a bus shelter, a window, a car or a seat in the bus or train?)* and property crime (4 items that related to theft) subscales of the International Self-Reported Delinquency questionnaire (ISRD; Junger-Tas et al.,1994; Junger-Tas, Haen Marshall, & Ribeaud, 2003). An example of a theft item is "*Have you ever stolen something from a store or warehouse".* An additional vandalism item "*Have you ever tampered or ruined (vandalize) objects on the streets or inside a building with paint, graffiti, or markers*"? from another delinquency questionnaire was also used (i.e., Baerveldt, Rossem & van Vermande, 2003). From that same questionnaire, we also included the additional item "*Have you ever done something for which you were arrested by the police?*" (Baerveldt et al., 2003). The answer-categories for all of the items were: 0 = Never; 0=Yes, but that was longer than 12 months ago; 1=Yes, once in the past 12 months; 2=Yes, twice in the past 12 months; 3= Yes, three times or more during the past 12 months. For the current study we only focused on delinquency within the last 12 months, thus adolescents who indicated that they have committed a delinquent act in the past, but have not done so in the past 12 months, were coded as 0 and were included in the analyses. An overall mean score was computed of the items, with higher means indicating higher levels of delinquent acts. The Cronbach's alpha's for year 1 and 2 were .73 and .82, respectively, indicating adequate reliability.

Delinquent Peer Norms in year 1was measured with the question: *How would the majority of your friends react if you would steal something, or buy something that was stolen?* The answer categories ranged from "*Fully approve it"* (=1) *to "strongly disapprove it*" (= 5). We adapted this question from a previous study (i.e., Van Keulen et al. (submitted). Scores were reversed coded for the current analyses, with higher score denoting higher levels of delinquent peer norms.

Peer pressure in year 1was measured with two selected items on the Peer Pressure Inventory (PPI; Clasen & Brown, 1985) that concerned stealing and vandalism. Thus we used specifically items that overlapped with the delinquency questionnaire that we administered (see above). For the stealing question, participants had to indicate whether they experienced peer pressure to "*not shoplift or steal anything" vs. "to steal something (shoplift, raid a locker, etc.)*". For the vandalism question, participants had to indicate whether they experienced peer pressure to "*not trash things or vandalize property" vs. "to trash or vandalize things (write on walls, break windows, etc.)"*. After participants had selected which statement corresponded with their experience, they further had to indicate to what extent that statement is true for them (i.e., "A Little," "Somewhat" or "A Lot"). However, there was also a "No Pressure" answer option that participants could choose, if they did not experience peer pressure to engage (or not to engage) in the delinquent behaviors. Scores ranged from -3 to 3, with a score of 0 indicating "No peer pressure". An overall mean score was computed, higher mean scores indicated more peer pressure to engage in delinquent behaviors. The Cronbach's alpha was .63, indicating acceptable reliability.

Negative mother-adolescent relationship quality was measured with the Negative Interaction scale of the Network of Relationships Inventory (NRI; Furman & Buhrmester, 1985) which was completed by adolescents and their mothers. Negative interactions were assessed via conflict (three items; e.g., 'How much do you and your mother disagree and quarrel?) and antagonism (three items; e.g., 'How much do you and your mother hassle or nag one another?) subscales, on a 5-point Likert scale ranging from 1 (*little to none*) to 5 (*could not be more*). A mean score was computed, with higher means indicating higher levels of negative mother-adolescent relationship quality. The Cronbach's alpha was .90, for the adolescent reports, denoting excellent reliability, and .86 for the mother reports, denoting good reliability. Previous research has also shown good reliability for this scale (see e.g., Dekovic, Wissink & Meijer, 2004; Defoe et al., 2013)

Statistical Approach

In Mplus 7.11 we initially ran two models (i.e., models 1 & 2) including multiple path-analyses while controlling for delinquency at T1. In model 1 (non multi-group model) we simultaneously regressed delinquency (T2) on delinquency (T1), peer pressure (T1), delinquent peer norms (T1), mother-adolescent relationship quality as reported by adolescents (T1), and on the interaction term constituting an interaction between peer norms and mother-adolescent relationship quality (T1).

In model 2 the exact same analyses were ran as in model 1, instead this time we substituted the interaction term between mother-adolescent negative and peer norms with an interaction term between negative mother-adolescent relationship quality and peer pressure. Thus we simultaneously regressed delinquency (T2) on delinquency (T1), delinquent peer norms (T1), peer pressure (T1), mother-adolescent relationship quality as reported by adolescents (T1), and on the interaction term constituting an interaction between peer pressure and mother-adolescent relationship quality (T1). We mean centered all variables to facilitate the interpretation of the hypothesized interaction effects.

To test for gender and adolescent phase (12-13 year olds; early adolescents versus 14-17 year olds; middle adolescents)[28] moderation effects, we additionally specified 2 multi-group models (models 3 & 4) for the *adolescent* report models (i.e., model 1a and 2a respectively), and followed up with analyses (model 5) to test whether the hypothesized parent and peer influences interaction effects on adolescent delinquency could be replicated in a smaller sample when mother reports on negative mother-adolescent relationship quality is used. Thus model 3 is a multi-group model for the interaction between peer norms X negative mother-adolescent relationship quality, and model 4 is a multi-group model for the interaction between peer pressure X negative mother-adolescent relationship quality. Specifically, the above-mentioned multi-group models (models 3 & 4) had 4 subgroups each, and per model. The 4 subgroups per multi-group model were: (1) early adolescent girls (*N*=140), (2) middle adolescent girls (*N*=191), (3) early adolescent boys (*N*=185), and (4) middle adolescent boys (*N*=199).

Considering that our moderator (i.e., negative mother-adolescent relationship quality) is continuous, to probe any significant moderation effects, we used the advanced Johnson-Neyman (J-N) technique that allowed us to plot CI's around simple slopes for all relevant values of the moderator (Bauer & Curran, 2005; Preacher, Curran, & Bauer, 2006; Rogosa, 1980, 1981). According to this procedure, negative mother-adolescent relationship quality moderates the relationship between the peer factors and delinquency for values of the moderator where the confidence bands do not contain zero. Accordingly, these identified values demarcate the boundaries of significance of the effect of the peer factors (independent variables) on delinquency (dependent variable) along the continuum of the scale for negative mother-adolescent relationship quality (moderator). This designated area(s) is more commonly called the "region of significance". One of the primary advantages of this procedure is that unlike the limited "pick a point" procedure in more traditional ANOVA approaches, where researchers investigate a continuous variable, but only test its effect at a few (often arbitrary) values, instead following the J-N procedure it is not required to arbitrarily choose a value for the moderator at which the conditional effects of the independent variables are estimated (Hayes, 2012).

28 There were 26 adolescents who were 16 years old and 1 adolescent who was 17 years old, thus most "middle adolescents" were between ages 14-15.

A Robust Maximum Likelihood estimator (MLR) was used, which accounted for non-normality and ensured that incomplete data could be included in the analyses (Satorra & Bentler, 1994), and all missing items were dealt with using the Full Information Maximum Likelihood (FIML) algorithm (Muthen & Muthen 2012). All the models had a perfect fit to the data (i.e., just-identified).

Results

Descriptive statistics

In Table 1 the descriptive statistics can be found, and the correlations between the variables of interest are in Table 2. All predictor variables (including mother reported negative mother-adolescent relationship quality) were significantly correlated with delinquency in year 1. Furthermore, all predictor variables besides peer pressure and mother-reported negative mother-adolescent relationship quality, were significantly correlated with delinquency in year 2. All correlations were in the expected directions. Finally, the means for mother versus adolescent reports on negative mother-adolescent relationship quality appeared to be of similar magnitude (Table 1). The mean of the outcome variable, delinquency in year two indicates that on average adolescents engaged one time in a delinquent act in the last 12 months. Furthermore, in year two 9.6% of the adolescents indicated that in the last 12 months, they did something for which they were arrested at least one time by the police.

Main analyses

The models without the multi-group comparisons (model 1 & 2) all yielded nonsignificant findings, except for a significant effect of delinquency in year 1 on delinquency in year 2. That is, delinquent peer norms, peer pressure, both mother and adolescent reports on negative mother-adolescent relationship quality in year 1 or the interaction between these peer and parent factors did not predict delinquency in year 2. However delinquency in year 1 consistently predicted delinquency in year 2 across the models (β's respectively: .42; .39; p<.01).

Next, for the multi-group model wherein we tested whether there was an interaction effect between peer norms and negative mother-adolescent relationship on delinquency (model 3), we found main effects but no interaction effects. Specifically, delinquent peer norms in year one predicted early adolescent girls delinquency one year later (β = .38; p= .02). However delinquent peer norms did not predict early or middle adolescent boys' delinquency. Additionally, higher levels of negative mother-adolescent relationship quality in year one predicted delinquency in middle-adolescent girls (β = .28; p= .04). Finally, negative mother-adolescent relationship quality did not predict boys' delinquency.

Table 1. Means and standard deviations of variables of interest

	Mean (*SD*)	Range
Delinquency year 1	.09 (.26)	0-2.71
Delinquency year 2	.14 (.38)	0-3
Peer norms year 1	2.08 (1.02)	1-5
Peer pressure year 1	-.56 (1.56)	-3-+3
Negative interaction year 1 (Adolescent reports)	1.77 (.82)	1-5
Negative interaction year 1 (Mother reports)	1.51 (.48)	1-4

Table 2. Bivariate correlations between variables of interest

	1	2	3	4	5	6
Delinquency W1	-					
Delinquency W2	.446**	-				
Peer pressure W1	.147**	.059	-			
M-A Conflict W1 (Adolescent reports)	.216**	.134**	.086	-		
Peer norms W1	.339**	.241**	.153**	.117**	-	
M-A Conflict W1 (Mother reports)	.256**	.154	.009	.341**	.104	-

Note. **p<.01; *p<.05;
M-A conflict = Negative mother-adolescent relationship quality; W1= wave 1; W2= Wave 2

As for the multi-group model wherein we tested the interaction effect between peer pressure and negative mother-adolescent relationship on delinquency (model 4), no main effects were found[29]. However, an interaction effect was found. Specifically, for early adolescent boys, the link between peer pressure and delinquency was moderated by negative mother-adolescent relationship quality (β = .10; p<.01). That is, the more negative mother-adolescent relationship quality in year one, the more strongly delinquent peer pressure predicts higher levels of delinquency one year later in early adolescent boys (Figure 1). Via the use of 95% confidence intervals (i.e., dashed curved lines), the plot graphically displays the testing of the link from peer pressure to delinquency (y-axis) against a null effect (b=0) across the entire range of negative mother-adolescent relationship quality (x-axis). Thus the black solid plot line shows that the more negative mother-adolescent relationship quality (x-axis), the more

29 Thus in contrast to model 3, there was no main effect of negative mother-adolescent relationship quality on middle adolescent girls' delinquency (p=.055).

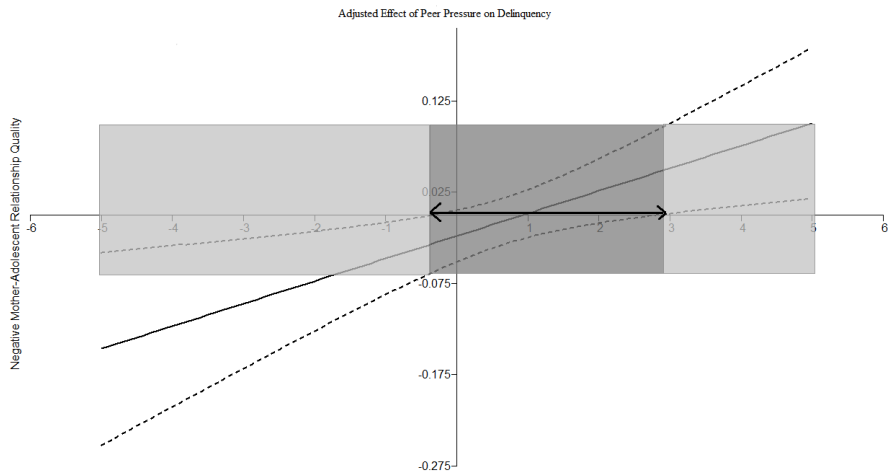

Figure 1. The solid plot line shows that the more negative mother-adolescent relationship quality (i.e., the moderator; x-axis), the more strongly peer pressure to engage in delinquency predicts adolescent delinquency (y-axis = the adjusted effect of peer pressure on delinquency). The dashed curved lines above and below the solid plot line represents 95% confidence bands (upper confidence interval and lower confidence interval, respectively) around the adjusted effect of peer pressure on adolescent delinquency. Accordingly, the dark gray shaded area represents the non-significant values of the moderator (the confidence bands includes the possibility of the adjusted effect of peer pressure on delinquency being equal to 0) , and the light gray shaded areas to the left and right represent the regions of significance.

strongly peer pressure to engage in delinquency predicts adolescent delinquency (y-axis = the adjusted effect of peer pressure on delinquency). More specifically, the simple slopes analysis showed that higher levels of peer pressure predicts higher levels of delinquency for adolescents who score roughly 2.90 standard deviations above (p=.04) and .45 below (p= .046) the average level of negative mother-adolescent relationship quality.

We also replicated this interaction effect in the subsample of early adolescent boys (*N= 66*) who had mother reports on negative mother-adolescent relationship quality in wave one (β = .33; p=.03)[30] (i.e., model 5). Furthermore, similar to the larger sample, in this subsample, adolescent delinquency in year 1 also predicted adolescent delinquency in year 2 (β = .70; p<.01), and no main effects existed for peer norms, peer pressure and mother reported negative mother-adolescent relationship quality. Thus using mother reports on negative mother-adolescent relationship quality, we replicate the findings we found when adolescents' reports are used for this measure.

Discussion

The current multi-informant longitudinal study investigated a possible interplay between parent and peer factors in adolescent delinquency. Extrapolating from social learning theories, we investigated whether negative mother-adolescent relationship quality exacerbates the hypothesized effects of delinquent peer norms and peer pressure on adolescent delinquency one year later and whether gender and adolescent phase (12-13 versus 14-16) moderate these linkages.

Our main analyses without the adolescent phase by gender multi-group models only yielded significant results for prior adolescent delinquency. That is, higher levels of delinquency in 12-16 year old boys and girls predicted higher levels of delinquency one year later, however there were no significant effects for delinquent peer norms, peer pressure, negative mother-adolescent relationship quality, or for the interaction between these peer and parent factors.

When looking specifically at early adolescents, results showed that delinquent peer norms consistently predicted early adolescent girls' delinquency, whereas this was not the case for early adolescent boys. Instead, for early adolescent boys, negative mother-son relationship quality was found to exacerbate the relation between delinquent peer pressure and adolescent delinquency. That is, the more negative mother-adolescent relationship quality, the more strongly peer pressure to engage in delinquency predicts adolescent delinquency one year later in early adolescent boys. These findings were also replicated in a smaller sample when mother reports were used for negative mother-adolescent relationship quality. As for middle adolescence, higher levels of negative mother-adolescent relationship quality predicted delinquency in middle-adolescent girls one year later. Our results support the general hypothesis of many social learning theories that delinquent

30 Although the subsample with adolescents whose mother participated in wave 1 (*N*=170) was large enough for the non multi-group models, the sample size of this subsample was not large enough for the multi-group analyses (which included "adolescent phase X gender" subgroups in addition to the interaction effect between negative mother-adolescent relationship quality and the delinquent peer influence factors). Particularly, the middle adolescent girls subgroup (*N*= 24) was too small to be included in such multi-group models, as a result we ran into estimation issues. Hence we limited these replication analyses using mother reports to the subsample of early adolescent boys (*N*=66), since we found a significant interaction effect in that specific sub-group.

peer affiliation predicts adolescent delinquency, but at the same time the current results suggest that this occurrence only predicts delinquency in *early* adolescence. Hence, the link between peer delinquency and subsequent adolescent delinquency might have been over-interpreted to some extent in prior studies that did not account for developmental phase moderation effects. Particularly early adolescents in the current study were more vulnerable to delinquent peers, perhaps because early adolescents have not yet fully developed the capacity to resiste peer influence (Steinberg & Monahan, 2007; see also Berndt, 1979). However, although delinquent peer norms was independently predictive of early adolescent girls' delinquency, for early adolescent boys's delinquency, the picture was more complex as the link from peer pressure to early adolescent boys' delinquency was interconnected with negative mother-adolescent relationship quality. In other words, when considering the effects of peer delinquency on early adolescents' boys delinquency, parent-adolescent relationship quality is a decisive factor, as the predictive power of peer pressure on adolescent delinquency was dependent on levels of negative mother-adolescent relationship quality.

Coercion theory hypothesizes that boys who have negative interactions with parents turn to delinquent peers, but our results further suggest that if this is the case, then not only does negative mother-adolescent relationship quality trigger delinquent peer affiliation, but it also amplifies the adverse consequences of delinquent peer affiliation. It is important to consider that results of studies on such interaction effects of parenting and delinquent peers on adolescent delinquency have been mixed, however. Nevertheless, one study that somewhat mirrors our results showed that positive mother-adolescent relationship quality when adolescents were in the 7th or 8th grade (ages 12-13) attenuated adolescent delinquency one year later, but contrary to the current results, a main effect of peer delinquency was also found (Mason et al., 1994; see also Vitaro et al., 2000). Unfortunately, potential additional moderation effects by gender and adolescent phase were not taken into account in Mason et al. (1994), limiting the comparisons that can be made with the current study. Finally, also noteworthy is that in addition to the above-described interaction model, Mason et al. (1994) tested a mediational model wherein mother-adolescent relationship quality was hypothesized to predict peer delinquency which in return predicted adolescent delinquency, and a cumulative model was also tested that included a cumulative index of these peer and parent predictors. Interestingly, only the interaction model with parent and peer factors predicted adolescent delinquency (Mason et al., 1994), which provides further support for the interaction effect that was found in the current study.

As for the absence of an interaction effect between parent and peer factors for early adolescent girls, perhaps during early adolescence another aspect of parenting is relevant for girls. Thus future studies could consider other parenting indices to determine when and how parents can moderate the effects that delinquent peer norms have on early adolescent girls' delinquency. Nevertheless, coercion theory does not delineate differences in gender in this regard, and meta-analytic findings show no gender differences in the link between parenting and delinquency in girls (Hoeve et al., 2009), however this meta-analysis did not account for peer influences.

Next, a puzzling question that arises from these results is: why do different forms of peer influence predict delinquency across gender in early adolescence? Specifically, what is the cause behind particularly perceived delinquent peer *norms* (indirect peer pressure) being relevant for early-adolescent girls' delinquency, whereas overt/direct peer *pressure* (but only when mother-adolescent relationship quality is taking into account) is relevant for early-adolescent boys' delinquency? Overall, boys have been shown to be more vulnerable to direct forms of peer pressure, thus our results are consistent with the literature (see e.g., Steinberg & Monahan, 2007; Steinberg & Silverberg, 1986).[31] Additionally, we know of at least one study that considered adolescent phase effects and reported that peer pressure was only predictive of early adolescent boys' delinquency, whereas this was neither the case for middle/late adolescent boys, and nor for girls in any adolescent phase (Worthen 2012)[32]. Hence, revisiting the question posed early, our findings in conjunction with the above-described findings from prior studies suggest that early adolescent girls (but not boys) might be more sensitive to *indirect* forms of peer pressure (evidenced by perceived social norms; Simmons-Morton & Farhat, 2010) that trigger delinquency, but that girls (compared to boys) appear to be capable of resisting direct forms of peer pressure, perhaps because different skills are required for these two forms of peer influence processes. As scholars have already noted, peer influence processes are complex and wide-ranging, accordingly, a comprehensive framework for peer influence *pro*cesses is crucially needed in order to reconcile findings across the existing various methodologically diverse studies with different designs and sample characteristics (for a critical review see: Brown & Larson, 2009; Simmons-Morton & Farhat, 2010). Nevertheless, the current study has at least pinpointed that during *early* adolescence, direct/overt forms of peer pressure (which is moderated by mother-adolescent relationship quality) might be more relevant for boys whereas indirect/perceived forms of peer pressure (conformity to peer norms) are more relevant for girls. Why such differences in peer influence processes exist across gender warrants future research.

Next, for middle adolescence, we found no evidence of delinquent peer influence in predicting delinquency for both girls and boys. As explained above, this finding is to be expected from previous studies that have assessed direct/overt forms of peer pressure, and showed that middle adolescents are more resistant to such peer influences (e.g., Steinberg & Monahan, 2007). However, as far as we know, we are

31 However, perhaps unexpectedly, other studies show that females report more peer pressure than males (Brown, 1982).

32 Worthen (2012) did not consider an interaction between parent and peer variables, however, thus we cannot not say for sure that the effect of peer pressure for early adolescent boys would have also been moderated by parent-adolescent relationship quality, as was the case in the current study.

the first to replicate these findings for more subtle forms of peer pressure such as perceived delinquent peer norms, and thus these findings await to be demonstrated in additional research. Although no links from our delinquent peer influence indices to delinquency were found in middle adolescence across gender, middle adolescent girls' relationship quality with mothers predicted delinquency instead. Thus our results suggest that when gender is taken into account (in addition to developmental differences and peer influences), independent links from negative mother-adolescent relationship quality to delinquency emerge for middle adolescent girls but not for boys. Perhaps poor relationship quality between particularly *fathers* and middle adolescent boys is what becomes a vulnerability factor for higher levels of middle adolescent boys' delinquency. Also, for boys, possibly parenting indices other than parent-adolescent relationship quality might be important, for example parent control might be more relevant. However, a meta-analysis on parenting and delinquency did not find such gender differences (Hoeve et al., 2009), then again, that meta-analysis did not take moderation by adolescent phase into account.

To summarize, to the best of our knowledge, the current study is the first to investigate, and to find, that a prominent aspect of Paterson's coercion theory about the adverse effect of parent-adolescent conflict on adolescent delinquency is most meaningful for adolescents who are pressured by their friends to engage in delinquency. However, we found that this interplay between mothers and peer factors is only present in early adolescent boys. Our consistent finding that indices of peer delinquency are only relevant for younger adolescents' delinquency, supports prior empirical studies (e.g., Steinberg & Monahan, 2007). However, it is conspicuous that whereas more direct forms of peer pressure is relevant for boys, more subtle/indirect perceived forms of peer pressure such as perceived social norms is more predictive of girl's delinquency. Our differential findings for boys and girls complicate the fundamental premises of social learning theories that suggest that mere delinquent peer affiliation is a predictor of adolescent delinquency, as our results show that different peer influence processes appear to be operating for boys and girls. Such moderation effects were perhaps masked in prior studies because the assumed processes that link peer delinquency to higher levels of adolescent delinquency were not assessed. To conclude, the present results propose that social learning theories on peer influences in delinquency would likely benefit from being more refined, by taking developmental and gender differences into account, but also by being more specific about the delinquent peer influence *processes* that predict adolescent delinquency, and acknowledging that such differential peer factors might also be interconnected with factors outside of the peer context (e.g., the family context).

Strengths, Limitations and Future Directions

The current longitudinal multi-informant study with an ethnically and socio-economically diverse sample provided some new insights into the possible mechanisms behind peer similarity in delinquency that predict subsequent adolescent delinquency. Of note is that capitalizing on a longitudinal design, although relatively short, we highlighted a potential prevention component for adolescent delinquency. That is, our time-lagged interaction assessed one year earlier suggests that mother-adolescent relationship quality at an earlier point in time can be a decisive factor in determining whether delinquent peer pressure will lead to an increase in adolescent delinquency in the future. Furthermore, replicating the interaction effect when mother reports are used speaks to the robustness of our results and it eliminates the possibility that the interaction effect was purely a source of shared method variance which could have produced bias results and/or could have reflected faulty projection of adolescents' behaviors on the relationship they have with their mothers (which might particularly be an issue for delinquent adolescents). However despite these overarching strengths, there are also some limitations that need to be addressed. First, although we examined effects from multiple layers of adolescents social network (mothers and friends), we did not consider father and siblings factors, but these significant others are likely also interconnected with adolescents' peer context. We expect that fathers might have similar effects as mothers whereas siblings might have similar effects as friends (see e.g., Defoe et al., 2013). Secondly, in the current study we emphasized the potential negative effects of peers on adolescents' behavior, but peers can also have positive influences (see e.g., Van Hoorn, Van Dijk, Meuwese, Rieffe & Crone, 2014). Thirdly, although studies show that both selection and influence processes predict adolescent behavior (Brown & Larson, 2009; Simmons-Morton & Farhat, 2010) due to the measurements we used, we do not know for sure to what extent selection effects might have influenced our results. Finally, the peer predictors we investigated might give us more information on delinquent peer influence processes compared to the more traditional method of assessing whether or not friends/peers' delinquency predict adolescents' own delinquency. However, an experimental design is needed in order to draw firmer conclusions about specific mechanisms.

Conclusion

The current study has pinpointed which delinquent peer factors likely contribute to delinquency in adolescent boys and girls, and importantly these factors are not one-size-fits all, as they appear to be different across gender and they appear to be only predictive of delinquency for *early* adolescents. For early adolescent girls, delinquent peer influences constituted a vulnerability factor that manifested via higher levels of delinquent peer norms, and lower levels of negative mother-adolescent relationship quality did not attenuate this link. Thus these results could suggest that interventions for delinquency in early adolescent girls might be fruitful if they target delinquent peer norms directly. Interestingly, in middle adolescence, however, negative mother-adolescent relationship quality predicts girls' delinquency, whereas peer influences become no longer relevant, which could

imply that intervention efforts for delinquent girls during middle adolescence would be perhaps more fruitful if they shift to improving parent-adolescent relationship quality during that phase. As for boys, delinquent peers and negative mother-adolescent relationship quality do not operate independently, as it is the interplay between peer pressure to engage in delinquency and negative mother-adolescent relationship quality that predicted higher levels of delinquency in early adolescent boys. In other words, delinquent peers increase adolescent delinquency, but only under certain conditions, such as when there are higher levels of negative mother-adolescent relationship quality in combination with higher levels of peer pressure to engage in delinquency , but this is only the case for early adolescent boys. Thus the current findings have highlighted potentially amendable characteristics of parent-adolescent relationship quality that make early adolescent boys vulnerable to delinquent peer pressure, and thus this could be valuable findings for interventions. Our longitudinal nature of our results suggest that ensuring fewer negative interactions between mother and adolescents at an earlier time point (in advance) could potentially curtail the negative effects delinquent peer pressure has on adolescent boys' delinquency in the future. This could perhaps also serve as an effective *prevention* effort.

Chapter 8

The Unique Roles of Intrapersonal and Social Factors in Adolescent Smoking Development

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I.N. Defoe developed the study concept and design and J.S. Dubas, L. Somerville, P. Lugtig and M.A.G van Aken gave advice and feedback. I.N. Defoe oversaw the data-collection. I.N. Defoe performed the data-analysis and expert advice was provided by P. Lugtig. I.N. Defoe and P. Lugtig interpreted the results. I.N. Defoe drafted the manuscript, and J.S. Dubas, L. Somerville, P. Lugtig and M.A.G van Aken provided critical revisions.

Abstract

Adolescence is a vulnerable period for the initiation and peak of many harmful risk-taking behaviors such as smoking, which is among the most addictive and deadliest behaviors. Generic meta-theories like the Theory of Triadic Influence (TTI) suggest that interrelated risk factors across multiple domains (i.e., intrapersonal and social/environmental) jointly contribute to adolescent smoking behavior. Yet, studies are lacking that investigate risk factors across different domains in the same study, which obscures whether each makes a unique contribution to the increase in smoking throughout adolescence or whether there is overlap across the domains. Hence, to fill this gap using a latent growth approach, the current accelerated longitudinal study investigated the collective contribution of multiple intrapersonal and social risk factors in the development of smoking behavior from ages 12 to 17 in 574 ethnically-diverse Dutch adolescents. Results from our latent growth model showed that whereas the contribution of motivational-intrapersonal factors like sensation-seeking was no longer significant in our stringent multivariate model, higher levels of impulsivity (cognitive-intrapersonal) and overt peer pressure (social) at age 12 proved to be robust and unique predictors of linear increases in adolescent smoking up until age 17. Consistent with the TTI, adolescent smoking progression does not occur in isolation and the determinants are wide-ranging as they stem from both intrapersonal and social domains. Thus focusing on such confluence of intrapersonal and social risk factors via prevention programs from as young as age 12 might halt the deadly increase in smoking behavior throughout adolescence.
Keywords: smoking, adolescence, cognitive, motivational, social

"Most of them just like smoking, and youth easily get addicted to smoking, even the youth who actually want to quit smoking. There's also youth that just want to act as if they're tough/cool and imitate others but later they begin to like it and then continue to do it their entire lives."
adolescent participant [33]

Adolescence is marked by significant changes in the intrapersonal and social domains. Concurrently, susceptibility to engage in harmful and addictive risk-taking behaviors increases as well (Steinberg, 2010). A pertinent example of such a risk-taking behavior is *smoking* (e.g., Baker, Brandon, & Chassin, 2004; Park, 2011), as nicotine is often regarded as one of the most addictive substances and it is related to a host of health complications (Centers for Disease Control and Prevention, 2010). Considering that adolescents are particularly susceptible to addiction (Chambers, Taylor & Potenza, 2003; Keshavan & Giedd, 2008), it is imperative that risk factors associated with the increase in smoking in adolescence are identified. Meta-theories like the Theory of Triadic Influence (TTI; Flay & Petraitis, 1994; Petraitis, Flay & Miller, 1995) posit that adolescent smoking does not occur in isolation and the determinants are wide-ranging as they stem from multiple interrelated intrapersonal and non-intrapersonal domains. However, risk factors across different domains are hardly investigated simultaneously within a single study. Hence, via a latent growth design, the current accelerated longitudinal study aims to investigate the unique roles of multiple intrapersonal and social risk factors in predicting the hypothesized increase in smoking among 574 adolescents from 12 to 17 years of age.

