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RESEARCH ARTICLE

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The association between risky decision making and attention-deficit/hyperactivity disorder symptoms: A preregistered assessment of need for cognition as underlying mechanism

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Abstract

Attention-Deficit/Hyperactivity Disorder (ADHD) is related to suboptimal decision making in experimental tasks and to real-life risk-taking behavior (RTB) such as substance abuse and unsafe traffic conduct. In this preregistered study, we tested whether these associations are mediated by need for cognition—the extent to which one tends towards, and enjoys, analytical thought. In a large sample of young adults (N = 463, M_{age} = 19.7 years), we tested whether need for cognition mediated the association between self-reported ADHD symptoms on the one hand and decision-making strategy complexity on an experimental gambling task and self-reported real-life RTB on the other hand. Preregistered confirmatory analyses indicated first that ADHD symptoms were positively associated with real-life RTB, but the association was not mediated by need for cognition. Second, ADHD symptoms were not related to decision-making strategy complexity, and need for cognition was not a significant mediator. Explorative analyses revealed that (a) need for cognition was associated with higher decision-making accuracy and slower reaction time; (b) need for cognition was related to inattentive but not to hyperactive/impulsive ADHD symptoms; (c) need for cognition was associated with health-related RTB but not interpersonal RTB; and (4) only the association between inattention and health-related RTB was mediated by need for cognition. We conclude that need for cognition is not a mediator in the association between ADHD symptoms and RTB. Additionally, we conclude that neither ADHD symptoms nor need for cognition predict decision-making strategy complexity. Implications for both future research and clinical practice are discussed.

KEYWORDS

need for cognition, decision making, attention-deficit/hyperactivity disorder (ADHD), risk-taking behavior, gambling task, mediation

Authors Jacqueline N. Zadelaar and Tycho J. Dekkers contributed equally.

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1 | INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder, characterized by high levels of inattention, hyperactivity, and impulsivity that lead to significant impairment across settings (American Psychiatric Association, 2013). The prevalence of ADHD is high, with prevalence rates of 5.9–7.2% in children and adolescents, 2.5–5% in adults, and 2–8% in college students (DuPaul, Weyandt, O'Dell, & Varejao, 2009; Thomas, Sanders, Doust, Beller, & Glasziou, 2015; Willcutt, 2012). ADHD is not only associated with individual impairment, the financial burden on society is large as well (Robb et al., 2011; Zhao et al., 2019). A substantial part of these costs is related to risk-taking behavior (RTB), which is increased in individuals with ADHD (Nigg, 2013). For example, ADHD is associated with substance abuse, traffic incidents, delinquency, sexual RTB, and unhealthy eating (see Pollak, Dekkers, Shoham, & Huizenga, 2019 for a review). Several recent meta-analyses comparing individuals with ADHD to controls on experimental decision-making tasks are in line with the findings on real-life risk taking: Individuals with ADHD are characterized by more risky, impulsive, and generally suboptimal (i.e., choosing the least favorable option more frequently) decision making (Dekkers et al., 2018; Dekkers, Popma, Agelink van Rentergem, Bexkens, & Huizenga, 2016; Mowinckel, Pedersen, Eilertsen, & Biele, 2015; Patros et al., 2016). Therefore, understanding the mechanisms that drive ADHD-related RTB is crucial.

ADHD-related suboptimal decision making may be associated with the use of suboptimal decision strategies (Dekkers et al., 2019). A decision strategy, which is a method of information processing to reach a decision (Payne, 1976; Payne, Bettman, Johnson, & Luce, 1995), can vary in complexity depending on the amount of information utilized and the way in which this is processed (Jansen, van Duijvenvoorde, & Huizenga, 2012). For example, the decision between a certain gain of $25,– and a 50/50 probability of gaining $100,– or losing $25,– can be made using several strategies. The most complex strategy would be to compute and compare the expected value (EV = gain × *P*(gain)+ loss × *P*(loss)) of options, thus using all available information in a computationally complex manner (Montgomery & Adelbratt, 1982; Rolls, McCabe, & Redoute, 2008). This would lead one to prefer the second option (EV= $37,50) over the first (EV= $25,–). An alternative would be to use a heuristic, a simple decision strategy on the basis of incomplete information. For example, in the "take-the-best" heuristic, options are compared only on the (subjectively) most valued, sufficiently discriminating attribute (Dietrich, 2010; Gigerenzer & Gaissmaier, 2011; Graefe & Armstrong, 2012; Hardman & Hardman, 2009; Newell, Lagnado, & Shanks, 2007). For example, if this attribute is amount of loss, this strategy presents the first option as superior. Less complex strategies may lead to suboptimal decisions but require less cognitive effort, which may be preferable when the cognitive demand is large or when motivation to invest cognitive effort is lacking (Kool, McGuire, Rosen, & Botvinick, 2010; Payne, Bettman, & Johnson, 1988; van Duijvenvoorde et al., 2016).

More complex decision making puts a greater demand on executive functioning (Bexkens, Jansen, Van der Molen, & Huizenga, 2016; DeStefano & LeFevre, 2004; Stewart, 2009). The links between ADHD and deficits in executive functions such as inhibition (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) and working memory (Kasper, Alderson, & Hudec, 2012) are firmly established. It is thus likely that individuals with ADHD demonstrate different, less complex decision strategies than typically developing individuals. For example, ADHD is characterized by a reduced ability to apply decision rules of varying complexity, which was ascribed to the extensively required cognitive demand (Dekkers et al., 2019; Mäntylä, Still, Gullberg, & Del Missier, 2012). Therefore, we hypothesize that suboptimal decision making observed in ADHD (Dekkers et al., 2016) is attributable to the use of less complex decision strategies.

