
Review

Neuropsychological assessment of the decision making process in children and adolescents: an integrative review of the literature

Avaliação neuropsicológica do processo de tomada de decisões em crianças e adolescentes: uma revisão integrativa da literatura

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Abstract

Objective: Nowadays there has been growing interest in the “hot” aspects of the executive functions related to the orbitofrontal cortex (OFC), in particular in the affective decision-making process in children and adolescents. We reviewed the available literature about the evaluation of decision making in children and adolescents. **Method:** We searched for papers published from 2000 to 2009 that studied children and/or adolescents until the age of 16 in the Lilacs and PubMed index. The papers were analyzed according to the paradigms used in the studies, the conclusions about the development of the decision-making process, and the ability to distinguish between the clinical population and the controls. **Results:** Thirty-six papers were selected. Compared to the amount of studies of adults, there are still few studies focusing on children and adolescents. Several versions derived from the IGT were developed in order to study decision-making processes in children and adolescents. **Discussion:** The IGT is the most used instrument. In preschoolers, simplified versions have been used with greater frequency. The different paradigms are useful in differentiating between normal and psychiatric disorder patients. The results are positively and significantly related to the frequency of impulsive behaviors in nonclinical populations.

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Keywords: Decision-making, Iowa Gambling Task, executive functions, cognitive development.

Resumo

Objetivo: Atualmente, tem havido um interesse crescente nos aspectos “quentes” das funções executivas relacionados ao córtex orbitofrontal, em particular na tomada de decisão afetiva em crianças e adolescentes. Revisamos a literatura sobre a avaliação da tomada de decisão em crianças e adolescentes utilizando o paradigma do *Iowa Gambling Task* e derivados. **Método:** Pesquisamos artigos publicados de 2000 a 2009, indexados no Lilacs e no PubMed e que estudaram crianças e/ou adolescentes até 16 anos. Os artigos foram analisados de acordo com os paradigmas utilizados nos estudos, as conclusões sobre o desenvolvimento no processo de tomada de decisão e a capacidade de distinção entre a população clínica e os controles. **Resultados:** Trinta e seis artigos foram selecionados. Os estudos envolvendo crianças e adolescentes ainda são poucos quando comparados àqueles realizados com população adulta. Foram desenvolvidas diversas versões derivadas do paradigma IGT a fim de estudar a tomada de decisão em crianças e adolescentes. **Conclusão:** O IGT é o instrumento mais utilizado. Em pré-escolares, versões simplificadas têm sido utilizadas com maior frequência. Os diferentes paradigmas se mostram úteis na diferenciação entre sujeitos normais e com transtornos psiquiátricos. Os resultados se relacionam de forma positiva e significativa com a frequência de comportamentos impulsivos em populações não clínicas.

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Palavras-chave: Tomada de decisão, *Iowa Gambling Task*, funções executivas, desenvolvimento cognitivo.

Introduction

Executive functions consist of an integrated set of cognitive processes that allows an individual to set behaviors to achieve goals, to assess the effectiveness and appropriateness of these behaviors, abandoning those that prove ineffective for those most adaptive, and thus to solve immediate problems from the medium to the long term. According to Lezak *et al.*¹, executive functions involve many serial components such as volition, planning, purposive action and effective performance. According to Welsh and Pennington², the components of executive functions are: a) the ability to inhibit or delay a response, b) the strategic planning of the sequence of actions, and c) the maintenance of a mental representation of a task, including information about the relevant stimuli and the desired goal.

Traditionally, researches related to executive functions in humans have focused almost exclusively on purely cognitive components,

called “cool” and often associated with the circuitry involving the dorsolateral prefrontal cortex. However, special attention has recently been given to emotional aspects of the executive functions, called “hot”, and often associated with the circuitry involving the orbitofrontal cortex, in special the process of decision-making³. Whereas the cool executive functions are related to abstract problems, the executive functions called “hot” are required in resolving problems involving affection and motivation⁴.

Decision-making can be defined as the process of choosing between two or more competing alternatives requiring analysis of costs and benefits of each option and the estimation of its consequences in the short, medium and long term. As the results of our decisions are uncertain, we can say that the process of decision making involves risk analysis. The ability to control impulses is closely related to decision-making since, in the threefold model of Patton *et al.*⁵, lack of planning impulsiveness reflects the tendency to make immediate

decisions without considering medium and long term consequences. Thus, we can say that decision making is essential to the social adaptation of an individual and it is particularly difficult when there is a greater need to weigh rewards and/or immediate and future losses.

In the last two decades, the process of decision making has received considerable attention especially after the publication of studies such as those of Damasio, Bechara and colleagues. In an initial study, Bechara *et al.*⁶ compared the performance of patients with lesions in the ventromedial prefrontal cortex with healthy subjects in the Iowa Gambling Task (IGT). The IGT involves several different cognitive processes, in particular working memory, impulse control, ability to estimate probabilities, and reversal learning⁷.

The Iowa Gambling Task consists of four decks of cards labeled "A", "B", "C" and "D". All decks lead to a fictitious financial reward for each choice. Decks "A" and "B" bring significantly higher rewards than decks "C" and "D" (twice the value). Some decks, however, also lead to a financial loss. In decks "A" and "C", the punishments are more frequent but of smaller magnitude, as they hold more cards with losses of smaller magnitude. In decks "B" and "D" the punishments are less frequent but of greater magnitude, as they contain fewer cards of great magnitude losses. Decks "A" and "B" are disadvantageous in the long run, leading to a financial loss whereas decks "C" and "D" are advantageous in the long run, leading to a financial gain. Before beginning the task, the subject is given a credit of \$ 2,000.00 (play money), which must be bet through the choice of cards. Participants are required to accumulate the largest amount of money possible. They are also told that the examiner will indicate the end of the game (the task finishes after the subject makes one hundred choices). It is believed that due to the unpredictability of the patterns of punishment and reward, the task is able to simulate real-life decision-making conditions.

