Examining the Role of Attention in the Iowa Gambling Task

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In this study, we examined the role of executive function and attention on *Iowa Gambling Task* (IGT) performance. In Experiment 1, we used a number monitoring task to place a load on attention, and a random number generation task to place a load on both attention and executive function to examine the relationship with IGT performance. Results showed that disrupting attention alone resulted in impaired IGT performance, but disrupting both attention and executive function resulted in no further impairment. In Experiment 2, we extended these findings by examining the contribution of attentional networks to IGT performance. We found that of the three networks described by Fan, McCandliss, Sommer, Raz, and Posner (2002), only the alerting network made a significant contribution to performance.

Keywords: Iowa Gambling Task, executive function, attention, Attentional Network Task

The *Iowa Gambling Task* (IGT) is a psychological assessment introduced by Bechara, Damasio, Damasio, and Anderson (1994) as a means of studying decision-making skills in patients who had suffered damage to the ventro-medial prefrontal cortex. The real-time gambling task mimics real-life decision-making situations, via monetary rewards and punishments (Bechara, 2017). In the task, participants receive a loan of $2,000 in facsimile money and are presented with four decks of cards. They select cards from the decks with the goal of maximizing their gains and minimizing their losses. Within each deck, all of the cards provide a monetary reward and a potential punishment, each of which is either a “bad” deck (i.e., disadvantageous) or a “good’ deck (i.e., advantageous). For each card drawn, participants see the amount gained, the amount lost, and a running total of the amount under or over the original $2,000. The purpose of the IGT is to determine if participants, through a trial-and-error process, learn that the good decks are more advantageous than the

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bad decks in the long run. Neuro-typical adults are typically able to find success in this manner by navigating to the good decks, while those with brain dysfunction may continue with the bad decks, even as the disadvantage becomes apparent.

As a result, the IGT inspired considerable interest in studying impairments in decision-making and is used in both clinical and research settings (e.g., Brevers, et al., 2012; Suhr & Hammers, 2010). For instance, the IGT has been used to study disease progression and the effect of treatment on Parkinson's disease (Evens, Hoeflier, Biber, & Lueken, 2016); the effects of brain injury on decision making (Ouerchefani, Ourchefani, Allain, Ben Rejeb, & Le Gall, 2018); and performance by participants who were diagnosed with mental/behavioral disorders such as psychosis (Woodrow, Sparks, Bobrovskala, Paterson, Murphey & Hutton, 2019). More recently, it has been used in studying excessive disorders such as gambling, alcohol use, violence and social media use (Kovacs, Richman, Janka, Maraz,& Ando, 2017; Meshi, Elizarova, Bender, & Verdejo-Garcia, 2019; Umbach, Leonard, Luciana, Ling, & Laitner, 2019).

Although the IGT is a frequently used measure of decision-making, the mechanisms underlying IGT performance require further study. For instance, executive functions (i.e. generalized control mechanisms that support and coordinate more complex cognitive functions; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000) play a role in an individual's IGT performance. However, it is not clear which executive functions are important for optimal performance or what happens to performance when these functions are compromised. Studies correlating performance on the IGT with various measures of executive function provided contradictory results. For example, Lehto and Elorinne (2003) found no correlation between performance on the *Wisconsin Card Sorting Task* (WCST), a neuropsychological test, and the IGT. Similarly, Van der Plas et al. (2009) examined the relationship between IGT performance and performance on measures of task switching, working memory, response inhibition, and cognitive flexibility. Of these, only the working memory scores were predictive of IGT performance. In contrast, Brand, Recknor, Grabenhorst and Bechara (2007) found that the WCST did correlate with performance on the last three blocks of the IGT.

Furthermore, there is evidence that cognitive processes other than executive functions also influence IGT performance. For example, Hinson, Jameson and Whitney (2002) used both a digit load task and a random number generation task to demonstrate that working memory load interfered with IGT performance. In a later study, Jameson, Hinson, and Whitney (2004) found that engaging in a working memory task impaired IGT performance. Findings by Cui, Wang, Shi, Liu & Chen

(2015) and Ouerchefani, Ourchefani, Allain, Ben Rejeb, & Le Gall (2018) also support the role of working memory as a contributor to IGT performance, but the exact role is still unclear.

