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Decision-making and cognitive abilities: A review of associations between Iowa Gambling Task performance, executive functions, and intelligence

Maggie E. Toplak [a,*], Geoff B. Sorge [a], André Benoit [a], Richard F. West [b], Keith E. Stanovich [c]

[a] Department of Psychology, Faculty of Health, LaMarsh Centre for Research on Violence and Conflict Resolution, York University, Canada
[b] James Madison University, United States
[c] University of Toronto, Canada

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ABSTRACT

The Iowa Gambling Task (IGT) has been used to study decision-making differences in many different clinical and developmental samples. It has been suggested that IGT performance captures abilities that are separable from cognitive abilities, including executive functions and intelligence. The purpose of the current review was to examine studies that have explicitly examined the relationship between IGT performance and these cognitive abilities. We included 43 studies that reported correlational analyses with IGT performance, including measures of inhibition, working memory, and set-shifting as indices of executive functions, as well as measures of verbal, nonverbal, and full-scale IQ as indices of intelligence. Overall, only a small proportion of the studies reported a statistically significant relationship between IGT performance and these cognitive abilities. The majority of studies reported a non-significant relationship. Of the minority of studies that reported statistically significant effects, effect sizes were, at best, small to modest, and confidence intervals were large, indicating that considerable variability in performance on the IGT is not captured by current measures of executive function and intelligence. These findings highlight the separability between decision-making on the IGT and cognitive abilities, which is consistent with recent conceptualizations that differentiate rationality from intelligence.

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* Corresponding author. 126 BSB, Department of Psychology, York University, 4700 Keele St., Toronto, Ontario, Canada M3J 1P3. Tel.: +1 416 736 5115x33710; fax: +1 416 736 5814.
E-mail address: mtoplak@yorku.ca (M.E. Toplak).

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1. Introduction

Over the past 16 years, behavioral performance on the Iowa Gambling Task (IGT) has been used as an index of decision-making performance. Impairment on this task was first demonstrated in patients with lesions in the ventromedial prefrontal cortex (VMPFC; Bechara, Anderson, Damasio, & Damasio, 1994). Since this initial study, many studies have shown group effects on the IGT in clinical populations, including patients with neurological disorders (Labudda et al., 2009; Mimura, Oeda, & Kawamura, 2006; Sinz, Zamarian, Benke, Wenning, & Delazer, 2008), participants with psychiatric disorders (Barry & Petry, 2008; Clark, Manes, Antoun, Sahakian, & Robbins, 2003; Kester et al., 2006; Nakamura et al., 2008; Noël, Bechara, Dan, Hanak, & Verbanck, 2007; Toplak, Jain, & Tannock, 2005), and different levels of development using non-clinical child and adult samples (Fein, McGillivray, & Finn, 2007; Lehto & Elorinne, 2003). An intriguing question is whether decision-making, as measured by the IGT, is related to other cognitive abilities, including executive functions (EFs) and intelligence. Using patients with VMPFC lesions, Bechara, Anderson, Damasio and Tranel (1998) reported a relative dissociation between IGT and working memory performance. Numerous studies have since examined the relationship between IGT performance, executive functions, and intelligence. The purpose of this review was to examine robustness of the claim that performance on the IGT is relatively disassociated from these cognitive abilities. A total of 43 studies have examined this association, and these were included in the present review.

2. Theory and method of the Iowa Gambling Task

The IGT was originally developed to capture the seemingly paradoxical clinical presentation of neurological patients with damage to the ventromedial sector of the prefrontal cortex (Bechara et al., 1994). The ventromedial prefrontal cortex has been linked with playing an important role in regulating parasympathetic activity, with successful suppression of affective responses to a negative emotional signal, and regulating stress reactivity (Gjedde & Geday, 2009; Hänsel & von Känel, 2008; Lyons, Parker, Katz, & Schatzberg, 2009; Milad et al., 2005, 2007). The patient E.V.R. was presented as a prototypical example of this phenomenon. E.V.R. displayed intact functioning on neuropsychological indices of intelligence and executive functions, average scores on the Wisconsin Card Sorting Test (WCST) and on measures of working memory. Yet E.V.R. often made poor choices that led to negative consequences, and he was unable to learn from his mistakes (Bechara et al., 1994). The IGT was therefore developed to capture uncertainty of real-life decision-making using rewards and punishments in patients such as E.V.R. Bechara et al. (1994) compared performance of E.V.R. and six additional ventromedial lesion patients with two different control groups: 44 normal control participants and nine patients with lesions in the occipital, temporal, and dorsolateral frontal regions. Results indicated that the patients with ventromedial lesions made significantly fewer selections from the advantageous decks that had a positive expected value and significantly more selections from the disadvantageous decks that had a negative expected value than both control groups (see description of IGT below). In addition, E.V.R. was tested on multiple occasions, and his performance remained stable after one month and six months, whereas performance of the normal controls improved over time. In summary, the IGT seemed to capture E.V.R.'s deficits that resulted in him making poor choices that lead to negative consequences. In addition, these deficits were not captured on conventional measures of executive functions and intelligence.

The IGT has since been adopted as an experimental measure that captures the uncertainty of real-life decision-making, and the IGT is now available as a computer administered standardized measure of decision-making impairment (Bechara, 2007). This test has provided a much needed measure of decision-making performance. Performance on the IGT has been used to examine impaired decision-making in many different clinical populations, such as individuals with ADHD (Ernst et al., 2003; Toplak et al., 2005), pathological gamblers (Toplak et al., 2007), schizophrenics (Kester et al., 2006; Nakamura et al., 2008), substance abusers (Barry & Petry, 2008; Bechara & Martin, 2004; Ernst et al., 2003), and psychopaths (Blair, Colledge, & Mitchell, 2001; Mahmut, Homewood, & Stevenson, 2008; Mitchell, Colledge, Leonard, & Blair, 2002).

2.1. The IGT task

The IGT is an individually administered test that was first described by Bechara et al. (1994). Test materials consisted of four decks of cards, each labeled as Deck A, B, C, and D. There was a total of 50 cards in each deck, for a total of 200 cards. Both monetary rewards and monetary penalties (if any) were labeled on the down side of each card. For example, some cards had a reward of $100 and some cards had both a reward of $100 and a penalty of $50. Each card in Decks A and B had a $100 reward on it and each card in Decks C and D had a $50 reward on it. The penalties on the cards were intermittent, as displayed in Table 1. The design of the task was such that Decks A and B were disadvantageous in terms of expected value, despite the large rewards indicated on the cards in these decks. In contrast, Decks C and D were advantageous in terms of expected value, despite the relatively smaller rewards indicated on the cards in these decks. Participants were told that they were free to switch between decks during the game and that the goal of the task was to maximize profit on a loan of $2000 in play money that they received at the beginning of the game. They were not told the total number of card selections they would be asked to make, but the task always ended after the participant had selected 100 cards. Participants selected cards one by one, and the examiner gave the participant the reward and collected the penalty after each card selection. In the original Bechara et al. (1994) study, number of deck selections from the disadvantageous decks (A and B) was subtracted from those from the advantageous decks (C and D), and this difference score was compared between the clinical and control groups. Subsequently, many other dependent measures have been derived for this task, but the most commonly used dependent measure followed Bechara et al. (1994) in using the difference score between the number of advantageous and disadvantageous choices.

2.2. IGT performance interpretation

Poor performance on the IGT has been attributed to dysregulation of somatic markers (Damasio, 1994, 1996, 1999). Namely, individuals who perform poorly on this task purportedly have weaker somatic or physiological cues to guide risky choices (Damasio, 1994, 1996, 1999). Somatic markers, or emotions, are suggested to assist by constraining the decision-making space, giving various alternatives preferential availability over other alternatives (Oatley, 1999). They serve an adaptive evolutionary human function, consistent with recent views of the role of emotion in cognitive science (Johnson-Laird & Oatley, 1992). Damasio (1994) argued that patients with ventromedial lesions lack the physiological cues needed to signal risky choices, as evidenced by skin conductance studies performed in his lab. Specifically, patients with ventromedial lesions, who also made poor choices on the IGT, failed to show the anticipatory skin conductance responses that were observed in non-clinical controls (Bechara, Damasio, Tranel, & Damasio, 1997; Bechara, Tranel, Damasio & Damasio, 1996). Further research examined task manipulations to rule out whether performance is attributable to sensitivity to punishment or rewards. Results indicated that patients with ventromedial lesions seem to be guided by immediate prospects and insensitive to future consequences, whether positive or negative; this

Table 1
The schedule of rewards and penalties in the four decks of the card task used in Bechara et al. (1994).

Card number	Deck A (+$100)[a]	Deck B (+$100)[a]	Deck C (+$50)[a]	Deck D (+$50)[a]
1				
2				
3	−$150		−$25	
4				
5	−$300		−$75	
6				
7	−$200		−$25	
8				
9	−$250	−$1250	−$75	
10	−$350		−$50	−$250
11				
12	−$350		−$25	
13			−$75	
14	−$250	−$1250		
15	−$200			−$250
16				
17	−$300		−$25	
18	−$150		−$75	
19				
20			−$50	
21		−$1250		−$250
22	−$300			
23				
24	−$350		−$50	
25			−$25	
26	−$200		−$50	
27	−$250			
28	−$150			
29			−$75	
30			−$50	
31	−$350			
32	−$250	−$1250		−$250
33	−$250			
34			−$25	
35			−$25	
36				
37	−$150		−$75	
38	−$300			
39			−$50	
40			−$25	
41		−$1250	−$50	−$250
42	−$300			
43				
44	−$350		−$50	
45			−$25	
46	−$200		−$50	
47	−$250			
48	−$150			
49			−$75	
50			−$50	

[a] Note: Only the penalty amounts varied in each deck, which are indicated in the Table. The reward amounts were consistent for each deck, which were $100 for Decks A and B and $50 for Decks C and D with each card selection.

tendency was defined as a "myopia for the future" (Bechara, Tranel, & Damasio, 2000).

Several articles have critiqued the methods, theory, and mechanisms that underlie IGT performance, and other methods have been developed in order to balance gain–loss frequency in the IGT (Chiu & Lin, 2007; Chiu et al., 2008; Lin, Chiu, Lee, & Hsieh, 2007). In addition, alternative scoring methods for the IGT have been suggested (Dunn, Dalgleish, & Lawrence, 2006). A theoretical debate has taken place as to whether participants have any awareness of somatic markers prior to making their choices on the IGT, and the argument has been advanced that the somatic marker explanation may need modification if participants have any conscious, explicit awareness knowledge of the reward/punishment schedule on the IGT (Maia & McClelland, 2004). Damasio (1994) countered with the argument that somatic markers may act overtly or covertly, and overt awareness is not inconsistent with the somatic marker hypothesis. Alternative interpretations have also been suggested for explaining performance on the IGT, including difficulty in reversal learning, risk-taking, and apathy (Dunn et al., 2006).