Suboptimal decision making may originate in a lower need for cognition. Need for cognition describes the extent to which one tends towards, and enjoys, analytical thought (Cacioppo & Petty, 1982; Cacioppo, Petty, & Feng Kao, 1984). Previous research revealed that individuals with a higher need for cognition make more rational decisions (Curseu, 2006), use more of the available information in their decision making (Nair & Ramnarayan, 2000; Verplanken, 1993), and are less susceptible to framing effects (Smith & Levin, 1996). This has been attributed to a positive association between need for cognition and information processing depth (Chatterjee, Heath, Milberg, & France, 2000; Simon, Fagley, & Halleran, 2004). Indeed, individuals with a low need for cognition were found to expend less cognitive effort during decision making and resort to simplistic decision strategies under time pressure more frequently, relative to individuals with a high need for cognition (Verplanken, 1993). This suggests that low need for cognition indeed relates to the use of suboptimal strategies.

Given that need for cognition positively relates to information processing depth, we conjecture that individuals low in need for cognition may underestimate potential negative outcomes, which has been related to increased RTB (Figner, Mackinlay, Wilkening, & Weber, 2009; Figner & Weber, 2011). This is supported by a study that found that individuals low in need for cognition performed worse at the Iowa Gambling Task because they were more sensitive to gains than to losses (Harman, 2011). In another study, individuals high in need for cognition displayed avoidance and minimization of negative outcomes (when decision difficulty was emphasized), whereas individuals low in need for cognition were largely unaffected (Steinhart & Wyer, 2009). Additionally, low need for cognition has been associated with reduced effectiveness of persuasive pro-health messages (e.g., promoting mammography for early cancer detection), along with a dislike for more complex messages in general, and an increased likelihood of ignoring details therein (Ruiter, Verplanken, De Cremer, & Kok, 2004; Schmid, Rivers, Latimer, & Salovey, 2008; Williams-Piehota, Schneider, Pizarro, Mowad, & Salovey, 2003). We therefore hypothesize that low need for cognition relates to increased RTB.

ADHD is likely characterized by lower need for cognition. This is implied by the Diagnostic and Statistical Manual of Mental Disorders 5 specification of "a reluctance to engage in activities that require mental effort" as ADHD symptom (American Psychiatric Association,

2013). Also, children and adolescents with ADHD used less effortful strategies in learning relative to controls (Egeland, Johansen, & Ueland, 2010), and differences between individuals with and without ADHD typically increase when the cognitive load of the task increases (Kofler, Raiker, Sarver, Wells, & Soto, 2016; Vaurio, Simmonds, & Mostofsky, 2009), potentially because of problems in investing mental effort. This is in agreement with several contemporary models of ADHD. According to Sergeant's (2005) influential cognitive-energetic model, effort allocation is one of the core deficits related to ADHD. Others would argue that it is the particularly aversive nature of the delay associated with cognitively demanding tasks that would account for a lower need for cognition in children and adolescents with ADHD (Sonuga-Barke, 2005). Motivational theories state that individuals with ADHD need higher levels of reinforcement than individuals without ADHD to apply the same level of cognitive effort (Dovis, Van der Oord, Wiers, & Prins, 2012; Luman, Oosterlaan, & Sergeant, 2005).

Although the link between ADHD and lower need for cognition seems plausible, the current preregistered study is the first study to directly test whether young adults with more ADHD symptoms demonstrate lower need for cognition. Crucially, we also investigated whether lower need for cognition mediated the effect of ADHD symptoms on both the complexity of decision making, as well as real-life RTB. That is, ADHD symptoms were expected to be negatively associated with need for cognition; need for cognition was expected to be positively related to decision-making strategy complexity (from now: decision-making complexity) and negatively related to real-life RTB.

ADHD symptomatology was measured dimensionally as this has several advantages over categorical case–control designs. First, several lines of evidence suggest that ADHD has a dimensional structure (for a review, see Coghill & Sonuga-Barke, 2012). Second, dimensional measures of ADHD have been repeatedly associated with RTB (Dekkers, Huizenga, Bult, Popma, & Boyer, n.d.; Shoham, Sonuga-Barke, Aloni, Yaniv, & Pollak, 2016; Spiegel & Pollak, 2019). Third, case–control designs as compared with dimensional measurements are associated with reduced power (Royston, Altman, & Sauerbrei, 2006).

2 | METHODS

2.1 | Participants

This study was preregistered using the AsPredicted template on Open Science Framework. The preregistration can be found on https://osf.io/tfrcx/. Therefore, all analyses are confirmatory unless indicated otherwise.

Participants were 463 first-year psychology students (71.5% females, M_{age} = 19.7 years) from the University of Amsterdam, the Netherlands. Their participation was part of a larger test administration, spanning for two sessions of 160 min each. The study was approved by the local Institutional Review Board, and all participants gave active consent.

According to Fritz and MacKinnon (2007), to detect small to medium-small effect sizes with a power of .8, a sample size between 162 and 558 participants is required, depending on the size of both paths making up the mediation (i.e., independent variable on mediator and mediator on dependent variable).

2.2 | Materials

ADHD symptoms were measured with the Adult ADHD Self-Report Scale (ASRS; DuPaul, Power, Anastopoulos, & Reid, 1998). On each of the 18 items, participants indicated on a 5-point Likert scale how frequently certain behaviors occurred in the past 6 months (i.e., "How often do you have problems remembering appointments or obligations?"). Higher scores indicate the presence of more ADHD symptoms. The ASRS has good psychometric properties (DuPaul et al., 1998) and is highly accurate in distinguishing clinical ADHD from non-clinical or subclinical ADHD Diagnostic and Statistical Manual of Mental Disorders IV classifications (Adler et al., 2012; Kessler et al., 2005). In the current sample (N = 463), internal consistency was good for the total scale (α = .80) as well as its factors (inattention, hyperactivity, and impulsivity). ASRS total scores were normally distributed, supporting our dimensional approach on ADHD. However, ASRS factor scores were slightly right skewed. For details, see supporting information.