During the course of the task healthy individuals progressively develop the strategy of selecting cards from decks C and D, resulting in greater long-term gains. Patients with lesions in the ventromedial prefrontal cortex do the opposite by selecting more cards from decks A and B, resulting in disadvantages in the long run^{6,8} despite the higher immediate gains. This pattern of results was called "myopia for the future"⁹ and it is characterized by a focus on immediate results, disregarding future consequences.

In a study aiming to determine if results were due to insensitivity to punishment, patients and controls were also assessed using the reverse version of the task¹⁰. In this reversed gambling task, the decks are characterized by constant punishment and unpredictable rewards. Again, the healthy controls selected more cards from the advantageous decks whereas the patients opted for the cards from the disadvantageous decks. These findings confirmed the interpretation of "myopia for the future".

Studies with patients with lesions in the ventromedial prefrontal cortex have highlighted the importance of the ventromedial/orbitofrontal circuitry for success in tasks involving the process of decision-making⁶. In addition to patients with ventromedial lesions, other clinical groups characterized by pathophysiological changes in prefrontal circuits, such as patients with Schizophrenia¹¹, Attention Deficit Hyperactivity Disorder (ADHD)¹²⁻¹⁴, Bipolar Disorder¹⁵ and Obsessive Compulsive Disorder¹⁶ demonstrate difficulties in the IGT, according to some studies. In nonclinical populations, behaviors characterized by changes in impulsivity (such as those involving multiple school suspensions) have also been connected to disadvantageous choices in the IGT¹⁷.

Since the preschool period is characterized by a significant development of the prefrontal cortex³, we can expect that the skills related to decision-making are not yet completely developed in childhood. Although it is believed that maturation of the frontostriatal circuits and their connections cannot occur completely until early adulthood¹⁸, alterations in the development of these circuits have been associated with functional impairment in several developmental disorders¹⁹.

Adolescence is a period in which the neural and physical developments are intensified by the demands of the environment and the

behavioral changes common in this period, such as the propensity to take risks, appear to be associated to neural immaturity²⁰. In the end of childhood, the still immature skills associated to decision making processes may contribute to the appearance of behaviors that lead, for example, to alcohol and drug abuse²¹. The disadvantageous decision-making events noticed in adolescents with schizophrenia can be explained by the presence of micro structural abnormalities in the orbitofrontal cortex¹¹.

In order to evaluate decision-making processes in children and adolescents, several variations of the Iowa Task Gambling were developed to adapt it to the targeted age groups.

Although there are many studies about the performance of adults on the Iowa Gambling Task, the number of studies related to decision-making in childhood and adolescence is still considerably low. The recent and rising interest in this area can be confirmed by the increasing number of scientific publications at the end of the last decade. The purpose of this article is to review the literature concerning the assessment of decision-making processes in children and adolescents up to the age of sixteen. In addition, the present study aims to evaluate the development of decision-making processes in children and adolescents from data obtained from different tasks used to assess decision-making by comparing the performance of normal children and that of children with neuropsychiatric disorders in this cognitive modality.

Methodology

This study is an integrative literature review. According to Whittemore²², an integrative review allows the inclusion of studies that used different types of methodologies (such as experimental and non-experimental research) in order to contribute to the presentation of a variety of perspectives – review of theories or evidences, definition of concepts, analysis of methodologies – on a particular topic in an attempt to interconnect isolated elements from available studies.

According to Ganong²³, the process of elaboration of the integrative review consists of several stages. The first stage is characterized by the hypotheses or questions to be answered. In the second stage, the databases and research that will provide the review sample are selected. After this stage, the description of the studies that will comprise the review sample is made. In the last two stages that of the process of elaboration of the integrative review, the results are interpreted and final report is made.

To guide the integrative review, the following questions were asked: What paradigms for the assessment of decision making are used in studies with children and adolescents aged up to sixteen years old? How can the development of the decision-making process in normal children and adolescents be characterized using data obtained from paradigms for the assessment of decision-making processes? Can the tasks associated to decision-making distinguish performance of normal children and adolescents from that of subjects with neuropsychiatric disorders?

The present study included all the papers about the paradigms for the assessment of decision making used in studies with children and adolescents aged up to sixteen in the period of January 1, 2000, to December 31, 2009, indexed in Lilacs and PubMed.

In order to refine this review, the sample was defined according to the following criteria:

- papers available in the database of PubMed and Lilacs;
- papers in English, Portuguese and Spanish with abstracts available in the database mentioned above for the period of January, 1 2000 to December 31, 2009;
- papers in which the sample was comprised of children and/or adolescents aged up to sixteen;
- papers that clearly established that the paradigm used to assess decision-making was the Iowa Gambling Task or one derived from it;
- papers indexed by the following terms, individually or in associations: decision-making/Iowa gambling task.

The established exclusion criterion was:

- literature review articles or case studies.

During the selection process, some articles were disqualified as they did not meet the inclusion criteria. We performed a search in the Pubmed database using the terms “decision making” and “Iowa gambling task” and found 238 articles.

After the initial reading of the abstracts obtained, 42 papers were discarded based on the presented criteria given that: 1) 11 papers were not published within the time limits established in this study; 2) 4 papers referred to studies with samples that included both human and animals; 3) 15 papers described studies performed with samples whose participants were older than sixteen, 4) 8 papers had no original data (narrative reviews, editorials, commentary, and clinical notes), 5) 3 were case studies, and 6) one paper was written in Chinese.

Among the 196 remaining articles, 33 were not evaluated because they were not available at the Portal Capes Journal or at the University of Wisconsin. The reading of the 163 remaining papers allowed selection of the 21 articles used in this review, and the exclusion of the other 142, because: a) 139 were conducted with subjects older than sixteen, b) two of them did not inform the age of the participants, c) one of them was performed on humans and rodents, and d) one was a literature review.

The research done in the Lilacs database using the same criteria resulted in four papers. None of them has been selected since three of them were performed on groups above the age limits and one of them was a literature review.

Then a reverse search was conducted from the references of the 21 selected papers to identify articles not found initially. After this verification other 15 papers were identified. At the end of the selection process of papers, 36 studies were included in the sample.