Theory of Triadic Influence

The TTI is a comprehensive theory that integrates risk-factors from multiple domains (intrapersonal, social, and environmental) that are derived from numerous sociological and psychological theories about onset and change of adolescent substance use, such as smoking and alcohol use (Flay, 1999; Flay & Petraitis, 1994; Petraitis et al., 1995). More recently the TTI has been used as a framework in research examining other addictive behaviors like gambling, or other risk-taking behaviors like risk-taking in traffic (for an overview see e.g., Snyder & Flay, 2012)[34].

33 The original quote as it appeared in the Dutch language: "De meeste vinden roken gewoon lekker en jongeren raken heel erg snel verslaafd aan roken ook de jongeren die eigenlijk willen stoppen en je hebt ook de jongeren die gewoon stoer willen lijken en die dan andere mensen nadoen maar die het daarna wel lekker vinden en die het dan hun hele leven blijven doen".

34 We were initially interested in focusing on smoking, gambling and traffic risk-taking behavior and collected data on these risk behaviors as well. However, we limit the current paper to smoking, since this behavior showed sufficient growth between ages 12-17, making it meaningful for us to

Intrapersonal factors can include cognitive functions, impulsivity, affective states thrill/sensation seeking that influence self-efficacy and internal motivation to use substances, and via decision making these intrapersonal factors ultimately predict the use of substances (Petraitis et al., 1995). Social factors can include parent and peer influences, (e.g., pressure to engage in substance use) which lead adolescents to comply with others and ultimately cause them to decide to engage in substance use (Petraitis et al., 1995). Finally, environmental factors include aspects of adolescents' neighborhood, cultures, general values that influence adolescents' belief and evaluations about the costs and benefits of substance use, which ultimately lead adolescents to decide to use substances (Petraitis et al., 1995). Thus TTI is a broad and complex theory that aims to emphasize the complete puzzle of causation of youth substance use (Flay, Snyder, & Petraitis, 2009).

Similar to ecological models, TTI proposes that intrapersonal factors are embedded within social factors which, are in turn embedded within broader cultural-environmental factors that contribute to attitudes about risk-behaviors (Snyder & Flay, 2012). However, unlike most models, TTI suggests that these three domains have different distances/levels from actual smoking behavior, labeled as ultimate (i.e., underlying), distal (i.e., predisposing), or proximal (i.e., immediate) levels of causation (Flay et al., 2009; Snyder & Flay 2012). In the current paper we investigate intrapersonal (cognitive and motivational factors) and social factors (susceptibility to peer influence and perceived peer pressure) that overlap with the TTI.

Intrapersonal Domain

According to the TTI, intrapersonal influences are hypothesized to affect (a) skills adolescents need to deal with situations when they offered cigarettes or other means of smoking, (2) adolescents' determination/intention whether or not to smoke (3) adolescents' smoking self efficacy/behavioral control (Flay, Petraitis, & Hu, 1995). For the current study we investigate four of the many factors related to the intrapersonal stream, namely, *impulsivity, inhibitory control, sensation seeking, and reward seeking*. Considering that this domain is very broad and consists of wide-ranging personality traits, we further subdivide intrapersonal factors into primarily cognitive-related behaviors (cognitive control: impulsivity and inhibitory control), and primarily motivational behaviors (reward sensitivity: reward seeking and sensation seeking).

Cognitive factors. Cognitive control is an umbrella term for wide-ranging executive functions (e.g., inhibitory control, impulsivity, working memory). Acquiring cognitive control facilitates the achievement of both short-term and long-term goals via adaptively organizing and coordinating thoughts and actions, especially in response to changing environmental contexts (Crone & Dahl, 2012; Luna, Garver, Urban, Lazar, & Sweeney, 2004). In the current paper we investigate *inhibitory control* and *impulsivity* aspects of cognitive control. Studies aiming to tap inhibitory control often employ the classic behavioral Go/NoGo task, which requires participants to inhibit motoric responses (for a review see: Casey & Caudle, 2013; Geier & Luna, 2009). On the contrary, "(reflection-)impulsivity", which is described as behavior resulting from a lack of forethought, is typically assessed via self-report questionnaires (Dalley, Everitt, & Robbins, 2011). The subjective (self-report) and objective (behavioral) measurements of cognitive control often fail to be related to each other, however, suggesting that there are multiple latent aspects to cognitive control (Buckholtz, 2015; Dalley et al., 2011). Accordingly, in the current study we employ a questionnaire that taps lack of forethought and a behavioral measure (i.e., Go/No Go task) to measure cognitive control. The TTI considers such cognitive-related factors as "ultimate level" influences within the intrapersonal domain (see Petraitis et al., 1995).

In relation to adolescent smoking development, as far as we know, there are no empirical studies on whether lower levels of inhibitory control (assessed via objective/behavioral measurements) predict subsequent smoking development from early to late adolescence (but see e.g., Reynolds, Karraker, Horn, & Richards (2003) for delay discounting in relation to smoking in adolescence). Nevertheless, cross-sectional studies containing late adolescents and emerging adults (17-25 years; mean age 18.60) have shown that non-smokers perform worse than smokers on the Go/NoGo task (although smokers had higher levels of self-reported impulsivity compared to non-smokers) (Dinn, Aycicegi, & Harris, 2004; see also Galvan, Poldrack, Baker, McGlennen, & London, 2011). In seeming opposition, a recent meta-analysis found that lessened inhibitory control as measured by the Go/ NoGo does predict smoking abuse/addiction in adult samples (Smith et al., 2014). Thus, although longitudinal studies spanning early to late adolescence are non-existent, the summarized mixed results could suggest that there are developmental differences underlying the relationship between inhibitory control and smoking since the predictive power of the Go/NoGo for smoking appears to differ for late adolescents and emerging adults versus more mature adult samples.

Next, although cross-sectional studies consistently find that self-reported impulsivity is related to smoking (for a review see Dawe, Gullo, & Loxton, 2004), only a handful of longitudinal studies have investigated this link with adolescent samples (e.g., Audrain-McGovern, et al., 2006; Elkins, King, McGue, & Iacono, 2006; Malmberg, et al., 2013; Quinn & Harden, 2013). An example of such a longitudinal study used a latent growth design and showed that impulsivity (labeled as "self-control" in that study) only had an indirect effect (via baseline peer smoking) on the baseline of smoking when adolescents were in the 9th grade (Audrain-McGovern, et al., 2006). However, there was no indirect or direct effect of impulsivity on the progression of adolescent smoking from the 9th grade to the 12th grade (Audrain-McGovern et al., 2006; see also Quinn & Harden, 2013). Yet, another longitudinal study showed that impulsivity traits measured at age 17 predicted new onsets of nicotine dependence at age 20 (Elkins, et al., 2006). In sum, whereas impulsivity

look into predictors of this progression of adolescent smoking.

has consistently been shown to concurrently predict adolescent smoking, evidence of this association is mixed in the limited existing longitudinal studies.

Motivational factors. Adolescents are hypothesized to be hyper-sensitive to rewarding and highly arousing stimuli, and some posit that this is the result of pubertal development (Forbes & Dahl 2011; Steinberg, 2004). This so-called "*reward sensitivity",* is conceptualized as a heightened behavioral *motivational* tendency to seek out rewards (in other words: *sensation-seeking* and accordingly *reward-seeking*), and heightened arousal in response to rewards (Galvan et al., 2013). Obviously, one of the reasons that adolescents engage in risk-taking behaviors like smoking, is because it can be both (directly) physically and socially rewarding. Reward-seeking adolescents smoke because they anticipate a reward (Baker et al., 2004). Sensation-seeking, however, has been defined more broadly as the pursuit of diverse novel, complex, and intense sensations or experiences and the willingness to take risks to acquire them (Zuckerman, 1979). To tap reward seeking and sensation-seeking we use two subscales of the Behavioral Approach System scale (BAS) of the classic Behavioral Inhibition & Activation questionnaire (BIS/BAS; Carver & White, 1994) that describes these behaviors as "affective responses/reactions", which are part of a "general motivational system that underlie behavior and affect" (Carver & White, 1994). Within the TTI such motivation constructs are considered as intrapersonal "ultimate-level" influences of smoking (Petraitis et al., 1995).

Numerous cross-sectional studies have shown support for a link between sensation-seeking and adolescent smoking (Leeman et al., 2014; Martin et al., 2002; Pokhrel, Sussman, Sun, Knaizer, & Massautov, 2010). Similarly, one longitudinal study showed that sensation seeking (termed "risk-taking" in that study) at grade 5 was predictive of levels of smoking 7 years later (Burt, Dinh, Peterson, & Sarason, 2000). However, a longitudinal latent growth study found that although smoking and sensation-seeking were concurrently associated at age 15/16, changes in sensation-seeking were not associated with changes in smoking from ages 15 to 26 years (Quinn & Harden, 2013). Thus whereas there is consistent support for concurrent associations between sensation-seeking and adolescent smoking, evidence for longitudinal associations are inconsistent.

With regard to the more specific *reward seeking*, a cross-sectional study of 14–25 year olds (mean age 16.11) reported that amongst multiple personality characteristics, the BAS was the best predictor of a composite substance abuse factor that included smoking (Knyazev, Slobodskaya, Harchenko, & Wilson, 2004). Likewise, a recent cross-sectional study with college students (18-25 years, mean age 19.41) showed that reward seeking was related to a composite score of substance use that included smoking (Richardson, Freedlander, Katz, Dai, & Chen, 2014). In sum, although longitudinal studies are lacking, there is some cross-sectional evidence that reward seeking predicts smoking in adolescence.

Social Domain

According to the TTI, the social domain includes adolescents' immediate social surroundings, such as the peer context that contribute to the social pressure adolescents experience to engage or not to engage in smoking (Flay et al., 1995). In the current paper we focus on peer influence. The TTI proposes that the peer context contributes to adolescent smoking behavior because peers affect (a) adolescents' subjective perceptions about the normativeness of smoking, (b) with whom adolescents are motivated to conform their behavior to (e.g., deviant peers), and (c) the social pressures adolescents experience to smoke (Flay et al., 1995). Accordingly, in the current study, we investigate two forms of *peer socialization* (see Simons-Morton & Farhat, 2010) that are consistent with the TTI, namely, whether directly perceived peer pressure and susceptibility to peer influence predict adolescent smoking development. Unlike perceived peer pressure, susceptibility to peer influence is when adolescents adopt peer norms whether or not there is direct/perceived pressure from peers to do so. Within the TTI framework, directly perceived peer pressure (labeled as "*pressures to use substances"*/ "*beliefs that important others encourage smoking"*) is considered as a "proximal" social influence, whereas susceptibility to peer influence (labeled as "*strong desire to please peers*") is considered as a "distal" social influence (Petraitis et al., 1995).

A handful of studies have shown that perceived peer pressure is associated with smoking in both early (e.g., Crockett, Raffaelli & Shen, 2006) and late adolescents (e.g., Santor, Messervey, & Kusumakar, 2000). Although more longitudinal studies on this link are needed, at least one latent growth study demonstrated that peer pressure (labeled as "peer encouragement"), predicted the initial stage and development of smoking from ages 11 to 18 (Duncan, Tildesley, Duncan & Hops, 1995). As for susceptibility to peer influence, one study showed that a similar "friend compliance" measure longitudinally predicted adolescent smoking (Otten, Brickjer, Liu, Comstock, & Peterson, 2011). Thus there is some evidence that both perceived peer pressure and susceptibility to peer influence are prospective predictors of adolescent smoking development.

Empirical Support for the TTI Framework

One of the primary reasons the TTI was developed, was to acknowledge that risk-factors tend to be interrelated, thus multiple risk factors should be simultaneously investigated within a single study (Flay et al., 1995). One of the few longitudinal studies that investigated multiple intrapersonal (e.g., sensation seeking) and social (e.g., peer compliance) factors reported that when tested univariately, although social factors were not significant, sensation seeking measured in grade 5 was a significant predictor of smoking in grade 12. However, the effect for sensation-seeking vanished for boys when it was tested in a multivariate model together with "rebelliousness" (Burt et al., 2000), which was a construct that resembled self-regulatory capacities. Another TTI-based study showed that whereas friend

compliance and rebelliousness in adolescence predicted smoking progression in young adulthood, thrill seeking (a component of sensation seeking), was not a significant predictor (Otten, et al., 2011). Finally, a study using the same sample as Otten, et al. (2011) found that scoring high on "friend compliance" contributed a significant probability to the overall probability that an adolescent would try smoking (transition 1), and transition from the first cigarette to monthly smoking (transition 2), and from monthly to daily smoking (transition 3) (Bricker et al., 2009). However, thrill seeking was only significant for transition 1 and 2, but not for transition 3 (Bricker et al., 2009). These three studies underscore why risk factors should not be investigated in isolation. This might produce inflated and biased conclusions about their influences. A noteworthy difference between the three summarized studies and the current study is that we additionally investigate risk factors in the cognitive-intrapersonal domain (impulsivity and inhibitory control).

Present Study

In the current study we investigate the developmental pattern of adolescent smoking, and whether TTI-consistent risk-factors in the intrapersonal (cognitive and motivational) and social (peer influence) domains at age 12 concurrently and prospectively predict the variation in the hypothesized growth of adolescent smoking from ages 12 to 17. We hypothesize that linear growth will be detected from ages 12 to 17. The current study adds to the literature by capitalizing on a latent growth design that facilitates the investigation of whether adolescents differ in their initial level and development of smoking (i.e., variance in baseline and progression of smoking), which is neglected in more traditional statistical models. Specifically, we include all predictors in a combined model to ascertain the unique role of each predictor in contributing to the development of smoking in adolescents. In this combined model we additionally account for putative effects of gender and educational track. Finally, an accelerated longitudinal design is used, which provides the advantage of modeling a longer developmental span (i.e., age 12 through 17 years) with the current two cohort sample of 574 adolescents who were either 12-13 years old or 14-15 years old at the beginning of the present 3-year study.

Method

Participants

The sample used in the current paper was part of a larger three year longitudinal study, in the Netherlands called "*The Adolescent Risk-Taking (ART) Project"*, which is a research project on adolescent risk-taking in multiple domains that began in 2012. We recruited the participants via schools throughout the Netherlands. In wave one, the adolescents (*N* = 602; 46.40% female) were either in the 1st or 3rd year of "preparatory middle-level applied education" (*VMBO* in Dutch) or "higher general continued education" (*HAVO* in Dutch). In the first wave, most adolescents (93.2%) reported that they were born in the Netherlands with 61.6% identifying as Dutch, 9.3% as Turkish or Turkish-Dutch, 7.4% as Surinamese or Surinamese-Dutch and 5.5% as Moroccan or Moroccan-Dutch, and the rest (16.2%) identified with various other ethnicities. In wave one adolescents in the youngest cohort were 12-14 years old and adolescents in the older cohort were 14-17 years old. The number of 16 (*N* = 26) and 17 year olds (*N* = 1) in the second cohort was very small, so we limited our analyses to the youngest 4 age cohorts. The 12-, 13-, 14-, 15- year-old cohorts were represented in wave one, and the sample sizes were *n* =178, 113, 170 and 113 respectively, with a total subsample of *N* = 574 for the current study. Via an accelerated longitudinal design procedure, these adjacent cohorts could be linked to form one continuous developmental trajectory spanning ages 12 through 15 during wave one. Of this subsample of 574 at wave one, 441 and 349 adolescents took part in wave two and three respectively.

Procedure

Participants were recruited from eight high-schools in six different regions in the Netherlands[35], the schools were first emailed and then called. We made it a priority to also recruit ethnically diverse schools. Parents received information letters about the research project as well as dissent letters that could be returned to the schools if parents did not want their children to participate in the study. At the beginning of the study, approximately 810 potential students could participate. Of these participants, 9.75 % did not have parental permission to participate, the other adolescents who did not participate refused to participate on their own, or were absent during the data-collections due to other conflicts (e.g., illness and thus absent). Adolescents with parental permission who were absent from school in wave one, could still partake in future waves, and new adolescents could also join the research after wave one.

Data-collection took place at schools, and was led by trained research assistants. Participants could choose to receive a chocolate candy worth 2 euros as a participation prize, or have their name entered in a raffle for a chance to win a 50 euro gift voucher. Data were collected annually for three years, with sample sizes across the three waves as 602, 582, and 442, respectively.

Measures

Latent factor models. We constructed latent factors for the variables of interest that consisted of two or more items, since latent factors are a recommended method to reduce measurement error (Kline, 2010). We only used items with sufficient standardized loadings of >. 30. Thus, it would be redundant to provide information on Cronbach alpha's, and instead, we provide information on the latent factor analysis.

35 In wave two and three we had seven schools participating as one school did not participate after wave one due to organizational changes at the school.

Smoking. *Smoking* behavior was assessed with the question "Do you smoke tobacco? (cigarette, cigar, shag, (water-)pipe)?", which was measured on a six point scale, namely: (1) No I have never smoked, (2) No, I do not currently smoke, but I used to smoke in the past, (3) Yes, less than once a month, (4)Yes, at least once a month, but not on a weekly basis, (5) Yes, at least once a week, but not every day, (6) Yes, every day. Adolescents who had never smoked or who have smoked in the past but do not currently smoke were coded as 0 and were included in the analyses (cf. Feummeler et al., 2013). Thus we converted the six point scale for smoking into a five point scale.

Cognitive factors. *Impulsivity* was assessed with a shortened validated version (Vitaro, Arseneault, & Tremblay, 1997; 1999) of the original Eysenck Impulsiveness Scale (Eysenck & Eysenck, 1978; Eysenck, Easting, & Pearson, 1984) and contained five items that tapped lack of forethought. This questionnaire was translated to Dutch, an example item was: *Do you generally do and say things without stopping to think?* The response format used was: 0 = Completely disagree; 1 = Disagree; 2 = Not disagree, not agree; 3 = Agree; 4 = Completely agree. All items on the impulsivity scale had at least a .30 loading on the factor, indicating adequate factor loadings.

Inhibitory control was assessed with the cued Go/No Go task (Fillmore, 2003, Fillmore, Rush, & Hays, 2006) which was programmed in OpenSesame (Mathôt, Schreij, & Theeuwes, 2012). Participants were instructed to respond to a go target (green rectangle) and withhold a response for a no-go target (blue rectangle). This task manipulates response prepotency as each target is preceded by a go cue (valid cues) or a no-go cue (invalid cues), and the orientation of these cues provided preliminary information about the probability that an actual go or no go target will occur. Vertically and horizontally presented cues signaled go and no-go cues, respectively. Vertically presented cues preceded the go target in 80% of the trials and preceded the no-go target in the remaining 20% of the trials. Horizontally presented cues preceded the no-go target in 80% of the trials and preceded the go target in the remaining 20% of the trials. Thus the cue feature in this task measures the ability to inhibit instigated "prepotent" responses; invalid cues impair response inhibition whereas valid cues facilitate response inhibition (Fillmore & Weafer, 2013). Particularly, for the invalid go cue trial, participants will typically fail to inhibit responses if a go/no go target appears afterwards (Fillmore et al., 2006).

Cues were white (i.e., non-colored) rectangles framed in 0.8 mm black outlines, and were presented in the center of a white background on the computer's monitor. Cues were presented vertically (height = 7.5 cm, width = 2.5 cm) or horizontally (height = 2.5 cm, width = 7.5 cm). The go and no-go targets were colored green and blue rectangles respectively (Fillmore et al., 2006).

Trials began with a presentation of a fixation point (+) for 800 milliseconds, after which a blank white screen appeared for 500 milliseconds. Hereafter a cue was presented for one of five stimulus onset asynchronies (SOAs=100, 200, 300, 400 and 500 milliseconds). Finally, a go or no-go target was presented and remained visible until participants either exhibited a response or did not respond after 1000 milliseconds. At the end of each trial there was an intertrial interval of 700 milliseconds (Fillmore et al., 2006).

The Go/ No Go task took approximately 10 minutes to complete, and included 250 trials representing all four possible cue-target combinations an equal number of times. Furthermore, for each of the five SOAs, a cue-target combination was presented and each cue-target combination was separated by an equal number of SOAs. The cue-target combinations and SOAs were presented in a random fashion. Per trial, recordings were made for whether participants elicited a response, and the reaction time (milliseconds) for such responses were recorded (for more detailed information see: Fillmore et al., 2006). In the current study the variable of interest was the proportion of failed inhibitions on a NoGo target following a Go cue (in other words: proportion incorrect key presses to no-go target following go cue).

Motivational factors. *Reward seeking* and *sensation seeking* were assessed with two sub-scales of the BAS (Carver & White, 1994) that have been used in past studies to measure these constructs, namely "BAS Drive" (four items) and "BAS fun seeking" (four items), respectively. We used a Dutch translated version of the BAS that was validated against the psychometric properties of the original BIS/BAS (Yu, Branje, Keijsers & Meeus, 2011). Answers to the questions were assessed using a 4-point response format, that ranged from "Very false for me" to "Very true for me".

Reward seeking was measured with the *BAS Drive* sub-scale, which measures the behavioral tendency to persistently pursue rewards and desired appetitive goals and reflects the extent to which (impending) rewards guide subsequent behavior (Beaver et al., 2006; Carver & White, 1994). An example item of BAS Drive is: "I go out of my way to get things I want". All items on this scale had sufficient factor loadings.

Sensation seeking was measured with the *BAS Fun Seeking* sub-scale, which is typically used to measure sensation seeking tendencies (Zuckerman, 2012; Franken & Muris, 2006, Ko et al., 2008), perhaps primarily because of its additional "novelty seeking" aspect that differentiates it from the other sub-scales of BAS. An example of an item on the BAS fun-seeking scale is "I crave excitement and new sensations". We excluded one item (i.e., "I will often do things for no other reason than that they might be fun") on this scale that had a factor loading of less than .30.

Social factors. *Susceptibility to peer influence* was measured with selected items on the Resistance to Peer Influence scale (RPI; Steinberg & Monahan, 2007), which is a self-report questionnaire that taps the degree to which adolescents are resistant to influence of their peers (Steinberg & Monahan, 2007). The psychometric properties of this scale have been cross-validated in a Dutch sample of adolescents (see Sumter, Bokhorst, Steinberg, & Westenberg, 2009). Eight of the 10 pairs of opposing statements in the RPI were selected to be used in the current study. Participants were instructed to first choose one of the answers per pair that described them, and thereafter decide whether their choice is 'really true' or 'sort of true'. For example, a pair of two statements was: "Some people would do something that they knew was

wrong just to stay on their friends' good side" versus "other people would not do something they knew was wrong just to stay on their friends' good side". A higher score indicates higher resistance to peer pressure. The item "Some people think it's better to be an individual even if people will be angry at you for going against the crowd. vs. Other people think it's better to go along with the crowd than to make people angry at you." Had a factor loading lower than .30, and was thus excluded.

Perceived peer pressure was measured with the reliable and validated Peer Pressure Inventory (PPI; Clasen & Brown, 1985), which measures different types of peer pressures adolescents perceived as well as the intensity of the perceived peer pressure. Participants were presented with pairs of opposing statements concerning peer pressure. Per pair, they were instructed to choose the statement that corresponds with their experience, and then indicate to what extent that statement is true for them (i.e., "A Little," "Somewhat" or "A Lot"). Participants could also choose the option "No Pressure", if they did not perceive any pressure from their friends to participate (or not to participate) in a particular behavior. Ten pairs of statements on the PPI that were selected as relevant for the larger longitudinal study on risk-taking, were used in the current study. Four items were related to substance use, two items measured vandalism and stealing, one item was related to school involvement, another item measured peer conformity and one item measured obedience towards parents. An example of a pair of statements is: Pressure to Smoke cigarettes vs. Pressure not to smoke cigarettes. Lower scores on the PPI indicated higher levels of perceived peer pressure. Our factor analysis showed that the following three items on the Peer Pressure Scale had very poor factor loadings (i.e., below .30): peer pressure to study/ do homework, peer pressure to shoplift/steal, and peer pressure to engage in vandalism. Thus we excluded these items.

Statistical Approach

Accelerated latent growth model. Latent growth modeling (LGM) is a comprehensive, powerful and flexible statistical technique for studying parametric development in both individuals and the sample as a whole (Duncan, Tildesley, Duncan, & Hops, 1995). In the current study we apply an accelerated longitudinal (also called cohort sequential) approach to model the hypothesized growth in smoking throughout adolescence using a latent growth model. Accelerated longitudinal designs consist of multiple independent and overlapping age cohorts that are statistically converged into one growth curve. In the current study, we used a multi-group framework for our cohort sequential models. Across groups, equality constraints were imposed on all free parameters (for details, see e.g., Duncan, Duncan, & Strycker, 2006). As reported earlier, adolescents who were 12 during wave one, constituted the "age 12 cohort", similarly we also had an age group cohort for 13 year olds, 14 year olds, and 15 year olds.

We estimated a hybrid model that included a factor model for our predictors, with latent variables that were used as predictors for the variance in the slope. Specifically, we used a four-step procedure for the LGM analyses. In the first step we investigated an unconditional growth curve, without predictors (cf Duncan et al., 1995). In a second step, we entered the control variables (i.e., gender and educational track) in the model, by regressing the intercept and slope on these control variables. In a third step, we investigated whether the independent variables individually predicted the growth parameters, that is, we regressed the intercept and slope on the level of the independent variables at age 12. This resulted in six models, namely one model per independent variable. In the fourth step, we included all predictors in one combined model, along with the potential covariates gender and educational track.

In subsequent analyses hereafter, we performed a stepwise backward elimination procedure based on p-values of the predictors in order to come to a final combined model (Duncan, et al., 2006). In other words, per step, we deleted the predictors with the highest p-values until a model with only significant predictors remained. Consistent with this format, each predictor is treated as if it were added last to the model (Duncan, et al., 2006). This procedure is recommended as it takes multicollinearity between variables into account and it avoids the deletion of relevant predictors (Duncan, et al. 2006).

Furthermore, a Robust Maximum Likelihood Estimator was used for all models (Satorra & Bentler, 1994) to account for non-normality and to ensure that incomplete data could be included in the analyses. Any item-missing or wave-missing data were dealt with using the Full Information Maximum Likelihood algorithm in Mplus 7.1 (Muthen & Muthen 2012).

Results

Preliminary Analyses

Gender was entered in the models as a dichotomous variable (boy = 0; 1= girl), and *educational track* was also dichotomized (VMBO/ lower educational track = 0; HAVO/higher educational track = 1). Next, we excluded unreliable smoking data for 8.89% of the subsample who gave inconsistent answers about their smoking history (i.e., participants who indicated that they had no experience with smoking, who in previous years indicated that they did have experience with smoking).

We also ran some bias checks to determine whether persons who dropped out the study (i.e., 15% of participants) after wave 1 were different from persons who remained in the study, with respect to gender, educational track and smoking levels.