Need for cognition was measured with the short form of the Need for Cognition Scale (NCS; Cacioppo et al., 1984), an 18 item self-report questionnaire that inquires interest in cognitively effortful tasks. Participants indicated on a 5-point Likert scale to what extent each given statement (e.g., "I would prefer complex to simple problems") was characteristic of them. Higher scores indicate more need for cognition. The NCS has good psychometric properties (Cacioppo, Petty, Feinstein, & Jarvis, 1996; for an overview, see Lins de Holanda Coelho, Hanel, & Wolf, 2018), and in the current sample, internal consistency was good (α = .85).

RTB was measured using the Risk Taking Questionnaire (RTQ), a 28-item Dutch self-report questionnaire concerning the frequency of engagement in risky behaviors (e.g., "Smoking cigarettes") in the past 4 weeks, as indicated on a 5-point Likert scale. We designed this questionnaire recently for use in an adolescent sample on the basis of the risk behavior questionnaire (Pat-Horenczyk et al., 2007), the adolescent version of the domain-specific risk-taking (Blais & Weber, 2006) and the ADorTI (Pollak & Aran, (n.d.), ADorTI (personal communication)). Two items from the recently created RTQ were deleted ("Run away from home" and "Staying out after curfew") because these were deemed inappropriate given the age of the current student sample, and one item was deleted because it correlated negatively with the total score of the questionnaire in another (yet unpublished) study. Higher scores indicate increased RTB. The internal consistency in the current sample was good (α = .75).

Decision-making strategy was measured using the gambling machine task (GMT; Jansen et al., 2012), a task frequently used to establish decision-making strategies (e.g., Bexkens et al., 2016;

Dekkers et al., 2019). The task features mixed gambles with certain gains and probabilistic losses, similar to other decision-making tasks like the Iowa gambling task (Bechara, Damasio, Damasio, & Anderson, 1994) and the Balloon Analogue Risk Task (Lejuez et al., 2002). Mixed gambles with both gain and losses are ecologically more valid than gambles with either gains or losses. Moreover, they provide more attributes on which the alternatives may vary, which increases maximum decision complexity and thus prevents ceiling effects. The GMT contained 40 items (20 items, twice repeated) wherein participants indicated which of two depicted gambling machines was most optimal. For each item, the two gambling machines varied on at least one to maximally three possible attributes: (a) amount of certain gain, (b) amount of loss, and (c) frequency of loss (i.e., the probability of loss; further note that the gain was always certain so therefore all gambling machines have the same probability of gain). An example of the GMT can be found in Figure 1.

Participants were instructed to choose the most favorable machine (see supporting information for participant instructions). If participants perceived both machines equally favorable, they could also respond "does not matter". No postdecision feedback was provided. An answer was considered correct when the participants chose the gambling machine with the highest EV. On 8 of the 40 items, EVs were equal; hence, the correct answer was "does not matter." Higher scores indicate more optimal decision making.

By item–response patterns, we can distinguish 18 decision strategies (see Table 1) congruent with lexicographic or compensatory decision rules (Gigerenzer & Goldstein, 1999; Hauser, 2014; Hauser, Ding, & Gaskin, 2009; Jansen et al., 2012; van Duijvenvoorde et al., 2016). Strategy distinction stems from four strategy characteristics: (a) the number of attributes considered (between zero and three), (b) the nature of considered attributes (gain, loss, and/or probability), (c) the order in which these are considered, and (d) the complexity of mental computations performed on the attributes (e.g., guess, compare, and multiply).

Complexity scores were first defined by the number of attributes involved, with strategies involving more attributes being considered more complex. As the guessing strategy involved none of the available attributes, it was considered simplest. Following the same logic, simple strategies (which involve a single attribute) were considered less complex than two-attribute sequential strategies, which were less complex than three-attribute sequential strategies.

The second criterion of strategy complexity was the complexity of mental computations, with integration followed by comparison being considered more complex than simple comparison. As such, the integrative and semi-integrative strategies were considered more complex than three-attribute sequential strategies. Finally, integration involving more attributes was considered more complex, making the integrative strategy more complex than the semi-integrative strategy. This resulted in complexity scores varying from 1 (*guessing*) to 6 (*computing EV in the integrative strategy*).

Differential decision-making strategy use was estimated via a model-based latent-mixture analysis using Bayesian inference, introduced in Steingroever, Jepma, Lee, Jansen, and Huizenga (2019). Building on earlier methods such as rule-assessment analysis (Siegler, Strauss, & Levin, 1981) and latent-mixture analysis (Huizenga, Crone, & Jansen, 2007; Jansen & Van der Maas, 1997, 2002), this method simultaneously infers the number and size of strategy groups (i.e., groups of individuals using the same strategy). More specifically, the method operates by assuming that each participants' responses to GMT items are generated by one of the decision-making strategies, each of which predicts a specific item–response pattern. Each individual can deviate from the predicted pattern according to an individual error rate ($\in_i$). Parameter z_i denotes the decision strategy assigned to participant *i*. Individuals were inferred to have used the strategy most frequently assigned across iterations (i.e., the most common value in parameter z_i). The method introduced in Steingroever et al. (2019) was expanded in the current study to include a semi-integrative decision-making strategy (the full code can be found on https://osf.io/ptd5b/). For details on chosen convergence checks, we refer to https://osf.io/tfrcx/.

