

Construct Validity of the Iowa Gambling Task

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Abstract The Iowa Gambling Task (IGT) was created to assess real-world decision making in a laboratory setting and has been applied to various clinical populations (i.e., substance abuse, schizophrenia, pathological gamblers) outside those with orbitofrontal cortex damage, for whom it was originally developed. The current review provides a critical examination of lesion, functional neuroimaging, developmental, and clinical studies in order to examine the construct validity of the IGT. The preponderance of evidence provides support for the use of the IGT to detect decision making deficits in clinical populations, in the context of a more comprehensive evaluation. The review includes a discussion of three critical issues affecting the validity of the IGT, as it has recently become available as a clinical instrument: the lack of a concise definition as to what aspect of decision making the IGT measures, the lack of data regarding reliability of the IGT, and the influence of personality and state mood on IGT performance.

Keywords Iowa gambling task · Decision making · Validity · Reliability · Executive function

Construct Validity of the Iowa Gambling Task

The Iowa Gambling Task (IGT) was created to assess real-world decision making in a laboratory setting (Bechara et al. 1994). Individuals are given \$2000 to start, and are told

to maximize profit over the course of 100 trials by selecting cards from one of four decks. On each draw, Decks A and B yield a profit of \$100 on average, and Decks C and D yield a \$50 profit on average. However, after 10 selections from Decks A and B, individuals have incurred a net loss of \$250, whereas after 10 selections from Decks C and D, individuals have incurred a net gain of \$250 (Bechara et al. 1994). Decks A and B have been termed “disadvantageous,” and selection from these decks is deemed risky, while Decks C and D are termed “advantageous” (Bechara et al. 1994). The IGT was originally administered using decks of paper cards; however, the computerized version of the task is more commonly used, with no differences between these two versions of the task (e.g., Bechara et al. 2000b; Bowman et al. 2005). Similarly, no differences have been shown when using real rewards or just earning “play money” (Bowman and Turnbull 2003). According to the newly published professional manual for the computerized IGT (Bechara 2007), performance on the IGT is also resistant to length of time delays between trials. Several outcome measures are commonly used, including total money won (van den Bos et al. 2006), the difference between total advantageous and total disadvantageous selections (Bechara et al. 1998; Bolla et al. 2005; Ernst et al. 2002; Ernst et al. 2003a, b; Franken and Muris 2005) and the pattern of this difference by 20-block trials over 100 card plays (Bechara et al., 2000b, 2001, 2002; Bowman et al. 2005; Fernie and Tunney 2006; Turnbull et al. 2005; van den Bos et al. 2006). Bechara (2007) provides normative data for the total score, the scores in each of 5 20-block subsets, and the total number of cards selected from each deck.

Since its creation, the IGT has been used as a behavioral indicator of risky decision making and it has recently become available as a clinical tool (Bechara 2007).

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However, a comprehensive review of the literature regarding the construct validity of the IGT has yet to be conducted. Construct validity assesses whether a test actually measures the construct it purports to measure (Cronbach and Meehl 1955), in this case, risky or “real world” decision making. Interestingly, the developers of the IGT did not define the construct of decision making beyond these descriptors. Decision making is a broad and complex construct, making this lack of clarification potentially problematic. However, the history of the IGT’s development provides additional information about the specific aspects of decision making that the IGT developers were attempting to assess with the task, and we will begin our review with an historical overview of the concept of decision making as it applies to the IGT.

Because the IGT was initially created to assess individuals with ventromedial prefrontal cortex damage who exhibited real-world decision making deficits but performed normally on other lab-based measures of cognitive functioning (Bechara et al. 1994; Bechara 2007), we will continue our review with construct validity evidence from neuroimaging, including studies of individuals with documented damage to the frontal lobe, as well as functional neuroimaging studies of the IGT in both clinical and nonclinical populations.

The professional manual for the IGT indicates that, in addition to inferring “the level of decision making capacity of an individual in relation to the general population”, an additional clinical use for the instrument is to “obtain information that supports a diagnosis” (Bechara 2007, p. 7). In addition to individuals with focal brain damage, the manual lists the following as appropriate populations for the IGT: addiction, differing age groups, obsessive-compulsive disorder, pathological gambling, psychoses, bipolar disorder, and attention-deficit/hyperactivity disorder. Thus, our review of the construct validity of the IGT will include a review of IGT findings in these clinical populations, as well as the relation of the IGT to other measures of decision making.

Defining Decision Making with the IGT

The creators of the IGT referred to the instrument as a behavioral measure of risky decision making, a complex, hard to define construct. Decision making involves, at its most basic level, the selection of one option from several alternatives. “Cold” cognitive reasoning and “hot” affective processing can both influence this process. “Cold” decision making is associated with rational and cognitive determinations of risks and benefits associated with options, and requires the knowledge of the risk/benefit ratio, the ability to retrieve them from memory, and the ability hold them in mind while comparing and contrasting them (working

memory), whereas “hot” decision making involves emotional and affective responses to the options (Seguin et al. 2007).

The idea of “hot” decision making is consistent with the somatic marker hypothesis, explained in detail by Bechara (2004) and summarized briefly here. The somatic marker hypothesis states that the experience of emotion is tied to the decision making process. This emotional experience may remain at the unconscious level, but can be viewed as “gut feelings” or “hunches,” the so-called somatic marker that guides decision making (Bechara et al. 1997). Damasio (1994) hypothesized that the somatic marker’s role in “hot” decision making is to assist the “cold” decision making process by unconsciously biasing the available response selections in a complex decision making task. In brief, consideration of a particular decision making situation will bring to mind mental images and associations important for that decision, which will in turn elicit bodily signals and emotional states associated with those images (somatic markers). Somatic markers are integrated automatically, involuntarily, and unconsciously by the ventromedial frontal lobes into the more conscious decision making process. However, when neurological damage affects brain areas associated with “hot” decision making, this can impair the “cold” decision making process as well.

There is evidence consistent with the somatic marker hypothesis and the role of “hot” decision making during the IGT. Over IGT trials, healthy controls eventually demonstrate an anticipatory electrodermal response to card selection; prior to selecting a card from a “risky” deck, they show a physiological reaction indicating that they are bodily experiencing the anticipated risk. However, individuals with ventromedial prefrontal cortex damage do not develop this anticipatory electrodermal response (Bechara et al. 1996). Other studies have shown positive correlations between the development of anticipatory skin conductance responses and better performance on a similar gambling task (Crone et al. 2004; Carter and Pasqualini 2004).

Some recent data suggest that not all aspects of the IGT are equal at detecting “cold” and “hot” decision making processes. Brand et al. (2007b) referred to selections during the first block of trials decision making under ambiguity, because there has not been time for a participant to experience any of the win/loss contingencies for the deck choices. Selections during the last block of trials were referred to as decision making under risk, because after many plays, participants should have experienced the different win/loss contingencies enough to know which decks are risky and which are not; thus, decisions to play a risky deck at that point would reflect a different decision process than a play of a risky deck early in the 100 trials. This difference in type of decision making assessed across trials of the IGT should be considered when collapsing

selections across blocks to create a summary score based on total advantageous and disadvantageous selections, and may be related to inconsistencies in research findings reviewed below when summary scores were used as the IGT dependent variable.

A Word on Reliability

To date, no studies have directly examined the reliability of the IGT. Reliability is a necessary but not sufficient aspect of validity and must be assessed before determining that a test is valid. Difficulties can be foreseen in assessing the temporal stability of the IGT, due to the potential for practice effects on later administrations. Support for this concern comes from several sources. For example, learning effects on a second IGT administration after a 1 week delay were found among adolescent and adult normal controls and adults with substance use disorders, but not among adolescents with behavior disorders (Ernst et al. 2003a, b). Similarly, smokers and nonsmokers both decreased risky responding on the IGT over the course of three administrations during one testing session (Lejuez et al. 2003). Learning effects were also noted in normal controls, abstinent cocaine users, and abstinent marijuana users over a 25-day delay (Verdejo-Garcia et al. 2007). It is unknown whether performance on the IGT would be reliable over time, due to learning effects and previous exposure to the task. The clinical manual does not address reliability of the IGT, nor does it comment on applicability of the IGT for retesting purposes (Bechara 2007). The lack of data regarding reliability of and practice effects on the measure may limit its applicability for assessing performance over multiple administrations (for example, in pre/post intervention studies).

