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Abstract

Objective: ADHD is related to decision-making deficits in real-life (e.g., substance abuse) and on experimental tasks (increased preference for risky options). In most tasks, risk and expected value are confounded (risky options have lowest expected value), making it impossible to disentangle risky from suboptimal (i.e., not choosing highest expected value) decision-making. We differentiated between risky and suboptimal decision-making in ADHD in two studies. **Method and Results:** First, on a multilevel meta-regression analysis ($k = 48$, $n_ADHD = 1{,}144$, $n_Control = 1{,}108$), ADHD and controls differed if the risky option was suboptimal (ADHD choosing more risky/suboptimal), whereas groups performed similar if the risky option was not suboptimal. Second, an empirical study showed that adults with ADHD ($n = 40$) made more suboptimal, but not more risky choices than controls ($n = 40$). **Conclusion:** These results contribute to a growing body of evidence that decision-making deficits in ADHD are driven by suboptimal decision-making and not by risk seeking. *(J. of Att. Dis. 2021; 25(4) 486-501)*

Keywords

ADHD, decision-making, risk-taking, expected value, meta-analysis

Introduction

ADHD has been related to a broad range of poor health outcomes (Nigg, 2013). For example, ADHD is characterized by a plethora of decision-making deficits, such as substance abuse, reckless driving, sexual risk-taking, and gambling (Barkley, Murphy, DuPaul, & Bush, 2002; Faregh & Derevensky, 2011; Flory, Molina, Pelham, Gnagy, & Smith, 2006; Lee, Humphreys, Flory, Liu, & Glass, 2011; Molina & Pelham, 2003; Sarver, McCart, Sheidow, & Letourneau, 2014). Real-life decision-making deficits in individuals with ADHD can have large negative consequences, both on an individual and a societal level (Nigg, 2013). For example, 26% to 45% of prison populations is diagnosed with ADHD (Eyestone & Howell, 1994; Ginsberg, Hirvikoski, & Lindefors, 2010; Rösler et al., 2004; Westmoreland et al., 2010; Young & Thome, 2011), and 30% of the adults diagnosed with substance use disorder have comorbid ADHD (Schubiner, 2005).

In experimental studies, gambling tasks are used to elucidate mechanisms underlying decision-making deficits (Sonuga-Barke, Cortese, Fairchild, & Stringaris, 2016). Performance on such tasks correlates with several real-life behaviors, such as delinquency, substance use, and the number of sexual partners (Parker & Fischhoff, 2005). In a recent meta-analysis, including 37 studies comparing ADHD and control groups on a gambling task, a small to medium effect size was found, which was interpreted as that ADHD was associated with more risky decision-making in such tasks (Dekkers, Popma, Agelink van Rentergem, Bexkens, & Huizenga, 2016).

But what is the origin of these decision-making deficits? In behavioral economics, there is a distinction between

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Table 1. Characteristics of the Iowa Gambling Task, Including the EV and Risk (*SD*) of All Decks, and Their Correlation.

Deck	*p* (gain)	Gain	*p* (loss)	Loss	EV	Risk (*SD*)	Correlation EV and risk (*SD*)
A	1	100	.5	−250	−25	202.3	
BB	1	100	.1	−1,250	−25	407.1	
CC	1	50	.5	−50	25	58.6	
D	1	50	.1	−250	25	90.5	$r = -.84$

Note. EV = expected value.

risky decision-making, defined as choosing the option with a high variance of potential outcomes, and suboptimal decision-making, defined as choosing the option with the lowest expected value (EV; Schönberg, Fox, & Poldrack, 2011; van Duijvenvoorde et al., 2015). In experimental paradigms used in psychopathology research however, risk and EV are often confounded. For example, on the Iowa Gambling Task (IGT), one of the most frequently used tasks, choices from Deck A and B are suboptimal in terms of EV and are also risky (although to different degrees; see Table 1 for calculations on the IGT as an example; see Supplement 1 for the calculations for all tasks included in the meta-analysis). Such negative correlations between risk and EV occur in most of the gambling tasks (see Table 2 for an overview of the correlation between risk and EV on the gambling tasks used in ADHD research; see Supplement 1 for calculations). Similarly, in real-life, risk and EV may often be confounded in the same direction, as most people would agree that reckless driving does not only increase the variance of outcomes but also yields a low EV, as a lifelong injury due to an accident is not compensated by the occasional joy of speeded driving or the relief related to reaching a destination more quickly. However, real-life risk-taking may also be advantageous. For example, talking with unfamiliar people at a party might feel socially risky for some, but in this case the safe choice (i.e., to avoid unfamiliar people) might lead to social anxiety and isolation. Similarly, in general, investing money, instead of saving, may be a risky but advantageous choice.

Because EV and risk are confounded in many studies, the effect of ADHD that was observed in the meta-analysis could be due to enhanced risk-taking or due to suboptimal decision-making.

Opting for the risky option may be due to different processes than opting for the suboptimal low EV option, as risk and EV are differentially coded in the brain (Mohr, Biele, & Heekeren, 2010; Mohr, Biele, Krugel, Li, & Heekeren, 2010; Paulsen, Platt, Huettel, & Brannon, 2011; van Duijvenvoorde et al., 2015). Differential processes are also supported by the observation that risk-taking is associated with subjective perception of value and not with subjective perception of risks (Parker, & Weller, 2015). Similarly, ADHD-related real-life risk-taking was associated with subjective value and not with subjective risks (Shoham, Sonuga-Barke, Aloni, Yaniv, & Pollak, 2016). From this perspective, it would be predicted that ADHD-related elevated risk-taking is associated with altered subjective

Table 2. Correlation Between Risk and Expected Value for Every Gambling Task That Was Used in the Previous and in the Current Meta-Analysis.

Task	Correlation risk and EV
Iowa Gambling Task[a] ($k = 15$)*	−0.84
Hungry Donkey Task[b] ($k = 4$)*	−0.84
Child Iowa Gambling Task[c] ($k = 3$)*	−0.97
Foregone Payoff Gambling Task[d] ($k = 2$)*	−1.00
Game of Dice Task[e] ($k = 4$)*	−0.96
Cambridge Gamble Task[f] ($k = 7$)#	1.00
Modified Cambidge Gamble Task[g] ($k = 1$)#	0.80
Gamble Task—risk aversion[h] ($k = 1$)#	0.27
Gamble Task—loss aversion[h] ($k = 1$)#	0.80
Clicking Paradigm[h] ($k = 4$)#	0
Jackpot magnitude[i] ($k = 1$)*	−0.63
Jackpot frequency[i] ($k = 1$)*	−0.53
Gambling Machine Task[j] ($k = 2$)#	−0.20
Probabilistic Discounting Task[k] ($k = 2$)#	0

Note. *k* represents the number of effect sizes using that particular tasks that were included in the current meta-analysis. On some tasks, participants had to perform the same item several times (e.g., in the Iowa Gambling Task, the characteristics of the four decks of cards were similar on each of the items that were administered). In these cases, the correlation between risk and EV was the same for all items. In the Table, these kinds of tasks are indicated by *. However, other tasks used items with differing characteristics (e.g., Gambling Machine Task). In these cases, correlations were calculated for all item types separately, and their mean is displayed in this table. In the Table, these kinds of tasks are indicated by #. Specific calculations on the correlations for each task are provided in Supplement 1. EV = p (gain) × gain + p (loss) × loss; Risk (*SD*) = $\sqrt{(p(\text{gain}) \times (gain - EV)^2 + p(\text{loss}) \times (loss - EV)^2)}$. EV = expected value.