2.3 | Procedure

Participants completed the questionnaires and the task on a computer as part of a larger test session. The GMT was administered first, followed by the RTQ, the ASRS, and the NCS. Performance was incentive compatible; after administration, five participants were

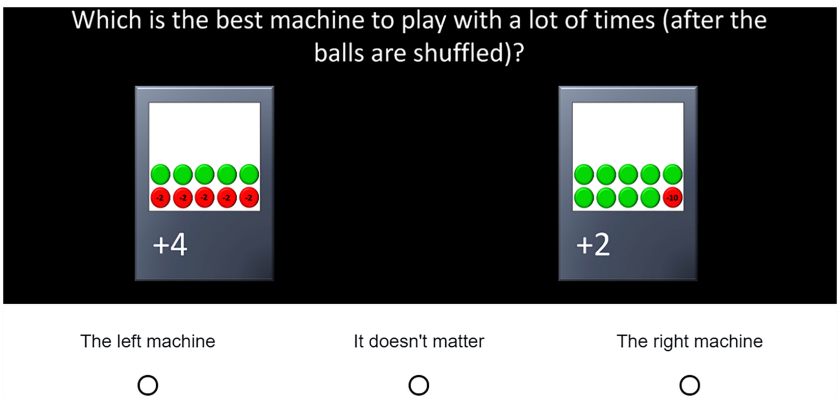


FIGURE 1 An example of a gambling machine task item: the positive white number on the machine indicates the amount of certain gain (CG), the negative number in the red ball(s) indicate(s) amount of loss (AL), and the number of red balls divided by the total number of balls in the machine indicates the frequency of loss (FL). Using the integrative decision-making strategy, one would calculate the expected value (EV) of each machine as EV = CG – (AL × FL). As such, $EV_{left} = 4 - \left(2 \times \frac{5}{10}\right) = 3$ and $EV_{right} = 2 - \left(10 \times \frac{1}{10}\right) = 1$, indicating that the left machine is more favorable [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Decision-making strategies and assigned complexity ratings

	Strategy type	Attributes	Description: decisions made on the basis of …	Complexity
1	Guessing	-	Randomly selecting choice options	1
2	Simple	FL	Frequency of loss	2
3	Simple	AL	Amount of loss	2
4	Simple	CG	Amount of certain gain	2
5	Sequential	FL > AL	Frequency of loss, if that fails amount of loss	3
6	Sequential	FL > CG	Frequency of loss, if that fails amount of certain gain	3
7	Sequential	AL > FL	Amount of loss, if that fails frequency of loss	3
8	Sequential	AL > CG	Amount of loss, if that fails amount of certain gain	3
9	Sequential	CG > FL	Amount of certain gain, if that fails frequency of loss	3
10	Sequential	CG > AL	Amount of certain gain, if that fails amount of loss	3
11	Sequential	FL > AL > CG	Frequency of loss, if that fails amount of loss, if that fails amount of certain gain	4
12	Sequential	FL > CG > AL	Frequency of loss, if that fails amount of certain gain, if that fails amount of loss	4
13	Sequential	AL > FL > CG	Amount of loss, if that fails frequency of loss, if that fails amount of certain gain	4
14	Sequential	AL > CG > FL	Amount of loss, if that fails amount of certain gain, if that fails frequency of loss	4
15	Sequential	CG > FL > AL	Amount of certain gain, if that fails frequency of loss, if that fails amount of loss	4
16	Sequential	CG > AL > FL	Amount of certain gain, if that fails amount of loss, if that fails frequency of loss	4
17	Semi-integrative	(FL × AL) > CG	Expected value of loss, if that fails use gain amount	5
18	Integrative	CG − (FL × AL)	Expected value	6

Note. Strategies range from the most basic (i.e., guessing) to simple (i.e., consider only one attribute), to sequential (i.e., consider several attributes sequentially), to semi-integrative (i.e., sequentially consider expected loss, then certain gain), and to integrative (i.e., consider expected value). Considered attributes are shown.
Abbreviations: AL, amount loss; CG, certain gain; FL, frequency loss.

randomly selected to receive a reward on the basis of the mean EV of the gambling machines they selected on the GMT. Rewards ranged between €5,– and €25,–.

2.4 | Data analysis

We tested two mediation models.[1] First, we tested if ADHD symptoms (ASRS score and continuous) predicted RTB (RTQ score and continuous) directly and indirectly via need for cognition (NCS score and continuous). Second, we tested if ADHD symptoms predicted decision-making complexity (continuous) directly and indirectly via need for cognition. For both mediation analyses, we used the PROCESS macro in SPSS (Hayes, 2018), Model 4, using standardized variables and 5,000 bootstrap samples.

On the GMT, participants were excluded if more than 20% of the easy items (i.e., 12 items where only one of the three attributes differed between both machines) were answered incorrectly, as this indicated no understanding of the task. Additionally, participants who spent less than 20% of the estimated time on the self-report questionnaires (i.e., <1 min) were excluded. These exclusion criteria were preregistered.

For the self-report questionnaires, outliers were detected on the basis of absolute deviation around the median using a threshold of 2.5 times the median absolute deviation (Leys, Ley, Klein, Bernard, & Licata, 2013). All analyses were run twice, once including and once excluding outliers, to see if and how the outliers influenced results. Both analyses are reported.

3 | RESULTS

3.1 | Decision-making complexity assignment

The number of participants assigned to each decision-making complexity score can be found in Table 2. The majority of participants (92.0%) was assigned to one of the three most complex scores.