Despite the fact that Damasio's classic patient. E.V.R. had no other cognitive or working memory deficits, and in contrast to Bechara et al.'s (1994) initial analysis, other investigators have posited working memory load as an important explanatory mechanism for variation on the IGT (Hinson, Jameson, & Whitney, 2002; Jameson, Hinson, & Whitney, 2004). Such inconsistencies bring into question the issue of the robustness of the finding that performance on the IGT is relatively independent of other cognitive abilities. Association between IGT performance and other cognitive abilities also bear on the construct validity of the IGT (Buelow & Suhr, 2009).

Bechara et al. (1998) claim, that decision-making and working memory performance were dissociated, was based on their observations of patients with bilateral damage to the ventromedial (VM) prefrontal cortex. In particular, these patients with VM lesions displayed significant impairments in decision-making performance, but seemed to display average levels of memory and intelligence. A sample of 21 normal controls, nine patients with ventromedial lesions, and 10 patients with dorsolateral/high mesial (DL/M) lesions were administered two working memory delay tasks and the IGT. Results indicated that patients with VM lesions were impaired on the IGT, and a sample of these patients displayed normal performance on the working memory tasks. In contrast, patients with right DL/M lesions were impaired on the working memory tasks but not on the IGT. Further, Bechara et al. (1998) argued that performance problems on the IGT and working memory problems were supported by different neural substrates. In particular, the IGT was designed to capture deficits in the VM prefrontal cortex which has links with the limbic system, where as working memory is supported by the dorsolateral prefrontal cortex. Overall, these results were interpreted as demonstrating some dissociation between working memory and IGT performance.

From this behavioral evidence, several authors have conceptually classified the IGT as a distinct measure of affective behavioral regulation (e.g., Chan, Shum, Toulopoulou, & Chen, 2008; Zelazo & Muller, 2002). More precisely, the IGT is posited to capture the implicit and affective cognitive processes involved in decision-making (Stanovich, 2004; Stanovich, Grunewald, & West, 2003; Toplak et al., 2005, 2007). The IGT is thought to uniquely account for variance in decision-making performance not currently attributable to either intelligence and/or conventional measures of executive function. The number of studies that has examined associations between IGT performance and other cognitive abilities, executive functions and intelligence has continued to grow, and the authors judge that number is now sufficient for a useful review of robustness of the claims of relative independence of the IGT.

3. Indices of executive functions and intelligence

We focused on three executive functions: inhibition of interference or of a prepotent response, shifting between tasks or mental sets, and updating and monitoring of working memory representations. Research using structural equation models has demonstrated some separability between these three types of executive functions (Friedman et al., 2006; Friedman et al., 2008; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Salthouse, Atkinson, & Berish, 2003).

3.1. Inhibition

Inhibition can generally be defined as the withholding or suppressing of attention or responses to irrelevant, non-target, or distracting stimuli (Enticott, Ogloff, & Bradshaw, 2006; Friedman &

Miyake, 2004; Nigg, 2000). In an extensive analysis, Nigg (2000) differentiated between different types of inhibition, including executive, motivational, and automatic attentional inhibition processes. Executive inhibition is defined as, 'processes for intentional control or suppression of response in the service of higher order or longer term goals' (Nigg, 2000, p. 238), and has been measured by paradigms, such as the Stroop (Strauss, Allen, Jorgensen, & Cramer, 2005; Stroop, 1935) and stop tasks (Logan, 1994; Logan & Cowan, 1984; Schachar & Logan, 1990). The phenomenon of the Stroop effect is that it takes participants longer to name an ink colour of a colour word printed in a contrasting colour (that is, naming the colour red when "blue" is printed in red ink). The Stroop effect has been used as an indicator of interference control, one type of inhibition (Nigg, 2000). The stop task, also used as a measure of inhibition, captures motor inhibition of a dominant or prepotent response. The main dependent measure of the stop task is stop-signal reaction time (SSRT), which is duration of the inhibitory response after a tone indicates that the motor response should be terminated. Motivational inhibition involves response to punishment cues and novelty, and automatic inhibition involves suppressing recently inspected stimuli and information at unattended locations (Nigg, 2000). Executive inhibition measures of the types described have been examined in relation to IGT performance.

3.2. Set-shifting

Set-shifting involves mental flexibility and the ability to maintain and shift between mental sets. Measures that have traditionally been used to index these skills include the Wisconsin Card Sorting Test (WCST) and the Trailmaking Test Part B (Pennington & Ozonoff, 1996). Although the WCST is a cognitively complex task (Strauss, Sherman, & Spreen, 2006), several investigators have explored its correlation with IGT performance. The most commonly used measures to assess executive control on the WCST are number of categories achieved and number of perseverative errors (Strauss et al., 2006). On the WCST, number of categories completed reflects the number of sequences of 10 consecutive correct matches (to a maximum of 6). A perseverative error includes the number of errors made after a new rule and after feedback has been provided that the previous rule is no longer correct. Similarly, time on Part B of the Trailmaking test has been reported to be most closely associated with other timed tests of executive function (Libon et al., 1994). In the Trailmaking Test Part B, participants are timed while they connect a series of letters and numbers in ascending order while alternating between numbers and letters. Set-shifting measures reflecting the ability to shift mental sets, such as on the WCST and Trailmaking Test Part B, were included in this review.

3.3. Working memory

Both neuropsychological and cognitive literatures acknowledge that working memory includes limited capacity storage for maintaining information for short periods of time and a manipulation function that permits mental operations on this information (Strauss et al., 2006; Unsworth & Engle, 2007a). Measures used as an index of working memory have included the Digit Span subtest and Self-Ordered Pointing Task. The Digit Span subtest involves the participant repeating digits in forwards and reverse order from an oral presentation by the examiner. Block Span and Spatial Span subtests are the visual-spatial versions of the Digit Span subtest. The self-ordered point task requires the participant to select a different design on each card in a series without selecting the same card twice. Measures of these types were included in the present review. Association between working memory and IGT performance has been of continued interest since the initial study by Bechara et al. (1994), where they reported that E.V.R. performed poorly on the IGT despite intact functioning on working memory. It is important to note that working memory has been used as an index of EF, but that working memory also displays strong connections with fluid intelligence based on structural equation modeling studies (Engle, Tuholski, Laughlin, & Conway, 1999; Kane, Hambrick, & Conway, 2005; Unsworth & Engle, 2005, 2007b).[1]

3.4. Intelligence

Intelligence, as measured on many commonly used tests, is often separated into verbal and nonverbal scores, which can be combined to produce a full-scale intelligence score. In the studies we review, several different intelligence indicators are used. All fit within the Cattell/Horn/Carroll (CHC) theory of intelligence (Carroll, 1993; Cattell, 1963, 1998; Horn & Cattell, 1967). Sometimes termed the theory of fluid and crystallized intelligence (symbolized Gf/Gc theory), this theory posits that tests of mental ability tap, in addition to a general factor (g), a small number of broad factors, of which two are dominant. Fluid intelligence (Gf) reflects reasoning abilities operating across of variety of domains—in particular, novel ones. It is measured by tasks of abstract reasoning such as figural analogies, Raven Matrices, and series completion. Crystallized intelligence (Gc) reflects declarative knowledge acquired from acculturated learning experiences. It is measured by vocabulary tasks, verbal comprehension, and general knowledge measures. There is a large literature on the theory and on the processing correlates of Gf and Gc (see Daniel, 2000; Duncan et al., 2008; Geary, 2005; Gignac, 2005; Horn & Noll, 1997; Kane & Engle, 2002; Mackintosh & Bennett, 2003; McGrew, 1997; McGrew & Woodcock, 2001; Taub & McGrew, 2004). In addition to Gf and Gc, other broad factors at the level termed stratum II are things like memory and learning, auditory perception, and processing speed (see Carroll, 1993, for a full account). All of these components are correlated with each other and with the general factor. Relevance of the theory to our present review is that all of the intelligence measures in the studies reviewed either measure Gf or Gc directly or they measure one of the other major stratum II components of the CHC theory. In the original study using the IGT, Bechara et al. (1994) reported that that their patient E.V.R. displayed intact functioning on intelligence measures.

The purpose of the current review was to examine the association between IGT performance and other cognitive ability measures, including executive functions and intelligence. We included studies that reported correlational analyses with IGT performance. Specifically, executive functions included in this review involved performance on tasks measuring inhibition, working memory, and set-shifting abilities. Measures of intelligence included performance on tests of verbal ability, nonverbal ability, or full-scale scores. The studies examined included clinical samples and non-clinical samples. Clinical samples were categorized as samples with neurological/degenerative conditions (such as epilepsy and Alzheimer's) and psychiatric conditions (such as schizophrenia and substance abuse disorders). Non-clinical samples included non-clinical child and adult samples. Correlational analyses in these studies were conducted either within the clinical and control groups or within the total sample, and analyses in studies with non-clinical samples were conducted within the total sample.

[1] Dual task methods have yielded mixed support for the impact of a dual task condition on IGT performance, with some studies suggesting that a secondary task negatively impacts IGT performance (Hinson et al., 2002; Jameson et al., 2004) and other studies indicating no impact of a dual task (Turnbull, Evans, Bunce, Carzolio, & O'Connor, 2005). It is unclear how performance on working memory tasks and dual task paradigms are related, and whether they are both taxing a central executive process. For example, Miyake, Friedman, Emerson, Witzki, and Howerter (2000) reported that a dual task paradigm was unrelated to measures of inhibition, working memory, and set-shifting in their structural equation model of these measures. Therefore, dual task paradigms were not included in the set of studies summarized in this review.

4. Review of associations between IGT performance, EF performance, and intelligence

We conducted a search using the *PubMed* online database to capture any articles that have used the IGT from 1994 [when Bechara et al. (1994) published the original paper on the IGT] to June, 2009. All articles were initially reviewed, and only those studies that reported statistical analyses of the relationship between IGT performance and the cognitive variables of interest were included in the current study. We identified a total of 43 studies; 11 of these reported correlational analyses with measures of inhibition, 18 of these studies reported analyses with measures of set-shifting, 15 of these studies reported analyses with measures of working memory, and 24 of these studies reported analyses with measures of intelligence. Table 2 summarizes number of studies identified based on sample (neurological, psychiatric, or non-clinical) and the measure of cognitive ability that was used in the analysis. Most of the studies included in this review used the original composite score performance of deck selections on the IGT (Bechara et al., 1994), namely, (Deck C + Deck D) − (Deck A + Deck B). We also included studies that analyzed only advantageous or disadvantageous choices, since these measures are linearly related to the classic C + D minus A + B composite, and they yield identical correlations to the classic measure. Studies that reported correlations in samples or analyses with less than 15 participants were excluded; only one study was excluded for this reason (Tranel, Bechara, & Denburg, 2002).