[a]Agay et al. (2010), Baker (2011), Bangma et al. (submitted), Ernst et al. (2003), Gonzalez-Gadea et al. (2013), Henderson (2007), Hobson, Scott, and Rubia (2011), Ibanez et al. (2012), Malloy-Diniz, Fuentes, Leite, Correa, and Bechara (2007; Malloy-Diniz et al., 2008), Mäntylä, Still, Gullberg, and Del Missier (2012), Masunami, Okazaki, and Maekawa (2009), Toplak, Jain, and Tannock (2005), Vaurio (2011).

[b]Geurts, van der Oord, and Crone (2006), Skogli, Andersen, Hovik, and Øie (2014; Skogli, Egeland, Andersen, Hovik, & Øie, 2014).

[c]Antonini, Becker, Tamm, and Epstein (2015), Garon, Moore, and Waschbusch (2006).

[d]Agay et al. (2010).

[e]Baker (2011), Drechsler, Rizzo, and Steinhausen (2008), Matthies, Philipsen, and Svaldi (2012), Wilbertz et al. (2012).

[f]Coghill, Seth, and Matthews (2013), DeVito et al. (2008), Pollak and Shoham (2015, 2017), Sørensen et al. (2017).

[g]Kroyzer, Gross-Tsur, and Pollak (2014).

[h]Pollak et al. (2016), respectively, experiment 1.1, 1.2, 2/3.

[i]Luman, Oosterlaan, Knol, and Sergeant (2008).

[j]Bexkens, Jansen, Van der Molen, and Huizenga (2015).

[k]Scheres et al. (2006).

perception of value leading to suboptimal decision-making. However, Paulsen et al. (2011) showed that there is a developmental decrease in the subjective evaluation of risks. If ADHD is conceptualized as delayed development (Shaw et al., 2007), it would be predicted that ADHD is characterized by increased risk-taking instead of suboptimal decision-making.

Disentangling risk seeking and suboptimal decision-making is highly relevant as it could eventually guide intervention programs aiming at diminishing decision-making deficits in individuals with ADHD. First experimental evidence favored the account that ADHD is associated with suboptimal decision-making, and not with risk seeking (Pollak et al., 2016). Adolescents with and without ADHD had to choose between safe and risky options that were similar in terms of EV. Adolescents with ADHD did not choose the risky option more often than controls, suggesting that when EV is controlled for, ADHD is no longer associated with decision-making deficits. The aim of the current study was to further disentangle risky and suboptimal decision-making in ADHD. This was investigated in two consecutive studies. First, an additional moderator analysis of the recent meta-analysis on decision-making in ADHD (Dekkers et al., 2016) was performed. In this meta-analysis, we modeled the confound between risky and suboptimal options. Meta-analyses include participants from several different studies, thereby enhancing generalizability of the findings. Second, to directly test the competing interpretations, an empirical study was performed in adults with and without ADHD, using a gambling task paradigm that enables the possibility to disentangle risky and suboptimal decision-making.

Study 1: Meta-Analytical Evidence

Method[1]

The same literature search was performed as was done previously (Dekkers et al., 2016), updated with seven studies until April 2018 (for all study characteristics, see Table 3). Inclusion criteria were as follows: (a) a comparison between an ADHD group and a typically developing control group, (b) performance on a gambling task, (c) availability of group means and standard deviations on the gambling task, either in text or by correspondence with the authors, (d) average IQ levels of both groups above 80. One exclusion criterion was added as compared with the previous study, that is, tasks in which the EV of the options changed dynamically within items (e.g., Balloon Analog Risk Task, Door Opening Task) were excluded. That is, as the main goal of this study was to compare outcomes on studies in which the risky option is advantageous with studies in which the risky option is disadvantageous, dynamic gambling tasks were excluded because the relationship between risk and EV varies within items of the task. In total, 34 studies were included, with 48 relevant effect sizes.

Meta-regression. Effect sizes were calculated in terms of standardized mean differences (Hedges' *g*), with positive effect sizes indicating more risky decision-making in ADHD groups. Random-effects meta-regression analyses were performed to account for between study variance. As some studies contributed multiple effect sizes, the meta-regression analysis consisted of three levels, with the effect size level nested within the study level (Cheung, 2014; Konstantopoulos, 2011; Van den Noortgate, López-López, Marín-Martínez, & Sánchez-Meca, 2013). Furthermore, in case of multiple effect sizes from the same study, this was accounted for using the "multiple endpoints" and/or "multiple treatments" method by Gleser and Olkin (2009). Potential publication bias (i.e., the tendency that significant results might be more likely to get published; Easterbrook, Gopalan, Berlin, & Matthews, 1991) was assessed by a regression test of funnel plot asymmetry, and using the trim and fill method (Duval & Tweedie, 2000; Egger, Smith, Schneider, & Minder, 1997). All analyses were performed in *R* with the metafor package (Viechtbauer, 2010).

Moderators. In the current study, two moderator analyses were performed: (a) a categorical moderator analysis in which studies in which the risky option was disadvantageous were compared with studies in which the risky option was similar to (i.e., EVs were equal) or more advantageous than the safe option, (b) a continuous moderator analysis on the correlation between risk and EV, as reported in Table 2.

Results

Publication bias.[2] Egger's test (Egger et al., 1997) indicated a symmetrical funnel plot ($z = 1.42$, $p = .16$). The trim and fill method (Duval & Tweedie, 2000) estimated that zero studies are missing on the left side of the funnel (see Figure 1). These analyses both suggest that there is no publication bias.

Risky versus suboptimal: Categorical moderator analysis. A multilevel meta-regression analysis including 48 effect sizes from 34 studies ($n_$ADHD = 1,144, $n_$Control = 1,108) was performed (see Figure 2). As a moderator, we compared studies in which the risky option was disadvantageous in terms of EV ($k = 32$) with studies in which the risky option was similar to or more advantageous than the safe option ($k = 16$). The proposed moderator was significant, $\beta_1 = .40$, $p = .018$, 95% confidence interval (CI) [.07, .72]; studies in which the risky option was also disadvantageous in terms of EV yielded a significant effect size ($\beta_0 = .37$, $p < .001$, 95% CI [.17, .56]), whereas studies in which the risky option was similar or more advantageous than the safe option did not ($\beta_0 = -.03$, $p = .831$, 95% CI [–.30, .24]).

Table 3. Demographic Characteristics, Effect Sizes, and Relationship Between Risk and Expected Value of Included Studies.

