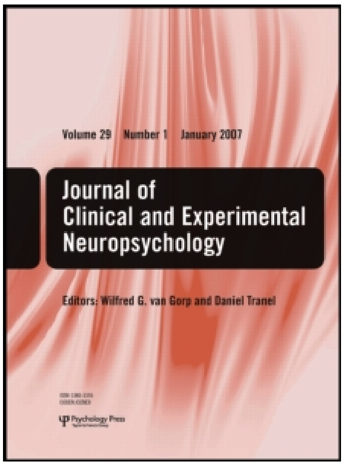

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Simon Dymond [a]; Matteo Cella [a]; Andrew Cooper [b]; Oliver H. Turnbull [c]
[a] Swansea University, Swansea, UK [b] Goldsmiths, University of London, London, UK [c] Bangor University, Bangor, UK

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The contingency-shifting variant Iowa Gambling Task: An investigation with young adults

Simon Dymond,[1] Matteo Cella,[1] Andrew Cooper,[2] and Oliver H. Turnbull[3]

[1]Swansea University, Swansea, UK
[2]Goldsmiths, University of London, London, UK
[3]Bangor University, Bangor, UK

The contingency-shifting variant Iowa Gambling Task (IGT), in which the reward and punishment contingencies of different decks of cards are systematically altered, was investigated with a large group of healthy young adults (n = 208). Our findings demonstrate that the onset of unsignaled, contingency-shift phases initially disrupted learning but that performance subsequently improved during each shift. Subjective experience ratings were positively correlated with performance across all phases. A regression model showed that performance early in the task, in Blocks 3 and 4, significantly predicted later ability to shift to the changing contingencies. Subdividing participants into high performer and low performer groups revealed an increased number of selections of previously good-now-bad decks in the latter group. Overall, the contingency-shifting variant IGT may have potential as a novel measure of reversal learning in experimental and clinical settings.

Keywords: Contingency shifting; Variant Iowa Gambling Task; Emotion-based learning.

In the past decade or so, the Iowa Gambling Task (IGT) has become one of the most popular methods of investigating emotion-based learning in several populations (e.g., Bechara, Damasio, Damasio, & Anderson, 1994; Bechara, Tranel, & Damasio, 2000; Bowman & Turnbull, 2003; Cella, Dymond, Cooper, & Turnbull, 2007; Dalgleish et al., 2004; Glicksohn, Naor-Ziv, & Leshem, 2007; Levine et al., 2005; Sevy et al., 2007). The original version of the IGT typically consists of five blocks of 20 trials and involves participants making choices from four concurrently available decks of cards for monetary gain/loss. Two of the decks (labeled A and B) result in frequent immediate high gain per choice (e.g., £100), but produce high-magnitude losses of differing frequencies depending on the deck, leading to a cumulative long-term loss (i.e., termed "the disadvantageous choice"). The remaining two decks (labeled C and D) typically result in lower immediate rewards, (e.g., £50), but also generate lower magnitude losses at the same frequency of punishment as Decks A and B, resulting in a cumulative long-term gain (i.e., termed "the advantageous choice"). A defining feature of performance on the IGT is the gradual adjustment to the affective consequences of reward and punishment, as participants initially sample cards from all of the decks before showing, by around the second block of trials, a choice preference for the advantageous decks (see Dunn, Dalgleish, & Lawrence, 2006).

In the original IGT, rewards are presented on every trial, and punishments are presented intermittently. Advantageous decision making, then, involves forgoing immediate gains with higher long-term losses for lower immediate gains and lower long-term losses. In a variant of the original task, Bechara et al. (2000) arranged the schedules such that the advantageous decks presented high immediate punishment but overall higher rewards, while the disadvantageous decks presented low immediate punishment but overall lower rewards. Patients with ventromedial prefrontal cortex (VMPFC) damage showed preference for the disadvantageous decks on both the standard and variant IGT. VMPFC patients were still impaired on both versions of the task even after increasing the delayed punishment or increasing the delayed rewards of the disadvantageous decks (Bechara

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Address correspondence to Simon Dymond, Department of Psychology, Swansea University, Singleton Park, Swansea, SA2 8PP, UK (E-mail: s.o.dymond@swansea.ac.uk).

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et al., 2000). Patients with major depressive disorder show impaired learning on the original, but not the variant, IGT (Must et al., 2006), while typically developing children and healthy adults show a clear developmental trend towards preferring the advantageous decks on both versions of the task (e.g., Crone, Bunge, Latenstein, & Van der Molen, 2005; Crone & Van der Molen, 2004; Davis, Patte, Tweed, & Curtis, 2007).