[1]There is considerable debate on the topic of mediation (see Hayes, 2018; Maxwell, Cole, & Mitchell, 2011). By using this term, we certainly do not intend to make causal inferences. In the current investigation, mediation can be interpreted as an indirect effect.

TABLE 2 The number of participants assigned to each decision-making complexity score

Decision-making complexity	*n*
1. Guessing	12
2. Simple	2
3. Sequential (two attributes)	24
4. Sequential (three attributes)	177
5. Semi-integrative	116
6. Integrative	132
Total	463

3.1.1 | Does need for cognition mediate the link between ADHD symptoms and decision-making complexity?

For the mediation analysis with decision-making complexity as dependent variable, 37 participants were excluded because they responded too fast on the ASRS (n = 3), NCS (n = 5), or they made too many mistakes on the simple GMT items (n = 35). Given that several participants met multiple exclusion criteria, the sum of these numbers exceeds the total number of excluded participants, resulting in a final sample size of N = 426. In this sample, 10 outliers were detected on the ASRS (n = 4) and/or NCS (n = 7). One participant had an outlying score on both measures. The final sample size excluding outliers was N = 416.

The results of the mediation analysis are depicted in Figure 2. The total effect of ADHD symptoms predicting decision-making complexity was not significant, b = .02, $t(424)$ = 0.41, and p = .68. This did not change after taking into account need for cognition as mediator, b = .02, $t(423)$ = 0.46, and p = .64.

ADHD symptoms did not predict need for cognition, b = −.05, $t(424)$ = −1.10, and p = .27. Need for cognition did not significantly predict decision-making complexity, b = .05, $t(423)$ = 1.03, and p = .30. Finally, the indirect effect was not significant, as the bootstrap derived 95% confidence interval contained 0 [−0.014, 0.004], indicating that ADHD did not predict decision-making complexity via need for cognition.

After excluding 10 outliers, results were almost similar; no effects changed in terms of significance (see Figure S3). Taken together, these results indicate that none of the expected effects were observed. That is, ADHD symptoms did not negatively predict need for cognition or decision-making complexity, need for cognition did not positively predict decision strategy complexity, and need for cognition did not mediate the expected negative association between ADHD symptoms and decision-making complexity.

3.1.2 | Does need for cognition mediate the link between ADHD symptoms and RTB?

For the mediation analysis with RTB as dependent variable, 18 participants were excluded for responding too fast on the ASRS (n = 3), RTQ (n = 14), and/or NCS (n = 5). Again, some of these participants were too fast on multiple questionnaires, causing the sum of these numbers to exceed the number of excluded participants. This led to a final sample of N = 445. In this sample, 17 outliers were detected on the ASRS (n = 5), RTQ (n = 6), and/or NCS (n = 7). Note that one participant had an outlying score on two measures. The final sample size excluding outliers was N = 428.

The results of the first mediation analysis are depicted in Figure 3. ADHD symptoms predicted RTB, b = .39, $t(443)$ = 8.97, and p < .001 (i.e., total effect). In other words, more ADHD symptoms were associated with increased RTB. This effect remained when need for cognition was added as a mediator, b = .40, $t(442)$ = 9.16, and p < .001.

ADHD symptoms did not predict need for cognition, b = −.07, $t(443)$ = −1.48, and p = .14. However, need for cognition did predict RTB, b = .10, $t(442)$ = 2.38, and p = .02. Adolescents reporting more need for cognition also reported more, instead of less, RTB. The indirect effect was not significant, as the bootstrap-derived 95% confidence interval contained 0 [−0.024, 0.003], that is, the association between ADHD and RTB was not mediated by need for cognition.

Excluding outliers, results were almost similar; no effects changed in terms of significance (see Figure S4). Taken together, ADHD symptoms indeed were related to RTB. However, neither the hypothesized link between ADHD symptoms and need for cognition nor the hypothesized mediation were supported. Moreover, contrary to expectations, higher need for cognition was related to increased instead of decreased RTB.

3.2 | Explorative analyses

ADHD is a heterogeneous disorder (Martel, Goth-Owens, Martinez-Torteya, & Nigg, 2010; Sonuga-Barke, 2005; Wåhlstedt, Thorell, &

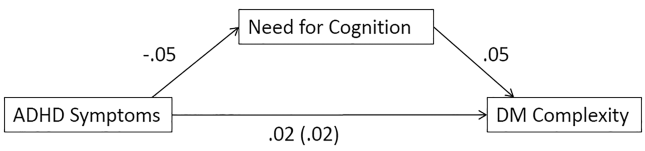


FIGURE 2 Mediation model: standardized regression coefficients for the association between attention-deficit/hyperactivity disorder (ADHD) symptoms and decision-making (DM) strategy complexity as mediated by need for cognition. The total effect is in parentheses

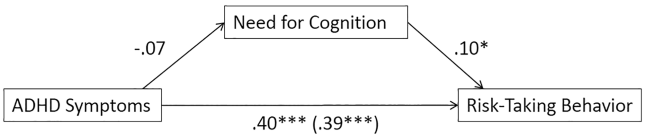


FIGURE 3 Mediation model: standardized regression coefficients for the association between attention-deficit/hyperactivity disorder (ADHD) symptoms and risk-taking behavior as mediated by need for cognition. The total effect is in parentheses. $^{*}p$ < .05. $^{***}p$ < .001