The overall strategy of this review was to be inclusive rather than selective. This becomes relevant because many of the studies we reviewed did not have our question (the relation between IGT performance and cognitive abilities) as their central focus. For this reason, several of the studies we wished to include in our review did not report actual *r*-values, reported only that they fell within a range of values, or reported only the nonsignificance of the associations. Three of 11 studies using inhibition did not report *r*-values and only indicated nonsignificance of the association; this was also the case for 11 of the 18 studies using set-shifting measures, six of 15 studies using working memory measures, and eight of 24 studies using measures of intelligence. Therefore, to have conducted a full meta-analytic synthesis would have over-represented the significant effects, the file-drawer problem (Rosenthal, 1979), despite the fact that most effects were reported as non-significant. Another problem was that analyses were not conducted consistently in studies that included a clinical sample and control group. That is, correlations were often conducted within only the clinical group, but then occasionally within the control group or the entire sample. In studies that included clinical samples, this was the case for all eight studies that examined inhibition in neurological or psychiatric samples, for 13 of 14 studies that used set-shifting measures, for eight of nine studies using working memory measures, and for 15 of 16 studies that included intelligence. Another important consideration is the "apples and oranges" problem in meta-analysis (Lipsey & Wilson, 2001). For example, neuropsychological conceptualizations parse the specific cognitive functions that are measured by intelligence (Lezak, 1995), when broadly these measures fall into integrated models of cognitive abilities as captured by the Cattell–Horn–Carroll Gf–Gc model (Strauss et al., 2006). As the studies reviewed in this paper predominantly reflect the neuropsychological literature, aggregation of measures included in the domains of EF and intelligence would have been a flawed approach to synthesize the literature in the current review. The approach used was to be inclusive of studies that have examined the relationship between IGT performance and EFs/intelligence, rather than exclude studies that might be debated as strong or weak indicators of the target domains. Inclusion of the broad set of studies in a meta-analytic review can lead to potentially misleading results and conclusions, reflecting one of the major weaknesses of a meta-analytic approach that aggregates data across studies (Lipsey & Wilson, 2001).

We used the reported correlation *r* as an effect size estimate (Rosenthal, 1994) and computed 95% confidence intervals for *r* using a standard error formula provided by Rosenthal (1994). All studies included in this review are summarized in Table 3, including citation, demographic characteristics, measure of cognitive ability, and correlations (effect sizes) and confidence intervals for the associations reported between IGT and cognitive ability performance. Details on the demographic characteristics of the samples include the target population, age, gender, and sample size. Table 4 provides a summary of the correlations (effect sizes) and confidence intervals from the studies included in this review. To facilitate comparison across the various measures, correlations in Table 4 were computed so that good performance on each measure was indicated by a positive score.

Table 2
Summary of studies that included statistical analysis of the association between IGT performance, executive functions, and intelligence (number of studies indicated in parentheses).

Neurological samples	Psychiatric samples	Developmental/non-clinical samples
Associations with executive functions: inhibition		
Epilepsy (1)	Substance use disorder (3)	Child (2)
Parkinson's (1)	ADHD (1)	Adult (1)
	Pathological gambling (1)	
	Bipolar disorder (1)	
Associations with executive functions: set-shifting		
Epilepsy (1)	Schizophrenia (4)	Child (2)
Parkinson's (1)	Substance use disorder (3)	Adult (2)
Alzheimer's (1)	Major depressive disorder (1)	
Traumatic brain injury (1)	Disruptive behavior disorder (1)	
	Psychopathy (1)	
Associations with executive functions: working memory/updating		
Epilepsy (1)	Substance use disorder (3)	Child (4)
Alzheimer's (1)	Schizophrenia (2)	Adult (2)
Traumatic brain injury (1)	ADHD (1)	
Associations with intelligence		
Epilepsy (1)	Substance use disorder (5)	Child (4)
Traumatic brain injury (1)	Schizophrenia (4)	Adult (2)
	Psychopathy (3)	
	ADHD (1)	
	Obsessive–compulsive disorder (1)	
	Borderline personality disorder (1)	
	Asperger's disorder (1)	

4.1. Inhibition

There was a total of 11 studies that examined the association between IGT performance and measures of inhibition: two in neurological samples (epilepsy and Parkinson's), six in psychiatric samples (three substance abuse, one ADHD, one pathological gambling, and one bipolar disorder), two in developmental child samples, and one in an adult non-clinical sample. Of the eight studies that included clinical samples, four only reported correlational analyses within the clinical group, and four reported correlational analyses within the total group that included both clinical and control participants. Measures used to index inhibition employed commonly used paradigms, including the Stroop, Go/No Go tasks, and the stop task. In addition, some less conventional measures were also used to measure inhibition, including the

Table 3
Summary of studies reporting correlations (effect size) [and 95% confidence intervals] between Iowa Gambling Task performance, executive functions (EF), and intelligence.

Study	Participants	Measures/variables used	Correlation and confidence interval for association between IGT and cognitive ability measure
Executive function domain: inhibition			
Neurological/degenerative disorders			
Epilepsy			
Labudda et al. (2009)	Individuals with temporal lobe epilepsy ($n=20$) and controls ($n=20$) $N=40$ (12 males, 28 females) Mean age: 33.6 ± 9.2 years	Colour Word Interference Test — Interference Trial IGT–CD minus AB	For temporal lobe epilepsy group ($n=20$):Interference and IGT, $r=-.47$, $p<.05$ [−.68, −.19] Correlations not reported for control group.
Parkinson's			
Mimura et al. (2006)	Adults with Parkinson's disease (PD; $n=18$) and controls ($n=20$) $N=38$ (11 males, 27 females) Mean age: approx. 69 years	Stroop Interference score IGT—amount money remaining after 100 trials	For PD group ($n=18$): Stroop and IGT, $r=-.18$, ns [−.31, .60] Correlations not reported for control group.
Psychiatric disorders			
Substance abuse disorders			
Bechara, Dolan, Denburg, Hindes, Anderson, et al. (2001)	Substance dependent individuals ($n=41$), VM lesion patients ($n=5$) and controls ($n=40$) $N=86$ (44 males, 42 females) Mean age: 37.9 ± 2.0 years	Stroop Interference score IGT	Substance dependence group ($n=41$): Stroop and IGT, Spearman's $r=.23$, ns, [−.08, .50] Correlations not reported for control group.
Quednow, Kühn, Hoppe, Westheide, Maier et al. (2007)	Ecstasy users ($n=19$), cannabis users ($n=19$), and controls ($n=19$) $N=57$ (all males) Mean age: 24.35 ± 4.81 years	Go/No Go (GNG) — total gain, commission errors, omission errors IGT	Correlation within groups not reported, only correlations within total sample reported. Total sample ($N=57$): Go/NoGo total gain and IGT, $r=.42$, $p<.01$ [.18, .62] Go/NoGo commission errors and IGT, $r=-.49$, $p<.01$ [.27, .66] Go/NoGo omission errors and IGT, reported as ns, r-value not reported
Verdejo-Garcia, Rivas-Pérez, Vilar-López, Pérez-García (2007)	Individuals with substance abuse disorders ($n=30$) and controls ($n=35$) $N=65$ (58 males, 7 females) Mean age: 31.2 ± 6.5 years	Revised Strategy Application Test (RSAT) % brief items IGT	Correlation within groups not reported, only correlations within total sample reported. Total sample ($N=65$): RSAT and IGT, $r=.28$, $p<.05$ [.04, .50]
ADHD			
Geurts, van der Oord, and Crone (2006)	Children with ADHD ($n=20$) and controls ($n=22$) $N=42$ (35 males, 7 females) Mean age: 10.0 ± 1.2 years	Stop task — stop-signal reaction time Go/No Go task —mean RT, % errors IGT–CD minus AB, number of choices from each deck for 100 trials	Correlation within groups not reported, only correlations within total sample reported. Total sample ($N=42$): Correlations reported from $r=.02$, ns [−.29, .32] to $r=.24$, ns [−.07, .51] with IGT variables, all r-values not reported
Pathological gambling			
Roca, Torralva, López, Cetkovich, Clark et al. (2008)	Pathological gambling population ($n=11$) and controls ($n=11$) $N=22$ (no data on sex or age)	Go/No Go commission errors, omission errors IGT	Authors state that there were no significant correlations between Go/NoGo and IGT performance in total sample, r-values not reported.
Bipolar disorder			
Christodoulou et al. (2006)	Patients with remitted bipolar disorder $N=25$ (10 male, 15 female) Mean age: 48.3 ± 10.4 years	Hayling Sentence Completion Task, Total error score IGT: A + B / C + D	Authors state correlations between Hayling and IGT ns, but r-values not reported
Developmental/non-clinical samples			
Child samples			
Hooper, Luciana, Conklin, and Yarger (2004)	Children and adolescents, three age groups: ages 9–10 ($n=49$), 11–13 ($n=54$), and 14–17 ($n=42$) years $N=145$ (66 males, 79 females) Mean ages: 9.8 ± .3, 12.92 ± .9, 16.4 ± 1.3 for each group	Go/No Go — hit rate, false alarm rates IGT, net advantageous choices	Total sample (statistically controlling for age; $N=145$): Go/No Go hit rate and IGT, $r=.04$, ns [−.12, .20] Go/No Go false alarm rates and IGT, $r=.09$, ns [−.07, .25]
Lamm, Zelazo, and Lewis (2006)	Child sample $N=33$ (15 males, 18 females) Mean age: 11.9 ± 2.8 years	Go/No Go reaction time Stroop Interference IGT:AB minus CD last 20 trials	Total sample ($N=33$) Go/No Go reaction time and IGT, $r=.36$, $p<.10$[.02, .63] Stroop and IGT, $r=-.11$, ns [−.44, .25]

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Table 3 (*continued*)