In addition, research indicates that attention (that is, the use of limited cognitive resources to interpret and use incoming perceptual information; Pashler, 1998) plays an important role in IGT performance. For example, Stocco, Fum, and Napoli (2009) had participants complete the IGT while engaging in a secondary task, in which the participants listened to a string of spoken numbers and determined if each number was odd or even. Participants completed the traditional 100 draws on the IGT followed by a 20 choice blind phase during which they received no feedback as to gains or losses. The authors discovered that if the secondary task occurred during the first phase (i.e., the 100 draws) performance was impaired in both phases. However, if the secondary task implementation occurred during the second phase, performance was not impaired. The authors hypothesized that the inability to allocate sufficient attentional resources to the IGT was a principal source of learning impairment on the task.

Gansler, Jerram, Vannorsdall, and Schretlen (2011) examined IGT performance using an *a priori* six factor hierarchical model of neuropsychological functioning. The researchers had 249 healthy participants complete the IGT plus a number of neuropsychological and clinical assessments (e.g., the *Connors Continuance Performance Task*, seven subsets of the *Wechsler Adult Intelligence Scales*-4th edition revised, and the *Trail Making Tests* parts A & B) and conducted a latent variable analysis on the results. The authors found that overall measures of attention exerted a large influence on performance, whereas executive functions showed an influence only in draws 41-100. Even then, the effect was moderate with attention accounting for a greater percentage of performance variance than executive function.

Although the idea of executive functions plays a crucial role in clinical and experimental psychology, the definitions are not always consistent. Typically, executive functions are defined as the processes that regulate voluntary behavior and are linked to frontal lobe functioning (Carlson, 2005; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010). These include inhibition or proponent responses, ability to shift mental sets, and goal maintenance, among others. Although specific definitions of working memory differ, it is commonly considered to be related to maintaining and manipulation of information for brief periods of time (Balldey, 1986; Unsworth & Engle, 2007). Using multiple assessments of both working memory and various executive functions, McCabe et al. (2010) concluded that the working memory and executive functions share an underlying component, attention, that accounts for much of the shared variance between the constructs. Because cognitive functions are not process pure, it can be difficult to tease out which functions contribute to specific task performance. For our first experiment, we chose to use the dual task paradigm.

The dual-task paradigm

Dual tasks are a key method to study the impact of interference with attention, working memory, and executive functions (Baddeley, 2007; Coomans, Vandenboossche, & Deroost, 2014). Placing a load on cognitive functions that are essential to a task, compromises task performance when compared to a no-load condition. Increased levels of research into cognitive functions resulted in the development of numerous types of secondary tasks. Divided attention tasks involve presentation of a distracter that requires frequent responses and is presented at the same time as the primary task (Mulligan & Peterson, 2008). According to the central-bottle neck model of dual-task performance, encoding of information requires a central resource that also influences response selection and memory retrieval. Frequent responses to distracter items will occupy the central bottleneck during data encoding, and presenting a secondary task in a different modality than the primary task enhances this effect.

A number-monitoring task is frequently used in dual task research. This task has a low error rate but high processing demands that tend to disrupt encoding of information (Park, Smith, Dudley & Lafronza, 1989). Performance on number monitoring tasks tend to be unaffected by experimental condition or age, making such tasks useful for a variety of research situations. Furthermore, monitoring tasks require only that participants keep a tally of the number of items that meet a criterion, rather than having to remember the items themselves (Fernandes & Moscovitch, 2000). Consequently, number monitoring tasks disrupt attention without affecting other cognitive processes.

The random number generation task (RNG) is also frequently used in dual-task research (Peters, Gisbrecht, Jelcic, & Merckelbach, 2007). RNG tasks vary in set sizes (e.g. 0-9), pacing techniques (e.g. use of a metronome), and response modalities (e.g. spoken, written). In whatever form, RNG is a complex task that loads on several executive functions. The task affects executive functions by requiring the participant to suppress stereotyped responses (inhibition) and to track and update responses (updating). Therefore, the RNG is a useful tool for testing how placing a load on executive functions affects IGT performance.

Because of the interrelated nature of cognitive resources in general, we chose to use a numbering monitoring task and a random number generation task. By selecting a task that divides attention without compromising other cognitive functions (number monitoring) and comparing IGT performance under this condition to performance under a condition in which attention and executive functions are compromised, we expect to show that once attentional capacity is reduced, placing a load on executive functions causes little additional reduction in IGT performance. Under a no-load condition, we expect IGT performance to mirror the established performance parameters of neurotypical adults and, consequently be significantly higher than in either of the dual-task conditions.