Table 1. Bivariate Concurrent Correlations for the Individual Items at Age 12

Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1. sm	-																											
2. i1	.03	-																										
3. i2	.09	.50†	-																									
4. i3	.08	.58†	.56†	-																								
5. i4	.13	.60†	.39†	.55†	-																							
6. i5	.13	.52†	.41†	.48†	.54†	-																						
7. rs1	-.03	-.03	.05	-.16*	-.14	-.10	-																					
8. rs2	.08	.16*	.11	.14	.10	.00	.21†	-																				
9. rs3	.07	-.02	-.11	-.02	.14	.04	.14	.22†	-																			
10. rs4	-.02	.04	.07	-.04	-.05	-.07	.42†	.22†	.18*	-																		
11. ss1	.07	.11	.17*	.18*	.13	.15*	-.11	.31†	.05	.12	-																	
12. ss2	-.01	.08	.05	.02	-.04	-.05	.18*	.14	.27†	.32†	.14	-																
13. ss3	.05	.13	.24†	.13	-.02	.07	-.08	.04	.12	.14	.14	.11	-															
14. ps1	.10	-.08	-.14	-.16*	-.07	-.04	.18*	-.19*	.18*	.05	-.28†	-.04	-.09	-														
15. ps2	-.02	-.28†	-.18*	-.30†	-.23†	-.26†	.23†	-.10	.13	.23†	-.31†	-.01	-.02	.36†	-													
16. ps3	-.08	-.23†	-.20*	-.26†	-.19*	-.22†	.13	-.21†	.05	.01	-.29†	-.06	-.07	.29†	.38†	-												
17. ps4	.00	-.24†	-.04	-.18*	-.18*	-.18*	.11	-.15	.04	.11	-.18*	.02	-.01	.28†	.20*	.45†	-											
18. ps5	-.10	-.05	-.17*	-.11	-.12	-.12	.04	-.08	-.01	.06	-.06	-.02	-.07	.05	.18*	.28†	.31†	-										
19. ps6	-.10	-.30†	-.24†	-.23†	-.34†	-.25†	.06	-.07	-.02	.10	-.17*	-.10	-.15	.27†	.35†	.39†	.30†	.33†	-									
20. ps7	-.15	-.28†	-.31†	-.29†	-.27†	-.35†	.20*	-.05	.03	.05	-.34†	.08	-.12	.19*	.30†	.44†	.32†	.30†	.41†	-								
21. pp1	-.02	-.08	-.07	-.08	-.11	-.18*	-.03	-.03	-.06	.00	.03	.00	.12	-.05	.00	.14	.02	.19*	.06	.15	-							
22. pp2	-.06	-.14	-.12	-.11	-.17*	-.21†	.04	-.04	-.06	.11	-.06	.02	.08	-.02	.14	.23†	.11	.26†	.22†	.22†	.75†	-						
23. pp3	-.03	-.03	.01	-.01	-.01	-.05	-.07	-.22†	-.05	-.10	-.15	-.05	.04	.13	.15	.21*	.10	.13	.10	.08	.35†	.40†	-					
24. pp4	-.13	-.11	-.12	-.10	-.17*	-.17*	.01	-.04	-.09	.06	.00	-.04	.02	-.04	.05	.14	.11	.23†	.19*	.19*	.73†	.85†	.41†	-				
25. pp5	-.02	-.08	-.08	-.08	-.05	-.20*	.02	.03	-.02	.11	.05	.04	.06	-.06	.03	.14	.05	.22†	.10	.19*	.73†	.81†	.40†	.86†	-			
26. pp6	-.04	-.14	-.04	-.07	-.08	-.15	-.02	-.05	.05	.16*	-.05	-.01	.05	.01	.19*	.22†	.18*	.06	.08	.13	.33†	.44†	.31†	.46†	.45†	-		
27. pp7	-.06	-.10	-.10	-.07	-.07	-.09	.11	.03	.16	.00	-.04	.08	-.01	.15	.04	.25†	.18*	.14	.09	.27†	.25†	.29†	.25†	.28†	.27†	.25†	-	
28. ic	.25*	.06	.13	-.04	.10	.16	.09	.06	.12	.11	.01	.16	-.14	.00	-.03	-.19	.02	-.25*	-.04	-.09	-.18	-.27*	-.03	-.17	-.13	.09	-.16	-

Note. sm= smoking i=impulsivity, rs=reward seeking, ss=sensation seeking, ps=susceptibility to peer influence, pp= peer pressure, ic=inhibitory control. The number behind the labels of the items denotes the item number on the scale. *p<.05. †p<.01

Table 2. Final Model: Unique and Robust Predictors of Adolescent Smoking Development[36]

Predictor	*B*	*SE*	*β*	*P*
Impulsivity	.12	.03	.26	<.01
Perceived peer pressure	-.06	.02	-.21	<.01
Educational track	-.13	.04	-.16	<.01

36 The p-value for reward-seeking was .051. B = .16; SE = .08; β = .15.

We controlled for age when examining smoking. There were no significant results for gender. However, for educational track and smoking, there were some significant differences. Students who only participated in the first wave did not differ from the other students with respect to educational track, however, they were heavier smokers ($F(1,519) = 10.52$, $p < .01$). Compared to wave 1, students who did not participate at the second wave were from a higher educational track ($\chi 2(1) = 5.24$, $p = .02$) and were heavier smokers ($F(1,519) = 5.57$, $p = .02$), while students who did not participate at the third wave were more likely to be from the lower educational tracks ($\chi 2(1) = 19.33$, $p < .01$), but they did not differ in their smoking levels. The results with respect to educational track are to be expected at wave 2, considering that one school that had students attending higher educational tracks dropped out of the study (as mentioned earlier). The results with respect to educational track are also to be expected at wave 3, since by that time some participants of the lower educational tracks had already finished high school, and thus did not take part in the school data-collections. Overall, these findings suggest that the sample of students who dropped out of the study were more likely to be heavier smokers[37].

Table 1 illustrates the correlations among the individual items at baseline (age 12). Only inhibitory control was significantly correlated with smoking at age 12.

Main Analyses

Fit indices for the unconditional model (step 1) (χ^2 (32) = 42.74; $p = .10$; TLI = .95 and RMSEA = .05) suggest that an accelerated longitudinal design is suitable for our data. Furthermore they suggest that the growth in smoking can be described adequately with a linear model. The intercept was not significantly different from 0 ($b_0 = .04$; $p = .27$), indicating that at age 12, nearly all the adolescents did not currently smoke (93.6%). However, at age 17 a total of 29.40% adolescents reported that they currently smoke. It should be noted that the lack of variance in the intercept produced estimation problems. Thus we constrained the variance of the intercept to 0, which solved these problems (see the above-mentioned model fit indices). Next, the slope was significant ($b_1 = .20$; $p < .01$) and there was significant variance in the slope (variance(b_1) = .15; $p < .01$). These results indicate that the mean level of smoking significantly increased each year with .20 units further on our five point scale for smoking. Thus at age 17, adolescents progressed on average 1 unit further on our five point scale. The significant variance indicates that adolescents differ in their rate of increase of smoking. In the second model that included the control variables, we found that educational track (but not gender) predicted faster increases in smoking. Specifically, adolescents with a lower educational track at age 12, showed faster increases in smoking behavior over time.

The separate models per predictor (i.e., step 3) showed that higher levels of impulsivity, sensation seeking, perceived peer pressure, and susceptibility to peer influence at age 12 predicted faster increases in smoking behavior. Results in the final combined model (see Table 2), after the backward deletion procedure, showed that higher levels of impulsivity (β = .26), greater perceived peer pressure (β = -.21), and lower educational track (β = -.16) were significant predictors of the increase in smoking from age 12 to 17[38]. Thus, unlike in the univariate model, sensation-seeking and susceptibility to peer influence were no longer significant in the multivariate model. This final combined model had a good fit to the data (χ^2 (506) = 619.87; $p < .01$; TLI = .96 and RMSEA = .04).

Discussion

The present accelerated longitudinal study was designed to investigate the developmental pattern of smoking behavior from ages 12 to 17 in 574 ethnically diverse Dutch adolescents. We used a meta-theory, the TTI, to investigate whether relevant risk factors at age 12 that were derived from intrapersonal (cognitive and motivational) and social domains (peer influence) would explain the hypothesized variance in the increase in smoking development throughout adolescence. Our results showed that the intercept (baseline of smoking) was not significant, and no variance was detected, indicating that nearly all participants (i.e., 93.6%) were non-smokers at age 12 whereas 29.40% of adolescents smoked at age 17. Although slightly higher, these prevalence statistics are quite comparable to population statistics in the Netherlands (Statistics Netherlands, 2015). Furthermore, we found significant variance in the slope showing that adolescents differ in the rate of increase in their smoking development. As for the TTI-based risk-factors, higher levels of self-reported impulsivity and perceived peer pressure at age 12 predicted faster increases in adolescent smoking behavior development when investigated alone and simultaneously in the same model. Interestingly, whereas sensation seeking (intrapersonal domain) was significant in a univariate model, its contribution became non-significant in the multivariate model wherein other intrapersonal and social predictors were simultaneously estimated. Finally, as for putative covariates, lower educational track at age 12 predicted faster increases in smoking behavior from age 12 to 17. Below we further discuss these findings and their implications in relation to the TTI and in light of findings from previous studies.

37 However, the readers should bear in mind that participants who did not participate in one wave were still allowed to participate in subsequent waves, and a cohort-sequential design which results in some overlapping age cohorts was used. Thus it is not straightforward to conclude to what extent these results can be interpreted and to what extent they are meaningful for our SEM models.

38 Reward-seeking had a p-value of .051 in the combined model.

Intrapersonal Factors

We found that self-reported impulsivity was a significant predictor of the increase in adolescent smoking. Although this is in line with the TTI and with cross-sectional studies that show that impulsivity and adolescent smoking are related, the small number of longitudinal studies that have investigated this link showed mixed findings (e.g., Audrain-McGovern et al., 2006; Elkens et al., 2006; Malmberg, et al. 2013; Quinn & Harden, 2013). However, the present study was distinct in that it measured impulsivity during early adolescence and treated it as a prospective longitudinal predictor of the growth in smoking throughout adolescence. Although replications are needed, the current study provides evidence showing that impulsivity during early adolescence serves as a robust predictor of increases in smoking behavior up until the age of 17.

We did not find a significant link between our behavioral measure of inhibitory control (i.e., Cued Go/No Go task) and smoking development. These opposing findings support the notion that has been put forward that although impulsivity and inhibitory control are both indices of cognitive control, they tap into subtle different abilities (Dalley, et al., 2011). This assertion also has implications for the TTI which suggests that cognitive-related factors (ultimate level) predict adolescent health risk behaviors, because our results suggest that some cognitive-related behaviors might be more relevant than others for predicting adolescent smoking progression. As far as we know, there are currently no studies that have investigated whether an experimental measure of inhibitory control prospectively predicts smoking development in adolescents, so our results are not directly comparable to the existing literature, and thus await to be replicated. At least for late adolescents and emerging adults, inhibitory control measured via behavioral tasks also did not predict smoking (Dinn, et al., 2004; Galvan et al., 2011).

A possible explanation for our null finding is that cognitive control might only be an issue for adults who suffer from nicotine dependence or addiction as was the case in a meta-analysis that showed that inhibitory control measured via the Go/No Go task was significantly lower in adult smokers versus non-smokers (i.e., Smith et al. 2014). These results might be similar for adolescent samples with nicotine dependence/addiction versus non-smoking adolescents, however this is just a speculation as we did not assess nicotine dependence/addiction in the current study. Perhaps in samples with persons with nicotine dependence/addiction, there might be more variability in inhibitory control, depending on the severity of nicotine dependence/addiction. Relatively little variability in our sample might also be due to the simplicity of the task (i.e., most participants made only a few errors), however we did not encounter any modeling issues concerning low variability. Moreover, the performance (i.e., the mean) on the inhibitory control task used in the current study was very similar to a study that employed the same task (labeled as the "Cued reaction time task" in that study) in a sample of adolescents who were 11 years on average (see Derefinko et al., 2008). Considered together, measurement error is not likely to be the cause of the current null finding. Instead, perhaps our sample size was not large enough to detect very small effects, however our sample size was larger than the sample size in similar studies with adult samples that did find that performance on the Go/No Go Task predict adult smoking behavior. Considered together, it also seems unlikely that a lack of power is the cause of our null finding.

As for the predictions of the TTI, although the TTI suggests that cognitive processes in general are risk factors for adolescent substance use, the current study suggests that inhibitory control is not relevant for adolescent smoking development, although it might be relevant for predicting the use of other substances in adolescents. Equally possible is that perhaps inhibitory control is more predictive of the onset of smoking, but not for the development of adolescent smoking, which we cannot conclude for sure with our data as there was negligible variability at baseline (age 12). Nevertheless, inhibitory control and smoking were significantly correlated at age 12 (see Table 1).

The current results underscore that when assessing cognitive control, diverse methods should be employed, as cognitive control is a heterogeneous construct, that involves wide ranging cognitive abilities that might not be strongly correlated with each other[39] (Dalley, et al., 2011), and that might have different effects on smoking as evident from the current study. Finally, our results also suggest that future studies on adolescent smoking development should focus more on the impulsivity (lack of forethought) aspect of cognitive control rather than the inhibitory aspect of cognitive control.

Motivational Factors

None of our motivational predictors proved to be unique and robust predictors of smoking progression in our combined model. This current longitudinal finding contradicts past cross-sectional studies that showed that particularly sensation-seeking in adolescents (e.g., Leeman et al., 2014; Martin et al., 2002; Pokhrel et al., 2010), and reward seeking in mid- (e.g., Knyazef, et al., 2004) and late- adolescents (Richardson et al., 2014) are concurrently related to adolescent smoking. On the one hand, we do note that if a statistical significance level of $< .05$ is used, then in a larger sample, reward seeking would have perhaps reached statistical significance as it had a p-value of .051 in our sample. On the other hand, considering that the p-values for the significant predictors in the combined model were all $p < .01$, it is clear that the other predictors are more likely to be relevant than reward seeking in the prediction of smoking development in the combined model. Also, taking into account that we ran multiple models, it is then more appropriate to use a p-value of .01 as the criterion for statistical significance. Thus all things considered we conclude that motivational predictors such as reward seeking and sensation seeking are less relevant for adolescent smoking development compared to other cognitive-intrapersonal and social predictors.

39 In the current study, inhibitory control and the impulsivity items were not significantly correlated at age 12 (Table 1).

Also interesting to note is that in our univariate model, sensation-seeking was a significant predictor of increases in smoking. However, this link did not hold up in our stringent multivariate model that also accounted for other motivational, cognitive and social predictors. Importantly, however, the current finding does concur with other longitudinal studies that have investigated sensation seeking simultaneously with peer factors (see Chun, 2015; Otten et al., 2011). Additionally, it is worth considering that at least one study that also accounted for peer factors showed that although scoring high on thrill seeking (component of sensation seeking) did *not* contribute a significant probability to the overall probability that an adolescent would transition from monthly to daily smoking, scoring high on thrill seeking did predict smoking onset and the transition to monthly smoking (Bricker et al., 2009). This finding, in combination with the current finding could imply that some risk factors outlined by the TTI might be more relevant for smoking onset, or the beginning phases of smoking, but not for smoking escalation (or smoking dependence/addiction).

Finally, the finding that social factors like peer pressure were found to be more predictive of adolescent smoking compared to motivational factors like sensation-seeking is in line with the TTI, because the TTI describes sensation seeking as a "ultimate" level influence, whereas peer pressure is described as a "proximal" level influence (Flay et al., 2009; Snyder & Flay 2012). Below we further describe the importance of social factors in adolescent smoking development.

Social Factors

Finally, consistent with the TTI, we investigated peer influences on adolescent smoking. Our results show that the effect of perceived peer pressure is above and beyond the significant links we found for the other risk factors on the development of adolescent smoking. Considered together, perceived peer pressure is not only a concurrent predictor of adolescent smoking (e.g., Crockett et al., 2006; Santor et al., 2000), but it is also a unique longitudinal predictor of smoking progression throughout adolescence, which mirrors the latent growth findings of Duncan et al., (1995).

Next, although susceptibility to peer influence was a significant predictor when tested individually, it became non-significant when tested in a multivariate model, whereas perceived peer pressure remained significant. Thus, susceptibility to peer influence is perhaps already an underlying component of perceived peer pressure[40], making it redundant to account for both of these peer pressure forms in the same model. This interpretation is in line with TTI, as although both susceptibility to peer influence and peer pressure are identified by TTI as risk-factors of the social domain, the former is described as a "distal/predisposing" influence, whereas the former is described as a "proximal/direct" influence of adolescent smoking. That is, although all levels of influence (ultimate, distal, proximal) influence behavior, the influence of proximal risk factors are more direct (Snyder & Flay 2012). Other studies that have investigated susceptibility to peer influence (i.e., Chun, 2015; Otten et al., 2011) did not simultaneously consider the more direct/proximal perceived peer pressure. Thus, our finding that after accounting for perceived peer pressure, susceptibility to peer influence becomes less relevant for adolescent smoking development, suggests that it would be worthwhile for future studies to include both measures to further investigate why and when this suppression might occur.

In sum, a combination of intrapersonal (particularly cognitive) and social risk-factors robustly and uniquely predicted the variance in increases in adolescent smoking. Specifically, higher levels of impulsivity (cognitive-intrapersonal) and perceived peer pressure (social) at age 12 predicted faster increases in smoking behavior from ages 12 to 17 above and beyond their individual effects. Moreover, more motivational risk factors such as sensation-seeking appeared to be no longer significant for increases in smoking behavior when cognitive and social factors were taken into account. In other words, the current results show that when investigating effects of sensation-seeking on adolescent smoking, significant cognitive and social factors like impulsivity and perceived peer pressure should be accounted for as they might override the predictive power of sensation-seeking when tested alone. This is one of the primary reasons the TTI was developed, namely to acknowledge that risk-factor tend to be interrelated (Flay, et al., 1995). More specifically, for the current study, this suppression of motivational factors as unique and robust predictors might be because cognitive and social factors already contain a motivational component. Perhaps motivational (affective) factors such as sensation-seeking can be seen more as underlying components of the cognitive domain (Duncan & Barrett, 2007), as well as underlying components of the social (peer) domain (Pfeifer & Blakemore, 2011). Along these lines, when cognitive and social risk factors are taken into account, an additional pure motivational component becomes redundant, and as our results suggest, this might be particularly true for increases in smoking throughout adolescence.

Finally, the effect sizes were moderate for (cognitive-intrapersonal) impulsivity and perceived (social) peer pressure whereas the effect size for educational track was small. This implies that the significant cognitive and social risk factors are of equal importance for the increases in smoking throughout adolescence, but that educational track is a relatively weaker predictor. Nevertheless, the mechanism by which educational track is linked to adolescent smoking increases warrants further investigation.

Strengths, Limitations and Future Directions

The current accelerated longitudinal study has provided new insights into the combined roles of interrelated but unique risk factors of adolescent smoking development. Furthermore, capitalizing on a stringent latent growth design via structural equation modeling, we were able to ascertain if variance exists in the

40 The correlation between the factors for perceived peer pressure and susceptibility to peer influence was $r = .24$.

baseline as well as the progression of smoking throughout adolescence. Finally, (a) we employed self-report as well as behavioral measures, (b) investigated intrapersonal as well as social predictors, (c) accounted for potential covariates such as gender and educational track, and (d) used latent factors, which accounts for measurement error. However, despite overcoming several methodological challenges of past studies, there are also limitations inherent in the current study that should be noted.

Readers should consider that during the data-collection for this Dutch sample of adolescents, on January 1st 2014, a law was implemented in the Netherlands that prohibits the sale of tobacco to individuals who are younger than 18 years old. In prior years, youth were allowed to purchase tobacco from the age of 16. As we mentioned in the introduction, such environmental and legal-related factors also influence the use of substances in adolescents. In our sample, 72.9% of 16 year olds reported they were non-smokers before the law changed, while 82.4% of the 16 year olds reported they were non-smokers after the law changed. Thus there was a decline in 16 year olds who smoked after the new law was implemented. Whether this change exerted significant influence on our findings cannot be known. Nevertheless, the fact that significant growth was observed in the model in spite of these societal shifts speaks to the robustness of the predictive model of smoking observed in the present study. Additionally, bias checks showed that persons who completely dropped out the study after wave one had higher smoking levels than persons who did not drop out altogether. However, persons who dropped out of the study after wave one was only 15% of the sample, and similar to what we mentioned above, our model was still robust enough to show significant increases in smoking despite the relatively high smoking levels of the participants who dropped out. Nonetheless, the results might not be generalizable to early heavy smokers since these students were more likely to drop out of the study. Future investigations would have to start at younger ages in order to examine whether the same factors predict smoking onset and development for these adolescents.

A methodological limitation is that we used only one item to measure smoking behavior, from which we can only conclude that adolescents smoke more often as they get older, but not that they increase in the amount they smoke. In the future, researchers could consider using more items, in particular quantity items (e.g., "how many cigarettes do you smoke per week?") since they could provide more information about the escalation of smoking, or even about nicotine addiction during adolescence.

Next, adolescents in the lower educational track showed faster increases in smoking. This raises the question as to whether there are other intrapersonal or social factors that are linked to educational track that might be the source of this link. This is an interesting and important avenue to explore in future research on adolescent smoking development. It is also important to point out that although educational track is a significant predictor of adolescent smoking progression, importantly our findings further imply that the significant cognitive-intrapersonal and social predictors are above and beyond any confounding effects of educational track.

Finally, it is also important to consider that the effect sizes were small to medium (β = .16-.26) in magnitude, but that predictors with even small effect sizes can be meaningful, particularly when dealing with health-related issues.

Conclusion

The current study suggests that cognitive-intrapersonal and social factors like impulsivity and perceived peer pressure are both of equal importance, as they uniquely contribute to adolescent smoking development when investigated simultaneously. Moreover, accounting for such cognitive-intrapersonal and social factors suppress the contribution of motivational-intrapersonal factors like sensation-seeking in predicting increases in smoking throughout adolescence. These findings underscore why it is essential to investigate the contribution of interrelated risk factors simultaneously, a strong assertion of the TTI. Had we not done so, the seemingly importance of sensation-seeking when tested alone might have led to inaccurate conclusions about its predictive power. Finally, these findings could have practical implications for the contents of prevention programs on adolescent smoking development. Most noteworthy is that the current study additionally pinpoints which confluence of risk factors are relevant for early prevention programs, and that tackling this confluence of factors, from as young as age 12, might halt the deadly increase in smoking behavior throughout adolescence.

Part 4:
Ethnic and cross-national differences in adolescent risk-taking

Chapter 9

The Longitudinal Link between Depressive Symptoms and Delinquency in Adolescence Moderation by Ethnicity, Adolescent Phase, and Gender

Author note:
This chapter is based on a manuscript in preparation to be submitted.

I.N. Defoe developed the study concept and design, and J.S. Dubas and M.A.G. van Aken gave advice and feedback. I.N. Defoe oversaw the data-collection. I.N. Defoe performed the data-analysis and interpretation. I.N. Defoe drafted the manuscript, and J.S. Dubas, and M.A.G. van Aken provided critical revisions.

Abstract

There is a well-documented co-occurrence of delinquency and depressive symptoms. However findings are mixed pertaining to a possible longitudinal link between these two problem behaviors. A developmental link from delinquency to depressive symptoms is hypothesized by the Failure model, whereas a reversed link is hypothesized by the Acting out model. Hence, the present 3-wave longitudinal paper used cross-lagged panel models to investigate bi-directional links between delinquency and depressive symptoms in adolescents (*N*=602 at baseline). Furthermore, we investigated whether the findings for this hypothesized longitudinal link were qualified by ethnicity (ethnic minority versus ethnic majority), adolescent phase (early versus mid-late adolescents) and gender. Surprisingly, higher levels of delinquency predicted lower levels of depressive symptoms in mid-late adolescent girls, which contradicts both of the above-described theoretical perspectives. For the entire sample, no ethnicity moderation effect was found. However, there was a significant gender by adolescent phase moderation effect, which showed support for both the Failure model (for early adolescent girls) and the Acting out model (for mid-late adolescent boys), but only for early adolescent girls. Furthermore, negative links from delinquency to depressive symptoms were found for mid-late adolescent girls. Hence the mixed findings found in previous studies for the longitudinal link between delinquency and depressive symptoms are perhaps because gender by adolescent phase moderation effects were not taken into account. Moreover, these complexities in the longitudinal link between delinquency and depressive symptoms have implications for both models as they neglect gender and adolescent phase moderation effects.

Key words: delinquency, depressive symptoms, ethnicity, adolescence, gender

Both delinquency and depression show a dramatic increase during adolescence. Such internalizing problems and externalizing problems differ particularly in the way they are expressed, such that to the outside world, delinquency problems for example are typically more apparent than depressive symptoms. However, despite their symptomatic dissimilarities, in non clinic-referred and clinic-referred adolescent samples, these two problem behaviors co-occur at alarming high rates (Angold & Costello, 1993; Loeber & Keenan, 1994; Wolff & Ollendick, 2006). The relatively high co-occurrence of delinquency and depressive symptoms is worrisome, as such co-occurrence within the same individual is associated with poorer treatment response and prognosis (Wolff & Ollendick, 2006). Moreover, when delinquency and depressive symptoms co-occur, the chance becomes even greater that depressive symptoms might go unnoticed, as it is likely that the expression of delinquency might overpower the expression of depressive symptoms, at least to the outside world. In addition to the established co-occurrence between delinquency and depressive symptoms, a critical (unresolved) question for successful prevention/ intervention programs is: what is the longitudinal sequence of these problem behaviors? Interestingly, not all studies find a longitudinal link between depressive symptoms and delinquency, and the directionality of the link (temporal order) differs across studies that do find such a link. Perhaps these inconsistent findings could be explained by moderators. However studies investigating the longitudinal link between depressive symptoms and delinquency in adolescence rarely investigate whether the temporal ordering differs across common moderators such as adolescent phase, gender, and ethnic background. Hence, the current 3-year longitudinal study aims to tackle these questions in a sample of ethnically and socio-economically diverse Dutch adolescents.

Temporal order: Two opposing Theoretical models

With regard to the co-occurrence of multiple psychological problems, although common risk factors might also be at play, Caron and Rutter (1991) explained that one problem might lay the groundwork for another to develop. Indeed studies that have controlled for common risk factors have shown a robust concurrent and longitudinal bidirectional association between depressive symptoms and delinquency (see e.g., Beyers & Loeber, 2003), although some studies still find a presence of common risk factors in addition to unique risk factors (Wolff & Ollendick, 2006). The Acting-out model (Carlson & Cantwell, 1980) and the Failure model (Capaldi, 1992) are among the two prominent models that aim to explain the co-occurrence and temporal ordering of depressive symptoms and delinquency in adolescence. Both models posit that one behavior subsequently predicts the occurrence of the other behavior, but the fundamental difference between these two models is their opposing views on the temporal order of depressive symptoms and delinquency. Specifically, the "Acting-out model" posits that depressive symptoms precede delinquency because youth who fail to cope with their depressive symptoms, such as "irritability",

subsequently begin to act out behaviors in the form of conduct problems, which "masks" their depression (Carlson & Cantwell, 1980; Wolff & Ollendick, 2006). In other words, they eventually externalize their internalizing problems. In contrast to the Acting out model, the Failure model postulates that delinquency precedes depressive symptoms because significant others (and society more generally) disapprove of delinquency, and thus delinquent adolescents encounter relationship problems with their social environment and such developmental failures trigger depressive symptoms (Capaldi, 1992).

First it should be pointed out that although the Failure model has received more empirical support compared to the Acting out model (e.g., Defoe, Farrington, & Loeber, 2013; Van der Giessen, et al., 2013; Wolff & Ollendick, 2006), the findings remain mixed and some studies have also simultaneously found support for both models. For example, two growth trajectory studies reported bidirectional positive relations between the growth in delinquency and depressive symptoms (Beyers & Loeber, 2003[41]; Measelle, Stice, & Hogansen, 2006). It should be noted further that although studies have found longitudinal linkages between delinquency and depressive symptoms, the direction of these linkages were not always in line with the Failure model and/or Acting out model. For instance, despite that one study found that under some circumstances a link from late adolescents' internalizing problems to adulthood externalizing problems existed (Masten et al., 2005), this finding was not in support of the Acting out model, because the link was negative and not positive, as the Acting out model suggests. Specifically, fewer broadband internalizing problems predicted more externalizing problems (Masten et al., 2005; for similar findings from middle to late adolescents, see also: Burt, Obradovic, Long, & Masten, 2008). Finally, despite the demonstrated *co-occurrence* between delinquency and depressive symptoms, still some studies fail to find any consistent longitudinal support for a relation between these problems (see e.g., Akse, Hale, Engels, Raaimakers, & Meeus, 2007; Overbeek, Vollebergh, Meeus, Engels, & Luijpers, 2001).

Considered together, despite the consistently demonstrated co-occurrence between delinquency and depressive symptoms, results are mixed concerning the existence and temporal order of a longitudinal link between these two behaviors. Hence, in the current study we further explore whether accounting for common moderators such as gender, adolescent phase and ethnic background in the hypothesized longitudinal link between depressive symptoms and delinquency might clarify some of the above-described inconsistent findings.

The Moderating Role of Adolescent Phase and Gender

As noted earlier, the rise in both depressive symptoms and delinquency occurs in adolescence, however adolescence is a heterogeneous period with distinct developmental phases. A recent study suggested that the median age for the onset of behavioral problems is 11 years, whereas the median age of onset for mood disorders such as depression is 13 years (Merikangas et al., 2010). These statistics might provide an explanation why in most studies externalizing problems predict internalizing problems (and not vice versa), in support of the Failure model. Furthermore, depressive problems tend to peak during early adolescence, and delinquency tends to peak in mid-late adolescence, whereas the co-occurrence between these behaviors is the strongest during mid-adolescence (Wolff & Ollendick, 2006). We are aware of only one study that investigated whether the co-occurrence and longitudinal link between psychological stress/depressive problems and delinquency differed for early adolescents versus middle adolescents versus late adolescence, however this study did not find such a link for either group (Overbeek, et al., 2001). Clearly, more studies that investigate the possibility of an adolescent phase moderation effect in the longitudinal link between depressive problems and delinquency are needed before firm conclusions can be drawn.

