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Risk taking, perceived risks, and perceived benefits across adolescence: A domain-specific risk-return approach

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Abstract

Adolescence is a phase of heightened risk taking compared to childhood and adulthood, which is even more prominent for specific adolescent populations, such as youth with attention-deficit/hyperactivity disorder (ADHD). Until now little is known about how perceived risks and benefits relate to adolescent risk taking. Here, we used the adolescent version of the Domain-Specific Risk-Taking (DoSpeRT) scale to investigate the likelihood of risk taking, perceived risks, perceived benefits, and their tradeoff in two studies. In the first longitudinal study, 375 11-to-23-year-olds completed the DOSPERT one up to three times. A second biannual longitudinal study included 180 11-to-20-year old boys diagnosed with ADHD (*N*=81), and an IQ and age-matched control group (*N*=99). Using mixed-effects models, we found a peak in likelihood of risk taking in mid-to-late adolescence, but only in the health/safety, ethical, and social domains of risk taking, with similar curvilinear patterns in perceived benefits (peaks) and perceived risks (dips). In both cohorts, perceived risks and benefits were significant predictors of risk taking in all domains, and perceived benefits related more strongly to risk taking than perceived risks. Moreover, perceived benefits increasingly related to risk taking across adolescence, a pattern that was found in recreational risk taking in both studies. Generally, we observed little differences in risk taking, and perceived risks and benefits between the ADHD and control group. However, risk-return models indicated that adolescents with ADHD displayed a heightened likelihood of risk-taking behavior in the social domain, and their perceived risks related less strongly to risk taking, relative to typically developing adolescents. Taken together, our results are consistent with the developmental peak in risk taking observed in real life and highlight the role of perceived risks and benefits in risk taking. These findings provide tentative entry points for possible prevention and intervention.

Keywords: Adolescence, risk taking, domains, ADHD, risk-return, multi-sample

1.0 Introduction

Adolescence is a life phase marked by pronounced social-affective and cognitive changes, and is an important phase for developing autonomy from parents by seeking out boundaries and engaging in novel experiences (Crone & Dahl, 2012). As a normative part of this transitional shift from childhood to adulthood, many adolescents show increased risk-taking behaviors such as being rebellious (e.g., staying out late), experimenting with substances (e.g., trying marihuana for the first time), or even showing reckless, health-detrimental behaviors (e.g., joy-riding, having unsafe sex), relative to children and adults (Duell et al., 2018; Eaton et al., 2008; Willoughby, Good, Adachi, Hamza, & Tavernier, 2013). Neurodevelopmental models have been influential in explaining adolescent risk taking, suggesting that an imbalance between heightened reward sensitivity and attenuated cognitive control underlies risk taking (Shulman et al., 2016; Somerville, Jones, & Casey, 2010; Steinberg, 2008). This heightened risk-taking behavior that is observed on a group level has, however, been challenged on an individual basis (not all adolescents take risks; Bjork & Pardini, 2015; Blankenstein, Schreuders, Peper, Crone, & van Duijvenvoorde, 2018; Romer, Reyna, & Satterthwaite, 2017), and these models have been questioned on their ability to disentangle the processes underlying individuals' risk taking. Behavioral economic models may explain risk-taking behavior with greater specificity. These models may be of particular interest to decompose behavioral changes in risk taking across development (van den Bos et al., 2017).

In formal behavioral models of risky choice, risk taking is decomposed in a 'risk' component (i.e., the variability in possible outcomes) and a 'return' component (i.e., the expected value of a choice's outcome; Weber, 2010). Psychological risk-return models argue that risk and benefit are inherently subjective: while increased perceptions of *risk* discourage risk taking, increased perceptions of *benefit* (return) promote risk taking (Weber, Blais, & Betz, 2002). Until now, a significant body of research in adolescence focuses on elements of the 'return' component of adolescent risk taking, which includes (subjective) expected value (Barkley-Levenson & Galván, 2014; Blankenstein & van Duijvenvoorde, 2019), reward sensitivity (e.g., Schreuders et al., 2018; Silverman, Jedd, & Luciana, 2015; Urošević, Collins, Muetzel, Lim, & Luciana, 2012; Urošević et al., 2014), or studied risk taking in situations in which risks and rewards cannot be disentangled (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Lejuez, Aklin, Zvolensky, & Pedulla, 2003; MacPherson, Magidson, Reynolds, Kahler, & Lejuez, 2010). Fewer studies have examined risk sensitivity only (e.g., (e.g., Blankenstein, Crone, van den Bos, & van Duijvenvoorde, 2016; Blankenstein, Peper, Crone, & Duijvenvoorde, 2017; Blankenstein & van Duijvenvoorde, 2019; Kim-Spoon et al., 2017), or explicitly disentangled both risk and return components to study adolescent risk taking (Van Duijvenvoorde et al., 2015). Here we aim to address this gap and examine developmental changes in risk taking across adolescent development as function of developmental changes in perceived risks and perceived benefits. Moreover, we address this in a longitudinal community sample and a sample of youth with a diagnosis of attention-deficit/hyperactivity disorder (ADHD), and matched controls.

A well-suited framework for such an analysis comes from the DOmain SPEcifi Risk Taking (DOSPERT) scale (Blais & Weber, 2006; Weber et al., 2002). Central in this approach is that risk-taking is driven by a trade-off between perceived risks and returns (Blais & Weber, 2006; Weber et al., 2002) and that risk taking varies depending on the context (i.e., domain) of the behavior. In the DOSPERT questionnaire, five core domains of risk taking are distinguished: health-safety endangering behavior (e.g., driving without a seat belt), recreational behavior (e.g., skiing on a slope that is too difficult), ethical behavior (e.g., cheating on an exam), social behavior (e.g., going against the opinion of the majority at school), or financial behavior (e.g., betting in an online game). Adult work has shown that health-endangering risk taking not necessarily coincides with risk taking in other domains, such as financial decisions, or in social situations (Frey, Pedroni, Mata, Rieskamp, & Hertwig, 2017; Hanoch, Johnson, & Wilke, 2006; Highhouse, Nye, Zhang, & Rada, 2017; Weller, Ceschi, & Randolph, 2015), and that age-related declines in risk taking throughout adulthood and old age are steeper in some domains (financial, recreational) than in others (social, ethical, health; Josef et al., 2016; Rolison, Hanoch, Wood, & Liu, 2014)).

Although prior work gives some indication about adolescent risk taking in different contexts, longitudinal research is needed to examine how perceived risks and benefits link to risk taking. Studies on adolescent risk taking frequently examine stereotypical health-detrimental risk taking (e.g., self-reported risky driving, binge drinking), and have observed increased levels of risk taking in mid-to-late adolescence (e.g., Blankenstein et al., 2016; Blankenstein et al., 2018; Duell et al., 2018). Other work on adolescence focused on both health risks and social risks (e.g., spending time with an unpopular peer), showing that concerns for health risks and for social risks declined across adolescence to adulthood, but that the decline for social risk was steeper than for health risks (Andrews, Foulkes, Bone, & Blakemore, 2020). This work suggests that adolescence is a period for heightened concern for social risk (Andrews et al., 2020), but it remains to be studied how this ‘concern’ informs risk-taking tendencies. Furthermore, previous adult and adolescent work suggested that seeing greater benefits in risky behaviors (such as attaining social status from drinking alcohol) promotes risk taking (drinking alcohol; Goldberg, Halpern-Felsher, & Millstein, 2002; Halpern-Felsher, Biehl, Kropp, & Rubinstein, 2004; Meier, Slutske, Arndt, & Cadoret, 2007; Song et al., 2009). Thus, to understand the dynamics of risk taking, an important question is how perceived risks and benefits relate to risk taking across several domains. Here, we address this core question in a community sample of adolescents and adolescents with and without ADHD.

