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Attention-deficit/hyperactivity disorder (ADHD) and risk-taking behavior: The case of suboptimal decision making

| Review

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Abstract: Attention-deficit/hyperactivity disorder (ADHD) is associated with increased overall engagement in risk-taking behavior, both in real life and on experimental laboratory tasks. The current paper reviews recent literature and developments in research on the connection between ADHD and risk-taking behavior. Specifically, it highlights the hypothesis that ADHD-associated risk-taking behavior is accounted for by a more general pattern of suboptimal decision making. Theoretical and clinical implications, including food choices, of this hypothesis are discussed.

Keywords: Attention-deficit/hyperactivity disorder; risk-taking behavior; decision making; food choice.

1. Risk-taking behavior and ADHD in real life

When clinicians and laypeople identify behaviors as risk-taking behaviors, they usually mean that these behaviors may harm oneself or others [1]. Behaviors that meet this definition include substance use, reckless driving, violence, and unprotected sex, as they may all damage one's health. Other behaviors that may be considered risky are gambling and having financial debts, as they may lead to serious problems.

Risk-taking behavior is more pronounced in people with attention-deficit/hyperactivity disorder (ADHD), a highly prevalent developmental condition that is defined by symptoms of inattention, hyperactivity, and impulsivity. Approximately 5–7% of children/adolescents and 2.5–5.0% of adults worldwide [2–4] meet the criteria of ADHD. A recent review concluded that people with ADHD are more likely to engage in several forms of risk-taking behavior, such as risky driving, substance use, aggression and delinquency, sexual risk-taking behavior, gambling, financial risk-taking behavior, and unhealthy eating [5]. As the current conceptualization of ADHD favors dimensional rather than categorical models [6], it may be important to note that risk-taking behavior also correlates with ADHD symptoms in the general population [7–9].

Most of the findings on ADHD and risk-taking behavior, however, largely relate to specific domains of risk-taking behavior. Assuming these behaviors all have certain unique characteristics (e.g., susceptibility to addiction may be related to substance use more than to other types of risk-taking behavior, sensation seeking to unprotected sex, or impaired social cognition to delinquency), the understanding of mechanisms that link ADHD to these *specific* risk-taking behaviors is of interest. However, as

people with ADHD usually demonstrate multiple different forms of risk-taking behavior, investigating potential mechanisms that explain the *overall* engagement in risk-taking behavior may be fruitful. To this end, measurement of the overall level of risk-taking behavior should include various activities that may result in serious harm, while representing different situations and life domains.

A recent study aimed to examine whether adult ADHD is associated with such a pervasive tendency to engage in risk-taking behavior across a spectrum of activities and domains. For this aim, the Adult Risk Taking Inventory (ARTI) has been developed and validated, measuring the likelihood and frequency of engagement in a spectrum of risk-taking behaviors [10]. The ARTI consists of 40 items representing a wide range of real-life activities that could produce physical or nonphysical harm (i.e., meeting the definition of risk-taking behavior as mentioned above). A sample of 200 adults with and without ADHD, carefully characterized in terms of demographic and clinical variables, completed the ARTI. Compared to adults without ADHD, adults with ADHD reported a larger tendency to engage in risk-taking behavior across multiple activities. Importantly, although adults with ADHD had higher rates of comorbid psychiatric disorders than controls, the presence of ADHD uniquely predicted risk-taking behavior beyond all comorbidities.

This link between ADHD and overall risk-taking behavior suggests that, potentially, similar mechanisms may be involved in different kinds of risk-taking behavior demonstrated by people with ADHD. The current paper aims to introduce a potential mechanism that was inspired by experimental models of risk-taking behavior.

2. Experimental assessment of risk-taking behavior in ADHD

Different from the clinical definition of risk as mentioned above, in economics and finance, risk is usually defined in terms of variance of the possible monetary outcomes [1]. When making a decision, each option has several consequences with corresponding probabilities. Summing up the outcomes, each multiplied by its associated probability, results in the option's expected value (EV). For an option with only two potential outcomes, one of gain and one of loss, EV is calculated as follows:

$$EV = p(\text{gain}) \times \text{gain} + p(\text{loss}) \times \text{loss}$$

The option to be chosen should be the one associated with the highest expected value. Using this framework, risk-taking behavior would be considered a preference for a higher-variance payoff holding expected value (EV) constant [1].