EXPERIMENT 1

In Experiment1, we examined how a number monitoring task and a RNG task influenced IGT performance. We compared the results of the dual-task conditions to each other and to the results of a no-load condition.

Method

Participants

A power analysis indicated that for three groups, an N of 52 was acceptable for an anticipated medium effect size, and this was confirmed using Cohen's (1992) primer regarding power analysis. Ninety undergraduate students participated in the study and were randomly assigned to one of three groups. Participants consisted of 56 females and 34 males. The average age was 21.3 years. Participants were screened for disorders known to affect performance on the IGT (e.g. mood disorders) and the data of 3 participants were excluded based on this screening, leaving a total of 87 participants (29 per condition).

Materials Iowa Gambling Task. The IGT is a simulated computerized gambling assessment that mimics real-life decision making. In this task, the participants received $2,000 in play money and instructions to play a particular card game using four decks of cards so that they lose the least amount of money while winning the most. Turning a card carries either a reward or a penalty or both. Two decks carried large rewards and penalties while the other two decks had smaller rewards but also carried smaller penalties. Playing from the disadvantageous decks led to long-term net loss, while playing from the advantageous decks led to a long-term net gain. The participants had no way to calculate the net gain or loss from each deck. The participants also had no way of predicting when a penalty would arise and no way of knowing how long they would have to play the game. The computerized IGT is identical to the original IGT except that the money amounts, gains, and losses are reported and recorded by the computer. The task is programmed in PEBL, simple programming language for creating and conducting many standard experiments. It is free software, licensed under the GPL, with both the compiled executables and source code available without charge.

Number monitoring task. In this task, participants heard numbers through a set of headphones and were asked to click a hand-held counter whenever they heard a number containing the number 3 (e.g., 13, 23, 33). The numbers were all spoken in a female voice and presented at 4-second intervals using Windows Media Player.

Random number generation task. Participants were required to produce random numbers at 750 millisecond intervals, as indicated by a digital metronome, throughout the IGT (Knott & Dewhurst, 2007). The participants were instructed to think of each number as being independent of the preceding numbers. Additionally, the numbers were not to have any obvious relationship to each other (i.e. familiar sequences or counting by increments), and participants were not restricted to using a set range of numbers (e.g., only numbers 1-10).

Procedure

Participants were tested individually in a quiet room during a 45-minute time period. Before beginning the session, each participant completed an informed consent and a demographic form. The single-task group completed the IGT without engaging in a simultaneous secondary task. The number-monitoring group received further instructions for the number-monitoring task and then completed the IGT while engaging in the task. The RNG group completed the IGT but was required simultaneously to produce random numbers at 725 milliseconds as timed by an electronic metronome. All participants were debriefed after completing the study.

Results and Discussion

Eighty-seven undergraduate students were randomly assigned to the single-task (ST) group, the random number generation group (RNG) or number monitoring group (NM). The responses were scored using the traditional method designed by Bechara, Damasio, Damasio, and Anderson (1994) in which the number of cards drawn from decks C and D (i.e., the good decks) are subtracted from the number of cards drawn from decks A & B (i.e., the bad decks).

An analysis of variance (ANOVA) with condition as a between-subjects variable revealed that IGT performance differed as a function of condition, F (2, 85) = 17.98, $p < .001$, $ή_p^2 = .620$ (see Figure 1). Planned comparisons revealed significant differences between the RNG condition and the ST condition, (t = 12.26; $p < .001$) and between the NM condition and the ST condition (t = 7.75; $p < .001$). However, there was no significant difference in IGT performance between the RNG condition and the NM condition (t = 1.04; p = .313), indicating that the RNG task (executive function task) and NM task (attentional task) resulted in equal impairments in IGT performance.