Results

Among the 36 articles reviewed, 13 (36.11%) were published between 2001 to 2005^{3,17,24-34} and 23 (63.89%) between 2006 and 2009^{11,35-56}. Thirteen of the selected papers are from the United States^{3,11,20,29,31,34,36,40,45,47,50,54,56}, six from Canada^{17,24,32,38,42-44,55}, five from the Netherlands^{17,25,30,33,37,41}, three from China^{21,50,51}, two from the UK^{21,48} and one from each of the following countries: Australia³⁹, Finland²⁸, Israel⁵⁶, Japan⁴⁹ and Romania⁵³.

Regarding the first objective of this review, the gathering of paradigms used for the evaluation of decision making processes addressed in studies with children and adolescents aged up to sixteen, it was observed that most studies related to the development of decision making used the Iowa Gambling Task or similar versions adapted for children and adolescents. Table 1 summarizes the different paradigms used to assess decision-making found.

Among the studies reviewed, only eleven used the Iowa Gambling Task to assess decision-making^{11,20,21,26,29,47-49,51,52,54}. Seven of them used variations very similar to the original task in which there were small changes in the amount of the loan, gains and punishments after the choices^{17,28,31,32,36,40,44}. Five used only the Children Gambling Task, proposed by Kerr and Zelazo^{3,34,45,53,55}. Five studies used the task of decision making proposed by Garon and Moore^{24,35,38,42,43}. Yet three other studies used some of the versions of the Hungry Donkey Task, developed by Crone and Van der Molen^{25,37,41}. The study by Crone and Van der Molen used, in addition to the standard and reversion versions of the Hungry Donkey Task, three different versions of the task (with different forms of feedback) while the study by Crone *et al.*³³ used the following tasks: a) Iowa Gambling Task in the forward and backward versions; b) versions of the standard and reverse Hungry Donkey Task and c) three different versions of the task (with different quantities of choice alternatives and percentage of punishment). Nevertheless the study by Bunch *et al.*³⁹ used, besides the Children Gambling Task, two less complicated versions of the task. The research of Gao *et al.*⁵⁰ used a version similar to the Children Gambling Task, in which changes were made in the disadvantageous

deck. Yechiam *et al.*⁵⁶ used, in addition to the standard version of the Iowa Gambling Task, a task that was modified from the original one and developed by the authors of the study.

Among the 36 studies, 15 investigated the performance of children with a neuropsychiatric diagnosis (or maladaptive behavior pattern typical of psychopathology in childhood and adolescence)^{11,17,25,27,32,35,36,45-49,56,57,61}. Table 2 presents the description of all the papers, considering the paradigm used, the study sample, the experimental design, the main results and the level of evidence generated by the study.

Discussion

Description of the paradigms used for decision making evaluation in children and adolescents:

We can notice that, despite the growing number of variations of IGT developed from the original task, the classic version is still the most widely used both in studies on the normal development of skills related to decision making and on clinical studies. It is worth mentioning that IGT is used mainly in samples with subjects whose age is equal to or older than seven years old. Adaptations of IGT are generally used in studies with children under the age of sixteen to facilitate understanding of the task.

Development of skills associated with decision making in childhood and adolescence in normal children

Researches using the Iowa Gambling Task (and its variants for evaluation in childhood and adolescence) suggest the progressive development of skills linked to decision making processes in childhood and adolescence^{26,29-31,33, 37,40,41,44}. In particular, these studies showed that children aged six and twelve years old select more cards from disadvantageous decks while adolescents aged thirteen to seventeen years old learn to select the cards from the advantageous decks during the task. These data suggest that children are more sensitive to immediate rewards. Furthermore, these findings are consistent with recent studies on brain development, which showed that pre-frontal circuits are among the last brain structures to mature both structurally and functionally. The difficulty that children demonstrated to learn to choose the cards from the advantageous decks resembles the difficulties presented by patients with amygdala or orbitofrontal³⁰ lesions and therefore they also seem to have, at some level, “myopia for the future”.

The age at which children begin to differentiate the advantageous from the disadvantageous cards seems to depend on the characteristics of the task associated to the decision-making processes used. In the study carried by Kerr e Zelazo³, children under four years old, for example, made more advantageous choices than it would be expected if they had performed just random choices in the task proposed by the authors of the study, the Children Gambling Task, comprised of two decks of fifty cards each. However, Luman *et al.*⁵⁷ suggest that CGT does not reflect daily decision making processes since the rejection of a choice leads automatically to the selection of the other choice.

In the study carried by Bunch *et al.*³⁹, the complexity of CGT was evaluated by introducing two less complicated versions of the task. At first, the gains are kept constant between the two decks and only losses vary. In the second, the opposite occurs, and only the gains vary. Children aged three to five years old were successful when the complexity of the task was reduced, but only five-year-old children have clearly demonstrated domain of the version developed by Kerr & Zelazo³. In a study carried by Garon & Moore³⁸, who used a modified task from IGT in which four blocks of cards holding drawings of bears and tigers (the bears indicate gain and the tigers indicate loss) were adopted, children under four were not able to significantly make more advantageous choices.

Table 1. Summary of the paradigms used for evaluation of decision making in children and adolescents

