

Why Adolescents with ADHD Take Risks: Biological, Cognitive and Social Mechanisms

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Summary and general discussion

Why adolescents with ADHD take risks: biological, cognitive and social mechanisms

The aim of this dissertation was to better understand why adolescents with ADHD, relative to typically developing adolescents, demonstrate higher levels of risk-taking behavior (RTB). Below, the main findings are summarized, integrated, and reflected upon, followed by recommendations for future research and a discussion of clinical implications.

Summary of main findings

Introduction (Section 1)

In Chapter 2, a literature review on the link between ADHD and RTB was provided, demonstrating that many different forms of RTB occur more often in people with ADHD than people without ADHD. These RTBs encompass driving under influence of alcohol; driving without license; traffic violations; nicotine, alcohol, marijuana and cocaine dependence or abuse; aggressive, criminal and delinquent behavior; early sexual activity; a high number of sexual partners; sexually transmitted diseases; teenage parenthood; gambling problems; compulsive buying; credit-card misuse; financial debts and unhealthy food consumption. Using a decision-theory framework, several mechanisms were proposed to explain these findings, such as executive functioning deficits, unwillingness to invest effort, sensation seeking, social influences from peers and parents, and comorbid disorders. This review also indicated that stimulant medication is an effective treatment for RTB in ADHD: stimulant use is associated with a reduced risk for substance use disorders, traffic accidents and conduct problems. Associations between stimulant medication and other forms of RTB are less investigated. In sum, the review in chapter 2 emphasizes the importance of studying ADHD-related RTB, and provides directions for research into associated mechanisms. More specifically, it indicated that several cognitive and social mechanisms may be of importance.

These, along with potential biological mechanisms were the focus of the remainder of the dissertation.

Experimental approaches to risk-taking behavior in ADHD (section 2)

Chapter 3 presented a meta-analysis of all gambling-task studies to date comparing an ADHD group with a control group on risk taking. A significant small-to-medium effect size was found, which was interpreted as more risky decision making in groups with ADHD. The effect was moderated by comorbid disruptive behavior disorders or, in case of adult samples, antisocial personality disorders: if this comorbidity was high in the ADHD group, the difference between ADHD and control groups in risky decision making was larger. The effect was not moderated by comorbid internalizing disorders, the age of the sample, and task explicitness.

Chapter 4 further unraveled these findings, which resulted in a more specific interpretation of the effect. With an additional moderator analysis, risk seeking and suboptimal decision making—which could both account for ADHD-related risky decision making observed in chapter 3—were disentangled meta-analytically: ADHD groups only demonstrated more risky decision making than controls when risk taking was suboptimal in terms of expected value; when risk taking was not suboptimal, groups performed similarly. These findings were complemented by novel empirical evidence in adults: on a gambling task where risk taking was suboptimal, groups with and without ADHD did not differ, but—crucially—on a gambling task where risk taking was optimal, controls demonstrated more risk taking than adults with ADHD. This implies that decision-making deficits observed in people with ADHD originate in difficulties in opting for the most optimal alternative (i.e., the alternative with the highest expected value), and not from risk seeking.

In chapter 5, the distinction between suboptimal decision making and risk seeking was again investigated, now using a task specifically designed for this purpose (i.e., Gambling

Machine Task). That is, the task did not only consist of items with alternatives with equal expected values and different levels of riskiness, but also of items with alternatives equal in riskiness but different in terms of expected values. Adolescents with ADHD consistently displayed more suboptimal decision making relative to controls, but groups did not differ in risk taking¹. These results closely resemble findings from chapter 4. In the second part of chapter 5, it was observed that adolescents with ADHD demonstrated less complex, less integrative decision-making strategies than typically developing adolescents. In the third part of chapter 5, ADHD-related decision-making deficits were also observed when the gambling task contained feedback (either full feedback on gains and losses as well as partial feedback on gains only). Adolescents with ADHD performed worse on both conditions.

Collectively, the results in the second section of this dissertation suggest that adolescents with ADHD show difficulties in optimizing their decision making: they use less complex decision strategies to arrive at their decision.

Biological and social influences on risk-taking behavior (section 3)

The third section of this dissertation focused on biological and social factors related to the link between ADHD and RTB. Chapter 6 described a meta-analysis on the dual-hormone hypothesis, which posits that the effect of testosterone on status-relevant behaviors like risk taking and aggression is stronger when cortisol levels are low, and is weaker when cortisol levels are high. The meta-analysis revealed small but significant main effects of testosterone, cortisol and—crucially—also demonstrated a small but significant testosterone-by-cortisol interaction on status, dominance, risk taking, aggression, and psychopathy. However, robustness analyses indicated that results should be interpreted with caution. It was concluded that there was only marginal support for the dual-hormone hypothesis.