Lesion Studies

The IGT was initially developed to assess decision making in individuals with damage to the prefrontal cortex, specifically, to the ventromedial prefrontal cortex (Bechara et al. 1994). In early studies, individuals with damage to the ventromedial prefrontal cortex selected significantly more cards from the disadvantageous decks than from the advantageous decks, as indicated by comparing the total number of selections from the two types of decks, whereas healthy controls and those with damage to other brain areas chose more from the advantageous decks (Anderson et al. 1999). Damage to the occipital or temporal lobe was not associated with IGT impairment (Bechara 2004). In initial validation studies, focus was specifically placed on the ventromedial prefrontal cortex, as previous case studies had shown correlations between real-world decision making deficits and focal damage to this area (Eslinger and

Damasio 1985). Collectively, results suggested that individuals with ventromedial prefrontal cortex damage show impairment on the IGT, whereas individuals with damage to the dorsolateral prefrontal cortex perform similarly to controls (Bechara et al. 1998, 2000b; Bechara and Damasio 2002; Bechara 2003; Fellows 2004).

Others have not found such specificity within the frontal cortex. For example, Manes and colleagues (2002) assigned patients with clearly defined frontal lobe lesions to one of the following groups: orbitofrontal cortex lesions, dorsolateral prefrontal cortex lesions, dorsomedial prefrontal cortex lesions, and large, nonspecific lesions that included the frontal lobe, in which the original ventromedial prefrontal cortex group (Bechara et al. 1994) would have been included as none had focal frontal lesions. Impairment on the IGT was seen in individuals with dorsolateral and dorsomedial prefrontal cortex damage, as well as in individuals with large lesions. Individuals with focal orbitofrontal cortex lesions performed similarly to normal controls. In a separate study, individuals with both ventromedial and dorsolateral prefrontal cortex lesions were impaired on the IGT, in terms of both the total number of advantageous/disadvantageous selections and the number of advantageous selections over time, in comparison to normal controls (Fellows and Farah 2005).

Differences in findings across these studies cannot be attributed to measurement issues, as all used the same IGT outcome measures. However, patient characteristics did vary, which may have led to differences in conclusions about specificity of the IGT to the ventromedial prefrontal cortex. In addition to differences in location and specificity of the frontal lesions in each study, the studies varied in their use of other behavioral indicators of poor decision making as an aspect of participant selection. In the original IGT validation study, part of the inclusion criteria for the ventromedial prefrontal cortex group was the presence of documented real life decision making deficits (Bechara et al. 1994). Later studies limited inclusion to individuals with focal frontal lesions that were confirmed with either MRI or CT (Fellows and Farah 2005; Manes et al. 2002); however, there was no requirement of behavioral evidence of decision making deficits for inclusion in these studies. Of note, Manes et al. (2002) also excluded individuals with current or past psychiatric diagnoses, whereas the other studies did not (Fellows and Farah 2005; Bechara et al. 1994). This is especially important given the relationship between IGT performance, affect, and personality characteristics that will be discussed later in the review.

Differences in IGT performance due to laterality of frontal damage have also been investigated, as it was hypothesized that right ventromedial prefrontal cortex damage would be sufficient to cause decision making deficits, due to the role of the right hemisphere in emotional

processing (Tranel et al. 2002). No difference in performance was found between individuals with right versus left dorsolateral prefrontal cortex damage (Bechara et al. 1998), although it was argued that no differences should have been seen as the IGT is linked to the ventromedial prefrontal cortex. However, individuals with right ventromedial prefrontal damage show IGT impairment, whereas those with left ventromedial prefrontal cortex lesions perform similarly to controls (Clark et al. 2003; Tranel et al. 2002). Manes et al. (2002) hypothesized that lesion laterality could have contributed to their conflicting findings, as previously discussed, in that 4/5 of the orbitofrontal cortex group had lesions in the left hemisphere, and 4/5 of the large lesion group had lesions in the right hemisphere.

Bechara and colleagues have also explored the effect of amygdala damage on IGT performance (Bechara et al. 1999). They found that 5 patients with focal amygdala damage also failed the IGT, although psychophysiological findings suggested that their reasons for failing were different than those in patients with ventromedial prefrontal cortex damage. Specifically, the patients with amygdala damage showed no psychophysiological reactivity to any stimuli (IGT-related or not), while the patients with ventromedial prefrontal cortex damage showed psychophysiological reactivity to the consequences of an IGT play (i.e., a win or a loss), just not to anticipated plays. Similar findings were reported by Brand et al. (2007a, b) in a sample of three patients with focal amygdala damage. Bechara and colleagues speculated that the decision making deficit seen in individuals with ventromedial prefrontal cortex damage is the result of problems integrating somatic information from multiple neural sources (including the amygdala, which has extensive bidirectional connections to this brain region), whereas IGT impairment in the patients with amygdala damage was likely related to their generalized impairment in emotional conditioning, which ultimately affected their “hot” decision making abilities. Similarly, Brand et al. (2007a, b) suggested that the complex nature of the IGT and other similar decision making tasks requires both “emotional” processing and “cognitive” processing. In other words, damage to neural systems involved in emotional reactivity and emotional conditioning, such as the amygdala, can affect IGT performance (and be related to other executive dysfunctions; see Brand et al. 2007a, b), as can damage to neural systems that affect memory and understanding of probabilities and of gain/loss information from prior trials. The idea that IGT performance can be affected by damage to the amygdala and other systems involved in emotional processing is consistent with the somatic marker hypothesis and “hot” decision making, as has been previously discussed. Complicating the interpretation of these findings is that the patients with amygdala damage in these studies

also incurred damage to the hippocampus, and thus further studies are needed to clarify what role hippocampal damage, and consequent memory impairment, might play in IGT performance.

Overall, the results of these studies show support for the link between IGT impairment and damage to the frontal cortex (especially the right frontal cortex) and amygdala, while damage to other areas of the brain is not associated with IGT impairment.

Functional Neuroimaging Studies

Findings from functional neuroimaging studies are generally consistent with lesion data and supportive of the idea that the IGT is related to frontal lobe functioning. In healthy controls and in various patient populations, activation to the medial orbitofrontal cortex is seen when completing the IGT (Adinoff et al. 2003; Bolla et al. 2003; Ernst et al. 2002; Grant et al. 1999; Tucker et al. 2004; Windmann et al. 2006).

Some studies have also shown that performance level on the IGT correlates with level of neural activation. Better performance on the IGT was correlated with increased activation to the orbitofrontal cortex among substance abusers (Bolla et al. 2003), and negatively associated with perfusion in the anterior cingulate gyrus and the middle, medial, and superior frontal gyri in cocaine-dependent individuals (Tucker et al. 2004). Schutter and van Honk (2005) demonstrated that frontal hypoarousal was associated with continued disadvantageous selections on the IGT among female healthy controls. Taken together, imaging studies support the idea that the IGT performance is related to frontal lobe functioning.

Correlations with Other Executive Function and Decision Making Tasks

Interestingly, although an important aspect of construct validity is the relation of the measure of interest to other measures of the same construct, few studies comment on the correlation of IGT performance to performance on other measures of executive function, in particular to other measures reflecting decision making skills.

Another test that shows good construct validity for the assessment of executive functioning is the Wisconsin Card Sorting Test (WCST; Strauss et al. 2006). Most studies have shown no relation between the WCST (i.e., completed categories, perseverative errors, total errors, failure to maintain set) and the IGT (i.e., total advantageous selections, selections per block) in either normal (Overman et al. 2004) or patient populations (Bechara et al. 2001; Grant et al. 2000; Ritter et al. 2004; Rotherham-Fuller et al. 2004). However, in a recent study, blocks 2, 4, and 5 of the

IGT were associated with WCST perseverative errors in a sample of normal adults (Brand et al. 2007a, b), suggesting a stronger correlation between the risky decision making component of the IGT and other executive function measures. Given that both the IGT and the WCST assess complex, multifaceted constructs, it is unclear which aspect of the IGT would be expected to correlate with any specific aspect of the WCST.

A few studies have also compared performance on the IGT to performance on the Balloon Analogue Risk Task (BART), another measure of risk-taking behavior (Lejuez et al. 2002). The BART was created to mimic real-world risk-taking, in that behavior would be rewarded up to a point, after which repeated engagement in that behavior would lead to lower outcomes (Lejuez et al. 2002). Participants are told to press a button to pump up a balloon, earning money for each pump, and to stop and collect the money before the balloon pops. Participants are not provided with any information about the likelihood the balloon will pop on any given trial. The BART has shown to correlate strongly with self-reports of behavioral risk-taking and to distinguish between smokers and non-smokers (Lejuez et al. 2002, 2003). No correlations were found between performance on the BART (i.e., adjusted number of pumps) and on the IGT (i.e., percentage of disadvantageous choices) among adult smokers (Lejuez et al. 2003).