Risk is defined as the variance around the EV [1]:

$$\text{Risk} = p(\text{gain}) \times (gain - EV)^2 + p(\text{loss}) \times (loss - EV)^2$$

Experimental risk-taking behavior enables the examination of preferences for higher- and lower- (or absent-) variance payoffs, controlling for theoretically relevant variables such as the magnitude of probabilities and gains/losses. In these experimental paradigms, participants choose between two or more options that differ in the amount and probability of gain or loss. Crucially, participants choose between an option with a fixed small gain (zero-variance payoff) and a probabilistic option resulting in a larger gain (high-variance payoff). Values of gains and losses, as well as the variance of payoff outcomes can be experimentally manipulated (see reference 11 for a detailed analysis of the characteristics of gambling tasks used in the ADHD literature). Narrative reviews and meta-analyses have demonstrated that on various experimental risk-taking behavior tasks, groups with ADHD prefer the risky (higher-variance payoff option) more often than control groups [12–14]. These consistently observed results are in line with the clinical literature revealing increased real-life risk-taking behavior in ADHD populations. Therefore, experimental risk-taking behavior may be considered a valid experimental model for ADHD-related risk-taking behavior and can be used for testing specific hypotheses regarding the variables that affect ADHD-related risk-taking behavior.

Decision theory implies that one's attitude towards risk is a continuum ranging from risk-seeking (extreme preference for risk) to risk-aversion (avoidance of risk), and is considered a personality trait [15]. Therefore, the pattern of excessive risk-taking behavior among individuals with ADHD both in real life and in the laboratory may depict them as risk-seekers. However, a recent study generated no evidence for a link between ADHD and risk-seeking [11]. Based on a meta-analysis, it was demonstrated that groups with ADHD chose the risky option more often than controls when the risky option was the less favorable one (in terms of EV), but not when the risky option was not the less favorable one. Furthermore, new experimental evidence indicated that individuals with ADHD chose the safe option more often than controls when the risky option was the favorable one [11]. Taken together, these findings suggested that ADHD-related risk-taking behavior is part of a more general pattern of inefficient decision making or suboptimal calculation of expected value. People with ADHD do not have an inherently risk-seeking personality but rather make inefficient or suboptimal decisions resulting in unfavorable choices.

What drives this suboptimal decision making? Recent studies explored potential mechanisms that are associated with both ADHD and suboptimal decision making. Heuristic models assume that decision-makers do not always consider all available information about amounts and probabilities of gains and losses. That is, they use heuristics that simplify the decision process by comparing options based on a limited set of characteristics [16]. Reliance on heuristics, rather than on integration of amounts and probabilities, may lead to suboptimal decision making on laboratory tasks. Thus, the link between ADHD and suboptimal decision making may be accounted for by an overreliance on heuristics.

Evidence for this account was provided by a recent study, in which decision-making strategies of adolescents with and without ADHD were compared [17]. Using a Bayesian latent mixture analysis, response patterns of adolescents were assigned to one of 18 possible strategies: these strategies range from very simple strategies (i.e., guessing), to intermediate complex sequential strategies (e.g., consider gain amounts first, then only consider loss amounts if gain amounts of options are similar), to complex integrative strategies (i.e., complete integration of all characteristics by computing expected values of options and choosing accordingly). Reliance of heuristics would be reflected less complex strategy use. On average, adolescents with ADHD adopted less complex decision-making strategies than typically developing adolescents. Also, the use of less complex strategies was related to suboptimal decision making performance on decision-making tasks with and without feedback [17]. This supports the notion that the link between ADHD and suboptimal decision making can be, at least partly, explained by the use of less complex decision-making strategies. The latter may be a consequence of overreliance on heuristics.

3. Inconsistency as an explanation

Optimal decision making depends on an accurate subjective evaluation of the options at stake. In the case of risk-taking behavior, the subjective value of an option depends on the weight that is given to the risk (i.e., the variance of possible outcomes). Notably, the weight that is given to the risk is dynamic and may fluctuate across time and context [18]. Greater inconsistency in the weight given to the risk, may explain the link between ADHD and suboptimal decision making.

Consider a gambling task in which the safe option is favorable (i.e., the expected value of the safe option is higher than the expected value of the risky option). A typical participant would assign a *relatively* consistent weight to the risk, resulting in choosing the safe option on a certain percentage of the trials. A participant with ADHD would assign a weight to the risk that is similar on average [7], but less consistent across trials. On those trials in which the subjective evaluation of the risk is higher for the participant with ADHD relative to the control participant, both will choose the safe option. On those trials in which the subjective evaluation of the risk is lower for the participant with ADHD relative to the control participant, the chances are higher that the participant with ADHD will choose the risky option. The net effect of the relative inconsistency of individuals with ADHD will therefore be more risky decision making.