Study	Participants	Measures/variables used	Correlation and confidence interval for association between IGT and cognitive ability measure
Shuster and Toplak (2009)	Healthy adults $N=99$ (30 male, 69 female) Mean age: 21.1 ± 4.0 years	Stop task — SSRT Stroop Interference IGT–AB minus CD last 50 trials, money won	Total sample ($N=99$) Stop task and IGT composite: $r=.13$, ns [−.07, .32] Stop task and IGT money won: $r=.29$, $p<.01$ [.10, .46] Stroop and IGT composite: $r=-.03$, ns [−.23, .17] Stroop and IGT money won: $r=.07$, ns [−.13, .27]
Executive function domain: set-shifting			
Neurological/degenerative disorders			
Epilepsy			
Labudda et al. (2009)	Individuals with temporal lobe epilepsy ($n=20$) and controls ($n=20$) $N=40$ (12 males, 28 females) Mean age: 33.6 ± 9.2 years	Modified Card Sorting Test (MCST) —number of categories completed, and perseverations IGT	Correlations within epilepsy group reported as ns, actual correlation values not reported Correlations not reported for control group.
Parkinson's			
Mimura et al. (2006)	Adults with Parkinson's disease ($n=18$) and controls ($n=40$) $N=58$ (11 males, 27 females) Mean age: approx. 69 years	WCST — total number of categories, perseverative errors IGT — amount money remaining	Parkinson's disease group ($n=18$): WCST categories and IGT, $r=-.19$, ns [−.31, .61] WCST persev errors and IGT, $r=-.38$, ns [−.11, .73] Correlations not reported for control group.
Alzheimer's			
Sinz et al. (2008)	Adults with Alzheimer's ($n=22$) and age-matched controls ($n=22$) $N=44$ (9 males, 35 females) Mean age: 75.9 ± 4.1 years	Odd-Man-Out (OMO) IGT: number of advantageous choices (C + D)test	Analyses were conducted within each group. No significant associations between OMO and IGT were reported, no *r*-values provided
Traumatic brain injury			
Levine et al. (2005)	Adults with TBI ($n=71$) and controls ($n=19$) $N=90$ (46 males, 44 females) Mean age: 30.6 ± 10.1 years	WCST — categories and perseverative previous criterion TMT — Time Part A and Time Part B IGT	TBI Group ($n=71$): WCST categories and IGT, $r=.36$, $p=.003$, [.14, .55] WCST perseverative previous criterion, $r=-.19$, $p=.12$ [−.05, .41] TMT-A and IGT, $r=-.31$, $p=.009$ [−.51, −.08] TMT-B and IGT, $r=-.15$, $p=.210$ [−.38, .09] Correlations not reported for control group.
Psychiatric disorders			
Schizophrenia			
Kester et al. (2006)	Adolescents with early-onset schizophrenia ($n=15$) and controls ($n=25$) $N=40$ (23 males, 17 females) Mean age: 16.5 ± 2.2 years	WCST — categories completed and perseverative errors IGT	Schizophrenia group ($n=15$): WCST perseverative errors (raw score) and IGT, $r=.33$, ns [−.22, .73] WCST categories completed and IGT, $r=.25$, ns [−.31, .68] Control group ($n=25$): WCST perseverative errors (raw score) and IGT, $r=.17$, ns [−.25, .53] WCST categories completed and IGT, $r=.33$, ns [−.08, .65]
Nakamura et al. (2008)	Adults with schizophrenia ($n=24$) and controls ($n=25$) $N=49$ (43 males, 6 females) Mean age: 40.1 ± 9.7 years	Trailmaking Test (TMT) — total time Part A and total Time Part B WCST — categories completed and perseverative errors IGT	Correlation between TMT and IGT within each group, and WCST and IGT within each group reported to be ns, actual correlations not reported
Ritter, Meador-Woodruff, and Dalack (2004)	Adults with schizophrenia ($n=20$) and controls ($n=15$) $N=35$ (all males) Mean age: 47.9 ± 8.1 years	WCST — % error, categories, % perseverative errors, % concept level, failure to maintain set IGT	Correlation between WCST and IGT within each group reported to be ns, actual correlations not reported
Shurman, Horan and Nuechterlein (2005)	Adults with schizophrenia ($n=39$) and controls ($n=10$) $N=49$ (33 males, 16 females) Mean age: 33.2 ± 9.3 years	WCST — number of categories completed, perseverative responses IGT	Schizophrenia group ($n=39$): WCST perseverative errors and IGT selections from Deck D: $r=-.40$, $p<.05$ [−.64,−.10] All other correlations reported to ns, *r*-values not provided Correlations not reported for control group.
Substance use disorder			
Barry and Petry (2008)	Adults with substance dependence ($n=131$) and controls ($n=37$)	Trailmaking Test — time on Trails B minus time on Trails A	Correlation within groups not reported, only correlations within total sample reported.

Table 3 (*continued*)

Study	Participants	Measures/variables used	Correlation and confidence interval for association between IGT and cognitive ability measure
Substance use disorder			
Barry and Petry (2008)	$N=138$ (114 males, 24 females) Mean age: 39.2 ± 9.0 years	IGT	Total sample ($N=168$): Trailmaking and IGT, $r=-.18$, $p<.05$ [.01, .34]
Bechara et al. (2001)	Substance dependent individuals ($n=41$), VM lesion patients ($n=5$) and controls ($n=40$) $N=86$ (44 males, 42 females) Mean age: 37.9 ± 2.0 years	WCST — number of categories completed, perseverative error score IGT	Substance dependence group ($n=41$): WCST perseverative errors and IGT: $r=-.01$, ns [−.31, .32] WCST number of categories and IGT: $r=.09$, ns [−.23, .39] Correlations not reported for control group.
Grant, Contoreggi, and London (2000)	Adults with substance dependence ($n=30$) and controls ($n=24$) $N=54$ (36 males, 8 females) Mean age: 33.3 ± 1.1 years	WCST — categories completed and perseverative errors IGT	Within each group, WCST and IGT reported to be ns, *r*-values not reported except that *r*'s<.20
Major depressive disorder			
Must, Szabó, Bódi, Szász, Zoltán et al. (2006)	Adults with MDD ($n=30$) and controls ($n=20$) $N=50$ (21 males, 29 females) Mean age: 43.3 ± 9.3 years	WCST — categories completed, perseverative errors IGT	Correlation within groups not reported, only correlations within total sample reported. Total sample ($N=50$): WCST and IGT reported to be ns, $r<.20$ in total sample
Disruptive behavior disorder			
Ernst et al. (2003)	Adolescents with ($n=33$)/without ($n=31$) disruptive behavior disorders and adults with ($n=30$)/without ($n=22$) substance dependency $N=116$ (92 males, 14 females) Mean age: 12.7 ± .7 years, 33 ± 5.6 years	WCST — failure to maintain set IGT	Only range of correlations provided for each group. Adolescents with behavior disorders ($n=33$): WCST and IGT: $r=-.15$ to−.21, ns Adolescent controls ($n=31$): WCST and IGT: $r=-.07$ to .12, ns Adult clinical and control samples: WCST and IGT reported to be ns, *r*-values not reported
Psychopathy			
Mahmut et al. (2008)	Comparing noncriminals with low or high psychopathy $N=101$ (27 males, 74 females) Mean age: 23.0 ± 7.2 years	Trailmaking Test — Part B IGT — Total risk choices (AB)	Correlation within groups not reported, only correlations within total sample reported. Total sample ($N=101$): Trailmaking Test — Part B and IGT, $r=.09$, ns [−.11, .29]
Developmental/non-clinical samples			
Child samples			
Hongwanishkul et al. (2005)	Children aged 3 ($n=33$), 4 ($n=32$) and 5 ($n=33$) years $N=98$ (50 males, 48 females) Mean age: 41.0 ± 3.8, 54.1 ± 3.6, 66.1 ± 3.0 months (overall 53.7 ± 3.5)	Dimensional change card sort (DCCS) Children's IGT–CD minus AB in last 20 trials	Total sample ($N=98$): DCCS and children's IGT, $r=.07$, ns [−.13, .27] Correlations remained non-significant after chronological age and mental age were statistically partialled.
Lehto and Elorinne (2003)	Children (ages 8–10, $n=51$) and adults (ages 19–53, $n=40$) $N=91$ (45 males, 46 females) Mean ages: 110.9 ± 3.8 months, 30.1 ± 9.6 years	WCST — number of categories and perseverative errors IGT — number of CD cards	Child sample ($n=51$): WCST number of perseverative errors and IGT, $r=-.32$, $p<.05$ [−.50,−.12] Other correlation reported to be ns, but actual *r*-value not reported Adult sample ($n=40$): WCST and IGT reported to be ns, actual *r*-values not reported
Adult samples			
Brand, Recknor, Grabenhorst, and Bechara (2007)	Healthy adults $N=97$ (49 males, 48 females) Mean age: 30.0 ± 10.4 years	WCST — number of categories and number of perseverative errors IGT	Total sample ($N=97$): IGT and WCST perseverative errors, $r=-.35$, $p<.001$ [−.52,−.16] Other correlation between WCST and IGT not reported
Denburg, Tranel, and Bechara (2005)	Young adults (ages 26–55, $n=40$) and older adults (56+, $n=40$) $N=80$ (40 male, 40 females) Mean age: Not provided	Trailmaking Test Parts A and B Time WCST — perseverative errors, categories completed IGT	Correlations reported for older group only ($n=40$). Trailmaking Part A and IGT, $r=-.01$, ns [−.32, .31] Trailmaking Part B and IGT, $r=-.03$, ns [−.34, .29] WCST perseverative errors and IGT, $r=-.23$, ns [−.51, .09] WCST categories and IGT, $r=.13$, ns [−.19, .43] Correlations not reported for young adults

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Table 3 (*continued*)

Study	Participants	Measures/variables used	Correlation and confidence interval for association between IGT and cognitive ability measure
Executive function domain: working memory			
Neurological/degenerative disorders			
Epilepsy			
Labudda et al. (2009)	Individuals with temporal lobe epilepsy ($n=20$) and controls ($n=20$) $N=40$ (12 males, 28 females) Mean age: 33.6 ± 9.2 years	Digit Span Forwards and Backwards Block Span Forward and Backward IGT	For temporal lobe epilepsy group ($n=20$): Digit Span Backwards and IGT net score, $r=.56$, $p<.01$ [.31, .75] All other correlations were reported as ns, actual r-values not reported Correlations not reported for control group.
Alzheimer's			
Sinz et al. (2008)	Adults with Alzheimer's ($n=22$) and age-matched controls ($n=22$) $N=44$ (9 males, 35 females) Mean age: 75.9 ± 4.1 years	Digit Span Forwards and Backwards IGT–C plus D, separate block analyses, net money earned	Analyses were conducted within each group. No significant correlations between IGT and the Digit Span task (Forwards or Backwards), but r-values not reported
Traumatic brain injury			
Levine et al. (2005)	Adults with TBI ($n=71$) and controls ($n=19$) $N=90$ (46 males, 44 females) Mean age: 30.6 ± 10.1 years	Self-Ordered Pointing (SOPT) IGT	TBI group ($n=71$): SOP and IGT, $r=-.40$, $p=.001$ [−.58, −.19] Correlations not reported for control group.
Psychiatric disorders			
Substance use disorder			
Johnson, Xiao, Palmer, Sun, Wang et al., (2008)	Adolescent binge drinkers ($n=22$), past 30-day drinkers ($n=45$), ever-drinkers ($n=53$) and never drinkers ($n=87$) $N=207$ (103 males, 104 females) Mean age: 16.2 ± 0.6 years	Self-Ordered Pointing Task (SOPT) — number of correct selections IGT	Correlation within groups not reported, only correlations within total sample reported. Total sample ($N=207$): SOPT and IGT, $r=.03$, ns [−.11, .17]
Martin et al. (2004)	Adults with ($n=46$)/without ($n=47$) HIV with substance dependence $N=93$ (all males) Mean age: 46.7 ± 5.6 years	Delayed nonmatch to sample (DNMS) task — mean percent correct IGT — # risky choices (A + B)	Correlation within groups not reported, only correlations within total sample reported. Total sample ($N=93$): DNMS and IGT, $r=-.08$, ns [−.29, .13]
Xiao, Bechara, Cen, Grenard, Stacy et al. (2008)	Adolescent smokers $N=208$ (104 males, 104 females) Mean age: 16.2 years	SOPT — total correct selections IGT	Correlation within groups not reported, only correlations within total sample reported. Total sample ($N=208$): SOPT — total and IGT, $r=.06$, ns [−.08, .20], controlling for age, gender and school-type
Schizophrenia			
Shurman et al. (2005)	Adults with schizophrenia ($n=39$) and controls ($n=10$) $N=49$ (33 males, 16 females) Mean age: 33.2 ± 9.3 years	Delayed Match to Sample Task (DMST) — mean RT IGT–CD minus AB, money gained, # of cards selected per deck	Schizophrenia group ($n=39$): Authors report no significant correlations between DMST and IGT, r-values not provided Correlations not reported for control group.
Wilder, Weinberger, and Goldberg (1998)	Adults with schizophrenia ($n=12$) and controls ($n=30$) $N=42$ (23 males, 19 females) Mean age: 31.1 ± 7.1 years	Letter number span IGT — number of cards selected per deck, net money earned	Correlation within groups not reported, only correlations within total sample reported. IGT performance did not correlate with letter number span task, r-values not provided
ADHD			
Toplak et al. (2005)	Decision-making in adolescents with ADHD ($n=44$) and controls ($n=34$) $N=78$ (52 males, 26 females) Mean age: 15.5 ± 1.5 years	Digit Span Forwards and Backwards Spatial Span IGT — # cards selected per deck, monetary outcome	Correlations conducted within each group and in the total sample. No significant correlations between working memory tasks and IGT, r-values not reported
Developmental/non-clinical samples			
Child samples			
Crone and van der Molen (2004)	Children and adolescents, four age groups: ages 6–9 ($n=61$), 10–12 ($n=61$), 13–15 ($n=59$), and 18–25 ($n=61$) $n=242$ (100 males, 142 females) Mean age: 7.9 ± .9, 11.1 ± .8, 13.8 ± .7, 20.3 ± 1.5 (overall 13.2 ± 1.0)	Digit Span Forwards and Backwards Working Memory Index IGT — # cards selected from CD, # cards selected from AB	Total sample: ($N=242$): Digit Span Backwards standard score and IGT — # adv choices, $r=.13$, ns [.00, .26] No other correlations provided
Hongwanishkul et al. (2005)	Children aged 3 ($n=33$), 4 ($n=32$) and 5 ($n=33$) years $N=98$ (50 males, 48 females) Mean age: 41.0 ± 3.8, 54.1 ± 3.6, 66.1 ± 3.0 months (overall 53.7 ± 3.5)	Self-Ordered Pointing Test Children's IGT–CD minus AB in last 20 trials	Total sample ($N=98$): SOPT and cIGT, $r=.33$, $p<.01$ [.14, .50] Correlations remained significant after chronological age and mental age were statistically partialled.
Hooper et al. (2004)	Children and adolescents, three age groups: ages 9–10 ($n=49$),	Digit Span Forwards and Backwards	Total Sample (statistically controlling for age; $N=145$):

