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Manipulating the decision making process: Influencing a "gut" reaction

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ABSTRACT

The present series of studies sought to examine how external factors influence behavioral decision making task performance. Utilizing the Iowa Gambling Task (IGT) to assess risky decision making, we examined the influence of a dual task paradigm (Study 1, Study 2), shifting task focus to decision making speed versus accuracy (Study 3), and varied intertrial intervals (Study 4). College student participants completed the IGT and decision making speed and the patterns of IGT selections by deck in the earlier (decision making under ambiguity) and later (decision making under risk) trials were examined. Participants completing the IGT while simultaneously completing a dual working memory task made slower decisions and failed to learn, compared to the single task participants, that Deck C was an advantageous deck. Participants told to focus on being as accurate as possible in their decisions selected more from Deck C, whereas participants told to focus on making the quickest possible decision selected more from Deck D. Manipulating the intertrial interval, giving participants more time to learn from feedback, did not affect decision making speed or accuracy. Implications for our understanding of how individuals decide on the IGT and how heuristics may develop are presented.

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Risky decision making; speed-accuracy tradeoff; working memory; Iowa gambling task; dual task

At the most basic level, decision making involves a choice between two or more options. In practice, numerous definitions exist that further refine specific subtypes of decision making with variations in how cognitive psychologists and neuropsychologists define the construct. In addition, researchers rely on varying methods to assess decision making, including self-reported responses to vignettes and performance on behavioral tasks. These studies collectively inform researchers about decision making more broadly, including the factors that affect the decision making process for better and for worse.

Neuropsychologists frequently use behavioral tasks to assess decisions made in the face of risks. Of these tasks, the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994) is the most commonly used. The IGT was created to assess real-world decision making impairments among individuals with known frontal lobe damage but who "passed" lab-based measures of executive functions. These patients frequently engaged in real-world behaviors demonstrating a myopic focus on short-term positive outcomes despite their potential long-term negative consequences. This focus on short-term over long-term results was not well captured on executive function tasks prior to the IGT. On the IGT, participants select cards from one of four decks (A,B,C,D). They are given a hypothetical $2000 loan to start and told to maximize profit over the course of 100 trials (Bechara et al., 1994). Participants know very little about the task at the start, other than: a) you will always win some money, b) you might sometimes lose some money, and c) some decks are better than others. Through trial-and-error feedback following each selection, participants learn the relative risks and benefits associated with each deck. Selections from Decks A and B result in high immediate gains ($100 per selection on average) but long-term negative consequences (net loss of $250 after 10 selections). Selections from Decks C and D instead yield lower immediate gains (average $50 per selection) but long-term positive outcomes ($250 average gain after 10 selections). Based on these long-term consequences, Decks A and B are termed disadvantageous and Decks C and D advantageous (Bechara et al., 1994). Continued selection from the disadvantageous decks, even as the risks become apparent, is termed risky decision making and is seen across various patient and non-patient populations (see Buelow & Suhr, 2009, for review). In addition, multiple factors can influence decisions on the IGT, such as personality characteristics, state mood, stress, and providing additional trials in which to learn to decide advantageously.

The IGT creators put forth the somatic marker hypothesis to explain how decisions are made on the task. Per this hypothesis (Bechara, Damasio, Tranel, & Damasio, 1997),

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emotions guide decision making. Somatic markers, or "gut feelings" that are felt throughout the body, can be viewed as hunches that guide subsequent decisions. Damasio (1994) believed these somatic markers encompassed "hot" or "system 1" (Kahnemann, 2011) decision making processes and were used by the body, potentially at an unconscious level, to guide "cold" or "system 2" decisions. In essence, the task creators theorized affective gut-feelings helped participants more quickly learn which decks were riskier and which were safer, resulting in more advantageous decision making. Evidence exists in favor of this hypothesis (Bechara, Tranel, Damasio, & Damasio, 1996; Carter & Pasqualini, 2004; Chiu, Huang, Duann, & Lin, 2018; Crone & van der Molen, 2004; Yechiam, Stout, Busemeyer, Rock, & Finn, 2005) and the role of the ventromedial prefrontal cortex in emotion-based decision making (e.g., Bechara, Damasio, Tranel, & Anderson, 1998; Eslinger & Damasio, 1985); however, others are more critical of the somatic marker hypothesis to understand decision making on the IGT and more generally (Chiu et al., 2008; Dunn, Dalgleish, & Lawrence, 2006; Webb, DelDonno, & Killgore, 2014). In addition, there is evidence learning occurs on the IGT, in that adding extra trials can improve decision making (Buelow, Frakey, Grace, & Friedman, 2013; Buelow, Okdie, & Blaine, 2013; Lin, Song, Chen, Lee, & Chiu, 2013). Further, cognitive modeling of the IGT suggests a complex interaction of cognitive, emotional, motivational, and response-based factors affect decision making on the task (e.g., Ahn, Busemeyer, Wagenmakers, & Stout, 2008; Busemeyer & Stout, 2002). The type of decision making assessed changes as the task progresses, mimicking decision making in the real world. During the first 20–40 trials, participants do not know much about the decks and are making decisions under ambiguity. Through trial-and-error feedback, participants begin to learn about the decks and instead make decisions under risk (last 60–80 trials; Brand, Recknor, Grabenhorst, & Bechara, 2007; Ko et al., 2010; Noel, Bechara, Dan, Hanak, & Verbanck, 2007). Thus, the IGT assesses components of both hot and cold decision making, as well as learning-based decision making during "under risk" conditions. Paulus (2005) summarized the three decision making processes occurring on the IGT as such: 1) assigning positive and negative (or advantageous and disadvantageous) labels to the deck options; 2) choosing one response option over the others; and 3) utilizing feedback to adapt the first two processes in the next decision. These processes mimic decision making in the real world and on tasks other than the IGT.

As debate continues regarding the influence of hot and cold processes in decision making, researchers are increasingly examining factors that may correlate with decision making to provide further clarity on the influential processes. Two of these factors are working memory and processing speed. Those high in working memory capacity and those low in working memory capacity perform equally well on a flanker task (Heitz & Engle, 2007). But, on the IGT, correlations with working memory tasks are inconsistent (see Toplak, Sorege, Benoit, West, & Stanovich, 2010, for review). A second line of research examines decision making in a dual task paradigm: participants perform a decision making task simultaneously with another task. It is thought completing a dual task could negatively affect performance due to splitting of attentional resources across tasks, depleting essential working memory resources. In fact, engaging in dual- or multitasking does impair task performance more broadly (Dromey & Shim, 2008; Nijboer, Borst, van Rijn, & Taatgen, 2016) and on decision making tasks specifically (Pabst, Brand, & Wolf, 2013; Pabst, Schoofs, Pawlikowski, Brand, & Wolf, 2013; Starcke, Pawlikowski, Wolf, Altsötter-Gleich, & Brand, 2011; Worthy, Otto, & Maddox, 2012). The negative effects on performance are seen even if the secondary task involves passively listening to music (Alley & Greene, 2008).

Processing speeds' relationship with decision making was also assessed in correlational and experimental designs. Gansler, Jerram, Vannorsdall, and Schretlen (2011a, 2011b) found negative correlations between processing speed and decision making on the IGT. They also found a negative correlation between speed and Deck D selections but a positive correlation with Deck A selections, indicating speed likely can affect accuracy on the task. Processing speed also mediates the relationship between age and performance on the IGT and Balloon Analogue Risk Task (Henninger, Madden, & Huettel, 2010). These studies, though few, indicate a potential relationship between overall processing speed and decision making that varies based on advantageous and disadvantageous deck selections.