Finally, not all adolescents are risk takers, and risk taking may be particularly pronounced in certain groups (Bjork & Pardini, 2015). One group of adolescents who are associated with extreme levels of risk taking are those diagnosed with ADHD. ADHD is a neurodevelopmental disorder characterized by excessive levels of inattention and/or hyperactivity and impulsivity, leading to impairments in multiple settings such as at home and in school (DSM-5, APA, 2013), and a risk for myriad negative life outcomes (Franke et al., 2018; Nigg, 2013; Young, 2000). Youths with ADHD show higher levels of risk taking in the lab and in real-life (Dekkers, Popma, van Rentergem, Bexkens, & Huizenga, 2016; Pollak, Dekkers, Shoham, & Huizenga, 2019). Prior work in adults from the general population found that ADHD symptoms were related to more risk taking and perceived benefits, but not to perceived risks, and that the association between ADHD symptoms and risk taking was exacerbated by perceived benefits (Shoham, Sonuga-Barke, Yaniv, & Pollak, 2020; Shoham, Sonuga-Barke, Aloni, Yaniv, & Pollak, 2016; Spiegel & Pollak, 2019). These findings in adults suggest that the relation between perceived benefits and risk taking may also be exaggerated in adolescents with ADHD relative to typically developing adolescents, particularly in mid-to-late adolescence. However, this has yet to be examined in an adolescent cohort across several domains, which may yield new insights into the underlying processes of risk taking in ADHD across adolescent development. In addition, the longitudinal development of risk taking and perceived risks and benefits across adolescents with and without ADHD allows to examine whether adolescents with ADHD follow a distinct developmental pattern of risk taking compared with controls.

The current study

In this multi-sample study, we took a domain-specific psychological risk-return approach to unravel adolescent daily life likelihood of risk taking across various domains, in a longitudinal community sample (*n*=375, 11-23 years) and in a longitudinal sample with adolescents with and without ADHD (*n*=81, *n*=99, resp., 11-20 years). To asses risk taking, perceived risks, and perceived benefits across five domains we used the adolescent version of the Domain-Specific Risk Taking questionnaire (DOSPERT; Figner, Van Duijvenvoorde, Blankenstein, & Weber, 2015). Earlier work has used this version in adolescent populations (Barkley-Levenson, Van Leijenhorst, & Galvan, 2013; Somerville et al., 2019). The Adult version has shown this scale to be a well-validated questionnaire to assess risk taking and perceived risks and benefits across five domains (Blais & Weber, 2006).

First, we expected that risk taking and perceived benefits are heightened in mid-late adolescence, and that perceived risks are lowered in this age range. In addition, we expected that adolescents with ADHD show increased risk taking, and an increase in perceived benefits, compared to an age-matched control group. In addition, we explored whether the developmental trajectories of risk taking, perceived risks, and perceived benefits differ between adolescents with and without ADHD.

Second, we examined risk-return tradeoffs (i.e., perceived risks and benefits). Here we expect that perceived benefits and perceived risks relate, respectively positively and negatively, to risk taking across adolescence, and that perceived benefits relate to risk taking more strongly than perceived risks. These risk-return tradeoffs may be altered in adolescents with ADHD. In this subgroup, we specifically expected an exaggerated weighting of benefits (Shoham et al., 2016). We also explored whether the association between perceived risks and benefits on risk taking changes throughout development differently for adolescents with and without ADHD.

We examined these patterns of risk taking, perceived risks, perceived benefits, and risk-return tradeoffs across various domains as specified in the structure of the DOSPERT questionnaire. Although different developmental patterns may arise between domains we take an explorative approach and do not formulate specific hypotheses for developmental or group-related differences between domains.

2.0 Methods

2.1 General Approach

We assessed the DOSPERT questionnaire in two independent studies. Study 1 includes a longitudinal community sample (three waves of data) and study 2 includes a longitudinal sample (two waves of data) with male adolescents with and without ADHD. We used linear mixed-effects models to first describe the developmental trajectories of the DOSPERT domain-specific subscales for each study, and next test our hypotheses on the effect of perceived risks and benefits on risk taking across development and domains.

2.2. Domain-Specific Risk Taking questionnaire **(DOSPERT)**

The adolescent DOSPERT questionnaire, based on the adult version (Blais & Weber, 2006; Weber et al., 2002), assesses risk taking, perceived risks, and perceived benefits for 38 risky behaviors, using 7-point Likert scales. Participants were asked to indicate how likely it is they would show the behaviors (risk taking; 1 = extremely unlikely, 7 = extremely likely), how risky they perceive the behaviors (perceived risk; 1 = not at all risky, 7 = extremely risky), and how beneficial they perceive the behaviors (perceived benefits; 1 = no benefits, 7 = great benefits). The three scales can each be broken down into five subscales representing specific domains: Health/Safety (e.g., '*Crossing the street while the light is red', 'Not wearing a seatbelt'),* Recreational (*´Skiing down a steep slope', 'Taking skydiving lessons'*), Ethical ('*Cheating on an exam', 'Taking credit for someone else's work'),* Social ('*Disagreeing with authority figures', 'Going against the opinion of the majority at school'*), and Financial ('*Betting all your allowance on an online gambling game', 'Spending a small amount of your savings to enter a talent show').* A full list of items can be found in the Supplementary Materials.

2.3. Intelligence

In both studies, IQ was estimated with the Dutch Wechsler Intelligence Scale for Children-III (WISC-III-NL, subtests Block Design and Vocabulary (Kort et al., 2002; Wechsler, 1991)) for adolescents up to 16 years, and the Dutch Wechsler Adult Intelligence Scale-IV (WAIS-IV, subtests Vocabulary and Block Design (community sample) or Vocabulary and Matrix Reasoning (ADHD-Control sample) for adolescents ages 16 years and older (Wechsler, 2008)). For the community sample, IQ was available for a subset of participants only (*n*=205 at T1 and *n*=240 at T2).

3.0 Study 1: Community sample

3.1 Methods

3.1.1 Participants and procedure

375 unique participants (age range 11-23 years, 52% female at T1) completed the DOSPERT for one up to three times (276 on T1, 240 on T2, and 124 on T3; time between T1 and T2: *M* = 1.97 years, *SD* = .22; time between T2 and T3: *M* = .52 years, *SD* = .10

years). Participants of study 1 were part of a longitudinal study (Braintime; e.g., (Braams, van Duijvenvoorde, Peper, & Crone, 2015; Peper, Braams, Blankenstein, Bos, & Crone, 2018; Peters & Crone, 2017)) on cognitive and affective (brain) development across adolescence, and of two cross-sectional studies examining risk-taking across age and in adolescence and young adulthood (Blankenstein et al., 2016; Blankenstein et al., 2017). Participants in these samples were recruited through the same recruitment websites and local lectures. In the longitudinal Braintime population specifically, participants reporting a neurological, endocrinological, or a mental-health disorder or the use of psychotropic medication were excluded on study entry. In this population, psychiatric disorders emerged in 34 cases (at T2 or T3) and all were maintained in the current analyses (Wierenga, Bos, van Rossenberg, & Crone, 2019). Attrition in the full longitudinal Braintime sample (8 - 29 years) is shown to be relatively low (e.g., van Duijvenvoorde et al., 2019; ~10%). From age 11 the DOSPERT questionnaire was administered in the Braintime and cross-sectional samples. Participants filled out the DOSPERT questionnaire online at home on all time points.