Table 3 (*continued*)

Study	Participants	Measures/variables used	Correlation and confidence interval for association between IGT and cognitive ability measure
	11–13 ($n=54$), and 14–17 ($n=42$) years $N=145$ (66 males, 79 females) Mean ages: 9.8 ± .3, 12.92 ± .9, 16.4 ± 1.3 for each group	IGT—net advantageous choices	Digit Span Forwards and IGT, $r=0$, ns [−.16, .16] Digit Span Backwards and IGT, $r=.15$, ns, [.01, .31]
Lamm et al. (2006)	Child sample $N=33$ (15 males, 18 females) Mean age: 11.9 ± 2.8 years	Digit Span Backwards IGT – AB−CD last 20 trials	Total sample ($N=33$) DSB and IGT, $r=0$, ns [−.35, .35]
Adult samples			
Denburg et al. (2005)	Young adults (ages 26–55, $n=40$) and older adults (56+, $n=40$) $N=80$ (40 male, 40 females) Mean age: N/A	Digit Span standard score IGT	Older adults ($n=40$): Digit Span and IGT, $r=-.08$, ns [−.29, .14] Correlations not reported for young adults
Fein et al. (2007)	Young adults (ages 18–55, $n=112$) vs older adults (56+, $n=52$) $N=164$ (67 males, 97 females) Mean age — young grp: 37.8 ± 10.7 Mean age—older grp: 73.7 ± 7.4	Paced Auditory Serial Addition Test (PASAT)—Accuracy IGT	Young adults ($n=112$): PASAT and IGT, $r=.32$, $p=.001$ [.14, .48] Older adults ($n=52$): PASAT and IGT: ns, *r*-value not reported
Associations with intelligence			
Neurological/degenerative disorders			
Epilepsy			
Labudda et al. (2009)	Individuals with temporal lobe epilepsy ($n=20$) and controls ($n=20$) $N=40$ (12 males, 28 females) Mean age: 33.6 ± 9.2 years	IQ – German Intelligence Battery – reasoning scale IGT	For temporal lobe epilepsy group ($n=20$): IQ and IGT, $r=.45$, $p<.05$ [.16, .67] Correlations not reported for control group.
Traumatic brain injury			
Levine et al. (2005)	Adults with TBI ($n=71$) and controls ($n=19$) $N=90$ (46 males, 44 females) Mean age: 30.6 ± 10.1 years	IQ — Shipley Institute of Living Scale, Vocabulary subtest IGT	TBI group ($n=71$): IQ and IGT, $r=.29$, $p=.02$ [.06, .54] Correlations not reported for control group.
Psychiatric disorders			
Substance use disorder			
Barry and Petry (2008)	Adults with substance dependence ($n=131$) and controls ($n=37$) $N=138$ (114 males, 24 females) Mean age: 39.2 ± 9.0 years	IQ — Shipley Institute of Living Scale, Vocabulary and Abstraction subtests IGT	Correlation within groups not reported, only correlations within total sample reported. Total sample ($N=168$): IQ and IGT, $r=.17$, $p<.05$ [.01, .33]
Bechara et al. (2001)	Substance dependent individuals ($n=41$), VM lesion patients ($n=5$) and controls ($n=40$) $N=86$ (44 males, 42 females) Mean age: 37.9 ± 2.0 years	IQ — WAIS-III verbal ability, nonverbal ability, and full-scale ability IGT	Substance dependence group ($n=41$): Full-scale ability and IGT, $r=.19$, ns [−.13 to .47] Verbal ability and IGT, $r=.29$, ns [−.02, .56] Nonverbal ability and IGT, $r=.03$, ns [−.29, .34] Control group (n = 40): Verbal ability and IGT, $r=.11$, ns, CI = −.21, .41] Other *r*-values not reported for control group
Fishbein, Eldreth, Matochik, Isenberg, Hyde et al. (2005)	Substance dependent individuals ($n=21$) and controls ($n=20$) $N=41$ (21 males, 20 females) Mean age: 27.6 ± 4.4 years	IQ — Shipley Institute of Living Scale, FSIQ estimate IGT — number of advantageous (C + D) choices	Correlation within groups not reported, only correlations within total sample reported. Total Sample ($N=41$): IQ and IGT disadvantageous choices, $r=-.34$, $p<.05$ [−.59,−.04]
Monterosso, Ehrman, Napier, O'Brien, and Childress (2001)	Adults with cocaine dependence $N=32$ (25 males, 7 females) Mean age: 39.0 ± 6.6 years	IQ Estimate — WAIS-III (Vocabulary and Block Design) IGT—total number of advantageous (C + D) choices	Adults with cocaine dependence (total Sample, $N=32$: IQ and IGT total number of advantageous choices, $r=.37$, $p=.037$ [.02, .64]
Quednow et al. (2007)	Ecstasy users ($n=19$), cannabis users ($n=19$), and controls ($n=19$) $N=57$ (all males) Mean age: 24.35 ± 4.81 years	IQ — Mehrfachwahl–Wortschatz–Intelligenztest (MWT-B) IGT	Correlation within groups not reported, only correlations within total sample reported. Authors stated IQ not related to IGT performance, no *r*-value reported
Schizophrenia			
Mata, Rodríguez-Sánchez, Pelayo-Terán, Pérez-Iglesias, González-Blanch et al. (2008)	Adults with schizophrenia who do ($n=61$)/do not ($n=71$) use cannabis $N=132$ (87 males, 45 females) Mean age: 26.7 ± 6.8 years	IQ — Verbal Comprehension Index from WAIS-III IGT	Correlation within groups not reported, only correlations within total sample reported. Total Sample ($N=132$): IQ and IGT, $r=.25$, $p=.006$ [.08, .41]

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Table 3 (*continued*)

Study	Participants	Measures/variables used	Correlation and confidence interval for association between IGT and cognitive ability measure
Nakamura et al. (2008)	Adults with schizophrenia ($n=24$) and controls ($n=25$) $N=49$ (43 males, 6 females) Mean age: 40.1 ± 9.7 years	Wechsler Adult Intelligence Scale (WAIS-III) — Full Scale IQ (FSIQ), Perceptual Organization Index IGT–CD minus AB, net money earned	Correlation between FSIQ and IGT within each group and between Perceptual Organization and IGT within each group reported to be ns, but actual *r*-values not reported.
Rodríguez-Sánchez, Crespo-Facorro, Perez-Iglesias, González-Blanch, Álvarez et al. (2005)	Adults with schizophrenia ($n=80$) and controls ($n=22$) $N=102$ (67 males, 35 females) Mean age: 25.8 ± 6.7 years	IQ — Verbal Comprehension Index from WAIS-III IGT	Correlation within groups not reported, only correlations within total sample reported. Total Sample ($N=102$): IQ and IGT, $r=.26$, $p=.008$ [.07, .43]
Wilder et al. (1998)	Adults with schizophrenia ($n=12$) and controls ($n=30$) $N=42$ (23 males, 19 females) Mean age: 31.1 ± 7.1 years	WAIS-III (short form) — Estimated IQ IGT — number of cards selected per deck, net money earned	Correlation within groups not reported, only correlations within total sample reported. Authors report no significant correlations between IGT performance and cognitive variables, but *r*-values not reported
Psychopathy			
Blair, Colledge, and Mitchell (2001)	Children with ($n=20$) and without ($n=23$) psychopathic tendencies $N=43$ (all males) Mean age: 13.2 ± 1.4 years	IQ – British Picture Vocabulary Scale – Estimated IQ IGT — # of cards selected from risky decks (A + B) for each 10 card blocks	Correlation within groups not reported, only correlations within total sample reported. Authors state no significant correlation between IQ and 10 card blocks on IGT; all *r's* reported to be <.17, but *r*-values not provided.
Losel and Schmucker (2004)	Adult prison inmates $N=49$ (all males) Mean age: 33.2 ± 7.0 years	IQ-WAIS – German version (Information, Similarities, Picture Completion, Block Design) – Estimated IQ IGT—Total A + B	Adult prison inmates (Total Sample, $N=49$): IQ and IGT, $r=-.02$, ns [−.31, .27]
Mahmut et al. (2008)	Comparing noncriminals with low or high psychopathy $N=101$ (27 males, 74 females) Mean age: 23.0 ± 7.2 years	IQ – NART – Estimated IQ IGT – Total A + B (risk choices)	Correlation within groups not reported, only correlations within total sample reported. Total sample: IQ and IGT, $r=-.38$, $p<.01$ [−.54, −.20]
ADHD			
Toplak et al. (2005)	Decision-making in adolescents with ADHD ($n=44$) and controls ($n=34$) $N=78$ (52 males, 26 females) Mean age: 15.5 ± 1.5 years	IQ – WASI – Estimated FSIQ IGT — # cards selected per deck, monetary outcome	Correlations conducted within each group and in the total sample. No significant correlations between IQ and IGT, *r*-values not provided
Obsessive–compulsive disorder			
Lawrence, Wooderson, Mataix-Cols, David, Speckens et al. (2006)	Adults with OCD ($n=39$) and controls ($n=40$) $N=79$ (40 males, 39 females) Mean age: 34.8 ± 10.7 years	IQ – NART –Estimated Verbal IQ IGT	Correlation within groups not reported, only correlations within total sample reported. Total Sample ($N=79$): IQ and IGT, $r=.16$, ns [−.06, .38]
Borderline personality disorder			
Haaland and Landro (2007)	Adults with borderline personality disorder with ($n=7$)/without ($n=13$) substance dependence, and controls ($n=15$) $N=35$ (10 males, 25 females) Mean age: 23.6 ± 5.4 years	IQ – WAIS-III (Block Design and Similarities) – Estimated IQ IGT	Correlation within groups not reported, only correlations within total sample reported Total Sample ($N=35$): IQ and IGT, $r=-.44$, $p=.009$ [−.68, −.13]
Asperger's disorder			
Johnson, Yechiam, Murphy, Queller, and Stout (2006)	Adolescents and young adults with Asperger's syndrome 4($n=15$) and controls ($n=14$) $N=29$ (21 males, 8 females) Mean age: 16.0 ± 2.3 years	IQ – WASI Estimated FSIQ IGT: advantageous selections	Asperger's syndrome ($n=15$): Authors state IQ and IGT performance was not significant for AS group, no *r*-values reported Controls ($n=14$): Correlations between IQ and IGT number of advantageous selections, $r=.85$, $p<.001$ [.59, .96]
Developmental/non-clinical samples			
Child samples			
Crone and van der Molen (2004)	Children and adolescents, four age groups: ages 6–9 ($n=61$), 10–12 ($n=61$), 13–15 ($n=59$), and 18–25 ($n=61$) $N=242$ (100 males, 142 females) Mean age: 7.9 ± .9, 11.1 ± .8, 13.8 ± .7, 20.3 ± 1.5 (overall 13.2 ± 1.0)	IQ — Raven's Standard Progressive Matrices IGT — # cards selected from CD	Authors state no relation between IQ and IGT was found in any age group, all *r's*<.18, but actual *r*-values not reported
Hongwanishkul et al. (2005)	Children aged 3 ($n=33$), 4 ($n=32$) and 5 ($n=33$) years $N=98$ (50 males, 48 females)	Estimated VIQ — PPVT-III Estimated PIQ — from Stanford Binet (Bead	Total sample ($N=98$): VIQ and cIGT, $r=.20$, ns[.00,.38]; PIQ and cIGT, $r=.08$, ns [−.12, .28];