¹ Adolescents also participated in studies described in chapter 7 and 8.

Next, in chapter 7, using a case-control design with adolescents with and without ADHD², it was tested whether testosterone, cortisol and their interaction mediated the link between ADHD on the one hand and risk taking (measured with a gambling task), and self-report measures of aggression and sensation seeking on the other hand. No evidence was found for this mediation, as none of the paths consistently revealed significant effects: (1) There was no effect of ADHD on testosterone and cortisol, and the effect of ADHD on testosterone × cortisol was inconclusive; (2) Opposite to expectations from dual-hormone theory, neither testosterone, cortisol nor testosterone × cortisol was associated with risk taking and aggression, and only testosterone was positively associated with sensation seeking; (3) Surprisingly, ADHD was not linked to risk taking, aggression and sensation seeking (although there was a significant effect of ADHD on the boredom susceptibility subscale of sensation seeking). Altogether, findings suggested that testosterone, cortisol and their interaction do not mediate status-relevant behaviors in adolescents with ADHD.

In chapter 8, it was investigated whether adolescents with ADHD are more susceptible to peer influence with regard to risk taking than adolescents without ADHD³. This was tested by incorporating a peer-influence manipulation into a well-established gambling task, the BART. It was also tested whether autonomic nervous system reactivity, an indicator of stress, mediated the link between ADHD and susceptibility to peer influence. All adolescents, regardless of ADHD status, displayed more risky behavior in a peer relative to a solo condition, indicating that susceptibility to peer influence seems to reflect a general characteristic of adolescents. Furthermore, higher autonomic reactivity (but only when indexed by the cardiac pre-ejection period) in the peer relative to the solo condition predicted peer-induced increases in risk taking. Again, these effects were not exacerbated by ADHD.

² Adolescents also participated in studies described in chapter 5 and 8.

³ Adolescents also participated in studies described in chapter 5 and 7.

Chapter 9 described three studies on the role of parental knowledge in explaining the link between ADHD and RTB. The first study replicated a previous study (Pollak, Poni, Gershay, & Aran, 2017) by demonstrating that parental knowledge mediated⁴ the link between ADHD and RTB: in adolescents with more ADHD symptoms, parental knowledge was lower; lower parental knowledge was associated with higher levels of domain-general RTB. In the second study, parental knowledge again mediated the link between ADHD symptoms and RTB, and was also positively associated with resistance to peer influence. In the third study, it was observed that parental knowledge also mediated the link between ADHD symptoms and homework problems.

In sum, the third section of this dissertation demonstrated that dual-hormone effects on status-relevant behaviors were small and not very robust. Also, testosterone, cortisol and their interaction did not explain the link between ADHD and several status-relevant behaviors. Social factors proved to be important: adolescents with ADHD were equally susceptible to peer influence as their unaffected peers, autonomic reactivity to peer influence was related to behavioral susceptibility to peer influence, and parental knowledge mediated the link between ADHD symptoms and RTB.

Personality traits related to risk-taking behavior (section 4)

The fourth section of this dissertation contains two studies on personality traits that may be implicated in both ADHD and RTB. Chapter 10 focused on sensation seeking – “seeking of varied, novel, complex and intense sensations and experiences and the willingness to take (...) risks for the sake of such experience” (Zuckerman, 1994). A brief instrument to assess sensation seeking in children was lacking in Dutch, and therefore the Brief Sensation Seeking Scale for Children (BSSS-C) was translated, and psychometric properties were investigated. Factor structure was similar to the original scale and internal consistency was high. Also, test-

⁴ Note that here, an effect of mediation is not a causal effect. Where mediation is mentioned, this indicates an indirect effect (see Hayes, 2018 for a statistical discussion on this topic).

retest and split-half reliability were acceptable. Sensation seeking correlated positively with attention problems and aggressive behavior, and boys reported higher levels of sensation seeking than girls, which was all interpreted as evidence for convergent and construct validity, respectively. The BSSS-C was concluded to be a valid and reliable instrument to measure sensation seeking in children, which is important as sensation seeking predicts several forms of RTB like aggression and substance abuse (Joireman, Anderson, & Strathman, 2003; Martin et al., 2002).