Processing speed contributions are also examined in the context of a speed-accuracy trade-off. In general, individuals may sacrifice speed for accuracy and accuracy for speed (Fitts, 1954; Payne, Bettman, & Johnson, 1992, 1988; Ratcliff, Thompson, & McKoon, 2015); however, factors associated with the decision making context could affect this relationship (see Hogarth & Karelaia, 2007, for review). Changing one's focus during a task can change priorities during the task, such as to focus on speed versus to focus on accuracy (e.g., Christensen-Szalanski, 1978, 1980; Payne, Bettman, & Johnson, 1993). Having participants focus on making quick decisions can increase the number of errors made (i.e., decrease accuracy; Busemeyer & Townsend, 1993; Wenzlaff, Bauer, Maess, & Heekeren, 2011) as they may not gather as much evidence prior to making a decision (Heitz, 2014; Rae, Heathcote, Donkin, Averell,

& Brown, 2014). Heuristics – rules and guidelines that can be quickly implemented in decision making – can also introduce bias and error (Kahneman & Tversky, 1973). They can at times lead to efficient, "fast-and-frugal" decision making as they provide a "search rule" to quickly find information required to make a decision (Hafenbradl, Waeger, Marewski, & Gigerenzer, 2016). Hot or system 1 processes may rely more heavily on heuristics than cold or system 2 processes, potentially introducing error in the process of making a quick decision. System 1 processes do take less time than system 2 processes (De Neys, 2006), and system 2 processes can be interrupted by increased cognitive load (such as during a dual task paradigm) resulting in slower and potentially less accurate responses (De Neys, 2006; De Neys & Schaeken, 2007). In addition, overburdened working memory resources could allow for distracting information to alter the decision making process, resulting in a less logical or more incorrect response (De Neys, Schaeken, & d'Ydewalle, 2005; De Neys & Verschueren, 2006). Taken together, there is evidence that the efficiency and accuracy of decision making can be affected by the use of heuristics and the availability of working memory resources during completion of a task.

It is possible a speed-accuracy trade-off exists in decision making, and that decision making speed could affect the quality of the decision. Decisions that focus on high gains are easier to make and, in fact, decision making speed is quicker when deciding on gains than on losses (Diederich, 2008; Diederich & Busemeyer, 2006; Simen et al., 2009). Reading information at a fast pace, versus at a slower pace, led to increased risk-taking on the Balloon Analogue Risk Task (BART; Chandler & Pronin, 2012). On the IGT more specifically, very few researchers examine decision making speed, focusing instead on accuracy/performance patterns. Vadham et al. (2007) reported both speed and type of decision on the IGT. Although not directly compared, their data suggest slower response times among those with more advantageous decisions. Better and slower decisions are seen in controls compared to those with pathological gambling (Goudriaan, Oosterlaan, de Beurs, & van den Brink, 2005). In addition, better decisions were made after a loss, if the individual first slowed down the decision (Brevers et al., 2015; Schilt, Goudriaan, Koeter, van den Brink, & Schmand, 2009). On the other hand, when participants have a shortened timeframe to make a decision (e.g., two seconds), decisions are riskier – and faster – than when they have four seconds to decide (Cella, Dymond, Cooper, & Turnbull, 2007). Giving even more time, however, does not affect accuracy on the IGT (six seconds; Bowman, Evans, & Turnbull, 2005). Thus, faster decisions can result in riskier decisions with long-term negative consequences for the decision maker.

The present studies

The present series of studies sought to further examine the influence of working memory and processing speed on decision making, utilizing the IGT as the measure of risky decision making. Evidence suggests there is some relationship between working memory and decision making, but the precise nature of the relationship is unclear. Can taxing working memory resources, such as through a dual task paradigm, negatively affect decisions? Does the speed-accuracy trade-off extend to assessment with the IGT? More broadly, the present studies seek to assess the extent to which decision making on the IGT is stable versus permeable and open to outside influences. In Study 1, we examine the influence of a working memory-based dual task paradigm on IGT performance. Study 2 attempts to replicate and expand this finding, while Studies 3 and 4 instead manipulate the focus on decision making speed and accuracy. Collectively, these studies seek to provide further clarification of what type of decision making the IGT assesses and whether decision making is a stable or permeable construct that is open to adjustment from situational factors. To the extent IGT performance is malleable, researchers and clinicians alike should be mindful of how task instruction variations can improve or hinder performance (and thus conclusions about decision making abilities).

Study 1

In Study 1, we sought to affect the decision making process by having participants complete a dual task paradigm. While completing the IGT, participants also completed a mentally-taxing working memory task. It was hypothesized that participants randomly assigned to the dual task condition would engage in riskier decision making (i.e., fail to learn to decide advantageously) compared to participants randomly assigned to the single task condition. In addition, we hypothesized that completion of the dual task paradigm would lead to slower responses on the IGT than completion of the single task paradigm.

Method

Participants

An a priori power analysis was conducted using G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009). A sample of 54 participants was required to detect a medium effect utilizing a mixed ANOVA comparing two groups, with $\alpha = .05$ and $1 - \beta = .95$.

Participants were 131 undergraduate students at a regional campus of a large midwestern university. All were enrolled in psychology courses in which course credit was assigned for participation in research studies. Three participants were removed from further analyses due to concerns about a previous administration of the IGT (e.g., the first 20 selections were all from one deck). This left a final sample of 128 participants (M_{age} = 18.70, SD_{age} = 1.77, range 18–29; 53 males; 68.4% Caucasian).

Measures and procedure

The study was approved by the University's Institutional Review Board, and all participants provided informed consent. All participants completed the standard computerized version of the Iowa Gambling Task (IGT) available through Psychological Assessment Resources (PAR; Bechara, 2007). The standard IGT is set to have a 500 ms intertrial interval. In addition to the previously provided information about the task, there are between-deck differences in the frequency and size of losses. Although Decks A and B are both considered disadvantageous decks, Deck A has a high frequency of lower losses (5/10 trials) whereas Deck B has a lower frequency of higher losses (1/10 trials). In addition, Deck C selections result in losses on 5/10 trials, whereas Deck D selections result in losses on 1/10 trials. Previous researchers have shown that Decks C and D are not equally advantageous, and Decks A and B are not equally disadvantageous (Chiu & Lin, 2007; Lin, Chiu, Lee, & Hsieh, 2007). In particular, focusing on the frequency of losses would indicate that Decks B and D might be more advantageous than Decks A and C, as selections from these decks would minimize the frequency of losses. Because of these concerns regarding the confound of frequency of losses and long-term outcomes, researchers increasingly examine each deck individually (e.g., Buelow & Suhr, 2013; Caroselli, Hiscock, Scheibel, & Ingram, 2006; Chiu et al., 2008). For the present study, the percentage of selections from each individual deck were calculated for the earlier (Trials 1–40) and later (Trials 41–100) trials.

Participants were randomly assigned to complete the IGT under one of two study conditions. In the single task condition (n = 79), participants completed the standard IGT on its own. In the dual task condition (n = 49), participants completed the IGT and a secondary working memory task simultaneously. Of note, participants were oversampled in the single task condition due to a co-occurring study. While completing the IGT, participants also completed a backwards digit span task. The researcher read aloud a series of digits, one per second, and participants repeated back the digits in reverse order. The task continued, despite participant errors, until the IGT was completed. It should be noted that deck selections continued while digit span trials were presented (i.e., simultaneous rather than sequential administration). Participants could have been making deck selections while also simultaneously either repeating back digits or listening for the next set of digits. After completion of the IGT, participants responded to a series of demographic questions before the debriefing. Course credit was then assigned.