Table 1 shows descriptive statistics of participants in study 1. We trimmed our sample of interest to include only participants up to 23-years. This age range covered the adolescent age range specifically, and allowed a sufficient number participants also in the edges of our age distribution (see Figure S1; King et al., 2018). Participant who did not complete the DOSPERT at T1 and/or T2 (e.g., because they were too young) were invited to complete the DOSPERT at T2 and/or T3. Cronbach’s alpha’s for each DOSPERT (sub)scale and time point are reported in Table S1. Internal consistency was deemed acceptable for the majority of scales.

Table 1. Participant characteristics of the community sample trimmed between ages 11-23.

	Time point		
	T1	T2	T3
N (female)	276 (145)	240 (125)	124 (76)
Age M (SD)	17.20 (3.05)	16.98 (2.67)	17.28 (2.79)
Age range	12.08 - 22.94	11.90-22.07	12.32 - 22.50
IQ M (SD)*	107.35 (10.02)	108.08 (10.32)	-
IQ range	80-130	80-147.5	-

*IQ was available for the Braintime subset of participants only, was measured at T1 (*n*=205) and T2 (*n*=240).

3.1.2. Data analyses

We used linear mixed effects models (*lmer)* as implemented in the *lme4* package in R (Bates, Sarkar, Bates, & Matrix, 2007). This method is suitable for longitudinal data because it takes into account the repeated nature of the data, and controls for dependency in measures within individuals and items (i.e., nesting in the data). Continuous independent variables were z-scaled and grand-mean centered. *P* values were computed using the lmerTest package (Kuznetsova, Brockhoff, & Christensen, 2017) using Satterthwaite's method. Age was analyzed including a linear and quadratic polynomial. The unit of analysis was the item level.

The starting point in our model-fitting procedures for each level of analysis was a 'maximal' model with respect to the random effects (Barr, Levy, Scheepers, & Tily, 2013). This maximal model included random intercepts for Participant and Item to account for the nesting in our data. Random slopes where included varying over participants and items for all our fixed effects of interest and could include – depending on the model – random slopes for Age(linear), Age(quadratic), Perceived Risks, Perceived Benefits, and their interactions. We then tested our hypotheses on the age-related change in Risk Taking, Perceived Risks and Perceived Benefits per domain. The maximal model for these age-related models is:

1. Risk Taking – Health Safety[a] ~ Age-linear + Age-quadratic

 (Age-linear + *Age-quadratic*) | *Participant)* +

 (Age-linear + *Age-quadratic*) | *Item)*

[a] The same models were estimated for each Domain and for the Perceived Risks and Perceived Benefits scales separately. Random effects are in italics.

Our main hypotheses concerned the effects of Perceived Risks and Perceived Benefits on the likelihood of risk taking across age. Specifically, for each domain separately we predicted risk taking from Age (linear and quadratic), Perceived Risks, Perceived Benefits, and their interactions. The maximal model for testing a Risk-Return model is:

2. Risk Taking– Health Safety[b] ~ (Age-linear + Age-quadratic) * (Perceived Risks + Perceived Benefits) +
   *(Age-linear + Age-quadratic) * (Perceived Risks + Perceived Benefits) | Participant)* +
   (Age-linear + Age-quadratic) * *(Perceived Risks + Perceived Benefits) | Item)*

   [b] These models were estimated for each Domain separately. Random effects are in italics.

These complex random effect structures may lead to convergence warnings in lme4. Our analysis plan to address convergence warnings is summarized in Figure S2. The final models that converged are reported in Table S2.

3.2. Results

3.2.1. Development of Risk Taking, Perceived Risks, and Perceived Benefits across domains in community sample

First, we examined our hypotheses on age-related differences in Risk Taking, Perceived Risks, and Perceived Benefits per domain. All age effects are visualized in Figure 1 per domain and statistics are summarized in Table 2, with significant effects in black and non-significant effects in grey. Risk taking peaked in mid-to-late adolescence for the Health-Safety domain, the Ethical, and Social domains. Risk taking in the Recreational and Financial domains did not show developmental changes.

Perceived Risks decreased and dipped in mid-late adolescence for the Health-

Safety, Recreational, and Ethical domains. Perceived Risks for the Social domain showed a linear decrease across adolescence. No significant change for the Financial domain was observed. Perceived benefits showed a mirrored pattern, peaking in mid-to-late adolescence for Health-Safety, Ethical, and Financial domains. Perceived Benefits for the Social domain increased linearly across adolescence. Finally, no age-related change in Perceived Benefits for the Recreational domain was observed.

Community sample

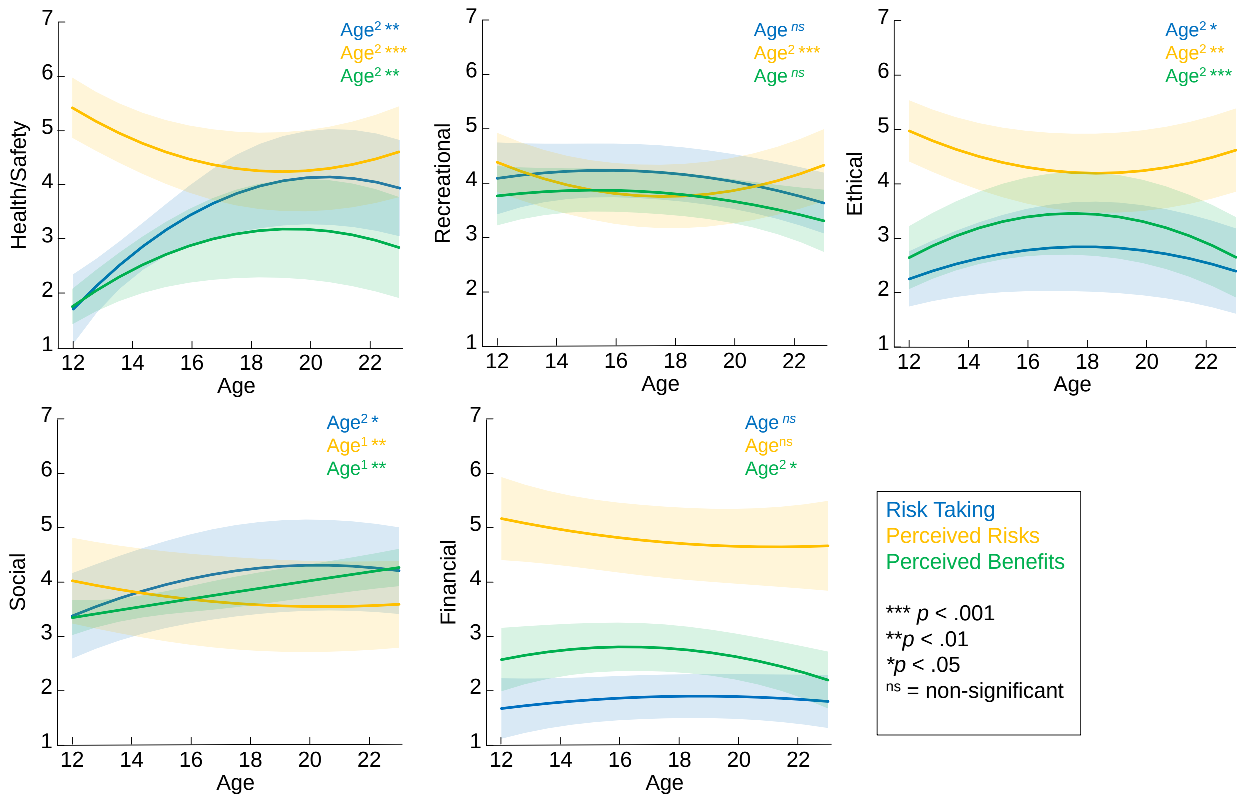

Figure 1. Development of Risk Taking (blue), Perceived Risks (orange), and Perceived Benefits (green) across all five domains for the community sample. The plots show marginal effects. Age^1 indicates a linear effect and Age^2 indicates a quadratic effect.