Another personality trait that may be related to the link between ADHD and RTB is need for cognition – “the extent to which one tends towards, and enjoys, analytical thought” (Cacioppo & Petty, 1982). In chapter 11, in a large sample of young adults, it was investigated whether low need for cognition mediated the link between ADHD symptoms and risky decision making. An association between ADHD symptoms and RTB was observed, but need for cognition did not mediate the link between ADHD symptoms and self-reported RTB, and also did not mediate the link between ADHD symptoms and decision-making strategy complexity. However, follow-up exploratory analyses showed that higher need for cognition was related to less inattention symptoms and to higher decision-making accuracy. Also, need for cognition mediated the link between inattention symptoms and health-related RTB.

In sum, the fourth section of this dissertation demonstrated that (1) sensation seeking can be easily measured in children with the valid and reliable BSSS-C and (2) need for cognition does not explain the link between ADHD and risky decision making (although this conclusion could be nuanced based on exploratory results).

Executive functioning in children with ADHD (section 5)

The fifth section of this dissertation focused on executive functioning in children with ADHD. This is relevant for the overall scope of the dissertation, as executive functioning

deficits are often observed in ADHD (Kasper, Alderson, & Hudec, 2012; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) and predict RTB in adolescence (Lahat et al., 2012; Peeters et al., 2015). In chapter 12, it was investigated whether the decline of executive functioning over time (i.e., time-on-task effects) originates in a depletion of executive resources or in a depletion of motivation. It was observed that time-on-task effects were stronger for children with ADHD than in controls on measures of inattention, but not on inhibition. Reinforcement improved performance on one of the two measures of inattention, indicating that time-on-task effects on inattention seem to originate in both depletion of executive resources (not counteracted by reinforcement) and depletion of motivation (indicated by the reinforcement-related improvement).

Chapter 13 investigated the relationship between executive functioning demands and gross motor activity levels in children with and without ADHD, to disentangle under which circumstances children with and without ADHD are (or are not) hyperactive. Children performed four digit span tasks with increasing central executive demands. When central executive demands increased, performance of all children declined, and disproportionately so for children with ADHD. All children exhibited higher levels of gross motor activity during the digit span tasks relative to a non-demanding baseline, and children with ADHD moved more than typically developing children under all conditions. Crucially, no differences in gross motor activity between the digit span conditions were observed. This indicates that gross motor activity level increases when children engage in cognitively demanding activities as compared to non-demanding activities, but remains at a similar level during any cognitively demanding task, instead of being linearly related to the cognitive demands. These findings suggest that children's activity level is related to the demands of the task, with higher movement when performing demanding vs. non-demanding activities.

In sum, the fifth section of this dissertation further added to the large body of evidence that children with ADHD demonstrate pronounced executive functioning deficits (although such deficits were not observed on measures of inhibition in chapter 12). Children with ADHD were characterized by a stronger decline of performance over time than controls, which could partly be counteracted by reinforcement. Furthermore, children with and without ADHD demonstrated higher levels of motor movement during cognitively demanding activities than during non-demanding activities.

Synthesis of findings

Overall, several biological, cognitive and social mechanisms explain why adolescents with ADHD take risks. At the **biological** level, the dual-hormone hypothesis has some potential to explain risk taking, although effects are small, and were not observed in relation to ADHD. Furthermore, adolescents that demonstrated highest sympathetic reactivity to peers were most susceptible to peer influence towards risk taking, although this finding was not exacerbated by ADHD. At the **cognitive** level, on gambling tasks, ADHD was consistently associated with suboptimal decision making, as reflected by choosing more often for the option with lowest mean outcomes. It was reasoned that this was due to their use of suboptimal decision strategies, which was corroborated by our findings demonstrating lower complexity of decision-making strategies in adolescents with ADHD. However, also at the cognitive level, it was observed that the personality trait need for cognition did not mediate the link between ADHD and risky decision making. At the **social** level, risk-encouragement by peers increased subsequent risk taking on a gambling task, but this effect was not specific for ADHD. However, higher levels of ADHD symptoms were consistently associated to lower levels of parental knowledge about their child, and lower parental knowledge was in turn associated with higher levels of RTB. These two social factors were also associated:

adolescents reporting higher levels of parental knowledge also reported higher resistance to peer influence.

Limitations: assessment of risk taking

In the discussion of each chapter, several strengths and limitations were highlighted. One of them is worth further discussion: the assessment of risk taking. Risk taking can be measured in several ways. The starting point of this dissertation was the well-established link between ADHD and real-life RTB. The evidence reviewed in chapter 2 was mainly derived from large population-based studies and prospective follow-up studies of children with ADHD. The main conclusion of these studies is consistent: ADHD is related to higher RTB across all domains. As this evidence is strong, this well-established distinction between groups with and without ADHD is used to evaluate measures of risk taking used in this dissertation. Do these measures also distinguish between groups with and without ADHD? Three different operationalizations were used: gambling tasks, self-report RTB questionnaires and personality questionnaires.