In recent years there has been interest in the extent to which the IGT might be regarded as a measure of "reversal learning." This argument is based on the claim that for some decks (i.e., Deck B) initial selection produces a rewarding response, followed by punishment after several selections. To investigate this issue, Fellows and Farah (2005) employed a "shuffled" variant IGT, in which the losses associated with each deck were moved to earlier in the first block of trials, and found that the learning profile of VMPFC patients was indistinguishable from that of controls. In explaining these atypical findings, Fellows and Farah (2005) suggested that reversal learning ability is built into the original IGT task (Fellows & Farah, 2005, p. 58).

There have been several other studies on reversal learning performance on tasks such as the IGT, though findings have often been inconclusive. Thus, Fellows and Farah (2003) showed that VMPFC damage, but not dorsolateral prefrontal cortex damage, impaired reversal learning performance on the IGT, with the degree of impairment correlated with improved performance on the shuffled variant IGT. Likewise, Brand, Recknor, Grabenhorst, and Bechara (2007) found that performance on specific executive function measures, such as the Wisconsin Card Sorting Task (WCST), which involves reversal learning abilities or sensitivity to reward contingency modifications, was correlated with performance on the last blocks of IGT trials only (see also Lehto & Elorinne, 2003; Mitchell, Colledge, Leonard, & Blair, 2002). Performance on the first block of IGT trials was not correlated with either the WCST measure or other IGT blocks. Brand et al. (2007) suggested that two potentially separable mechanisms, decision making under ambiguity and decision making under risk, operate during the first and latter blocks of the IGT trials, respectively. Correlations with the WCST were only found in the later trial blocks (when decisions are made under risk) because reversal learning, which is indexed by the WCST, was not implicated until later in the task after punishment has been experienced.

In the context of these complex (and at times ambiguous) findings, we note that there are several limitations in investigating reversal learning on the traditional IGT (and indeed the WCST). Firstly, deck selection is not controlled by the investigator, so that it might take a few trials, or very many trials, before a participant encounters punishment on a particular deck. Also important is the argument of Fellows and Farah (2003) of claiming reversal learning in the standard IGT based on the effects of a single negative experience on a deck, rather than the cumulative effects of sustained selection (i.e., nine rewarding experiences followed by one punishment is argued to constitute reversal). We note that the IGT appears to be at least partially based on "aggregate learning" over many trials, as evidenced by apparently normal performance with patients with both substantial working-memory impairments (Bechara, Damasio, Tranel, & Anderson, 1998) and profound episodic memory impairment (Turnbull & Evans, 2006).

Finally, we note that the role of reversal learning in IGT performance has been investigated through correlations between the original IGT and either different tasks (e.g., reversal learning tasks; Fellows & Farah, 2003) or executive function tests (e.g., WCST; Brand et el., 2007) rather than tasks specifically designed to assess aggregate learning reversal. It seems entirely appropriate therefore to seek to measure reversal learning with the IGT, where the reversals are based on aggregate learning on multiple trials and where the onset of the reversal is controlled by the experimenter.

Recently, Turnbull, Evans, Kemish, Park, and Bowman (2006) employed a unique contingency-shifting modification of the IGT. During the contingency-shifting variant IGT, the reward and punishment contingencies were systematically altered following initial exposure to the standard 100 trials. In a nonautomated study conducted with people with schizophrenia and healthy participants, Turnbull et al. introduced three successive, signaled "shift-periods" with modified contingencies such that the decks that were previously advantageous became disadvantageous, and vice versa. Healthy participants showed normal levels of learning during the later trials of each shift-period, which were almost indistinguishable from those of people with schizophrenia who scored high in positive symptoms, but not from those who scored high in negative symptoms.

These findings highlight flexible, emotion-based learning in schizophrenia that involves shifting or reversal learning: something that researchers had previously known people with schizophrenia to have difficulties with (e.g., Pantelis et al., 1999). The contingency-shifting variant IGT devised by Turnbull et al. (2006) offers considerable promise as a means of investigating the flexible use of emotion-based learning and further elucidating the role played by reversal learning in IGT performance. It is important to note that we use the term "contingency-shifting" to refer to a progressive modification of the reward and punishment contingencies of the IGT and not to abilities described by similar, related terms such as "set-shifting" (e.g., Dias, Robbins, & Roberts, 1996).