***p < .001, **p < .01, *p < .05 , ^{ns} not significant.

Table 2. Statistics for the age models for each scale and domain for the community sample. Significant results are in black, non-significant results are in grey.

	Risk Taking			Perceived Risks			Perceived Benefits		
Effect	**b**	**SE**	**p-value**	**b**	**SE**	**p-value**	**b**	**SE**	**p-value**
Health/Safety									
Intercept	3.50	0.28	< .001	4.52	0.31	< .001	2.84	0.36	< .001
Age linear	43.36	13.54	.012	-16.51	8.57	.084	21.79	8.57	.032
Age quadratic	-19.57	5.29	.003	13.74	3.31	< .001	-15.28	3.74	.001
Recreational									
Intercept	4.12	0.25	< .001	3.92	0.29	< .001	3.76	0.20	< .001
Age linear	-7.46	5.23	.149	-2.18	3.50	.535	-7.98	4.32	.068
Age quadratic	-6.48	3.85	.099	11.62	2.99	< .001	-5.60	4.21	.188
Ethical									
Intercept	2.70	0.37	< .001	4.38	0.34	< .001	3.24	0.36	< .001
Age linear	3.94	5.19	.460	-8.22	5.01	.117	1.84	4.49	.686
Age quadratic	-10.63	4.63	.037	12.01	3.45	.001	-16.57	3.60	< .001
Social									
Intercept	4.07	0.41	< .001	3.68	0.42	< .001	3.78	0.11	< .001
Age linear	15.21	4.35	.004	-7.91	2.65	.006	16.02	4.41	.002
Age quadratic	-7.45	3.23	.037	3.63	2.29	.118	-0.20	3.08	.948
Financial									
Intercept	1.85	0.21	< .001	4.80	0.33	< .001	2.69	0.22	< .001
Age linear	2.37	2.76	.408	-8.38	4.23	.056	-5.35	3.10	.089
Age quadratic	-2.60	2.45	.310	3.09	3.46	.373	-6.70	2.88	.023

3.2.2. Risk-return approach per domain

We applied risk-return models per domain to examine whether perceived risks and benefits related to individuals’ likelihood of risk taking. Pearson correlations between scales and domains are depicted in Figure S3. Statistics for the risk-return models can be found in Table 3. The risk-return models confirmed that as expected, perceived risks were negatively related to risk taking for all domains, which may suggest that perceiving greater risks discourages risk-taking likelihood (Weber et al., 2002). On the other hand, perceived benefits positively related to risk taking, consistent with the idea that seeing greater benefits increases risk-taking likelihood. In addition, perceived benefits more strongly related to risk taking behavior than perceived risks (see Table 3).

Interestingly, we also observed an age-related change in the relation between perceived risks and benefits and risk-taking behavior. Specifically, for Recreational risks we observed that perceived benefits related to risk taking more strongly in older adolescents. This suggests that for older adolescents, perceived benefits increasingly related to their risk taking. More specifically, with increasing age, high perceived benefits increasingly relate to individuals' higher Recreational risk taking, while low perceived benefits increasingly relate to lower Recreational risk taking. These effects are visualized in Figure 2, where we plotted the effects of Perceived Benefits on Recreational risk taking for two age bins (11-17, 17-23 years, based on a median split, for visualization purposes only).

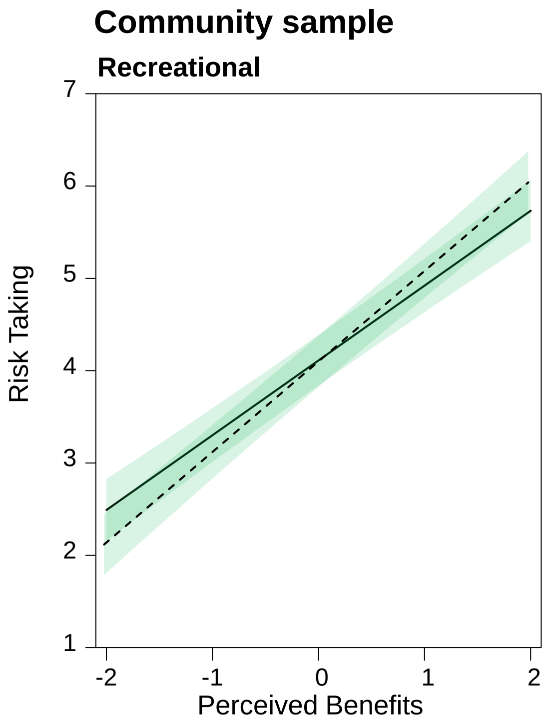

Figure 2. Plot (marginal effects) of the significant Age * Perceived Benefits interaction on risk taking in the Recreational domain for the Community sample. The solid line indicates 11-to-17-year-olds, the dashed line indicates 17-to-23-year-olds. The shades represent the 95% confidence interval. Age lines are for visualization purposes only. Age was included as a continuous variable in all analyses.

Table 3. Statistics for the risk-return models of the community sample. Significant results are in black, non-significant results are in grey. PR = Perceived Risks; PB = Perceived Benefits.

	Health/Safety			Recreational			Ethical			Social			Financial		
Effect	**b**	**SE**	**p**	**b**	**SE**	**p**	**b**	**SE**	**p**	**b**	**SE**	**p**	**b**	**SE**	**p**
Intercept	3.54	0.15	< .001	4.10	0.13	< .001	2.59	0.20	< .001	4.06	0.34	< .001	1.84	0.13	< .001
Age linear	0.43	0.12	.007	-0.09	0.06	.160	0.01	0.04	.819	0.11	0.03	.004	0.04	0.04	.349
Age quadratic	-0.13	0.04	.006	0.00	0.04	.928	-0.05	0.04	.223	-0.09	0.03	.022	-0.01	0.04	.798
Perceived Risk	-0.55	0.06	< .001	-0.40	0.05	< .001	-0.29	0.04	< .001	-0.29	0.06	.001	-0.23	0.04	< .001
Perceived Benefit	0.74	0.04	< .001	0.89	0.04	< .001	0.66	0.09	< .001	0.55	0.09	< .001	0.41	0.05	< .001
Age linear * PR	-0.05	0.04	.199	0.02	0.04	.622	0.03	0.03	.238	-0.02	0.04	.638	0.02	0.03	.474
Age linear * PB	0.02	0.03	.609	0.11	0.03	< .001	0.03	0.04	.427	-0.05	0.03	.127	0.03	0.03	.316
Age quadratic * PR	0.04	0.03	.174	-0.03	0.03	.369	0.00	0.03	.944	-0.02	0.03	.528	0.01	0.03	.555
Age quadratic * PB	-0.06	0.04	.122	-0.03	0.03	.247	-0.04	0.03	.147	-0.03	0.02	.179	0.00	0.03	.863