Gambling tasks enable unraveling mechanisms associated with risk taking as they allow for experimental manipulations (e.g., peer influence manipulations as in chapter 8, or assessment of strategies as in chapter 4). The conclusion from the meta-analysis on gambling tasks (chapter 3) is consistent with real-life findings: ADHD is associated with risky decision making (although effects are small). But what does risky decision making on these tasks represent? As shown in chapter 4, risk taking is confounded with suboptimal decision making in many gambling tasks. Chapter 4 and 5 conclude that ADHD is not associated with risk seeking as such, but with suboptimal decision making (i.e., opting for alternatives with lower outcomes, on average). These results qualify the idea that ADHD is associated with risk taking in real life and yield a new hypothesis: The well-established increased engagement in real-life RTB in ADHD originates in difficulties choosing the most optimal alternative.

In the studies where the BART was used as index of risk taking (chapter 7 and 8), no differences between adolescents with and without ADHD were observed, whereas differences were found on several versions of the Gambling Machine Task. In sum, gambling tasks are valuable to disentangle mechanisms, but do not always distinguish groups with and without ADHD.

Another way of measuring RTB is by the use of questionnaires. This has the disadvantage that mechanisms cannot be experimentally manipulated, but the advantage is that responses may be closer related to the real-life behavior of interest. In four studies in the current dissertation (reported in chapters 9 and 11), participants were asked to indicate how often they engage in a broad range of RTB. On all occasions, results were as expected: the more ADHD symptoms, the more adolescents/young adults engaged in RTB. Chapters 9 and 11 demonstrated how such questionnaire data can still be used to investigate underlying mechanisms, although only in a correlational way. A related method is to measure personality constructs that are associated to RTB, such as sensation seeking. In chapter 10, a significant correlation between attention problems and sensation seeking was found in children. In chapter 7, however, no differences in sensation seeking were observed between adolescents with and without ADHD. The consistent findings regarding self-reported RTB and the inconsistent findings regarding sensation seeking tentatively suggest the former to be a better measure of risk taking.

In sum, all these ways to measure risk taking have proven valuable. Gambling tasks enable precise unraveling of different mechanisms, but do not differentiate between groups very well. Questionnaires asking participants how often they engage in RTB may be most closely related to real life RTB, but offer less possibilities to study underlying mechanisms.

Future directions

Several directions for future studies emerge from the findings in this dissertation. First, suboptimal decision making, also reflected by the use of less complex decision-making strategies, was consistently observed in relation to ADHD (chapter 4 & 5, also see Pollak et al., 2016). The next step would be to directly test the hypothesis that suboptimal decision making is the driving mechanism behind ADHD-related real-life RTB. A potential challenge to achieve this step is that the task should offer the possibility to assess such suboptimal decision making strategies, and at the same time should be ecologically valid. Although performance on some gambling tasks has been related to real-life RTB (e.g., Lejuez, Aklin, Zvolensky, & Pedulla, 2003), a large gap still exists (Pollak, Shalit, & Aran, 2018; Schonberg, Fox, & Poldrack, 2011) as the dynamics of real-life RTB are hard to capture in an experimental task. With respect to ecological validity, chapter 8 describes an effort to bridge this gap: peer influence was incorporated in the BART, which potentially better reflects adolescents' daily life, in which most RTBs occur with peers. It is recommended to further develop ecologically valid gambling tasks. Some other examples worth mentioning are added frustration, induced depletion or boredom (Matthies, Philipsen, & Svaldi, 2012; Silva, Patrianakos, Chein, & Steinberg, 2017). A suggestion for future research would also be to develop gambling tasks in virtual reality environments, which are suitable to create a sense of immersion that better reflects daily life (Parsons et al., 2017). The challenge will be to redesign these tasks such that suboptimal decision strategies can be assessed.