TABLE 3 Effects (standardized coefficients) of explorative mediation analyses

Model		Effects				
		IV → DV (total effect)	IV → DV (direct effect)	IV → M	M → DV	IV → M → DV (indirect effect)
1	IV = inattention M = NC DV = DMSC	.068	.074	−.103*	.058	95% CI [−0.020, 0.004]
2	IV = hyperactivity M = NC DV = DMSC	−.063	−.059	−.082	.045	95% CI [−0.017, 0.005]
3	IV = impulsivity M = NC DV = DMSC	.026	.023	.066	.049	95% CI [−0.005, 0.014]
4	IV = inattention M = NC DV = IRTB	.243***	.253***	−.138**	.071	95% CI [−0.029, 0.002]
5	IV = hyperactivity M = NC DV = IRTB	.202***	.208***	−.092	.056	95% CI [−0.020, 0.003]
6	IV = impulsivity M = NC DV = IRTB	.258***	.256***	.064	.020	95% CI [−0.006, 0.010]
7	IV = inattention M = NC DV = HRTB	.330***	.347***	−.138**	.125**	95% CI [−0.039, −0.002][a]
8	IV = hyperactivity M = NC DV = HRTB	.294***	.304***	−.092	.105*	95% CI [−0.027, 0.001]
9	IV = impulsivity M = NC DV = HRTB	.355***	.352***	.064	.054	95% CI [−0.003, 0.016]

Abbreviations: DMSC, decision-making complexity; DV, dependent variable; HRTB, health-related risk-taking behavior; IRTB, interpersonal risk-taking behavior; IV, independent variable; M, mediator; NC, stion.

[a]indicates a 95% confidence interval not containing zero.

*$p < .05$. **$p < .01$. ***$p < .001$.

Bohlin, 2009) consisting of multiple distinguishable domains (Caci, Bouchez, & Baylé, 2009; Hesse, 2013; Kim, Lee, & Joung, 2013; Reuter, Kirsch, & Hennig, 2006). Similarly, distinct domains may exist in RTB (e.g., recreational and financial RTB, see Hanoch, Johnson, & Wilke, 2006). If a construct is explained by multiple factors, then a single total sum score may not represent variability in the data as good as scores on each distinct factor (i.e., measured construct) and possibly these factors relate to one another differently than do overall ADHD symptoms and RTB scores. To account for this, a factor analysis is applied to the data of both questionnaires, the ASRS and RTQ, revealing the number of constructs measured by each. Need for cognition is expected to be unidimensional (Cacioppo et al., 1984) but is subjected to the same methods for uniformity.

An exploratory factor analysis was performed on the ASRS data in Mplus (Muthén & Muthén, 2017), comparing a 1- to 5-factor model, using the default oblique GEOMIN rotation (Muthén & Muthén, 2012). The number of underlying factors was dictated by the best fitting model, as based on the Bayesian information criterion (Bhat & Kumar, 2010; Schwarz, 1978). Lower Bayesian information criterion values indicate a better model fit. Yielded factor loadings were multiplied with item scores to calculate a new, weighed sum score for each of the resulting factors. The same was done for the RTQ and NCS data.

In the decision-making data set ($N = 426$), a 3-factor model was found to explain the ASRS data best. The first factor had the highest loadings on items pertaining to attention (e.g., Item 2, "How often do you have difficulty getting things in order when you have to do a task that requires organization?"), the second factor on items concerning hyperactivity (e.g., Item 13, "How often do you feel restless or fidgety?"), and the third factor on items about impulsivity (e.g., Item

16, "When you're in a conversation, how often do you find yourself finishing the sentences of the people you are talking to, before they can finish them themselves?"). The NCS data were best explained by a 1-factor solution, namely, need for cognition.

In the RTB data set (N = 445), factor analyses revealed that the ASRS and NCS data were best explained by a 3- and 1-factor model, respectively. As factor loadings were similar to those reported in the decision-making data set, these factors were assigned the same interpretation. The RTQ data were best explained by a 2-factor model. On the basis of factor loadings, the first factor appeared to represent behavior with interpersonal risks (e.g., "Lying to parents or friends" or "Disobeying authorities"), whereas the second factor pertained more to behavior associated with health-related risks (e.g., "Cycling/driving under the influence of alcohol/drugs" or "Smoking cigarettes"). The exact results of the factor analyses, including factor loadings, can be found in the supporting information.

Separate mediation analyses were performed wherein inattention, impulsivity, or hyperactivity (standardized scores) predicted either decision-making complexity (see Table 3, Models 1–3) or interpersonal or health-related RTB (see Table 3, Models 4–9) directly and indirectly via need for cognition. We used separate mediation analyses rather than testing all effects of interest in one model, as the latter would produce conditional effects. That is, the regression weight (i.e., effect) of a single independent variable would depend on its correlation with other independent variables (Alexopoulos, 2010; Ziglari, 2017), as well as potential correlations between dependent variables (Field, 2013). This would give rise to complex interpretations, which would be unwarranted given the purely explorative nature of these analyses. No multiple testing corrections were applied as these analyses are purely explorative, intended only to generate rather than test research hypotheses (Bender & Lange, 2001; Rothman, 1990; Streiner & Norman, 2011).

All effects in mediation analyses involving decision-making complexity were nonsignificant (see Table 3, Models 1–3), except that inattention negatively predicted need for cognition. This lack of effects brought forth the question if ADHD symptoms and need for cognition were even related to GMT performance. As such, two exploratory linear regression analyses were performed to see how ADHD symptoms or need for cognition related to GMT accuracy and reaction time.[2] ADHD symptoms did not significantly predict GMT performance, b = .01, $t(423)$ = 0.22, and p = .82; or GMT reaction time, b = .08, $t(423)$ = 1.65, and p = .10. However, need for cognition did predict both GMT performance, b = .14, $t(423)$ = 2.82, and p < .01; and reaction time, b = .19, $t(423)$ = 3.88, and p < .001. This suggests that increased need for cognition results in better GMT performance and longer reaction times.