N°	Version	Description	
1	a) Iowa Gambling Task (IGT)	In the text body	
	b) Reversed version of the Iowa Gambling Task (IGT)		
2	Variations of the Iowa Gambling Task	There are modifications in the value of the loan, gains and penalties after choices	
3	Children Gambling Task (CGT)	The general rule, as in the adult format of the paradigm, is that choices that lead to greater immediate gains can bring harmful consequences in the long run whereas choices that lead to smaller immediate gains may lead to greater gains in the long term. In the adult format, the reinforcement is symbolic and the cards are divided into four decks whereas in the children format the reinforcement is concrete and the cards are divided into two decks. In this version, only fifty cards are selected by the participant. Gains are represented by smiling faces and losses by sad faces. In the two cells, the number of earnings is constant throughout the cards, but the number of losses is variable	
4	a) Standard Version of the Hungry Donkey Task	In the task, the participant is introduced to four doors (A, B, C and D) and a donkey positioned below the doors. The choice of a door leads to gains or losses of apples. The participant is told to maximize his number of apples. The total gain is shown by a horizontal bar displayed at the bottom of the screen, which at the beginning of the task is half green and half red. The green part increases with the gains and the red part increases with the losses. In the direct version, the participant receives four apples when he selects the gates A and B; and two apples when he selects the gates C and D. Losses, if any, vary between 8 and 12 apples in door A, 50 in door B, between 1 and 3 in the door C and are equivalent to 10 in door D. In the reverse version of the task, the punishment is presented before the reward. Selecting the doors A and B result in a loss of four apples whereas selecting the doors C and D result in a loss of two apples. The gains, however, vary, and are greater for choices involving greater losses. Therefore, the ports A and B are more advantageous in relation to doors C and D because even having greater immediate losses, they provide greater long-term gains	
	b) Reversed version of the Hungry Donkey Task		
5	Versions of the Hungry Donkey Task with different conditions of feedback	There are used three different versions of the task: without feedback, with global feedback and with feedback related to a specific door	
6	Other versions of the Hungry Donkey Task	a) AACC (four choices, 50% punishment)	Four doors are presented and the amount of loss and gain follows the scheme AACC (resembling two decks A and two decks C of the original Gambling Task), resulting in unpredictable losses (standard version) and unexpected earnings (reverse version) on 50% of the stimuli
		b) AC (two choices, 50% punishment)	In the task, two doors are displayed and the amount of gains and losses follows the scheme AC (similarly to the decks A and C of the original version of the Gambling Task) with unpredictable gains (standard version) and unpredictable losses (reverse version) on 50% of the stimuli
		c) BD (two choices, 10% punishment)	Two doors are displayed and the amount of gains and losses follows the schema BD (similarly to the blocks B and D of the original Gambling Task), with unpredictable earnings (standard version) and unpredictable losses (reverse version) on 10% of the stimuli
7	Garon and Moore's adaptation of the original version of IGT	Four decks of cards are used, two of which are advantageous and the other two are disadvantageous. Each deck has 26 cards. Each card from the disadvantageous decks has two bear pictures (which indicates a win of two tokens); some of them have also tiger pictures (indicating a loss of tokens). In the advantageous decks, each card has a bear picture (which indicates the win of a token) and some of them have also tiger pictures (indicating loss of tokens). The examinee is instructed to select 36 cards in the task	
8	Three modified versions of the Gambling Task Children	a) Ternary-relational version	The gain-loss contingencies were identical to the CGT (Kerr and Zelazo, 2004)
		b) Binary-relational version (gain)	Cards in deck A indicate a gain of one reward and the loss of zero or one reward. Cards in deck B indicate a gain of two rewards and a loss of zero or one
		c) Binary-relational version (loss)	Cards in deck A indicate a gain of one reward and a loss of zero or one reward. Cards in deck B indicate a gain of one reward and a loss of zero or five rewards
9	Modified versions of the Children Gambling Task	a) The task used in this experiment is identical to the Children Gambling Task except for the addition of three cards of demonstration and the corresponding increase in the number of cards in each deck from 50 to 53	
		b) The material used in this experiment is identical to the first one, except for modifications made in the disadvantageous deck. This deck contains 16 cards with no loss, 11 cards with four losses, 10 cards with five losses, 16 cards with six losses	

Table 2. Analysis of the selected review articles regarding methodology and results