		Clinical group		Typically developing control group								
First author (year)	Group comparison	*N* (% men)	*M* age in years (*SD*)	*N* (% men)	*M* age in years (*SD*)	Task	Outcome measure	*M* Cl Gr (*SD*)	*M* TD (*SD*)	SMD (*SE*)	Risky = disadv.	M Corr. risk & EV
Agay, Yechiam, Carmel, and Levkovitz (2010)	ADHD + MPH vs. TD + Placebo	13 (38)	31.7 (7.9)	16 (63)	32.4 (7.7)	IGT	Proportion choices disadv. decks	0.40 (0.03)	0.42 (0.03)	−0.65 (0.38)	Yes	–0.84
	ADHD + Placebo vs. TD + Placebo	13 (46)	33.2 (8.6)					0.40 (0.03)	0.42 (0.03)	−0.65 (0.38)		
	ADHD + MPH vs. TD + Placebo	13 (38)	31.7 (7.9)			FPGT	Proportion choices disadv. decks	0.31 (0.06)	0.24 (0.03)	1.49 (0.42)	Yes	−1
	ADHD + Placebo vs. TD + Placebo	13 (46)	33.2 (8.6)					0.35 (0.06)	0.24 (0.03)	2.33 (0.48)		
Antonini, Becker, Tamm, and Epstein (2015)	ADHD vs. TD	67 (76)	8.9 (1.5)	30 (67)	9 (1.8)	IGT	Adv.–disadv. choices (rescored)	−0.97 (19.52)	7.07 (15.43)	−0.43 (0.22)	Yes	–0.97
	ADHD + ODD vs. TD	33 (73)	9.4 (1.8)					2.39 (22.31)		−0.24 (0.25)		
Baker (2011)	ADHD vs. TD	18 (67)	11.6 (2.5)	18 (67)	11.6 (2.3)	IGT	Proportion choices of adv. decks—final block (rescored)	−0.44 (0.15)	−0.61 (0.19)	0.97 (0.35)	Yes	−0.84
						GDT	Risky choices	6.7 (5.3)	6.8 (4.8)	−0.02 (0.33)	Yes	−0.96
Bangma et al. (in preparation)	ADHD vs. TD	47 (NA)	NA	84 (NA)	NA	IGT	Disadvantageous choices	43.00 (18.01)	41.64 (20.89)	0.07 (0.18)	Yes	−0.84
Bexkens, Jansen, Van der Molen, and Huizenga[a] (2015)	ADHD vs. TD	35 (77)	14.9 (1.1)	106 (52)	14.3 (1.4)	GMT	Accuracy (rescored)	−0.64 (0.14)	–0.69 (0.12)	0.43 (0.20)	Yes	–0.2
	ADHD + DBD vs. TD	6 (33)	14.3 (1.2)					−0.71 (0.15)		−0.17 (0.42)		
Coghill, Seth, and Matthews (2013)	ADHD vs. TD	83 (100)	8.9 (1.7)	66 (100)	9.0 (1.7)	CGT	Risk-taking	0.56 (0.14)	0.51 (0.14)	0.34 (0.17)	No	1
DeVito et al. (2008)	ADHD + placebo vs. TD	21 (100)	10.0 (2.1)	22 (100)	10.3 (1.6)	CGT	Amount bet	69.8 (14.34)	66.67 (9.85)	0.25 (0.31)	No	1
	ADHD + MPH vs. TD							60.5 (13.34)		−0.52 (0.31)		
Drechsler, Rizzo, and Steinhausen[b] (2008)	ADHD vs. TD	23 (91)	12.2 (0.8)	24 (96)	11.9 (0.6)	GDT	Risky choices	4.77 (2.45)	3.16 (1.86)	0.73 (0.30)	Yes	−0.96
Ernst et al. (2003)	ADHD vs. TD	10 (50)	29.9 (7.3)	12 (50)	28.8 (6.6)	IGT	Adv.–disadv. choices (rescored)	−4.3 (22.2)	−6.3 (28.5)	0.07 (0.43)	Yes	−0.84
Garon, Moore, and Waschbusch[c] (2006)	ADHD vs. TD	21 (81)	9.83 (1.8)	21 (81)	9.68 (1.9)	IGT	Adv. choices (rescored)	−10.4 (1.3)	−11.56 (1.28)	0.89 (0.32)	Yes	−0.97
Geurts, van der Oord, and Crone (2006)	ADHD vs. TD	20 (85)	9.9 (1.1)	22 (82)	10.0 (1.3)	HDT[d]	Adv.–disadv. choices (rescored)	−46.4 (68.49)	−43.4 (87.34)	0.04 (0.31)	Yes	−0.84
Gonzalez-Gadea et al. (2013)	ADHD vs. TD	22 (64)	35.3 (12.7)	21 (52)	38.3 (14.4)	IGT	Adv.–disadv. choices (rescored)	−4.51 (21.13)	−12.22 (21.03)	0.36 (0.31)	Yes	−0.84
Henderson (2007)	ADHD vs. TD	13 (69)	11.9 (1.2)	14 (57)	12.5 (1.2)	IGT	Adv.–disadv. choices (rescored)	8.36 (15.87)	0.86 (9.96)	0.55 (0.39)	Yes	−0.84
Hobson, Scott, and Rubia (2011)	ADHD ± DBD vs. TD	31 (84)	13.3 (1.8)	34 (74)	13.1 (2)	IGT	Disadv. choices (only 2nd half of task)	27.51 (7.51)	21.59 (9.44)	0.68 (0.26)	Yes	−0.84
Ibanez (2012)	ADHD vs. TD	12 (92)	31.4 (11.0)	25 (64)	35.1 (11.2)	IGT	Adv.–disadv. choices (rescored)	−1571 (635.9)	−1847.1 (564.1)	0.46 (0.36)	Yes	−0.84

(continued)

Table 3. (continued)