Further, the IGT manual states that individuals with poor memory and *poor performance on other executive tasks* are likely to perform poorly on the IGT (Bechara 2007). Deficits were noted on both working memory tasks (i.e., delayed response and delayed nonmatching to sample) and on the IGT among individuals with ventromedial lesions (Bechara et al. 1998). Manes and colleagues (Manes et al. 2002) found that individuals in the large lesion and dorsolateral cortex groups were impaired on both the IGT and on a spatial working memory task, whereas individuals in the orbitofrontal cortex group were not significantly different from controls on either the IGT or the spatial working memory task. In addition, Brand et al. (2007a, b) found evidence for broader executive function impairment in their three patients with focal amygdala damage who performed poorly on the IGT. Taken together, these results indicate that performance on the IGT is related to performance on various working memory and executive function tasks.

Developmental Aspects of the IGT

Executive functions develop as individuals reach adulthood (Carlson 2005), and the frontal lobes continue to develop into adolescence (Segalowitz and Davies 2004). Further, age-related declines in executive functions (Rhodes 2004), as well as in gray matter density and activity levels in the

frontal lobe structures (Grady et al. 2006; Zimmerman et al. 2006) have been shown. Therefore, age-related changes in executive tasks are expected, and studies showing age-related changes in IGT performance would further support its validity as a measure of executive functioning.

Children and Adolescents According to cross-sectional research, age and IGT performance are positively related, in that greater selections are made from advantageous decks with increasing age (Blair et al. 2001; Hooper et al. 2004; Kerr and Zelazo 2004; Garon and Moore 2007). Several studies have used a “child-friendly” version of the IGT, in which participants are asked to “feed a hungry donkey” instead of selecting cards from decks; the exact format of the instrument remains the same (e.g., Crone and van der Molen 2004). Adults, but not adolescents, learn to make advantageous choices on this task (Crone et al. 2003; Crone and van der Molen 2004). This finding has been replicated utilizing the original IGT (Overman et al. 2004).

Three studies have shown no effect of age on the IGT. Groups of 3-, 4-, and 6-year-olds were compared on a simplified version of the IGT, with no effect of age on task performance (Garon and Moore 2004). When adolescents have been compared to one another, no age-related changes, in terms of the number of advantageous selections, have been shown (Ernst et al. 2003a, b; Lehto and Elorinne 2003). However, in all three studies, there was a restricted range of ages being compared, likely contributing to the lack of findings.

Older Adults Few studies have compared older and younger adults on IGT performance, with conflicting results. In two comparisons of adults ages 26–55 to adults ages 56–85, a large portion of the older adults, though less than half of the group, showed impairment on the IGT, as defined by total advantageous versus disadvantageous selections (Denburg et al. 2005, 2006). These results were supported by Fein et al. (2007), who found a greater number of adults ages 56–85 were impaired on the IGT in comparison to adults ages 18–55. Unfortunately, neither study provided further assessment of the subpopulation of older adults who were impaired on the IGT, to determine whether they had other evidence for executive functioning or decision making impairment. On the other hand, in a comparison of adults ages 18–35 to adults ages 65–88, no age-related effects were noted on the IGT: both groups showed a preference for the advantageous decks as indicated by greater selections from those decks over time (Wood et al. 2005). Of note, these studies utilized different outcome variables on the IGT, which may have contributed to the differing conclusions. As previously stated, the use of performance on the 5th block of trials as the dependent variable may diminish differences between the age groups,

as differences in speed of learning on the task may decrease by this last block of trials, which may be a more specific measure of risky decision making. In addition, the Wood et al. (2005) study excluded individuals in their 40s and 50s, which may have also impacted the results.

Clinical Uses of the IGT

The IGT manual (Bechara 2007) specifies that the instrument is appropriate for assessment of the following populations: focal brain damage, addiction, obsessive compulsive disorder (OCD), pathological gambling, psychosis, bipolar disorder, and attention deficit hyperactivity disorder (ADHD). The following outlines the key research findings in these and other clinical populations.

Substance Abuse Numerous studies have investigated IGT impairment among substance abusing and dependent individuals, due to evidence of clear real world decision making deficits in this population and evidence for involvement of the frontal lobe in addiction disorders (Fein et al. 2004). In general, significant impairments on the IGT have been found, in comparison to healthy controls, in individuals dependent on various substances including alcohol, cocaine, opioids, and marijuana (Bartzokis et al. 2000; Bechara et al. 2001, 2002; Bechara and Damasio 2002; Bechara and Martin 2004; Bolla et al. 2003, 2005; Bowden-Jones et al. 2005; Ernst et al. 2003a, b; Fein et al. 2004; Goudriaan et al. 2005; Grant et al. 2000; Mintzer and Stitzer 2002; Monterosso et al. 2001; Pirastu et al. 2006; Rotherham-Fuller et al. 2004; Stout et al. 2004, 2005; Verdejo-Garcia et al. 2006, 2007; Verdejo-Garcia and Perez-Garcia 2007; Whitlow et al. 2004; Yechiam et al. 2005).

A major methodological limitation in this literature is the high likelihood that individuals are abusing multiple substances. In fact, in many of the studies cited above, the focus was on a primary drug of dependence that led the individuals into treatment, but there was often abuse of multiple substances. Interestingly, evidence suggests that the use of multiple substances can increase impairment on the IGT above and beyond the impairment shown by the use of one substance (Bechara and Martin 2004; Grant et al. 2000; Rotherham-Fuller et al. 2004; Yechiam et al. 2005).

Another methodological limitation to the substance abuse literature is whether or not individuals were abstinent from their substance of abuse at the time of the evaluation. Although some findings indicate better performance, relative to nonabstinent substance users, following a period of abstinence (e.g., Bartzokis et al. 2000), other research suggests that IGT impairment in polysubstance abusers is maintained even in abstinence, relative to normal controls

(Fishbein et al. 2005). In general, IGT performance among substance dependent individuals is impaired when compared to normal controls, and this impairment appears to last through a period of abstinence.

Not surprisingly, given these methodological limitations, there are conflicting findings reported in the literature. For example, no differences were found between abstinent cocaine-dependent individuals ($n=13$) and normal controls ($n=15$; Adinoff et al. 2003). They noted that the cocaine-dependent individuals were not polysubstance users, which may have partly accounted for the differing findings. The results regarding IGT performance in nicotine dependent individuals are particularly conflicting: Field et al. (2006) found that nicotine deprivation increases impulsive responding on the IGT, in turn decreasing overall performance, when compared to ad libitum smokers, whereas others have shown no differences between smokers and nonsmokers on the IGT (Harmesen et al. 2006; Lejuez et al. 2003).

It is notable that, for the most part, studies of IGT performance in individuals with substance abuse problems have interpreted poor performance on the IGT as a *consequence* of frontal lobe damage related to the substance of abuse. The IGT manual (Bechara 2007), however, states that poor performance on the IGT among substance addicted individuals indicates poor decision making, not frontal lobe damage from substance use. For example, the use of multiple substances of abuse may be linked to more severe addiction, which could be related to more extensive brain damage, but may also be reflective of premorbidly poor decision making and greater comorbid psychopathology (Midanik et al. 2007). Recent studies have acknowledged the possibility that premorbid personality characteristics, such as sensation seeking, or premorbid dysfunction, such as psychopathy, may be linked both to the propensity to abuse multiple substances and to poorer performance on the IGT (Suhr and Tsanadis 2007).

Pathological Gambling Similar to substance abuse, pathological gambling is an example of uncontrolled risk taking in everyday life, and individuals with pathological gambling problems have shown deficits on various executive and decision making tasks (Brand et al. 2005). However, pathological gambling itself is not neurotoxic, as substance abuse can be, and thus findings of IGT impairment in these populations can help to clarify the relation of IGT performance to risky decision making above and beyond direct evidence for brain dysfunction. Pathological gamblers, in comparison to normal controls, show impairments on the IGT, in that they fail to shift towards the advantageous decks over learning trials (see Goudriaan et al. 2004, for a review; Cavedini et al. 2002; Linnet et al. 2006). In a study of pathological gamblers, detoxified

alcoholics, individuals with Tourette's syndrome, and normal controls, Goudriaan et al. (2005) found that pathological gamblers were impaired on the IGT, and were indistinguishable from detoxified alcoholics. In each of these studies, pathological gamblers were impaired on the IGT, consistent with the observation of everyday difficulties in decision making.

Pathological gamblers often have comorbid disorders that may influence performance on the IGT. Gamblers can have comorbid substance abuse (Ciarrocchi 1993), which, as previously discussed, can negatively impact IGT performance. It is important to consider that these comorbid diagnoses, and other personality characteristics (such as sensation seeking), and not just the individual's "primary diagnosis," may play a role in poor performance on the IGT.