Paper	Decision-making task version	Sample	Results
Blair <i>et al.</i> (2001)	1A	43 boys with behaviors related to psychopathy (mean age = 13.7 +/- 1.86 years) and 23 boys in the control group (mean age = 12.75 +/- 0.83 years)	Children of the clinical group chose more cards from the disadvantageous decks than the control group in the IGT
Stanovich <i>et al.</i> (2003)	2	Three groups of participants (mean age = 16.2, +/- 1.7 years): a) 45 students without school suspension during the evaluation period; b) 18 students with one suspension in the same period; c) 27 students with more than one suspension in the same period	Students who received multiple suspensions chose more disadvantageous cards than the other two groups in the second half of the decision making task
Ernst <i>et al.</i> (2003)	1 A	a) 33 adolescents with behavioral problems (91% male, mean age = 12.6 +/- 0.7 years); b) 31 adolescents of the control group (55% male, mean age = 12.8 +/- 0.7 years)	Adolescents with behavioral problems showed a worse performance than the control group of adolescents
Letho and Eloorinne (2003)	2	30 boys and 21 girls, 30 second graders (mean age = 100.5 +/- 3.7 months), 21 fourth graders (mean age = 125.8 +/- 4.0 months)	There was no significant difference between the number of advantageous choices among children and adults
Crone <i>et al.</i> (2003)	4A e 4B	105 adolescents aged between 12 and 13 years old and 74 adolescents aged between 15 and 16 years old	Individuals who had a low score on the SSS had a worse performance only in the standard version of the ICGT
Overman (2004)	1A	420 males, 60 participants (50% male) of each school year between the sixth and twelfth grade	Reports of substance use and risky behaviors were not significantly correlated with performance on cognitive tasks. Performance on the Wisconsin Card Sorting Test didn't present differences between gender, history of substance abuse and did not correlate with performance on the IGT. The older adolescents presented a higher performance on the IGT than the younger
Kerr and Zelazo (2004)	3	48 children from two age groups: 3 years (n = 24) and 4 years (n = 24), 50% of each sex. Among children under 3 years, the mean age is 42.5 months, range between 37 and 47 months and among children of four years old the average is 53, ranging between 48 and 59	The 4-years old children selected more low risk cards at the expense of those at high risk over the blocks of choices. Moreover, they made more advantageous choices than 3-years old children in the last three blocks of the task
Crone and Van der Molen (2004)	Experimento 1: versões 4 A, 4 B e 5B Experimento 2: versões 4 A e 4 B	Experiment 1: three groups of participants: a) 61 children aged between 6 and 9 years; b) 61 children aged between 10 and 12 years; c) 61 university students aged between 18 and 25. Experiment 2: three groups of participants: a) 30 children 7-8 years (57% male, mean age = 7.8 +/- 0.85 years); b) 30 children aged between 11 and 12 years (63% female, mean age = 11.3 +/- 0.79 years); c) 29 children aged between 15 and 16 years (65% male, mean age = 15.8, +/- 0.79 years)	The advance of age of the participants was related to the greater amount of more advantageous choices during the task. The ability of inductive reasoning was not related to advantageous choices in the decision making task. Working memory does not influence the development trend presented in the decision-making task
Garon and Moore (2004)	6	a) 20 children under 3 years of age (70% male, mean age = 43.65 months); b) 24 children aged 4 years old (67% male, mean age = 53.79 months); c) 25 children under six years of age (68% female, mean age = 77.6 months)	The girls chose more cards from the advantageous alternatives than it would be expected if they had performed just random choices, but the boys showed no difference in the choice of advantageous and disadvantageous alternatives
Hooper <i>et al.</i> (2004)	2	145 participants aged between 9 and 17 years (54.5% male, mean age = 12.89 +/- 2.75 years) divided into three groups: a) 49 children aged from 9 to 10 years (49% female, mean age = 9.84 +/- 0.32 years); b) 54 children aged from 11 to 13 years (56% female, mean age = 12.92 +/- 0.90 years); c) 42 adolescents aged from 14 to 17 years (60% female, mean age = 16.41 +/- 1.31 years)	Compared with younger groups, the group of adolescents aged between 14 and 17 years made more selections of advantageous cards in the IGT and shifted their choices toward the advantageous decks earlier along the sequence of stimuli. The group of older participants also showed better performance by inhibiting a prepotent response (to avoid errors related to false alarm on the task Go/No-Go) and were able to handle a larger amount of information in working memory
Toplak <i>et al.</i> (2005)	2	Two groups of adolescents aged 13 to 18 years old (mean age = 15.5 +/- 1.5 years): a) 44 adolescents (86% male) with ADHD, while 45% of these were diagnosed with ADHD predominantly inattentive type and 55% with ADHD combined type; b) 34 control group adolescents	Adolescents with ADHD made less advantageous selections than the controls – selected more cards from the deck B and fewer cards in the deck D than normal adolescents
Crone <i>et al.</i> (2005)	a) 1 A e 1 B b) 4 A e 4 B c) 6 A, 6 B e 6 C	a) 46 children aged between 7 and 9 years (54% male, mean age = 8.53 years); b) 49 children aged between 10 and 12 years (55% male, mean age = 11 years); c) 45 adolescents (51% male, mean age = 13.46) aged between 13 and 15 years	Age was positively correlated with a greater number of advantageous choices throughout the task. In the BD version, there was a clear developmental trend in the choice of advantageous alternatives; however this trend was not manifested when the punishment was frequent (50%)
Hongwanishkul <i>et al.</i> (2005)	3	98 children aged between 3.0 and 5.9 years: a) 33 children aged three years (51.5% male, mean age = 41.02 +/- 3.84 months); b) 32 children aged four years (50% male, mean age = 54.06 +/- 3.61 months); c) 33 children aged five years (51.5% male, mean age = 66.13 +/- 3.0 months)	In CGT, the performance of children aged five years old was better than the performance of children aged three years old. The performance of children aged three years old was significantly worse than it would be expected if they had performed just random choices
Garon <i>et al.</i> (2006)	7	Two groups of children aged from 6 to 13 years: a) 21 children with ADHD (mean age = 9.86 +/- 1.71), with 10 of these children (80% male) classified as highly anxious and depressed children and 11 (82% male) classified as having ADHD only (slightly anxious or depressed)	Children from the clinical subgroup with anxiety and depression symptoms were better able to perform the task of decision making than children with only ADHD