First author (year)	Group comparison	Clinical group		Typically developing control group		Task	Outcome measure	*M* Cl Gr (*SD*)	*M* TD (*SD*)	SMD (*SE*)	Risky = disadv.	M Corr. risk & EV
		N (% men)	*M* age in years (*SD*)	*N* (% men)	*M* age in years (*SD*)							
Kroyzer, Gross-Tsur, and Pollak (2014)	ADHD vs. TD	32 (63)	15.5 (1.4)	32 (66)	15.9 (1.8)	CGT[e]	Sum of bet	55.96 (13.82)	64.18 (15.44)	−0.55 (0.25)	No	0.8
Luman, Oosterlaan, Knol, and Sergeant (2008)[f]	ADHD vs. TD	22[g] (78)	9.7 (1.4)	20 (75)	9.4 (1.4)	JP–M	% choices Jackpot A (rescored)	−31.26 (6.52)	−46.95 (14.86)	1.37 (0.34)	Yes	−0.63[h]
		23 (78)				JP–F		−45.95 (10.98)	−49.78 (12.16)	0.33 (0.31)	Yes	−0.53
Malloy-Diniz, Fuentes, Leite, Correa, and Bechara (2007)	ADHD vs. TD	50 (56)	33.7 (11.7)	51 (39)	32.2 (12.9)	IGT	Adv.–disadv. choices (rescored)	−5.6 (20.9)	−22.8 (23)	0.78 (0.21)	Yes	−0.84
Malloy-Diniz et al. (2008)	ADHD vs. TD[i]	25 (60)	31.8 (9.1)	25 (40)	32.1 (8.5)	IGT	Adv.–disadv. choices (rescored)	−5.01 (23.93)	−21.13 (21.99)	0.69 (0.29)	Yes	−0.84
Mäntylä, Still, Gullberg, and Del Missier (2012)	ADHD vs. TD	31 (55)	30.8 (12.6)	32 (53)	29.8 (10.8)	IGT	Money earned (rescored)[j]	342 (619)	−61 (812)	0.55 (0.26)	Yes	−0.84
Masunami, Okazaki, and Maekawa[k] (2009)	ADHD vs. TD	14 (93)	11.5 (2.2)	11 (55)	11.7 (1.7)	IGT	Adv. choices (rescored)	−8.75 (1.32)	−9.33 (0.85)	0.49 (0.41)	Yes	−0.84
Matthies, Philipsen, and Svaldi (2012)	ADHD vs. TD	15 (53)	38.1 (11)	16 (50)	32.4 (14.4	GDT	Safe–unsafe choices (rescored)	−6.13 (10.29)	−13.88 (5.08)	0.94 (0.38)	Yes	−0.96
Pollak and Shoham (2015)	ADHD vs. TD	15 (60)	14.8 (1.4)	15 (73)	14.6 (1.8)	CGT–	Sum of bet	72.4 (14)	66.9 (17.3)	0.34 (0.37)	No	1
		15 (73)	15 (1.6)	15 (53)	15.8 (1.9)	CGT+		51.1 (22.2)	67.7 (21.6)	−0.74 (0.38)		
Pollak et al. (2016) exp. 1[l]	ADHD vs. TD	37 (68)	15.3 (1.4)	35 (60)	15.9 (1.9)	GT–ra	% risky choices	42.69 (29.77)	49.09 (26.46)	−0.22 (0.24)	No	0.27
		38 (68)		36 (60)		GT–la		36.94 (12.36)	37.37 (13.56)	−0.03 (0.24)		0.8
Pollak et al. (2016) exp. 2	ADHD vs. TD	40 (65)	15 (1.3)	40 (65)	15.1 (1.4)	CP–i	% risky choices	39.28 (25.23)	31.25 (21)	0.34 (0.23)	Equal	0
						CP–e		36.94 (13.22)	37.39 (14.1)	−0.03 (0.22)		
Pollak et al. (2016) exp. 3	ADHD vs. TD	17 (76)	15.2 (1.7)	16 (75)	15.4 (1.6)	CP–	% risky choices	39.09 (12.29)	35.29 (12.67)	0.30 (0.35)	Equal	0
		16 (69)	15.4 (1.6)	16 (63)	15.6 (1.7)	CP+		44.66 (14.17)	53.52 (8.96)	−0.73 (0.37)		
Pollak, Shalit, and Aran (2018)	ADHD vs. TD	31 (42)	24.8 (2.8)	31 (45)	24.8 (3.0)	CGT	Sum of bet	73.63 (9.99)	71.53 (9.32)	0.21 (0.25)	No	1
Scheres et al. (2006)	ADHD vs. TD (children)	12 (83)	8.8 (1.6)	13 (69)	9.1 (1.7)	PDT	Area under the curve	0.6 (0.15)	0.59 (0.14)	0.05 (0.40)	Equal	0
	ADHD vs. TD (adolescents)	10 (70)	14.4 (1.6)	11 (73)	14.3 (1.5)			0.62 (0.09)	0.55 (0.14)	0.51 (0.44)		0
Skogli, Andersen, Hovik, and Øie (2014)[a]	ADHD vs. TD (boys)	37 (100)	11.2 (1.9)	29 (100)	11.4 (1.9)	HDT	Adv.–disadv. choices (rescored)	4.16 (36.56)	−15.1 (34.52)	0.53 (0.25)	Yes	–0.84
	ADHD vs. TD (girls)	32 (0)	12.0 (2.0)	18 (0)	11.6 (1.9)			−15 (35.27)	11.67 (23.01)	−0.83 (0.31)		
Skogli, Egeland, Andersen, Hovik, and Øie (2014)[m]	ADHD vs. TD	75 (56)	12.0 (1.4)	50 (64)	12.0 (2.0)	HDT	Adv.–disadv. choices (rescored)	−4.88 (24.56)	−5.08 (33.05)	0.01 (0.18)	Yes	−0.84
Sørensen et al. (2017)	ADHD vs. TD	36 (69)	10.2 (1.3)	34 (56)	10.0 (1.0)	CGT	Proportion of bet	0.54 (0.10)	0.55 (0.16)	−0.07 (0.24)	No	1

(continued)

Table 3. (continued)

First author (year)	Group comparison	Clinical group		Typically developing control group		Task	Outcome measure	*M* Cl Gr (*SD*)	*M* TD (*SD*)	SMD (*SE*)	Risky = disadv.	M Corr. risk & EV
		N (% men)	*M* age in years (*SD*)	*N* (% men)	*M* age in years (*SD*)							
Toplak, Jain, and Tannock (2005)	ADHD vs. TD	44 (86)	15.6 (1.4)	34 (41)	15.4 (1.5)	IGT	Adv.–disadv. choices (rescored)	4.64 (22.55)	−6.21 (30.48)	0.41 (0.23)	Yes	−0.84
Vaurio[n] (2011)	ADHD vs. TD	22 (77)	12.0 (2.1)	21 (65)	12.8 (2.4)	IGT°	Adv.–disadv. choices (rescored)	−0.06 (0.62)	−0.69 (0.64)	0.99 (0.32)	Yes	−0.84
Wilbertz[p] (2012)	ADHD vs. TD	28 (54)	37.1 (9.1)	28 (50)	36.7 (9.3)	GDT	% risky choices	24.93 (21.39)	28.79 (22.59)	−0.17 (0.27)	Yes	−0.96

Note. *N* reported in this table corresponds to number of participants on the relevant outcome measure. Abbreviations: Cl Gr = Clinical Group; TD = Typically Developing control group; SMD = Standardized Mean Difference; Disadv. = Disadvantageous; Corr. = Correlation; EV = expected value; MPH = Methylphenidate; IGT = Iowa Gambling Task; FPGT = Foregone Payoff Gambling Task; Adv. = Advantageous; ODD = Oppositional Defiant Disorder; GDT = Game of Dice Task; GMT = Gambling Machine Task; DBD = Disruptive Behavior Disorder; CGT = Cambridge Gambling Task; HDT = Hungry Donkey Task; JP-F/M = Jackpot Frequency/Magnitude; GT(–ra/la) = Gamble Task (risk aversion/loss aversion); CP(–i/e/±) = Clicking Paradigm (implicit/explicit/with/without feedback); PDT = Probabilistic Discounting Task.

[a]In these cases, demographics, moderators, and outcome measure were based on different number of participants.

[b]Data on two consecutive rounds of the Game of Dice Task (GDT) were reported separately. These data were averaged for both the ADHD and control group.

[c]The authors provided Iowa Gambling Task (IGT) outcome data on four separate blocks; these were averaged for both the ADHD and control group.

[d]Outcome data are averages of the normal and reversed Hungry Donkey Task (HDT).

[e]An adapted version of the Cambridge Gambling Task (CGT) was used, in which a 50–50 block was added. Therefore, the correlation between risk and expected value (EV) differs from other studies using the CGT.

[f]Data on the Jackpot Task were provided separately for two subgroups of participants (one group in which the frequency condition was administered first and one group in which the magnitude condition was administered first); these data were averaged for the ADHD and control group, for both the frequency and magnitude condition.

[g]Note that one participant dropped out. To fit the data of these studies into the analyses according to Gleser and Olkin (2009), we set *N* at 22, as these analyses cannot control for dependency if *N* is different.

[h]Note that the temporal aspects of this task (i.e., increasing magnitude/frequency of penalties) could not be taken into account to calculate the correlation between risk and EV.

[i]There were two control groups (English and Portuguese); we used the Portuguese control group, as the clinical group was also performing the IGT in Portuguese.

[j]Usual outcome measures in IGT studies were not available.

[k]Outcome data on the IGT were provided by the author for five blocks separately, these data were averaged for both the ADHD and control group.

[l]There was one dropout in both groups, hence the different *n*.

