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Disadvantageous decision making is cited as one of the premier problems in childhood development, underlying risky behavior and causing adolescents to make poor choices that could prove detrimental later in life. However, there are relatively few studies looking at the development of decision making in children and adolescents, and fewer still comparing it with the performance trajectories of more typically developing cognitive functions. In the current study, we measured the affective decision-making abilities of children and adolescents 8- to 17-years-old using the Iowa Gambling Task (IGT; Bechara, 2007) in conjunction with a battery of established cognitive neuropsychological assessments. In contrast to the typical linear development of executive functions, affective decision-making abilities progressed in a J-shaped curve. Younger, more developmentally naive children performed better on the IGT than older, early-adolescent individuals, with performance becoming advantageous again toward the end of the teenage years. This trajectory is thought to coincide with asymmetric neural development in early adolescents, with relatively overactive striatal regions creating impulsive reward-driven responses that may go unchecked by the slower developing inhibitive frontal cortex. This trajectory is in stark contrast with the linear development of memory, speed of processing, and other cognitive abilities over the ages.

Keywords: decision making, adolescent development, prefrontal cortex, nucleus accumbens, executive functions

Adolescence is a time when increasingly important decisions are made that can permanently influence an individual's path into adulthood. Study habits, recreational activities, and choice of peer groups can affect future adult lives, and mistakes made in the naiveté of youth can have a lasting negative impact. As children grow physically and cognitively more responsibility is placed upon them, but do children's and adolescents' decision-making capabilities warrant this increase in accountability? In both humans and animals, adolescence has been identified as a time of high potential for risk taking (Spear, 2000; Steinberg, 2004, 2007). While for the vast majority this period of sensation seeking is not problematic, and is even looked upon as advantageous from evolutionary or developmental perspectives, for a small portion of the population faulty decision making and risk taking can become pathological, potentially leading to more severe problems later in life (Spear, 2000).

Affective decisions are commonly thought to be "hot" executive functions, involving input from the rational cognitive regions of the prefrontal cortex (PFC) as well as from the more emotional and reactive limbic system (Bechara, Damasio, & Damasio, 2000; Bechara & Van der Linden, 2005; Damasio, 1994; Hooper, Luciana, Conklin, & Yarger, 2004). Conversely, "colder" cognitive functions, such as attention and working memory, tap solely into these cortical executive areas. The dorsolateral (dlPFC) and ventromedial (vmPFC) prefrontal cortices, areas most influential in rational decision making, are the last brain regions to fully develop, not approaching adult functioning until the early 20s (Blakemore & Choudhury, 2006; Casey, Galvan, & Hare, 2005; Casey, Tottenham, Liston, & Durston, 2005; Giedd, 2004; Giedd et al., 1999; Gogtay et al., 2004; Sowell, Thompson, Tessner, & Toga, 2001). However, other more value-driven regions of the brain, such as the ventral tegmental area and nucleus accumbens (NAc), develop earlier during adolescence (Bjork et al., 2004; Blakemore & Choudhury, 2006; Durston et al., 2006; Ernst et al., 2005).

Due to these differing developmental trajectories, the regions involved in reward processing can become more influential in some adolescents during instances of stimulus valuation than the inhibiting areas of the PFC (Galvan et al., 2006; Steinberg, 2004, 2007). The impairments that can accompany this staggered neural development seem to be isolated to affective decision making without affecting an individual's performance on other executive functions. We are interested in exploring the changing ability in decision making in children and adolescents during maturation and determining whether this progression differs from the improvement of other cognitive processes. On the basis of the developmental literature, we believe that the uneven chronological development in the subcortical and prefrontal regions will result in affective decision-making ability, as measured by the Iowa Gambling Task (IGT; Bechara, 2007), progressing in a nonlinear fash-

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ion, whereas more typical tests of cognition and executive function will improve linearly with maturation.