Inattention, hyperactivity, and impulsivity positively predicted both interpersonal and health-related RTB (total effect), even when taking into account the effect of need for cognition (direct effect; see Model 4–9 in Table 3). Inattention, but not hyperactivity or impulsivity, negatively predicted need for cognition. Need for cognition positively predicted health-related RTB in analyses wherein either inattention or impulsivity was also included in the model. Finally, the effect of inattention on health-related RTB was negatively mediated by need for cognition (indirect effect). That is, increased inattention predicted decreased need for cognition, but, counterintuitively, need for cognition positively predicted health-related RTB. These results suggest that all facets of ADHD relate to RTB, but only the association between inattention and health-related RTB is mediated by need for cognition, although in a counterintuitive way.

[2]For these explorative analyses on reaction time, we used mean reaction times within participants across GMT items.

4 | DISCUSSION

This is the first study to investigate whether need for cognition (i.e., the extent to which one tends towards, and enjoys, analytical thought; Cacioppo & Petty, 1982; Cacioppo et al., 1984) mediates the associations between ADHD symptoms and suboptimal decision making (Dekkers et al., 2018, 2016; Mowinckel et al., 2015; Patros et al., 2016), as well as RTB (Nigg, 2013; Pollak et al., 2019). ADHD symptomatology was expected to relate to reduced need for cognition that in turn was expected to result in the use of less complex decision-making strategies and increased RTB, presumably due to a diminished tendency to consider all relevant information.

Confirmatory preregistered analyses revealed that both ADHD symptoms and need for cognition were unrelated to decision-making complexity. Consequently, need for cognition did not mediate the association between ADHD and decision-making complexity. The absence of an association between decision-making strategy and ADHD symptoms may be interpreted in two ways. First, self-evidently, that there is no such association, thereby contradicting earlier findings (Dekkers et al., 2016; Mäntylä et al., 2012; Masunami, Okazaki, & Maekawa, 2009). Second, decision-making deficits may predominantly be apparent in the most severe end of the continuum of ADHD symptoms, which is possibly underrepresented in the current sample. Future studies in a broader sample are needed to test the latter interpretation.

Explorative analyses revealed that need for cognition related to more accurate decision-making performance and slower reaction times. As this could not be attributed to the use of more complex decision-making strategies, it may instead be indicative of an association between need for cognition and the complexity of the selection process of a decision-making strategy. Potentially, individuals high in need for cognition select the most efficient (i.e., least complex yet accurate) strategy per decision (a selection process which in itself is effortful), whereas those lower in need for cognition settle on the same strategy for all decisions (which is less effortful). Identifying the most efficient strategy per decision would likely add to the reaction time but may prevent errors during the decision-making process itself, thus increasing accuracy. This explanation is consistent with longer reaction times and increased decision accuracy as observed in the data, as well as earlier findings that individuals high in need for cognition vary more in the amount of information accessed during decision

making (Verplanken, 1993). We therefore speculate that need for cognition may be associated with the complexity of the selection of a decision-making strategy.

In accordance with expectations, ADHD symptoms positively predicted RTB, suggesting that more ADHD symptoms are associated with more real-life RTB. The association between ADHD symptoms and RTB was confirmed by all subsequent exploratory analyses on different symptom clusters of ADHD and different forms of RTB: inattention, hyperactivity, and impulsivity were independently found to predict both interpersonal (e.g., stealing) and health-related (e.g., substance abuse) RTB positively. These findings align with a wealth of literature showing increased real-life RTB like substance abuse, risky driving, gambling, antisocial behavior, and unsafe sex in ADHD populations (see Nigg, 2013; Pollak et al., 2019 for reviews on ADHD and RTB). Additionally, these findings suggest that the association between ADHD and RTB is not limited to a specific cluster of ADHD symptoms or a certain dimension of RTB.

Against expectations, ADHD symptoms were unrelated to need for cognition, need for cognition was associated with increased rather than decreased RTB, and the effect of ADHD symptoms on RTB was not mediated by need for cognition. Explorative analyses indicated that need for cognition was only associated to increased, instead of decreased, health-related RTB. In personality literature, need for cognition is linked to other traits like openness to new ideas and experiences (Fleischhauer et al., 2010; Sadowski & Cogburn, 1997; Tuten & Bosnjak, 2006), curiosity (Olson, Camp, & Fuller, 1984), and novelty seeking (Cacioppo & Petty, 1982; Crotts, 1993). Arguably, this would explain the exploratory finding that need for cognition predicted health-related RTB (e.g., unsafe traffic conduct, sexual RTB, and substance use) but not interpersonal RTB (e.g., disobeying parents or teachers), as the former includes more novel or experiential behaviors. Future studies are needed to disentangle need for cognition from related personality traits like openness to experience and novelty seeking.

We hypothesized an association between ADHD symptoms and need for cognition, yet no such association was found. Exploratory analyses revealed that only inattention—and not hyperactivity and impulsivity—was related to a reduced need for cognition. This finding is intuitive, as many inattentive ADHD symptoms are particularly reflective of problems with cognitive demands, whereas hyperactivity/impulsivity is only linked to problems with cognitive demands more indirectly (but see Vahid & Gheysar, 2012). For example, avoidance of tasks that requires a lot of thought, difficulty focusing on details, difficulty remembering things, and keeping overview are all likely to result in a decreased need for cognition (Westbrook & Braver, 2016). Previous work also revealed that need for cognition is associated with the inability to maintain attention during ongoing cognitive tasks (Osberg, 1987). Besides illustrating the value of distinguishing between different symptom clusters of ADHD when studying it in relation to cognitive constructs, these results also impose nuance on the hypothesized association between ADHD symptoms and need for cognition to pertain only to inattention symptoms of ADHD.