Data analysis

To examine differences in performance on the IGT, several mixed ANOVAs were conducted in SPSS. For each, selections from a particular deck were examined by earlier (Trials 1–40) and later (Trials 41–100) trials (Block; within-subjects variable) and group assignment (Group; between-subjects variable). One additional mixed ANOVA was conducted on the average decision making speed, or timing, in milliseconds. Finally, a series of Pearson's correlations were calculated assessing relationships between decision making speed and accuracy for selections from each deck on the early and later trials.

Study 1 results

IGT performance by deck

See Table 1 for means and standard deviations. For Deck A, there was not a significant Group by Block interaction, $F(1,126) = 0.26$, $p = .614$, $\eta_p^2 = .002$. The main effect of Block was significant, $F(1,126) = 57.22$, $p < .001$, $\eta_p^2 = .312$, indicating that participants selected less from Deck A as the task progressed. The main effect of Group was also not significant, $F(1,126) = 0.28$, $p = .595$, $\eta_p^2 = .002$.

For Deck B, there was also not a significant Group by Block interaction, $F(1,126) = 1.38$, $p = .242$, $\eta_p^2 = .011$. The main effect of Block was significant, $F(1,126) = 4.91$, $p = .029$, $\eta_p^2 = .037$, indicating that participants selected less from Deck B as the task progressed. The main effect of Group was also not significant, $F(1,126) = 0.39$, $p = .532$, $\eta_p^2 = .003$.

For Deck C, there was a significant Group by Block interaction, $F(1,126) = 4.23$, $p = .042$, $\eta_p^2 = .032$. Participants in the single task paradigm chose more from Deck C as the task progressed, $p = .005$; however, participants in the dual task paradigm showed no

Table 1. Study 1: IGT performance and timing with and without a secondary task presented as mean (*M*) and standard deviation (*SD*).

Variable	Single Task		Dual Task	
	M	SD	M	SD
Decision Making Under Ambiguity				
A 1–40	21.71	7.56	20.71	6.63
B 1–40	32.37	10.82	29.54	8.38
C 1–40	21.30	9.36	26.38	10.16
D 1–40	24.62	12.33	23.37	8.99
Decision Making Under Risk				
A 41–100	15.25	7.32	15.07	8.52
B 41–100	27.32	14.60	27.99	14.75
C 41–100	25.53	15.45	25.58	10.11
D 41–100	31.90	17.84	31.33	20.39
Decision Making Speed				
Time 1–40	1016.15	581.78	2650.91	1428.13
Time 41–100	748.10	426.25	2717.01	2100.07

IGT performance is presented as percent selections from each individual deck (A, B, C, D) across the earlier (Trials 1–40) and later (Trials 41–100) trials. Timing is presented as the average time in milliseconds to a decision in the earlier and later trials.

change in their Deck C selections, p = .984. The main effect of Block was not significant, $F(1,126) = 1.97$, $p = .163$, $\eta_p^2 = .015$, and neither was the main effect of Group, $F(1,126) = 2.10$, $p = .150$, $\eta_p^2 = .016$.

For Deck D, there was not a significant Group by Block interaction, $F(1,126) = 0.04$, $p = .848$, $\eta_p^2 = .000$. The main effect of Block was significant, $F(1,126) = 18.58$, $p < .001$, $\eta_p^2 = .129$, indicating greater selections from Deck D as the task progressed. The main effect of Group was also not significant, $F(1,126) = 0.17$, $p = .678$, $\eta_p^2 = .001$.

In summary, the IGT performance analyses indicate that participants, independent of group assignment, learned to avoid Deck A in favor of Deck D as the task progressed. In addition, only those participants in the single task paradigm learned through the trial-and-error feedback that Deck C was an advantageous deck.

IGT timing

A mixed ANOVA on the IGT timing variables found a significant Group by Block interaction, $F(1,122) = 4.74$, $p = .031$, $\eta_p^2 = .037$, and a significant main effect of Group, $F(1,122) = 80.20$, $p < .001$, $\eta_p^2 = .397$. The main effect of Block was not significant, $F(1,122) = 1.73$, $p = .191$, $\eta_p^2 = .014$. Independent of Block, participants in the dual task paradigm responded slower than participants in the single task paradigm. Those in the single task paradigm made quicker decisions in the later trials (Trials 41–100) than in the earlier trials (Trials 1–40), $p = .004$, whereas there were no differences in decision making speed across trials in the dual task paradigm group, $p = .590$.

Additional analyses on digit span and the IGT

We also examined performance on the dual task, digit span, to see if better performance on digit span was associated with lower IGT performance (i.e., shifting focus to the secondary task negatively affected IGT performance). On average, participants answered 59.89% of the dual task trials correctly (SD = 9.62, range: 42.86–78.13%). Pearson's correlations were then calculated between dual task accuracy and IGT performance and timing variables. Results indicated a significant negative correlation between dual task accuracy and selections from Deck A during only the later trials, $r(42) = -.343$, $p = .026$ (remaining correlations were $p > .066$). No correlations were found between dual task accuracy and IGT decision making speed, $ps > .630$.

Finally, Pearson's correlations were calculated between decision making speed and task performance. On the earlier trials, there was a negative relationship between speed and Deck B selections, $r(124) = -.217$, $p = .015$, and a positive relationship between speed and Deck C selections, $r(124) = .187$, $p = .038$. No significant correlations emerged for the later trials, $ps > .172$. In sum, participants selected more from Deck C and less from Deck B, during the earlier trials, when decision making speed was slower than when it was faster.

Study 1 discussion

The present study examined two hypotheses. We hypothesized that participants in the dual task condition would engage in riskier decision making than those in the single task condition. Our results partially supported this hypothesis. Although all participants learned to avoid Deck A and select from Deck D as the task progressed, only participants in the single task condition also learned to choose from Deck C, the other advantageous deck (Bechara et al., 1994). This pattern of decision making is consistent with the most advantageous decision making strategy outlined in the IGT manual (Bechara, 2007), as individuals are avoiding the deck associated with "pathological" decision making and selecting from the most advantageous deck.

Previous studies have noted the existence of a prominent Deck B phenomenon (e.g., Overman et al., 2004; Ritter, Meador-Woodruff, & Dalack, 2004; Sevy et al., 2007), in which participants tend to make selections from Decks B and D as the task progresses. It is believed that this altered decision making strategy is based on minimizing the frequency of losses (selections from Decks B and D) rather than focusing on long-term consequences of one's decisions. As good (advantageous) decisions should result in long-term benefits rather than long-term costs, Deck C is still a better deck to continue to choose from compared to Deck B (Bechara, 2007). Our results indicate that distractions during decision making tax working memory resources, in turn leading to implementation of a less beneficial decision making strategy. Completing a dual task paradigm likely failed to allow participants to learn the nuances of Deck C (i.e., higher frequency of immediate losses but long-term positive outcomes) that make it an advantageous deck.