The Iowa Gambling Task

The IGT is one of the most widely used assessments of affective decision making (Bechara, Damasio, Damasio, & Anderson, 1994; Dunn, Dalgleish, & Lawrence, 2006). The IGT requires participants to choose among four decks of cards (A, B, C, and D) that give varying amounts of pay-offs and losses. Two decks are advantageous, resulting in overall net gains, and the remaining two decks are disadvantageous, yielding overall net losses. The big wins of the disadvantageous decks make them initially appealing, but normal healthy individuals typically begin avoiding those decks midway through the game as they realize they also come with greater losses. However, individuals who are overly impulsive and display a tendency toward instant gratification or myopia for the future continue to choose from these riskier decks, indicating impaired decision making (Bechara & Van der Linden, 2005). This impairment is thought to be mediated by an overactive emotional or impulsive system, or by an underactive inhibitive ability (Bechara & Van der Linden, 2005).

The IGT taps into the reward and inhibition circuitry controlled by the PFC and amygdala (Ernst et al., 2002; Li, Lu, D'Argembeau, Ng, & Bechara, 2010) and is well established as a measure of real-life decision making (Bechara, 2007; Toplak, Sorge, Benoit, West, & Stanovich, 2010). It has been used to identify decision-making disabilities in patients with vmPFC lesions (Bechara, Damasio, et al., 2000; Bechara, Damasio, Tranel, & Anderson, 1998; Bechara, Tranel, & Damasio, 2000), obsessive–compulsive disorder (Cavedini, Riboldi, D'Annucci, et al., 2002), psychopathy (van Honk, Hermans, Putman, Montague, & Schutter, 2002), schizophrenia (Sevy et al., 2007), and affective disorders (Jollant et al., 2005), among other pathologies. It has also been useful in assessing otherwise healthy individuals who display instances of impaired decision making in daily life such as pathological gamblers (Cavedini, Riboldi, Keller, D'Annucci, & Bellodi, 2002) and individuals with substance abuse problems (Bechara & Damasio, 2002; Bechara et al., 2001; Bechara, Dolan, & Hindes, 2002; Bechara & Martin, 2004).

Rationale for the Current Study

Previous studies testing children and adolescents on the IGT either have largely focused on small age subsets (such as early childhood or older adolescents), comparing performance solely within one age bracket (Carlson, Zayas, & Guthormsen, 2009; Gao, Wei, Bai, Lin, & Li, 2009; Garon & Moore, 2004; Kerr & Zelazo, 2004), or have grouped them into overly broad age spans when comparing performance (Crone & van der Molen, 2004; Huizenga, Crone, & Jansen, 2007; Overman, 2004; Overman et al., 2004). Most of these ordinal group comparisons have demonstrated linear increases in IGT performance by age (Cauffman et al., 2010; Crone & van der Molen, 2004; Hooper et al., 2004; Huizenga et al., 2007; Overman et al., 2004). However, we speculate that this may be a function of inadequate sampling, which is insensitive to the gradual changes in neural development and executive functions that occur during the transition from childhood to adolescence. To address this issue, we scored our participants continuously by age, enabling a wider exploration of the subtle differences in choice selection among younger participants.

Another novel aspect of the current study is the use of a broader battery of psychological tests to assess different aspects of executive function. These tasks have been tested for correlations with the IGT in studies of adult clinical and normal populations, but not in children and adolescents. Therefore, it is not yet established if the same associations (or lack thereof) between the IGT and other executive functions hold true during early development. By comparing performance on the IGT with other measures of executive function, we aim to assess the differential cognitive demands of affective decision making.

We investigated the distinction between the mechanisms of affective decision making (as measured by the IGT) and those of simple inhibition or impulse control (commonly assessed with a go/no-go task). We also tested participants' working memory abilities, because in the IGT participants must be able to remember previous deck responses and incorporate these prior outcomes into new theories about the most advantageous choice (Bechara, Damasio, et al., 2000). Similarly, the IGT requires set shifting for participants to amend their strategies as they receive new information from deck choice results. Both the Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Talley, Kay, & Curtiss, 1993) and the Trail Making Test-B (TMT-B; Reitan, 1971) were included in the battery as tests of set-shifting ability, often administered in conjunction with the IGT (Brand, Recknor, Grabenhorst, & Bechara, 2007; Hooper et al., 2004; Lehto & Elorinne, 2003). We also analyzed the reaction time performance of individuals on the IGT as further evidence of the linear progression of cold cognitive speed of processing compared with the hot affective net score performance on the IGT.