In general, little research exists on the link between depressive symptoms and delinquency in adolescents, and this is particularly the case when it comes to research on girls (Wolff & Ollendick, 2006). However, there are profound gender differences in the prevalence rates of these behaviors. Whereas prevalence rates of depression are higher in girls, delinquency is higher in boys. There is evidence that the co-occurrence between delinquency and depressive symptoms is stronger in females than males or nonexistent in males (Knox, Carey, & Kim, 2003; Overbeek et al., 2001). As for the temporal ordering, both bi-directional (Wiesner, 2003) and unidirectional (Ritakillio, et al., 2008) links from depressive symptoms to delinquency have been reported in girls, whereas, at least one study reported that an unidirectional link from delinquency to depressive symptoms existed only in boys (Wiesner, 2003; however the latter link was found at only one of the three measurement points). In contrast, gender moderation effects were absent in a recent 4-year longitudinal cross-lagged panel study that reported unidirectional links from externalizing problems to internalizing problems for both adolescent boys and girls (Van der Giessen et al., 2013). It should be noted that although the results of these studies are inconsistent with regards to gender moderation effects, their samples differed with respect to adolescent developmental phase. That is, Van der Giessen, et al. (2013) included early adolescents, Ritakillio, et al. (2008) included mid-adolescents, and Wiesner (2003) included mid/late adolescents. Thus, even though their results do not overlap, overall conclusions drawn should be done with caution, as these studies are not directly comparable due to their samples' differences in adolescent phase. These inconsistent findings also provoke the hypothesis that in addition to probable gender and adolescent phase moderation effects, a gender by adolescent phase moderation effect (i.e., early adolescent girls vs. mid-late adolescent girls vs. early adolescent boys vs. mid-late adolescent boys) might also be likely. Hence, we consider all these possible moderation effects

41 However, Beyers and Loeber (2003) found more evidence for a relationship from depression to delinquency as this link was more robust.

in the current study when examining the hypothesized longitudinal link between depressive symptoms and delinquency.

The Moderating Role of Ethnicity: Ethnic Minority versus Ethnic Majority Youth

Although research on ethnic differences is sorely lacking, similar to differences in socio-economic status, cultural differences are often ubiquitous in the field of psychology, as human behavior is strongly affected by ethnic/cultural values. For example, although the Netherlands is a multicultural society with a substantial amount of foreign migrants (21.7%, Statistics Netherlands, 2016a), psychology related Dutch scientific articles rarely include a substantial amount of ethnic minority Dutch youth. The majority of the ethnic minority youth in the Netherlands are 2nd generation immigrants from Morocco, Turkey and Suriname (Ftitache, 2015). Of the group of non-western foreign migrants, 19.4% is Turkish, 17.1% is Surinamese, 18.7% is Moroccan and 7.3% is Dutch-Caribbean (Statistics Netherlands, 2016b). Although these subgroups of non-western migrants differ to some extent in their immigration history and religious beliefs, they overlap greatly on psychological factors. Particularly, unlike the individualistic Dutch culture where Western values of autonomy/independence of the individual often prevail, the non-western ethnic minority groups tend to place a higher value on interpersonal relations, collectivism, conformism, and social harmony (Janssens, Pels, Dekovic, & Nijsten, 1999). Another notable difference is that overall psychological adjustment might be lower in ethnic minority youth compared to ethnic majority Dutch youth (Ftitache, 2015). For example, in the Netherlands ethnic minority youth are over-represented in the juvenile justice system (Statistics Netherlands, 2014). However, such differences in delinquency between ethnic majority youth and ethnic minority migrant youth are not consistently found when self-reports or parent reports are used (see e.g., Ftitache, 2015; Paalman et al., 2015; Stevens et al., 2003; Murad, Joung, Lenthe, Bengi-Arslan, & Crijnen, 2003; Dekovic, Wisssink, & Meijer, 2004). As for internalizing problems, ethnic minority youth in the Netherlands appear not be overrepresented, however, this might particularly be the case when teacher reports are used, but on self-report and parent measures, they sometimes score higher than their ethnic majority youth counterparts (see e.g., Janssen et al., 2004; Stevens et al., 2003; Vollebergh et al., 2005; for an overview see: Ftitache, 2015).

Nearly all of the existing studies on ethnic differences in internalizing and externalizing problems among Dutch youth are cross-sectional. Nevertheless, a recent 10-year study showed that non-western ethnic minority youth scored higher on conduct problems on all the five time points, but differences in emotional problems were negligible or small, with non-western ethnic minority youth scoring lower than their ethnic Dutch majority youth counterparts (Duinhof, Stevens, Van Dorsselaer, Monshouwer, & Vollebergh, 2015). Then again, a recent longitudinal study with at-risk youth showed that over four years ethnic minority youth of Moroccan decent scored lower than their Dutch counterparts on conduct problems, and for depression the former scored lower than the latter (Paalman et al., 2015). As for ethnic differences in the co-occurrence of delinquency and depression, although Paalman et al. (2015) reported an association between these two internalizing and externalizing problems, ethnic differences were absent over the four years. However these findings await to be replicated in future studies with a substantial amount of ethnic minority youth.

Taken together, scientific research within the field of psychology in The Netherlands (compared to the US for example) on ethnic minority youth is small but growing. However, most of the current Dutch research including ethnic minority youth is descriptive, longitudinal studies are needed, and the existing cross-sectional studies show mixed findings (Ftitache, 2015). Accordingly, the current study is unique in that it is one of the few Dutch studies that include a substantial sample of ethnic minority youth to allow the investigation of ethnicity moderation effects using a longitudinal design (but see also e.g., Paalman et al., 2015). Specifically, we use an ethnically-diverse sample to explore whether ethnic minority versus ethnic majority moderation effects exist in the hypothesized link between depressive problems and delinquency. Considering that the investigated ethnic minority groups as a whole are more similar to each other on psychological adjustment factors, in comparison with the Western-ethnic majority group, we combine the non-Western ethnic minority groups when comparing them to the Western ethnic majority group (cf. Ftitache , 2015). Moreover, since ethnicity (i.e., minority versus majority ethnic groups) and socioeconomic status are often confounded (Deković, et al., 2004), we control for SES when testing for ethnicity moderation effects.

Current study

In the current study we investigate whether a longitudinal link between depressive symptoms and delinquency exists among a sample of ethnically and socioeconomically diverse adolescents (*N*= 602 at baseline) who have been followed for three years (12-15 years old at baseline). Furthermore we investigate whether gender, adolescent phase (early versus mid/late adolescence) gender in combination with adolescent phase (i.e., early adolescent girls, mid-late adolescent girls, early adolescent boys, mid-late adolescent boys) and ethnicity (ethnic (non-Western) minority versus ethnic Majority) moderate the temporal order of these links, while accounting for potential SES confounding effects in the latter moderation model.

Method

Sample

The sample used in the current study was part of a larger 3 year longitudinal project in the Netherlands on adolescent risk-taking in multiple domains, which

began in 2012 (for detailed information see: Defoe, Dubas, Somerville, Lugtig & Van Aken, in press). We recruited the participants via schools throughout the Netherlands. Annual data-collections took place for three years, with sample sizes of 602, 582, and 442, respectively across the waves. In wave 1, the adolescents (46.40% female) were either in the 1st or 3rd year of "preparatory middle-level applied education" (*VMBO* in Dutch) or "higher general continued education" (*HAVO* in Dutch). Adolescents in their first year of high school were 12-14 years old and adolescents in their 3rd year of high school were 14-17 years old In the first wave, most adolescents (93.2%) reported that they were born in the Netherlands with 61.6% identifying as Dutch, 9.3% as Turkish or Turkish-Dutch, 7.4% as Surinamese or Surinamese-Dutch and 5.5% as Moroccan or Moroccan-Dutch, and the rest (16.2%) identified with various other ethnicities. Nearly half (47.7%) of the 602 adolescents were unaware of their mothers' highest level of completed education, partly because their mothers (12.1 %) were born abroad, in countries where the educational system was not comparable to the Dutch educational-system. For the other half, 6.8% of their mother did not complete secondary education, 36.8% completed a lower-middle level vocational training and 3.9% completed university level education.

Procedure

We recruited participants from 8 high-schools in 6 different regions in the Netherlands[42].Parents received dissent letters that could be returned to the schools if parents refused to let their children participate in the study. Adolescents who were absent from school in wave one, could still participate in subsequent waves if they had parental permission, and new adolescents could also participate after wave one.

The data-collections which were led by trained research assistants and took place at schools of the participants. Participants were offered the choice between a chocolate candy worth 2 euros as a participation prize, or to have their name entered in a raffle for a chance to win a 50 euro gift voucher.

Measures

Depressive symptoms were reported by adolescents at each of the three measurement waves via the Depressive Mood List (DML; Kandel & Davies 1982), which was translated to Dutch by Deković (1996). Adolescents indicated how often within the last 6 months they experienced depressive symptoms. The questionnaire contained 6 items, example items are "*Feeling nervous or tense*" and "*Worrying too much about things*". The answer categories were: 0= Never; 1= Rarely; 2= Sometimes; 3= Often; 4= Always. Means scores were computed, with higher means denoting higher levels of depressive symptoms. Cronbach alpha's were .79, .85 and .81, for wave 1, 2, and 3 respectively, all indicating good reliability.

42 In wave two and three seven schools participated as one school no longer participated after wave one due to organizational changes at the school.

Delinquency was measured with 7 items tapping vandalism (1 item*; Have you ever damaged something on purpose, such as a bus shelter, a window, a car or a seat in the bus or train?)* and property crime (4 items that related to theft) of the International Self-Reported Delinquency questionnaire (ISRD; Junger-Tas et al.,1994; Junger-Tas, Haen Marshall, & Ribeaud, 2003). An example theft item is "*Have you ever stolen something from a store or warehouse".* An additional vandalism item "*Have you ever tampered or ruined (vandalize) objects on the streets or inside a building with paint, graffiti, or markers*"? and an additional delinquency item "*Have you ever done something for which you were arrested by the police?*" from another delinquency questionnaire were also used (i.e., Baerveldt, Rossem & van Vermande, 2003). The answer-categories for all of the items were: 0 = Never *or* Yes, but that was longer than 12 months ago; 1=Yes, once in the past 12 months; 2=Yes, twice in the past 12 months; 3= Yes, three times or more during the past 12 months. Thus, the current study investigates delinquency within the last 12 months, accordingly, adolescents who indicated that they have committed a delinquent act more than 12 months ago were coded as 0. A mean score was computed, with higher means reflecting more delinquency involvement. The Cronbach's alpha's over the years were .73, .82, and .71, respectively, denoting adequate reliability.

Ethnicity (i.e., the moderator variable) was captured with a dummy variable, 0 = non-Western ethnic minority (i.e., Turkey, Morocco or another country in Africa, Suriname, Caribbean and Asia); 1= Western ethnic majority (i.e., Dutch). Adolescents with at least one parent who was born in a non-western country were classified as "non-Western ethnic minority" (see also: Duinhof et al., 2015).

Social Economic Status (SES) was measured in wave 1, via adolescent's reports on their mother's highest level of education. This continuous variable that ranged from 0=no education to 8=university was used as a proxy for SES.

Strategy of Analyses

We investigated the hypothesized link between depressive symptoms and delinquency, with transactional or autoregressive crosslagged models (Jöreskog, 1970) in Mplus version 7. The autoregressive paths signify continuity within the variables which were tested by regressing the repeatedly assessed variables over the three years on their immediate prior values. We also included two-year stability paths in the models, unless otherwise specified. The cross-lagged, cross-time paths represent associations between the repeated assessments of depressive symptoms and delinquency. Finally, the model also allowed for crossectional (or within-wave) correlations between parallel assessed variables. To test for adolescent phase (i.e., 12-13 year olds; early adolescents versus 14-17 year olds; mid-late adolescents[43]) gender, gender by adolescent phase (i.e., early adolescent girls vs.

43 Most "mid-late adolescents" were between ages 14-15 at wave 1, as 26 adolescents were 16 years old and 1 adolescent was of 17 years old.

mid-late adolescent girls vs. early adolescent boys vs. mid-late adolescent boys), and ethnicity (i.e., non-Western ethnic minority versus Western ethnic majority) moderation effects, we additionally specified four multi-group models. We used Wald tests to determine whether the moderation effects (i.e., differences across the subgroups in the multi-group models) were significant. Wald-tests further showed that the cross-lagged paths and reverse cross-lagged paths in each model could be constrained to be equal across the waves, thus the models were time invariant.

We used SES as a control variable in the ethnicity multi-group models. That is, we regressed this variable on depressive symptoms and delinquency in wave 1, 2 and 3 (Newsome, 2015). Considering that only half of the adolescents were aware of their mother's highest level of education, we ran analyses with and without this proxy of SES. However, the conclusions of the results were the same with and without controlling for SES, thus in the current paper, we report the results including SES as a control variable.

Model fit was determined using the Comparative Fit Index and Tucker Lewis Index (CFI and TLI; acceptable values > .90) (Bentler, 1990) and the root mean squared error of approximation (RMSEA; acceptable values < .08) (Browne & Cudeck, 1993). For the adolescent phase multi-group models, we included additional two-wave stability paths for delinquency in year 1 to delinquency in year 3 for young adolescent boys, and in the adolescent phase by gender multi-group model we included such a path for the mid-adolescent boys subgroup, as this improved model fit. All final models had a good fit to the data. A possible non-normal distribution of the study variables was accounted for by using a MLR estimator, in order to facilitate robust standard errors, and this estimator also allows the inclusion of missing cases.

Results

Descriptive analyses

The means and standard deviations can be seen below per adolescent phase (Table 1), gender (Table 2), and ethnicity (Table 3). At each time point girls had significantly higher means on depressive symptoms ((wave 1: ($F(1, 599) = 5.54$, $p = .02$); wave 2: ($F(1, 573) = 16.41$, $p < .01$); wave 3: ($F(1, 435) = 9.76$, $p < .01$)), whereas boys consistently had higher means on delinquency (wave 1: ($F(1, 587) = 62.39$, $p < .01$); wave 2: ($F(1, 555) = 54.27$, $p < .01$); wave 3: ($F(1, 432) = 49.38$, $p < .01$)). As for adolescent phase, early adolescents had significantly higher levels for delinquency than mid/late adolescents, but only in wave 3 ($F(1, 435) = 4.62$, $p = .03$).", and the latter had higher levels of depressive symptoms than the former for each measurement wave ((wave 1: ($F(1, 587) = 16.41$, $p < .01$); wave 2: ($F(1, 554) = 16.89$, $p < .01$); wave 3: ($F(1, 432) = 12.70$, $p < .01$)). Finally, the levels of delinquency did not significantly differ across ethnicity, however ethnic minority youth reported higher levels of depressive symptoms than ethnic majority youth, but only at wave 1

Table 1. Means And SD's for Early Adolescents' and Mid-Late Adolescents' Delinquency and Depressive Symptoms across the Three Waves

Adolescent Phase	DEL W1	DEL W2	DEL W3	DEP W1	DEP W2	DEP W3
Early adolescents	.07(.20)	.12(.28)	.14(.27)	1.32(.69)	1.36(.79)	1.42(.82)
Mid-Late adolescents	.11(.31)	.15 (.44)	.08(.28)	1.55(.71)	1.65(.83)	1.69(.70)

Note. DEP = Depressive symptoms; DEL = Delinquency; W1 = wave 1; W2 = wave 2; W3= wave 3

Table 2. Means And SD's for Boys' and Girls' Delinquency and Depressive Symptoms Across the Three Waves

Gender	DEL W1	DEL W2	DEL W3	DEP W1	DEP W2	DEP W3
Boys	.12(.27)	.20(.49)	.15(.34)	1.24(.62)	1.30(.78)	1.30(.71)
Girls	.07(.25)	.07(.18)	.07(.17)	1.68(.74)	1.79(.80)	1.81(.79)

Note. DEP = Depressive symptoms; DEL= Delinquency; W1 = wave 1; W2 = wave 2; W3= wave 3

Table 3. Means and SD's for Ethnic Minority versus Ethnic Majority Adolescents' Delinquency and Depressive Symptoms across the Three Waves

Ethnicity	DEL W1	DEL W2	DEL W3	DEP W1	DEP W2	DEP W3
Ethnic Minority	.08(.21)	.16(.50)	.12(.32)	1.53(.75)	1.55(.85)	1.66(.86)
Ethnic Majority	.09(.25)	.12(.31)	.12(.29)	1.39(.68)	1.50(.78)	1.47(.73)

Note. DEP = Depressive symptoms; DEL = Delinquency; W1 = wave 1; W2 = wave 2; W3= wave 3

($F(1, 535) = 4.66$, $p = .03$) and wave 3 ($F(1, 322) = 4.49$, $p = .04$), but not at wave 2. These significant differences in levels of delinquency and depressive symptoms across adolescent phase, gender and ethnicity underscore the importance of exploring moderation by these variables in the hypothesized link between delinquency and depressive symptoms. The correlations for the entire sample can be seen in Table 4. The co-occurrence of delinquency and depressive symptoms in the entire sample was only significant in wave 2.

Table 4. Correlations between Variables of Interest

	1	2	3	4	5	6
1 DEL W1	-					
2 DEL W2	.45**	-				
3 DEL W3	.34**	.47**	-			
4 DEP W1	.07	.01	.02	-		
5 DEP W2	-.02	.13**	.10	.55**	-	
6 DEP W3	-.04	-.01	.04	.49**	.65**	-

Note. ***p*<.01; DEP = Depressive symptoms; DEL= Delinquency; W1 = wave 1; W2 = wave 2; W3= wave 3

Main analyses

The cross-lagged path models for the full/overall sample, per gender, per adolescent phase, per adolescent phase by gender, and per ethnicity are depicted in figures below.

Overall model

In the overall model (Figure 1), higher levels of delinquency modestly predicted lower levels of depressive symptoms over the years.

Adolescent Phase model

No cross-lagged paths were present in the early adolescent model (Figure 2), and although delinquency predicted lower levels of depressive symptoms across the years in the mid/late adolescent model (Figure 3), there was no significant adolescent phase moderation effect.

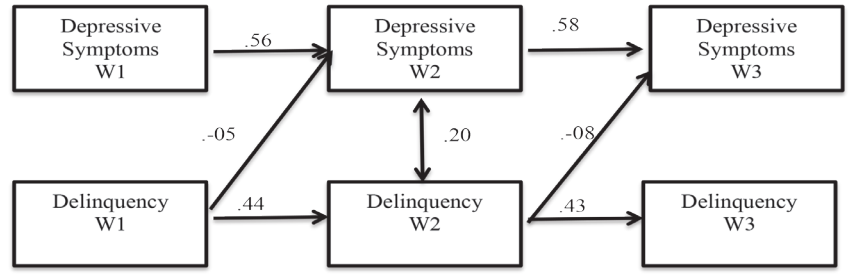

Figure 1. Overall model with full sample. Only significant paths are depicted. Two wave stability paths are not depicted.

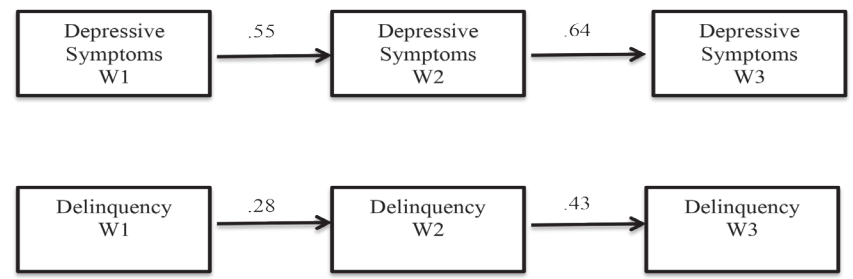

Figure 2. Early adolescents (Adolescent phase multigroup model). Only significant paths are depicted. Two wave stability paths are not depicted.

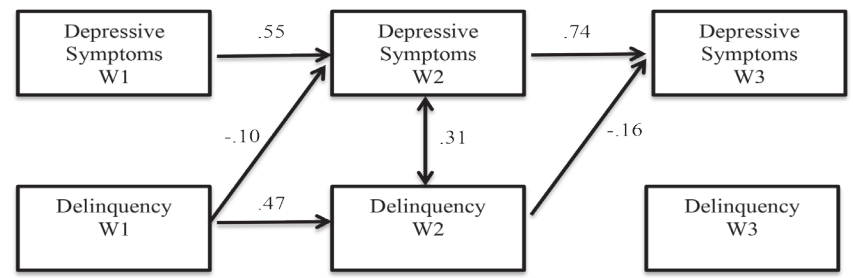

Figure 3. Mid-Late adolescents (adolescent phase multi group models). Only significant paths are depicted. Two wave stability paths are not depicted.

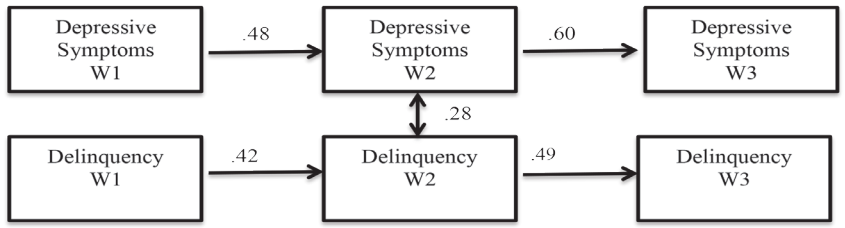

Figure 4. Boy model (Gender multi-group model). Only significant paths are depicted. Two wave stability paths are not depicted.

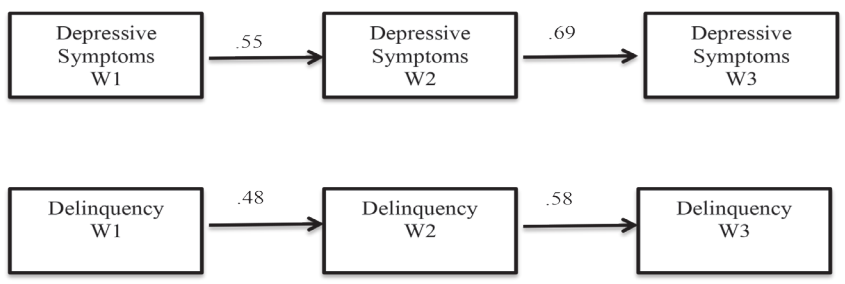

Figure 5. Girl model (gender multigroup model). Only significant paths are depicted. Two wave stability paths are not depicted.

Gender model

We found no cross-lagged paths when we separated boys (Figure 4) and girls (Figure 5).

Gender by Adolescent Phase

The multi-group models for the gender by adolescent phase analyses showed that there was a positive link from delinquency to depressive symptoms for early adolescent girls (β=.11; *p* = 04). However, this link was negative in mid/late adolescent girls (β = -.18; *p* <.01 for delinquency in wave 1 to depressive symptoms in wave 2; and β = -.12; *p* <.01 for delinquency in wave 2 to depressive symptoms in wave 3). Specifically, higher levels of delinquency predicted fewer levels of depressive symptoms. As for boys, no cross-lagged links were found for early adolescents. However for mid/late adolescent boys there was a positive link from depressive symptoms to delinquency (β = .15; *p* =.03 for depressive symptoms in wave 1 to delinquency in wave 2; and β = .31; *p* =.03 for depressive symptoms in wave 2 to delinquency in wave 3), such that higher levels of depressive symptoms predicted

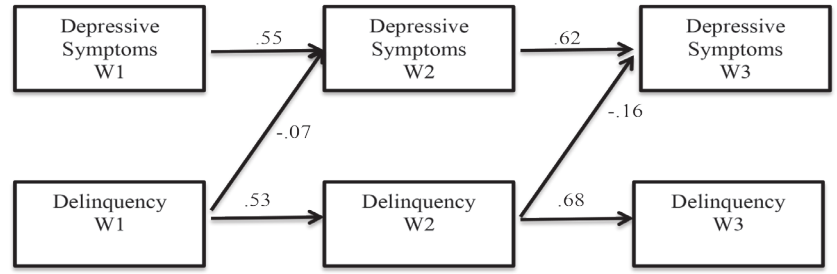

Figure 6. Ethnic minority model (Ethnicity multi-group model). Only significant paths are depicted. Two wave stability and SES paths are not depicted.

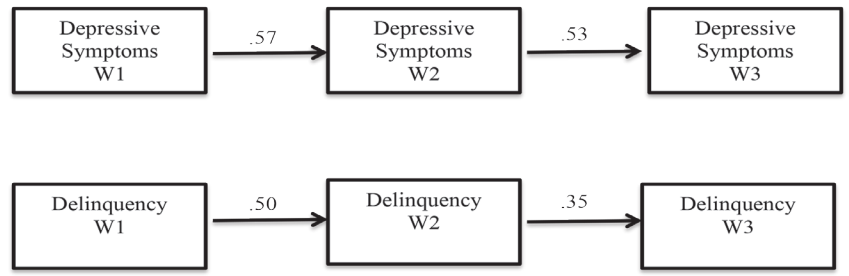

Figure 7. Ethnic majority model (Ethnicity multi-group model). Only significant paths are depicted. Two wave stability and SES paths are not depicted.

higher levels of delinquency. Moreover, this link was significantly different from the respective link in mid/late adolescent girls Wald $\chi 2$ (1) = 3.91, *p* <. 05) and from that respective link in early adolescent boys Wald $\chi 2$ (1) = 4.17, *p* = .04), thus a significant moderation effect was present.

Ethnicity multi-group models

While controlling for SES, we found a significant negative link from delinquency to depressive symptoms in the minority sample (Figure 6), but not in the majority sample (Figure 7), however, there was no significant moderation effect.

Discussion

The current 3-year longitudinal study used two opposing models, that is, the Acting out model and the Failure model as theoretical frameworks to investigate the hypothesized longitudinal link between depressive symptoms and delinquency in adolescents. Furthermore, we investigated whether gender, adolescent phase, gender by adolescent phase, and ethnicity moderated the temporal order of these links. Whereas the Failure model suggests that delinquency predicts depressive symptoms, the Acting out model suggests that depressive symptoms predict delinquency. We generally found medium to large stability for both depressive symptoms and delinquency, thus prior levels of these problem behaviors were robust predictors of future problem behaviors in the same domain, and the rank order of adolescents on these problem behaviors remained stable over time. These stability effects were higher or comparable to what was found in similar studies (see e.g., Overbeek et al. 2001; Van der Giessen et al., 2013). Moreover, while controlling for stability and cross-lagged paths, we found a significant positive association between depressive symptoms and delinquency at wave 2 in the overall model, in boys and in mid/late adolescents, which was comparable in size to previous cross-lagged panel studies (i.e., Van der Giessen et al., 2013). That the co-occurrence was particularly present in mid-adolescence is in accordance with the literature (for a review see: Wolff & Ollendick, 2006).

As for the cross-lagged paths, we found support for both the Failure model and Acting out model. Namely, for early adolescent girls, higher levels of delinquency predicted higher levels of depressive symptoms, which is in accordance with the Failure model, and for mid/late adolescent boys, higher levels of depressive symptoms predicted higher levels of delinquency, which is in accordance with the Acting out model. Interestingly, in the overall model, we found an unanticipated link: that is, higher levels of delinquency predicted lower levels of depressive symptoms one year later. Follow-up multi-group models showed that this link was particularly present in mid/late adolescent girls. This link was also particularly found in the ethnic minority subsample, but no moderation effect of ethnicity was present. These negative cross-lagged paths from delinquency to depressive symptoms are not consistent with the Failure model or the Acting out model. Interpretations of these findings are discussed below.

Longitudinal links between Depressive Symptoms and Delinquency

In accordance with the Failure model, follow-up gender by adolescent phase analyses showed that delinquency in early adolescent girls predicted depressive symptoms one year later. To our knowledge, only one previous study investigated similar moderation of adolescent phase effects (i.e., Overbeek et al., 2001) but found no such effects and the results of previous studies that have investigated gender moderation effects have been mixed. However, we could not locate any studies that investigated "gender by adolescent phase" effects in the link between depressive symptoms and delinquency. Thus our results that the Failure model might be most relevant for early adolescent girls await to be replicated. Nevertheless, perhaps our results suggest that particularly early adolescent girls' delinquency is a risk factor for depressive symptoms because in accordance with societal norms, early adolescents (compared to older adolescents), and particular girls are expected to be the least deviant. Thus, delinquent early adolescent girls might be rejected quicker by their social circle which could cause them to pull back from society, and in turn this might ultimately lead to depressive symptoms. This speculation is supported by a study that showed that kindergarten children who exhibit aggressive/violent and oppositional defiant behaviors were consequently rejected and victimized by their peers, which predicted internalizing problems (including depressive symptoms) in fourth grade (Van Lier & Koot, 2010). Although these cascading effects were equal for boys and girls, they await to be replicated in an adolescent sample to determine whether they might be more relevant for girls during early adolescence.

Next, support was also found for the Acting out model in mid/late adolescent boys. Interestingly, most studies do not find support for the Acting out model (but see e.g., Beyer & Loeber, 2003), however our findings suggest that this is perhaps the case because studies do not consider gender by adolescent phase moderation effects. Interestingly, delinquency is known to peak in mid/late adolescents (around ages 15-19), and particularly boys are overrepresented in delinquency statistics (e.g., Farrington, 1986; Puzzanchera, Adams & Hockenberry, 2012). Thus, reasoning from the Acting out model, perhaps around the peak of delinquency during mid/late adolescence, boys in particular try to mask their depressive symptoms by engaging in heightened levels of delinquency.