[m]Two ADHD groups (different subtypes) were investigated: age and HDT outcome scores were averaged to create one ADHD group.

[n]Outcome data on the IGT were provided by the author for five blocks separately, these data were averaged for both the ADHD and control group.

[°]A slight adaptation of the IGT was used to make it more suitable for children, see Hooper, Luciana, Conklin, and Yarger (2004).

[p]Data on two consecutive sessions of the GDT were reported separately. These data were averaged for both the ADHD and control group.

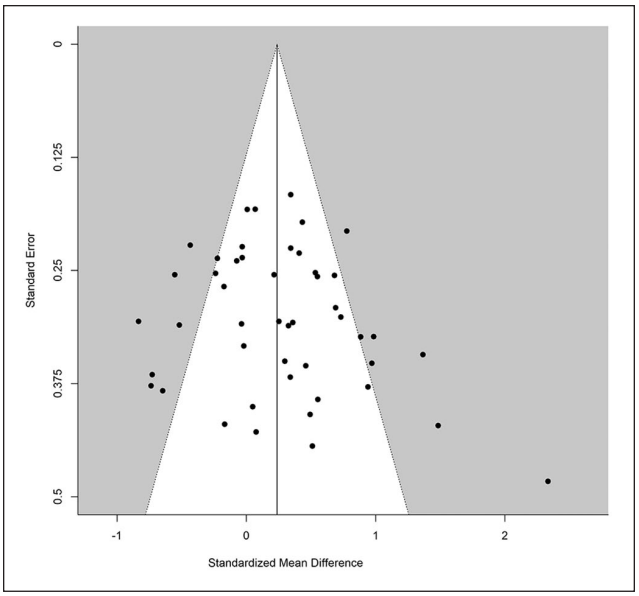


Figure 1. Funnel plot.
Note. Dots indicate standardized mean differences of studies comparing ADHD and controls, with positive values indicating higher risky decision-making in ADHD groups and negative values indicating higher risky decision-making in controls. Standard errors are depicted on the y-axis.

Risky versus suboptimal: Continuous moderator analysis. Similarly, a continuous moderator analysis was performed including the correlation between EV and risk (see Table 1 for the correlations of all tasks included into the analysis). The moderator was significant ($\beta_1 = -.26$, $p = .017$, 95% CI [–.48, –.05]; see Figure 3), implying that effect sizes are larger (i.e., more risky decision-making in ADHD groups as compared with controls) when the correlation between risk and EV is negative. That is, when risky decision-making is less advantageous, group differences are larger, with ADHD groups engaging in more risky/disadvantageous decision-making than controls. When risky decision-making is more advantageous, group differences become smaller.

Conclusion

The first study showed that effect sizes (indicating more risky decision-making in groups with ADHD than controls) are larger when risky options are disadvantageous as compared with when they are similar to (i.e., EVs were equal) or more advantageous. The results of this moderator analysis can be explained in two different ways. First, individuals with ADHD have, as compared with controls, problems in maximizing EV resulting in more risky choices when risky options are disadvantageous. Second, however, these results might also imply that participants with ADHD are more risk seeking than controls, and therefore choose the risky option more often when it is disadvantageous. However, when the risky option is not disadvantageous, they do not choose the risky option more often than controls, as controls will engage in risk-taking in this case as well, because it is advantageous.

These two interpretations yield different predictions regarding the case in which the risky option is *advantageous*. According to the first interpretation, people with ADHD would choose the risky option *less* often than controls when risky is advantageous, as they are less capable of maximizing EV. On the other hand, according to the second interpretation, people with ADHD should choose the risky option either *more* or *as often as* controls, as they favor risky options. To test these two competing explanations, which could not be disentangled meta-analytically, we conducted an empirical study in adults with ADHD.

Study 2: Empirical Evidence in Adults With ADHD

To test the two explanations mentioned above, an empirical study in adults with and without ADHD was performed. In this study, risk and EV were manipulated: A gambling task was administered, consisting of a risky and a safe option, in which the EV of the risky option was either lower than the safe option ("risky is disadvantageous") or higher than the safe option ("risky is advantageous"). The two aforementioned explanations thus yield different hypotheses.

Hypothesis 1: If decision-making deficits in ADHD originate in difficulties in maximizing EV, participants with ADHD as compared with controls are expected to make fewer advantageous choices. In other words, in the "risky is disadvantageous" condition, they would choose the risky option *more* often than controls, whereas in the "risky is advantageous" condition, they would choose the risky option *less* often than controls.
Hypothesis 2: If decision-making deficits in ADHD originate in enhanced seeking of risks, participants with ADHD would, as compared with controls, make more risky choices in the "risky is disadvantageous" condition. In the "risky is advantageous" condition, they would either (H2a) make more risky choices than controls or (H2b) they would make as many risky choices as controls.

Method

The study was approved by the institutional review board (IRB) and written informed consent was obtained from all participants.

Participants. Students with and without ADHD were recruited from the University. Groups comprised participants with similar age range, gender, and years of education. To be included in the ADHD group, participants had to