We also hypothesized that participants in the dual task condition would decide slower than participants in the single task condition. In fact, we found that participants in the dual task condition did respond slower on both the earlier and later trials compared to those in the single task condition. In addition, our supplemental analyses found a slower rate of decision making speed was associated with more selections from Deck C and less from Deck B in the earlier trials. Thus, engaging in a dual task paradigm during decision making slows down the rate of decision making and also affects the pattern of deck selections. This finding may show further evidence of the speed-accuracy tradeoff in the decision making process. Individuals may slow down their decision making to compensate for a distractor, seeking greater accuracy in their responses. This shift in decisions to Deck C amongst those in the single task condition and those who had a slower overall response rate may indicate that the nuances that make Deck C an advantageous deck require cognitive effort to detect. Thus, these results provide support for the theory that learning does occur on the IGT (see Dunn et al., 2006, for review). The dual task likely shifted the attentional/working memory resources needed to learn from feedback Deck C is an advantageous deck. In addition, these results are in keeping with previous research suggesting that participants will change their decision making strategy to engage in the less cognitive taxing approach, which can interfere with optimal decision making (e.g., Kool, McGuire, Rosen, & Botvinick, 2010). This avoidance of cognitive effort diminishes with increasing age (Sullivan-Toole, DePasque, Holt-Gosselin, & Galvan, 2019), but may affect college-aged participants such as were in our study.

Several factors could have affected our findings. First, it is possible that individual differences in working memory ability could affect a participant's ability to multi-task. Those with higher working memory skills might have been better able to compensate for the dual task condition, with less effect on IGT performance. The digit span task was completed by several different research personnel. It is possible that random fluctuations occurred in the rate of stimulus presentation, both within and across research personnel. It is also unclear whether the specific rate of digit span presentation led to the slower rate of decision making on the IGT, or if the slower decision making process was due to the presence of a dual task itself (and not the rate of presentation).

Study 2

In Study 2, we sought to further clarify and expand upon our results from Study 1 by again having participants complete a single or dual task paradigm. It is possible that participants began to select from Deck C because slowing down decision making shifted their focus to long-term outcomes rather than the frequency of immediate wins/losses. To account for the concerns noted in Study 1 and to further examine this hypothesis, we made the following changes to Study 2: 1) working memory was assessed prior to the study manipulations; 2) the dual task paradigm was standardized across participants; and 3) two dual task manipulations were included: a fast rate and a slow rate. We hypothesized that, similar to Study 1, participants would slow their rate of decision making on the IGT in the dual task conditions compared to the single task condition. In addition, participants in the dual task-slow condition would have longer reaction times on the IGT than participants in the dual task-fast condition. In terms of task performance, we hypothesized that participants in the dual task-slow condition would decide more advantageously than participants in the dual task-fast condition, and performance of participants in the single task condition would be more advantageous than both of the dual task groups.

Study 2 method

Participants

Participants were 187 undergraduate students at a regional campus of a large midwestern university. All were enrolled in psychology courses in which course credit was assigned for participation in research studies. Eleven participants were removed from further analysis due to failure to complete the entire IGT (n = 4), concerns about effort during testing (n = 4), or concerns about a previous administration of the IGT (n = 3). This left a final sample of 176 participants (M_{age} = 18.69, SD_{age} = 1.22, range 18–30; 76 males; 66.4% Caucasian).

Measures and procedure

The study was approved by the University's Institutional Review Board, and all participants provided informed consent. At the start of the study session, participants completed the Letter-Number Sequencing subtest from the Wechsler Adult Intelligence Scale (WAIS-IV; Wechsler, 2008). Participants heard a series of numbers and letters, and were tasked with repeating back the numbers first, in order from lowest to highest, followed by the letters in alphabetical order. Trials increased in length and the task ended when participants missed all trials at a given length/level. A total score was calculated and served as an estimate of working memory ability.

Participants again completed the PAR version of the IGT (Bechara, 2007). The task and scoring were the same as in Study 1. Participants were randomly assigned to complete the IGT under one of three study conditions. In the control condition (n = 58), participants took the standard IGT with no changes (single task). In the fast (n = 58) and slow (n = 60) conditions, participants completed the standard IGT while simultaneously completing a backwards digit span task. The digit span task was prerecorded, so that all participants experienced the same trials. However, those in the fast condition heard the digit span trials presented at one number per second, and those in the slow condition heard the digit span trials presented at one number per two seconds. The recorded digits were identical, with a differing amount of space between their presentations. The task continued, despite participant errors, until the IGT was completed. As in Study 1, participants could have been making selections on the IGT while repeating back a series of digits or listening for the next digits to occur. After completion of the IGT, participants responded to a series of demographic questions before the debriefing. Course credit was then assigned.

Data analysis

Correlations were calculated between working memory ability and performance on the IGT, and group differences in working memory were also assessed. To examine differences in performance on the IGT, a series of mixed ANOVAs were conducted. Group assignment (single task, dual task-fast, dual task-slow) was the between-subjects variable, and Block (early trials, later trials by deck) was the within-subjects variable. An additional mixed ANOVA was conducted on the timing data. Significant group effects were followed-up with Tukey post-hoc comparisons. Finally, a series of Pearson's correlations were calculated assessing relationships between decision making speed and accuracy across percent selections from each deck in the early and later trials.

Study 2 results

Pre-manipulation working memory

A one-way ANOVA was conducted to assess between-group differences in pre-manipulation working memory on Letter-Number Sequencing. No group differences emerged, $F(2,169) = 1.54$, $p = .217$. In addition, no correlations emerged between Letter-Number Sequencing and performance on the IGT, $ps > .288$. See Table 2 for means and standard deviations.

IGT performance by deck

For Deck A, there was not a significant Group by Block interaction, $F(2,173) = 0.03$, $p = .966$, $\eta_p^2 = .000$. The main effect of Block was significant, $F(1,173) = 52.23$, $p < .001$, $\eta_p^2 = .232$, indicating that participants

Table 2. Study 2: IGT performance and timing as a function of slow and fast presentation rate presented as mean and standard deviation.

	Fast		Slow		Control	
Variable	M	SD	M	SD	M	SD
LNS	16.71	3.99	15.87	4.80	17.18	3.31
Decision Making Under Ambiguity						
A 1–40	21.64	5.78	22.79	6.61	20.99	7.62
B 1–40	28.10	9.05	29.63	10.59	32.89	8.87
C 1–40	24.66	5.99	24.21	6.18	22.33	7.83
D 1–40	25.60	9.04	23.38	9.64	23.79	11.28
Decision Making Under Risk						
A 41–100	17.13	6.99	18.28	7.95	16.12	10.36
B 41–100	27.90	11.87	31.33	15.90	31.90	15.14
C 41–100	22.04	8.40	22.97	11.85	22.47	13.95
D 41–100	32.70	16.71	27.22	16.46	29.51	14.17
Decision Making Speed						
Time 1–40	3825.99	2297.95	3254.08	2335.37	1159.75	608.88
Time 41–100	2973.64	2087.37	2534.86	2406.80	726.41	370.87

LNS = Letter–Number Sequencing; IGT performance is presented as percent selections from each individual deck (A, B, C, D) across the earlier (Trials 1–40) and later (Trials 41–100) trials. Timing is presented as the average time in milliseconds to a decision in the earlier and later trials.

selected less from Deck A as the task progressed. The main effect of Group was also not significant, $F(2,173) = 1.43$, $p = .243$, $\eta_p^2 = .016$.

For Deck B, there was also not a significant Group by Block interaction, $F(2,173) = 0.58$, $p = .562$, $\eta_p^2 = .007$. The main effect of Block was not significant, $F(1,173) = 0.03$, $p = .871$, $\eta_p^2 = .000$, nor was the main effect of Group, $F(2,173) = 2.80$, $p = .064$, $\eta_p^2 = .031$.