OCD and Schizophrenia Frontal lobe dysfunction and poor performance on neuropsychological tasks are common in schizophrenia (Ritter et al. 2004; Shurman et al. 2005) and OCD (Rauch 2000). Impairments on the IGT are seen in schizophrenia when compared to healthy controls (Ritter et al. 2004; Shurman et al. 2005) and to patients with OCD (Whitney et al. 2004). Interestingly, in these studies, no differences were found in WCST performance among the groups being compared. On the other hand, several studies have found no differences between schizophrenic patients and normal controls (Bark et al. 2005; Cavallaro et al. 2003; Evans et al. 2005; Rodriguez-Sanchez et al. 2005; Wilder et al. 1998). These conflicting results are not due to a confound of the dependent variable used, as these differing results held for the difference between total advantageous and total disadvantageous selections (Bark et al. 2005; Cavallaro et al. 2003; Rodriguez-Sanchez et al. 2005; Whitney et al. 2004), as well as for this difference in each of the five blocks of trials (Bark et al. 2005; Evans et al. 2005; Ritter et al. 2004; Rodriguez-Sanchez et al. 2005).

Cavallaro et al. (2003) hypothesized that dorsolateral prefrontal cortex dysfunction is associated with schizophrenia, whereas ventromedial prefrontal cortex dysfunction is associated with OCD. In their study, patients with schizophrenia exhibited a higher number of perseverative errors on the WCST than controls and patients with OCD, while patients with OCD selected more disadvantageously on the IGT than patients with schizophrenia and controls, consistent with their hypothesis. In contrast, other studies have found no IGT impairment in patients with OCD relative to healthy controls (Lawrence et al. 2006) or individuals with trichotillomania (Grisham et al. 2007), as performance improved over time in all groups. Individuals with combined schizophrenia and OCD symptoms do worse on the IGT and the WCST than individuals with only schizophrenia or OCD symptoms (Whitney et al. 2004). It

is possible that individuals with both schizophrenia and OCD symptoms have dysfunction in both the ventromedial prefrontal cortex and dorsolateral prefrontal cortex, which would explain these results.

Attention-Deficit/Hyperactivity Disorder Although ADHD is a disorder often linked to the frontal lobes (i.e., Zang et al. 2005), only two published studies could be found that examined IGT deficits among adults meeting DSM-IV criteria for ADHD. In the most recent (Malloy-Diniz et al. 2007), 50 adults diagnosed with ADHD based on independent interviews with a neurologist and a psychologist (14 met diagnostic criteria for inattentive subtype and 36 met criteria for combined subtype) were compared to 51 healthy controls. Participants were tested off medication. Individuals with ADHD made significantly more disadvantageous decisions on blocks 3, 4, and 5 of the IGT. These results were in direct contrast to the results of a previous study comparing adults with ADHD ($n=10$; subtype unknown) to healthy volunteers ($n=12$; Ernst et al. 2003a, b). Adults in the ADHD group met DSM-IV criteria for ADHD in childhood and adulthood, as assessed with the NIMH Diagnostic Interview Schedule. Those using stimulants refrained from their use for 48 h prior to the testing session. No differences were noted between adults with ADHD and healthy controls on the IGT, when examining the difference between total advantageous and total disadvantageous selections. It is possible that their lack of findings was related both to small sample size and to use of only the total score in their IGT analysis. In a recent study in our laboratory (Zimak et al. 2008), we compared 16 adults with ADHD (tested off medication) to 23 adults who self-reported high levels of current ADHD symptoms but did not meet diagnostic criteria for the disorder (no evidence for childhood symptoms based on self-report and collateral information), and 31 controls. Most of the ADHD sample would have been characterized as predominantly inattentive type. Interestingly, the individuals with current ADHD symptoms, but not ADHD diagnoses, were the most impaired on the last quintile of the IGT, with the ADHD diagnosis group actually performing the best of the three groups.

These inconsistent findings raise concerns about the usefulness of the IGT in ADHD diagnosis, and also raise questions about the factors that might be associated with IGT impairment in ADHD; for example, symptomatic presentation (inattentive versus hyperactive/impulsive symptoms), or even personality characteristics. For example, Malloy-Diniz et al. (2007) reported significant correlations between poor IGT performance and high scores on self-reported impulsive personality characteristics using the Barratt Impulsivity Scale (Barratt et al. 1999) in his ADHD sample. However, in data from our lab, both ADHD

symptom and ADHD diagnosis groups were significantly higher on measures of impulsivity than controls (Zimak et al. 2008). Thus, further research is needed to examine the usefulness of the IGT in ADHD evaluation.

Other Clinical Populations The following populations have also been the subject of IGT research. Findings from these studies, however, provide support both for and against the construct validity of the IGT as a measure of risky decision making and/or frontal lobe dysfunction.

Psychopathy A major personality disorder that involves decision making deficits, and where there is evidence of frontal lobe dysfunction, is psychopathy (Ross et al. 2007). The primary sampling source for these studies has been prison inmates, and varying results have been found. Inmates with psychopathic traits, as measured by the Psychopathy Checklist Revised, performed worse on the IGT than inmates without psychopathic traits (Mitchell et al. 2002); these researchers demonstrated a similar pattern of findings in boys with psychopathic traits as part of another study utilizing the Psychopathy Screening Device (Blair et al. 2001). However, others have not found IGT impairment in inmates with psychopathic traits, also as measured by the Psychopathy Checklist Revised (Losel and Schmucker 2004; Schmitt et al. 1999). Neither of these studies controlled for substance use/abuse, however. In each of these studies, high scorers on these measures, indicating a number of psychopathic traits, were compared to low- and middle-scorers on the measure to assess any differences on IGT performance. Stout et al. (2005) found that high numbers of antisocial characteristics were related to IGT performance in substance users, but that personality characteristics were not correlated with IGT performance in nonusers. Again, the issue of comorbidity is a factor in determining the factor or factors related to poor IGT performance in such clinical populations.

Neurological and Medical Conditions Researchers have investigated IGT performance in individuals with various neurological and medical conditions that have previously been associated with risky behavior or frontal lobe dysfunction. For example, impairments on the IGT have been found in HIV+ males when compared to HIV– males (Hardy et al. 2006; Martin et al. 2004), and Huntington's and Parkinson's disease patients when compared to healthy controls (Campbell et al. 2004; Czernecki et al. 2002; Perretta et al. 2005; Stout et al. 2001). These findings have included several dependent variables from the IGT, including total advantageous minus disadvantageous selections, and selections over trial blocks. Eating disorders have been theorized to relate to obsessive-compulsive-like behaviors, and individuals with eating disorders show similar impair-

ment on the IGT to those seen in individuals with true OCD (Cavedini et al. 2004; Davis et al. 2004). For the most part, these studies are supportive of the construct validity of the IGT as a test of risky decision making that may reflect frontal lobe dysfunction. However, IGT impairment has also been found in chronic pain populations in comparison to pain-free healthy controls (Apkarian et al. 2004; Mongini et al. 2005). Such findings do not necessarily support the relation of the IGT to the frontal lobe, nor to the cognitive construct of decision making; rather, these findings raise concern about other variables that are potentially related to IGT performance, such as negative affect, which will be discussed in more detail below.

Personality Characteristics and Affect In early work on the IGT, Bechara and colleagues (Bechara et al. 2000a) suggested that a significant minority of “normal” controls who performed poorly on the IGT may in fact score high in “cognitive disinhibition,” which they defined as having a personality style that lead to “myopia for the future” that would explain their pattern of IGT performance. However, very little research has been conducted to examine the personality correlates of IGT performance. While such work might be supportive of the IGT's construct validity, it also has implications for interpretation of “impaired” performance in individuals who complete the IGT as part of a clinical evaluation.

Personality Characteristics Poor IGT performance has been seen in children with high amounts of sensation seeking/disinhibition (Crone et al. 2003), in those low in shyness relative to those high in shyness (Addison and Schmidt 1999), and in those who are high in behavioral activation but low in behavioral inhibition (van Honk et al. 2002). Two studies examined the relationship of IGT to personality characteristics reflecting behavioral inhibition and behavioral activation. Franken and Muris (2005) found that individuals scoring high on a measure of Reward Responsiveness had better performance on the IGT; however, these researchers utilized different reward/punishment discrepancies than those in the original IGT task, and their overall sample performed more poorly on the IGT than those in comparison studies. Suhr and Tsanadis (2007) found that individuals scoring high on Reward Responsiveness and Fun Seeking personality traits had worse performance on the IGT. Overall, the results of the few studies that have explored personality correlates of IGT performance in nonclinical samples suggest that underlying personality characteristics, independent of a psychological disorder, mental disorder, or frontal lobe dysfunction, may impact performance on the IGT.