The present study sought to extend the findings of Turnbull et al. (2006). We were interested in exploring the potential of the contingency-shifting variant IGT as a putative measure of reversal learning ability in a large sample of young adults. To do so, we adapted the procedure of Turnbull et al. in the following ways. First, Turnbull et al. used a nonautomated version of the task and real-money rewards throughout. Although no significant differences have been observed between automated and nonautomated formats (Bowman, Evans, & Turnbull, 2005) or when real and hypothetical rewards have been used (Bowman & Turnbull, 2003), the variability of control group IGT performance (e.g., Dunn et al., 2006, pp. 251–252; Glicksohn et al., 2007) across studies employing identical tasks suggests that a replication and extension of Turnbull et al.'s findings would be salutary. Second, Turnbull et al. did not measure participants' subjective experience ratings of the relative "goodness" and "badness" of the decks (Bowman et al., 2005). Recording subjective ratings allows for an examination of the effects of the shift-periods on emotion-based learning and may permit an identification of when during the task the rules governing choices become explicit (Brand, Labudda, & Markowitsch, 2006; Brand et al., 2007; Maia & McClelland, 2005). Finally, Turnbull et al. signaled each of the three shift-periods to participants, which may have influenced subsequent choices. The present study was undertaken to address these issues and to provide a detailed analysis of contingency-shifting IGT performance with a large cohort of young adults.

METHOD

Participants

A total of 208 undergraduates (95 male, 113 female) from Swansea University participated in return for course credit. Ages ranged between 18 and 38 years (M = 21.38, SD = 4.11). An independent samples t test revealed no significant difference in age between males and females, $t(206) = -0.518$, $p = .605$. Participants had a mean of 14.94 (SD = 2.67) years of education (see Evans, Kemish, & Turnbull, 2004).

Materials and procedure

An automated version of the IGT, programmed in Visual Basic® 6.0, was employed. Participants received general instructions about the task that were based on Bechara et al. (2000; see Appendix) and completed a total of 220 trials of the IGT in two phases: 100 trials of the original version of the task (Phase 1) followed by 120 trials of a contingency-shifting variant IGT involving three successive shifts of reward and punishment (Phase 2).

Phase 1: Original IGT

Participants were instructed to select cards from four concurrently available blue-colored decks (labeled sequentially A, B, C, and D). The computer program randomly determined which two of the decks were to be "advantageous" and "disadvantageous," respectively, for each participant (Fernie & Tunney, 2005; Lin, Chiu, Lee, & Hsieh, 2007; Pecchinenda, Dretsch, & Chapman, 2006). That is, the spatial location of the advantageous and disadvantageous decks was not restricted to the left (i.e., A and B) or right (i.e., C and D) of the computer screen.[1] Randomly determining advantageous and disadvantageous decks at the outset of the task for every participant excludes location preference as a potential factor governing performance. Once determined, the positions of the decks remained unchanged until the end of the task.

A loan of £1,000 of virtual money was displayed at the bottom right of the screen and was updated immediately following choices with gains and/or losses. Participants always won £100 if they selected a card from the "disadvantageous" decks and always won £50 if they selected a card from the "advantageous" decks. The amount of losses varied between £150 and £350 for Deck A, £1,250 for Deck B, between £25 and £75 for Deck C, and £250 for Deck D. In the case of gains, a sentence stating, "You won X! X added to your total" appeared on the screen, and the amount of money won was added to the total. In the case of gains and loss, the message presented was "You lose £1,250! £1,250 has been deducted from your total." This onscreen feedback was displayed for 5 s, before a 2-s intertrial interval (ITI). Phase 1 ended after 100 trials.

Phase 2: Contingency-shifting IGT

Immediately after Phase 1 (i.e., without interruption), three contingency-shift phases, each consisting of two blocks of 20 trials, were introduced (Turnbull et al., 2006). The onset of each unsignaled shift phase involved a systematic modification of the reward and punishment contingencies of Phase 1 (participants' positions within the decks continued into Phase 2). During the three 40-trial contingency-shift phases, the advantageous decks (C and D) were successively replaced by Decks A and D (Shift Period 1), A and B (Shift Period 2), and B and C (Shift Period 3; see Figure 1). Each contingency-shift period began immediately following the 100th (Shift Period 1), 141st (Shift Period 1), and 181st trial (Shift Period 1), respectively. Table 1 shows the net win/loss for each deck in each shift period. Phase 2 consisted of a total of 120 trials.

Subjective experience ratings

After every 20 trials in both phases, participants were asked to provide subjective experience ratings in terms of how "good" or "bad" they felt each deck to be (Evans,

Deck	Phase 1	Phase 2		
		Shift 1	Shift 2	Shift 3
A	–	+	+	–
B	–	–	+	+
C	+	–	–	–
D	+	+	–	–

Figure 1. The good (+) and bad (–) decks during Phase 1 and each of the three shift phases of Phase 2.