Finally, in the overall sample, in the ethnic minority sample and in mid/late adolescent girls, we found a surprising link that is not in line with the Acting out model and/or the Failure model, namely, higher levels of delinquency predicted lower levels of depressive symptoms one year later. Although no ethnicity moderation effect was found for this link (while controlling for SES), higher delinquency scores significantly predicted lower depressive symptoms one year later in ethnic minority youth, and although this negative relationship also existed in ethnic majority youth, it was not significant. In contrast, an adolescent phase by gender moderation effect was present for this link, such that the negative link from delinquency to depressive symptoms in mid/late adolescent girls was significantly different from that respective link in early adolescent girls (as discussed above this link was positive in early adolescent girls). These findings suggest whereas delinquency predicts higher depressive symptoms in early adolescent girls, when girls get older delinquency could become a protective factor against depressive symptoms. However, to the best of our knowledge, no study has reported a negative

longitudinal link from delinquency to depressive symptoms in adolescence. Hence, replication would be essential, and thus these findings should be interpreted with caution.

Strengths, limitations and future research

The current study is unique in that it included an ethnically and socioeconomically-diverse sample that was large enough to investigate important understudied moderators in the link between delinquency and depressive symptoms. Furthermore, the current study used strict cross-lagged panel models accounting for concurrent associations, stability, and prior levels of the behaviors of interest. But there are some limitations that should be mentioned also. First, there was a mismatch between the time frame adolescents had to report on their delinquent behaviors and depressive symptoms. Specifically, adolescents had to report the presence of depressive symptoms over the last 6 months, whereas they reported on their delinquent behaviors in the last 12 months. Whether this affected the association between these two behaviors cannot be traced, but the substantial association we found between delinquency and depressive symptoms at wave 2 imply that the difference in time frame did not obscure existing associations between these two behaviors. Additionally, although cross-lagged panel models are highly informative and rigorous, they do not account for growth/decline in variables of interest, which could also be relevant to take into account (see e.g., Beyers & Lober, 2003; Measle et al., 2006). Finally, and in the same vein, although cross-lagged panel models account for reversed effects, prior levels of behaviors, stability and concurrent associations, and are thus among the statistical models that come close to facilitating causal inferences, strictly speaking, causality can only be determined with experimental research.

Conclusion

The current study showed that a co-occurrence of delinquency and depressive symptoms appears particularly in mid-adolescence. However the longitudinal link between these two problem behaviors is complex, as it is qualified by a gender by adolescent phase moderation effect. No ethnicity moderation effects were found. As for the significant adolescent by gender moderation effects, the current findings suggest that the Failure model that predicts that higher levels of delinquency lead to higher levels of depressive symptoms, might be particularly meaningful for early adolescent girls. Additionally, the reversed link as predicted by the Acting out model, that is, higher levels of depressive symptoms to higher levels of delinquency was particularly relevant for mid/late adolescent boys. Thus both of these prevailing models on the developmental link between delinquency and depressive symptoms are relevant, but as the current results suggest, they are relevant in different phases of adolescence and their relevance differs for boys and girls. Hence, these results demonstrate why particularly gender and adolescent phase moderation effects are essential to consider when investigating the link between these two dissimilar behaviors. Although we did not find any ethnicity moderation effects in the linkages, the ethnic differences (i.e., ethnic minority youth reporting more depressive symptoms than ethnic majority youth in wave 1 and 3) we found show that ethnicity is still important to consider. Future studies with preferably ethically and socio-economically diverse samples spanning multiple adolescent phases are needed to further explore some of the unique findings and hypotheses put forward in the current study.

Chapter 10

Alcohol and Cannabis Use in Adolescents in the Caribbean and Europe: The Role of Intentions and Substance Use-Specific Parent-Adolescent Communication

Author note:
This chapter is based on a manuscript in preparation to be submitted.
I.N. Defoe developed the study concept and design, and J.S. Dubas and M.A.G. van Aken gave advice and feedback. I.N. Defoe and J.S. Dubas oversaw the data-collection. I.N. Defoe performed the data-analysis and interpretation. I.N. Defoe drafted the manuscript, and J.S. Dubas, and M.A.G. van Aken provided critical revisions.

Abstract

Using the Theory of Triadic Influence (TTI) as a theoretical framework, the current two-wave longitudinal study compared hypothesized links between adolescent alcohol and cannabis use on St. Maarten (*N*= 350 at baseline) versus The Netherlands (*N* = 602 at baseline). Furthermore, we examined whether intention to use these substances and parent-adolescent specific communication about these substances predicted the use of these substances, while additionally controlling for gender and age. For adolescents on St. Maarten, higher levels of alcohol use predicted higher levels of cannabis use, whereas for adolescents in the Netherlands, a reversed link was true, that is, higher levels of cannabis use predicted higher levels of alcohol use. The temporal order found for St. Maarten is more in line with the TTI. Next, for both the St. Maarten and the Netherlands samples, intention to use alcohol predicted alcohol use, which corresponds with a strong assertion of the TTI, but bidirectional links were also found. Finally, we did not find that intention to use cannabis predicted cannabis use, nor did parent-adolescent specific communication about the use of substances predict alcohol or cannabis use. Thus both cross-national similarities and differences were found. These findings are discussed within a TTI framework.

Key-words: culture, substance use, intentions, parenting practices, adolescence

Can you think of some reasons why you or other youth use soft drugs?
"No, to be honest not. I think it's the same as with smoking and drinking".
adolescent participant [44]

"So what we get drunk? So what we smoke weed? We're just having fun. We don't care who sees. So what we go out? That's how it's supposed to be. Living young and wild and free" (Wiz Khalifa and Snoop Dogg ft. Bruno Mars, 2011). Indeed, these lyrics are the epitome of how some adolescents celebrate their increasing freedom. That is, the adolescence phase is marked by exploration, experimentation and excitation, which could involve substance use, particularly alcohol and cannabis/marijuana use. Adolescence is a phase wherein individuals increasingly navigate the world independent of their parents' supervision, and this phenomenon is globally evident, from the Caribbean islands, like St. Maarten to European countries like the Netherlands. For many adolescents, during this exploration phase they increasingly come in contact with popular substances in the youth culture such as alcohol and cannabis. Although experimentation to some extent could be adaptive (Baumrind, 1987), experimenting with such addictive substances could particularly be harmful for the still developing brain and the psychologically vulnerable adolescent (see e.g., Marshall, 2014; Parkes et al., 2007; Pistis et al., 2004; Grant & Dawson, 1998; Moore et al., 2007). What is more, is that individuals who use both alcohol and cannabis typically use these substances at the same time, and recent accumulating research shows that such simultaneous use makes alcohol and cannabis even more dangerous (Subbaraman & Kerr, 2015; Pacek, Malcolm, & Martins, 2012). Yet, research is sorely lacking on the co-occurrence of alcohol and cannabis use in adolescents, and the limited research rarely capitalizes on longitudinal designs (cf Pacek, Martins, & Crum, 2013) to ascertain the temporal order of these behaviors.

The Theory of Triadic influence (TTI; Flay & Petraitis, 1994) hypothesizes that the use of of more acceptable or licit substances such as alcohol could subsequently trigger the use of other substances such as cannabis (see also: gate-way drug hypothesis; Kandel, 1975), and one possible explanation for this link is that the use of alcohol produces favorable attitudes for cannabis (Flay et al., 1999). However, besides that such related behaviors might predict each other, The TTI further suggests that distal factors, such as social factors like parents' behaviors and attitudes towards alcohol and cannabis use, and adolescents' intention to use these substances predict the use of these substances. Finally, the TTI predicts that there might be ultimate level common causes of alcohol and cannabis use (Flay, Petraitis, & Hu, 1995), but that even such overlapping causes might behave in different ways across similar risk-taking behaviors (Flay et al., 1995).

44 The original quote as it appeared in the Dutch language: "Nee eerlijk gezegd niet. Denk hetzelfde als bij roken en drinken.."

To this end, the goals of the current two-sample longitudinal paper that uses a sample of Dutch-Caribbean adolescents from St. Maarten and a sample of Dutch-European adolescents from The Netherlands (i.e., two (island-) countries within the Kingdom of The Netherlands) is two-fold. First, using two waves of data, and while controlling for age and gender, we investigate the temporal order of alcohol and cannabis use in these two samples. Secondly, we investigate linkages between (a) intention to use alcohol and cannabis the following year, (b) parent-specific communication about the use of these substances and (c) the use of these substances in adolescents the following year.

Theory of Triadic Influence

The TTI is a comprehensive meta-theory that posits that three *domains/ streams of influence* consisting of intrapersonal, social and cultural domains are relevant for predicting adolescent risky behaviors. The TTI hypothesizes that risk-factors in these domains influence adolescents' risky behaviors such as substance use because they have an effect on the *intention/decisions* of adolescents about substance use, which is directly predictive of adolescents' engagement in substance use. Furthermore, a unique hypothesis of the TTI is that risk-factors in each stream of influence has different distances from the actual risky behavior, namely, proximal (i.e., immediate), distal (i.e., predisposing) and ultimate (i.e., underlying). Extrapolating from the TTI, the current paper investigates whether parent specific communication about alcohol and cannabis use (*distal* level influence of the social stream) predict adolescents' intentions (*proximal* level of influence) about substance use while controlling for age and gender (ultimate level of the intrapersonal stream; Dusseldorp, Klein, & Velderman 2014; Flay, Snyder, & Petraitis, 2009). The TTI proposes that such a process occurs because parents' behaviors and attitudes concerning adolescent substance use contribute to adolescents' perceived norms about these substances which ultimately lead to the intention/decision to engage or not to engage in substance use. Moreover, we also investigate adolescents' intention to use alcohol and cannabis and parent specific communication about these substances directly predict adolescent engagement in these behaviors. These TTI-based hypotheses have been investigated primarily in samples from Europe and from the USA (e.g., Dusseldorp et al., 2014), but studies that have tested such important psychological theories rarely use samples from the Caribbean or Latin America more generally.

St. Maarten

St Maarten/Saint-Martin (or St. Martin collectively) is constitutionally two countries but geographically one island in the Caribbean. The Southern half of the island "St. Maarten" is a constituent country of the Kingdom of the Netherlands, whereas the Northern half of the island "Saint-Martin" is an overseas collectivity of France[45]. For the current study, a sample of adolescents from St. Maarten is used. Both alcohol use and cannabis use are common on St. Maarten, but is the former is far more socially acceptable than the latter. Like all Caribbean islands, St. Maarten celebrates carnival wherein alcohol is an important beverage (Barrows & Room, 1991). With over 100 nationalities, St. Maarten is an ethically and racially diverse island, with the third largest ethnic group consisting of Jamaican-St. Maarteners (Arrindell, 2014)[46]. Jamaica, is one of the larger and well-known Caribbean islands world-wide, because of its reggae music and Rastafari religion, which are also linked to the popularization of cannabis use. However, cannabis is technically illegal on St. Maarten, although that law is rarely enforced, and purchasing alcohol under age 18 is also illegal, but typically no identification card (ID) is requested when purchasing alcohol.

Compared to the Netherlands and other countries in the Western world, scientific research on St. Maarten is marginal. Moreover, most existing research on St. Maarten is descriptive and cross-sectional. Thus, references will sometimes be made to research on larger Caribbean islands (e.g., Jamaica), when no such research exists on St. Maarten. A recent large scale research on St. Maarten showed that 72.6% of 12-19 year olds on St. Maarten have experience with drinking alcohol at least once (PAHO, 2013), similarly another large scale study (*N*=1078) showed that this prevalence rate was 79.4% for adolescents between 14-19 years (*M*age = 15.6) (McBride et al., 2015). Furthermore, 7% of the adolescents had experience with binge drinking, and 23.6% have ever been drunk (PAHO, 2013). As for cannabis use, whereas 28.5% of adolescents in a study conducted in 2001, reported to have used cannabis at least once (McBride et al., 2005), more recently, at least 10 years later this amount dropped to 20.2% (PAHO, 2013). As for the co-occurrence of alcohol and cannabis use, these two behaviors have been shown to be associated in at least two studies with St. Maarten youth (McBride, 2005; PAHO, 2013). Another study including 9 Anglophone Caribbean islands showed that the use of alcohol and cannabis were significantly related, and that although both alcohol and cannabis use were more prevalent in male adolescents, the significant association between these two behaviors was larger in female adolescents (Ohene, Ireland, & Blum, 2005). However, these studies were cross-sectional, thus the temporal ordering of cannabis and alcohol use could not be determined.

We could not locate any studies conducted on St. Maarten that investigated *intention to use substances* and *parent-adolescent communication* about substances in relation to adolescent substance use. Nevertheless, as for the parent-adolescent

45 The original inhabitants of St. Maarten were Carib-Indians, before the European colonizers settled on the Caribbean island and eventually brought Africans to St. Maarten and to the rest of Latin America as part of the Transatlantic slave trade. Interestingly, although St. Maarten is a Dutch island, it has a more (Anglophone Northeastern) Caribbean culture (Arrindell, 2014) mixed with considerable influence from the USA.

46 Over 70% percent of St. Maarten's population was born elsewhere, with most of the population being natives of other Caribbean islands or Latin America, more generally.

relationship more broadly, at least one study reported that a "great" adolescent-parent relationship was related to lower levels of alcohol use among 14-18 year old St. Maarten youth, but surprisingly only a "great" relationship with father (but not with mother) was related to lower levels of drug use (which also included marijuana use) (Mc. Bride et al., 2005). Additionally, another study conducted on the Bahamas islands, reported that parental communication predicted parental monitoring knowledge, however only parental monitoring predicted substance use in 6th grade Bahamian adolescents (Cottrell et al., 2007). Finally, a longitudinal study showed that lower parental control at ages 11-13 predicted higher levels of substance use (including alcohol and marijuana use) in 14-15 year old Bahamian youth (Wang et al., 2013).

The Netherlands

The Netherlands, is a country in Western Europe, it is the largest country within the Kingdom of The Netherlands, and it is the only country in The Kingdom of the Netherlands that is located in Europe. The Netherlands is a multi-cultural society with 21.7% of its population consisting of foreign migrants (Statistics Netherlands, 2016a). The Netherlands is well-known for its liberal views on cannabis use. Cannabis is legal in the Netherlands to some extent, making The Netherlands one of the few countries to legalize cannabis for persons 18 years and older. There are also liberal views concerning alcohol use in the Netherlands. However, recently in 2014, the legal drinking age was increased from age 16 to age 18.

The majority (79%) of 12-18 year olds in the Netherlands have had an alcoholic drink at least once, which is similar to the prevalence rates on St. Maarten. However, 67% of these youth in the Netherlands have experience with binge drinking, which is almost 10 times as high as the prevalence rate in St. Maarten youth. Additionally, 46.1% of adolescents aged 11-16 in the Netherlands have reported being drunk, which is almost twice as high compared to St. Maarten youth (Stichting Nederlands Instituut voor Alcoholbeleid [STAP], 2011). As for cannabis, in 2011, 17.3% of adolescents between the ages of 12-19 reported to have used cannabis at least once in the Netherlands (Verdurmen et al., 2012), which is similar to the prevalence rate on St. Maarten in 2013. As for the relationship between alcohol and cannabis use in adolescents in the Netherlands, alcohol use and drugs (including cannabis) abuse were shown to be interrelated (i.e., "cluster"), but only in young adolescents (12-15 years) (Van Nieuwenhuijzen et al., 2009).

Next, as for TTI-based predictors of substance use, a large scale longitudinal study (*N*=1023) showed that intention to start using cannabis prospectively predicted cannabis use in early adolescents in the Netherlands (Malmberg, 2012), similarly, another longitudinal study with 12 year olds showed that intention not to use cannabis and alcohol predicted lower levels of these behaviors 6 months later (Carvajal, 2002)[47].

47 A composite score which also included tobacco use was included.

Research on parent-adolescent substance use-specific communication is also rare in the Netherlands, but such research is still more common than on St. Maarten. Studies on a link between frequency of parent-adolescent alcohol specific communication and adolescent alcohol use have been mixed, however (cf Mares, van der Vorst, Engles, & Lichtwarck-Aschoff , 2011). For example, there is some evidence that frequency of communication predicts lower levels of alcohol use (Mares et al., 2011), while other studies have shown that such communication predicts higher levels of adolescent alcohol use (van der Vorst,, Engels, Meeus, Deković, & Van Leeuwe, 2005; see also Van der Vorst, Burk, & Engles, 2010), and yet other studies found no significant longitudinal links (e.g., Van den Eijnden, van de Mheen, Vet, & Vermulst, 2011).As for parent-adolescent cannabis use-specific communication, we could locate no studies that have measured this research question, nonetheless, one recent study demonstrated that restrictive cannabis-specific parental rules predicted lower levels of cannabis use in 12-16 year olds (Vermeulen-Smit, Verdurmen, Engels, & Vollebergh, 2015).

Present study

The TTI postulates that adolescents' intention to use substances and parents' behaviors and attitudes contribute to substance use in adolescents. Additionally, the TTI also predicts that alcohol use might further predict the use of cannabis. The current cross-national longitudinal study was designed to investigate these TTI-based hypotheses. Moreover, theoretically, cannabis use could perhaps also predict alcohol use, and the use of both of these substances might predict adolescents intention to use these substances in the future (although not an explicit hypothesis of the TTI). Thus we also investigate plausible bidirectional effects, and stability effects as the TTI predicts that prior involvement with substance use is the best predictor for future substance use (Flay et al., 1995; see Figure 1). Finally, we additionally control for age and gender. This two sample study is based on two waves of data from adolescents on St. Maarten and The Netherlands, who were either in their 1st or 3rd year of high school at wave 1.

Method

The Netherlands

Participants

Participants in the current study were from the first two waves of a 3-wave longitudinal study in the Netherlands on adolescent risk-taking. The data-collections began in 2012, and were conducted once per year. At baseline, most adolescents (93.2%) reported that they were born in the Netherlands, with 61.6% identifying as Dutch while the remaining 38.4% identified with other ethnic minority groups in

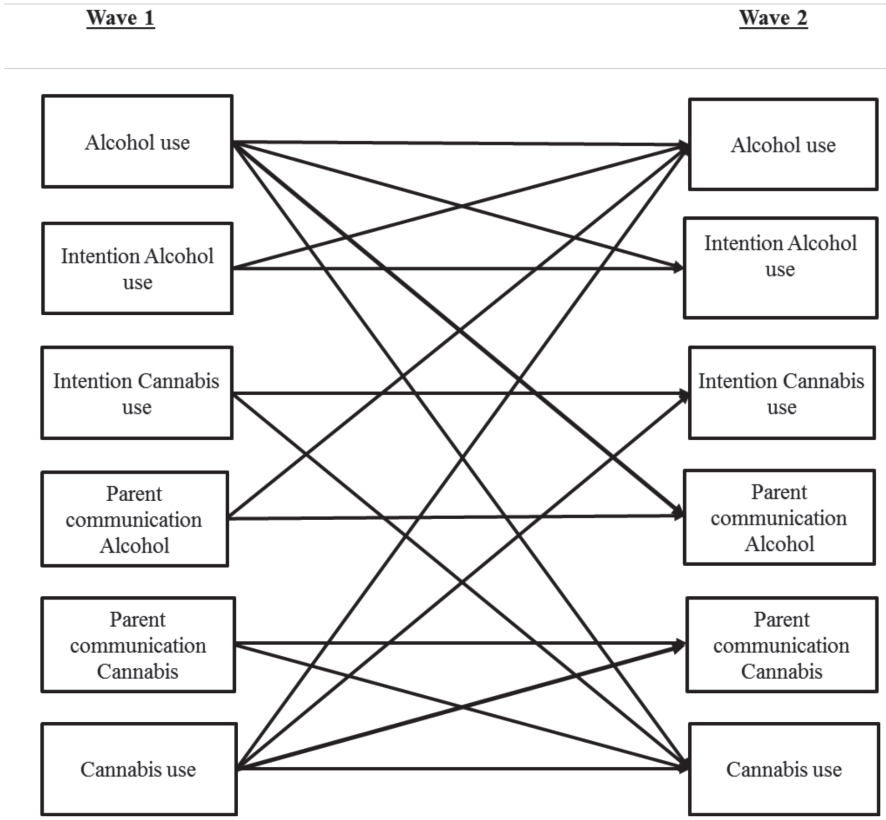

Figure 1. Investigated paths (control variables and correlations are not depicted).

the Netherlands. Specifically, 9.3% identified as Turkish or Turkish-Dutch, 7.4% as Surinamese or Surinamese-Dutch, 5.5% as Moroccan or Moroccan-Dutch, 1.1% as (Dutch-)Caribbean, and 15.1% identified with various other ethnicities. In wave 1 and 2 the sample consisted of 602 (46.50% female) and 582 (45.40% female) adolescents respectively. At baseline adolescents (*M*age13.50 years (*SD* = 1.23))[48] were in their 1st or 3rd year of the "preparatory middle-level applied education" or "higher general continued educational" track high schools. Nearly half (47.7%) of the 602 adolescents were unaware of their mothers' highest level of completed education. This was partly because their mothers (12.1 %) were born abroad, in countries where the educational system was not comparable to the Dutch educational-system.

48 For one adolescent we did not have information on age.

Procedure

The data-collections took place at schools during regular school hours, and were led by trained research assistants. A total of 8 high-schools in 6 different regions in the Netherlands agreed to participate, and parents received information letters about the research project as well as dissent letters. Participants could choose to receive a chocolate candy worth 2 euros as a participation prize, or have their name entered in a raffle for a chance to win a 50 euro gift voucher (for extensive information on the design of the study see Defoe, Dubas, Somerville, Lugtig, & van Aken, in press).

Measures

Alcohol use was assessed with five items that were adapted from previous studies (e.g., Monshouwer, 2008, Nieuwenhuijzen, 2009). The first question was: *Do you drink alcohol?* Answer categories ranged from 0 = No, I have never drunken alcohol to 5 = Yes, every day. The remaining four questions measured risky alcohol behaviors such as binge drinking, engaging in alcoholic games and pre-drinks. An example item: *How many times during the past four weeks did you drink five or more alcoholic drinks in a row? For example at a party or in one night?* The answer categories ranged from 0 = 0 times to 4= 6-8 times. A mean score was computed from the standardized items, with higher scores indicating more alcohol use. Cronbach's alpha for the Netherlands sample was .89 in wave 1 and 2, indicating good reliability. Cronbach's alpha for the St. Maarten sample was .86 and 87 in wave 1 and 2, respectively indicating good reliability.

Cannabis use was assessed with one question, which was a similar question to what is used in previous studies (e.g., Monshouwer 2008; Reijneveld, 2002; Nieuwenhuijzen et al., 2009), namely: *Do you use soft drugs? (cannabis, weed, hash).* The answer categories ranged from 0= No, I have never used marihuana to 5= Yes, every day.

Intentions to use alcohol and cannabis were measured with one question each. Namely, *Do you think that you will (still) drink alcohol next year*? For cannabis: *Do you think that you will (still) be using soft drugs next year?* The answer categories for both items were: 1= Extremely unlikely, 2= Moderately unlikely, 3= Somewhat unlikely 4= Not Sure , 5= Somewhat likely, 6= Moderately likely and 7= Extremely likely.

Parental communication about alcohol and cannabis use were measured with one item each. Namely: *Do you talk with at least with one of your parents about responsible drinking of alcohol (or about preventing the use of alcohol)?* For cannabis: *Does at least one of your parents talk with you about preventing the use of marihuana?* Answer categories, were: 0 = never, rarely, 1=sometimes, 2= often, 3=very 4 = often.

Strategy of Analyses

We investigated the hypothesized links with transactional or autoregressive cross-lagged models (Jöreskog, 1970) in Mplus version 7. The autoregressive paths signify continuity within the variables, which were tested by regressing the repeatedly assessed variables on their immediate prior value (i.e., stability effects). The cross-lagged (cross-time) paths represent associations between the repeated assessments of the variables. Finally, the model also allowed for cross-sectional (or within-wave) correlations among the parallel assessed variables (see figure 1, for the paths that were included in the models). Finally, we modeled gender and age as control variables. That is, we regressed these variables on all of the variables in wave 1 and 2 (Newsom, 2015).

Model fit was determined using the Comparative Fit Index and Tucker Lewis Index (CFI and TLI; acceptable values > .90) (Bentler, 1990) and the root mean squared error of approximation (RMSEA; acceptable values < .08) (Browne & Cudeck, 1993). The model had a good fit to the data (χ^2 (20) = 54.36; p < .01; TLI = .93; CFI = .98 and RMSEA = .05). A possible non-normal distribution of the variables was accounted for by using a robust maximum likelihood (MLR) estimator, in order to ensure robust standard errors, and this estimator also allows the inclusion of missing cases.

St. Maarten

Participants

The adolescents from St. Maarten in the current study were drawn from a study that was very similar to the above-described research project that was conducted in the Netherlands. The main differences are that the project in the Netherlands consisted of 3 waves, whereas on St. Maarten it consisted of 2 waves, additionally whereas parents took part in the Netherlands, on St. Maarten only adolescent reports were gathered. On St. Maarten, the data-collections took place in January 2013 (first wave), and January 2014 (second wave).

In wave 1 and 2 the sample consisted of 350 (52.9% female) and 282 (59.8% female) adolescents respectively. At baseline, 72% of the adolescents indicated that they were born on the Dutch side of the island, whereas 7.8% were born on the French side of the island. The remaining adolescents were born on other (Dutch-) Caribbean islands, and 4% were born in the Netherlands. Most of the adolescents (68.2%) identified as a *St. Maartener*, 10.4% as Dutch-Caribbean, 9.8% as Caribbean, 6.5% as a Dutch, and the remaining adolescents identified with various other ethnicities. Similar to the Netherlands, lower vocational education (VMBO, but called VSBO on St. Maarten; 78%) students and higher general secondary education (HAVO; 22%) students participated, and these participants were divided over two cohorts. Namely, at the start of the study, participants were either in their first (46%%) of third (54%) year of high school. The adolescents were between the ages 11-19 at wave one (with most adolescents being between the ages 12-17; mean age 14.19 (SD=1.67)). In the second wave, the adolescents had a mean age of 15.06 (*SD* = 1.57).

More than a third of the adolescents (38.4%) were unaware of their mothers' highest level of completed education. This was partly because their mothers (15.8 %) were born abroad, in countries where the educational system was not comparable to the educational-systems on St. Maarten. Of the participants who knew this information, 37% of their mothers completed high school, and 18.1 % completed university.

Procedure

The two high schools on St. Maarten that were based on a Dutch-education curriculum participated in the study. Similar to the data-collections in the Netherlands, parents could sign a passive consent form if they did not want their children to participate in the research. The participants filled out the questionnaire at their high schools during regular school hours, under supervision of trained research assistants. The questionnaire, took about 45-60 minutes to complete, and experimental tasks followed hereafter. Movie tickets and lunch vouchers were raffled among the participants.

Measures

See this section for the Netherlands sample, as the measures used for St. Maarten and the Netherlands sample were identical.

Strategy of analyses

See this section for the Netherlands sample, as the strategy of analyses for St. Maarten and the Netherlands sample were identical. However, in the St. Maarten model an extra path from intention to use alcohol (wave 1) to intention to use cannabis (wave 2) was added to make the model fit better, as the CFI was .90, but the recommended value is >.90 (all the other fit statistics were adequate). The fit for the final model is: (χ^2 (19) = 32.93; p = .02; TLI = .93; CFI = .99 and RMSEA = .04).

Results

Descriptive findings

The correlations for wave 1 for the Netherlands are in Table 1, and the correlations for St. Maarten are in Table 2. A complete correlation table is available from the first author upon request. For both the Netherlands and St. Maarten, alcohol use and cannabis use were significantly correlated (r's = .49; .43 respectively) at baseline. The mean of alcohol use was .33 (SD=.71), .57 (*SD*=1.02) for wave 1 and 2 respectively for the Netherlands, and .61 (*SD*=.88) and .73 (*SD*=.96) for St. Maarten. The mean of cannabis use was .14 (SD=.59), and .32 (SD=.96) for wave 1 and 2 respectively for the Netherlands, and .38 (*SD*=.94) and .52 (*SD*=1.10) for St. Maarten.