Table 3 (*continued*)

Study	Participants	Measures/variables used	Correlation and confidence interval for association between IGT and cognitive ability measure
	Mean age: 41.0 ± 3.8, 54.1 ± 3.6, 66.1 ±3.0 months (overall 53.7 ± 3.5)	Memory and Pattern Analysis) Children's IGT — CD minus AB in last 20 trials	Correlations remained non-significant after chronological age was statistically partialled.
Hooper et al. (2004)	Children and adolescents, three age groups: ages 9–10 (n = 49), 11–13 (n = 54), and 14–17 (n = 42) years N = 145 (66 males, 79 females) Mean ages: 9.8 ± .3, 12.92 ± .9, 16.4 ± 1.3 for each group	Estimated FSIQ — Block Design and Vocabulary from WISC-III or WAIS-III IGT—net advantageous choices	Total sample (statistically controlling for age; N = 145): FSIQ (prorated) and IGT net adv choices, r = .10, ns [−.06, .26]
Lehto and Elorinne (2003)	Children (ages 8–10, n = 51) and adults (ages 19–53, n = 40) N = 91 (45 males, 46 females) Mean ages: 110.9 ± 3.8 months, 30.1 ±9.6 years	IQ — Raven's Standard Progressive Matrices IGT — # of adv cards (C + D)	Correlations were ns in both child and adult samples, no r-values provided
Adult samples			
Fein et al. (2007)	Young adults (ages 18–55, n = 112) vs older adults (56+, n = 52) N = 164 (67 males, 97 females) Mean age — young grp: 37.8 ± 10.7 Mean age — older grp: 73.7 ± 7.4	IQ – NART IGT	Correlation within groups not reported, only correlations within total sample reported. Total Sample (N = 164): IQ and IGT, r = .11, p = .15[−.04, .26
Patrick, Blair, and Maggs (2008)	Adult female population N = 72 (all females) Mean age: 21.1 ± .8 years	IQ — Peabody Picture Vocabulary Test-III, IGT	Adult females (total sample, N = 72): VIQ and IGT, r = .26, p < .05 [.03, .46]

Note. Unless otherwise specified, the variable used for the IGT is the total number of advantageous cards minus the total number of disadvantageous cards (or CD − AB) for the 100 trials, as reported by Bechara et al. (1994). 95% confidence interval shows lower and upper limit.

Revised Strategy Application Test (Verdejo-Garcia, Rivas-Perez, Vilar-Lopez, & Perez-Garcia, 2007), described as a measure of self-regulation, and the Hayling Sentence Completion Task (Christodoulou, Lewis, Ploubidis, & Frangou, 2006). Some of these studies had a single dependent variable, such as an interference score on the Stroop task, but other studies used tasks, such as the Go/No Go task, that has multiple dependent measures (e.g., omission errors and reaction time on the Go/No Go task).

Because of multiple dependent measures and multiple comparisons within a study, the 11 studies produced 21 possible correlations for examination. Three of the 11 studies produced a single significant correlation and one study produced two significant correlations. Thus, of the 21 possible correlations across the 11 studies, only five were significant. Based on these results, performance on the IGT and measures of inhibition seem to be relatively dissociated. Correlations were generally low, with a median value calculated as r = .13 based on correlations reported in the studies. This median value is likely a higher estimate, as many studies did not report values for non-significant correlations.

4.2. Set-shifting

There was a total of 18 studies that examined the association between IGT performance and measures of set-shifting: four in neurological samples (epilepsy, Parkinson's, Alzheimer's, and traumatic brain injury), ten in psychiatric samples (four in schizophrenia, three substance abuse, one major depressive disorder, one behaviour disruptive disorder, and one psychopathy), and four in non-clinical samples, including two child and two adult samples. Of the 14 studies that included clinical samples, five reported correlational analyses within the clinical group, but not within the control group, five reported analyses within the clinical and control groups, three reported correlational analyses within the total group including clinical and control participants, and one study reported analyses within each clinical and control group and with the total group. Measures used to index set-shifting included commonly used paradigms, including the Wisconsin Card Sorting Test (WCST) and the Trailmaking Test, Parts A and B, and these were indeed the most commonly used measures in the studies included in this review. The Dimensional Change Cart Sort (DCCS) Test (Hongwanishkul, Happaney, Lee, & Zelazo, 2005), which is a modified version of the WCST, was used with all of the children. In addition, the Odd-Man-Out test (Sinz et al., 2008) was also used to measure set-shifting. Some of these measures had a single dependent variable, such as time on the Trailmaking Test, Part B, but other measures had multiple dependent measures (e.g., total number of categories completed and number of perseverative errors on the WCST). In some cases actual correlations were only reported when the association was significant.

Because of multiple dependent measures and multiple comparisons within a study, the 18 studies produced 38 possible correlations for examination. Five of the 18 studies produced a single significant correlation. Thus, of the 38 possible correlations across the 18 studies, only five were significant. These results suggest that domains of set-shifting and IGT performance seem to be relatively dissociated. A median correlation value of r = .15 was calculated, based on studies that reported values. This median value is likely high, given that many studies did not report values for non-significant correlations.

4.3. Working memory

There was a total of 15 studies that examined the association between IGT performance and measures of working memory: three in neurological samples (epilepsy, Alzheimer's, and traumatic brain injury), six in psychiatric samples (three substance abuse, two schizophrenia, and one ADHD), and six in non-clinical samples (four in developmental child samples and two in adult samples). Of the nine studies that included clinical samples, four reported correlational analyses within the clinical group and not the control group, four reported correlational analyses within the total group including clinical and control participants, and one reported correlational

Table 4
Summary of correlations (effect size) [and 95% confidence intervals] reported within clinical, control group, and total (clinical and control groups collapsed) samples.

Study	Clinical group		Control group		Total group	
	Correlation	95% CI	Correlation	95% CI	Correlation	95% CI
Executive function domain: inhibition						
Neurological/degenerative disorders						
Epilepsy						
Labudda et al. (2009)	$r=.47$, $p<.05$	[.03, .77]	NR		NR	
Parkinson's						
Mimura et al. (2006)	$r=.18$, ns	[−.31, .60]	NR		NR	
Psychiatric disorders						
Substance abuse disorders						
Bechara et al. (2001)	$r=-.23$, ns	[−.50, .08]	NR		NR	
Quednow et al. (2007)	NR		NR		From ns, (r NR) to $r=.49$, $p<.01$	[.27, .66]
Verdejo-Garcia et al. (2007)	NR		NR		$r=.28$, $p<.05$	[.04, .50]
ADHD						
Geurts et al. (2006)	NR		NR		From $r=.02$, ns to $r=.24$, ns	[−.29, .32] to [−.07, .51]
Pathological Gambling						
Roca et al. (2008)	NR		NR		ns, (r NR)	
Bipolar Disorder						
Christodoulou et al. (2006)	ns, (r NR)		NR		NR	
Developmental/non-clinical samples						
Hooper et al. (2004)	N/A		N/A		From $r=-.09$, ns to $r=.04$, ns	[−.25, .07] to [−.12, .20]
Lamm et al. (2006)	N/A		N/A		From $r=.11$, ns to $r=.36$, $p<.10$	[−.25, .44] to [−.02, .63]
Shuster and Toplak (2009)	N/A		N/A		From $r=-.03$, ns to $r=.29$, $p<.01$, $p<.01$	[−.23, .46] to [.10, .46]
Executive function domain: set-shifting						
Neurological/degenerative disorders						
Epilepsy						
Labudda et al. (2009)	ns		NR		NR	
Parkinson's						
Mimura et al. (2006)	From $r=-.19$, ns to $r=.38$, ns	[−.61, .31] [−.11, .73]	NR		NR	
Alzheimer's						
Sinz et al. (2008)	ns		ns		NR	
Traumatic Brain Injury						
Levine et al. (2005)	From $r=.15$, ns to $r=.36$, $p=.003$	[−.09, .38] [.14, .55]	NR		NR	
Psychiatric disorders						
Schizophrenia						
Kester et al. (2006)	From $r=.25$, ns to $r=.33$, ns	[−.31, .68] [−.22, .73]	From $r=-.17$, ns to $r=.33$, ns	[−.59, .16] [−.53, .25]	NR NR	
Nakamura et al. (2008)	ns		ns		NR	
Ritter et al. (2004)	ns		ns		NR	
Shurman et al. (2005)	$r=.40$, $p<.05$, all other ns	[.10 to .64]	NR		NR	
Substance use disorder						
Barry and Petry (2008)	NR		NR		$r=.18$, $p<.05$, all other ns	[.03 to .32]
Bechara et al. (2001)	$r=.01$, ns	[−.31, .32]	NR		NR	
Grant et al. (2000)	ns (r's<.20)		ns (r's<.20)		NR	
Major Depressive Disorder						
Must et al. (2006)	NR		NR		ns (r<.20)	
Disruptive behavior disorder						
Ernst et al. (2003)	$r=.15$ to .21, ns		$r=-.12$ to .07, ns		ns, (r NR)	
Psychopathy						
Mahmut et al. (2008)	NR		NR		$r=.09$, ns	[−.11, .29]
Developmental/non-clinical samples						
Child Samples						
Hongwanishkul et al. (2005)	N/A		N/A		$r=.07$, ns	[−.13, .27]
Lehto and Elorinne (2003)	N/A		N/A		$r=.32$, $p<.05$,	[.05, .55]
Child					all other ns	
Adult					ns	
Adult Samples						
Brand et al. (2007)	N/A		N/A		From $r=\sim.35$, $p<.001$	[.16, .52]
Denburg et al. (2005)	N/A		N/A		From $r=.03$, ns to $r=.23$, ns	[−.29, .34] to [−.09, .51]
Older adults						
Younger adults					NR	