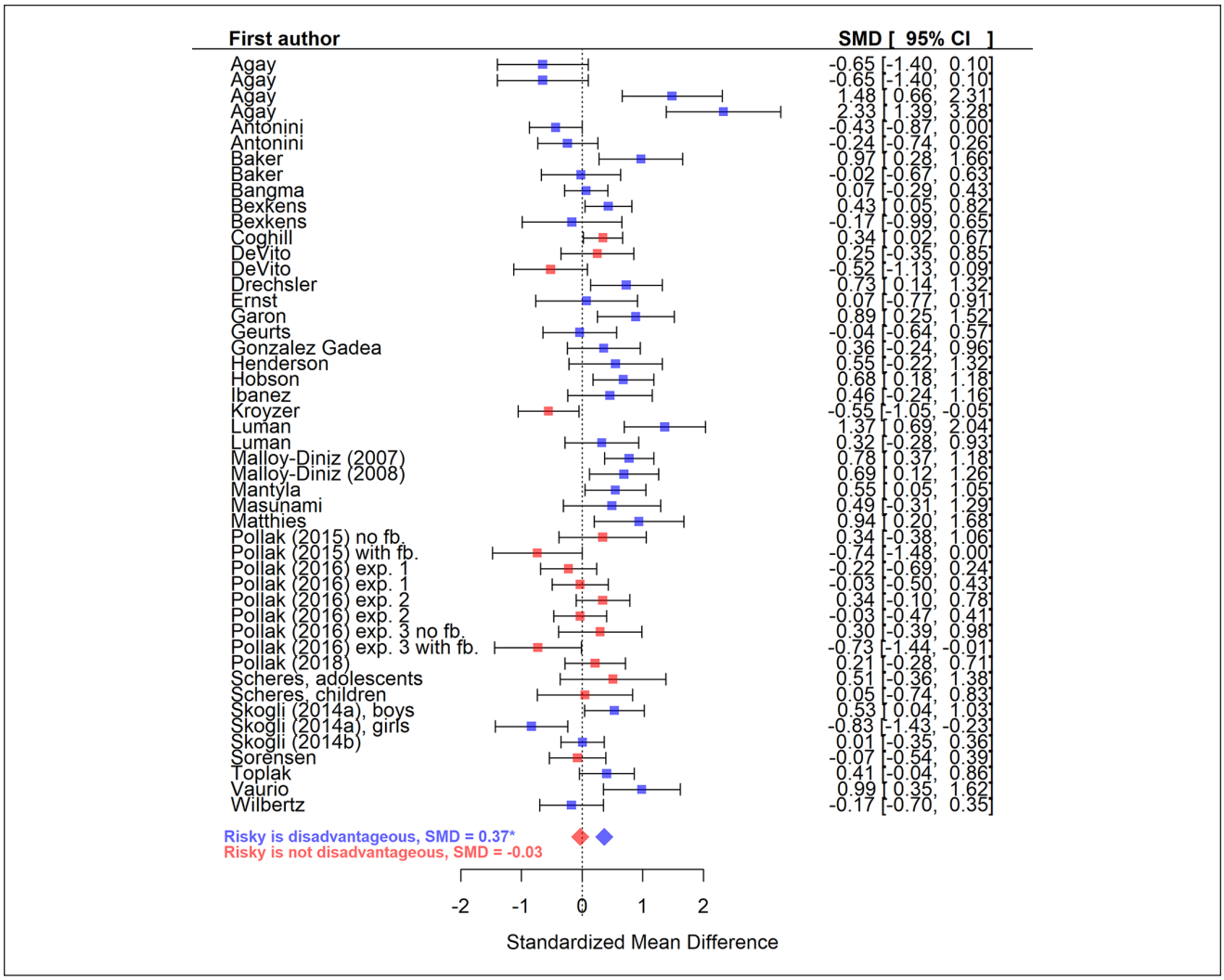


Figure 2. Forest plot including categorical moderator analysis.

Note. The standardized mean difference refers to the effect size of the study, with positive values indicating more risky decision-making in ADHD groups and negative values indicating more risky decision-making in controls. Studies in which the risky option was disadvantageous as compared with the safe option are marked in blue (dark gray), whereas studies in which the risky option was similar to or more advantageous than the safe option are marked in red (light gray). Several studies contain more than one effect size; see Table 3 for more details on these different effect sizes. SMD = Standardized Mean Difference; CI = confidence interval.

*$p < .001$.

have a history of a diagnosis of ADHD made by a neurologist, psychiatrist, or psychologist, and in addition participants had to meet *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM-5*; American Psychiatric Association [APA], 2013) criteria for ADHD on the ADHD module of the Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime Version (K-SADS-PL, Kaufman et al., 1997), adapted for adults (see below). History of ADHD was ruled out for controls using the same diagnostic tool. Exclusion criteria for both groups were self-reported history of a serious neurological illness (i.e., epilepsy, cerebral palsy) or severe head injury, and a self-reported history of psychotic or bipolar depressive disorder. As depression was found to be associated with enhanced risk aversion (Smoski et al., 2008), a $>$ 2 *SD* above average score on the depression subscale of the Hebrew Version of the Brief Symptoms Inventory (BSI; Derogatis & Melisaratos, 1983; Gilbar & Ben-Zur, 2002) was considered an exclusion criterion as well for both groups (see below for a detailed description).

Initially, 88 students were recruited. Two potential ADHD participants were excluded, one because of not meeting the K-SADS-PL criteria for ADHD, and the other because of a $>$ 2 *SD* score on the BSI. Six potential control participants were excluded: two because of meeting the K-SADS-PL criteria for ADHD, and four because of

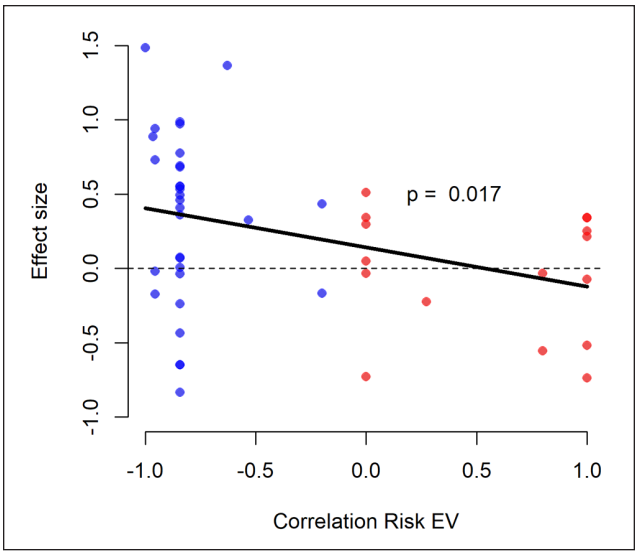


Figure 3. Continuous moderator analysis.
Note. Every dot represents a study comparing an ADHD group with a control group. The value on the y-axis represents the effect size, with positive values indicating higher risky decision-making in ADHD groups and negative values indicating higher risky decision-making in controls. The value on the x-axis represents the correlation between risk and EV in the gambling task that was used in that particular study. Color coding resembles Figure 2. EV = expected value.

endorsing the BSI exclusion criteria. Power analysis using G*Power 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that the remaining 80 participants could identify a medium effect ($\eta_p^2 = 0.09$), using analysis of variance (ANOVA) at 0.05 significance level and power of 0.8. The majority of the participants from both groups were randomly assigned to one of the two task conditions. However, the last participants that were recruited to the study were non-randomly assigned, to ensure that age, gender, and years of education were equally distributed.

As medication used to treat ADHD was found to affect gambling task performance (DeVito et al., 2008), participants were instructed not to take such medication in the 24 hrs preceding the experiment.

Materials. Participants completed a demographic questionnaire providing background information on age, gender, education, and history of diagnosis of and treatment for ADHD.

Confirmation of ADHD diagnosis was obtained by an adaptation of the ADHD module from the K-SADS-PL (Kaufman et al., 1997). Probes tapping childhood symptoms were worded in the past tense, and probes for current symptoms were modified using examples of behavior appropriate for adults. Diagnosis of ADHD was set according to the *DSM-5* criteria, requiring endorsement of symptoms in both childhood and adulthood. This method was used before with satisfactory inter-rater reliability and convergent and divergent validity with other scales (Magnusson et al., 2006).

The Hebrew version of the Adult ADHD Self-Report Scale (ASRS-V1.1; Kessler et al., 2005; Zohar & Konfortes, 2010) was completed as a dimensional measure of ADHD symptoms, which was used to characterize the groups. The ASRS includes 18 items corresponding to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*; APA, 1994) diagnostic criteria of ADHD, each measured for its frequency on a Likert-type scale ranging from 1 ("*never*") to 5 ("*very often*"). The questionnaire has high internal consistency, moderate sensitivity, and high specificity (Adler et al., 2006).

The Hebrew Version of the BSI (Derogatis & Melisaratos, 1983; Gilbar & Ben-Zur, 2002) is a self-report scale in which participants rate the extent to which they have been bothered (0 = "*not at all*" to 4 = "*extremely*") by various psychopathological symptoms in the past week. The inventory consists of several subscales, of which the depression subscale was used for the current study's exclusion criterion.

Clicking Paradigm. The Clicking Paradigm was designed according to Hertwig and Erev's (2009) description tasks. The task was programmed in E-Prime and consisted of 24 problems, which were presented in random order. In each problem, participants had to choose between two options (cards) that were displayed on the computer screen, one with a safe outcome and the other with a probabilistic outcome (see Supplement 2). Immediately after choosing between options, participants received feedback on the amount of points they had won on that trial.