[1]Consistent with convention, we continue to refer to the advantageous and disadvantageous decks as "C and D" and "A and B," respectively, although the labels corresponding to the good and bad decks were in fact randomly determined for each participant.

TABLE 1
Net win/loss per 20 trials for each of the decks during Phase 1 and each of the three shift periods of Phase 2

		Win/loss[a]				*Decks*	
	Shift	*A*	*B*	*C*	*D*	*"Good"*	*"Bad"*
Phase 1		2,000/2500	2,000/2500	1,000/500	1,000/500	C+D	A+B
Phase 2	1	1,000/500	2,000/2500	2,000/2500	1,000/500	A+D	B+C
	2	1,000/500	1,000/500	2,000/2500	2,000/2500	A+B	C+D
	3	2,000/2500	1,000/500	1,000/500	2,000/2500	B+C	A+D

Note. The two advantageous ("good") and disadvantageous ("bad") decks in each phase/period are also shown.
[a]In UK£ Sterling.

Bowman, & Turnbull, 2005). Ratings were made using a slider-scale from 0 to 10 (where 0 = *very bad* and 10 = *very good*).

RESULTS

Mean net score and subjective ratings

The mean net score was calculated by subtracting disadvantageous selections from advantageous selections [(C + D) – (A + B)]. A net score above zero is indicative of advantageous selections, while a net score below zero implies disadvantageous selections. Figure 2 shows that there was a steady increase in learning for all participants over the five blocks of Phase 1. A repeated measures analysis of variance (ANOVA) showed that participants significantly improved across the five trial blocks, $F(4, 828) = 44.38$, $p < .0001$, $\eta^2 = .18$ (Greenhouse–Geisser adjusted). Contrast analyses showed that there were significant increases in learning from Block 1 to Block 2, $F(1, 207) = 28.05$, $p < .0001$, $\eta^2 = .12$, from Block 2 to Block 3, $F(1, 207) = 10.98$, $p = .001$, $\eta^2 = .05$, and from Block 3 to Block 4, $F(1, 207) = 7.25$, $p = .008$, $\eta^2 = .03$, but not from Block 4 to Block 5, $F(1, 207) = 2.62$, $p = .11$, $\eta^2 = .012$. In the first contingency-shift period, Figure 2 shows that there was a substantial impairment in choice of advantageous decks; mean net score for the whole sample returned to slightly below chance levels compared to the final block of Phase 1. This would suggest that the initial contingency shift was successful in disrupting the established contingency learning. In terms of performance within each discrete shift period, repeated measures *t* tests showed that there was a significant increase in mean net score within the first, $t(207) = –2.74$, $p = .007$, and the third, $t(207) = –2.81$, $p = .005$, contingency-shift periods but not for the second, $t(207) = –1.88$, $p = .061$.

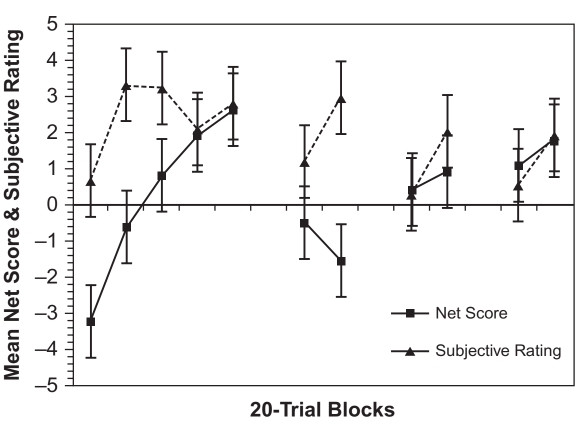

Figure 2. Mean net score and subjective ratings for all participants for the five 20-trial blocks in Phase 1 and the six 20-trial blocks in Phase 2. Error bars represent two standard errors.