Paper	Decision-making task version	Sample	Results
Kester <i>et al.</i> (2006)	1A	15 adolescents diagnosed with schizophrenia (mean age = 15.9 +/-2.7 years, 60% male) and 25 healthy adolescents (mean age = 17.1 +/-1.8 years, 56% male)	In the decision making task, adolescents with schizophrenia had a significantly lower performance when compared to healthy adolescents; the clinical group chose more cards from the disadvantageous decks throughout the task
Johnson <i>et al.</i> (2006)	2	a) 15 individuals with Asperger syndrome (mean age = 16.1 +/-2.3 years, 73% male); b) 14 controls (mean age = 15.9 +/- 2.4 years, 71% male)	The two groups had similar proportions of total advantageous choices. The group of adolescents with Asperger syndrome showed a pattern of unusual selection of cards characterized by frequent changes of choice between the decks
Crone and Van der Molen (2007)	4A e 4B	a) 22 children aged between 8 and 10 years (55% female); b) 29 children aged between 12 and 14 years (52% female); c) 30 adolescents aged between 16 and 18 years (77% female)	The results suggest that the ability to make advantageous choices is not developed until late adolescence. The development of decision-making skills was accompanied by differences between groups of participants related to anticipatory autonomic responses
Garon and Moore (2007)	7	44 children (54.5% male) aged between 41 and 59 months (mean age = 51 +/- 7.11 months)	Children with high extroversion factor in the Child Behavior Questionnaire chose more often the disadvantageous deck
Bunch <i>et al.</i> (2007)	8	a) 24 children aged 3 years (50% male; boys with a mean age = 44.75 +/- 2.45 months and girls with mean age = 44.42 +/- 2.28 months); b) 24 children aged 4 years (50% male; boys with mean age = 56.67 +/- 2.10 months and girls with mean age = 52.17 and +/- 2.95 months); c) 24 children aged 5 years (50% male; boys with a mean age = 65.33 +/- 3.50 months and the girls with a mean age = 64.33 +/- 4.14 months)	Children from the three age groups selected cards from the advantageous deck and avoided cards from the disadvantageous deck when the correct selections depended only on information about the gains or only on information about the losses (binary-relational versions). Only children aged 5 years old demonstrated clearly domain of the ternary-relational/children gambling task version
Olson <i>et al.</i> (2007)	2	a) 52 participants aged between 9 and 17 years (52% male, mean age = 13:50 and +/-2.58 years); b) 40 participants aged between 18 and 23 years (43.5% male, mean age = 20.37 +/- 1.69 years)	The performance on the task of "delay discounting" was related to IGT performance indicating that the ability to delay gratification is associated with affective decision making
Huizenga <i>et al.</i> (2007)	4A e 4B	a) 61 children aged between 6 and 9 years (54% male); b) 60 children aged between 10 and 12 years (45% male); c) 59 adolescents aged between 13 and 15 years (19.6% male)	The results showed that the privileged strategy in all age groups was the focus on the frequency of gain and loss related to the doors (the dominant dimension corresponding to the first rule). This strategy has become more pronounced with age
Garon and Moore (2007b)	7	a) 66 children aged 4 years, aged between 47 and 53 months (54.5% male, mean age = 50.8 months); b) 75 children aged 4 years, aged between 54 and 59 months (50.7% male, mean age = 56.5 months)	Older children made more advantageous choices than younger children. While the younger children chose more cards from the disadvantageous deck than it would be expected if they had performed just random choices, the older children made more choices in the advantageous deck
Garon and Moore (2007)	7	Experiment 1: a) 22 children aged between 41 and 47 months (56.5% male, mean age = 3.8 years); b) 21 children aged between 55 and 59 months (52.3% male, mean age = 4.10 years) in the delay of gratification task, only 21 children aged between 41 and 47 months, and 21 children aged between 55 and 59 months participated of the study. Experiment 2: a) 63 children aged between 36 and 47 months (49.2% male, mean age = 3.6 years); b) 73 children aged between 48 and 59 months (42.46% male, mean age = 4.5 years)	Experiment 1: Whereas children aged 3½ years demonstrated a tendency to prefer the cards of the disadvantageous deck, children aged 4½ years demonstrated preference for the advantageous deck. Experiment 2: In the condition of the task in which each child was asked which deck was better and why and which deck was worse and why, the performance of children aged 4½ years old was higher than the performance of the same children on the control version of the task. The version of the task in which participants were instructed to place the figure of the tiger and the bear next to each of the decks in order to symbolize which one was the best and worst did not benefit children aged 4 ½ years
Hooper <i>et al.</i> (2008)	2	153 participants aged between 9 and 17 years (52% female, mean age = 12.85 +/- 2.73 years)	Adolescents with high scores in neuroticism preferred the disadvantageous decks during the task while those with low scores chose more cards from the advantageous decks in the last block of the task; the relationship between neuroticism and performance on the IGT was only significant for the male adolescents
Bubier and Drabick (2008)	3	63 children from impoverished families (mean age = 7.79 +/- 1.08 years) with 38% of first grade (58% male), 35% of second grade (50% male), 25% of third grade (50% male) and their primary caregivers	Boys and girls did not differ regarding decision making. The performance in the CGT was related to the presence of ADHD and ODD in boys but not in girls
Xiao <i>et al.</i> (2008)	1 A	181 participants of the tenth grade from four different schools: a) an academic high school of high academic status; b) an academic high school of low to medium academic status; c) a vocational school of medium academic status; d) a vocational school of low academic status	Adolescents who had smoked in the last 7 days demonstrated lower performance on the decision making task when compared to teens who said they had smoked but not in the last 30 or 7 days, as indicated by an abnormal curve of learning and a score significantly lower in the IGT. There were no differences in performance on the SPOT among adolescents who had smoked in the last 7 and those who had never smoked