Affect/Mood Data also suggest impairments in IGT could be related to negative affect. Research suggests that mood

can influence judgments regarding perceived frequency of risk and risky decision making (Arkes et al. 1988; Finucane et al. 2000; Johnson and Tversky 1983; Nygren 1998). Consistent with these non-IGT findings, Must and colleagues (Must et al. 2006) demonstrated that patients with major depressive disorder were impaired on the IGT. Similarly, Suhr and Tsanadis (2007) found that higher negative mood was related to riskier performance on the IGT in a nonclinical sample; of note, their personality findings reviewed above held even after controlling for negative mood. In summary, although few studies have considered the contribution of state mood to IGT performance, these findings do suggest that it will be important to consider affective state when interpreting IGT performance, particularly given the high comorbidity of depressed mood with many of the clinical disorders in which the IGT is utilized.

Bottom Line

Construct validity of a neuropsychological instrument can be shown if research indicates that the test actually measures what it purports to measure. Evidence for construct validity is important to interpretation of findings in research using the IGT and to its use in a clinical setting.

Evidence suggests that the IGT assesses “hot” decision making processes, as emotional processing is associated with performance on the task (and is consistent with the somatic marker hypothesis). In fact, some evidence suggests that the risky decision making component of the IGT is more apparent in the last trials of the task (Brand et al. 2007a, b) than in earlier trials. Future research with the IGT should utilize performance across blocks of trials as a basis for comparison between groups in order to further address this possibility. Using only a composite score on the IGT may be a major contributor to the inconsistencies in the IGT literature to date.

With regard to the IGT’s relationship to frontal lobe functioning, individuals with damage to the ventromedial prefrontal cortex, as well as those with large lesions encompassing the frontal lobes, are impaired on the IGT. Individuals with focal dorsolateral and dorsomedial frontal lesions, as well as occipital and temporal lobe lesions, have not shown impairment on the IGT, although patients with amygdala damage do. Functional neuroimaging studies show increased activation to the orbitofrontal cortex during the IGT, which again lends support to its validity as a measure of functioning of the prefrontal cortex and its connections to the amygdala, consistent with the somatic marker hypothesis. Of course, the IGT is a behavioral measure, not a measure of brain structure, and thus is only appropriately used in assessment of frontal lobe dysfunction

in conjunction with other medical and neurological findings as part of a comprehensive assessment.

With regard to its relationship to other measures of executive functioning and decision making, additional research is needed. Mixed results have been found when performance on the IGT is compared to performance on the WCST, the BART, and various working memory tasks. Impairments in cognitive skills that are part of “cold” decision making processes could in fact affect performance on the IGT. Additional studies may be able to help determine the nature of the relationship of the IGT with other tasks, which is crucial to interpretation of IGT findings within the context of a comprehensive clinical assessment.

Evidence for the ecological validity of the IGT is also needed, as it is unclear what the relationship is between performance on the task and in a real-world assessment of decision making. The clinical studies reviewed above do suggest a link between IGT and real-world clinically relevant risky behaviors, including substance use disorders, gambling, and psychopathic behavior. However, further work on behavioral indicators of risk within these populations would also be beneficial. For example, longitudinal studies of treatment naïve substance abusers may demonstrate that IGT performance at the beginning of treatment is related to treatment outcome and relapse, which would also provide ecological validity for the IGT as a measure of risky decision making. In addition, more research is needed on the relation of IGT performance to non-clinical risky decision making and behavior, such as financial or medical risky decision making.

With regard to developmental issues, age-related changes have been shown on the IGT, but results are mixed. Executive functions, and the frontal lobes in general, develop throughout childhood and adolescence. Increases in performance on the IGT, in that more cards were selected from the advantageous decks, were seen with increasing age among children, adolescents, and young adults. Studies with older adults have shown mixed results. Further research is needed to better understand developmental aspects of the IGT, particularly for older adults, and the relationship of IGT performance to other cognitive abilities in the older population.

Although the preponderance of evidence supports the IGT as a measure of risky decision making that may reflect dysfunction of frontal lobe structures or frontal connections, our review also identified three issues important to use of the IGT as a clinical instrument. The first critical issue is that the IGT is a behavioral measure, not a measure of a brain structure, and in fact is a complex behavioral measure assessing a complex construct. As with any neuropsychological instrument, performance on the IGT cannot be interpreted in isolation. The pattern of performance on the

IGT, in concert with performance on other executive functioning measures as well as on other neuropsychological measures including memory and working memory, will need to be interpreted in the context of the patient's history, current mood, personality, other symptoms, neurological findings, etc.

The second critical issue involves reliability/practice effects. A few researchers have utilized a two-time design, and have shown consistent learning effects on the IGT (i.e., performance improves on repeated administrations). Research into the reliability of the IGT itself has yet to be conducted, and was not discussed in the clinical manual (Bechara 2007). As mentioned above, this is critical when considering the use of IGT as a repeated measure in longitudinal research or when clinically interpreting performance on the IGT in a pre/post treatment design.

The third critical issue is the growing evidence for the relationship of personality and state mood to IGT performance. This is of crucial importance in interpreting IGT performance in individuals for whom impulsive or sensation seeking personality tendencies and/or negative mood might well be a factor explaining both engagement in or experience of the clinical behavior and poor IGT performance. In other words, an impulsive/sensation seeking personality may well have lead to the clinical disorder (substance abuse, traumatic brain injury), as well as being associated with poor IGT performance. Thus, interpretation of IGT performance as reflecting only the consequences of the clinical disorder may be inaccurate. There has been little to no acknowledgment to date of the potential contribution of premorbid personality and/or state dependent mood on IGT performance in existing clinical literature. Future research studies using the IGT as a dependent variable should consider the role of premorbid personality characteristics and state mood when interpreting the performance of their participants. In addition, these limitations may affect the IGT's ability to be used effectively as a clinical instrument to judge an individual's performance. At the very least, these findings suggest that concurrent assessment of personality and state mood be part of a clinical evaluation using the IGT, and that the results of such tests be considered when interpreting the clinical significance of IGT findings.

References

- Addison, T. L., & Schmidt, L. A. (1999). Are women who are shy reluctant to take risks? Behavioral and psychophysiological correlates. *Journal of Research in Personality*, 33(3), 352–357.
- Adinoff, B., Devous, M. D., Cooper, D. B., Best, S. E., Chandler, P., Harris, T., et al. (2003). Resting regional cerebral blood flow and gambling task performance in cocaine-dependent subjects and healthy comparison subjects. *American Journal of Psychiatry*, 160, 1892–1894.
- Anderson, S. W., Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1999). Impairment of social and moral behavior related to early damage in human prefrontal cortex. *Nature Neuroscience*, 2(11), 1032–1037.
- Apkarian, A. V., Sosa, Y., Krauss, B. R., Thomas, P. S., Fredrickson, B. E., Levy, R. E., et al. (2004). Chronic pain patients are impaired on an emotional decision-making task. *Pain*, 108, 129–136.
- Arkes, H. R., Herren, L. T., & Isen, A. M. (1988). The role of potential loss in the influence of affect on risk-taking behavior. *Organizational Behavior and Human Decision Processes*, 42(2), 181–193.
- Bark, R., Dieckmann, S., Bogerts, B., & Northoff, G. (2005). Deficit in decision making in catatonic schizophrenia: an exploratory study. *Psychiatry Research*, 134, 131–141.
- Barratt, E. S., Stanford, M. S., Dowdy, L., Liebman, M. J., & Kent, T. A. (1999). Impulsive and premeditated aggression—a factor analysis of self-reported acts. *Psychiatry Research*, 86, 163–173.
- Bartzokis, G., Lu, P. H., Beckson, M., Rapoport, R., Grant, S., Wiseman, E. J., et al. (2000). Abstinence from cocaine reduces high-risk responses on a gambling task. *Neuropsychopharmacology*, 22(1), 102–103.
- Bechara, A. (2003). Risky business: emotion, decision-making, and addiction. *Journal of Gambling Studies*, 19(1), 23–51.
- Bechara, A. (2004). The role of emotion in decision-making: evidence from neurological patients with orbitofrontal damage. *Brain and Cognition*, 55(1), 30–40.
- Bechara, A. (2007). *Iowa gambling task professional manual*. Lutz: Psychological Assessment Resources.
- Bechara, A., & Damasio, H. (2002). Decision-making and addiction (part I): impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologia*, 40, 1675–1689.
- Bechara, A., & Martin, E. M. (2004). Impaired decision making related to working memory deficits in individuals with substance addictions. *Neuropsychology*, 18(1), 152–162.
- Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition*, 50(1–3), 7–15.
- Bechara, A., Tranel, D., Damasio, H., & Damasio, A. R. (1996). Failure to respond autonomically to anticipated future outcomes following damage to prefrontal cortex. *Cerebral Cortex*, 6, 215–225.
- Bechara, A., Damasio, H., Tranel, D., & Anderson, S. W. (1998). Dissociation of working memory from decision making within the human prefrontal cortex. *The Journal of Neuroscience*, 18(1), 428–437.
- Bechara, A., Damasio, H., Damasio, A. R., & Lee, G. P. (1999). Different contributions of the human amygdala and ventromedial prefrontal cortex to decision-making. *The Journal of Neuroscience*, 19, 5473–5481.
- Bechara, A., Damasio, H., & Damasio, A. R. (2000a). Emotion, decision making, and the orbitofrontal cortex. *Cerebral Cortex*, 10(3), 295–307.
- Bechara, A., Tranel, D., & Damasio, H. (2000b). Characterization of the decision-making deficit of patients with ventromedial prefrontal cortex lesions. *Brain*, 123(11), 2189–2202.
- Bechara, A., Dolan, S., Denburg, N., Hinds, A., Anderson, S. W., & Nathan, P. E. (2001). Decision-making deficits, linked to a dysfunctional ventromedial prefrontal cortex, revealed in alcohol and stimulant abusers. *Neuropsychologia*, 39, 376–389.
- Bechara, A., Dolan, S., & Hinds, A. (2002). Decision-making and addiction (part II): myopia for the future or hypersensitivity to reward? *Neuropsychologia*, 40, 1690–1705.
- Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science*, 275, 1293–1295.