4.0 Study 2

4.1 Methods

4.1.1 Participants and procedure

180 unique participants of study 2 completed the DOSPERT questionnaire at T1 (ADHD: 81, controls: 99) and 115 at T2 (ADHD: 53, controls: 62). Time between waves was on average 1.41 years (*SD* = .22). Participants of study 2 were part of a longitudinal study on the development of risk-taking behavior in male adolescents with ADHD and IQ-matched controls (age range 11-20 years). Data of this study has previously been reported in (Dekkers, Huizenga, et al., 2020; Dekkers, Popma, et al., 2020), where an elaborate description and recruitment of this sample can be found. Adolescents with ADHD were included if they 1) had been diagnosed with ADHD before by a mental health professional, 2) scored in the subclinical or clinical range on the inattention or hyperactivity/impulsivity subscale of the Disruptive Behavior Disorders Rating Scale (DBDRS) (Oosterlaan, Scheres, Antrop, Roeyers, & Sergeant, 2000), *and* (3) scored above the diagnostic threshold for any ADHD presentation according to the parent Diagnostic Interview Schedule for Children (DISC-IV) (Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000). Table 5 depicts a brief overview of participant characteristics of the ADHD group and the control group for each time point (see also Table S4 for an elaborate overview of participant characteristics). Cronbach's alpha's are depicted in Table S5 in the supplementary materials. Internal consistency was deemed acceptable for most subscales.

Table 5. Participant characteristics of the ADHD-Control sample. For a full description of this sample including comorbidity, see supplementary Table S4.

		Group	
	Time point	ADHD	Control
N	T1	81	99
	T2	53	62
Age *M* (*SD*)	T1	14.88 (1.77)	14.98 (1.38)
	T2	16.08 (1.76)	16.51 (1.43)
Age range	T1	11.78-19.16	12.15-19.35
	T2	13.19-20.45	13.67-20.08
IQ *M* (*SD*)	T1	103.4 (13.72)	101.83 (12.96)
	T2	-	-
IQ range	T1	80-138	80-132
	T2	-	-

4.1.2. Data analyses

We took the same approach in study 2 as in study 1, but additionally examined the role of Group (ADHD and Control, coded using a sum-to-zero contrast) and included a linear age term only due to the more restricted age range (11-20 years), with most participants between ages 12-17 (see Figure S1), and a reduced number of time points (two instead of three). The maximal model for these age-related models is:

1. Risk Taking – Health Safety[a] ~ Age-linear * Group +
(Age-linear | Participant) +
*(Age-linear * Group | Item)*

[a] The same models were estimated for each Domain and for the Perceived Risks and Perceived Benefits scales separately. Random effects are in italics.

We also tested the effects of perceived risks and benefits on the likelihood of risk taking across age (risk-return models). Specifically, for each domain separately we predicted risk taking from age, perceived risks, perceived benefits, and their interactions. The maximal model for testing a Risk-Return model is:

2. Risk Taking– Health Safety[b] ~ Age-linear * Group * (Perceived Risks + Perceived Benefits) +
   *(Age-linear * Group | Participant)* +
   *(Age-linear * Group * Perceived Risks | Item)* +
   *(Age-linear * Group * Perceived Benefits | Item)*

   [b] These models were estimated for each Domain separately. Random effects are in italics.

Similarly to study 1, these complex random effect structures may lead to convergence warnings in lme4. Our analysis plan to address convergence warnings is summarized in Figure S2. The final models that converged are reported in Table S3.

4.2. Results

4.2.1 Development of Risk Taking, Perceived Risks, and Perceived Benefits across domains for ADHD and Controls

We tested age patterns across groups in separate linear mixed models (see Figure 3 and Table 6). Similar to the community sample, we observed that risk taking increased across age in Health/Safety and Social domains, whereas Recreational, Ethical, and Financial risk taking showed no developmental change. Contrary to expectations, these models indicates that adolescents with and without ADHD reported equal levels of risk taking.

Perceived risks decreased across age for Health/Safety, Recreational, and Social domains. The development of perceived risks in Recreational and Ethical domains was qualified by an Age*Group interaction effect, such that perceived risks decreased across age for control participants but remained stable for participants with ADHD. Again, perceived risks for the Financial domain were not characterized by developmental change or group differences.

Finally, perceived benefits increased across age for Health/Safety and Social domains, but this did not differ between groups. The other domains (Recreational, Ethical, Financial) showed no developmental change, nor group differences.