Table 4 (*continued*)

Study	Clinical group		Control group		Total group	
	Correlation	95% CI	Correlation	95% CI	Correlation	95% CI
Executive function domain: working memory						
Neurological/degenerative disorders						
Epilepsy						
Labudda et al. (2009)	$r=.56$, $p<.01$, all other ns	[.31, .75]	NR		NR	
Alzheimer's						
Sinz et al. (2008)	$r=.68$, $p<.05$, all other ns	[.37, .86]	NR		NR	
Traumatic Brain Injury						
Levine et al. (2005)	$r=.40$, $p=.001$	[.19, .58]	NR		NR	
Psychiatric disorders						
Substance use disorder						
Johnson et al. (2008)	NR		NR		$r=-.03$, ns	[−.17, .11]
Martin et al. (2004)	NR		NR		$r=-.08$, ns	[−.29, .13]
Xiao et al. (2008)	NR		NR		$r=.06$, ns	[−.08, .20]
Schizophrenia						
Shurman et al. (2005)	ns		NR		NR	
Wilder et al. (1998)	NR		NR		ns	
ADHD						
Toplak et al. (2005)	ns		ns		ns	
Developmental/Non-clinical samples						
Child Samples						
Crone and van der Molen (2004)	N/A		N/A		$r=.13$, ns; all others NR	[.00, .26]
Hongwanishkul et al. (2005)	N/A		N/A		$r=.33$, $p<.01$	[.14, .50]
Hooper et al. (2004)	N/A		N/A		From $r=0$, ns to $r=.15$, ns	[−.16, .16] to [−.01, .31]
Lamm et al. (2006)	N/A		N/A		$r=0$, ns	[−.35, .35]
Adult Samples						
Denburg et al. (2005)	N/A		N/A		$r=-.08$, ns	[−.29, .14]
Older adults						
Fein et al. (2007)	N/A		N/A		$r=.32$, $p=.001$	[.14, .48]
Young adults						
Associations with intelligence						
Neurological/degenerative disorders						
Epilepsy						
Labudda et al. (2009)	$r=.45$, $p<.05$	[.16, .67]	NR		NR	
Traumatic brain injury						
Levine et al. (2005)	$r=.29$, $p=.02$	[.06, .54]	NR		NR	
Psychiatric disorders						
Substance use disorder						
Barry and Petry (2008)	NR		NR		$r=.17$, $p<.05$	[.01, .33]
Bechara et al. (2001)	From $r=.03$, ns to $r=.29$, ns	[−.29, .34] [−.02, .56]	NR		NR	
Fishbein et al. (2005)	NR		NR		From $r=-.34$, $p<.05$ to $r=.33$, $p<.05$	[−.59,−.04] to [−.58,−.02]
Monterosso et al. (2001)	$r=.37$, $p=.037$	[.02, .64]	N/A		N/A	
Quednow et al. (2007)	NR		NR		ns	
Schizophrenia						
Mata et al. (2008)	NR		NR		$r=.25$, $p=.006$	[.08, .41]
Nakamura et al. (2008)	ns		ns		ns	
Rodriguez-Sanchez et al. (2005)	NR		NR		$r=.26$, $p=.008$	[.07, .43]
Wilder et al. (1998)	NR		NR		ns	
Psychopathy						
Blair et al. (2001)	NR		NR		ns, (r's<.17)	
Losel and Schmucker (2004)	$r=-.02$, ns	[−.31, .27]	N/A			
Mahmut et al. (2008)	NR		NR		$r=.38$, $p<.01$	[.20, .54]
ADHD						
Toplak et al. (2005)	ns		ns		ns	
Obsessive–compulsive disorder						
Lawrence et al. (2006)	NR		NR		$r=.16$, ns	[−.06, .38]
Borderline personality disorder						
Haaland and Landro (2007)	NR		NR		$r=-.44$, $p=.009$	[−.68,−.13]
Asperger's disorder						
Johnson et al. (2006)	ns		$r=.85$, $p<.001$	[.59, .96]	NR	
Developmental/non-clinical samples						
Child Samples						
Crone and van der Molen (2004)	N/A		N/A		ns (r's<.18)	
Hongwanishkul et al. (2005)	N/A		N/A		From $r=.08$, ns to $r=.20$, ns	[−.12, .28] [.00, .38]
Hooper et al. (2004)	N/A		N/A		$r=.10$, ns	[−.06, .26]
Lehto and Elorinne, 2003 Children and adults	N/A		N/A		ns	

(*continued on next page*)

Table 4 (*continued*)

Study	Clinical group		Control group		Total group	
	Correlation	95% CI	Correlation	95% CI	Correlation	95% CI
Adult Samples						
Fein et al. (2007)	N/A		N/A		$r = .11$, $p = .15$	[−.04, .26]
Patrick et al. (2008)					$r = .26$, $p < .05$	[.03, .46]

Note. Correlations have been computed so that good performance on each measure is indicated by a positive score.
NR = Not reported, N/A = Not available.

analyses within the clinical and control groups and in the total sample. Tasks used to index working memory employed commonly used paradigms, including the Digit Span subtest, Spatial Span subtest, Letter Number Span, self-order pointing, and the PASAT. Some less conventional tasks were also used to measure working memory, including the Block Span test (Labudda et al., 2009) and the Delayed Nonmatch to Sample task (Martin et al., 2004). Some of these working memory tasks had a single dependent variable, such as a total score, but others had multiple dependent measures.

Because of multiple dependent measures and multiple comparisons within a study, the 15 studies produced 25 possible correlations for examination. Four of the 15 studies produced a single significant correlation. Thus, of the 25 possible correlations across the 15 studies, only four were significant. Based on these studies, performance on the IGT and measures of working memory seem to be relatively dissociated. A median value of $r = .06$ was calculated based on those studies that reported *r*-values. This median value may still be an overestimate, given that many studies did not report values for non-significant correlations.

4.4. Intelligence

There was a total of 24 studies that examined the association between IGT performance and measures of intelligence: two in neurological samples (epilepsy and traumatic brain injury), 16 in psychiatric samples (five substance abuse, four schizophrenia, three psychopathy, one ADHD, one obsessive–compulsive disorder, one borderline personality disorder, and one Asperger's Disorder), and six in non-clinical samples (four in developmental child samples and two in adult samples). Of the 18 studies that included clinical samples, three reported correlational analyses within the clinical group and not the control group, two reported correlational analyses within the clinical group but did not have a control group in the study, one study reported correlational analyses within both the clinical and control groups, two studies reported correlational analyses within the clinical group, control group, and within the total sample, and ten studies reported correlational analyses within the total group only. Tasks used to index intelligence included commonly used instruments, including the Wechsler measures of intelligence, the Stanford Binet, and Raven's Progressive Matrices. Less conventional measures of intelligence included the Shipley Institute of Living Scale (Barry & Petry, 2008), the NART (Mahmut et al., 2008), PPVT (Hongwanishkul et al., 2005), and measures of intelligence from other languages (such as the German version of the WAIS; Losel & Schmucker, 2004). Although most of these measures had a single score, such as a full-scale estimate of intelligence, some studies reported multiple scores, such as verbal and nonverbal estimates of intelligence. Moreover, in some studies, the correlations were only reported when the associations were significant.

Because of multiple dependent measures and multiple comparisons within a study, the 24 studies produced 31 possible correlations for examination. Ten of the 24 studies produced a single significant correlation. Thus, of the 31 possible correlations across the 24 studies, only ten were significant. Based on these studies, performance on the IGT and intelligence seem to be relatively dissociated. A median value of $r = .23$ was calculated based on those studies that reported correlational analyses. This median value is likely an overestimate, given that many studies did not report values for non-significant correlations.

Table 5
Summary of Studies reporting significant associations between IGT performance and cognitive abilities.

Cognitive ability domain	Studies		Correlations	
	Total number examined	Number with at least one significant correlation	Total number examined	Number attaining statistical significance
Inhibition	11	4 (36%)	21	5 (24%)
Set-shifting	18	5 (28%)	38	5 (13%)
Working memory	15	4 (27%)	25	4 (16%)
Intelligence	24	10 (42%)	31	10 (32%)

5. General discussion

In this review, we examined 43 studies that have reported the association between IGT performance and cognitive abilities. Our review included studies that examined samples of participants with neurological disorders, psychiatric disorders, and non-clinical child and adult samples. Of the studies that examined the association between IGT and inhibition, only five out of 21 correlational analyses reported a statistically significant association. Of studies that examined the association between IGT and set-shifting, only five out of 38 correlational analyses reported a significant association. Of studies that examined the association between IGT and working memory, only four out of 25 correlational analyses reported a significant association. Finally, of the studies that examined the association between IGT and intelligence, only ten out of 31 correlational analyses reported a significant association. Table 5 provides an overall summary of the correlations reported between IGT performance and cognitive abilities across all of the studies included in this review. Table 5 presents results in terms of the percentage of studies with at least one significant correlation and in terms of the percentage of correlational comparisons, amalgamated across studies, that attained significance. On a study basis, substantially less than 50% of the investigations displayed a single significant correlation. Amalgamated across studies in all four domains, only 24 of a total of 115 correlational comparisons (20.8%) were statistically significant. Then, actual correlations were generally low, with median values in the four domains of $r = .18$, .15, .06, and .23. It should be noted that even these low values are likely to be on the high side, because some of the studies did not report values for non-significant correlations.