- Blair, R. J. R., Colledge, E., & Mitchell, D. G. V. (2001). Somatic markers and response reversal: is there orbitofrontal cortex dysfunction in boys with psychopathic tendencies? *Journal of Abnormal Child Psychology*, 29(6), 499–511.
- Bolla, K. I., Eldreth, D. A., London, E. D., Kiehl, K. A., Mouratidis, M., Contoreggi, C., et al. (2003). Orbitofrontal cortex dysfunction in abstinent cocaine abusers performing a decision-making task. *Neuroimage*, 19, 1085–1094.
- Bolla, K. I., Eldreth, D. A., Matochik, J. A., & Cadet, J. L. (2005). Neural substrates of faulty decision-making in abstinent marijuana users. *Neuroimage*, 26, 480–492.
- Bowden-Jones, H., McPhillips, M., Rogers, R., Hutton, S., & Joyce, E. (2005). Risk-taking on tests sensitive to ventromedial prefrontal cortex dysfunction predicts early relapse in alcohol dependency: a pilot study. *Journal of Neuropsychiatry and Clinical Neuroscience*, 17(3), 417–420.
- Bowman, C. H., & Turnbull, O. H. (2003). Real versus facsimile reinforcers on the Iowa gambling task. *Brain and Cognition*, 53, 207–210.
- Bowman, C. H., Evans, C. E. Y., & Turnbull, O. H. (2005). Artificial time constraints on the Iowa gambling task: the effects of behavioural performance and subjective experience. *Brain and Cognition*, 57, 21–25.
- Brand, M., Kalbe, E., Labudda, K., Fujiwara, E., Kessler, J., & Markowitsch, H. J. (2005). Decision-making impairments in patients with pathological gambling. *Psychiatry Research*, 133(1), 91–99.
- Brand, M., Grabenhorst, F., Starcke, K., Vandekerckhove, M. M. P., & Markowitsch, H. J. (2007a). Role of the amygdala in decisions under ambiguity and decisions under risk: evidence from patients with Urbach-Wiethe disease. *Neuropsychologia*, 45, 1305–1317.
- Brand, M., Recknor, E. C., Grabenhorst, F., & Bechara, A. (2007b). Decisions under ambiguity and decisions under risk: correlations with executive functions and comparisons of two different gambling tasks with implicit and explicit rules. *Journal of Clinical and Experimental Neuropsychology*, 29, 86–99.
- Campbell, M. C., Stout, J. C., & Finn, P. R. (2004). Reduced autonomic responsiveness to gambling task losses in Huntington's disease. *Journal of the International Neuropsychological Society*, 10, 239–245.
- Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology*, 28(2), 595–616.
- Carter, S., & Pasqualini, M. C. S. (2004). Stronger autonomic response accompanies better learning: a test of Damasio's somatic marker hypothesis. *Cognition and Emotion*, 18, 901–911.
- Cavallaro, R., Cavedini, P., Mistretta, P., Bassi, T., Angelone, S. M., Ubbiali, A., et al. (2003). Basal-cortico-frontal circuits in schizophrenia and obsessive-compulsive disorder: a controlled, double dissociation study. *Biological Psychiatry*, 54, 437–443.
- Cavedini, P., Riboldi, G., Keller, R., D'Annunzi, A., & Bellodi, L. (2002). Frontal lobe dysfunction in pathological gambling patients. *Biological Psychiatry*, 51, 334–341.
- Cavedini, P., Bassi, T., Ubbiali, A., Casolari, A., Giordani, S., Zorzi, C., et al. (2004). Neuropsychological investigation of decision-making in anorexia nervosa. *Psychiatry Research*, 127(3), 259–266.
- Ciarrochi, J. W. (1993). Rates of pathological gambling in publicly funded outpatient substance abuse treatment. *Journal of Gambling Studies*, 9, 289–293.
- Clark, L., Manes, F., Antoun, N., Sahakian, B. J., & Robbins, T. W. (2003). The contributions of lesion laterality and lesion volume to decision-making impairment following frontal lobe damage. *Neuropsychologia*, 41, 1474–1483.
- Cronbach, L. J., & Meehl, P. E. (1955). Construct validity in psychological tests. *Psychological Bulletin*, 32, 281–302.
- Crone, E. A., & van der Molen, M. W. (2004). Developmental changes in real life decision making: performance on a gambling task previously shown to depend on the ventromedial prefrontal cortex. *Developmental Neuropsychology*, 25(3), 251–279.
- Crone, E. A., Vendel, I., & van der Molen, M. W. (2003). Decision-making in disinhibited adolescents and adults: insensitivity to future consequences or driven by immediate reward? *Personality and Individual Differences*, 35(7), 1625–1641.
- Crone, E. A., Somsen, R. J. M., van Beek, B., & van der Molen, M. W. (2004). Heart rate and skin conductance analysis of antecedents and consequences of decision making. *Psychophysiology*, 41, 531–540.
- Czernecki, V., Pillon, B., Houeto, J. L., Pochon, J. B., Levy, R., & Dubois, B. (2002). Motivation, reward, and Parkinson's disease: influence of dopatherapy. *Neuropsychologia*, 40, 2257–2267.
- Damasio, A. R. (1994). *Descartes' error*. New York: Grosset/Putnam.
- Davis, C., Levitan, R. D., Muglia, P., Bewell, C., & Kennedy, J. L. (2004). Decision-making deficits and overeating: a risk model for obesity. *Obesity Research*, 12(6), 929–935.
- Denburg, N. L., Tranel, D., & Bechara, A. (2005). The ability to decide advantageously declines prematurely in some normal older adults. *Neuropsychologia*, 43, 1099–1106.
- Denburg, N. L., Recknor, E. C., Bechara, A., & Tranel, D. (2006). Psychophysiological anticipation of positive outcomes promotes advantageous decision-making in normal older persons. *International Journal of Psychophysiology*, 61, 19–25.
- Ernst, M., Bolla, K., Mouratidis, M., Contoreggi, C., Matochik, J. A., Kurian, V., et al. (2002). Decision-making in a risk-taking task: a PET study. *Neuropsychopharmacology*, 26, 682–691.
- Ernst, M., Grant, S. J., London, E. D., Contoreggi, C. S., Kimes, A. S., & Spurgeon, L. (2003a). Decision making in adolescents with behavior disorders and adults with substance abuse. *American Journal of Psychiatry*, 160, 33–40.
- Ernst, M., Kimes, A. L., London, E. D., Matochik, J. A., Eldreth, D., Tata, S., et al. (2003b). Neural substrates of decision making in adults with attention deficit hyperactivity disorder. *American Journal of Psychiatry*, 160, 1061–1070.
- Eslinger, P. J., & Damasio, A. R. (1985). Severe disturbance of higher cognition after bilateral frontal lobe ablation: patient EVR. *Neurology*, 35, 1731.
- Evans, C. E. Y., Bowman, C. H., & Turnbull, O. H. (2005). Subjective awareness on the Iowa gambling task: the key role of emotional experience in schizophrenia. *Journal of Clinical and Experimental Neuropsychology*, 27, 656–664.
- Fein, G., Klein, L., & Finn, P. (2004). Impairment on a simulated gambling task in long-term abstinent alcoholics: neurobiological, behavioral, and environmental relations to drinking. *Alcoholism: Clinical and Experimental Research*, 28(10), 1487–1491.
- Fein, G., McGillivray, S., & Finn, P. (2007). Older adults make less advantageous decisions than younger adults: cognitive and psychological correlates. *Journal of the International Neuropsychological Society*, 13, 480–489.
- Fellows, L. K. (2004). The cognitive neuroscience of human decision making: a review and conceptual framework. *Behavioral and Cognitive Neuroscience Reviews*, 3, 159–172.
- Fellows, L. K., & Farah, M. J. (2005). Different underlying impairments in decision-making following ventromedial and dorsolateral frontal lobe damage in humans. *Cerebral Cortex*, 15(1), 58–63.
- Fernie, G., & Tunney, R. J. (2006). Some decks are better than others: the effect of reinforcer type and task instructions on learning in the Iowa gambling task. *Brain and Cognition*, 60, 94–102.
- Field, M., Santarcangelo, M., Sumnall, H., Goudie, A., & Cole, J. (2006). Delay discounting and the behavioral economics of cigarette purchases in smokers: the effects of nicotine deprivation. *Psychopharmacology*, 186, 255–263.
- Finucane, M. L., Alhakami, A., Slovic, P., & Johnson, S. M. (2000). The affect heuristic in judgments of risks and benefits. *Journal of Behavioral Decision Making*, 13(1), 1–17.