A mean net subjective rating was calculated by subtracting the ratings of the disadvantageous decks from the subjective ratings of the advantageous decks. Figure 2 shows that there was a large increase in subjective ratings after the first block in Phase 1. A repeated measures ANOVA showed that subjective ratings differed significantly across the five trial blocks, $F(4, 828) = 25.17$, $p < .0001$, $\eta^2 = .11$ (Greenhouse–Geisser adjusted). Contrast analyses showed that there was a significant increase in subjective ratings from Block 1 to Block 2, $F(1, 207) = 60.50$, $p < .0001$, $\eta^2 = .23$, no significant change from Block 2 to Block 3, $F(1, 207) = 0.198$, $p = .66$, $\eta^2 = .001$, a significant decrease in subjective rating from Block 3 to Block 4, $F(1, 207) = 8.77$, $p = .003$, $\eta^2 = .04$, and a significant increase in subjective rating from Block 4 to Block 5, $F(1, 207) = 4.50$, $p = .035$, $\eta^2 = .02$. Figure 2 further shows a trend of increasing subjective ratings between the first and the second block of each of the contingency-shift periods in Phase 2. Repeated measures *t* tests did indeed show that there were significant increases in mean net subjective ratings within the first, $t(207) = –5.32$, $p < .0001$, second, $t(207) = –4.65$, $p < .0001$, and third, $t(207) = –3.81$, $p < .0001$, contingency-shift periods. A Pearson product–moment correlation between the IGT mean net score and subjective experience ratings revealed a positive correlation in Phase 1 ($r = .22$, $p < .0001$) and Phase 2 ($r = .19$, $p < .0001$).

Stepwise multiple regression was conducted to investigate factors predicting Phase 2 performance. The dependent variable of the regression model was the total mean net score of the contingency-shift phase. Predictors entered were: Phase 1 Blocks 1, 2, 3, 4, and 5 mean net score, Blocks 1, 2, 3, 4, and 5 mean net subjective rating, age, years of education, and gender. Variables were included and excluded from the final model on the basis of significant values of partial correlation (p in .05 and p out .10, respectively). Only three predictors entered into the model, accounting for almost 28% of the contingency-shift performance, $R^2 = .277$, $F(3, 207) = 26.11$, $p < .0001$. The strongest predictor was Block 3 mean net score (standardized $b = .39$, $p < .0001$), followed by Block 4 mean net score (standardized $b = .2$, $p = .007$) and Block 1 mean net score (standardized $b = -.15$, $p = .013$). Although largely accounted for by the mean net score of Blocks 3 and 4, the regression findings showed that poor performance in Block 1 predicts good performance during Phase 2. No other variables were found to significantly predict performance in Phase 2.

Contingency-shift learning

The analyses presented above show clear evidence of improvements in learning across the original version of the task (Phase 1) and impairments in learning with the contingency shifts (Phase 2), most notably in the first contingency-shift period. Analyses with the whole sample, however, tend to mask substantial individual differences in learning performance across both the normal and the shift phases. As our focus in the current paper is the contingency-shift version of the IGT in young adults, we sought to focus further on learning in each of the contingency-shift subphases. On the basis that Bechara and Damasio (2002) had previously suggested that a score of 10 or greater on the standard phase of the task characterized advantageous performance, we elected to include in subsequent analyses only those individuals who had achieved a mean net score equal to or greater than 10 in the normal IGT phase ($N = 69$). In other words, the focus is on those participants who had shown some success in learning the original reinforcement contingencies. An inspection of contingency-shift performance for this subsample revealed substantial differences in performance. A total of 39 of the participants had a total mean net score above 10 for the contingency-shift phase ($M = 35.05$, $SD = 21.66$: high performers), while 26 participants had mean net scores below 0 for the contingency-shift phase ($M = -13.04$, $SD = 13.85$: low performers). A total of 4 participants who scored 0 or just above chance on the contingency-shift phase were not considered in subsequent analyses. An independent samples t test revealed a highly significant difference in mean net score between these two groups, $t(63) = 10.02$, $p < .0001$. Independent t tests performed on high and low performers for age and education did not reveal any significant differences between the groups ($p > .05$); similarly a chi square test did not reveal a gender difference between the groups, $\chi^2(2) = 0.11$, $p > .05$. Likewise, a repeated measures t test did not reveal significant differences in subjective ratings between the high and low performer groups in any block of either Phase 1 or Phase 2 (all $p > .05$). Based on the clear differences in contingency-shift performance for the high performers and low performers, we used these two groups in subsequent analyses of contingency-shift performance.

To further explore differences in deck selections between the two groups over the three shift periods, a mixed factor 3 (shift period) × 4 (deck) × 2 (group) analysis was conducted. Of most interest was a significant three-way interaction between group, shift period, and deck, $F(6, 378) = 12.63$, $p < .0001$, $\eta^2 = .17$ (Greenhouse–Geisser adjusted). Figure 3 shows the pattern of deck selection for the two groups in each shift period. The two groups appear to display more differentiated selection of decks in Shift Periods 2 and 3 than in Shift Period 1. Simple interactions indicated that there was no significant deck by group interaction in Shift Period 1, $F(3, 189) = 2.13$, $p = .098$, $\eta^2 = .03$ (Greenhouse–Geisser adjusted), however there were significant deck by group interactions for Shift Period 2, $F(3, 189) = 17.98$, $p < .0001$, $\eta^2 = .22$ (Greenhouse–Geisser adjusted) and Shift Period 3, $F(3, 189) = 17.21$, $p < .0001$, $\eta^2 = .22$ (Greenhouse–Geisser adjusted).