Second, it would be valuable to assess whether ADHD is associated to positive RTB. This dissertation predominantly focused on excessive RTB as being negative, given the serious consequences RTBs like substance abuse and speedy driving can have. In some occasions, however, RTB can be positive: it can benefit well-being, the potential costs could be relatively mild and the RTB could be legal and socially acceptable (Duell & Steinberg,

2019). Some examples of positive RTB are trying new hobbies, being spontaneous, asking others on a date, and talking with strangers. Interestingly, low self-regulation has been associated with more negative risk taking and with less positive risk taking (see Duell & Steinberg, 2019 for a short review). As ADHD is related to decreased self-regulation (Barkley, 1997), it would be expected that people with ADHD engage less in positive risk taking. This hypothesis is in line with findings from chapter 4, where lower levels of risky decision making were observed in adults with ADHD, relative to controls, on a gambling task in which risk taking was beneficial. However, this reasoning contrasts clinical observations of patients with ADHD who often report positive RTB. Future research is needed to assess whether there is a link between ADHD and positive risk-taking behavior, and if so, in what direction.

Third, the link between parental knowledge and susceptibility to peer influence (chapter 8 and 9) should be further studied. As demonstrated in chapter 9, higher levels of parental knowledge about their child were related to a larger resistance to peer influence. Longitudinal or intervention studies are needed to establish the causal direction of this link. Intervention studies could for example focus on increasing parental knowledge, and then test the hypothesis that this also results in a higher resistance to peer influence, altogether leading to decreased RTB.

A fourth recommendation is to directly measure the link between executive functioning deficits and decision making in ADHD. The fifth section (chapter 12 and 13) of this dissertation added to a large body of research on executive functioning deficits related to ADHD (Huizenga, van Bers, Plat, van den Wildenberg, & van der Molen, 2009; Kasper et al., 2012; Willcutt et al., 2005). In several other chapters of this dissertation, it was speculated that executive functioning deficits potentially drive problems in decision making. For example, less complex, less integrative decision-making strategies observed in adolescents

with ADHD relative to controls (chapter 5) could potentially be explained by deficits in response inhibition (necessary to withhold one from responding based on a single, salient characteristic) and working memory (necessary to calculate expected values, or to update strategies based on feedback). A direct test of the hypothesis that decision-making deficits in ADHD could be explained by executive dysfunctioning would advance the understanding of decision making in ADHD, but is lacking thus far. Relatedly, in chapter 12 it was observed that children with ADHD are particularly sensitive to effects of depletion. A recent study linked mental fatigue to risk taking in late adolescents (Silva et al., 2017). Especially given the well-established link between ADHD and sleep problems (Cortese, Faraone, Konofal, & Lecendreux, 2009), the hypothesis that mental fatigue could be implicated in the link between ADHD and RTB is likely, and should be further investigated.

Fifth, future researchers into ADHD and RTB should consider whether they include a clinical ADHD group using a case-control design (as was done in chapters 5, 7, 8, 12 and 13), or whether they measure ADHD dimensionally in community samples. This decision reflects one of the most fundamental debates in psychiatry and psychology: whether mental disorders should be described categorically or dimensionally. For the investigation of the link between ADHD and RTB, both approaches have proven valuable. Case-control designs allow to make conclusions about certainly impaired, strictly classified people, and therefore enable translation of research findings into clinical practice where identical classification systems are used. Many of the large cohort and prospective studies reviewed in chapter 2 used categorical approaches, showing that those who meet ADHD criteria are at risk for several forms of RTB. This could guide targeted prevention and intervention programs. However, others (e.g., RDoC; Insel et al., 2010) promote more dimensional approaches of psychopathology, arguing that for example ADHD symptoms are distributed along a continuum and that categorization is not justified given this continuous distribution (see

Coghill & Sonuga-Barke, 2012 for a review on categorical vs. dimensional classification in child and adolescent psychiatry). As described in chapters 9 and 11, continuously measured ADHD symptoms in community samples were also related to RTB. The latter approach has some pragmatic advantages, as it is easier for researchers to test large community samples, relative to the labor-intensive approach that is necessary to conduct properly powered case-control studies.

Two other future directions are worth mentioning, although these do not directly follow from the studies in this dissertation. First, it would be worthwhile to investigate decision-making deficits in other than ADHD groups. Although there are several good reasons to investigate decision making in ADHD, other disorders are also likely to place people at risk for decision-making problems, potentially leading to real-life RTB. Several of the assumed mechanisms in the current dissertation are also relevant for adolescents with other disorders than ADHD (e.g., executive dysfunctioning, peer- and parenting problems). The most obvious candidates are disruptive behavioral disorders, which are in itself partly defined by RTB, but internalizing disorders are also likely to be associated with decision-making problems. In internalizing disorders, decision-making is likely hesitant and risk-averse (anxiety disorders), or pessimistic and disengaged (mood disorders; Sonuga-Barke, Cortese, Fairchild, & Stringaris, 2016); both styles could also result in suboptimal decision making. Therefore, a theoretical framework for a transdiagnostic approach on decision making, as advocated by the National Institute of Mental Health's Research Domain Criteria (RDoC (Cuthbert & Insel, 2013; Insel et al., 2010), has been described recently (Sonuga-Barke et al., 2016). If similar suboptimal decision making patterns appear across disorders, diagnostic categories would prove little value and treatment could potentially focus on decision making as transdiagnostic factor instead (Sonuga-Barke et al., 2016).