Table 1. Correlations for Netherlands at wave 1

	1	2	3	4	5	6
1. Alcohol	-					
2. IntAlc	.642**	-				
3. ComAlc	.143**	.119**	-			
4. Drugs	.492**	.338**	.060	-		
5. IntDrug	.303**	.269**	.045	.612**	-	
6. ComDrug	.052	.081*	.647**	-.003	.001	-

Note. ***p*<.01; **p*<.05; IntAlc = Intention to use alcohol; ComAlc = parent-adolescent communication about alcohol; Drugs= Cannabis use; IntDrug= Intention to use Cannabis; ComDrug = parent-adolescent communication about cannabis

Table 2. Correlations for St. Maarten at wave 1

	1	2	3	4	5	6
1. Alcohol	-					
2. IntAlc	.556**	-				
3. ComAlc	.037	.023	-			
4. Drugs	.432**	.342**	.045	-		
5. IntDrug	.359**	.374**	-.033	.708**	-	
6. ComDrug	-.027	-.070	.352**	-.043	-.072	-

Note. ***p*<.01; **p*<.05; IntAlc = Intention to use alcohol; ComAlc = parent-adolescent communication about alcohol; Drugs= Cannabis use; IntDrug= Intention to use Cannabis; ComDrug = parent-adolescent communication about cannabis

As for prevalence rates, for The Netherlands sample, 23.1% of adolescents at wave 1, had experience with drinking alcohol at least once, whereas this percentage was 46.7% for St. Maarten. As for cannabis, in the sample of the Netherlands, 7.3% adolescents have used cannabis at wave 1, and on the St. Maarten, this percentage was 19.2%.When considering the prevalence rates *per* age (12 year olds versus 15 year olds), a somewhat similar pattern of cross-national differences emerge, particularly for older adolescents, for which substantial cross-national differences were found. Specifically, at age 12, youth who had experience with alcohol on St. Maarten (19.8%) was roughly 10% higher than 12 year olds in The Netherlands (7.9%). As for cannabis, prevalence rates were similarly low with none of the 12 year olds on St. Maarten having had experience with cannabis, and only 1.1% of the 12 year olds in The Netherlands had used cannabis at least once. The biggest differences between the countries were found for the 15 year olds. On St. Maarten 67.3% of the 15 year olds reported to have used alcohol at least once, compared to 49.7% of 15 year olds in the Netherlands. When it comes to cannabis, while 37.3% of the 15 year olds on St. Maarten have used cannabis, 16.8% of the 15 year olds in the Netherlands have used cannabis. When interpreting the results, readers should bear in mind that the sample sizes per age in the Netherlands were at least twice as large as the sample sizes on St. Maarten. For example, at wave 1, of the participants who reported on the alcohol experience question, 52 of these participants were 15 year olds in the St. Maarten sample, whereas, the sample size for the Netherlands was 113 for the 15 year olds.

As for binge drinking, and being drunk at wave 1, 26.1% and 14.1 % of youth from St. Maarten had experience with this in the last 4 weeks, whereas the prevalence rates for The Netherlands were 19.5% and 6.5%, respectively. As for using alcohol and cannabis at the same time (i.e.. together), for the sample of the Netherlands, 2.7 % have had experience with this at wave 1, and 9,8% have had experience with this at wave 2. For the St. Maarten sample, these percentages were 8.5% and 11.4% respectively.

On St. Maarten, 39.5% of the adolescents indicated that their parents do *not* talk to them about the use of alcohol, whereas this percentage was almost half as much in the Netherlands, where 20.5% of parents never talk to their adolescents about alcohol. Interestingly, for parental communication about cannabis use, however, the prevalence rates were very similar for St. Maarten and the Netherlands. Specifically, on St. Maarten, 27.7% of the parents never talk to their adolescents about cannabis use, and this percentage was 25.8% for parents in The Netherlands.

Main findings

In Figure 2, the significant stability and cross-lagged paths for the Netherlands are shown (the control variables age and gender are not depicted). For age, we found significant links showing that being older predicted higher levels of alcohol and cannabis use in wave 1 and 2, and being a boy predicted higher levels of

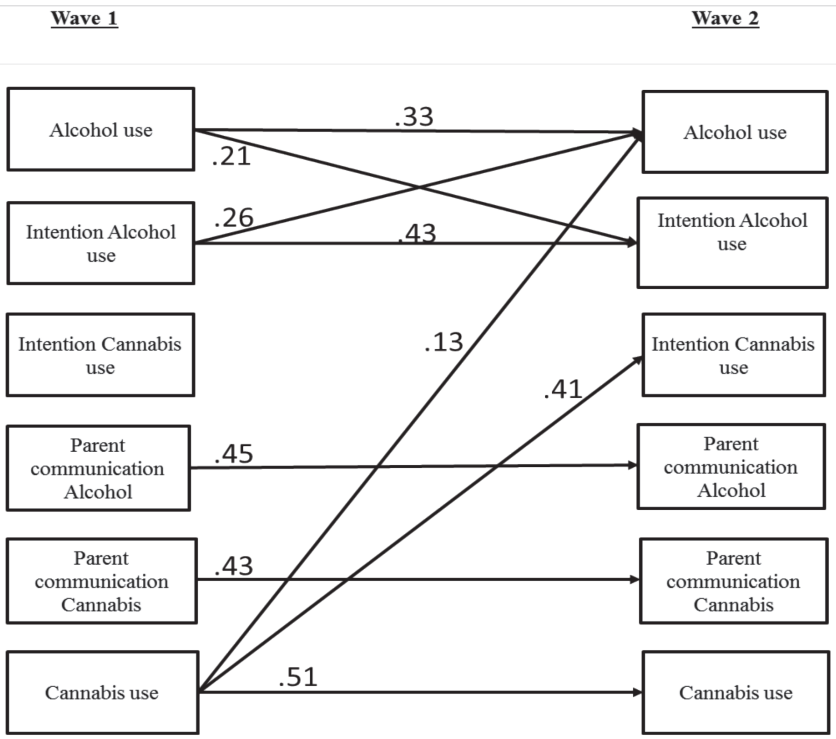

Figure 2. Path model for the Netherlands. Only significant paths are depicted.

cannabis use in wave 1 and 2. As for the variables of interest, intention to use alcohol predicted alcohol use, and a reversed link was also found. Additionally, cannabis use predicted alcohol use and intention to use cannabis.

In Figure 3, the significant stability and cross-lagged paths for St. Maarten are depicted (the control variables age and gender are not depicted). For age, we found significant links showing that being older predicted higher levels of alcohol and cannabis use in wave 1, and being a boy predicted higher levels of cannabis use in wave 1. Furthermore, similar to the Netherlands sample, intention to use alcohol predicted alcohol use, and a reversed link was also found. Additionally, alcohol use predicted cannabis use.

Discussion

Alcohol and cannabis are two common substances in youth culture, in both less-westernized regions such as the Caribbean and westernized parts of the world such as Western Europe. However, risk factors associated with alcohol and

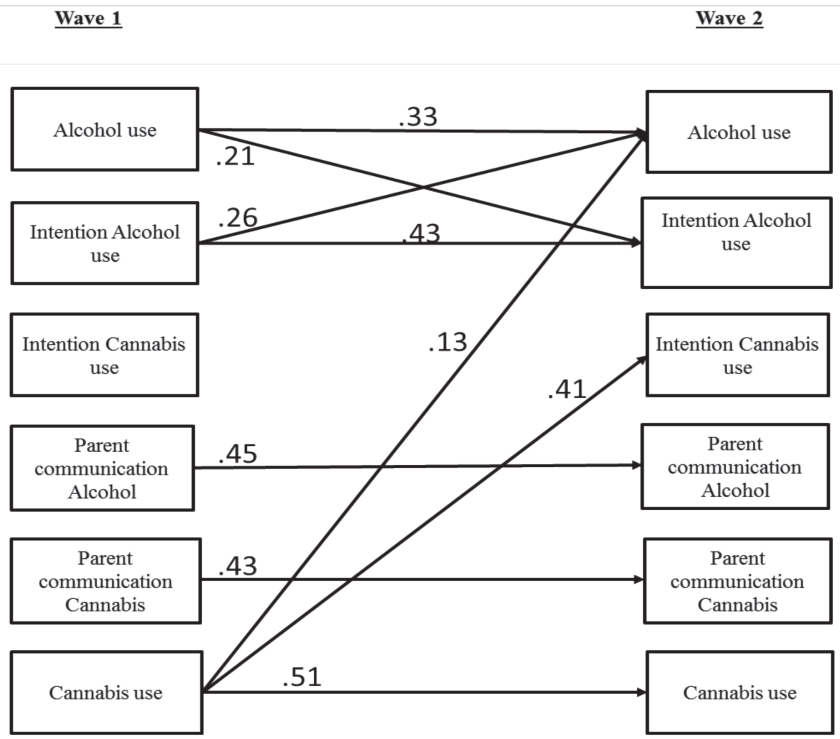

Figure 3. Path model for St. Maarten. Only significant paths are depicted.

cannabis use and their co-occurrence might differ across different parts of the world. Inspired by a TTI framework, the current two-wave cross-national study investigated whether the use of one of these substances increases the use of the other (i.e., the temporal order), and whether the TTI-based risk-factors *intention to use substances* and *parent-adolescent substance-use specific communication* predict these risk behaviors. Two samples of youth were used, a sample from St. Maarten (Dutch Caribbean) and a sample from the Netherlands (Western Europe). Strict SEM cross-lagged models per sample were employed that simultaneously tested the above-described multiple paths, while also estimating reversed effects, stability effects, concurrent associations and while controlling for age and gender. Finally, we also simultaneously tested for bidirectional links between intention to use these substances and parent-adolescent substance-use specific communication.

The prevalence rates for St. Maarten and the Netherlands showed only small differences for 12 year olds, but 15 year olds on St. Maarten had more experience with alcohol and cannabis use compared to 15 year olds in the Netherlands at the start of the study. Next, when it comes to simultaneous use of alcohol and cannabis, as explained in the introduction section, adolescents who use cannabis and alcohol

at the same time (i.e., together) are at higher risks for the detrimental consequences that such behaviors could have (e.g., Pacek et al., 2012). Prevalence rates for The Netherlands and St. Maarten were somewhat similar with regard to this, especially at wave 2. At wave 1, the prevalence rates were 2.7% and 8.5%, respectively, and at wave 2 roughly 10% of the adolescents on St. Maarten and the Netherlands have had experience with using alcohol and cannabis together. Furthermore, and consistent with the TTI and past empirical investigations, significant moderate correlations were found for alcohol and cannabis use for both youth in The Netherlands and on St. Maarten (e.g., for St. Maarten, see: PAHO, 2013, Mc Bride 2005; for the Netherlands see: Nieuwenhuijzen et al., 2009 for similar findings).

Next, intention to use alcohol and cannabis was positively correlated with the actual use of these substances for both (island-) countries. However, across the two (island-) countries, there were differences between the correlations for parental specific substance use communication on the one hand and the use of these substances, as well as the intention to use these substances on the other hand. Namely, for St. Maarten there were no associations between parent communications about substances with the use of these substances by adolescents, nevertheless parents who communicate with their adolescents about the use of alcohol, also communicate with their adolescents about the use of cannabis. For the Netherlands, the latter finding was also true, and the correlation was almost twice as high (.35 versus. 65, respectively). Additionally, and interestingly, frequency of parental communication about alcohol use in the Netherlands was correlated with *higher* levels of alcohol use, but no significant correlations were found for parental communication about cannabis use and the use of cannabis by adolescents in the Netherlands. As for comparisons with previous studies, we could locate no studies based on St. Maarten/ Caribbean youth or youth from the Netherlands that investigated this research question that relates to the *frequency* of parental communication (but for studies on the quality of parent communication and parental control in the Caribbean, see: Wang et al. (2013); and for the effects of cannabis-specific parental rules in the Netherlands see: Vermeulen-smit et al., 2015). Although research is clearly needed in both the Netherlands and the Caribbean when it comes to the frequency of parent cannabis-specific communication, nonetheless, the current findings that frequency of parental communication about alcohol is correlated with a *higher* use of alcohol by adolescents is consistent with some previous studies in The Netherlands (see e.g., Spijkerman et al., 2008; Van der Vorst et al., 2008). The latter finding goes against conventional wisdom, but it might suggest that parents who suspect alcohol use in their adolescents, are the ones who talk more with their adolescents about alcohol use (Bell, 1968). Thus this is a *cause and effect* issue, which the results of our stringent cross-lagged panel analyses in the following paragraphs aimed to disentangle, by simultaneously controlling for reversed effects, while also accounting for concurrent associations, and prior behavior (i.e., stability effects).

Cross-lagged links

First, as predicted by the TTI, we found that both on St. Maarten and in the Netherlands, engagement in one substance use predicted engagement in the other substance use a year later (e.g., Flay et al., 1995), above and beyond any significant contributions of gender and age. However, interestingly, the longitudinal associations (i.e., temporal order) between these substance use behaviors on St. Maarten and The Netherlands were different. Specifically, whereas higher levels of alcohol use on St. Maarten predicted subsequent higher levels of cannabis use, for the Netherlands, a reversed link was true, that is, higher levels of cannabis use predicted higher levels of subsequent alcohol use. For St. Maarten, the use of alcohol is generally acceptable. In that sense, it is to be anticipated that adolescents begin using alcohol first which is less norm-breaking within the St. Maarten culture, and higher levels of alcohol use subsequently predict higher levels of cannabis use, which is in accordance with the TTI and accordingly with the drug gate-way hypothesis (Flay, 1999; Kandel, 1975). However, the link we found for the Netherlands from cannabis use to alcohol use contradicts the TTI, and it is also rarely supported by empirical findings. Nonetheless, such a *reversal of the drug-gateway hypothesis* (Vanyukov et al., 2012) has been found for other drugs too, moreover, reductions in alcohol use over time has not been found to be related to reductions in non-alcohol substances in some studies (for an extensive review see Vanyukov et al., 2012), which also does not support the traditional gate-way hypothesis.

At least two reasons can be given for this unexpected "reversal of the drug gate-way hypothesis" that was observed among adolescents from the Netherlands. First, perhaps such a link was not found in previous studies as they typically did not control for potential bidirectional effects, and because they included ethnically homogenous samples, as most studies in the psychological sciences originating from the Netherlands primarily include ethnic majority Dutch youth (cf Ftitache, 2015). As for a possible moderating effect of ethnicity, at least one American study that investigated such effects in the co-occurrence of alcohol and cannabis disorders showed that this co-occurrence differed across ethnicity (Pacek, et al., 2012). Secondly, perhaps heavy drinking among adolescents in The Netherlands (e.g., binge drinking), is in part due to cannabis use, as one recent longitudinal study based on adults from the USA demonstrated that cannabis use predicts alcohol use disorder (Blanco et al., 2016). These findings still need to be replicated in an adolescent sample, however.

Taken together, considering that the temporal order of alcohol and cannabis use is not the same across St. Maarten and Netherlands, raises questions about the generalizability of the drug gateway hypothesis, which typically classifies alcohol as the gate-way drug to cannabis use. However, at the same time the TTI recognizes that the drug gate-way hypothesis might be too simplistic and predicts that the use of substances might co-occur because they additionally have overlapping risk factors (Flay, Petraitis, & Hu, 1995). No such overlapping risk factors were found in

the current study. All in all, future studies are needed to identify whether common risk factors might exist that could additionally explain the co-occurrence of alcohol and cannabis use in youth.

Next, with regard to the link from intention to use alcohol and cannabis use, for both the Netherlands and St. Maarten samples, we found a link from intention to use alcohol to higher levels of alcohol use one year later, which corresponds with the a strong assertion of the TTI, and past research (e.g., Flay et al., 1995). However, additionally, we also found that higher levels of alcohol use predicted more intent to use alcohol one year later for adolescents in both (island-)countries. Although this latter finding is not explicitly hypothesized by the TTI, it signifies that the more adolescents use alcohol the more their intentions increase to drink alcohol the following year. That is, just as intentions predict behavior, former behavior predicts intentions.

As for cannabis use, interestingly, for the Netherlands sample, intention did not predict cannabis use, instead cannabis use predicted intention to use cannabis one year later. This finding suggests that adolescents' intention to use cannabis is not predictive of whether or not adolescents will actually use cannabis, thus other factors appear to be more relevant for cannabis use in adolescents in the Netherlands. As demonstrated above, prior research in the Netherlands on intentions to use cannabis among adolescents is scarce, but in contrast to our study, at least one study that investigated this link, found that intentions to use cannabis did predict cannabis use in adolescents (Malmberg et al., 2012). However, the findings of Malmberg et al. (2012) might not be directly comparable to the current study as it was a cross-sectional study that consisted of primarily ethnic majority Dutch adolescents (97%), and it further did not estimate or control for reversed effects. Similar to the current study, another study with youth from Belgium (Flanders; i.e., the Dutch-speaking part of Belgium) also did not find a link from intention to use cannabis to cannabis use in adolescents (Victoir et al., 2007), then again, unlike the current study, Victoir et al. (2007) was cross-sectional and thus could not simultaneously investigate bidirectional links, which limits the comparisons that can be made with the current study. Considered together, more studies are needed that take bidirectional effects into account, in order to draw firmer conclusions about the link between intentions and substance use.

For St. Maarten youth, there were no longitudinal relations between cannabis use and intention to use cannabis. As far as we know, there are no existing studies on St. Maarten and in the Caribbean more generally, that have assessed this research question, thus our findings await to be replicated in other samples, especially in that part of the world. Nevertheless, together, these findings suggest that factors other than the TTI-based risk factors examined in the current study, might be more relevant for the prediction of cannabis use behavior on St. Maarten and in the Netherlands.

Finally, we did not find that communication with parents about substances predict the use of substances, for both youth in the Netherlands (despite the significant positive correlation found between these behaviors) and on St. Maarten, and this finding is consistent with some of the limited studies that have investigated this link (e.g., Ennett et al., 2001; Jackson et al., 1999). However, it should be noted, that prior studies on the role of frequency of parental communication in predicting substance use have been mixed (Van der Vorst, Burk, & Engles, 2010). Perhaps, as other studies have demonstrated, it might be that the quality (versus frequency as assessed in the current study) of the communication matters more for both adolescents in Europe and the Caribbean, as well as explicit rule-setting (e.g., Miller-day 2008; Wang et al., 2013). For example, one longitudinal study in the Caribbean with youth from the Bahamas islands, showed that lower parental control and higher levels of problematic parent-adolescent communication predicted higher levels of substance use, which was measured with a composite score including cannabis use (Wang et al., 2013). As for the Netherlands, although numerous studies has demonstrated the effect of parent substance use specific practices on adolescent alcohol use (e.g., Vorst, et al., 2010), we are aware of no studies that have specifically investigated whether the *frequency* of the parent-adolescent communication predicts adolescent cannabis use. However, at least one recent study in the Netherlands showed that restrictive parental rules about cannabis use predicted lower levels of adolescent cannabis use (Vermeulen-Smit, et al., 2015). Taken together, similar to the issues addressed above concerning parent-adolescent alcohol-specific communication, more research is also needed that examines the content as well as the frequency of parent-adolescent cannabis-specific communication.

Strengths, Limitations and Future directions

Like all cross-national studies, the results of the current study are important as they challenge the generalizability about behaviors across cultures, countries, and regions of the world. A notable strength of the current study is that it was longitudinal, as particularly longitudinal cross-national studies are lacking. However, like many cross-national studies, some of the cross-national differences found in the current study might be due to other (TTI-based) sociocultural factors that were not directly assessed in the current study. Hence, there might be some confounds in the current study that need to be considered when interpreting the cross-national differences. First, whereas the minimum age for alcohol use on St. Maarten is 18 years, at the time of the data-collection, the legal age for drinking alcohol in the Netherlands was 16 years. Also, adolescents on St. Maarten were on average more than 6 months older than the adolescent in the Netherlands, which could further account for their higher levels of substance use. Nevertheless, virtually all of the adolescents in the St. Maarten sample (97.4%) and in The Netherlands sample (95.5%) were under the legal drinking age at wave 1. However, the informal policies concerning the purchase of alcohol substantially differ across the two (island-)

countries. Specifically, the laws on alcohol (and cannabis) in the Netherlands are more strongly enforced compared to St. Maarten. For example, on St. Maarten it is uncommon to show your I.D. when purchasing alcohol, whereas in the Netherlands this is common practice. Reasoning along those lines, perhaps youth on St. Maarten have easier access to alcohol than youth in The Netherlands, and perhaps this can explain the relatively higher percentage of alcohol experience among St. Maarten youth. Availability of substances and weak public policies on substances are all ultimate level risk factors of the cultural stream as predicted by the TTI (see e.g., Flay et al., 1995). Future studies could investigate directly how these socio-cultural differences across countries might predict adolescent levels of substance use.

Next, there were some measurement limitations. Single item measures were used to assess alcohol intentions, cannabis intentions, cannabis use, and for parent communication about alcohol and cannabis, and thus we could not assess the reliability of these measures. Furthermore, we did not distinguish between communications with mothers versus fathers. However, future studies could re-consider this, as mothers in Western countries communicate more about alcohol use with their offsprings (Mares et al.,2011), although attitudes of mothers versus father do not seem to have differential effects on adolescent alcohol use (Van der Vorst et al., 2006).

This study appears to be among the first studies to investigate the link between *frequency* of parent-adolescent cannabis-use specific communication and adolescent cannabis use. Clearly, more research on the risk factors and consequences of adolescent cannabis use is needed especially considering the accumulating findings about its adverse consequences for adolescent (mental-) health (e.g., de Graaf et al., 2010). Parent-child communication is often the center of substance use interventions (Mares, et al., 2011), however the current study has consistently demonstrated that the frequency of communication does not have any longitudinal links to alcohol use and cannabis use in adolescents on St. Maarten and in The Netherlands. Finally, concerning the study design, the current study was not an experiment, thus causal inferences are limited.

Conclusions

The present study has demonstrated the importance of cross-national studies and why caution must always be taken when generalizing results and theories across countries. In accordance with a strong assertion by the TTI, we found that intention to use alcohol predicted alcohol use in adolescents in The Netherlands and on St. Maarten. Then again, in both countries a reversed link was found showing that alcohol use also predicted intention to use alcohol in the future (one year later), which is not in line with the TTI. Hence, the TTI would be even more refined if it considers a pathway from intention to use alcohol to alcohol use, which would be considered as a so-called "feedback loop" in TTI's terminology. However, when it comes to cannabis use, intention to use cannabis was not a significant predictor for adolescents in both (island-) countries, which strongly contradicts the TTI. Instead, prior cannabis use predicted future cannabis use, in both (island-)countries, which is in line with the TTI, in fact the TTI predicts that prior involvement with substance use is the most important predictor for future substance use (Flay et al., 1995). Furthermore, for St. Maarten, we found that cannabis use was predicted by higher levels of alcohol use, which corresponds with the TTI and a reversed link was true for the Netherlands. The different temporal ordering found for alcohol use and cannabis use across the (island-)countries is surprising. The reason behind this reversal of the drug gateway hypothesis across countries warrants more research. Clinically-referred adolescents were not included in the current study, and thus the substance use prevalence was relatively low. However, the cross-national differences that emerged could perhaps still imply that culture might complicate diagnosis of substance use comorbidity in adolescents (Maser & Dinges, 1993), and since culture is ubiquitous, it should not be ignored.

Chapter 11

Summary and General Discussion

11.1 Aims of this Dissertation

While paying close attention to individual and developmental differences, the current dissertation aimed to investigate (a) to what extent experimental scientific evidence shows support for risk-taking being a unique feature of adolescence (part 1), (b) the role of peers versus parents and siblings in adolescent risk-taking while accounting for individual factors (biological, cognitive, affective, gender, age/adolescent phase) (part 2 & 3), and (c) ethnic and cross-national differences in the links between risk factors and risk behaviors (part 4). These research questions were examined primarily using an ethnically-, socioeconomically- and educationally-diverse sample while accounting for individual, developmental and cultural differences. Finally, a mixed methodological approach was used, consisting of meta-analytic, cross-sectional, longitudinal, and experimental methods. The aims of the current dissertation were largely inspired by the three streams of influence that are outlined in the Theory of Triadic Influence (TTI; individual, social, cultural streams), and also by more specific contemporary theories on adolescent risk-taking. In the current chapter, first, the key findings per chapter (chapters 2-10) are briefly summarized. This is followed by an extensive and integrative summary of the findings, in which the findings are related to theory, and compared with the findings of previous studies. Secondly, practical and theoretical implications are discussed, followed by strengths, limitations and suggestions for future directions. For future directions, not only are the quantitative results drawn upon, but the adolescents' own views on risk behavior are also considered. Finally, the conclusion summarizes the take home message of the current dissertation.

11.2 Key Findings and Integrative Summary

Below, Table 1 provides a summary with the key findings per chapter (for chapters 2-10), followed by an integrative summary of the findings.

Table 1. Summary of Key Findings

Chapter	Key Findings
Part 1: *A Theoretical and Experimental Account of Heightened Adolescent Risky Decision Making:*	
2	Adolescents do not always engage in heighted risky decision making compared to children and adults, early adolescents engage in more risky decision making than mid-late adolescents, but early adolescents take equal levels of risks as children. Moderators related to affective and cognitive components on tasks were identified. A hybrid model "*developmental neuroecological model of risk-taking*" was developed based on the finding that age differences in risk-taking in the laboratory and theories on age differences in risky decision making do not always concur with real-world risk-taking accounts. This inconsistency is perhaps because age differences in risk-taking in the real-world are confounded with a crucial risk opportunity component, which is emphasized in the new "*Developmental neuro-ecological model of risk-taking*".
Part 2: *An Experimental Investigation of the Roles of Parents, Peers, and Siblings in Adolescent Risk-Taking*	
3	Experimental risky decision making tasks, such as the stoplight game (risky simulated driving task), can be informative to understand adolescent risk-taking in the real-world, as risky decision making on this task, predicted delinquency, alcohol use, and risky traffic behavior, regardless of whether such a task is completed alone or in the presence of peers.
4 (study 1 & 2)	Mere peer presence does not lead to higher risk-taking on the stoplight game for all adolescents (study 1 and 2) There is a gender by peer presence moderation effect showing that boys and girls engage in equal levels of risks when completing the stoplight game alone, but boys engage in more risks than girls when they played the stoplight game in the presence of two same-sex peers (study 1).
5 (study 1 & 2)	Mere peer presence does not lead to higher risk-taking on the timer Columbia Card Task (CCT; risky gambling task) for all adolescents (study 1). Earlier maturing adolescents, engaged in heightened risk-taking in the presence of peers on the CCT, and this effect was stronger for girls. However, pubertal timing was not related to risk-taking when adolescents (boys and girls) completed the CCT alone (study 1). Mere mother presence, father presence, and sibling presence lead to adolescents engaging in fewer risks on the CCT (study 2).
Part 3: *A Longitudinal Investigation of the Roles of Parents, Peers, and Siblings in Adolescent Risk-Taking*	
6	When it comes to externalizing problems (aggression and delinquency), longitudinal results show that older siblings' and peers' externalizing problem *behaviors* predict adolescent externalizing problems, whereas for mothers, it is the negative *relationship* quality with their adolescent offsprings that predict adolescent externalizing problems.
7	Peer influence is particularly relevant for early adolescence, when it comes to predicting adolescent delinquency. Delinquent peer norms predict early adolescent girls delinquency one year later The link from delinquent peer pressure to early adolescent *boys'* delinquency is exacerbated when boys have higher levels of negative relationship quality with their mothers.

8	Deviant peer pressure is also relevant for substance use such as smoking, above and beyond significant effects of individual factors such as impulsivity and lower educational track. Affective/motivational factors (sensation seeking) were no longer significant risk factors in the prediction of increases in smoking from ages 12-17 when social (peer pressure) and cognitive (impulsivity) factors, and educational track (control variable) were simultaneously estimated.
Part 4: *Ethnic and Cross-national Differences in Adolescent Risk-taking*	
9	Externalizing risk behaviors such as delinquency are correlated with internalizing problems such as depressive symptoms, particularly in middle adolescence, but the longitudinal link is complex as it is qualified by a gender x adolescent phase moderation effect. Early adolescent girls: higher levels of delinquency predict higher levels of depressive symptoms over three years. Mid/late adolescent girls: higher levels of delinquency predict lower levels of depressive symptoms over three years. Mid-late adolescent boys: higher levels of depressive symptoms predict higher levels of delinquency over three years. Although ethnic minority youth report more depressive symptoms (for 2 of the 3 waves), the delinquency-depressive symptoms link is not moderated by ethnicity.
10	Alcohol and cannabis use are significantly correlated, but the temporal order of the significant longitudinal link between these problem behaviors differ for adolescents from St. Maarten and from the Netherlands. For St. Maarten: Alcohol use predicted cannabis use one year later. For The Netherlands: Cannabis use predicted alcohol use one year later. Intention to use alcohol predicted alcohol use one year later and the reversed was also true for both adolescents from St. Maarten and the Netherlands. Intention to use cannabis does not predict cannabis use for both (island) countries. Mother-adolescent specific substance use communication does not predict alcohol or cannabis use for both (island-) countries.