For Deck C, there was again not a significant Group by Block interaction, $F(2,173) = 0.95$, $p = .391$, $\eta_p^2 = .011$, nor a significant main effect of Block, $F(1,173) = 2.30$, $p = .131$, $\eta_p^2 = .013$. The main effect of Group was also not significant, $F(2,173) = 0.38$, $p = .684$, $\eta_p^2 = .004$.

For Deck D, there was not a significant Group by Block interaction, $F(2,173) = 0.88$, $p = .419$, $\eta_p^2 = .010$. The main effect of Block was significant, $F(1,173) = 30.21$, $p < .001$, $\eta_p^2 = .149$, indicating greater selections from Deck D as the task progressed. The main effect of Group was not significant, $F(2,173) = 1.72$, $p = .182$, $\eta_p^2 = .019$.

To further examine our hypotheses regarding specific differences between the dual task groups, planned comparisons were conducted. We hypothesized participants in the dual task-slow condition would decide more advantageously than participants in the dual task-fast condition, so we examined the pattern of deck selections in these two groups. The two dual task groups did not differ in earlier (Trials 1–40) deck selections, *ps* > .228. In addition, no differences emerged in later (Trials 41–100) deck selections, *ps* > .062.

In summary, the IGT performance analyses indicate that participants, independent of group assignment, learned to avoid Deck A in favor of Deck D as the task progressed. Minimal between-group differences emerged in performance.

IGT timing

A mixed ANOVA on the IGT timing variables found a main effect of Block, $F(1,173) = 38.48$, $p < .001$, $\eta_p^2 = .182$, and significant main effect of Group, $F(2,173) = 31.79$, $p < .001$, $\eta_p^2 = .269$. The Group by Block interaction was not significant, $F(2,173) = 1.30$, $p = .274$, $\eta_p^2 = .015$. Independent of block, participants in the single task paradigm decided quicker than participants in either dual task paradigm, *ps* < .001. There was not a difference in decision making speed between the dual task-slow and dual task-fast groups, $p = .120$. Independent of group, participants decided quicker in the later than in the earlier trials, $p < .001$.

Additional analyses on digit span and the IGT

We also examined performance on the dual task, digit span, to see if better performance on digit span was associated with lower IGT performance (i.e., shifting focus to the secondary task negatively affected IGT performance). On average in the dual task-fast condition, participants completed 56.90 (*SD* = 19.67) digit span trials and answered 19.93 (*SD* = 17.49) trials correctly (34.10% correct on average). In the dual task-slow condition, participants completed an average of 27.53 (*SD* = 9.36) digit span trials and answered 11.65 (*SD* = 8.23) trials correctly (42.25% correct on average). Participants completed more digit span trials in the fast than in the slow condition, $t(116) = -10.41$, $p < .001$, with no difference in accuracy between groups, $t(116) = 1.93$, $p = .056$. Pearson's correlations were then calculated between digit span accuracy and IGT performance and timing variables. Independent of dual task condition speed, there was a positive correlation between letter-number sequencing score and digit span accuracy, $r(115) = .282$, $p = .002$. There were no significant correlations between digit span accuracy and speed, *ps* > .159, or performance on the IGT, *ps* > .089.

Finally, Pearson's correlations were calculated between decision making speed and task performance. Decision making speed was correlated with earlier Deck A, $r(176) = .237$, $p = .002$, and Deck B, $r(176) = -.195$, $p = .009$, selections. In addition, decision making speed was positively correlated with later Deck A selections, $r(176) = .162$, $p = .032$ (i.e., slower decision makers continued to choose more from Deck A).

Supplemental analyses: Comparing study 1 and study 2

A combined dataset (e.g., integrated data analysis; Braver, Thoemmes, & Rosenthal, 2014; Curran & Hussong, 2009) was created to compare results from Study 1 and Study 2 as both examined the influence of a dual task on decision making with slight variations in the study procedure. Performance in the combined single-task group was compared to performance in a combined "dual task" group. Mixed ANOVAs were conducted with Study (Study 1, Study 2) and Condition (single task, dual task) as the between factors and Block (early trials, later trials) as the within factor. For Deck A, there was only a significant main effect of Block, $F(1,300) = 105.85$, $p < .001$, $\eta_p^2 = .261$. Participants, independent of Study or Condition, chose more from Deck A in the earlier than in the later trials. For Deck B, there were no significant findings (*ps* > .062). For

Deck C, there was a significant Block by Condition interaction, $F(1,300) = 5.95$, $p = .015$, $\eta_p^2 = .019$. The single task group selected more from Deck C as the task progressed, $p = .036$, whereas there was no difference in selections across time for the dual task group, $p = .184$. For Deck D, there was a significant main effect of Block, $F(1,300) = 45.02$, $p < .001$, $\eta_p^2 = .130$, as all participants selected more from Deck D as the task progressed.

For the timing data, there were several significant effects. All participants, independent of Study or Condition, made quicker decisions in the later than earlier trials, $F(1,296) = 22.58$, $p < .001$, $\eta_p^2 = .071$. Participants in the dual task condition decided slower than participants in the single task condition, $F(1,296) = 114.74$, $p < .001$, $\eta_p^2 = .279$. The Block by Study interaction was also significant, $F(1,296) = 11.56$, $p = .001$, $\eta_p^2 = .038$, indicating that in Block 1 but not Block 2, participants in Study 2 decided slower than participants in Study 1, $p = .010$. This finding is not unexpected, as the secondary task's speed varied in Study 2 and the recording may have been more distracting than the researcher's voice in Study 1. In addition, the Block by Study by Condition interaction was also significant, $F(1,296) = 5.26$, $p = .023$, $\eta_p^2 = .017$. In the dual task group, responses in Block 1 were slower in Study 2 than in Study 1, $p = .002$, likely due to the fast and slow manipulations in Study 2.

Study 2 discussion

The results supported several of our hypotheses. We hypothesized that participants would slow their rate of decision making in the dual task conditions compared to the single task condition, and that the dual task-slow would be slower than the dual task-fast. These hypotheses were partially supported. Although both dual task conditions were slower than the single task condition, the dual task conditions did not differ from each other in terms of decision making speed.

In terms of task performance, we hypothesized that participants in the dual task-slow condition would decide more advantageously than participants in the dual task-fast condition, and performance of participants in the single task condition would be more advantageous than both of the dual task groups. We found, just as in Study 1, all participants learned to avoid Deck A and select from Deck D as the task progressed. Unlike in Study 1, we did not find significant differences between groups in Deck B and C selections. We did, however, replicate our finding that slower decisions were associated with fewer Deck B selections in the early trials, likely indicating that slowing down decision making speed allows for additional time to learn from the trial feedback. However, we also found an unexpected relationship between slower decision making speed and *increased* Deck A selections. This is contrary to the results of Study 1, and also runs counter to our theory regarding decision making speed and Deck B selections. It is possible that individuals who decided more slowly on the task were taking their time to sufficiently sample from each deck and incorporate the feedback into subsequent decisions.

We made several changes to Study 2 that could have affected the results. We assessed whether our Study 1 results were due to pre-manipulation differences in working memory ability. Study 2 found no correlation between pre-manipulation working memory and performance on the IGT, not any between-group differences in working memory ability. The standardization of the dual task paradigm and the incorporation of two different rates of presentation likely affected our results. It appears that completing a dual task itself, rather than how fast or slow that dual task is presented, affects the decision making process.