Paper	Decision-making task version	Sample	Results
Johnson <i>et al.</i> (2008)	1 A	208 participants of the tenth grade aged between 14 and 18 years (mean age = 16.18 and +/- 0.63, 50% male) from 4 different schools, with 104 of them studying in an academic high school of high academic status or in an academic high school of low/medium academic status, and 104 studying at a vocational school of medium academic status or a vocational school of low academic status	Adolescents who had smoked in the last 7 days showed lower performance on the decision making task when compared to teenagers who said they had smoked but not in the last 30 or 7 days; as indicated by an abnormal curve of learning and a score significantly lower in the IGT
Oldershah <i>et al.</i> (2009)	1 A	133 participants aged between 8 and 12 years: a) 54 participants with self-harm history (mean age = 15.8, +/- 1.5, 90.7% females) divided into two subgroups: a) 30 participants that experienced a self-harm episode within the previous 30 days and 24 participants that have experienced the last self-harm episode within a period longer than one month; b) 22 subjects diagnosed with depression (mean age = 15.7 +/- 1.3 years; 90.9% female); c) 57 healthy subjects (mean age = 15.8, +/- 1.5 years, 80.7% female)	In the decision making task, the performance of adolescents who practiced self-harm (including those teenagers with current episodes and those who have had the last episode more than one month prior to the survey) did not differ significantly from healthy adolescents and the group of participants with depression. When the group of adolescents who committed self-harm has been subdivided in adolescents with current episodes showed poorer performance on the task of decision making
Masunami <i>et al.</i> (2009)	1 A	a) 14 children (92.8% male, mean age of 11.5 +/- 2.2 years) diagnosed with ADHD; b) 11 control children (54.5% male, mean age = 11.7 and +/- 1.7 years)	Children with ADHD did not demonstrate differences in measures of skin conductance neither when they receive rewards nor when they received punishments as compared to control children
Gao <i>et al.</i> (2009)	9	Experiment 1: a) 30 children aged 3 years (54% male); b) 30 children aged 4 years (54% female). Experiment 2: a) 60 children aged 3 years (50% male); b) 61 children aged 4 years (52% female); c) 60 children aged 5 years (52% female)	The performance of children aged 4 years old was better than the performance of children aged 3 years old. The performance of children aged 5 years old was higher than that of children aged 4 years old. Modest differences in the contingencies of gain/loss between the advantageous and disadvantageous decks to did not influence qualitatively the pattern of performance of the children
Xiao <i>et al.</i> (2009)	1 A	181 participants from four different schools: a) an academic high school of high academic status; b) an academic high school of low to medium academic status; c) a vocational school of medium academic status; d) a vocational school of low academic status	Adolescents who consumed excessive amounts of alcohol had a lower performance in the IGT compared to adolescents who have never drunk or adolescents who drank only occasionally. The decision-making task was able to predict the amount of drinking and alcohol-related problems regardless of past conduct related to drink, the capacity of working memory and impulsivity
Gao <i>et al.</i> (2009)	1 A	298 children (149 twin pairs, 54% female); the socioeconomic data were obtained from the caregivers when the children were between 9 and 10 years (mean age = 9.60 +/- 0.60 years) while the neurocognitive tasks and the measures concerning psychopathic tendencies were collected after 2.3 years (mean age = 11.9 +/- 0.69 years)	The results revealed that risky decision-making is associated with trends related to psychopathy only in children from families of high academic standard. Boys were more likely to develop symptoms related to psychopathy than girls
Heilman <i>et al.</i> (2009)	3	a) 15 girls aged 3 years (mean = 39.6 +/- 0.8 months), b) 17 boys aged 3 years (mean = 41.11 +/- 0.65 months), c) 15 girls aged 4 years (mean = 52.66 +/- 0.65 months), d) 15 boys aged 4 years (mean = 53.06 +/- 0.65 months)	In the decision making task, the performance of children aged 4 years was better than the performance of children aged 3 years old. The difference in performance of children of different age groups was independent of changes in the development of inductive reasoning, language and working memory. The influence of gender on decision-making is apparent only in children aged 3 years old. There is a significant correlation between performance on the CGT and children's knowledge about the task in the group of children aged 4 years
Janis and Nock (2009)	1 A	The paper presents two studies, only the first one among teenagers. In this study 94 participants aged 12 to 19 years are evaluated: a) 64 individuals with a history of non-suicidal self-harm (79.7% female, mean age = 17.4 years +/- 1.8 years); b) 30 young controls (73.3% females, mean age = 16.7 +/- 2.0 years)	Performance measures on the CPT and IGT were correlated, and the measures in the CPT and the question related to impulsivity (K-SADS-PL) made to the participants were correlated as well. Performance measures in the IGT and questions related to impulsivity (K-SADS-PL) were negatively correlated
Morrongiello <i>et al.</i> (2009)	3	a) 31 children aged between 7 and 8 years (48% male, mean age = 25.8 +/- 0.64 years); b) 35 children aged between 9 and 10 years (46% male, mean age = 9.92 +/- 0.53 years); c) 36 children aged between 11 and 12 years (54% male, mean age = 12.05 +/- 0.59 years)	There were no significant differences related to age or sex of the participants. In the first block, there was a predominance of risk-taking. Participants made more advantageous choices throughout the task, which is related to risk prevention. Scores related to sensation seeking was positively correlated with performance on Balance Beam, but were not associated with performance on the IGT
Yechiam <i>et al.</i> (2009)	1 A e 10	43 children and adolescents aged between 9 and 21 years: a) 15 children and adolescents diagnosed as having an autistic spectrum disorder (93.3% male, mean age = 15.6 +/- 2.8 years); b) 28 controls (92.8 % male, mean age = 15.6 +/- 3.6 years)	Although the two groups of participants had learned to make advantageous choices during the task, there was a lower rate of learning in the clinical group. The performance of the clinical group was characterized by frequent changes of choice between the decks

Regarding the difference in performance between boys and girls, the results are still controversial. Although some studies that investigated the difference between pre-school boys and girls in tasks related to decision making found no significant differences between sexes^{3,29,34}, girls made more advantageous choices than boys in the study carried by Garon & Moore²⁴. Moreover, male adolescents appear to have a better performance than female adolescents^{26,29}. Differences in the approaches of these studies may explain the heterogeneity of the results.

According to Van Leijenhorst *et al.*⁵⁸, comparisons between studies indicate that the performance of adolescents is not yet equal to that of adults. These findings indicate that the ability to distinguish between advantageous and disadvantageous decks is still developing in adolescence^{26,31}.

Indeed, despite the fact that complete maturation of decision-making abilities is only achieved by late adolescence, early assessment of these skills can be useful in identifying difficulties in the decision process, considering that the executive functions of the type "hot" are highly connected to non-adaptive behavior in children and adolescents such as school suspension^{17,27}, smoking and alcohol use^{46,47}.

Despite the lack of longitudinal studies that assessed the relationship between decision making and adaptive behaviors in adolescence and adulthood, some studies on other executive "hot" functions such as the delaying of gratification lead to a predictive relationship between early development of this type of executive function and future adaptive behavior. For example, Mischel *et al.*⁶⁴ noted that at the age of 4, the decision to wait to receive a greater reward could positively predict social and cognitive skills, the ability to cope with adverse affective situations, and the performance on academic attitude tests during adolescence.

The performance of preschoolers in delaying gratification tasks was also able to predict a more efficient performance on tests of inhibitory control at the age of eighteen^{63,65}. Therefore, the assessment of difficulties in executive "hot" function tasks in children has potential application in the identification of deficits and risks related to social and adaptive skills in the short and medium/long term. However, longitudinal studies about the relationship between initial development in decision-making processes and adaptive outcomes in the late teens are necessary.

Comparison between clinical groups (or maladaptive behavior) and normal children on tests of decision-making

Among the articles reviewed, four of them are studies in which the sample is composed of children and/or adolescents with attention deficit hyperactivity disorder (ADHD)^{57,59-61}. ADHD is characterized by some as a disorder of executive functions. Children with ADHD have many difficulties in executive functions, and deficits in inhibitory function are considered the most important in one of the main theories explaining this disorder⁵⁹. ADHD can also be explained by difficulties in learning schemes of reinforcement⁵⁷ and in delaying the reward or in dealing with long waiting intervals⁶⁰. Thus, one can say that individuals with ADHD constitute an important clinical group for the understanding of the skills related to decision-making.