Finally, several studies in this dissertation were preregistered and predominantly resulted in null-findings. In general, findings are less likely to reflect reality when methodology is more flexible (Ioannidis, 2005). Preregistration precludes this flexibility, and therefore it is expected that these null findings from preregistered studies reflect reality more closely than significant findings from non-preregistered studies that enabled exploration of the data. In line with Open Science initiatives (Nosek et al., 2015), further implementation of such preregistered studies is advocated.

Clinical implications

A first and obvious clinical implication is that RTB deserves considerable attention in clinical practice. ADHD increases the risk for any form of RTB (chapter 2), which may have serious consequences for adolescents and their environment. Two questions emerge: (1) Do clinicians spend considerable attention to RTB when working with adolescents with ADHD? and (2) do they adequately estimate the risk for RTB in ADHD populations? This was tested in a small pilot survey, distributed among colleagues working in an academic center for child- and adolescent psychiatry. Two noticeable findings emerge. First, as can be seen in Table 1, most clinicians do not systematically pay attention to all forms of RTB, both during assessment as well as during intervention. Most attention goes to aggression, criminal behavior and substance use; whereas gambling, traffic conduct, financial behavior and anti-conception are less often topic of conversation.

However, the relatively low consideration of RTB in clinical practice when working with adolescents with ADHD seems to contrast the knowledge about the prevalence of RTB in ADHD populations. As can be seen in Table 2, clinicians overestimate the prevalence or risk ratios of most forms of RTB in ADHD.

When working with adolescents (12-18 years old) with ADHD, how often is this an explicit topic of conversation during ...			
	Assessment (n = 11)	Non-pharmacological intervention (n = 14)	Pharmacological intervention (n = 3)
Traffic conduct	20.3%	27.4%	25.7%
Alcohol use	50.0%	59.9%	70.3%
Smoking	45.8%	47.8%	51.0%
Drugs use	63.6%	58.3%	83.3%
Eating habits	27.5%	33.9%	28.7%
Gambling	21.5%	24.1%	22.7%
Aggression	68.0%	72.7%	59.3%
Criminal behavior	52.1%	60.9%	54.7%
Sex	45.2%	36.9%	32.7%
Anti-conception/STD prevention	8.4%	26.6%	35.0%
Financial behavior	21.2%	31.0%	17.7%

Table 1. Clinicians were asked how often they pay attention to several specific forms of RTB when working with adolescents with ADHD (during assessment, non-pharmacological, and pharmacological intervention). Note that the survey only included respondents with experience with at least 5 adolescents with ADHD.

	Responses (n = 17)	Benchmark
How much more likely is it for adults with ADHD to be involved in serious traffic accidents as compared to adults without ADHD?	2.31	1.46 (adjusted hazard ratio; Chang, Lichtenstein, D'Onofrio, Sjölander, & Larsson, 2014)
How many of the 17-year olds diagnosed with ADHD in childhood smoke?	60.8%	23.6% (Molina et al., 2013)
How many of the 17-year olds diagnosed with ADHD in childhood have used marijuana more than once?	64.2%	32.1% (Molina et al., 2013)
How many adults with ADHD has obesity?	28.6%	28.2% (Cortese et al., 2016)
How many adolescents/young adults with ADHD have gambling problems?	29.9%	11.8% (Theule, Hurl, Cheung, Ward, & Henrikson, 2016)
How many of the adolescents in youth detention meet criteria for ADHD?	68.7%	30.1% (Young, Moss, Sedgwick, Fridman, & Hodgkins, 2015)
How many adolescents/young adults with ADHD at least once had casual sex without condom in the last year?	54.2%	15.0% (Flory, Molina, & Pelham, 2006)
How much more likely is it for adolescents with ADHD to have a baby as compared to adolescents without ADHD between age 12 and 16?	1.92	3.62 (incident risk ratio; Østergaard, Dalsgaard, Faraone, Munk-Olsen, & Laursen, 2017)
How many adults with ADHD have a savings account?	27.4%	53.3% (Bangma et al., 2019)
How many adults with ADHD has a debt (excluding mortgage, study loan)?	46.5%	48.9% (Bangma et al., 2019)

Table 2. Clinicians' estimates of RTB in ADHD populations, as compared with benchmarks reported in the literature.