Now, consider a task in which the risky option is favorable (i.e., the expected value of the risky option is higher than the expected value of the safe option). A typical participant would assign a relatively consistent weight to the risk, resulting in choosing the risky option on a certain percentage of the trials. A participant with ADHD would assign a weight to the risk that is similar on average, but, again, less consistent across trials. On those trials in which the subjective evaluation of the risk is lower for the participant with ADHD relative to the control participant, both will choose the risky option. On those trials in which the subjective evaluation of the risk is higher for the participant with ADHD relative to the control participant, the chances are higher that the participant with ADHD will choose the safe option. The net effect of the relative inconsistency of individuals with ADHD in this case will be less risky decision making.

To examine this hypothesis on ADHD-related inconsistent risk weighting, we reanalyzed the data from the experimental study by Dekkers and colleagues [11], which was described above. For each participant, a consistency index was calculated. This was achieved by first calculating the risk index (i.e., the variance of possible monetary outcomes) for the risky option of each item. Second, we calculated the weight that must be given to this risk, provided that the participant is indifferent between the risky and the corresponding safe option. For example, in one of the items participants were offered a choice between a safe option of 2.2 points (100% probability) and a risky option of 7 points with 93% probability and -30 points with 7% probability. The expected value of the risky option was $(0.93 \times 7) + (0.07 \times -30) = 4.4$, whereas the expected value of the safe option was 2.2. The risk index of the risky option was $0.93 \times (7 - 4.4)^2 + 0.07 \times (-30 - 4.4)^2 = 89.12$. Based on the risk-return model (see reference 15), we used the following equation

to calculate the weight assigned to the risk (in the case that a participant is indifferent between these two options):

Value of the safe option = EV of the risky option

+ *b*(variance of the risky option)

According to this equation, a participant with a risk weight of $b = -0.025$ would be indifferent between the two options, safe or risky ($2.2 = 4.4 + -0.025 \times 89.12$). Therefore, if a participant chose the risky option on this item, it could be inferred that this person had a risk weight that is equal to or greater than $b = -0.025$. Examination of each participant's risk weights across all items would allow to determine her or his overall risk weight. If participants follow the proposed model, each participant's choices would be perfectly consistent with a single risk weight. However, as people's choices are often not perfectly consistent, each participant was assigned a risk weight that yielded the highest proportion of choices consistent with that assignment. That proportion was considered the consistency index, with higher levels indicating that the weight assigned to the risk was more consistent. Finally, the consistency index was compared across groups. It was found that adults with ADHD had a significantly lower consistency index than controls ($M_{CONTROL} = 0.76$, $SD_{CONTROL} = 0.11$, $M_{ADHD} = 0.70$, $SD_{ADHD} = 0.11$, $t(78) = 2.47$, $p < 0.05$), suggesting that the weight they assigned to the risk was less consistent across trials. These findings suggest that ADHD is linked to greater inconsistent risk weighting, leading to suboptimal decision making.

3. Generalization of the suboptimal decision-making hypothesis to other domains

Suboptimal and inconsistent decision making may affect choices on other domains as well. For example, people with ADHD may have problems with optimally and consistently assigning a weight to the *effort* that is needed to receive a reward, resulting in an inconsistent allocation of effort. In real life, inconsistent allocation of effort might be reflected, on the one hand, in situations in which people with ADHD would be reluctant to engage in effortful tasks when it is needed, but on the other hand, in other situations, may invest too much effort in vain.

In a study by Winter et al. [19], 50 children with and without ADHD performed a strength test where they were instructed to squeeze a hand dynamometer as hard as they could and maintain that force for five seconds, to estimate their maximal muscle strength. Importantly, visual feedback regarding the strength of the grasp was provided on a computer screen throughout the task. In some of the subsequent trials, the participants had to squeeze the dynamometer 85% of the baseline for receiving a 2-point reward. Some of the participants failed to recruit sufficient effort to accomplish the threshold of 85% of the baseline maximum effort, and such insufficient effort events occurred more often in participants with ADHD relative to controls. On the other hand, some of the participants, although instructed to squeeze the hand dynamometer 85% of the baseline, exceeded their own baseline maximum strength value on some trials. Interestingly, such extra effort events also occurred more often in participants with ADHD than controls. These findings suggest that when effort is needed to receive a reward, children with ADHD are characterized by a difficulty to allocate the optimal amount of effort, rather than by a tendency to minimize effort.