We are unsure why our Study 1 Deck C result did not replicate in Study 2. We conducted an integrated data analysis of our Study 1 and Study 2 findings to further examine between-study differences in deck selections or decision making speed. Overall, it appears that there is an effect of completing a dual task on decision making speed. Regardless of the specific study manipulation, completing a dual task slowed down decision making compared to completing a single task. We also see that, overall and independent of manipulations, participants are able to learn to avoid Deck A in favor of Deck D. Completing a dual task, independent of the details of that task, does appear to negatively affect the process of learning that Deck C is an advantageous deck. Given the higher frequency of immediate losses in Deck C compared to the other advantageous deck, Deck D, and compared to Deck B (a disadvantageous deck with a lower frequency of losses), it is more difficult to learn Deck C is an advantageous deck. Completing a secondary working memory task during decision making seems to impair one's ability to learn Deck C is an advantageous deck. It is possible that slowing down decision making further could improve this learning process.

Study 3

In the next study, we sought to further examine the speed-accuracy trade-off seen in our first set of studies. In Study 3, we manipulated the task instructions to shift participant focus toward either making as fast a decision as possible (speed) or making the best possible decision (accuracy). Few studies have directly examined the influence of instruction changes, to focus on speed versus accuracy, on the IGT. DeDonno and Demaree (2008) told participants either that they had enough time to learn to decide advantageously on the IGT or that they did not have enough time to learn to decide advantageously. Following this instruction, all participants were told they had just two seconds to pick a card each time it appeared. Results indicated that telling participants they did not have enough time resulted in riskier decisions (i.e., selected more from Decks A and B than C and D) than among those told they had enough time. On non-IGT tasks, changing instructions to have participants focus on either the speed of responses or the accuracy of responses affects performance (e.g., Huang et al., 2015). We hypothesized that participants in the accuracy manipulation would decide more advantageously (i.e., select more from Decks C and D) than participants in the speed manipulation, but that decision making speed would be faster in the speed than in the accuracy condition.

Study 3 method

Participants

Participants were 116 undergraduate students at a regional campus of a large midwestern university. All were enrolled in psychology courses in which course credit was assigned for participation in research studies. Three participants were removed due to computer malfunction during the IGT (n = 2) or concerns about a previous administration of the IGT (n = 1). This left a final sample of 113 participants (M_{age} = 18.50, SD_{age} = 1.07, range 18–26; 41 males; 61.9% Caucasian).

Measures and procedure

The study was approved by the University's Institutional Review Board, and all participants provided informed consent. Participants were randomly assigned to one of two study conditions. In the speed condition (n = 49), participants viewed a set of instructions for the IGT that ended with the following statement: "Please make the quickest possible decision on each round. We will be keeping track of how long it takes you to finish this task." In the accuracy condition (n = 64), participants instead viewed IGT instructions that ended with the following statement: "Please make the best possible decision on each round. We are NOT keeping track of how long it takes you to finish this task." All other components of the IGT instructions, as well as the IGT administration, was the same across groups. After completion of the IGT, participants responded to a series of demographic questions before the debriefing. Course credit was then assigned.

Data analysis

To examine differences in performance on the IGT, a series of mixed ANOVAs were conducted. Group assignment (speed, accuracy) was the between-subjects variable, and Block (early trials, later trials by deck) was the within-subjects variable. An additional mixed ANOVA was conducted on the IGT decision making speed in milliseconds. Significant group effects were followed-up with Tukey post-hoc comparisons. Finally, a series of Pearson's correlations were calculated assessing relationships between decision making speed and accuracy across percent selections from each deck in the early and later trials. See Table 3 for means and standard deviations.

Study 3 results

IGT performance by deck

For Deck A, there was not a significant Group by Block interaction, $F(1,111) = 0.04$, $p = .849$, $\eta_p^2 = .000$. The main effect of Block was significant, $F(1,111) = 4.08$, $p = .046$, $\eta_p^2 = .035$, indicating that participants selected less from Deck A as the task progressed. The main effect of Group was also not significant, $F(1,111) = 1.85$, $p = .177$, $\eta_p^2 = .016$.

For Deck B, there was also not a significant Group by Block interaction, $F(1,111) = 0.16$, $p = .687$, $\eta_p^2 = .001$.

Table 3. Study 3: IGT performance and timing presented as mean and standard deviation.

	Speed Focus		Accuracy Focus	
Variable	M	SD	M	SD
Decision Making Under Ambiguity				
A 1–40	17.66	11.17	19.80	10.00
B 1–40	38.59	16.05	37.03	15.97
C 1–40	19.43	9.92	19.69	10.00
D 1–40	24.32	11.59	23.48	10.45
Decision Making Under Risk				
A 41–100	15.24	10.21	17.89	12.42
B 41–100	36.94	15.25	33.88	16.47
C 41–100	17.78	10.38	23.83	16.49
D 41–100	29.38	12.43	24.40	10.93
Decision Making Speed				
Time 1–40	938.90	467.40	978.28	427.46
Time 41–100	705.62	287.85	684.36	254.32

IGT performance is presented as percent selections from each individual deck (A, B, C, D) across the earlier (Trials 1–40) and later (Trials 41–100) trials. Timing is presented as the average time in milliseconds to a decision in the earlier and later trials.

The main effect of Block was not significant, $F(1,111) = 2.14$, $p = .146$, $\eta_p^2 = .019$, and neither was the main effect of Group, $F(1,111) = 0.61$, $p = .437$, $\eta_p^2 = .005$.

For Deck C, there was a significant Group by Block interaction, $F(1,111) = 5.89$, $p = .017$, $\eta_p^2 = .050$. The main effects of Block, $F(1,111) = 1.01$, $p = .318$, $\eta_p^2 = .009$, and Group, $F(1,111) = 2.74$, $p = .101$, $\eta_p^2 = .024$, were not significant. There were no differences in Deck C selections across blocks for the speed-focused participants, $p = .346$. For those in the accuracy-focused group, selections from Deck C increased in Block 2 compared to Block 1, $p = .010$.

For Deck D, there was a significant Group by Block interaction, $F(1, 111) = 4.18$, $p = .043$, $\eta_p^2 = .036$. The main effect of Block was significant, $F(1,111) = 8.60$, $p = .004$, $\eta_p^2 = .072$, indicating greater selections from Deck D as the task progressed. The main effect of Group was not significant, $F(1,111) = 3.22$, $p = .075$, $\eta_p^2 = .028$. The speed-focused group selected more from Deck D on Trials 41–100 than Trials 1–40, $p = .001$, whereas no difference emerged in Deck D selections across time for the accuracy-focused group, $p = .501$.

In summary, the IGT performance analyses indicate that participants, independent of group assignment, learned to avoid Deck A as the task progressed. Only those in the accuracy-focused group selected more from Deck C as the task progressed, and only those in the speed-focused group selected more from Deck D as the task progressed.

IGT timing

A repeated-measures ANOVA on the IGT timing variables found a significant main effect of Block, $F(1,111) = 98.42$, $p < .001$, $\eta_p^2 = .470$. The main effect of Group was not significant, $F(1,111) = 0.04$, $p = .852$, $\eta_p^2 = .000$, and neither was the Group by Block interaction, $F(1,111) = 1.17$, $p = .281$, $\eta_p^2 = .010$. Independent of group assignment, participants made quicker selections on Trials 41–100 than on Trials 1–40, $p < .001$.

Additional analyses on the IGT

Finally, Pearson's correlations were calculated between decision making speed and task performance. No significant correlations were found between decision making speed and deck selections in either the earlier, $ps > .153$, or later, $ps > .191$, trials.