Although Geurts *et al.*⁶¹ have suggested that children with ADHD do not switch strategies in response to punishment in the same way as healthy subjects do, the differences between the performance of controls and children with Attention Deficit Disorder and Hyperactivity in the used gambling task were not significant. According to Masunami *et al.*⁴⁹, children with ADHD and healthy children may have different strategies and patterns of choice, which are hardly detectable by the number of cards selected from the advantageous decks. Since Luman *et al.*⁵⁷ proposed that children with ADHD have increased sensitivity to immediate reinforcement; the differences in strategies related to decision-making processes may be the result of changes in sensitivity to reinforcement and punishment⁴⁹.

In a study carried by Garon *et al.*³⁵, two groups of children aged six to thirteen were evaluated. The first group was composed of 21

children with ADHD, while 10 of these children were diagnosed as depressed or very anxious and 11 as a little anxious and depressed (only with ADHD), and the second group was composed of healthy children. The findings of this study showed that children with ADHD only chose significantly fewer cards from decks with less immediate rewards and have learned over time. In contrast, children in the clinical group with high rates of anxiety and depression symptoms were able to perform better on the task of gambling compared with children with only ADHD. The authors of this study suggest that the presence of an internalizing disorder may have a protective effect on children with ADHD when dealing with schedules of reinforcement learning over time. In the study carried by Toplak *et al.*³² with adolescents aged 13 to 18, adolescents with ADHD made less advantageous selections than the controls. It must be emphasized that Bubier and Drabick⁴⁵ also found poorer performance related to affective decision-making in boys with externalizing disorder symptoms, using the Children Gambling Task. The authors suggest that, at least in male children, the symptoms of Oppositional Defiant Disorder and ADHD are related to more immediate decisions, which may be associated with an attenuation of the autonomic sympathetic response, thus reinforcing the role of somatic markers in decision making.

Children with externalizing behavior disorders such as attention deficit disorder and hyperactivity (ADHD) and conduct disorder, are likely to present disadvantageous decision-making results due to impulsivity, aversion to delay gratification, intensified sensitivity to immediate reward and a propensity for risky behaviors^{57,59,60}. These conditions contribute to a higher incidence of disorders related to substances used among those adolescents than among the general population⁶⁰, which exemplifies the relationship between difficulties in decision-making processes and maladaptive behaviors in children and adolescents with psychopathology.

Besides children and adolescents with ADHD, studies about the following populations were found in this literature review: a) adolescents with behavioral problems and/or who received suspensions in school^{17,27}; b) adolescents with a history of alcohol and/or cigarette abuse when compared with individuals of similar age, but without history of drug abuse^{46,47}; c) adolescents with schizophrenia¹¹; d) adolescents with high disinhibition²⁵; and e) adolescents who exhibit behaviors of current self-mutilation compared with those who have had this type of behavior⁴⁸; f) children diagnosed with Asperger syndrome³⁶ or any disorder within the autism spectrum⁵⁶. In all studies mentioned above, atypical choice pattern indicative of difficulties in decision making in clinical groups (and maladaptive behaviors) compared with children and adolescents with typical behavior can be verified.

Thus, it is observed that difficulties in decision-making are related to psychopathology and/or maladaptive behaviors. Studies with adolescents who demonstrate behaviors of current self-mutilation compared with those who have had this type of behavior⁴⁸ exemplify this relationship. The decision-making skills seem to have a direct relationship with the recent of episodes of self-mutilation. Adolescents who had self-mutilation behaviors have demonstrated deficits in decision-making skills, marked by a greater attraction for more immediate and rewarding solutions than individuals that showed self-mutilation in the past⁴⁸.

Different clinical or maladaptive behavior populations share difficulties concerning affective decision-making. Changes in the development of the prefrontal circuits are common in the aforementioned disorders and are associated with difficulties in executive "hot" function tasks³. Thus, deficits in decision-making skills do not seem to be specific to a particular clinical population, but common to several diseases associated with impaired prefrontal lobe¹⁴. It must be emphasized that some disorders such as generalized anxiety disorder seem to exert a protective effect on the process of decision making in children with attention deficit disorder and hyperactivity³⁵. To evaluate this effect of anxiety on the process of decision making, further studies to evaluate these findings in other pathologies in which generalized anxiety disorder appears as comorbidity are needed.

We can see from the findings reported that the evaluation of decision making skills in children and adolescents, besides useful in the clinical characterization of different psychopathologies, has also a potential use as an indicator of function and social adaptation within each disorder^{17,27,46,47,48,51,54}. Additional investigations about this relationship in children and adolescents with psychiatric disorders are needed.

Conclusion

Despite the increasing use of evaluation paradigms of decision-making skills derived from IGT in children and adolescents samples, we can notice that the frequency of these studies is still much lower if compared with those performed on adult subjects⁶².

However, the findings reported here are consistent not only with the beneficial effect of age on performance but also with the suitability of such tasks for discriminating children and adolescents with neuropsychiatric disorders and/or maladaptive behaviors. These data reinforce the potential for clinical use of tests involving decision making in this age group; however this use should be preceded by studies on psychometric properties of IGT and its variants. Future studies using these paradigms of assessment should also take into account the impact of other variables involving personality, mood, motivation, and socio-demographic characteristics in order to enable a better understanding of their performance determinants.

We consider that the present study, though limited to scientific literature published between 2000 and 2009, included a significant portion of literature on evaluating paradigms of decision-making processes in children and adolescents since we have found no publications prior to 2000 that fit the search criteria of this review. Furthermore, we can see a growing interest in the topic of evaluation of decision making in children and adolescents as 63% of papers reviewed here were published in the last four years. Thus, it appears that the study of the evaluation of the process of decision making in childhood and adolescence is a relatively recent area and one of growing interest in developmental neuropsychology.

From the data presented, it is evident the importance of paradigms for evaluating the process of decision making both to the study of the development of such cognitive functions and to the two potential clinical applications in the field of diagnosis and in the structuring of plans to prevent and treat maladaptive behaviors in normal and psychopathology populations.

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