At the Intersection: An Integrative Summary of the Findings

Table 1 provided a summary of the key findings for chapter 2-10, in the current section an integrative summary of these chapters is given. The meta-analysis in chapter 1 showed that it is important to study risk-taking behaviors in adolescents, as the meta-analytic findings generally revealed that adolescence, particularly early adolescence, is a vulnerable period for heightened risk-taking compared to adulthood and mid-late adolescence, however, not compared to childhood. Specifically, (early) adolescents engaged in more risk-taking on risky decision making tasks than adults and mid-late adolescents (which is consistent with Neurodevelopmental imbalance models and Fuzzy Trace Theory), but took equal levels of risks as children when task characteristics were held equal (which is inconsistent with both of these theoretical frameworks and real-life accounts). However, meta-regression analyses revealed that adolescents engaged in more risks than adults, particularly on tasks that provided immediate outcome feedback on rewards (gains) and losses. Reasoning from *social neurodevelopmental imbalance models*, one would conclude that particularly outcome feedback on rewards of those tasks are driving heightened adolescent risk-taking compared to adult risk-taking (Albert & Steinberg, 2011; Somerville et al., 2010; but see Bjork et al., 2004, 2010; Paulsen et al., 2012). As for adolescents compared to children risk-taking, in accordance with Fuzzy Trace Theory, meta-regression analyses further revealed that adolescents take fewer risks than children on tasks that provide a sure/safe option (Reyna & Ellis, 1994; Reyna & Farley, 2006)). Hence it was concluded that risk opportunity might be one of the primary reasons adolescents engage in more risks than children in the real-world, but in the lab adolescents generally engage in equal levels of risks as children. Moreover, when provided the opportunity to avoid risk-taking (i.e., a sure/safe option), adolescents actually avoid taking risks more often than children. Such results on age differences in risk-taking on experimental risky decision making tasks are meaningful for understanding real-world risk-taking, as results in chapter 3 went on to show that adolescents' performance on a risky driving task (stoplight game) predicted self-reported real-world risk-taking behaviors in multiple domains (for similar findings see: Kim-Spoon et al., 2016) , regardless of whether or not adolescents completed this risk-taking task in a low emotionally arousing context or in a highly emotionally arousing context (i.e., with no peer presence versus in the presence of peers).

The papers in chapters 4 and 5 used two different experimental risky decision making tasks, namely a risky driving task (i.e., the stoplight game; chapter 4) and a risky gambling task (i.e., the CCT; chapter 5) to further investigate adolescent risk-taking. Results on both tasks showed that mere peer presence does not have a main effect on adolescent's risky decision making (*chapters 4 & 5*), which contradicts social neurodevelopmental imbalance models (Gardner & Steinberg, 2005; Steinberg, 2008), but supports findings of accumulating studies (see e.g., Reynolds et al., 2014). However when gender (i.e., social context x gender) is accounted for, boys take more risks than girls in the presence of peers, but boys and girls take equal levels of risks when completing the risky driving task alone (chapter 4; for a similar findings, see: Boer, Peeters, & Koning, 2016). Furthermore, when gender in combination with pubertal timing (i.e., social context x pubertal timing x gender) is additionally taken into account, earlier maturing girls engaged in heightened risk-taking in the presence of peers to a greater extent than earlier maturing boys on the risky task (chapter 5).

Considered together, in the real-world, it appears that adolescents engage in deviant behaviors (e.g., delinquency) particularly when they are in company of their peers (Steinberg, 2004). However, the present results (chapter 4 and 5) revealed that it is perhaps just not mere peer presence that triggers deviant behavior, that is, when just gender is taken into account, boys engage in more risks than girls in the presence of peers, but when gender in combination with pubertal timing is taken into account, both girls and boys in the peer condition show a relationship between pubertal timing and risk taking such that earlier pubertal timing is associated with greater risk taking, however, this relationship is steeper for females than males. In contrast, in the alone condition, there is no evidence of a relationship between pubertal timing and risk-taking, neither in boys nor girls. The TTI does not hypothesize about pubertal effects, nonetheless, the current results are partially in

line *social re-orientation theory*, however this theory is not explicit about a gender moderation effect (Forbes & Dahl, 2010).

Importantly, the current results underscore that peer influence effects on risky decision making are complex, that mere peer presence does not tell the full story, and that peer socialization mechanisms might matter. Accordingly, longitudinal results of the correlational studies in the current dissertation further revealed that perhaps higher levels of externalizing problems (delinquency and aggression; chapter 6), or even more specific peer mechanisms such as delinquent peer norms and peer pressure (chapters 7 and 8) could further explain why and when peer socialization might lead to heightened risk-taking in adolescents. More specifically, when gender and adolescent phase are taken into account, for early adolescent girls delinquent peer norms (and not delinquent peer pressure) predicted delinquency one year later (chapter 7). For boys, delinquent peer pressure (and not delinquent peer norms) predicted adolescent delinquency one year later, but only when there were higher levels of mother-adolescent negative relationship quality (chapter 7). Moreover mother-adolescent negative relationship quality also predicted adolescents' externalizing problems over 4 years (chapter 6) and middle-adolescent girls' delinquency one year later (chapter 7). Although parents' externalizing problem behaviors do not predict adolescent externalizing problems (chapter 6), other types of parental behaviors might still influence adolescent risky decision making, as mere mother and father presence decreased risky decision making in 12-19 year old adolescents (chapter 5; for similar findings on mother presence, see Telzer et al., 2015).

When considering other adolescent real-world risk behaviors besides externalizing problems, deviant peer pressure is also important for increases in smoking from ages 12 to 17, even when significant individual factors such as impulsivity are taken into account, and when gender and educational track are accounted for (chapter 8). Thus the influence of peers appears to be robust even when accounting for the influences of parents, siblings and intrapersonal factors.

When comparing friends'/peers' to siblings' effects, the current dissertation adds to the literature by demonstrating that (older) siblings appear to have similar effects as friends on adolescent risk-taking as revealed by the longitudinal paper in chapter 6. First, particularly *older* sibling externalizing problems predicted adolescent externalizing problems above and beyond the aforementioned significant roles of mother-adolescent negative relationship quality and friend externalizing problems (chapter 6). However, whereas the mere presence of peers did not have an effect on risk-taking (chapter 4 and chapter 5; study 1), the mere presence of siblings led to fewer levels of risky decision making (chapter 5). Then again, perhaps, similar to what was found for peers (chapter 5; study 1), pubertal timing by gender effects might have also moderated sibling presence effects on adolescent risk-taking, that is sibling presence might also lead to heightened risky decision making, perhaps more so in girls. Chapter 5 appears to be the first study that investigated sibling presence effects on adolescent risky decision making, thus the findings await to be replicated in future studies. Of note, is that although mother, father and sibling presence all lead to fewer levels of adolescent risky decision making (chapter 5; study 2), different mechanisms for parents versus siblings might be at play. For example, it is possible that adolescents engaged in fewer risks in the presence of their parents because parents typically discourage risks, but that they engaged in fewer risks in the presence of their siblings to set a positive example, especially if their siblings are younger.

Next, as for cultural differences in the links between adolescent risk factors and risk behaviors, interesting ethnic and cross-national similarities and differences were highlighted (chapter 9 & 10). While the relationship quality between mother and adolescents is a predictor of adolescent risk-taking (chapters 6 & 7), frequency of communication about substances, which is also a component of parenting, did not predict alcohol use and cannabis use of adolescents both in the Netherlands and on St. Maarten (chapter 10; for similar findings see: e.g., Ennett et al., 2001; Jackson et al., 1999), when adolescent intention to use these substances, gender and age (individual factors) were also taken into account. Thus, it appears that the frequency of parent-adolescent substance use-specific communication is not enough to predict adolescent substance use, but perhaps a combination of *frequency* and *quality* of communication is essential (Miller-day 2008; Wange et al., 2013). Next, intention *to use alcohol* predicted alcohol use for adolescents in the Netherlands and on St. Maarten (see also: Carvajal, 2002) while controlling for age and gender, which supports a strong assertion of the TTI, while intention to use cannabis did not predict adolescent cannabis use for both (island-) countries, which is inconsistent with the TTI. Additionally, for adolescents in both (island-) countries, a reversed link was found from alcohol use to intention to use alcohol one year later, but no such reversed link existed from cannabis use to intention to use cannabis. Furthermore, an interesting cross-national *difference* in the longitudinal link between alcohol and cannabis use emerged, that is, whereas alcohol use predicted cannabis use in adolescents from St. Maarten one year later, the reverse was true for adolescents in the Netherlands. This so-called "reversal of the gate-way hypothesis" that was found for the Netherlands sample is rare, but it has been reported a few times in adult samples (see e.g., Blanco et al., 2016). These findings highlight why researchers must be careful with generalizing empirical findings and theories across different countries and cultures.

Additionally, chapter 9 demonstrated that the longitudinal link between externalizing problems such as delinquency and internalizing problems such as depressive symptoms is also complex, as an overall link was found that showed that higher levels of delinquency predicted lower levels of depressive symptoms over three years, but this link was further qualified by a gender x adolescent phase moderation effect (no ethnicity moderation effect was found). Surprisingly, this negative link from delinquency to depressive symptoms was particularly relevant for mid-late adolescent girls. For early adolescent girls, delinquency predicted

depressive symptoms, which supports the Failure model (Capaldi, 1992), although the Failure model does not hypothesize that such a link would be particularly relevant for early adolescent girls. Quite the opposite, for mid-late adolescent boys, higher levels of depressive symptoms predicted higher levels of delinquency, which is consistent with the Acting out model (Carlson & Cantwell, 1980), and with the TTI. However, the TTI and the Acting out model do not explicitly hypothesize that gender and/or adolescent phase might moderate this link. These findings were the same for ethnic minority versus ethnic majority Dutch adolescents, however ethnic minority youth reported higher levels of depressive symptoms than ethnic majority Dutch adolescents. In sum, whereas depressive symptoms served as a risk factor for delinquency, delinquency also served as a risk factor for depressive symptoms, but not in all adolescents, as a gender by adolescent phase moderation effect was present. Hence, the mixed findings found in previous studies for the longitudinal link between delinquency and depressive symptoms might be in part due to relevant moderators that were not considered in previous studies. Considered together, chapters 9 and 10 suggest that the links between adolescent risk factors and risk behaviors are diverse across gender, adolescent phase and to some extent across culture/countries. However, it appears that there are larger cross-national differences than differences across ethnicities within a country.

In sum, across chapters 2-10, support for multiple theories and the TTI was found as multiple theory-driven individual and social risk factors predicted adolescent risk-taking, but these links were not the same for all adolescents, and cultural and cross national differences existed. Peer influences were also robust above and beyond significant contributions of other social and individual factors, but again, not for all adolescents. That is, individual and developmental differences that are often neglected in theories and empirical studies were found.

11.3 Theoretical and Practical Implications

Besides theoretical implications, some of which are already evident from the previous integrative summary of findings, a couple of tentative practical implications with regard to the clinical practice can be drawn. The three implications that are discussed below are all related to the three aims outlined at the beginning of the Introduction and Discussion sections of the present dissertation. Moreover, a fourth and final implication concerns whether *the TTI is sufficient for explaining risk factors associated with adolescent risk-taking*. It should be noted, however, that when it comes to the clinical implications, it would be imperative to first replicate the current results with clinical samples. Moreover, it would further be of added value if future studies could replicate the correlational findings using experimental methods in order to be able to infer causality more strongly. Finally, the current findings could also provide pivotal insight for policy making.

Implication 1: On the Importance of Risk Opportunity: Is risky decision making a unique feature of adolescence?

The current implication section is relevant for the general assertion by the TTI that adolescents are more susceptible to engage in risk behavior (Flay, Snyder, & Petraitis, 2009). Moreover, contemporary theories such as *neurodevelopmental imbalance models* (e.g., Somerville et al., 2010; Steinberg, 2007) and Fuzzy Trace theory (Reyna & Rivers, 2008) postulate that adolescents are more susceptible than children and/or adults to engage in heightened risk-taking, and the former theory states that this is the case particularly in emotionally arousing contexts. However, the last two decades, like no other have criticized the widely held notion that risk-taking is a unique feature of adolescents (e.g., Arnett, 2000; Willoughby, Tavernier, Hamza, Adachi, & Good, 2013). The meta-analysis on age differences in risky decision making presented in the current dissertation added fuel to that debate, as it showed that adolescents (12-19) only generally engage in more risk-taking than adults (which is consistent with neurodevelopmental imbalance models, Fuzzy Trace Theory and real-life accounts), but, that they engage in equal levels of risk-taking as children on experimental risk-taking tasks (which contradicts both theoretical frameworks and real-life accounts). Furthermore, adolescents particularly engaged in more risky decision making than adults on tasks with immediate outcome feedback on rewards and losses, which might lend support to neuro-developmental imbalance models, whereas they actually engaged in fewer risks than children on tasks with a sure option, which is in line with the Fuzzy Trace Theory (Reyna & Rivers, 2008).

To reconcile the above-described findings of risk-taking in the laboratory versus risk-taking in the real-world, and, as predicted by theories, a convergence of neuro-psychological and ecological models, into a hybrid model termed "developmental neuro-ecological model of risk-taking" was put forward as the main conclusion of the meta-analysis. This new theoretical model acknowledges that neurodevelopment might play a role in age differences in risk-taking, but that opportunity plays a decisive role also. Additionally, although adolescents and children are equally susceptible to engaging in similar levels of risk-taking, the new model also suggests that processes leading up to this behavior might be different. For example, given the opportunity to exhibit risk-taking, the overall suboptimal immaturity of control-related brain regions in children might lead to heightened risk-taking in children, whereas the disadvantageous imbalance of top-down control processes being too weak to counteract the affective-motivational processes triggered in adolescence might equally lead to heightened risk-taking in adolescents. This new model aims to emphasize that varying risk opportunity with age in the real world perhaps obscures actual age differences in risk-taking, and that completing a risk-taking task under more controlled settings might reflect an individual's true propensity to take risks, since risk opportunity will be equal for all participants regardless of age. Risk opportunity is particularly decisive when comparing adolescent versus children risk-taking and early adolescent versus older adolescent risk-taking in the

real-world, as (older) adolescents obviously have more opportunities than children and early adolescents to engage in risk-taking in the real-world (e.g., substance use, driving while drunk). Interestingly, it appears that when adolescents (11-19) have the option to opt out of a risky situation, however, they choose to do so more often than children. These results indicate that if children had the same opportunity as adolescents in the real-world, they might actually engage in equal or more risks than adolescents. This is a thought-provoking hypothesis, as it could imply that not only are measures needed to protect (early) adolescents from tempting risk-taking opportunities, but that equal (or even more) efforts need to be continued in order to help protect children from such situations.

As for adolescents versus adult risk-taking, it is to be expected that a similar pattern of age differences in risk-taking will emerge for adolescents versus adults whether in the real-world or the lab, as risk opportunity is not such a decisive factor across these two age groups. That is, in the real-world adolescents increasingly have more opportunities to engage in the risk behaviors.

The meta-analysis showed that adolescent take more risks than adults in general, and especially on tasks with immediate outcome feedback on rewards and losses. Extrapolating from neurodevelopmental imbalance models, one could conclude that feedback on reward on these tasks is leading to heightened adolescent risk-taking. However, it should be noted that it might also be the case that (in addition to outcome feedback on rewards), adolescents engaged in more risk-taking than adults on immediate outcome feedback tasks, because of the (a) immediacy of the feedback, (b) the feedback on losses. Hopefully in the future researchers will make use of more decomposable tasks in order to be able to draw firmer conclusions about such important issues.

Taken together, revisiting the question posed at the beginning of this implication section: The current meta-analytic findings suggest that perhaps risky decision making might not be a unique feature of adolescence. Moreover, it might be of added value for future empirical studies and theories on heightened adolescent risk-taking, to consider a risk opportunity factor, especially when comparing adolescent versus children risk-taking and early adolescent versus mid-late adolescent risk-taking. Furthermore, when employing risky decision making tasks, researchers should be aware that adolescents (versus adults) are sensitive to immediate outcome feedback on rewards and losses, more over the effect of this type " immediate reinforcement" on adolescent risk behavior could also have implications for the clinical practice. Finally, adolescents engage in higher levels of risky decision making than adults in general. Perhaps this finding could be relevant for policy makers involved in the juvenile justice system, especially when deciding the developmental appropriate lawful treatment of adolescents. This includes pertinent current debates such as the appropriate legal age boundaries in order to decide which adolescents should be treated as adults and at what age they should be allowed to make important decisions independent of their parents' approval.

Implication 2: The role of peers versus parents and siblings in adolescent risk-taking while accounting for individual factors: How robust is peer influence?

The current implication section is relevant for the social stream of the TTI, and thus for social learning theories, social neurodevelopmental imbalance models and social re-orientation theory, as these theories posit that peers influence heightened risk-taking in adolescents.

Peers versus parents

Indeed, when reasoning from findings that adolescents typically engage in deviant behaviors when they are with their peers (Steinberg, 2004), the presence of peers could also be seen as a social "risk opportunity" factor. That is, a peer context might facilitate heightened risk-taking particularly among adolescents. However, what the current dissertation showed is that mere peer presence does not increase risk-taking in *all* adolescents. Instead the current results proposed that mere peer presence might only increase risk-taking in boys when gender is taken into account. Thus social neurodevelopmental imbalance models could consider incorporating an effect of gender in its hypothesis about a mere peer presence effect on adolescent risk-taking. Additionally, other findings in the current dissertation demonstrated the importance of pubertal maturation and peer effects in heightened adolescent risk-taking, which supports certain claims of the social re-orientation theory of adolescents (Forbes & Dahl, 2010).

Quite the opposite to the results found for peer presence, when it came to parent presence, results showed that adolescents engaged in fewer risks in the presence of fathers and mothers. Although theories are lacking on how parent presence might influence adolescent risk-taking, the authors of the only other study that investigated whether mother presence lowers adolescent risky decision making, concluded that the significant finding that was found, is the first to show experimental evidence of the protective effects of parental supervision on adolescent risk-taking (Telzer et al., 2015).

As for social learning theories on social influences (e.g., Bandura, 1977) by which the social stream of the TTI is inspired, the current dissertation highlighted two important social learning mechanisms that might explain the consistently demonstrated finding of peer similarity in adolescent delinquent behavior, namely delinquent peer norms for early adolescent girls and delinquent peer pressure for early adolescent boys. Such gender by adolescent phase moderation effects were perhaps masked in previous investigations because the assumed processes that link peer delinquency to subsequent adolescent delinquency were not assessed. Moreover, besides adolescent delinquency, deviant peer pressure is also a relevant predictor of adolescent smoking development, above and beyond significant effects of impulsivity and educational track, thus social learning theories of peer delinquency might also generalize to substance use. Furthermore, peer

externalizing problems predicted adolescent externalizing problems above and beyond significant links from mother-adolescent negative relationship quality to adolescent externalizing problems (aggression and delinquency) across 4 years. Then again, mother adolescent negative relationship quality exacerbated the link between delinquent peer pressure and early adolescent boys' delinquency. Thus, the current findings also suggested that mothers could play a role in determining whether delinquent peer pressure will predict adolescent risk-taking.

Considered together, robust support was found for the social stream of the TTI, and accordingly for social learning theories. However, at the same time, the present results propose that social learning theories on peer influences in delinquency would likely benefit from considering developmental (adolescent phase) and gender differences, by specifying the exact delinquent peer influence *processes* that fuel subsequent adolescent delinquency, and by considering that such differential peer factors might also be interwoven with factors outside of the peer context (e.g., the family context).

As for the clinical practice with regard to the influence of parents, the present results might have identified potentially amendable characteristics of parent-adolescent relationship quality that make early adolescent boys vulnerable to delinquent peer pressure, accordingly, this could be valuable findings for interventions. The longitudinal nature of the current results imply that ensuring fewer levels of negative relationship quality between mothers and their early adolescent sons at an earlier time point (in advance) could potentially curtail the negative effects delinquent peer pressure has on early adolescent boys' delinquency in the future. This could perhaps serve as an effective *prevention* effort too. Targeting mother-adolescent negative relationship quality could also predict lower levels of delinquency in middle adolescent girls. However, when it comes to middle adolescent boys, other parent than the ones investigated here would apparently be more relevant for predicting delinquency.

Peers versus siblings

When it comes to the role of peers versus the role of siblings, theories are lacking on the role of siblings (versus the role of friends/peers) in adolescent risk-taking. Nonetheless, the current findings show that social learning theories on deviant peer influences in adolescent externalizing problems, could be generalized to (older) siblings. Particularly, older siblings equally contribute to the prediction of subsequent externalizing problems in adolescents, regardless of the gender composition of the sibling dyad, and while accounting for the significant roles of parents and friends. Although sibling negative relationship quality did not predict adolescent externalizing problems, as suggested by the *coercion theory*, the results still support the general claim by coercion theory that siblings are relevant for the development of adolescents' externalizing problems. Taken together, the role of friends/peers and siblings qualitatively differ from the role of mothers in adolescent externalizing problems, that is for friends and siblings, it is the externalizing problem *behavior* (via delinquent peer norms and delinquent peer pressure) that matters whereas for mothers it is the *quality of their relationship* with their adolescent offspring that matters.

As for clinical implications with regard to the influence of siblings, interventions for adolescent problem behavior that includes siblings (e.g., family based therapy) are very rare (Namysłowska & Siewierska, 2010). However, the current findings suggest that adolescent interventions for treating externalizing problems could consider the inclusion of siblings (in addition to parents) (see e.g., Namysłowska & Siewierska, 2010). Accessing siblings (who to the same extent as peers can influence adolescent externalizing problems) for such interventions is certainly more realistic than trying to reach out to the adolescent's entire (delinquent) peer groups which is virtually an impossible task (although this could also lead to desirable results). Hence, these findings could have implications for the clinical practice.

Revisiting the question posed in the title of the current implication section: Peer influences do appear to be robust above and beyond significant contributions of other social (parents and siblings) and individual factors e.g., (impulsivity), but again, not for all adolescents. That is, peer presence only had an effect on adolescent risky decision making when gender and/or pubertal timing moderation effects were taken into account. Moreover, when adolescent phase is taken into account delinquent peer influences appear to be especially relevant for *early* adolescence, and different peer processes appear to be important for boys (i.e., delinquent peer pressure) versus girls (delinquent peer norms). Finally, for externalizing problems, the role of peers was similar to the role of siblings, an issue that has gotten relatively little attention.

Implication 3: Are the links between adolescent risk factors and risk behaviors the same across ethnicities and countries?

The Failure model and Acting out model concur that delinquency and depressive symptoms co-occur. The current dissertation demonstrated that this is particularly the case for middle adolescents. Ethnic minority adolescents and ethnic majority adolescents had equal levels of delinquency, but ethnic minority adolescents reported more depressive symptoms. The longitudinal link, however, between delinquency and depressive symptoms was equal for ethnic minority and ethnic majority Dutch youth, that is, lower levels of delinquency predicted more depressive symptoms. This link was further qualified by a gender by adolescent phase moderation effect. For example, results showed that the Failure model is most relevant for early adolescent girls. Support was also found for the Acting out model which postulates that depressive symptoms could lead to delinquency (and externalizing problems more generally), then again this link was found only in mid-late adolescent boys. These complexities in the longitudinal link between delinquency and depressive symptoms in adolescents have implications for the Failure model and Acting

out model, as these theories neglect gender and adolescent phase moderation effects, but ethnicity moderation effects do not appear to be relevant for this link. Furthermore, these could also be relevant findings that could be taken into account by clinicians who treat early adolescent girls with delinquency problems, and mid-late adolescent boys with depressive symptoms as particularly these adolescents might be at a higher risk for maladaptive outcomes (see e.g., Wolff & Ollendick, 2006).

Next, for both youth from St. Maarten and from the Netherlands, alcohol use and cannabis use significantly co-occur. However, as for the longitudinal link between these behaviors, a surprising cross-national difference emerged, that suggests that the drug gate-way hypothesis is more relevant for adolescents on St. Maarten. The unanticipated findings for the Netherlands that showed a reversal of the drug gate-way hypothesis could perhaps (partially) be related to within-country ethnic differences. For example, an American study showed that the co-occurrence of alcohol and cannabis use disorders differed across ethnicity (Pacek, Malcom, & Martins, 2012).Thus considering that the sample of the Netherlands was ethnically/culturally diverse, with a substantial amount of the adolescents identifying with ethnicities of non-western countries, could perhaps suggest that an ethnicity moderation effect could also be important for future studies to consider (see chapter 9). In any case, the the current diverse findings with regard to the temporal order of alcohol and cannabis use for St. Maarten and The Netherlands, suggest that the drug gate-way hypothesis might not be applicable across countries/cultures.

As for clinical implications, for adolescents in The Netherlands, lowering cannabis use might also predict lower levels of alcohol use. However, for adolescents on St. Maarten, lowering the levels of alcohol use might predict lower levels of future cannabis use. Thus, clinicians treating adolescents for one of these substances should bear in mind that they often co-occur, and that they have a longitudinal relationship which each other, on top of that the temporal order of this longitudinal relationship might differ across countries.

Revisiting the question embedded in the title of the current implication section, the concluding answer is that the link between risk-factors and risk behaviors are to some extent similar across ethnicities and countries, and there are more differences between countries compared to within-countries ethnicity differences for the constructs that were assessed.

Implication 4: Is the TTI sufficient for explaining risk factors associated with adolescent risk-taking?

The current dissertation has demonstrated that some risk factors that the TTI explicitly hypothesizes about are important for predicting adolescent risk-taking. They include factors from the intrapersonal stream (intention to use alcohol, impulsivity), social stream (peer pressure, peer norms, the presence of parents, mother-adolescent relationship quality) and the importance of the cultural stream

was demonstrated by some of the ethnicity and cross-national differences that were found (Flay, 1999). Moreover, the TTI predicts that risk-factors are often interrelated and should be investigated simultaneously. For example, the importance of this assertion of the TTI was evident in chapter 8, as affective factors (sensation seeking) were no longer significant risk factors in the prediction of increases in smoking from ages 12-18 when social (peer pressure) and cognitive (impulsivity) factors were simultaneously estimated. Although the TTI is obviously extremely comprehensive, there might be some important gaps that need to be addressed when it comes to the completeness of the TTI, however. These gaps are discussed in the following paragraphs.

Despite the demonstrated support for the TTI, some of the current findings also imply that the TTI might be missing some additional paths. Particularly, the consistent cross-national findings in the current dissertation suggest that a path from risk behaviors to intention to engage in risk behaviors might be of added value for the TTI (i.e., in addition to the already existing path in the TTI, from intention to engage in risk behavior to actual risk behavior). However, a related point is that the TTI-based hypothesis that postulates that intention to use a substance predict the actual use of that substance, might not be true for all substances, as the current results consistently showed that intention to use cannabis did not predict adolescent cannabis use the following year for both youth from St. Maarten and the Netherlands. Next, although the TTI emphasizes the family system in adolescent risk taking, the role of siblings is not considered, perhaps because the role of siblings in adolescent development is largely neglected (compared to parent and peer influences) in empirical research and theories (but see: Buist, 2010; Dunn, 2005; Patterson, 1984, 1986). However, consistent with the relatively few past studies that have investigated sibling influences in adolescent externalizing problems (e.g., Buist, 2010; Craine, Tanaka, Nishina & Conger, 2009), the current study also found that particularly externalizing problems of older siblings is a relevant risk factor for externalizing problems in adolescents. All in all, the inclusion of hypotheses related to sibling relationships would be of added value for the TTI.

Next, the TTI aims to give a developmental perspective on adolescent risk behavior, and recognizes that gender differences are important (Flay et al., 1995). However, the TTI does not explicitly address why or how adolescent phase and gender might affect the hypotheses that are put forward by this theory. This shortcoming of the TTI needs to be refined more as the current dissertation showed that when risk opportunity is held equal for all age groups, particularly early adolescents versus mid-late adolescents are susceptible for heightened risk-taking. Moreover, gender and adolescent phase moderation effects for some of hypotheses that form the core of the TTI were found (e.g., there were significant effects for gender by adolescent phase moderation effect in peer pressure on adolescent delinquency). Additionally, pubertal timing moderated peer presence effects in adolescent risky decision making. Although the TTI recognizes the necessity of biological risk-factors, this

theory is not explicit about how pubertal maturation might influence adolescents' risk-taking. Thus the TTI could further consider pubertal factors as they appear to be particularly important for adolescent risky decision making. Hence, perhaps the predictive power of the TTI could be further improved if new hypotheses are considered that are derived from contemporary (social) neurodevelopmental imbalance models and social re-orientation theory of heightened adolescent risk-taking, wherein puberty plays an important role.

Revisiting the question posed at the beginning of this implication section: The TTI is very comprehensive, and abundant support has been found for this theory in the current dissertation. However, the current dissertation has also highlighted some limitations of the TTI. Some of these limitations include the lack of hypotheses on pubertal development, sibling, gender and adolescent phase effects on adolescent risk behavior, as well as the lack of hypotheses on possible reversed effects from risk behavior engagement to intentions to engage in risk behavior.

11.4 Strengths, Limitations and Future directions

Strengths

The current dissertation capitalized on both experimental and longitudinal studies, used meta-analytic methods, investigated understudied social influences such as siblings and fathers, and more direct social mechanisms such as peer pressure and peer norms (in addition to investigating just having deviant friends as a mechanism), and paid attention to ethnic and cross-national differences. Moreover, rigorous statistical techniques and multi-informant reports were used to substantiate the conclusion of the results found. Finally, the importance of studying individual and developmental differences was demonstrated, as multiple gender and adolescent phase moderation effects existed. But as always, there are some limitations that might have implications for the current results.