In the "risky is disadvantageous" condition, the value of the safe option was 50% higher than the EV of the probabilistic option. For example, participants had to choose between (a) 18 certain points (i.e., safe option) and (b) a risky option of 20 points at a probability of 60% (higher outcome) and 0 points at a probability of 40% (the lower outcome). In this case, the EV of the safe option is 18 and that of the risky option is 12, that is, the value of the safe option is 50% higher than the EV of the risky option.

In the "risky is advantageous" condition, the value of the probabilistic option was 50% higher than the EV of the safe option. Participants had to choose between, for example, (a) 6 certain points (i.e., safe option) and (b) a risky option of 20 points at a probability of 60% or 0 points at a probability of 40%. In this case, the value of the safe option is 50% lower than the EV of the risky option (6 and 12, respectively).

Within the 24 probabilistic options, eight items involved low probabilities of the lower outcome of the gamble ($p < .1$), eight items involved moderate probabilities ($.2 < p < .4$), and eight items involved probabilities of $p = .5$ (see Supplement 2 for a graphical depiction of the task and for the parameters of all 24 items).

Participants were provided with detailed explanations regarding the task and had the opportunity to ask for clarifications if needed (see Supplement 2 for specific task

Table 4. Demographic and Clinical Characteristics by Diagnostic Group and Task Condition.

Diagnostic group	Control		ADHD		
Condition	Risky disadv. (n = 20)	Risky adv. (n = 20)	Risky disadv. (n = 20)	Risky adv. (n = 20)	Group comparison
Age in years *M* (*SD*)	28.40 (4.49)	28.95 (4.52)	29.30 (3.21)	29.30 (3.91)	$F(3, 76) = 0.218$ ($p = .883$)
Gender	11 males	11 males	11 males	11 males	$\chi^2(3) = 0.0$ ($p = .1$)
Years of education *M* (*SD*)	16.15 (1.79)	16.50 (2.84)	15.90 (2.13)	15.95 (2.09)	$F(3, 76) = .295$ ($p = .829$)
ADHD presentation					
Predominantly inattentive			9	10	
Predominantly hyperactive/impulsive			1	2	
Combined type			10	8	$\chi^2(2) = 0.608$ (p = .805)
Use of medication to treat ADHD					
No use			8	4	
Occasional use			6	5	
Regular use			6	11	$\chi^2(2) = 2.895$ (p = .270)
ASRS total score *M* (*SD*)	37.85 (5.46)	38.85 (7.03)	60.45 (6.69)	61.30 (5.16)	$F(1, 76) = 193.47$ ($p < .001$)
Inattention *M* (*SD*)	17.80 (4.10)	18.20 (3.65)	29.20 (5.43)	27.55 (8.95)	$F(1, 76) = 61.57$ ($p < .001$)
Hyperactivity-impulsivity *M* (*SD*)	20.05 (3.25)	20.65 (4.72)	31.25 (2.91)	30.10 (8.74)	$F(1, 76) = 72.37$ ($p < .001$)
BSI general severity index *M* (*SD*)	0.51 (0.43)	0.60 (0.33)	0.89 (0.43)	1.03 (0.41)	$F(1, 75) = 19.61$ ($p < .001$)

Note. Disadv. = Disadvantageous; Adv. = Advantageous; ASRS = Adult ADHD Self-Report Scale; BSI = Brief Symptom Inventory.

instructions). Participants were told that after completion of the task, the computer would randomly choose one of the items, and they would receive the value of that choice in money. Response time was unlimited and participants were instructed to ask for breaks whenever they wanted. After completion, participants received the value of one of their winning choices, randomly chosen by the computer, with a conversion rate of 1 point—1 Israeli Shekel (~0.25 Euro).

Procedure. The sessions took place at the ADHD and Decision Making Lab at the University or at the participants' houses, according to the preference of the participant. At the beginning of the session, participants were informed regarding the procedure, after which written informed consent was obtained. It was ascertained that participants did not take stimulant medication 24 hrs before testing. Participants completed the K-SADS-PL interview, the Clicking Paradigm, and the questionnaires in this order. At the end, participants received either 20 Israeli Shekels (~5 Euros) or a course credit, as well as the number of points they won converted to Shekels. The duration of the entire session was approximately 45 min.

Statistical approach. Risky choice was defined as choosing the risky, rather than the safe option, and the number of risky choices was summed for each participant. This was used as outcome measure in all analyses. ANOVA was used to test the effects of diagnostic group (ADHD vs. controls) and task condition (risky is advantageous vs. risky is disadvantageous) on the number of risky choices.

Results

Sample characteristics. Demographic and clinical characteristics of the sample are presented in Table 4. Groups did not differ in age, gender, and years of education. Within the ADHD group, ADHD presentations and regular use of medication were distributed equally across conditions. As expected, more ADHD symptoms were observed in the ADHD group compared with controls.

Decision-Making Task

According to the Kolmogorov-Smirnov test, the number of risky choices was normally distributed in each of the four study groups. Test location (i.e., home or lab) did not have a significant effect on the number of risky choices, $t(78) = .32$, $p = .75$.

The ANOVA revealed a large main effect of condition, $F(1, 76) = 124.68$, $p < .001$, $\eta_p^2 = .621$ (Figure 4), indicating more risky choices in the "risky is advantageous" condition than in the "risky is disadvantageous" condition.

No main effect of group was found, $F(1, 76) = .204$, $p = .653$, $\eta_p^2 = .003$ (Figure 4), implying that participants with ADHD were not more risk seeking than controls. Crucially, contrasting the second, but supporting the first hypothesis, there was a group by condition interaction of medium size, $F(1, 76) = 5.70$, $p = .019$, $\eta_p^2 = .070$. Follow-up t tests indicated that (a) in the "risky is disadvantageous" condition, participants with ADHD did not choose the risky option significantly more often than controls, but the direction of the difference was in the hypothesized direction:

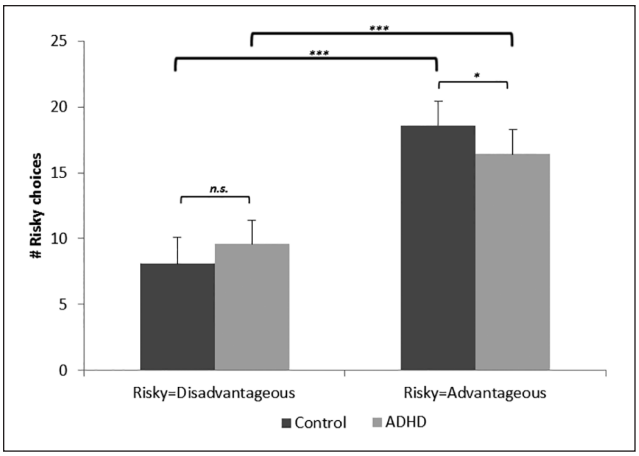


Figure 4. Number of risky choices over groups and conditions.
Note. *ns* = not significant.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

participants with ADHD tended to choose the risky option more often than controls, $t(38) = -1.35$, $p = .187$, and (b) in the "risky is advantageous" condition, participants with ADHD made fewer risky choices than controls, that is, they more often opted for the disadvantageous option, $t(38) = 2.05$, $p = .048$.

Altogether, based on these results, there is more support for the first hypothesis than for the second hypothesis: ADHD is linked to suboptimal but not linked to risky decision-making.