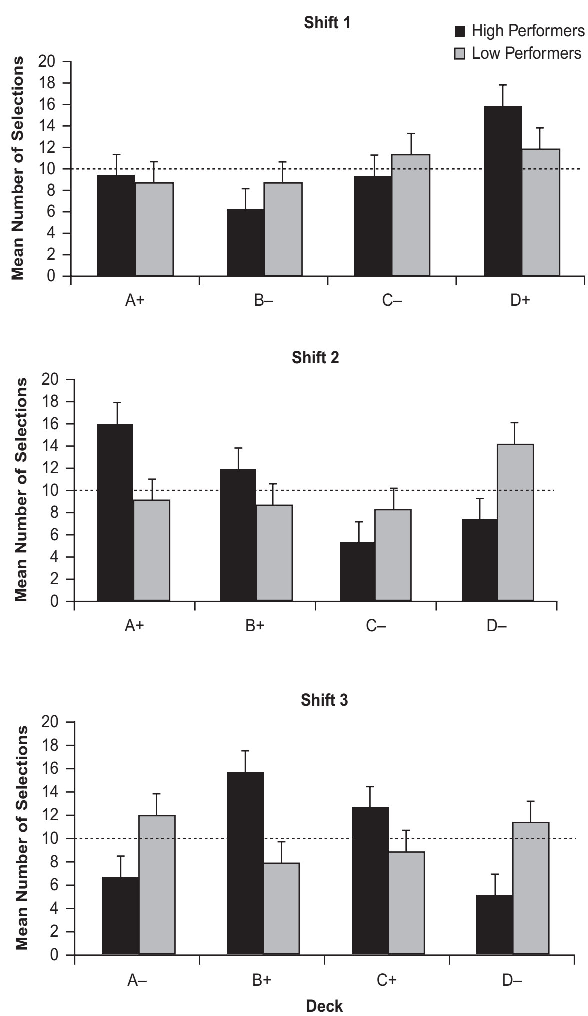

Figure 3. Mean number of deck selections for the high and low performing groups across each of the three contingency-shift periods in Phase 2. The horizontal line indicates chance responding (i.e., equal selections from each of the four decks).

To further explore deck selection differences within each shift period, Bonferroni-adjusted pairwise comparisons (using a threshold p value of .004) were made across the two groups for each individual deck across each shift period. These showed that there were no significant differences between the groups in all deck selections in the first shift period (all $p > .05$) or in Deck C in Shift Period 3 ($p = .041$), while there were significant differences across all other deck selections in Shift Periods 2 and 3 (all $p < .001$). Despite the lack of difference in deck selection in Shift Period 1, Figure 3 indicates that good performers tend to pick more from the deck that has remained "good" from the normal phase of the task in the first shift period (Deck D), whereas there were clearly no differences between the groups for the deck that shifted from "bad" to "good" (Deck A). These findings also highlight that individual differences in shift ability are more apparent after the first shift period and further show that differences in performance are relatively stable after the first shift period. The significant deck by group interactions in Shift Periods 2 and 3 shown in Figure 3 clearly highlight the differential response patterns across the groups that lead to good and poor contingency-shift performance. The poor performers in Shift Period 2 are characterized by increased responding to the deck that has changed from "good" to "bad" for that shift period (Deck D) relative to the deck that has stayed bad from Shift Period 1 (Deck C). This implies that poor performance is characterized by poor shift ability and/or a combination of response perseveration based on lack of sensitivity to negative feedback. This distinction across "bad" decks disappears for the poor performers in Shift Period 3, however, as there are no significant differences in their selections from both "bad" decks in this shift period ($p > .05$).

Flexible contingency-shift learning

As shown in Figure 1, each contingency-shift period comprises two decks changing contingencies (from "bad" to "good," and vice versa) and two of the decks having the same contingency as that for the previous shift period. In order to examine differences in performance as a function of absolute and progressive contingency shifts, we calculated an index of flexible contingency-shift learning for each deck. This *index of flexible learning* was calculated by dividing the cumulative number of selections of each deck by the total number of trials for which the deck had a particular contingency immediately after a contingency shift. The index was calculated for every block of 20 trials. For example, in the first block of 20 trials in Shift Period 1, the number of selections of Deck A would be divided by 20 as this is the cumulative number of trials for which this deck has been "good" (i.e., it has changed from being "bad" in the original phase of the IGT, to "good" in the first shift block). In the same block of trials, the cumulative selections of Deck B would be divided by 120, as the contingency for this deck has not changed from the original phase. The index of flexible learning thus provides a measure of deck selection weighted by the number of trials for which a deck has had "good" or "bad" contingencies in effect. The weighted scores can range from 0 (no selection in any trials from that particular block) to 1 (deck selected on all trials with the same contingency).