These typically colder executive functions have been shown to improve linearly as individuals age and mature. We predicted that our study would demonstrate a similar linear progression across the ages on these executive function tests; however, we believe that affective decision-making ability and performance on the IGT should show a different developmental trajectory, with younger children outperforming older adolescents. Considering the distinct systems proposed to control these functions, as well as the different paths of developmental improvement we predicted across these systems, we also anticipated an absence of any significant correlation between hot and cold executive functions.

Our study investigated a range of young individuals, beginning in middle childhood at age 8 and extending through adolescence up to age 17. Due to the delayed development of the PFC, the overactivation of the NAc in adolescents on tasks that emphasize monetary reward (Ernst et al., 2005; Galvan et al., 2006), and the IGT's reliance on these areas, we predicted that younger adolescents would make the most disadvantageous choices on the IGT, focusing on decks with higher immediate payoffs rather than potential long-term rewards and punishments. Conversely, we anticipated that younger children whose brains are in an earlier stage of maturation would make fewer disadvantageous deck choices, not driven by this impulsive desire for reward. Thus, we hypothesized that ability on the IGT would progress in a nonlinear, U-shaped trajectory with younger children (8 and 9 years old) performing more advantageously than older children. By the end of the teenage years (16 to 17 years old) we predicted that ability would have significantly improved, as neural development continues and cognitive processes become more efficient.

Method

Participants

One hundred twenty-two (68 male) children and adolescents between the ages of 8 and 17 years were recruited to participate in the study. Three individuals did not complete the IGT, and 18 others failed to complete one or more of the other assessments due to technical issues and/or time constraints.

There were no significant differences in mean IQ between any of the age groups, and all fell within the normal range. (See Table 1 for demographic information.)

Procedure

Participants were tested either individually or in pairs on the campus of the University of Southern California. Students were recruited at local schools, camps, and recreation centers and were accompanied to the university by a parent or designated family member; both child and guardian provided written informed consent for the child's participation. Children were paid $15 per hour for their time, and the accompanying adult was compensated $5. All study and consent protocols were approved by the University of Southern California's Institutional Review Board.

All participants received the same battery of neuropsychological assessments, beginning with the IGT to combat performance variation due to fatigue. Other tests in the battery included a variety of intelligence, executive function, and memory assessments. Testing took between 2 and 3 hr to complete and was conducted in a single session.

Measures

IGT. In the computerized version of the IGT, the participant is presented with four decks of cards labeled A, B, C, and D on the screen, and with a key press he or she can select a card from any of the four decks. The participant is expected to make 100 card selections throughout the game, without knowing in advance how many trials he or she will have. Two of the decks (A and B) are equivalent in terms of overall net loss, and two of the decks (C and D) are equivalent in terms of overall net gain. The gains and losses for each card selection are set so that in every block of 20 cards from Deck A or Deck B there is a total potential gain of $1,000, interrupted by unpredictable losses amounting to $1,250. For Decks C and D, the gains for each block total $500, interrupted by potential net losses of $250. In Deck B the punishment is less frequent, but of a higher magnitude than in Deck A, where the punishment is more frequent but in smaller amounts. Similarly, in Deck D losses are less frequent and of higher magnitude relative to those in Deck C. Thus, Decks A and B are equally "disadvantageous" in the long term, whereas Decks C and D are equally "advantageous." The task detects whether people learn from experiences with negative outcomes and make appropriate choices.

Tests of intelligence, executive function, and memory.

Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). The WASI is a shortened version of the Wechsler Adult Intelligence Scale (Wechsler, 1999). The WASI provides a composite Full Scale IQ score from verbal and performance subscales, each consisting of two subtests chosen on the basis of their high loading on general intellectual ability. The WASI is designed for use with a broad age range (from 6 to 89 years of age) and is nationally standardized.

WCST. This test is designed to measure set shifting and abstraction, that is, the ability to display flexibility in the face of changing reinforcement (Grant & Berg, 1948; Heaton et al., 1993). In the WCST, a stimulus card is presented to the participant on a computer screen. The task is to match this card to one of four key cards; however, the participant is not told how to match the cards, only whether a match is right or wrong. The matching rules change as the game progresses, and participants must adapt their strategy based on feedback from the game. The mistakes made during this learning process are analyzed to arrive at a score; we used perseverative error scores as a dependent measure, which is standard for WCST performance evaluation.