A second implication is that it is important to take the adolescents' social environment into account when working with risk-taking adolescents. Adolescents with ADHD are more often rejected by their peers (de Boo & Prins, 2007), and are more often involved with deviant peers (Bagwell, Molina, Pelham, & Hoza, 2001). Although their susceptibility to peer influence is similar to typically developing adolescents (chapter 8), the likelihood of getting into such situations is much higher for adolescents with ADHD. Parents may have a potential

protective role against the negative influences by peers in relation to RTB: As shown in chapter 9, higher levels of parental knowledge were associated with lower levels of RTB, and were also related to higher resistance to peer influence. Increasing parent-child relationship quality, aiming to increase disclosure from adolescents towards their parents may therefore be promising in making these adolescents more resistant to peer influence. The current findings suggest that systemic treatment (Cottrell & Boston, 2002), or modules specifically aiming at parent-child interaction (e.g., Parent Management Training Oregon; Forgatch & Patterson, 2010), could be fruitful in ultimately reducing RTB.

However, susceptibility to peer influence could turn into something positive when peers have a prosocial influence. Experimental studies demonstrate that adolescents are also susceptible to peer influence in case these peers guide them towards prosocial instead of risky behavior (see van Hoorn, Fuligni, Crone, & Galván, 2016 for a review). Therefore, encouraging the establishment of meaningful relationships with prosocial, non-deviant peers could be an aim in itself.

A third clinical implication would be to focus treatment on suboptimal decision making. Chapters 3-5 consistently conclude that adolescents with ADHD demonstrate suboptimal decision making, defined as making the decision with the lower overall outcome. Their strategies are less complex, which implies information is less well integrated before making a decision. Teaching adolescents with ADHD more sophisticated decision-making strategies could be achieved using normative decision-making models (Furby & Beyth-Marom, 1992). Such an approach ideally consists of four steps: identify all options (A: speeding on my scooter, B: driving below maximum speed), establish consequences of options (A>B: more fun, faster at destination, higher risk of accidents), weigh these consequences, and then make a decision based on integration of all this information. The weights people assign to several consequences of options may differ, they are subjective. Therefore, given the example above,

some adolescents may arrive at the conclusion that speeding on their scooter is the best idea. However, explicitly making them think about all possible options and related consequences likely increases the complexity of their decision strategy (i.e., more information is taken into account), and increases the probability of more optimal decision making. Not much research exists on how to achieve this treatment goal. A study in intellectually disabled people found that the introduction of visual aids led to more integrative decision making (Bailey, Willner, & Dymond, 2011). Achieving integration of information in ADHD populations is particularly complicated because the positive consequences of desired decisions often emerge in the future and these delayed rewards are generally discounted by adolescents with ADHD (Jackson & MacKillop, 2016). Solution-focused therapy could be beneficial for guiding adolescents with ADHD in integrating all information to reach long term life goals and to refrain from seemingly attractive but risky behaviors, as solution-focused therapy specifically reformulates long term goals into small steps that could be realized on the shorter term (De Shazer & Berg, 1997).

Fourth, next to psychosocial interventions as suggested above, positive effects of methylphenidate on several forms of RTB were reported. As summarized in chapter 2, stimulant medication use in people with ADHD is associated with lower risk for substance abuse and traffic accidents, lower rates of aggression and criminality and lower rates of non-intentional injuries (also see Ghirardi et al., 2019 for a recent population-wide study). Given these findings, clinical evaluations of the effectiveness of stimulant medication should not only focus on core symptoms of ADHD, but also assess potential effects on RTB. Potentially, the effect of stimulant medication on decreased RTB is mediated by improved decision making skills. Two studies on the association between stimulant medication and decision making yield mixed evidence: children with ADHD placed more conservative bets when taking methylphenidate relative to placebo (DeVito et al., 2008), but in adults with ADHD,

methylphenidate did not affect decision making (Agay, Yechiam, Carmel, & Levkovitz, 2010). Larger double-blind randomized controlled trials are recommended to test whether stimulant medication decreases RTB via improved suboptimal decision making in adolescents with ADHD.