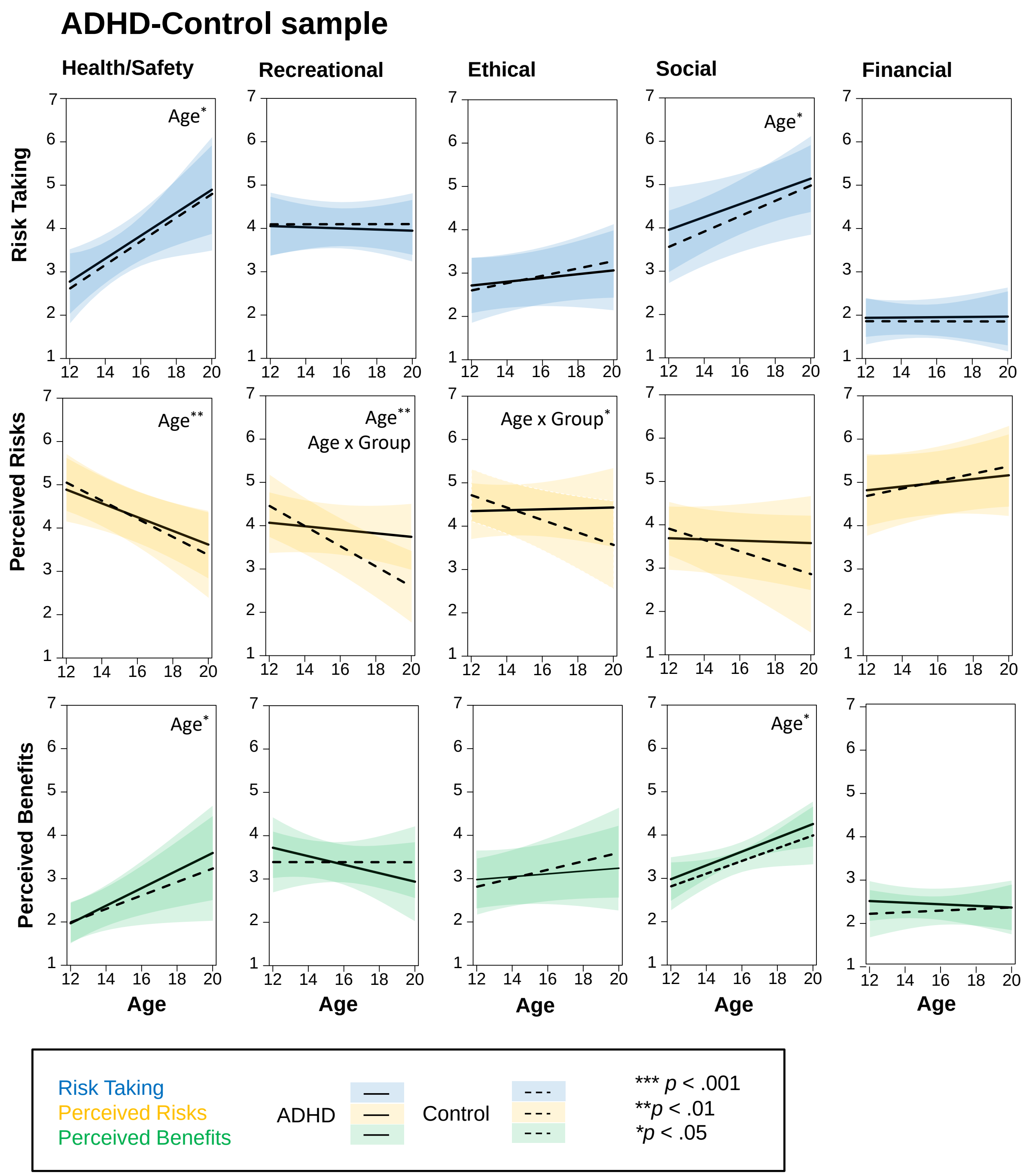

Figure 3 . Development of Risk Taking (blue), Perceived Risks (orange), and Perceived Benefits (green) across all five domains, for adolescents with ADHD (solid line) and Controls (dashed line). The plots show marginal effects. Shades around the lines indicate the 95% confidence interval. $^{***}p < .001$, $^{**}p < .01$, $^{*}p < .05$, ^{ns} not significant.

Table 6. Statistics for the age models of the ADHD-Control sample. Significant effects are displayed in black, non-significant effects are in grey.

	Risk Taking			Perceived Risks			Perceived Benefits		
Effect	**b**	**SE**	**p-value**	**b**	**SE**	**p-value**	**b**	**SE**	**p-value**
Health/Safety									
Intercept	3.63	0.26	< .001	4.33	0.30	< .001	2.61	0.30	< .001
Age	22.39	7.97	.019	-15.31	4.25	.001	14.90	5.59	.021
Group	0.06	0.08	.423	0.01	0.07	.919	0.07	0.06	.268
Age * Group	-0.32	3.40	.925	2.11	3.32	.527	1.98	2.78	.479
Recreational									
Intercept	4.05	0.23	< .001	3.79	0.30	< .001	3.39	0.21	< .001
Age	-0.54	4.09	.896	-11.41	3.31	.001	-4.11	4.83	.397
Group	-0.04	0.10	.664	0.14	0.07	.058	0.00	0.09	.965
Age * Group	-0.58	3.62	.874	8.02	3.29	.016	-4.06	4.78	.398
Ethical									
Intercept	2.88	0.32	< .001	4.30	0.32	< .001	3.13	0.34	< .001
Age	5.67	4.03	.175	-5.88	4.13	.163	5.77	3.91	.149
Group	-0.02	0.07	.833	0.08	0.07	.250	-0.03	0.07	.665
Age * Group	-1.81	3.18	.571	6.79	3.39	.049	-2.88	3.46	.409
Social									
Intercept	4.32	0.38	< .001	3.55	0.42	< .001	3.43	0.09	< .001
Age	12.64	4.58	.020	-5.67	4.06	.191	11.91	4.27	.016
Group	0.14	0.09	.109	0.09	0.06	.131	0.10	0.08	.198
Age * Group	-1.15	2.81	.685	4.56	2.50	.079	0.47	2.72	.863
Financial									
Intercept	1.90	0.20	< .001	4.98	0.38	< .001	2.37	0.16	< .001
Age	0.12	3.23	.971	4.63	3.34	.174	-0.01	2.93	.997
Group	0.05	0.05	.379	-0.01	0.08	.918	0.08	0.06	.181
Age * Group	0.16	2.22	.944	-1.51	3.07	.624	-1.33	2.47	.594

4.2.2. Risk-return approach across domains for adolescents with ADHD and Controls

A central question concerned whether risk taking was related to perceived risks and perceived benefits across domains, and whether this differed across participants with and without ADHD. Figure S4 depicts Pearson's correlations between the scales and domains on T1. To formally test whether perceived risks and benefits were related to individuals' risk-taking likelihood, and whether this differed between groups, we ran risk-return models per domain (Table 7). Similar to the community sample, perceived risks negatively related to risk taking across all domains, indicating that perceiving greater risks relate to a lower likelihood to take risks. Perceived Benefits positively related to risk taking, and perceived benefits related to risk-taking behavior more strongly than perceived risks (see Table 3).

For risk taking in the Recreational domains, we additionally found age-related differences in the relation between perceived benefits and risk taking. Here, perceived benefits increasingly related to Recreational risk-taking behavior across adolescence. This effect is visualized in Figure 4, where we have plotted the effect of Perceived Benefits on risk taking for two age bins (12-15 years and 15-20 years based on a median split; age bins for visualization purposes only). This effect did not differ between adolescents with ADHD and controls. A similar finding was found in the Ethical domain (but see Table S3 on convergence warnings for the Ethical domain model).

For Social risks, we observed a significant Group effect (with adolescents with ADHD reporting higher likelihoods of risk taking than controls) and a Group by Perceived Risks effect. This indicates that perceived risks related to lower reports of social risk taking in control participants, while this was less pronounced for participants with ADHD.

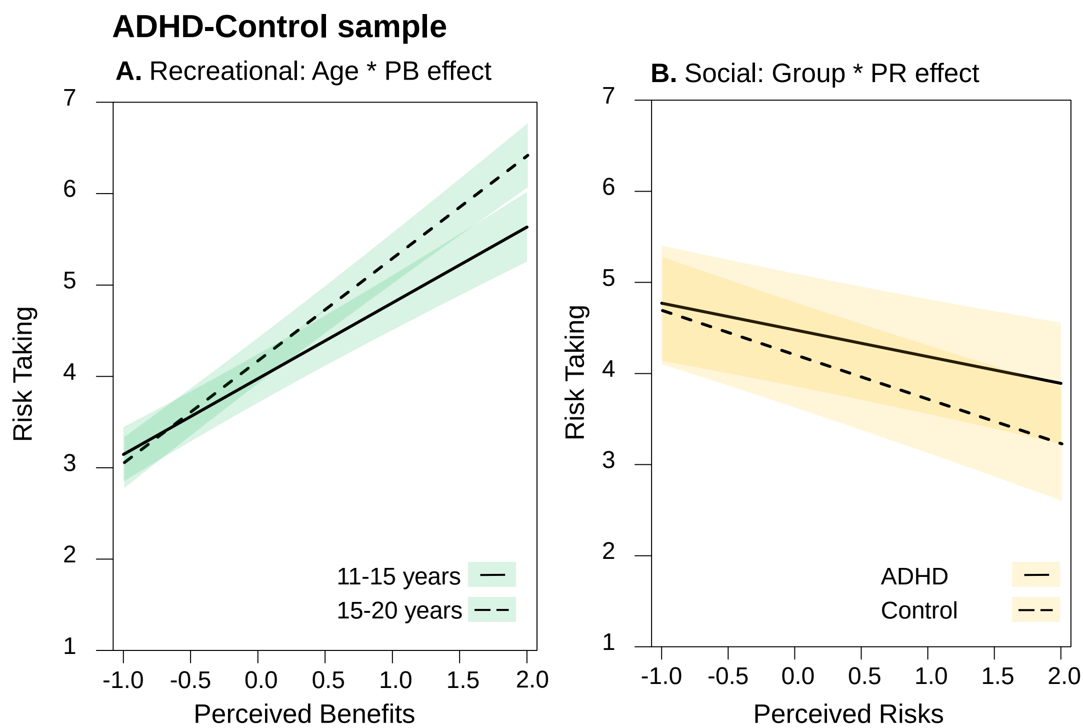

Figure 4. Results of the risk-return models of the ADHD-Control sample. Plots show marginal effects. The shades represent the 95% confidence interval. **A.** Significant Age *