Figure 4 shows the index of flexible learning for the high and low performing groups. A mixed factor 6 (block) × 4 (deck) × 2 (group) analysis showed a significant three-way interaction, $F(15, 1{,}410) = 21.33$, $p < .0001$, $\eta^2 = .19$ (Greenhouse–Geisser adjusted). Figure 4

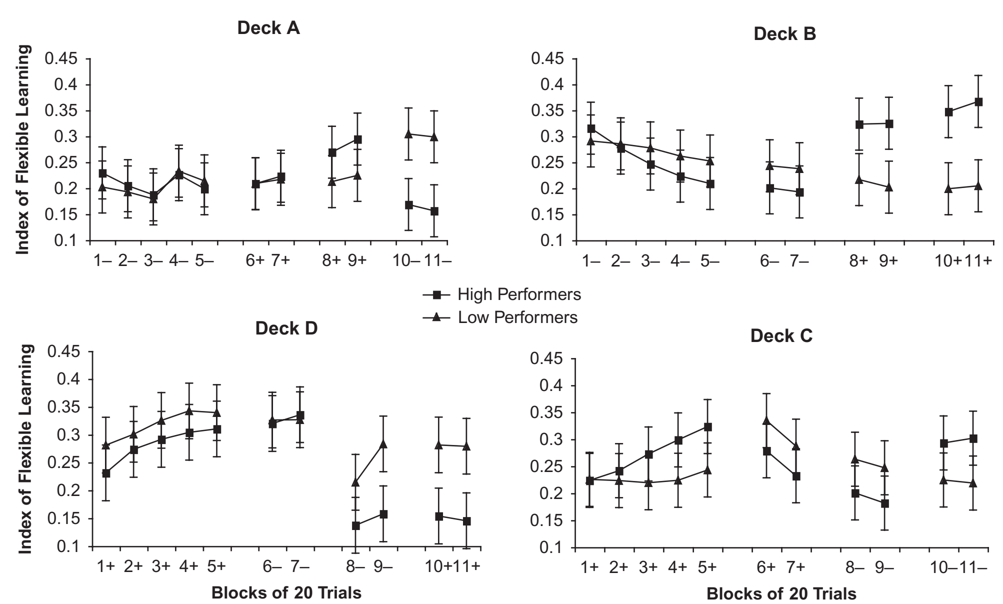

Figure 4. Weighted proportion (index of flexible learning) of deck selections for the high and low performing groups across each of the decks during Phase 1 and Phase 2.

shows distinct patterns of weighted deck selections for each of the groups across the six blocks of trials. It is noticeable that differences in deck selections across the two groups are more substantial in the latter four blocks of trials, as noted earlier. Focusing on the low performers group, there is a differentiation across decks in terms of their disadvantageous selections. With Deck A, this group selected this deck relatively infrequently when the deck was "good" in the first four blocks of trials, yet responded significantly more frequently when the deck shifted to "bad" in the final two blocks, $F(1, 44) = 12.87$, $p = .001$. With Deck B, there was a relatively undifferentiated pattern of responding across all blocks, with no significant differences in weighted deck selection across all blocks. With Deck C, there was a steadily declining rate of weighted deck selection across the six blocks. There was no significant increase or decrease in selection when this deck shifted to good in the final two blocks of the task. Finally, with Deck D, the low performers group had a similar pattern of weighted deck selection to the group that performed well in the first two blocks of trials. However, while they decreased their selections significantly from Block 2 to Block 3, $F(1, 44) = 25.22$, $p < .0001$, when this deck turned "bad," they subsequently increased selections from this deck from Block 3 to Block 4, $F(1, 44) = 22.83$, $p < .0001$, and maintained a relatively high rate of disadvantageous selections for the remaining blocks.

DISCUSSION

The present findings offer novel insights into the question of flexible emotion-based learning on the contingency-shifting variant IGT, carried out with a sufficiently large sample size so that a range of possible relationships between important variables could be investigated. As in previous studies, participants showed normal levels of learning during Phase 1 (e.g., Bowman & Turnbull, 2003; Cella et al., 2007; Turnbull et al., 2006). Similarly, as in the previous study, the onset of the first contingency modification in Phase 2 initially disrupted learning but it soon recovered to earlier levels. The two subsequent shift periods resulted in similar decrements in learning.