Conclusion

The second study aimed to contrast two competing hypotheses regarding ADHD-related risky decision-making, reflecting either risk seeking or difficulty in maximizing EV. The EV of the safe option was manipulated to be either higher or lower than the EV of the risky option. Participants with ADHD made fewer risky choices than controls when the risky option was advantageous. This pattern indicates that ADHD is not associated with risk seeking, but rather with suboptimal decision-making.

General Discussion

ADHD is associated with decision-making deficits in daily life (Barkley et al., 2002; Faregh & Derevensky, 2011; Flory et al., 2006; Lee et al., 2011; Molina & Pelham, 2014; Sarver et al., 2014). Furthermore, in experimental studies, ADHD is also characterized by decision-making deficits (Dekkers et al., 2016). However, until now it remained unclear whether these deficits originate in risk seeking, or whether they reflect difficulties in optimizing the EV of decisions. As risk and EV are confounded in most gambling tasks, it was not possible to distinguish these two explanations.

The current study showed that ADHD is related to suboptimal decision-making, and not to risk seeking. Meta-regression moderator analyses showed significantly more decision-making deficits in ADHD when risky options were disadvantageous than when risky options were not disadvantageous. In addition, an empirical study showed that adults with ADHD made fewer risky choices than controls when the risky option was advantageous. Altogether, this supports a growing body of evidence that ADHD is not related to risk seeking but to suboptimal decision-making (Pollak et al., 2016; Sørensen et al., 2017).

Suboptimal decision-making related to ADHD can be explained in several ways. First, executive functions like working memory and inhibition are needed to integrate all different characteristics of options to establish the EV of the different options (Brand, Labudda, & Markowitsch, 2006). More specifically, working memory is needed to remember previous gains and losses and to update the values of the different alternatives accordingly, and inhibition is needed to prevent one from choosing impulsively for the tempting but suboptimal alternative (Brand, Recknor, Grabenhorst, & Bechara, 2007). Therefore, the profound executive functioning deficits in people with ADHD (Huizenga, van Bers, Plat, van den Wildenberg, & Van der Molen, 2009; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Wilcutt, Doyle, Nigg, Faraone, & Pennington, 2005) could explain their suboptimal decision-making. Also, executive functioning is needed to learn from experience, for example, by updating the values of the different alternatives as a consequence of outcomes of previous decisions. According to many theories, ADHD is associated with difficulties in learning from experience (Luman, Tripp, & Scheres, 2010). Similarly, ADHD could be linked to difficulty with EV optimization due to arithmetic problems, as comorbidity between ADHD and mathematical disorders is substantial (Capano, Minden, Chen, Schachar, & Ickowicz, 2008).

Second, suboptimal decision-making in ADHD could be explained by effects of motivation. ADHD is related to aberrant reinforcement sensitivity (Luman et al., 2010; Sonuga-Barke, 2003), meaning that higher amounts of reinforcement are necessary to perform optimally (e.g., Dovis, Van der Oord, Wiers, & Prins, 2012). However, most gambling task studies in ADHD did not reinforce their participants (Dekkers et al., 2016). Therefore, participants with ADHD might have performed below their optimal ability.

Third, individuals with ADHD tend to have difficulty investing mental effort (*DSM-5*, 6th criterion) and may therefore prefer not to invest mental effort in calculating EV. To save mental effort, individuals with ADHD might not base their decisions on a comparison of EVs but use easier decision-making heuristics instead. Using heuristics, parts of information are ignored to increase efficiency (Gigerenzer & Gaissmaier, 2011). For example, a study on adolescents with behavioral disorders showed that only

11.7% of them integrated all different attributes of options (i.e., comparing EVs), whereas others used simpler heuristic strategies (Bexkens, Jansen, Van der Molen, & Huizenga, 2015).

The current study is not without limitations. First and most importantly, the conclusion that suboptimal decision-making and not risk seeking is the underlying mechanism in real-life decision-making deficits in ADHD leans on the assumption that experimental decision-making tasks model real-life decision-making well. Although some of these tasks have shown satisfactory correlations with real-life risk-taking (Lejuez et al., 2007), it is difficult to capture the dynamics of daily life in a laboratory task (Pollak et al., 2018). Laboratory tasks are generally not very emotionally appealing for participants; the stakes are often low and gains are usually associated with only moderate degrees of gratification. In real-life, however, the stakes are often higher and the perceived gratification related to risky decisions is often much larger (e.g., in case of criminal activities, speedy driving, unsafe sex, substance abuse).

Therefore, a future challenge is the development of more ecologically valid, emotionally appealing decision-making tasks. Peer influence designs may be a potentially fruitful direction in this respect. Peer influence may increase the ecological validity, as it creates an atmosphere more comparable with real-life. More specifically, gains and losses may be perceived as higher in the presence of peers (e.g., crashing in a driving simulator may be more embarrassing if your best friend is watching than when driving alone). Previous studies showed that adolescents or young adults took more risks on a traffic-related gambling task or on driving simulators, as compared with a condition in which they performed the task alone (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Gardner & Steinberg, 2005; Rhodes, Pivik, & Sutton, 2015; Weigard, Chein, Albert, Smith, & Steinberg, 2014).

Second, the current study did not address comorbidity with other externalizing disorders. Disruptive behavioral disorders (DBDs) are highly comorbid in ADHD (Jensen et al., 2001). As some of the symptoms of these disorders are synonymous with risk-taking, analyzing participants with ADHD in subgroups with and without comorbid DBDs might be informative for future studies, thereby investigating whether the subgroups of ADHD with and without comorbid DBDs are characterized by different levels of suboptimal decision-making and/or risk seeking.

The current study is relevant for both research and clinical practice. From a theoretical point of view, it is important to distinguish between risk seeking and suboptimal decision-making. Methodologically, for future studies, it is recommended to move beyond traditional gambling tasks, in which risk and EV are confounded. A potential new research direction is to provide participants real-life dilemmas, in which risk-taking is the advantageous instead of the disadvantageous option (e.g., investing money, talking to unfamiliar people at a party). Based on the current study, the prediction is that ADHD, in these cases, will be associated with decreased, rather than increased risk-taking behavior. Furthermore, our findings may shift the focus, in conceptualizing ADHD-related decision-making from a positive risk attitude toward a difficulty in EV maximization. For clinical practice, the finding that individuals with ADHD are not risk seeking as such is important. Treatment for individuals with ADHD should focus on improving the quality of their decision-making, as they tend to make suboptimal decisions more often. If the three mechanisms which we proposed above (executive functioning deficits, aberrant reinforcement sensitivity, and avoidance of mental effort) are found to explain decision-making deficits in ADHD, clinical practice should focus on these mechanisms. Furthermore, our findings demonstrate that ADHD relates not only to increased risk-taking (when the risky option is disadvantageous) but also to decreased risk-taking (when the risky option is advantageous). Hence, a new focus in clinical practice may be the identification of those real-life situations in which risk-taking is advantageous and help clients with ADHD to choose these preferable options.

To conclude, the current study showed, using both meta-analytical and experimental methods, that ADHD-related decision-making deficits are driven by suboptimal decision-making and not by risk seeking in itself.

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Declaration of Conflicting Interests

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Notes

1. Please note that the methods used in this study are the same as in the previous study (Dekkers, Popma, Agelink van Rentergem, Bexkens, & Huizenga, 2016), and therefore show a high degree of similarity.
2. As this is the only possibility, these analyses were performed assuming independency of effect sizes.

Supplemental Material

Supplemental material for this article is available online.

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*References marked with an asterisk indicate studies included in the meta-analysis.

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