Limitations

In the current dissertation, emphasis was put on the negative effects that peers have on adolescents. But that is not always the case, as the experimental studies in the current dissertation consistently showed that peer presence did not lead to an increase in risk-taking for all adolescents. Other studies also show that peers can have positive effects, for example, correlational studies have shown that close friendships with an absence of deviant behavior actually predict fewer externalizing problems in adolescents (Malcolm et al., 2006). Thus building on the current dissertation, future studies should also consider the positive effects that peer relationships might have on adolescent development, as this could serve as a protective factor for adolescent risk-taking. It would especially be informative to capitalize on experimental designs for such studies (see e.g., Van Hoorn, Van Dijk, Meuwese, Rieffe & Crone, 2014).

A related issue when studying peer relationships is whether it is peer selection effects or peer influence effects that are operating. The current experimental studies that manipulated peer presence solved this issue, however the longitudinal studies on peer factors in the current dissertation might be subjected to the debate concerning peer influence versus peer selection. Unfortunately, the statistical techniques that were used in the longitudinal studies cannot appropriately tease these two peer mechanisms apart. On a side note, as for sibling influences, sibling relationships might evade such *selection versus influence* debates, as adolescents cannot select their siblings.

Future directions

First, some future directions that were inspired by the results of the meta-analysis that was presented in the current dissertation will be discussed. One of the many advantages of a meta-analysis is that it can reveal certain gaps in the literature that warrant additional research. First, the obvious importance of opportunity in age differences in risk-taking that was put forward by the findings of the meta-analysis presented in the current dissertation highlights that a challenge for future research is to create a risk-taking paradigm in which risk-taking opportunity can be manipulated in an ecologically valid and meaningful manner. This could bring us closer to understanding true age differences in risk-taking. Perhaps peer presence could also be viewed as a "social risk opportunity" for adolescents, as explained earlier. However, more experimental studies that manipulate peer presence in a risk-taking paradigm would be needed, in order further ascertain the role of such peer effects in heightened adolescent risk-taking. Accumulating body of research would enable a meta-analysis that could also more reliably determine whether peer presence is indeed a social risk opportunity factor for adolescents.

In the current dissertation, limited evidence for peer presence effects on adolescent risk-taking was found in two papers, and delinquent peer pressure (for boys) and delinquent peer norms (for girls) were found to be relevant predictors of subsequent adolescent delinquency (particularly in early adolescence). Thus this could imply that a logical next step is for future studies to manipulate peer pressure and/or peer norms, instead of just manipulating mere peer presence. It would also be worthwhile for future studies to investigate whether delinquent sibling pressure and delinquent sibling norms are the mechanisms that link externalizing problems in siblings to adolescent externalizing problems. When it comes to peer pressure, at least two experimental studies with college students (Reynolds et al., 2014; Shepherd, Jane, Tapscott, & Gentile, 2011) reported that peer encouragement to take risks (in other words: *deviant peer pressure*), moderated peer presence effects on risk-taking. It would further be necessary for forthcoming studies to try and replicate these findings in (younger) adolescent samples, using both experimental and longitudinal designs, and also taking pubertal maturation and gender by adolescent phase effects into account, as these factors were relevant moderators of

peer influences in the papers presented in the current dissertation. This necessity was also demonstrated by the meta-analysis presented in the current dissertation, which revealed that experimental studies on adolescent risk-taking often fail to take such relevant moderators into account.

Next, the findings that early adolescent boys appear to be susceptible to negative influences of delinquent peer pressure, particularly when they have higher levels of negative relationship quality with their mothers, underscore the necessity for future studies to also simultaneously investigate multiple social influences (from the family context and peer context), as these different social influences are often interwoven in predicting adolescent risk-taking. The same holds for social, affective and cognitive risk factors, as they also tend to be interrelated, which was also demonstrated in the present dissertation.

Finally, more cross-national studies are needed that also include non-western (island-) countries. The limited studies on cross-national comparisons often overlook the Caribbean islands. The Caribbean, however, provides an interesting avenue for *behavioral and social sciences* research because of its rich and diverse culture that is a mixture of both western and non-western traditions. A striking cross-national difference that emerged in the current dissertation is that the temporal order of the longitudinal link between alcohol and cannabis use is not the same for youth living on St. Maarten and The Netherlands. Future studies could look into further explanations behind this finding, for example, the availability of substances across countries might be a decisive factor in determining which substances are used first or more by adolescents. Moreover, not only cross-national differences are pervasive and therefore are meaningful for the clinical practice, but within-country ethnic differences are also important to consider, as the current dissertation revealed mean levels differences in depressive symptoms between ethnic minority and ethnic majority Dutch youth, a finding that deserves more scientific inquiry in the future.

Finally, as mentioned earlier, adolescents who took part in the ART project also had the opportunity to answer open questions, for which they were asked to give motivations/reasons for youth involvement with risk behaviors. Indeed, many of the risk/protective factors that were covered in the current dissertation were prominent in the answers that were provided by the adolescents. This overlap can also be seen in some of the adolescents' quotes that are cited at the beginning of some of the chapters in the current dissertation. However, what was perhaps even more prominent and surprising in the answers that the adolescents provided, was that an abundance of "functional" reasons (e.g., to relieve pain, depression, worries or problems) were mentioned for engagement in risk behaviors (particularly for substance use behaviors). These functional "risk factors" are not typically the focus of contemporary questionnaires on adolescent risk-taking (but see e.g., Boys, Marsden, & Strang, 2000; Kuntsche, Knibbe, Gmel, & Engels, 2006). Hence, functional reasons for risk-taking should perhaps also be the center of adolescent risk-taking research in the future, as this could prove to be a valuable contribution to further understanding the complexities of adolescent risk-taking.

11.5 Conclusions

The current dissertation has demonstrated that behavioral scientists have a complex task when it comes to predicting adolescent risk-taking, which is influenced by a plethora of individual (intentions to use substances, impulsivity), social (e.g., peers, parents, *and* siblings) and cultural (e.g., cross-national differences) factors. However, adolescents do not always engage in heightened risky decision making compared to children and adults, and early adolescents engage in more risky decision making than mid-late adolescents. Laboratory findings and theories on age differences in risky decision making do not always concur with real-world risk-taking accounts, perhaps because age differences in risk-taking in the real-world are confounded with risk opportunity. Risky decision making tasks predict real-world risk behaviors in multiple domains (delinquency, alcohol use, risky traffic behavior). As for social influences, peer presence, peer pressure, peer norms, peer externalizing problems contribute to adolescent risky decision making and risk behavior, but not for *all* adolescents. That is, individual (e.g., gender) and developmental (e.g., adolescent phase, pubertal timing) differences exist. When it comes to externalizing problems (aggression and delinquency), it appears that older siblings and peers play the same role, as their externalizing problem *behaviors* matter, whereas it is the *relationship* quality of parents (mothers) with their adolescent offsprings that matter. Finally, cross-national differences exist in the temporal ordering of different substance use behaviors (alcohol and cannabis use), and overall there were more differences between countries (i.e., St. Maarten and The Netherlands) compared to within-country ethnicity differences. The current dissertation has shown that individual and developmental differences in the above-described relevant predictors make the puzzle of adolescent risk-taking even more complex. But, hopefully the current dissertation has also contributed a piece to solving this complex puzzle.

References

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Summary in Dutch (Samenvatting in het Nederlands)

Design en Methodologie

Het huidige proefschrift is hoofdzakelijk gebaseerd op een experimentele longitudinale studie (*N* = 602 bij aanvang) in Nederland genaamd het ART project, welke gericht is op risicogedrag onder adolescenten. Gedurende een periode van drie jaar (2012, 2013 en 2014) hebben de adolescenten elk jaar een uitgebreide vragenlijst ingevuld. Een deel van hun moeders en vaders heeft ook vragenlijsten ingevuld tijdens het 1e en 2e jaar. Daarnaast hebben de adolescenten meerdere cognitieve taken uitgevoerd en aan experimentele sessies meegedaan waarin zij taken waarbij risicovolle beslissingen moesten worden genomen uitgevoerd, alleen of met leeftijdsgenoten. Bovendien hebben een aantal van de adolescenten van deze longitudinale studie ook meegedaan aan extra experimentele sessies, waarin zij cognitieve taken en risicovolle beslissingstaken hebben uitgevoerd alleen, of met hun moeder, en/of vader, en/of broer of zus. In totaal hebben 36 gezinnen hieraan meegedaan. Naast de studie in Nederland, beschrijft één artikel in dit proefschrift een steekproef onder adolescenten die deelnamen aan een soortgelijke 2-jarige longitudinale studie op St. Maarten (*N*= 350 bij aanvang), al deden familie leden niet mee aan dit onderzoek. Tenslotte, beschrijft ook één artikel (hoofdstuk 6) een steekproef onder adolescenten (*N*=497) die onderdeel zijn van het project 'Research on Adolescents Development And Relationships (RADAR; zie bijvoorbeeld Keijsers et al., 2012), hetgeen een prospectieve longitudinale studie in Nederland betreft. Vragenlijst data van vier jaarlijkse meetmomenten werd geanalyseerd voor 497 Nederlandse adolescenten en hun broers en/of zussen, vaders, moeders, en zelf-aangewezen beste vrienden.

Een integratieve samenvatting van de resultaten

In de huidige sectie wordt een integratieve samenvatting van hoofdstukken 2-10 gegeven. De meta-analyse beschreven in hoofdstuk 2 laat zien dat het belangrijk is om risicovolle gedragingen van adolescenten te onderzoeken. De meta-analytische bevindingen toonden over het algemeen aan dat de adolescentie, in het bijzonder de vroege adolescentie, een kwetsbare periode is voor verhoogd nemen van risico's in vergelijking met de volwassenheid en midden/late adolescentie, maar niet in vergelijking met de kindertijd. In andere woorden, (vroege) adolescenten namen meer risico's in riskante beslissingstaken dan volwassenen en midden/late adolescenten (wat consistent is met de Neurodevelopmental imbalance models en de Fuzzy Trace Theory), maar namen evenveel risico's als kinderen wanneer de taak eigenschappen gelijk worden gehouden (wat niet consistent is met beide theoretische kaders en de dagelijks leven). De meta-analyse toonde echter ook aan dat met name bij taken die direct feedback gaven over de uitkomsten, zoals winst of verlies, adolescenten meer risico's namen dan volwassenen. Op grond van de social neurodevelopmental imbalance models zou geconcludeerd kunnen worden dat vooral de uitkomst feedback met betrekking tot winst van deze taken, leidt tot het verhoogd nemen van risico's door adolescenten in vergelijking met volwassenen (Albert & Steinberg, 2011; Somerville et al., 2010; maar zie ook Bjork et al., 2004, 2010; Paulsen et al., 2012). Wanneer het nemen van risico's door adolescenten wordt vergeleken met dat van kinderen , toonden meta-regressie analyses verder aan dat, in overeenstemming met de Fuzzy Trace Theory, adolescenten minder risico's namen dan kinderen op taken die een zekere/veilige optie hadden (Reyna & Ellis, 1994; Reyna & Farley, 2006). Hieruit volgde de conclusie dat de mogelijkheid om risico's te nemen waarschijnlijk een van de primaire redenen is dat adolescenten in het dagelijkse leven meer risico's nemen dan kinderen. Echter, nemen kinderen en adolescenten evenveel risico's in een laboratorium. Bovendien als er de mogelijkheid is om risico's te vermijden (oftewel de aanwezigheid van een zekere/veilige optie), dan vermijden adolescenten risico's vaker dan kinderen. Deze resultaten met betrekking tot de leeftijdsverschillen in het nemen van risico's zijn relevant om risicogedrag in het dagelijks leven te begrijpen. Dit te meer gezien de resultaten in hoofdstuk 3 voorts aantoonden dat de prestatie van adolescenten op een risicovolle auto-rijden taak (stoplicht spel) risicovol gedrag voorspelde in meerdere domeinen van het dagelijks leven (voor vergelijkbare bevindingen zie Kim-Spoon et al., 2016), onafhankelijk van of de adolescenten deze risicovolle taak uitvoerden in een laag prikkelende emotionele omgeving of in een hoog prikkelende emotionele omgeving (oftewel met of zonder de aanwezigheid van een leeftijdsgenoot).

De artikelen in hoofdstuk 4 en 5 gebruikten twee verschillende experimentele risicovolle beslissingstaken, namelijk een risicovolle auto-rijden taak (i.e., het stoplicht spel, hoofdstuk 4) en een risicovolle gok taak (i.e., de Columbia Card Task; CCT; hoofdstuk 5), om het nemen van risico's onder adolescenten verder te onderzoeken. Resultaten voor beide taken toonden aan dat de aanwezigheid van een leeftijdsgenoot geen hoofdeffect heeft op het maken van risicovolle beslissingen van adolescenten (hoofdstuk 4 & 5), wat de social neurodevelopmental imbalance models tegenspreekt (Gardner & Steinberg, 2005; Steinberg, 2008), maar de bevindingen van accumulerende onderzoeken ondersteunt (zie bijv., Reynolds et al., 2014). Als geslacht (i.e., sociale context x geslacht) wordt meegerekend, dan blijkt dat jongens meer risico's namen dan meisjes in de aanwezigheid van leeftijdsgenoten, maar dat jongens en meisjes gelijke risico's namen wanneer zij de risicovolle auto-rijden taak alleen uitvoerden (hoofdstuk 4; zie Boer, Peeters & Koning, 2016). Daarnaast als geslacht in combinatie met pubertal timing (i.e., sociale context x pubertal timing x geslacht) wordt meegerekend, dan namen meisjes die vroeg ontwikkelden meer risico's in de aanwezigheid van leeftijdsgenoten dan jongens die vroeg ontwikkelden (hoofdstuk 5).

In het dagelijks leven blijkt dat adolescenten meer deviant gedrag (bijv. delinquentie) tonen, vooral als zij in de aanwezigheid van leeftijdsgenoten zijn (Steinberg, 2004). Echter, de huidige resultaten (hoofdstuk 4 en 5) tonen aan dat het misschien niet puur de aanwezigheid van leeftijdsgenoten is dat deviant gedrag uitlokt, maar dat als alleen geslacht wordt meegerekend, jongens meer risico's nemen dan meisjes in de aanwezigheid van leeftijdsgenoten, maar als geslacht en

pubertal timing meegerekend worden, dan laat pubertal timing een relatie zien met risico nemen bij meisjes en jongens in de leeftijdsgenoot conditie (maar niet in de alleen conditie). Namelijk, vroege pubertal timing is gerelateerd aan meer risico's nemen, hoewel deze relatie sterker is voor meisjes dan voor jongens. Daarentegen in de alleen conditie, is er geen bewijs voor een relatie tussen pubertal timing en het nemen van risico's, noch voor jongens, noch voor meisjes. De Theory of Triadic Influence (TTI) maakt geen veronderstellingen over effecten van pubertal timing, niettemin zijn de huidige resultaten in lijn met de social re-orientation theory, al heeft deze theorie niet expliciet betrekking op een geslacht moderatie effect (Forbes & Dahl, 2010).

Belangrijker nog, de huidige resultaten benadrukken dat de invloed van leeftijdsgenoten op het maken van risicovolle beslissingen complex zijn, en dat enkel de aanwezigheid van een leeftijdsgenoot niet het hele verhaal vertelt, maar dat socialisatie mechanismes mogelijk ook belangrijk zijn. Overeenkomstig laten de longitudinale resultaten van de correlatie onderzoeken in het huidige proefschrift verder zien dat mogelijk meer externaliserende problemen (delinquentie en agressie; hoofdstuk 6) en meer specifieke mechanismes gerelateerd aan leeftijdsgenoten, zoals delinquente normen en druk van leeftijdsgenoten (hoofdstuk 7 en 8), kunnen verklaren waarom en wanneer socialisatie met leeftijdsgenoten kan leiden tot verhoogd nemen van risico's in adolescenten. Meer specifiek, wanneer geslacht en fase van de adolescentie mee worden gerekend, dan voorspellen de delinquente normen (maar niet de delinquente druk) van leeftijdsgenoten voor vroege adolescente meisjes delinquentie een jaar later (hoofdstuk 7). Voor jongens voorspelde delinquente druk (maar niet delinquente normen) van leeftijdsgenoten delinquentie een jaar later, maar alleen als er een hogere mate was van moeder-adolescent negatieve relatiekwaliteit (hoofdstuk 7). Bovendien voorspelde moeder-adolescent negatieve relatiekwaliteit ook de externaliserende problemen van adolescenten over een periode van 4 jaar (hoofdstuk 6) en delinquentie van midden-adolescente meisjes een jaar later (hoofdstuk 7). Al voorspellen externaliserende problemen van ouders niet de externaliserende problemen van adolescenten (hoofdstuk 6), zouden andere vormen van ouderlijke gedragingen het maken van risicovolle beslissingen van adolescenten kunnen beïnvloeden, gezien de aanwezigheid van moeder of vader het nemen van risico's verlaagde in 12-19-jarige adolescenten (hoofdstuk 5; voor vergelijkbare bevindingen m.b.t. moeder aanwezigheid, zie Telzer et al., 2015).

Als er naast de externaliserende problemen gekeken wordt naar andere risicovolle gedragingen van adolescenten in het dagelijkse leven, dan is druk van deviante leeftijdsgenoten ook belangrijk voor een toename in roken tussen de leeftijd van 12 en 17, zelfs wanneer significante individuele factoren, zoals impulsiviteit, geslacht en onderwijsniveau meegerekend zijn (hoofdstuk 8). De invloed van leeftijdsgenoten lijkt dus robuust te zijn, zelfs wanner de invloed van ouders, broers of zussen, en individuele factoren zijn meegerekend.

Het huidige proefschrift voegt ook toe aan de literatuur als de effecten van vrienden/leeftijdsgenoten en de effecten van broers of zussen worden vergeleken door aan te tonen dat (oudere) broers of zussen vergelijkbare effecten lijken te hebben op het nemen van risico's onder adolescenten als vrienden, wat aangetoond werd in het longitudinale artikel in hoofdstuk 6. Ten eerste, voorspelden vooral de externaliserende problemen van *oudere* broers of zussen de externaliserende problemen van adolescenten, bovenop de eerder genoemde significante rol van moeder-adolescent negatieve relatiekwaliteit en externaliserende problemen van vrienden (hoofdstuk 6). Echter, hoewel puur de aanwezigheid van leeftijdsgenoten geen hoofdeffect had op het nemen van risico's (hoofdstuk 4 en 5), leidde de aanwezigheid van broers/zussen tot verminderd nemen van risico's (hoofdstuk 5). Echter, het is ook mogelijk dat net als in hoofdstuk 5 (onderzoek 1), zouden geslacht en pubertal timing een rol kunnen spelen in het voorspellen van risicogedrag onder adolescenten: de aanwezigheid van broers/zussen zou ook tot verhoogd nemen van risico's leiden, misschien vooral bij meisjes. Hoofdstuk 5 schijnt het eerste onderzoek te zijn die de effecten van de aanwezigheid van een broer of zus op het nemen van risico's in adolescentie heeft onderzocht, waardoor de resultaten nog gerepliceerd moeten worden in latere onderzoek. Van belang is dat hoewel de aanwezigheid van moeder, vader en broer/zus allemaal tot een verlaagde mate van risico nemen leidde (hoofdstuk 5, onderzoek 2), andere mechanismes mogelijk belangrijker zijn voor ouders in vergelijking met broers/zussen. Bijvoorbeeld, het is mogelijk dat adolescenten minder risico's nemen in de aanwezigheid van hun ouders omdat ouders over het algemeen risico's ontmoedigen, maar dat zij minder risico's namen in de aanwezigheid van broers/zussen omdat zij een positief voorbeeld wouden zijn, vooral als de broer/zus jonger dan hen is.

Vervolgens, als gekeken wordt naar culturele verschillen in de relaties tussen adolescente risico factoren en risicogedrag, dan zijn er verschillende interessante etnische en transnationale verschillen die benadrukt kunnen worden (hoofdstuk 9 en 10). Terwijl de relatiekwaliteit tussen moeder en adolescent een voorspeller is van het nemen van risico's door adolescenten (hoofdstuk 6 & 7), voorspelde frequentie van communicatie over middelen, een onderdeel van de opvoeding, niet alcohol of cannabis gebruik door adolescenten in zowel Nederland als op St. Maarten (hoofdstuk 10; voor vergelijkbare bevindingen zie bijv., Ennett et al., 2001; Jackson et al., 1999), als de intentie van adolescenten tot gebruik van deze middelen, geslacht en leeftijd (individuele factoren) ook werden meegerekend. Het schijnt dus dat de frequentie van ouder-adolescent middelengebruik-specifieke communicatie niet genoeg is om middelengebruik van adolescenten te voorspellen, maar dat een combinatie tussen frequentie en kwaliteit van de communicatie mogelijk wel essentieel is (zie Miller-day, 2008; Wange et al., 2013). Daarnaast voorspelde de intentie om alcohol te gebruiken alcohol gebruik van adolescenten in Nederland en op St. Maarten (voor vergelijkbare bevindingen zie Carvajal, 2002) als gecontroleerd werd voor leeftijd en geslacht, wat een sterke bevestiging van de TTI ondersteunt.

De intentie om cannabis te gebruiken voorspelde echter niet het cannabis gebruik van adolescenten in beide landen, wat in tegenstelling is tot de TTI. Bovendien werd voor adolescenten in beide landen een omgekeerde relatie gevonden van alcohol gebruik naar intentie om alcohol te gebruiken een jaar later, maar deze omgekeerde relatie werd niet gevonden voor cannabis gebruik. Daarnaast werd een interessante transnationaal verschil in de longitudinale relatie tussen alcohol en cannabis gebruik gevonden, namelijk dat hoewel alcohol gebruik in adolescenten op St. Maarten het gebruik van cannabis een jaar later voorspelde, het omgekeerde gevonden werd voor adolescenten uit Nederland. Dat het zogenaamde 'reversal of the gate-way hypothesis' werd gevonden voor de Nederlandse jongeren is zeldzaam, maar is in verschillende onderzoeken onder volwassenen wel gerapporteerd (zie bijv., Blanco et al., 2016). Deze bevindingen benadrukken waarom onderzoekers voorzichtig moeten zijn met het generaliseren van empirische resultaten en theorieën tussen landen en culturen.

Bovendien toont hoofdstuk 9 aan dat de longitudinale relatie tussen externaliserende problemen, zoals delinquentie, en internaliserende problemen, zoals depressieve symptomen, ook complex is aangezien een algemene relatie werd gevonden die er op wees dat hogere maten van delinquentie lagere maten van depressieve symptomen voorspelden over een periode van drie jaar. Deze relatie werd verder wel genuanceerd door een "geslacht x fase van adolescentie" moderatie effect. Voor vroeg adolescente meisjes, voorspelde hogere maten van delinquentie hogere maten van depressieve symptomen, wat het Failure model ondersteunt (Capaldi, 1992), al veronderstelt het Failure model niet dat deze relatie vooral relevant zal zijn voor vroeg adolescente meisjes. Daartegenover, voorspelden depressieve symptomen voor midden/laat adolescente jongens hogere maten van delinquentie, wat consistent is met het Acting Out model (Carlson & Cantwell, 1980) en de TTI. Deze beide theorieën veronderstellen echter niet dat geslacht en/of fase van de adolescentie deze relatie zou modereren. De bevindingen waren hetzelfde voor Nederlandse etnische minderheids- en etnische meerderheidsadolescenten, al rapporteerde etnische minderheidsjongeren wel hogere maten van depressieve symptomen dan etnische meerderheidsjongeren. Samenvattend, hoewel depressieve symptomen een risicofactor waren voor delinquentie, was delinquentie tegelijkertijd ook een risicofactor voor depressieve symptomen, alleen niet voor alle adolescenten, gezien een "geslacht x fase van adolescentie" moderatie effect ook aanwezig was. De gemengde bevindingen naar de longitudinale relatie tussen delinquentie en depressieve symptomen die dus in eerdere onderzoeken waren gevonden, zijn mogelijk te wijten aan bepaalde relevante moderatoren die niet in deze eerdere onderzoeken waren meegenomen. Samengenomen suggereren hoofdstuk 9 en 10 dat de relaties tussen adolescente risicofactoren en risico gedragingen divers zijn afhankelijk van geslacht, fase van adolescentie, en tot een zekere mate ook cultuur/land. Het blijkt echter dat er grotere transnationale verschillen zijn dan verschillen tussen etniciteiten binnen één land.

Samenvattend, door hoofdstuk 2 tot en met 10 heen is ondersteuning gevonden voor meerdere theorieën en de TTI, gezien meerdere theorie-gedreven individuele en sociale risicofactoren het nemen van risico's door adolescenten voorspelden. Deze relaties waren echter niet hetzelfde voor alle adolescenten en er zijn culturele en transnationale verschillen. De invloed van leeftijdgenoten was robuust bovenop de significante bijdragen van andere sociale en individuele factoren, maar weer niet voor alle adolescenten. Dat wil zeggen, individuele en ontwikkelingsverschillen die vaak in theorieën en empirische onderzoeken worden verwaarloosd, werden gevonden.

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"...Love liberates. It doesn't bind. Love says, 'I love you. I love you if you're in China. I love you if you're across town. I love you if you're in Harlem. I love you... I would like to be near you. I'd like to have your arms around me. I'd like to hear your voice in my ear. But that's not possible now, so I love you, go..."~ Maya Angelou
My parents have embodied this quote fully when it comes to them letting me travel to Holland on my own as a teenager to follow my dream of furthering my studies and working on my career. My father (my hero), my mother (my super woman), I salute both of you for loving me unconditionally. After 10 years, you will finally visit me in Holland for my PhD defense, I can't wait... I love you!
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Ivy

About the author

Ivy Defoe is originally from the Dutch Caribbean island of St. Maarten. Right after completing high school (VWO) at the Milton Peters College, she moved to the Netherlands in 2006 for her studies and career. She did a bachelor's and master's degree in Developmental Psychology at the VU University Amsterdam (thesis supervisor: Prof. dr. Pol van Lier). During her master's she did a clinical internship at a residential treatment facility for adolescents with severe behavior problems, and received her basic psychodiagnostic registration (*BAPD*). Following her master's degree, she was a voluntary research-trainee at the Adolescent Development department of Utrecht University, led by Prof. dr. Wim Meeus (research traineeship supervisors: Dr. Loes Keijsers and Dr. Skyler Hawk). Hereafter, she began a 5-year PhD degree in July 2011 at The Developmental Psychology department of Utrecht University (PhD supervisors: Prof. dr. Marcel van Aken and Prof. dr. Judith Semon Dubas). Her PhD project was funded by the Netherlands Organisation for Scientific Research (NWO), and it was entitled the *Adolescent Risk Taking (ART) project*. Additionally, alongside her PhD project, Ivy coordinated a similar experimental-longitudinal research project on St. Maarten. One of the articles in the current dissertation is based on that research project. Her PhD also consisted of lecturing and supervising students with their Bachelor and Master theses. In addition to her PhD duties, she has been an active member in academic committees, and she has organized various academic events. During her PhD, Ivy also organized and participated in numerous (inter-) national conferences. At conferences of the Society for Research on Adolescence (SRA), she was a recipient of the Best Research Poster award in Canada in 2012 and of the Emerging Scholar Travel Award in Baltimore in 2016.

Ivy has also gained international experience during her PhD: Via an Utrecht University Travel Grant, she did an internship at *The Institute of Criminology* at the University of Cambridge (supervisors: Prof. dr. David Farrington and Prof. dr. Rolf Loeber). Via a Fulbright Scholarship she did an internship at the *Affective Neuroscience and Development Lab* of Harvard University (supervisor: Dr. Leah Somerville). Additionally, during her PhD she received other scholarships and awards from the organization Stichting Jo Kolk Studiefonds, Utrecht Centre for Child and Adolescent Studies (CAS), the Consultative Body for Dutch Caribbean People in The Netherlands (OCAN), and the Government of St. Maarten.

Ivy finished her PhD dissertation in July 2016, and hereafter she accepted a post-doctoral position at *Annenberg Public Policy Center* at the University of Pennsylvania, where she will conduct research on policy-relevant questions concerning adolescent risk-taking.

*Included in this dissertation

International publications

***Defoe, I.N.**, Dubas, J. J. S., Figner, B., & van Aken, M.A.G. (2015). A meta-analysis on age differences in risky decision making: Adolescents versus children and adults. *Psychological Bulletin*, *141*(1), 48-84.

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***Defoe, I.N.**, Keijsers, L., Hawk, S.T., Branje, S., Dubas, J.J.S., Buist, K., Frijns, T., Van Aken, M.A.G., M., Koot, H.M., Van Lier, P.A.C., & Meeus, W. (2013). Siblings versus parents and friends: Longitudinal linkages to adolescent externalizing problems. *Journal of Child Psychology and Psychiatry, 54* (8), 881-889.

Manuscript under review

***Defoe, I.N.**, Dubas, J.J.S., & van Aken, M.A.G. (under review). On Breaking the Vicious Cycle of Peer Similarity in Adolescent Delinquency: The Moderating Role of Mothers

Dutch publications

Defoe, I.N. (2013). De rol van broers en zussen bij het externaliserende gedrag van adolescenten (The role of siblings in adolescent externalizing behaviors). *Tijdschrift voor Psychiatrie (Journal of Psychiatry), 55*(6), 453.

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