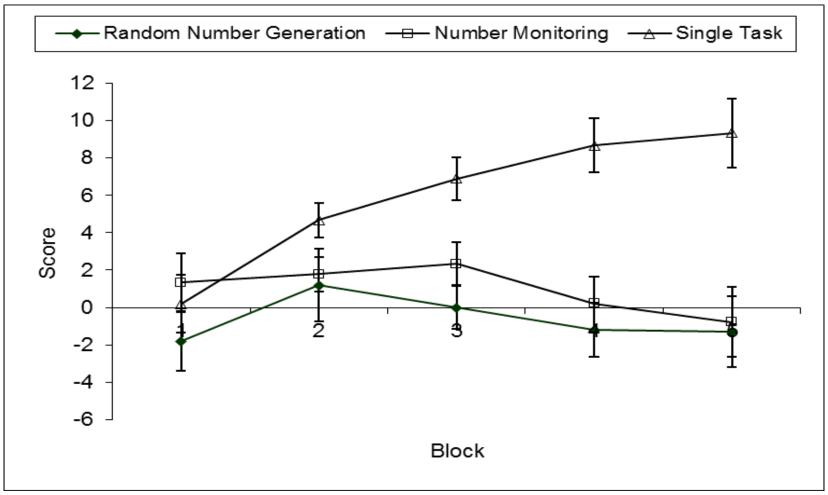

Figure 1. IGT performance by block based on task condition

To summarize, we used a dual-task paradigm to compare IGT performance under a normal condition (i.e. single task), a divided attention condition (i.e. number monitoring), and a condition in which a load was placed on both attention resources and executive function (i.e. random number generation). Results showed that both the random number generation and the number monitoring tasks disrupted IGT performance, with performance in the dual-task groups decreasing as the task progressed. Because the RNG task places a load on multiple cognitive resources, it is presumably more demanding than the number-monitoring task. However, there was no significant difference in performance between the two dual-task groups. Given that the RNG depletes attentional resources as well as EF resources, these results suggest that disrupting attention is sufficient to impair IGT performance, and placing a load on executive functions does little to impair performance further. These results support Gansler et al.'s (2011) hypothesis that IGT is a multi-trait task that involves attentional domains to a greater extent than executive function.

Attentional networks Attention is a goal-oriented process related to selecting relevant information from incoming sensory stimuli (Mackie, Van Dam, & Fan, 2013) and is a primary component of cognitive control. Fan, Wu, Fossella, and Posner (2001) identified three separate neural systems that comprise the single concept of attention: the alerting network, the orienting network, and the executive control network. Imaging studies support this conceptualization. The alerting network depends largely on the frontal and parietal lobes in the right hemisphere on the brain whereas the parietal lobe and the subcortical structures associated with eye movement make up the orienting network. The executive control network relies on anterior cingulate and lateral prefrontal cortex of the brain. Although attentional networks have been mapped using neuroimaging, research tying each network to specific behavioral and cognitive process is still lacking. In a second experiment, we examined the relationship between attention networks and IGT performance using the *Attentional Network Test* (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002). The ANT examines three separate, independent functional components of attention (Fan et al., 2002; Fan, Gu, Guise, Liu, Fossella, Wang, & Posner, 2009).

EXPERIMENT 2

In Experiment 2, we used the *Attentional Network Test* to explore the contributions of the alerting, orienting, and executive control networks to IGT performance.

Method

Participants Forty seven undergraduate students participated in the study. Participants consisted of 29 females and 16 males. The average age was 22.7 years. Participants were screened for disorders known to affect performance on the IGT (e.g., mood disorders), and none of the participants were excluded based on this screening. We then used a bootstrapping technique to expand the original sample to 461. Bootstrapping techniques basically resample results from completed studies and is acceptable for conducting analyses such as analysis of variance, regression coefficients, odds ratios, and multivariate statistics (Singh & Xie, n.d.)

Materials *Iowa Gambling Task.* (same as described in Experiment 1). *Attentional Network Test (ANT).* The ANT was designed to identify the three attentional networks drawing from the use of flanker tasks and cuing tasks, two paradigms frequently used in attention research (Fan et al., 2002). Each trial begins with a cue that indicates that a target is about to appear (central cue and double cue conditions) and where the target is to appear (spatial cue condition). The no-cue trails use the same targets but without the cue preceding the target appearance. The target display contains a central target arrow and flanker arrows. The flanker arrows are either pointing in the same direction as the target arrow (congruent) or the opposite direction (incongruent). Participants indicate the direction of the target arrow by pushing the appropriate key on the computer keyboard.

The alerting phase is measured by subtracting the mean response time (RT) of the double-cue condition from the mean RT of the no-cue condition. A deficit in the ability to disengage attention from the cue and direct it at the target can be inferred by slower response times to the target (Fan et al., 2009). The orienting effect is calculated by subtracting the mean RT of the spatial-cue conditions from the mean RT of the center-cue condition (Fan et al., 2002). Finally, the executive control of attention was calculated by subtracting the mean RT of all congruent conditions, summed across cue conditions, from the mean RT of the incongruent conditions. As with alerting, slow RTs to the target indicate a deficit in that network.