TMT-B. Trails B is a simple behavioral test measuring speed of processing and attention (Reitan, 1971). Participants are required to connect a series of numbers and letters, alternating between the two, as quickly as possible. This task requires set shifting, working memory, and inhibition of a previously correct

Table 1
Participant Demographic Information

		Sex (%)		Race/ethnicity (%)				
Age (years)	*N*	Male	Female	African American	Hispanic	White	Other[a]	IQ: *M* (*SE*)
8	18	50.0	50.0	33.3	11.1	22.2	33.3	108.8 (3.44)
9	8	75.0	25.0	25.0	62.5	12.5	0.0	108.9 (3.96)
10	14	64.3	35.7	42.9	28.6	21.4	7.1	100.4 (3.52)
11	16	68.7	31.3	37.5	37.5	6.2	18.8	104.9 (4.52)
12	12	41.7	58.3	25.0	41.7	16.7	16.7	100.8 (5.07)
13	14	64.3	35.7	21.4	57.1	14.3	7.1	96.9 (4.39)
14	7	42.9	57.1	57.1	28.6	14.3	0.0	98.3 (2.26)
15	9	44.4	55.6	55.6	33.3	11.1	0.0	99.4 (3.08)
16	8	37.5	62.5	62.5	25.0	12.5	0.0	98.1 (4.39)
17	16	56.2	43.8	31.2	25.0	18.8	25.0	105.5 (3.73)
Total	122	55.7	44.3	36.9	33.6	15.6	13.9	102.8 (1.32)

[a] Other participants are primarily of mixed racial background and did not identify with one ethnicity more strongly than another.

response. The score consists of the individual's time to complete the task.

Self-ordered pointing task (SOPT). The SOPT is a computerized memory assessment measuring one's capacity for response inhibition and working memory load (Peterson, Pihl, Higgins, & Lee, 2002; Petrides & Milner, 1982). In the task participants are presented with a screen of 12 distinct objects and are told to select each object once during the course of 12 sequential trials. In each trial the same 12 items are presented in different spatial locations on the screen, forcing participants to keep track of their responses in working memory on the basis of the stimuli themselves, rather than their locations. Typical administration consists of six sets of the 12 trials, and participants' scores consist of the total number of novel stimuli selected throughout each of the 12 trials.

Conners' continuous performance test (CPT-II; Conners, 2002). CPT-II is a computerized go/nogo task used to assess motor inhibition/impulsivity and sustained attention (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). Participants are presented with a computer screen that flashes a random letter at varying intervals ranging from 1 to 4 s. Participants are asked to press the space bar every time a letter besides the letter *X* flashes on the computer screen. Commission and perseveration errors are used to assess performance.

Results

Data were analyzed using SPSS version 17.0 for Mac (PASW Statistics). Group differences were analyzed using one-way analyses of variance (ANOVA) followed by Tukey post hoc analyses and paired samples *t* tests. Rates of improvement on the IGT, both within and across ages, were measured using linear and quadratic regressions. *R*-squared values were used to measure variance; associations were analyzed using Pearson correlations. All significance levels (α) were set at .05.

IGT Performance

Performance on the IGT was assessed in the standard manner using net scores, measured by subtracting the total number of disadvantageous deck choices from total advantageous decisions. To assess learning over time, performance was also broken down into five blocks of 20 trials. A regression analysis with age as a continuous variable against IGT net scores was significant for a quadratic slope, both independently (Step 1) and when controlling for gender and IQ (Step 2; $\beta = 2.05$, $p = .02$, $R^2 = .06$; see Figure 1 and Table 2). A similar regression analysis measuring a linear slope was not significant for either condition ($\beta = 0.1$, $p = .29$, $R^2 = .01$), demonstrating that the variable of age-squared significantly improved the prediction power of the model. In a second analysis, identical regressions for both linear and quadratic models were conducted for net scores excluding the first 20 trials from the task. This analysis produced similar results, again showing significant predictive power for the quadratic model ($\beta = 1.81$, $p = .04$, $R^2 = .06$) but not for the linear model ($\beta = 0.14$, $p = .15$, $R^2 = .02$). Neither gender nor IQ had a significant effect on IGT performance for any condition.