Study 3 discussion

The results partially supported our hypotheses. Participants in the accuracy condition selected more from Deck C as the task progressed, whereas participants in the speed condition selected more from Deck D as the task progressed. However, there were no between-group differences in decision making speed in either the earlier or later trials although the means were in the predicted direction. Altering the task instructions to shift focus to making the best possible decision appears to increase focus on Deck C as an advantageous deck. Thus, the present results fit in with our previous studies, and suggest that learning Deck C is an advantageous deck takes time and effort compared to learning Deck D is advantageous. Giving individuals time to focus on making the best possible decision (i.e., taking away any direct or indirect focus on making quick decisions) leads to a better understanding of Deck C, a deck with frequent losses but long-term positive consequences. Our instructions might not have significantly slowed down decisions, but it did lead to improved learning on the task. Participants focused on accuracy learned to select from decks with long-term positive outcomes, and avoid the "second best" strategy of minimizing the frequency of losses. Participants focused on speed instead appeared to focus on the most obviously correct deck, Deck D. Changing how participants view the task leads to changes in their actual performance on the task. However, we did not have a control condition in which participants were told to give equal weight to both speed and accuracy.

Study 4

In Study 4, we focused on a separate component of the decision making process that could have affected our previous results, seeking to provide further clarification as to processes that might versus might not explain our findings. We manipulated the speed-accuracy trade-off by instead manipulating the length of the intertrial interval. Previous research has reached conflicting conclusions as to whether increasing or decreasing the time to make a decision affects performance (e.g., Bowman et al., 2005; Cella et al., 2007). We investigated whether increasing the intertrial interval would give participants more time to learn from the previous trial's feedback. As this was not directly manipulated in the previous studies, it is unknown to what extent participants might have increased this interval on their own, such as by waiting longer between trials while in the dual-task paradigm. We tested the hypothesis that longer intertrial intervals would be associated with more advantageous decisions than shorter intertrial intervals.

Study 4 method

Participants

Participants were 165 undergraduate students at a regional campus of a large midwestern university. All were enrolled in psychology courses in which course credit was assigned for participation in research studies. Six participants were removed from further analyses due to computer malfunction during the IGT (n = 4) or concerns about a previous administration of the IGT (n = 2). This left a final sample of 159 participants (M_{age} = 18.49, SD_{age} = 0.66, range 18–25; 75 males; 65.6% Caucasian).

Measures and procedure

The study was approved by the University's Institutional Review Board, and all participants provided informed consent. Participants were randomly assigned to one of two study conditions. In each group, participants completed the IGT with a differing intertrial interval. In one group (n = 52), participants experienced a 1000 ms delay between each decision. In another group (n = 51), participants instead experienced a 2000 ms delay between each decision. Both groups were compared to a control group (n = 56) that experienced the standard 500 ms delay between decisions. The control group was made up of participants completing other studies during the same semester as the experimental conditions. All other components of the IGT instructions, as well as the IGT administration, was the same across groups. After completion of the IGT, participants responded to a series of demographic questions before the debriefing. Course credit was then assigned.

Data analysis

To examine differences in performance on the IGT, a series of mixed ANOVAs were conducted. Group assignment (500, 1000, 2000 ms) was the between-subjects variable, and Block (early trials, later trials by deck) was the within-subjects variable. An additional mixed ANOVA was conducted on the IGT decision making speed in milliseconds. Significant group effects were followed-up with Tukey post-hoc comparisons. Finally, a series of Pearson's correlations were calculated assessing relationships between decision making speed and accuracy across percent selections from each deck in the early and later trials. See Table 4 for means and standard deviations.

Study 4 results

IGT performance by deck

For Deck A, there was not a significant Group by Block interaction, $F(2,156) = 0.66$, $p = .520$, $\eta_p^2 = .008$. The main effect of Block was significant, $F(1,156) = 22.84$, $p < .001$, $\eta_p^2 = .128$, indicating that participants selected less from Deck A as the task progressed. The main effect of Group was also not significant, $F(2,156) = 0.001$, $p = .999$, $\eta_p^2 = .000$.

For Deck B, there was not a significant Group by Block interaction, $F(2,156) = 1.74$, $p = .179$, $\eta_p^2 = .022$, nor a significant main effect of Group, $F(2,156) = 0.61$, $p = .544$, $\eta_p^2 = .008$. The main effect of Block was significant, $F(1,156) = 4.16$, $p = .043$, $\eta_p^2 = .026$, indicating participants selected more from Deck B as the task progressed.

For Deck C, there was not a significant Group by Block interaction, $F(2,156) = 0.61$, $p = .546$, $\eta_p^2 = .008$. The main effects of Block, $F(1,156) = 2.32$, $p = .130$, $\eta_p^2 = .015$, and

Table 4. Study 4: IGT performance and timing as a function of intertrial interval presented as mean and standard deviation.

	500 ms		1000 ms		2000 ms	
Variable	M	SD	M	SD	M	SD
Decision Making Under Ambiguity						
A 1–40	21.65	6.51	22.69	5.19	21.76	6.09
B 1–40	34.06	11.50	34.23	11.88	33.87	11.56
C 1–40	24.29	5.89	23.27	6.63	22.21	6.53
D 1–40	18.91	8.37	19.81	7.05	21.37	7.77
Decision Making Under Risk						
A 41–100	18.54	7.75	17.55	8.14	18.50	10.32
B 41–100	37.83	15.06	33.49	15.18	38.50	18.66
C 41–100	22.56	8.22	23.30	10.71	20.33	9.85
D 41–100	21.07	10.48	25.10	12.07	22.68	15.03
Decision Making Speed						
Time 1–40	1098.34	750.28	1180.22	474.36	1119.99	582.24
Time 41–100	799.30	466.14	1085.61	598.16	1132.76	1042.70

IGT performance is presented as percent selections from each individual deck (A, B, C, D) across the earlier (Trials 1–40) and later (Trials 41–100) trials. Timing is presented as the average time in milliseconds to a decision in the earlier and later trials.

Group, $F(2,156) = 1.80$, $p = .168$, $\eta_p^2 = .168$, were also not significant.

For Deck D, there was not a significant Group by Block interaction, $F(2,156) = 1.56$, $p = .213$, $\eta_p^2 = .020$. The main effect of Block was significant, $F(1,156) = 9.26$, $p = .003$, $\eta_p^2 = .056$, indicating greater selections from Deck D as the task progressed. The main effect of Group was not significant, $F(2,156) = 1.29$, $p = .278$, $\eta_p^2 = .016$.

In summary, the IGT performance analyses indicate that participants, independent of group assignment, learned to avoid Deck A in favor of Decks B and D as the task progressed.

IGT timing

A repeated-measures ANOVA on the IGT timing variables found a significant main effect of Block, $F(1,156) = 6.85$, $p = .010$, $\eta_p^2 = .042$, and a significant Group by Block interaction, $F(2,156) = 3.62$, $p = .029$, $\eta_p^2 = .044$. The main effect of Group was not significant, $F(2,156) = 1.61$, $p = .202$, $\eta_p^2 = .020$. Independent of group assignment, participants made quicker selections on Trials 41–100 than on Trials 1–40, $p = .010$. On Trials 1–40, no significant differences emerged in response times, *p*s > .491. On Trials 41–100, participants in the 500 ms group responded quicker than participants in the 1000 ms ($p = .045$) and 2000 ms ($p = .021$) groups.

Additional analyses on the IGT

Finally, Pearson's correlations were calculated between decision making speed and task performance. A positive correlation was found between speed and Deck A selections on the early trials, $r(159) = .174$, $p = .028$. In addition, on the later trials, a negative correlation for Deck B selections was found, $r(159) = -.213$, $p = .007$.