Similarly, people with ADHD may have problems optimally and consistently assigning a weight to a delay that is associated with a reward. Impulsivity, one of the main clinical characteristics of ADHD, has been associated with steeper delay discounting rates, which is the phenomenon of giving more weight to present than to future outcomes [20]. One of the most popular paradigms to examine this is the delayed-choice task, in which participants are offered a choice between a small immediate reward and a larger delayed reward. Participants who frequently choose the immediate reward schedule are considered impulsive [20]. Meta-analyses demonstrate that on a delayed-choice task, people with ADHD tend to choose the small-immediate reward more often than controls, suggesting that they show a steeper delay discounting rate [21–23].

The suboptimal decision making account suggests an alternative hypothesis to explain delay discounting in ADHD, holding that ADHD is linked to a difficulty in assigning an optimal and consistent weight to delays, rather than to a bias towards the immediate reward. In most cases, at least on experimental delayed-choice tasks, the delayed option is the favorable one, as indicated by a majority of people (for example, given a choice between $33 today and $80 in 14 days, most people would agree that the "correct" choice is to wait and receive the larger amount [24]). However, it is important to note that small-immediate options are not necessarily the unfavorable options. Consider a choice between $47 today and $50 in 160 days. Most people would agree that the sensible choice would be the small-immediate option [24]. According to the suboptimal decision making account, compared to controls, people with ADHD would indeed prefer the small-immediate reward more often when the

delayed reward option is favorable. However, compared to controls, they would prefer the delayed reward more often when the small-immediate option is favorable. This hypothesis is currently tested in our lab.

4. Clinical implications

Suboptimal decision making reflects a new approach to ADHD-related functional impairment in general, and to risk-taking behavior in particular. Hitherto, the clinical literature focused on excessive risk-taking behavior by people with ADHD, which by definition may have harmful consequences. Thus, substance use may lead to addiction, smoking to somatic diseases, unprotected sex to sexually transmitted diseases, reckless driving to accidental injury, unhealthy food choices to obesity and so forth. Hence, risk-taking behavior should be evaluated and monitored routinely in individuals with ADHD.

The finding that for people with ADHD, risk-taking behavior may be driven by suboptimal decision making suggests that interventions for people with ADHD should focus on improving the quality of their decision-making. This can be achieved by learning and practicing adaptive strategies. For example, based on normative decision-making models, clients can learn strategies to decompose complex problems into a series of simpler steps, thereby reducing reliance on heuristics [25] and diminishing the executive functioning demands [26]. Furthermore, interventions may also target the context in which the decision maker acts, in a manner that favors adaptive choices

An example of an intervention that targets the context is how food is displayed in cafeterias, where offering healthy food at the beginning of the line or at eye level can contribute to a healthier choice [27]. This intervention strategy was employed in a recent study [28]. A real-life field study was conducted in a university cafeteria that offers a variety of food. The foods were categorized into healthy (e.g., salad, egg sandwich) and unhealthy (e.g., pastry, high-fat cream-cheese sandwich) foods. The experiment included three conditions, each taking place during eight days: (a) No advertising: no manipulation was conducted; (b) Healthy advertising: a healthy sandwich (with eggs and vegetables) was advertised and located at customer's eye level; (c) Unhealthy advertising: an unhealthy sandwich (with high-fat cream-cheese) was advertised and located at customer's eye level. Both advertisements encouraged consumption of that specific sandwich ("the sandwiches are perfect for busy mornings"). The advertisements were colorful and included a picture of the sandwich filling, and the short slogan was mentioned above. On the no advertising days, university students with ADHD chose unhealthy food items about three times more often relative to students without ADHD. Crucially, during the days of advertising, students with ADHD consumed more of the advertised sandwiches (regardless of whether it was healthy or not), compared with the days without advertising, whereas the food choices of students without ADHD were unchanged. Furthermore, advertising healthy food eliminated the difference between groups in the overall number of healthy/unhealthy food choices [28]. These findings suggest that highlighting the positive aspects of healthy food is an effective strategy for changing eating patterns of adults with ADHD. More generally, this example demonstrates the potential of targeting context to improve decision making in ADHD populations.

Finally, according to the suboptimal decision-making account, people with ADHD may find it difficult to resist risk-taking, immediate gratification, and effortless opportunities, but may at the same time be excessively careful, pre-planned and effortful. Hence, a new focus in clinical practice may be the identification of those real-life situations in which risk taking, impulsive, and effortless behavior is favorable. For example, people with ADHD may be too cautious in taking social risks such as expressing their views in a public situation, meeting authority figures, or asking academic help from teachers and peers. Therapy should also target these situations and offer strategies to improve decision making, which in these cases could ultimately lead to *increased* risk-taking.

Conflict of interest

The authors declare no conflict of interest**.**

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