Perceived Benefits interaction on risk taking in the Recreational domain. The solid line indicates 11-15-year-olds, the dashed line indicates 15-20-year-olds. Age lines are for visualization purposes only. Age was included as a continuous variable in all analyses. **B.** Significant Group * Perceived Risks interaction effect on risk taking in the Social domain. The solid line indicates participants with ADHD, the dashed line indicates control participants.

Table 7. Statistics for the risk-return models of the ADHD-Control sample. Significant results are in black, non-significant results are in grey. PR = Perceived Risks; PB = Perceived Benefits.

	Healthy/Safety			**Recreational[1]**			**Ethical[1]**			**Social[1]**			**Financial**		
Effect	**b**	**SE**	**p**	**b**	**SE**	**p**	**b**	**SE**	**p**	**b**	**SE**	**p**	**b**	**SE**	**p**
Intercept	3.62	0.17	< .001	4.10	0.12	< .001	2.82	0.16	< .001	4.34	0.30	< .001	1.92	0.14	< .001
Age	0.22	0.10	.049	-0.02	0.07	.786	0.07	0.06	.259	0.18	0.05	.004	0.03	0.05	.527
Perceived Risks	-0.72	0.06	< .001	-0.41	0.07	< .001	-0.36	0.05	< .001	-0.39	0.05	< .001	-0.23	0.06	.004
Perceived Benefits	0.66	0.07	< .001	1.00	0.05	< .001	0.85	0.07	< .001	0.59	0.08	< .001	0.50	0.07	< .001
Group	0.06	0.07	.380	-0.03	0.08	.748	0.01	0.05	.846	0.14	0.06	.037	0.03	0.05	.458
Age * PR	-0.04	0.05	.341	0.02	0.05	.603	-0.10	0.04	.011	-0.04	0.05	.443	-0.03	0.05	.590
Age * PB	0.02	0.05	.672	0.16	0.05	.001	0.01	0.05	.776	-0.03	0.04	.372	0.03	0.06	.588
Age * Group	0.00	0.06	.975										-0.02	0.05	.653
PR * Group	0.01	0.04	.806	0.00	0.05	.987	0.01	0.04	.735	0.10	0.04	.028	0.03	0.04	.470
PB * Group	0.04	0.05	.348	0.00	0.05	.987	0.00	0.04	.921	0.04	0.04	.343	0.02	0.05	.723
Age * PR * Group	0.00	0.04	.921										0.04	0.04	.304
Age * PB * Group	0.01	0.04	.784										-0.03	0.06	.632

[1]In these domains three-way interactions were not included in order to pursue a maximal model structure as described in our analysis plan (see Figure S2).

5.0 Discussion

The current study applied a risk-return framework to examine risk taking in several domains (Health/Safety, Recreational, Ethical, Social, Financial) in two longitudinal studies: one study including a community sample (11-23 years; thee time points) and one study including male adolescents with and without ADHD (11-20 years; two time points). Across domains, we mostly observed quadratic changes across age in the community sample, with risk taking and perceived benefits peaking in mid-to-late adolescence, while perceived risks were lowest around this age range. Moreover, risk-return regression models showed that risks and returns related to self-reported risk taking, with perceived benefits (returns) showing a stronger effect on risk taking than perceived risks. Moreover, with increasing age, perceived benefits increasingly related to risk taking in the Recreational domain specifically. This effect was robust across both samples. In the ADHD-control sample, adolescents with and without ADHD reported equal levels of risk taking, perceived risks, and perceived benefits. However, risk-return models indicated that adolescents with ADHD reported higher levels of risk taking than controls in the Social domain specifically. Finally, these risk-return models showed that perceived risks less strongly related to risk taking for the ADHD compared to the typical developing group. In the following sections we first discuss the community study's finding in further detail, after which we focus on the findings in the ADHD-Control study.

5.1. Development and risk-return effects of DOSPERT scales in a community sample

Adolescence has often been described as a period of increased risk taking, and although individual differences are large (e.g., Blankenstein et al., 2018), epidemiological reports observe an increase in risk-taking behavior in adolescence such as traffic accidents, crime rate, and substance abuse (Eaton et al., 2008; Romer et al., 2017). In the community sample we observed a similar developmental pattern, in which risk taking increases and/or peaks in mid-late-adolescence across several domains, specifically, Health/Safety, Ethical, and Social domains (~17-20 years). Although in real-life risk taking may peak even later in adolescence/young adulthood, our pattern of results show that these self-report scales across different domains follow an age-expected developmental pattern which suggests these self-report measures could be informative for understanding real-world risk taking.

As expected, perceived risks and benefits showed developmental patterns that paralleled the developmental changes in risk taking. Perceived benefits increased and peaked, and perceived risks decreased and dipped, in mid-late adolescence for most domains. However, in the Social domain perceived risks linearly decreased, and perceived benefits linearly increased across adolescence. Tentatively, these patterns suggest that perceived risks and benefits in the Social domain have a protracted developmental curve and may flatten and/or peak even later in adolescence.

A central question was to what extent perceived risks and benefits relate to risk-taking likelihood across adolescence. Our risk-return models showed that, as expected, perceiving more risks related to decreased risk taking, whereas perceiving more benefits related to increased risk taking. These results are consistent with the idea that perceiving more risks discourages risk taking and perceiving more benefits promotes risk taking. Moreover, as expected, generally perceived benefits related to risk taking more strongly than perceived risks across domains.

In addition, we observed that in the Recreational domain the relation between perceived benefits and risk taking increased linearly with age. This finding is consistent with the idea that across development, benefits may increasingly promote risk-taking behavior. We are strengthened in this interpretation by the robustness of these findings because we observed the same effect in the ADHD-control sample, in which perceived benefits also related more strongly to risk taking in older adolescents. These findings lead to two important insights. First, these results confirm earlier findings that show the importance of benefit perception in risk-taking behavior (Shoham et al., 2016; Zhang, Zhang, & Shang, 2016) and extend these in a longitudinal adolescent sample. That is, these findings suggest that reducing perceived benefits in a given situation (e.g., lowering the fun of going off-piste skiing) or potentially, highlighting the benefits of not taking the risk, may be most effective to reduce risk taking (Albert & Steinberg, 2011). Secondly, these results suggest that the effectiveness of such interventions may increase across adolescence, which is an intriguing avenue for future intervention efforts. Nonetheless, whether this effect is specific for risk taking in some domains only is important to examine and confirm in future studies.