Despite several strengths of the current study (e.g., preregistered methodology and large sample size), some limitations warrant consideration. First, we used a continuous measure of ADHD symptoms rather than comparing a group meeting diagnostic ADHD criteria with a typically developing control group. As such, reported effects may not directly translate to a clinical ADHD population. However, treating psychopathology as a dimensional construct finds support with many who argue that a dichotomous approach relies on arbitrary cutoffs and underestimates sample heterogeneity (Coghill & Sonuga-Barke, 2012; Pollak, Poni, Gershy, & Aran, 2017). The latter is especially relevant in ADHD, given its heterogeneous nature (Martel et al., 2010; Sonuga-Barke, 2005; Wåhlstedt et al., 2009). Moreover, a dimensional approach to psychiatry in general is recommended by the RDoC framework by the National Institute of Mental Health (Cuthbert, 2014; Cuthbert & Insel, 2013).

A second and related limitation is the use of a university student sample. As need for cognition generally correlates with intelligence (Fleischhauer et al., 2010), this group is likely to have an above-average need for cognition. Indeed, approximately 81% of the participants scored in the top half of the need for cognition scoring range. Similarly, a large majority of participants used relatively complex decision-making strategies, that is, sequential three-attribute, semi-integrative and integrative strategies. Potentially, the expected mediating effects of need for cognition only become apparent at wider ranges of need for cognition. Similarly, hypothesized effects related to decision-making strategy complexity may become visible only if a sufficient proportion of the sample utilizes simpler decision strategies (e.g., Bexkens et al., 2016; Dekkers et al., 2019). We therefore recommend the use of a more (cognitively) diverse sample in future research.

A final limitation is that the implemented performance-dependent reward may have been insufficiently motivating, considering that the reward was distributed among only five randomly selected participants. Consequently, participants may not have performed to the best of their abilities and were potentially lacking motivation to exert cognitive effort, which could influence the results in many directions. However, this explanation is unlikely because 92% of the participants used one of the three most complex (out of six) decision-making strategy types, which suggests that participants were willing to invest cognitive effort and motivation was adequate.

The current operationalization of decision strategies is similar to earlier work defining decision strategies in terms of their consecutive elementary information processing (EIP) operations (e.g., read, multiply, and compare; Chase, 1978; Johnson & Payne, 1985; Payne et al., 1988). In these studies, the number of EIPs involved was used as a measure for the effort a strategy required. The main difference between the current and the EIP approach is focus, namely, on complexity versus effort—which are related but distinct constructs (Paquette & Kida, 1988).

On a related note, the current study infers strategy assignment by comparing an individuals' observed item–response pattern with those predicted by each decision strategy (Steingroever et al., 2019). An alternative approach would be process tracing, which assesses

cognitive processes directly (Beach & Pedersen, 2019; Collier, 2011; George, Bennett, Lynn-Jones, & Miller, 2005) through techniques such as thinking-aloud protocols, tracing of eye and mouse movements, and active information search (Beach & Pedersen, 2019; Ford, Schmitt, Schechtman, Hults, & Doherty, 1989; Payne, Bettman, & Johnson, 1993; Svenson, 1979). Although the latter is recognized for directly rather than indirectly studying the construct(s) of interest, process tracing lacks error modeling and runs an increased risk for inferential biases (Della Porta & Keating, 2008; Einhorn, Kleinmuntz, & Kleinmuntz, 1979). Literature empirically comparing process tracing and outcome-based approaches is scarce, though a combination of the two has been shown to work well in assigning decision strategies to individuals (Riedl, Brandstätter, & Roithmayr, 2008). Future research may look towards combining the current method with process tracing techniques for a more complete overview of decision strategy as a construct.

Future studies are also needed to investigate the potential influence of numeracy, the understanding of and ability to utilize numbers (Peters et al., 2006), which may be relevant for several reasons. First, numeracy is related to EV sensitivity (Jasper, Bhattacharya, Levin, Jones, & Bossard, 2013), which seems especially relevant as the most complex strategy distinguished by the GMT involves comparing EVs. Second, numeracy has been associated with better risk perception (Reyna, Nelson, Han, & Dieckmann, 2009) and to heightened risk sensitivity (Peters, 2012). Third, ADHD has frequently been found associated with reduced numeracy and mathematical skills (Lewandowski, Lovett, Parolin, Gordon, & Codding, 2007; Silva et al., 2015; Van Luit, Kroesbergen, & Naglieri, 2005), and low numeracy mediated the link between ADHD and financial decision-making problems in adults (Bangma et al., 2019). This suggests the involvement of numeracy in the association between ADHD, decision strategy complexity, and RTB.

The current study has some tentative implications for young adults high in ADHD symptoms. First and most obviously, the link between ADHD symptoms and RTB implies that—next to targeting core ADHD symptoms—RTB should always be considered in the assessment and treatment of young adults high in ADHD symptoms. Second, young adults with high levels of inattention demonstrate lower levels of need for cognition. Potentially, these inattentive individuals with low need for cognition may avoid tasks that require cognitive effort, which may impede them on the long term (e.g., in the occupational domain; Adamou et al., 2013). In these cases, treatment could focus on learning strategies to diminish the cognitive effort a certain task requires, such as breaking hard tasks into different pieces, and using cognitive tools such as checklists and agendas to diminish cognitive demands (Boyer, Geurts, Prins, & Van der Oord, 2015; Johnson & Reid, 2011), or applying for a tutor (Azevedo, Cromley, & Seibert, 2004).

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CONFLICT OF INTEREST

All authors declare that they have no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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