Overall, these results suggest a lack of strong associations between IGT performance and the cognitive abilities examined in these research studies. The majority of studies reported a non-significant relationship. Only a minority of correlational comparisons was

significant, and even the significant associations were modest in size with wide confidence intervals. Given that the bulk of the correlations reviewed in this study were non-significant, many of the significant correlations could very well reflect Type 1 error or the file-drawer problem, that only significant effects are published. When one interprets the aggregate of findings in this review, the number of non-significant associations substantially outweigh the number of significant associations that have been reported in the empirical literature. The IGT is a complex task, and the lack of associations and modest associations do not suggest that IGT performance represents some separate module, but rather highlights important separability between the constructs of decision-making and cognitive abilities. The small number of associations that was obtained between IGT performance and these neuropsychological indices may be more indicative of the presence of multiple deficits in functioning in clinical populations (Pennington, 2002) and emergence of considerable cognitive growth during development (Davidson, Amso, Anderson, & Diamond, 2006). In this way, decision-making performance may be somewhat contingent on intact neuropsychological abilities, for example, to maintain and update information during the IGT task.

6. Understanding the association between decision-making and other cognitive abilities

The IGT was initially developed in order to account for the clinical observations of E.V.R., who displayed intact functioning on measures of executive functions and intelligence but made poor choices that lead to negative consequences in his everyday functioning (Bechara et al., 1994). Based on research using patients with lesions in ventromedial and/or dorsolateral/high mesial regions in conjunction with differences between these groups in behavioral performance on the IGT, it was inferred that the neuropsychological functions between these regions were separable (Bechara et al., 1998). Based on this original work, it was expected that this distinction would be apparent in a review of research studies that have directly examined the relationship between IGT performance and these cognitive abilities.

The idea of the separability of decision-making and cognitive abilities is consistent with recent conceptualizations that distinguish rationality and decision-making from intelligence (Stanovich, 2009a; Stanovich, West, & Toplak, in press). Cognitive scientists recognize two types of rationality: instrumental and epistemic. The simplest definition of instrumental rationality is: behaving in the world so that you get exactly what you most want, given the resources (physical and mental) available to you. Somewhat more technically, we could characterize instrumental rationality as the optimization of the individual's goal fulfillment. Economists and cognitive scientists have of course refined the notion of optimization of goal fulfillment into the technical notion of expected utility (Baron, 2008; Dawes, 1998). The other aspect of rationality studied by cognitive scientists is termed epistemic rationality. This aspect of rationality concerns how well beliefs map onto the actual structure of the world. The IGT would most clearly relate instrumental rationality, because it straightforwardly involves maximizing net profit in a particular task environment. This classification is consistent with research reviewed in the Introduction of this paper indicating that subpar performance on the IGT is associated with many behavioral problems that result in difficulties adapting to the environment. People who fail to maximize their goals – that is, who are low in instrumental rationality – score poorly on the IGT.

Such an association is consistent with viewing the IGT as a measure of instrumental rationality. Is it consistent with our finding of the relative independence of IGT performance and cognitive ability? Yes it is, because in our view cognitive ability (i.e., intelligence) and rationality are conceptually and empirically separable. They are conceptually distinct because intelligence is not an exhaustive measure of cognitive functioning. For one thing, intelligence tests fail to tap important metacognitive strategies and cognitive styles that are critical components of what has been termed the reflective mind (Stanovich, 2009a; Sternberg, 2003). These components of cognition travel under a variety of names in psychology – thinking dispositions or cognitive styles being the two most popular. Many thinking dispositions concern beliefs, belief structure and, importantly, attitudes toward forming and changing beliefs – in short, they tap aspects of epistemic rationality. Other thinking dispositions concern a person's goals and goal hierarchy—in short, they tap aspects of instrumental rationality. Examples of some thinking dispositions that have been investigated by psychologists are: actively open-minded thinking, need for cognition (the tendency to think a lot), consideration of future consequences, need for closure, superstitious thinking, and dogmatism (see Ackerman & Heggestad, 1997; Baron, 2008; Cacioppo, Petty, Feinstein, & Jarvis, 1996; Kruglanski & Webster, 1996; Perkins, 1995; Stanovich, 1999, 2009a; Sternberg, 2003; Sternberg & Grigorenko, 1997; Strathman, Gleicher, Boninger, & Edwards, 1994). Conceptually, such aspects of rational thought (what Stanovich, 2009a calls the reflective mind) are separate from intelligence because they are not assessed by the measures that operationalize the intelligence construct. Thus in our conceptualization, performance on the IGT is a phenotypic indicator of decision-making skill, that is, instrumental rationality. This conceptualization is somewhat different from some neuropsychological conceptualizations that identify the IGT as an executive function. In our view, executive functions are underlying processes that may or may not support instrumentally rational behavior. The IGT is a direct indicator of the degree of instrumentally rational behavior, thus the IGT is not linked to EF by definition, and neither is it necessarily conceptually linked. In our view it is an empirical question whether this overt indicator of decision-making skill relates to the underlying processes that carry the term EF.

Another conceptual difference between intelligence and rationality concerns a distinction long made by psychometricians—that between typical performance situations and optimal (sometimes termed maximal) performance situations (see Ackerman, 1994, 1996; Ackerman & Heggestad, 1997; Ackerman & Kanfer, 2004; see also, Cronbach, 1949; Matthews, Zeidner, & Roberts, 2002). Typical performance situations are unconstrained in that no overt instructions to maximize performance are given, and the task interpretation is determined to some extent by the participant. The goals to be pursued in the task are left somewhat open. The issue is what a person would typically do in such a situation, given few constraints. Typical performance measures are measures of the reflective mind—they assess in part goal prioritization and epistemic regulation. In contrast, optimal performance situations are those where the task interpretation is determined externally. The person performing the task is instructed to maximize performance and is told how to do so. Thus, optimal performance measures examine questions of efficiency of goal pursuit—they capture the processing efficiency of the algorithmic mind (see Stanovich, 2009a). All tests of intelligence or cognitive aptitude are optimal performance assessments, whereas measures of critical or rational thinking are often assessed under typical performance conditions. In terms of the distinction between typical and optimal performance situations, the IGT clusters more with the former. While the participant is instructed to try and maximize profit on the IGT, the participant is not given any specific instructions on how to do maximize. Such ambiguity leaves the task interpretation somewhat open to the participant which is characteristic of typical performance situations.

Conceptual separation aside, there is ample empirical evidence that measures of intelligence and measures of rationality show considerable dissociation. Some measures of rational thought show modest correlations with cognitive ability (in the range of .20 to .35), but many rationality tasks show no association with cognitive ability (Bruine de Bruin, Parker, & Fischhoff, 2007; Klaczynski & Lavallee,

2005; Klaczynski & Robinson, 2000; Kokis, Macpherson, Toplak, West, & Stanovich, 2002; Macpherson & Stanovich, 2007; Parker & Fischhoff, 2005; Sá & Stanovich, 2001; Stanovich & West, 2000, 2008; Toplak & Stanovich, 2002, 2003; Toplak et al., 2007).

Stanovich and West (2008; see also, Stanovich et al., in press) have described a model that predicts the degree of association between intelligence and performance on rational thinking tasks. The low proportion of the studies reporting significant correlations between IGT performance and cognitive abilities is consistent with this model. Three levels of processing are distinguished in the Stanovich and West (2008) model—the autonomous level, the algorithmic level, and the reflective level. The second of these is tapped by maximal performance tasks such as the EF and intelligence measures of the literature reviewed here. In contrast, impaired performance on the IGT may be attributable to problems in the autonomous mind. The autonomous mind is separable from the algorithmic mind and has also been termed the autonomous *set* of systems (TASS) because it includes processes of implicit and instrumental learning, Darwinian modules, overlearned associations, and, most importantly, processes of behavioral regulation by the emotions. TASS processes are autonomous and respond automatically to triggering stimuli. Execution of TASS processes is neither dependent on input from or under the control of analytic processes (Stanovich, 2009b). Viewing the IGT as largely tapping the latter is consistent with Damasio's (Damasio, 1994, 1996, 1999) original interpretation of this task—that poor performance on the IGT is associated with dysregulation of somatic markers. The task has been classified as an indicator of TASS by other subsequent investigators as well (Stanovich et al., 2003; Toplak et al., 2007).

While some have suggested that IGT performance is another index of EF (Buelow & Suhr, 2009), we would argue for the separability of IGT performance from EF and intelligence. Specifically, IGT performance relates to rational responding in both the laboratory and the real world because it measures aids to behavioral regulation (e.g., emotions, somatic markers) that arise from the autonomous mind. The latter are largely dissociated from intelligence (Anderson, 2005; Baron-Cohen, 1995; Reber, Walkenfeld, & Hernstadt, 1991; Saffran, Aslin, & Newport, 1996; Vinter & Detable, 2003; Vinter & Perruchet, 2000; Zacks, Hasher, & Sanft, 1982). The conclusions of the current paper are consistent with other studies that have suggested that neuropsychological indices of EF and intelligence leave a large amount of unexplained variance in IGT performance (Levine et al., 2005).

7. Relevant methodological considerations

The bulk of the research literature has used the original composite (C + D) − (A + B) score from the IGT, across all decks and trials, and indeed, the current review focused on including those studies that have used this index as it has been more consistently used. However, this overall composite does not take into account the implicit learning that takes place during this task, namely that participant card selections from 1–40 may be classified as decision-making under ambiguity and participant card selections 41–100 may be classified as being the decision-making under risk (Noël et al., 2007; Sinz et al., 2008). The relative cognitive resources required for this task may vary slightly depending on whether the participant is experimenting with the decks during the initial learning phase or whether the participant is selecting a risk strategy during the latter half of the task. Some evidence supports that inhibitory processes may be more important during the latter half of the task, when the participant is aware of the risk status of each deck and must make informed choices to maximize gain and minimize loss (Noël et al., 2007). Others have also suggested alternative scoring methods that take these task phases into account (Dunn et al., 2006). Phase of the IGT task may impact the relative association between IGT performance, EF, and intelligence, but it would not likely impact the conclusion of the current paper. Considerable variance on the IGT would likely remain unexplained by these neuropsychological variables.

The odds of the IGT correlating significantly with measures in the cognitive ability domain also did not vary systematically across the various clinical and non-clinical samples. For example, 10 of 23 correlations based on combined clinical and non-clinical samples were significant, eight of 23 correlations based on only clinical samples were significant, and five of 23 correlations based on only non-clinical samples were significant. This would argue against likelihood that the relatively persistent absence of significant correlation between IGT and the cognitive ability measures was merely the consequence of restricted ranges resulting from the reviewed studies' heavy reliance on clinical samples.

The IGT has been used as a measure of decision-making that seems to capture a “myopia for the future.” IGT performance across these studies is often completely dissociated, as indicated by near zero correlations with IQ and EFs. A minority of studies displayed small to modest associations between IGT performance and IQ or EFs. The overall pattern of findings suggests more separability than commonality among the IGT and these cognitive abilities, suggesting that decision-making should not be considered a type or subcategory of EFs or IQ. These findings are consistent with current conceptualizations of rationality and intelligence that highlight the separability between cognitive abilities, as indexed on measures of intelligence and executive functions, and decision-making performance.

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