Development and risk-return effects of DOSPERT scales in adolescents with and without ADHD

In the ADHD-control sample we observed similar developmental patterns of risk taking, and perceived risks and benefits, and domain-specificity as in the community study. Even though the ADHD-control sample presents a more restricted age range, and therefore examine linear age-effects only, these developmental findings fit well with those of the community sample.

A main focus in this study was to study differences between adolescents with and without an ADHD diagnosis. Contrary to our expectations, our simple age models indicated that adolescents from both groups reported similar levels of risk-taking likelihood across most domains. Epidemiological data indicate that youth with ADHD show increased risk taking on a variety of domains including health-safety domains (Nigg, 2013; Pollak et al., 2019; Young, 2000). ADHD is however a heterogenous disorder (e.g., see Insel et al., 2010), and participants may vary widely on symptoms of inattention or hyperactivity which may impact absence of group differences. The current study used a case-control design, with samples matched on age and IQ. A prior laboratory study with the current sample also found no group differences in risk taking (Dekkers, Popma, et al., 2020), and other studies also report only small-to-moderate group differences in laboratory risk-taking behavior (Dekkers et al., 2016). However, prior DOSPERT studies in community samples of adults did report associations between ADHD symptoms and (Health/Safety) risk taking, suggesting this association may be evident when examining ADHD symptoms continuously (Shoham et al. 2016). Future research may formally test this hypothesis in adolescent age groups as well.

Furthermore, in contrast to our hypothesis we did not observe group differences in perceived *benefits* across domains. An unexpected finding was that in the Recreational and

Ethical domains the developmental decrease in perceived *risks* across age was less pronounced in adolescents with ADHD compared to controls. A tentative interpretation may be that adolescents with ADHD are sometimes described by a positive illusory bias (i.e., they provide extremely positive reports of their own behaviors), which limit the validity of self-report measures (Owens, Goldfine, Evangelista, Hoza, & Kaiser, 2007). However, it is doubtful whether a positive illusory bias would be limited to self-reported risk perceptions and more prominent in older ages. Alternatively, these findings may indicate that adolescents with ADHD are characterized by a maturational delay (Shaw et al., 2007) that may manifest in risk processing specifically. Speculatively, adolescents with ADHD do not learn about risks similarly as typical developing adolescents leading them to show little developmental change in their risk perceptions compared to typically developing adolescents. Nonetheless, based on the current results it remains unclear what drives these group-based developmental differences in perceived risks. To better understand developmental changes in adolescents with and without ADHD with respect to risk taking, perceived risks, and perceived benefits, future large-scale research is needed using a broader age range, including children and young adults (Li, 2017).

In addition, we investigated the risk-return framework in the ADHD-Control sample. Contrary to our expectations, no heightened effect of perceived benefits was observed in adolescents with ADHD compared to matched controls. However, we did observe that risk taking in the Social domain was differentially related to perceived risks in adolescents with ADHD, compared to typically developing youth. Particularly, our findings are consistent with with the idea that perceiving more risks discourages social risk taking more for typical developing adolescents compared to adolescents with ADHD. This resonates with the group effect we observed in this model, in which youth with ADHD were found to take more risks in the Social domain, relative to typically developing youth. Together, these findings suggest that adolescents with ADHD *perceive* social risks, but may not *integrate* these risk perceptions in their likelihood for social risk taking. This result is in line with prior work suggesting that adolescents with ADHD tend to make suboptimal decisions, rather than seek risks per se (Dekkers et al., 2018; Pollak et al., 2019) in the Social domain. The social risk items in the DOSPERT reflected social skills people display in daily life (e.g., standing up to peers, disagreeing with authority figures), and social risk taking such as rebelling against social norms (spending time away from family, spending time on a hobby instead of doing homework). Although epidemiological data indicate that adolescents with ADHD show heightened health-endangering risks, they also struggle in the social domain such that they experience more peer rejection, and their social problems increase the likelihood of involvement with deviant peers (Bagwell, Molina, Pelham Jr, & Hoza, 2001; De Boo & Prins, 2007; Ferguson, 2000; Hoza, 2007; Nijmeijer et al., 2008). To what extent these findings are specific to the Social domain is a question that needs to be confirmed in future studies. This may yield important entry points for intervention and prevention efforts in adolescents with ADHD within a social context.

5.3 Strengths, limitations, and future directions

This study had a number of strengths. Results of the community sample, characterized by a large sample, broad age range, and three time points, increase our confidence in the findings of the development of self-reported risk taking, perceived risks, perceived benefits and their dynamics. In addition we focused on various domains of risk taking, where prior studies predominantly focused on risk taking from a health-risk perspective only, or on general levels of risk taking (Blankenstein et al., 2018; Sherman, Steinberg, & Chein, 2017). Another strength is the inclusion of a longitudinal ADHD-Control sample, thereby focusing on adolescent risk taking beyond typical development.

Nonetheless, this study suffered from a number of limitations which should be addressed in future research. First, reliability for some of the DOSPERT scales was low. For instance, the Financial domain (risk taking), but also the social domain (perceived risks) suffered from poor reliability in both studies. Therefore, a formal validation study of the current adolescent DOSPERT scales is warranted and currently underway. Second, although we included a large number of participants from a broad adolescent age range, we did not include children (e.g., 8-12 years) and adults (e.g., 24-30 years) in both samples. The inclusion of these age groups may provide additional information on the increase and decrease in risk taking across development (Li, 2017). However, the DOSPERT as currently used was deemed most applicable for an adolescent age range, strengthening our choice to focus on this age-range specifically. Including a broader age range would warrant the inclusion of a children-specific DOSPERT as well as the validated adult DOSPERT questionnaire. Third, the ADHD sample included only boys. ADHD symptoms may be differentially manifested in girls than in boys (Gershon & Gershon, 2002), and accordingly may differentially be related to risk taking and its underlying components. Relatedly, prior research in an adult population has shown that ADHD symptomology was related to perceiving greater benefits of hypothetical risk-taking behavior (Shoham et al., 2016). Future research may thus investigate the *dimensional* association between ADHD symptoms, perceived benefits, and actual risk-taking behavior in an adolescent cohort.

5.4. Conclusion

The current study shows novel insights in the widely studied topic of adolescent risk taking, by taking a domain-specific risk-return approach in two samples: a longitudinal community study and a longitudinal ADHD case-control study. We observed adolescent peaks in risk taking and perceived benefits across development, while perceived risks decreased across age. Notably, risk taking related to heightened perceived benefits, and lowered perceived risks, which becomes more pronounced with age, particularly for recreational risk taking. Finally, our findings indicate that adolescents with ADHD may take more risks in the social domain and are characterized by a suboptimal integration of risk perceptions in risk-taking tendencies, which suggest a possible entry point for future research and interventions. In sum, this study indicates the importance of focusing on domains and individual differences in perceived risks and perceived benefits, in the multidimensional construct of adolescent risk taking.

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Author contributions

NEB: data curation, investigation, formal analysis, visualization, writing – original draft, writing – review & editing; JvH: data curation, investigation, writing – review & editing; TJD: data curation, investigation, writing – review & editing; AP: writing – review & editing; BJ: writing – review & editing; EW: writing – review & editing; YP: writing – review & editing; BF: formal analysis, writing – review & editing; EAC: conceptualization, writing – review & editing, funding acquisition, HMH: conceptualization, writing – review & editing, funding acquisition, ACKvD: conceptualisation, investigation, writing – original draft, writing – review & editing, formal analysis, funding acquisition, supervision. All authors approved the final version of the manuscript.

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