Fifth, lower levels of the personality trait need for cognition were associated with inattention symptoms (chapter 11). Avoidance of effortful tasks, potentially originating in a low need for cognition, is a characteristic that is often observed in clinical practice (see <https://www.youtube.com/watch?v=Uo08uS904Rg> for a useful video to introduce this topic in therapy with adolescents/adults with ADHD), and may cause significant impairment (Adamou et al., 2013). As argued in chapter 11, strategies aimed at decreasing cognitive effort associated with a task, by for example breaking tasks apart or applying tools like checklists and agenda's (Boyer, Geurts, Prins, & Van der Oord, 2015; Johnson & Reid, 2011) could be useful treatment aims.

Sixth, the Dutch translation of the Brief Sensation Seeking Scale for Children can be easily used in clinical practice. Psychometric properties of this short self-report measure for elementary school-aged children were good (chapter 10). Assessment of sensation seeking in this young age group is relevant to screen those children at risk for several forms of RTB later in life, as sensation seeking predicts substance abuse, sexual RTB and gambling problems (Newcomb & McGee, 1991). Selective prevention of RTB could target those children high in sensation seeking at an early age.

The value of scientist-practitioner projects

The research described in this dissertation is the result of a scientist-practitioner project, a collaboration between the University of Amsterdam and De Bascule, academic center for child- and adolescent psychiatry, in which PhD research was combined with clinical education. Contrary to medicine, these constructions are rare in psychology. Scientist-

practitioners are important for several reasons: they are more likely to develop clinically relevant research questions, they understand how to do research in patient populations, they are able to translate research findings into clinical practice, and they are well equipped to critically evaluate clinical practice. In the current project, these valuable aspects of scientist-practitioner projects were fruitful. Research questions were partly derived from clinical practice (see “from practice to science” boxes in the general introduction), and large-scale studies were successfully conducted in clinical practice. Research findings were also translated to clinical practice. This was done, for example, by also writing papers for the professional field (e.g., chapter 3 and 12 were rewritten in Dutch for professionals) and by giving presentations at conferences for clinicians, and at schools. In addition, there was also a direct effect on clinical practice. By doing so, positive impact can be made easily. For example, by raising the topic of sexual RTB during therapy, a 15-year old adolescent with ADHD admitted to never use a condom, because he thought these could only be bought legally from the age of 18. This example does not stand alone, and in these cases one does not need extensive clinical training to intervene effectively.

Several gaps still exist between science and clinical practice. Perhaps the most crucial gap relates to the question whether scientific findings, especially about treatments, generalize to clinical practice (Kazdin, 2008). A few examples: (1) Researchers often prefer homogeneous groups to enable standardization, clinical practice is very heterogeneous; (2) The most severely impaired patients do not often enroll in clinical studies, whereas clinicians are most in need of knowledge about these patients; (3) Statistical significance is different from clinical significance (a significant p-value is not the same as an improved patient); (4) Studies often suggest one size fits all treatments, whereas clinicians struggle to tailor their intervention to their particular patient.

Although not all of these gaps were applicable to the studies in the current dissertation, as most apply to intervention studies, awareness of these gaps is pivotal. In the case-control studies reported in chapters 5, 7 and 8, no adolescents with comorbid disorders were excluded from the ADHD group. This creates a more heterogeneous ADHD group, and findings are more likely to reflect the ADHD population that visits mental healthcare institutions. With this approach, large samples are necessary to allow subgroup analyses, which are needed to test whether findings were not better explained by comorbid disorders.

To summarize, scientist-practitioners are important, for science and for clinical practice. Both universities and mental healthcare institutions should contribute to expand the number of scientist practitioners. Mental healthcare institutions should acknowledge that this will ultimately improve the quality of their care, and universities should acknowledge this will improve the relevance of research. Funding agencies should not only value research output, but should encourage researchers to also work in clinical practice. Recent developments in the Netherlands (e.g., RINO's Topklas) that work into this direction are promising, but further progress is needed.

Conclusion: why adolescents with ADHD take risks

Easy questions often have difficult answers. Several biological, cognitive and social mechanisms were hypothesized to contribute to increased engagement in RTB in adolescents with ADHD. Evidence for biological mechanisms was weak to non-existent: Sympathetic reactivity to peers did predict consequent risk taking, but this effect was not specific for ADHD, and dual-hormone mechanisms did not explain the link between ADHD and RTB. Evidence for cognitive mechanisms was observed: Suboptimal decision-making and less complex decision-making strategies were related to ADHD. Evidence for social mechanisms was also observed: Susceptibility to peer influence was substantial (but not specific for ADHD) and parental knowledge mediated the link between ADHD symptoms and RTB. The

studies described in this dissertation pave the way for further studies on the mechanisms underlying RTB in ADHD. Ultimately, these endeavors should lead to more satisfactory answers on the bigger question: how to make adolescents with ADHD take less risks.