A one-way between-groups ANOVA using a quadratic term for age and IGT net performance was also conducted, confirming that the overall difference in scores across age groups was significant, $F(1, 109) = 5.45$, $p = .02$. However, after Tukey post hoc analysis, the only difference in mean net IGT scores that approached significance was between 12- and 17-year-olds, with a mean difference of 22.84 ($SE = 7.58$, $p = .09$). Further analysis was conducted comparing age differences in scores using independent samples *t* tests, and significant differences in performance were found between 8- and 12-year-olds, $t(26) = 2.17$, $p = .04$; 17- and 12-year-olds, $t(25) = 2.76$, $p = .01$; and 17- and 10-year-olds, $t(27) = 2.08$, $p = .05$. Large mean differences in scores were also found between ages 13 and 17, 12 and 15, and 12 and 16 at a significance level (α) of .10.

Reaction Time (RT)

There was a significant negative correlation between mean RT for all IGT card choices and age ($r = -.32$, $p < .001$). This is consistent with the cognitive developmental literature showing increases in speed of processing as children age. There was no interaction between RT and overall ability on the IGT. Upon further investigation, when split into high- and low-performing

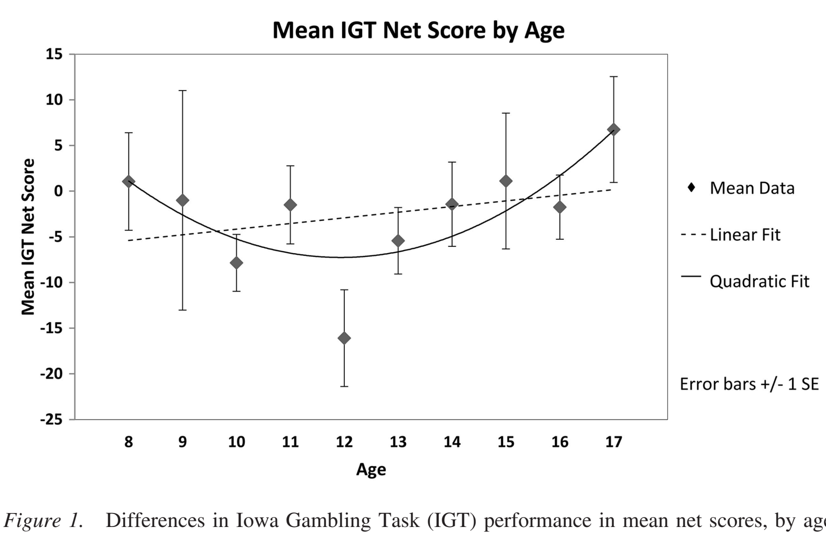

Figure 1. Differences in Iowa Gambling Task (IGT) performance in mean net scores, by age.

Table 2
Summary of Linear and Quadratic Regression Analyses for the Effect of Age on Iowa Gambling Task Scores, Both Singularly and When Controlled for Gender and IQ, and for Both Total Net Scores and Scores From Blocks 2–5 Only

	Total net score			Block 2–5		
Model/step	B	*SE* B	β	B	*SE* B	β
			Model 1 (Linear)			
Step 1						
Age	.62	.59	.1	.79	.57	.13
R^2	.01			.02		
Step 2						
Age	.64	.60	.1	.84	.58	.13
Gender	.76	3.61	.02	.62	3.45	.02
IQ	.05	.12	.04	.09	.12	.07
R^2	.01			.02		
			Model 2 (Quadratic)			
Step 1						
Age	−12.92	5.48	−1.92*	−10.78	5.27	−1.73*
Age^2	.54	.22	2.03*	.46	.21	1.87*
R^2	.06*			.06*		
Step 2						
Age	−12.57	5.69	−1.94*	−10.39	5.47	−1.67
Age^2	.53	.23	2.05*	.45	.22	1.81*
Gender	.34	3.55	.01	.27	3.41	.01
IQ	−.01	.12	−.01	.04	.12	.03
R^2	.06*			.06*		

* $p < .05$.

groups on the basis of overall positive or negative net scores, there were no differences between the two groups on overall RT or on RT on advantageous decks. However, on disadvantageous decks, low performers displayed significantly faster responses than high performers, mean RT = 1,420.05 and 1,835.30, respectively; $t(111) = 2.37$, $p = .02$. Participants with net IGT scores of zero were excluded from this analysis.