Participants indicated whether a centrally located arrow was pointing to the left or the right by pressing the left or right arrows on the computer keyboard. The target arrows are surrounded by one of three kinds of flankers: congruent, incongruent and neutral. In the congruent flanker condition, the arrows are pointing the same direction as the target arrow. In the incongruent condition, the arrows are pointing in the opposite direction of the target. In the neutral condition, the flanker consists of dashes rather than arrows. Prior to the presentation of the target, participants receive a cue that might or might not help them anticipate where the target will appear.

There are also three cue conditions: no cue (no cue is presented prior to the target: 12 trials), double cue (both cues flash briefly before the appearance of the target: 12 trials) and spatial cue (the cue flashes temporarily before the target is presented: 48 trials). The cue types and flanker conditions are manipulated throughout the task.

Procedure Participants were tested individually in a quiet room during a 45-minute time period. Before beginning the session, each participant completed an informed consent and a demographic form. All participants completed the IGT and the ANT. For the ANT, participants completed 24 practice trials during which they are provided with feedback about their accuracy. Participants then completed three blocks of 96 trials for which they were not given feedback.

Results and Discussion

Each variable was entered into a regression equation. Only one of the three variables, alerting, was a significant predictor of IGT performance (β = .31, t = -2.16, p= .032; see Table 1). These findings are consistent with our prediction that only the alerting network would be relevant for optimal IGT performance. Being able to disengage attention from irrelevant information and focus on important information allows for recognition of the IGT payoff schedule. Once participants recognize this pattern, they are better able to engage in beneficial game strategies.

Table 1. Multiple regression coefficients

	Beta	t-score	Significance
Alerting	.310	-2.16	.032
Orienting	.024	0.157	.876
Conflict	.140	0.905	.371

These results are not surprising, given that the IGT does not require participants to focus attention on a particular portion of the monitor screen to choose their cards or to see the results. The results are displayed until the next draw of a card, giving participants time to observe all the details presented on the screen. Thus orienting is not likely to be a strong factor in task performance. Similarly, there are no conflicts or need for participants to disengage and reengage attention to observe and understand the results. The self-paced nature of the IGT makes orienting and executive control of attention less important to the overall results.

GENERAL DISCUSSION

Although researchers and clinicians frequently use the IGT, there is still some debate on the role of various cognitive abilities, such as attention and executive functions. In our first experiment, we examined the effects of placing a load on attention and of placing a load on attention and executive functions compared to a no-load condition. As anticipated, placing a load on attention resulted in impaired performance. Placing a load on attention plus executive functions also significantly decreased performance; however, the decrease was not significant. Because the RNT depletes attentional resources as well as executive functions, it is not surprising that participants in this condition also suffered a decline performance. However, it could be expected that the further depletion of cognitive resources (i.e. executive functions) would depress performance to a significant degree over simple attention depletion. Given that this didn’t occur, we argue that full attention is a necessary, if not sufficient, condition for peak performance on the IGT.

In our second experiment, we sought to identify which attentional networks significantly contribute to IGT performance. Early work linked IGT performance to the development of somatic markers (Bechara & Damasio, 2005; Bechara, Damasio, Tranel, & Damasio, 2005), which is an automatic and effortless process. The alerting network focuses attention on a specific task or piece of information, whereas the other networks (orienting and conflict) involve more effortful cognitive manipulations. Based on the relationship between the IGT and the SMH, we theorized that alerting contributes the most to IGT success. Our results support this idea. As discussed earlier, the IGT does not require participants to shift their attention or to resolve conflicts regarding incoming information. Therefore, although these networks do contribute to performance, they play a lesser role.

We examined only two executive functions and used only two dual-task conditions. Given that Friedman and colleagues (2008) have shown that executive function measures are not process-pure, further research using a variety of EF tasks is needed to reduce variance caused by non-executive factors. A second limitation lies with the demographics of our sample. In both experiments, female participants greatly outnumbered the male participants. Males tend to do better on the IGT than females (Bolla, Eldreth, Matochik, & Cadet, 2004); therefore, further research is needed to determine if these findings are consistent with males.

A final area for potential research involves modeling the individual differences (e.g. executive functions, working memory) that underlie IGT performance. Only a few studies have examined individual differences in IGT performance (e.g. Harman, 2011; Suzuki, Hirota, Takasawa, & Shigemasu, 2003). Work in this area could help explain variability in IGT performance, both in clinical and neurotypical populations.

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