Study 4 discussion

The results failed to support our hypotheses. No significant differences were found in individual deck selections, in either the earlier or later trials, as a function of the intertrial interval. Manipulating the intertrial interval did, however, alter decision making speed more generally. A longer intertrial interval was associated with slower decision making speed during the later trials. These results are in keeping with previous research showing constraints on decision making speed does not change performance (Bowman et al., 2005), but contrary to research suggesting that the length of the time constraint affects advantageous decision making (Cella et al., 2007). The results of Study 4 indicate that increasing the intertrial interval to give participants more time to learn from the trial feedback did not in turn improve decision making. Thus, it is not likely that this is an adequate explanation for the previous study findings and instead we focus the remaining discussion on the influence of working memory and processing speed in system 1 (hot) and system 2 (cold) decision making processes.

General discussion

The present series of studies directly examined the influence of working memory and processing speed on decision making, utilizing the IGT as the specific assessment of decision making. We first tackled the question, can we manipulate decision making by taxing working memory resources? Across two studies, the answer to this question is yes. Completing a dual task, in turn depleting working memory resources, slows down the rate of decision making and changes the overall pattern of the decisions. Participants completing a dual task were not distracted from Deck D, the most advantageous deck, but failed to learn that Deck C was also an advantageous deck. Although Deck C and Deck D both have lower immediate rewards and long-term gains, they differ in the amount (low in Deck C, high in Deck D) and frequency (low in Deck D, high in Deck C) of immediate losses. Participants who were distracted by the dual task paradigm might have only focused on the frequency of losses when deciding to choose Deck D instead of Deck C. Taxing working memory resources may have prevented participants from fully examining the benefits of Deck C (e.g., De Neys, 2006; De Neys & Schaeken, 2007; De Neys et al., 2005; De Neys & Verschueren, 2006), instead focusing on the more "obvious" minimized frequency of immediate losses associated with Deck D. When able to focus on the task itself, participants are able to navigate the nuances of the decks and consider both short- and long-term consequences of their decisions. It is possible that participants are developing different heuristics regarding the decks, depending in part on the task circumstances. One heuristic may be "easier" to develop, as participants consistently learn Deck D is an advantageous deck. A second heuristic may be more difficult to develop, as distracted participants had difficulty learning Deck C is an advantageous deck.

We next tackled the question, can we manipulate decision making by changing the focus on speed versus accuracy? Well, it depends. Telling someone to focus on accuracy and making the best possible decision increases selections from Deck C, whereas telling someone to focus on making the quickest possible decision increases selections from Deck D. This finding is consistent with our first results, in that learning Deck C is advantageous is more difficult than learning Deck D is advantageous. However, giving someone more time to learn from their decisions does not affect performance. Increasing the intertrial interval did not result in improved decision making, consistent with previous research (Bowman et al., 2005). Taken together, it appears that a heuristic that Deck D is good develops naturally as participants progress through the task, as it occurs when participants are distracted by a competing task and when instructed to work quickly. A heuristic that choosing from Deck C is also a good decision takes a greater level of effort to learn, as it occurs when participants are not distracted by a competing task and when they are instructed to work as accurately as possible. In both cases, we are providing additional evidence that learning does occur on the IGT.

The present results suggest that it may be easier to determine that Deck D is advantageous that it is to determine Deck C is advantageous. If participants are focusing, at least in part, on the frequency of losses and not just long-term outcomes, then Deck D becomes a good deck to choose from for two reasons (lower loss frequency, long-term gains) whereas Deck C is only advantageous for one reason (long-term gains). The initial gut feeling or reaction that Deck D is a good deck may be much quicker to emerge than the reaction the Deck C is a good deck. This theory is consistent with previous research suggesting that at times the intuitive response is actually the logical (and correct) response (e.g., De Neys & Pennycook, in press) and does not require additional time to engage system 2 processes (e.g., Bago & De Neys, in press, 2019). Some of this more recent research suggesting that the initial "gut feeling" or intuitive response is not always incorrect goes against the learning-based theories of decision making on the IGT, as well as thinking that heuristics are frequently biased toward incorrect responses (for further critique of the dual process theory of decision making, see Evans & Stanovich, 2013).

Our findings suggest that decision making task performance can vary depending on external circumstances during the task administration. Variations in how task instructions are presented could lead the individual to focus on speed versus accuracy of decision making, in turn changing the pattern of decisions made. Being distracted, such as by thinking about an upcoming or recently completed task, could also distract the individual from learning to decide advantageously (i.e., creating an internalized "dual task" paradigm). Researchers and clinicians alike should be mindful of the extent to which how task instructions are presented, and the order of tasks in a testing session, could influence performance on the IGT and other decision making tasks. We provided further evidence that the decision making assessed with the IGT is sensitive to external factors (see Figure 1), and these factors should be taken into consideration when assessing overall decision making ability.

Limitations

There are several important limitations to the present studies. The IGT was the sole decision making instrument utilized. Although it is the most commonly used

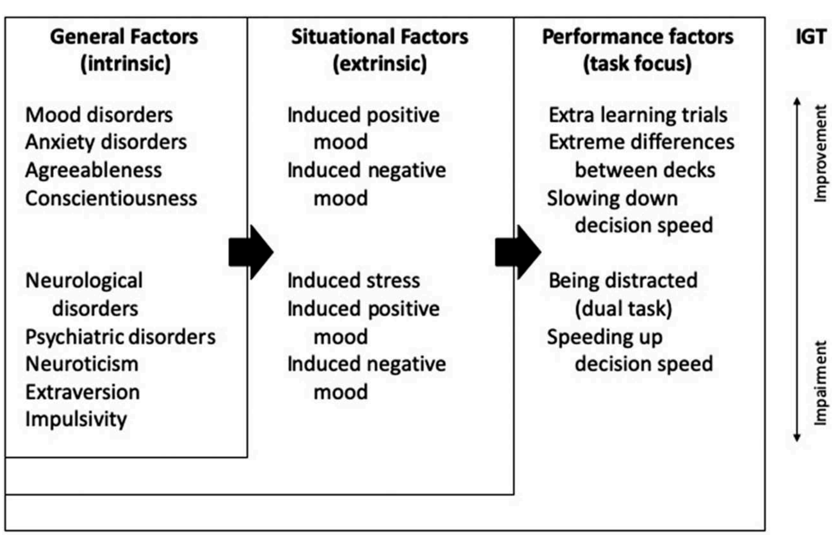

Figure 1. Factors influencing performance on the Iowa Gambling Task (IGT).

behavioral decision making tasks by clinical neuropsychologists, and the only task standardized for use in clinical evaluations, questions remain as to what precisely the IGT assesses. It is important that this study be replicated with additional measures of decision making. Also, the current study included only samples of college students, and should be replicated with a broader and more diverse sample of participants. We were adequately powered to detect medium effects, but underpowered to detect small effects.

Conclusions and future directions

In sum, decision making, as assessed by performance on a common behavioral task, is affected by both internal and external factors. Being distracted while making decisions and focusing on speed versus accuracy can result in less advantageous decisions. As the IGT was designed to mimic real-world decision making, these findings suggest mechanisms by which individuals may engage in increased risk-taking behaviors in real life. Instead of a "gut" reaction, the current study points to decision making as a permeable process, influenced by task focus and distraction. Clinicians and researchers alike should be mindful of situational or performance factors, such as how task instructions are presented, that could significantly affect performance patterns. Future research should continue to explore the subtle ways decision making happens in real life.

Disclosure statement

No potential conflict of interest was reported by the authors.

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