Executive Functions Test Results

Standard executive function tests of ability (TMT-B, WCST, and CPT-II) were significantly negatively correlated with age (TMT-B: $r = -.54$, $p < .001$; WCST: $r = -.33$, $p < .001$; CPT-II Commissions: $r = -.30$, $p = .001$; CPT-II Perseverations: $r = -.18$; $p = .05$), such that performance improved significantly over age either in a decrease of the time it took to complete the task (TMT-B) or in a decline in the number of perseverative errors and commissions generated (WCST, CPT-II). SOPT scores did not significantly improve with age. Using raw scores, no significant correlation was found between IGT ability and performance on any other assessment administered during testing (see Table 3). Within these executive function tests, IQ scores did significantly relate to WCST performance ($r = -.32$, $p < .001$) and CPT-II ability ($r = -.38$, $p < .001$), with a significant negative correlation between IQ and the number of perseverations on both tests, as well as a significant positive correlation with SOPT scores ($r = .32$, $p = .001$). Similarly, WCST performance significantly covaried with SOPT working memory scores, $F(3, 102) = 5.68$, $p = .001$, and TMT-B time, $F(4, 114) = 9.949$, $p < .001$.

Discussion

This study examined the effect of age on affective decision making, comparing IGT performance, in addition to a battery of other cognitive measures, across ages 8 to 17. We predicted that IGT performance would progress in a U-shaped trajectory, reflecting developmental patterns in the PFC and subcortical regions of the brain, whereas colder cognitive skills would improve linearly by age.

Processing speed and executive function assessments improved linearly with age, whereas IGT performance followed a quadratic regression curve over the course of development. After we excluded the first block of trials, which can consist of mostly random deck choices, a quadratic regression still predicted the model on a

Table 3
Correlations Between Iowa Gambling Task and Other Neuropsychological Assessments

Neuropsychology test	*R*	*p*
IQ	.026	.782
WCST Persev Errors	−.042	.649
SOPT	.177	.238
Trails Time	−.100	.286
CPT-II Confidence Index	−.056	.551

Note. WCST Persev Errors = Wisconsin Card Sorting Test Perseverating Errors; SOPT = Self-Ordered Pointing Task; Trails Time = Trail Making Test-B; CPT-II Confidence Index = Conners' Continuous Performance Test Confidence Index.

significant level, whereas the linear regression did not. Therefore, our results support a J-curve model of development, with most young participants failing to show preference for either deck, consistent disadvantageous performance from ages 10 to 13, and an improvement in ability from age 14 to peak performance at age 17. Early adolescents (age 12) had the lowest mean net scores, and ages 10, 12, and 13 all consistently performed disadvantageously throughout the task, never achieving a positive block of 20 trials. However, the only significant difference in scores among the younger participants was between 8- and 12-year-olds. Seventeen-year-old participants were the only age group to consistently perform advantageously on the IGT.

The impaired performance in early adolescents could be due to a heightened sensitivity to large payoffs of the disadvantageous decks, instigated by increased reward system activation in the NAc (Casey, Galvan, et al., 2005; Ernst et al., 2005; Galvan et al., 2006; Steinberg, 2007). Greater activation in the NAc in reward situations has previously been seen in adolescents, compared with children and adults (Ernst et al., 2005; Galvan et al., 2006). Alternatively, this impairment could stem from an inability to resist the riskier decks because of underdeveloped PFC impulse control. Due to delayed PFC development, children and adolescents must rely on more diffuse regions of the brain when performing executive function tasks, making them less efficient and effective in response to cognitive demands (Bjork et al., 2004; Blakemore & Choudhury, 2006; Casey, Tottenham, et al., 2005; Casey et al., 1997; Steinberg, 2007). Younger children may have performed less disadvantageously than early adolescents as they are globally less developed, potentially making them less sensitive to the high reward decks. Finally, older adolescents may have begun to choose advantageously once their PFC development had sufficiently progressed and they were able to inhibit initial impulsive responses. It is important to keep in mind that these impairments in early adolescence are not indicative of pathology, and as the frontal areas develop young adolescents will continue to gain better control and improve their executive function abilities. Additionally, the neurodevelopmental explanation for these results is not derived from direct brain imaging investigations of children and adolescents using the IGT. Although informed by the current literature, this hypothesis is speculative, and further research employing imaging modalities is needed to test the predictions of this model.