- Fishbein, D., Hyde, C., Eldreth, D., London, E. D., Matochik, J., Ernst, M., et al. (2005). Cognitive performance and autonomic reactivity in abstinent drug abusers and nonusers. *Experimental and Clinical Psychopharmacology*, 13(1), 25–40.
- Franken, I. H. A., & Muris, P. (2005). Individual differences in decision-making. *Personality and Individual Differences*, 39(5), 991–998.
- Garon, N., & Moore, C. (2004). Complex decision-making in early childhood. *Brain and Cognition*, 55, 158–170.
- Garon, N., & Moore, C. (2007). Developmental and gender differences in future-oriented decision-making during the preschool period. *Child Neuropsychology*, 13, 46–63.
- Goudriaan, A. E., Oosterlaan, J., de Beurs, E., & Van den Brink, W. (2004). Pathological gambling: a comprehensive review of biobehavioral findings. *Neuroscience and Biobehavioral Reviews*, 28, 123–141.
- Goudriaan, A. E., Oosterlaan, J., de Beurs, E., & van den Brink, W. (2005). Decision making in pathological gambling: a comparison between pathological gamblers, alcohol dependents, persons with Tourette syndrome, and normal controls. *Cognitive Brain Research*, 23, 137–151.
- Grady, C. L., Springer, M. V., Hongwanishkul, D., McIntosh, A. R., & Winocur, G. (2006). Age-related changes in brain activity across the adult lifespan. *Journal of Cognitive Neuroscience*, 18, 227–241.
- Grant, S., Bonson, K. R., Contoreggi, C., & London, E. D. (1999). Activation of the ventromedial prefrontal cortex correlates with gambling task performance: a FDG-PET study. *Society for Neuroscience Abstracts*, 25, 1551.
- Grant, S., Contoreggi, C., & London, E. D. (2000). Drug abusers show impaired performance in a laboratory test of decision making. *Neuropsychologia*, 38, 1180–1187.
- Grisham, J. R., Brown, T. A., Savage, C. R., Steketee, G., & Barlow, D. H. (2007). Neuropsychological impairment associated with compulsive hoarding. *Behaviour Research and Therapy*, 45, 1471–1483.
- Hardy, D. J., Hinkin, C., Levine, A. J., Castellon, S. A., & Lam, M. N. (2006). Risky decision making assessed with the gambling task in adults with HIV. *Neuropsychology*, 20(3), 355–360.
- Harmen, H., Bischoff, G., Brooks, A., Hohagen, F., & Rumpf, H. J. (2006). The relationship between impaired decision-making, sensation seeking, and readiness to change in cigarette smokers. *Addictive Behaviors*, 31, 581–592.
- Hooper, C. J., Luciana, M., Conklin, H. M., & Yarger, R. S. (2004). Adolescents performance on the Iowa gambling task: implications for the development of decision making and ventromedial prefrontal cortex. *Developmental Psychology*, 40(6), 1148–1158.
- Johnson, E. J., & Tversky, A. (1983). Affect, generalization, and the perception of risk. *Journal of Personality and Social Psychology*, 45(1), 20–31.
- Kerr, A., & Zelazo, P. D. (2004). Development of 'hot' executive function: the children's gambling task. *Brain and Cognition*, 55, 148–157.
- Lawrence, N. S., Wooderson, S., Mataix-Cols, D., David, R., Speckens, A., & Phillips, M. L. (2006). Decision making and set shifting impairments are associated with distinct symptoms dimensions in obsessive-compulsive disorder. *Neuropsychology*, 20(4), 409–419.
- Lehto, J. E., & Elorinne, E. (2003). Gambling as an executive function task. *Applied Neuropsychology*, 10(4), 234–238.
- Lejuez, C. W., Read, J. P., Kahler, C. W., Richards, J. B., Ramsey, S. E., Stuart, G. L., et al. (2002). Evaluation of a behavioral measure of risk taking: the Balloon Analogue Risk Task (BART). *Journal of Experimental Psychology: Applied*, 8, 75–84.
- Lejuez, C. W., Aklin, W. M., Jones, H. A., Strong, D. R., Richards, J. B., Kahler, C. W., et al. (2003). The balloon analogue risk task (BART) differentiates smokers and nonsmokers. *Experimental and Clinical Psychopharmacology*, 11, 26–33.
- Linnet, J., Rojksjaer, S., Nygaard, J., & Maher, B. A. (2006). Episodic chasing in pathological gamblers using the Iowa gambling task. *Scandinavian Journal of Psychology*, 47, 43–49.
- Losel, F., & Schmucke, M. (2004). Psychopathy, risk taking, and attention: a differentiated test of the somatic marker hypothesis. *Journal of Abnormal Psychology*, 113(4), 522–529.
- Malloy-Diniz, L., Fuentes, D., Borges Leite, W., Correa, H., & Bechara, A. (2007). Impulsive behavior in adults with attention deficit/hyperactivity disorder: characterization of attentional, motor and cognitive impulsiveness. *Journal of the International Neuropsychological Society*, 13, 693–698.
- Manes, F., Sahakian, B., Clark, L., Rogers, R., Antoun, N., Aitken, M., et al. (2002). Decision-making processes following damage to the prefrontal cortex. *Brain*, 125, 624–639.
- Martin, E. M., Pitrak, D. L., Weddington, W., Rains, N. A., Nunnally, G., Nixon, H., et al. (2004). Cognitive impulsivity and HIV serostatus in substance dependent males. *Journal of the International Neuropsychological Society*, 10, 931–938.
- Midanik, L. T., Tam, T. W., & Weisner, C. (2007). Concurrent and simultaneous drug and alcohol use: results of the 2000 national alcohol survey. *Drug and Alcohol Dependence*, 90, 72–80.
- Mintzer, M. Z., & Stitzer, M. L. (2002). Cognitive impairment in methadone maintenance patients. *Drug and Alcohol Dependence*, 67, 41–51.
- Mitchell, D. G. V., Colledge, E., Leonard, A., & Blair, R. J. R. (2002). Risky decisions and response reversal: is there evidence of orbitofrontal cortex dysfunction in psychopathic individuals? *Neuropsychologia*, 40(12), 2013–2022.
- Mongini, F., Keller, R., Deregibus, A., Barbalonga, E., & Mongini, T. (2005). Frontal lobe dysfunction in patients with chronic migraine: a clinical-neuropsychological study. *Psychiatry Research*, 133, 101–106.
- Monterosso, J., Ehrman, R., Napier, K. L., O'Brien, C. P., & Childress, A. R. (2001). Three decision-making tasks in cocaine-dependent patients: do they measure the same construct? *Addiction*, 96, 1825–1837.
- Must, A., Szabo, Z., Bodi, N., Szasz, A., Janka, Z., & Keri, S. (2006). Sensitivity to reward and punishment and the prefrontal cortex in major depression. *Journal of Affective Disorders*, 90(2–3), 209–215.
- Nygren, T. E. (1998). Reacting to perceived high- and low-risk win-lose opportunities in a risky decision-making task: is it framing or affect or both? *Motivation and Emotion*, 22, 73–98.
- Overman, W. H., Frassrand, K., Ansel, S., Trawalter, S., Bies, B., & Redmond, A. (2004). Performance on the IOWA card task by adolescents and adults. *Neuropsychologia*, 42, 1838–1851.
- Perretta, J. G., Pari, G., & Beninger, R. J. (2005). Effects of Parkinson disease on two putative nondeclarative learning tasks: probabilistic classification and gambling. *Cognitive and Behavioral Neurology*, 18(4), 185–192.
- Pirastu, R., Fais, R., Messina, M., Bini, V., Spiga, S., Falconieri, D., et al. (2006). Impaired decision-making in opiate-dependent subjects: effect of pharmacological therapies. *Drug and Alcohol Dependence*, 83, 163–168.
- Rauch, S. L. (2000). Neuroimaging research and the neurobiology of obsessive-compulsive disorder: where do we go from here? *Biological Psychiatry*, 47, 168–170.
- Rhodes, M. G. (2004). Age-related differences in performance on the Wisconsin card sorting test: a meta-analytic review. *Psychology and Aging*, 19, 482–494.
- Ritter, L. M., Meador-Woodruff, J. H., & Dalack, G. W. (2004). Neurocognitive measures of prefrontal cortical dysfunction in schizophrenia. *Schizophrenia Research*, 68, 65–73.
- Rodriguez-Sanchez, J. M., Crespo-Facorro, B., Iglesias, R. P., Bosch, C. G. B., Alvarez, M., Llorca, J., et al. (2005). Prefrontal