Going beyond the effects of age on performance, there was a striking trend between ability on the IGT and choice reaction times for the varying decks in the task. Individuals who performed disadvantageously on the IGT had significantly faster responses on negative decks compared with advantageous performers. This could reflect an overall degree of impulsivity in disadvantageous performers, regardless of age, and an inclination toward the high-reward decks. There was also a significant general trend toward a decrease in RT as participants aged, but no significant interaction between IGT ability and response times. This is notable as it further indicates a separate neural network used for cold versus hot executive functions, with speed of processing developing in a linear manner, whereas scores on the IGT improved curvilinearly.

There was no significant correlation between IGT performance and any other executive function assessment. Instead, ability on tests of simple impulse control improved linearly over age and were significantly correlated with one another. This is demonstrated in the significant linear improvement in TMT-B, WCST, and CPT-II performance across age groups, as well as the SOPT at a nonsignificant level. This finding is confirmed in earlier work on cognitive development in children and adolescents (Best, Miller, & Jones, 2009; Huizinga & van der Molen, 2007; Luciana, Conklin, Hooper, & Yarger, 2005; Reitan, 1971) and corroborates our hypothesis of separate developmental trajectories and neural mechanisms being involved in affective decision making compared with cold executive functions.

Prior studies on child and adolescent decision making have largely reported linear increases in IGT performance through late adolescence (Cauffman et al., 2010; Crone & van der Molen, 2004; Hooper et al., 2004; Overman et al., 2004). However, the majority of these investigations have studied the two age groups separately or have clustered them into 2- to 3-year increments (Carlson et al., 2009; Cauffman et al., 2010; Crone & van der Molen, 2004; Gao et al., 2009; Garon & Moore, 2004; Hooper et al., 2004; Huizenga et al., 2007; Kerr & Zelazo, 2004; Overman et al., 2004). Conversely, we have tested and compared each age individually, allowing a more detailed assessment of cognitive development and potentially elucidating previously unseen trends. Our results suggest that affective decision making does not begin a linear progression until the onset of adolescence, and this delayed improvement, initiated by a preliminary decrease in ability, is what creates the unique J-curve in our results. This explanation, although consistent with theoretical accounts of neural development, is speculative. We emphasize that direct brain imaging investigations will be necessary to validate a neurobiological account of these results. We also caution about the statistical robustness of these data, and it is important to keep in mind that during development there is a large amount of variation within participants of the same age.

Our study focused on the trajectory of performance improvements in executive functions across the ages, concentrating on the Iowa Gambling Task. We also explored the correlation between the IGT and other neuropsychological assessments, trying to elucidate the relationship between affective decision making and other more typically developing executive abilities, such as attention, speed of processing, and working memory. Further research on this topic should include fMRI analysis during the IGT to corroborate theories on the widespread cortical and subcortical activation in children and adolescents compared with adults (Bjork et al., 2004; Durston et al., 2006). A direct investigation of the relationship between regional brain development and IGT performance would be extremely beneficial to the field. Also, our study was limited by its cross-sectional approach; it would be advantageous to track the same children through development and puberty in a longitudinal study. This would help to ensure that these differences in IGT and executive function performances are due to maturation and neural development and are not merely correlational.

Finally, it is important to remember that this study is limited to children and adolescents living in the United States and is not necessarily applicable to other populations. It would be advisable to extend this research to other nations to determine whether these developmental trends are limited to Western cultures and academic systems or if they are more universally applicable.

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