- cognitive functions in stabilized first-episode patients with schizophrenia spectrum disorders: a dissociation between dorso-lateral and orbitofrontal functioning. *Schizophrenia Research*, 77, 279–288.
- Ross, S. R., Benning, S. D., & Adams, Z. (2007). Symptoms of executive dysfunction are endemic to secondary psychopathy: an examination in criminal offenders and noninstitutionalized young adults. *Journal of Personality Disorders*, 21, 384–399.
- Rotherham-Fuller, E., Shoptaw, S., Berman, S. M., & London, E. D. (2004). Impaired performance in a test of decision-making by opiate-dependent tobacco smokers. *Drug and Alcohol Dependence*, 73, 79–86.
- Schmitt, W. A., Brinkley, C. A., & Newman, J. P. (1999). Testing Damasio's somatic marker hypothesis with psychopathic individuals: risk takers or risk averse? *Journal of Abnormal Psychology*, 108(3), 538–543.
- Schutter, D. J. L. G., & van Honk, J. (2005). Electrophysiological ratio markers for the balance between reward and punishment. *Cognitive Brain Research*, 24, 685–690.
- Segalowitz, S. J., & Davies, P. L. (2004). Charting the maturation of the frontal lobe: an electrophysiological strategy. *Brain and Cognition*, 55, 116–133.
- Seguin, J. R., Arseneault, L., & Tremblay, R. E. (2007). The contribution of “cool” and “hot” components of decision-making in adolescence: implications for developmental psychopathology. *Cognitive Development*, 22, 530–543.
- Shurman, B., Horan, W. P., & Nuechterlein, K. H. (2005). Schizophrenia patients demonstrate a distinctive pattern of decision-making impairment on the Iowa gambling task. *Schizophrenia Research*, 72, 215–224.
- Stout, J. C., Rodawalt, W. C., & Siemers, E. R. (2001). Risky decision making in Huntington's disease. *Journal of the International Neuropsychological Society*, 7, 92–101.
- Stout, J. C., Busemeyer, J. R., Lin, A., Grant, S. J., & Bonson, K. R. (2004). Cognitive modeling analysis of decision-making processes in cocaine abusers. *Psychonomic Bulletin and Review*, 11, 742–747.
- Stout, J. C., Rock, S. L., Campbell, M. C., Busemeyer, J. R., & Finn, P. R. (2005). Psychological processes underlying risky decisions in drug abusers. *Psychology of Addictive Behaviors*, 19(2), 148–157.
- Strauss, E., Sherman, E. M. S., & Spreen, O. (2006). *A compendium of neuropsychological tests: Administration, norms, and commentary*. New York: Oxford University Press.
- Suhr, J. A., & Tsanadis, J. (2007). Affect and personality correlates of the Iowa gambling task. *Personality and Individual Differences*, 43, 27–36.
- Tranel, D., Bechara, A., & Denburg, N. L. (2002). Asymmetric functional roles of right and left ventromedial prefrontal cortices in social conduct, decision-making, and emotional processing. *Cortex*, 38, 589–612.
- Tucker, K. A., Potenza, M. N., Beauvais, J. E., Browndyke, J. N., Gottschalk, P. C., & Kosten, T. R. (2004). Perfusion abnormalities and decision making in cocaine dependence. *Biological Psychiatry*, 56, 527–530.
- Turnbull, O. H., Evans, C. E. Y., Bunce, A., Carzolio, B., & O'Connor, J. (2005). Emotion-based learning and central executive resources: an investigation of intuition and the Iowa gambling task. *Brain and Cognition*, 57, 244–247.
- Van den Bos, R., Houx, B. B., & Spruijt, B. M. (2006). The effect of reward magnitude differences on choosing disadvantageous decks in the Iowa gambling task. *Biological Psychology*, 71, 155–161.
- van Honk, J., Hermans, E. J., Putman, P., Montagne, B., & Schutter, D. J. (2002). Defective somatic markers in sub-clinical psychopathy. *Neuroreport*, 13(8), 1025–1027.
- Verdejo-Garcia, A., & Perez-Garcia, M. (2007). Profile of executive deficits in cocaine and heroin polysubstance users: common and differential effects on separate executive components. *Psychopharmacology*, 190, 517–530.
- Verdejo-Garcia, A., Vilar-Lopez, R., Perez-Garcia, M., Podell, K., & Goldberg, E. (2006). Altered adaptive but not veridical decision-making in substance dependent individuals. *Journal of the International Neuropsychological Society*, 12, 90–99.
- Verdejo-Garcia, A., Benbrook, A., Funderburk, F., David, P., Cadet, J.-L., & Bolla, K. I. (2007). The differential relationship between cocaine use and marijuana use on decision-making performance over repeat testing with the Iowa Gambling Task. *Drug and Alcohol Dependence*, 90, 2–11.
- Whitlow, C. T., Liguori, A., Livengood, L. B., Hart, S. L., Mussat-Whitlow, B. J., Lamborn, C. M., et al. (2004). Long-term heavy marijuana users make costly decisions on a gambling task. *Drug and Alcohol Dependence*, 76, 107–111.
- Whitney, K. A., Fastenau, P. S., Evans, J. D., & Lysaker, P. H. (2004). Comparative neuropsychological function in obsessive-compulsive disorder and schizophrenia with and without obsessive-compulsive symptoms. *Schizophrenia Research*, 69, 75–83.
- Wilder, K. E., Weinberger, D. R., & Goldberg, T. E. (1998). Operant conditioning and the orbitofrontal cortex in schizophrenic patients: unexpected evidence for intact functioning. *Schizophrenia Research*, 30, 169–174.
- Windmann, S., Kirsch, P., Mier, D., Stark, R., Walter, B., Gunturkun, O., et al. (2006). On framing effects in decision making: linking lateral versus medial orbitofrontal cortex activation to choice outcome processing. *Journal of Cognitive Neuroscience*, 18(7), 1198–1211.
- Wood, S., Busemeyer, J., Koling, A., Cox, C. R., & Davis, H. (2005). Older adults as adaptive decision makers: evidence from the Iowa gambling task. *Psychology and Aging*, 20(2), 220–225.
- Yechiam, E., Stout, J. C., Busemeyer, J. R., Rock, S. L., & Finn, P. R. (2005). Individual differences in the response to forgone payoffs: an examination of high functioning drug abusers. *Journal of Behavioral Decision Making*, 18, 97–110.
- Zang, Y. F., Jin, Z., Weng, X. C., Zhang, L., Zeng, Y. W., Yang, L., et al. (2005). Functional MRI in attention-deficit hyperactivity disorder: evidence for hypofrontality. *Brain & Development*, 27, 544–550.
- Zimak, E., Suhr, J., Fox, L., & Riddle, T (February, 2008). ADHD diagnosis, ADHD symptoms, and risky behavior. Presented at the International Neuropsychological Society conference, Kona, HI.
- Zimmerman, M. E., Brickman, A. M., Paul, R. H., Grieve, S. M., Tate, D. F., & Gunstad, J. (2006). The relationship between frontal gray matter volume and cognition varies across the healthy adult lifespan. *American Journal of Geriatric Psychiatry*, 14, 823–833.