The present study had sufficient sample size to investigate the key issue of variability in IGT performance with healthy participants, a concern that has been raised previously in relation to this literature (Caroselli, Hiscock, Scheibel, & Ingram, 2006; Dunn et al., 2006, pp. 251–252; Glicksohn et al., 2007). We performed a number of analyses to better understand the ways in which important themes covary, which reveal interesting trends that underpin flexible decision making. Perhaps most striking was the observation that there were substantial individual differences in performance on both the original and the contingency-shift IGT phases. Approximately two thirds of the present sample underperformed during the original IGT phase, according to Bechara and Damasio's (2002) criterion of advantageous performance. This suggests that before the contingency-shifting task may be used in clinical settings, it must be sufficiently robust to account for individual differences in performance during the original IGT phase.

Focusing only on participants who had a mean net score equal to or greater than 10 in the original IGT phase, we divided participants into groups of high performers and low performers, based on their performance during the contingency-shifting phase. Analysis of the contingency-shift phase with these two groups highlighted distinct patterns of deck selection across the contingency-shift periods. The results indicated that responses were more differentiated in the latter periods of the contingency-shift phase than in the first shift period. In addition, low performers tended to incorrectly choose decks that had shifted in reinforcement contingency, rather than simply choose decks that were "bad" in the standard phase. This would suggest that the task is sufficiently sensitive to measure reversal learning processes through an inability to shift reinforcement contingency as indicated by the patterns of response perseveration shown by low performers (Fellows & Farah, 2005).

Given that the contingency-shifting variant IGT meets the necessary requirements for classification as a measure of reversal learning (i.e., systematic, and repeated, reversal of reinforcement contingencies), our findings do not appear to support the claim of Fellows and Farah (2003, 2005) that reversal-learning ability is implicated primarily during the initial IGT trial blocks. Our findings from the regression model showed that performance during the third and fourth blocks of trials (i.e., more than halfway through the task) in Phase 1 predicted shift performance in Phase 2. That is, participants who performed better in the later IGT trial blocks in Phase 1 tended to be better at shifting when the contingencies subsequently changed in Phase 2, presumably because of an enhanced reversal learning ability.

Notwithstanding the findings of the regression model, it is perhaps difficult to directly compare across studies because Fellows and Farah's (2003, 2005) claim rests on findings obtained with the shuffled variant IGT, in which the losses associated with each deck were moved to earlier in the first block of trials, and improvements in performance were measured by comparison with performance on the standard IGT and a separate reversal-learning task. Also, it is noteworthy that in the Fellows and Farah (2003) study, carryover effects cannot be ruled out as tasks were administered in a fixed order, and correlations were not conducted between overall, aggregate performance on the reversal learning task and the two versions of the IGT. Indeed, only "degree of improvement" (Fellows & Farah, 2005, p. 61) was estimated based on performance in the second IGT task (the shuffled variant IGT). Nevertheless, while further research is needed to determine the precise role, if any, played by reversal learning in the original IGT, the present findings suggest that the contingency-shifting variant IGT holds considerable promise as a novel means of investigating reversal learning.

The present study extended the analysis of subjective experience to the contingency-shifting variant IGT and reveals greater roles for subjective awareness than might previously have been anticipated (Bechara, Damasio, Tranel, & Damasio, 1997; Bechara et al., 2000). The subjective experience ratings of the relative "goodness" and "badness" of the decks were initially quite low (but still above chance) during Phase 1, but by the second block of trials had increased and remained relatively stable. Consistent with previous findings, ratings remained higher than IGT performance across all blocks (Bowman et al., 2005; Cella et al., 2007; Evans et al., 2005), suggesting that all participants, both high performers and low performers, had greater awareness of the reward/punishment schedules of the different decks than their behavioral performance implied (cf. Bechara et al., 2000; but see Evans et al., 2005; Maia & McClelland, 2005). This finding was replicated in Phase 2, with ratings progressively falling during the first block of each shift period and then increasing by the second block, although the level at which ratings increased gradually declined during each shift period. This suggests that participants may come to rely less and less on intuitive/subjective sources of knowledge as they become more familiar with the parameters of the task. Indeed, it is likely that explicit cognitive strategies play a role in guiding card selections later in the task. Regardless of the precise nature of the relationship between cognitive or emotion-based strategies in IGT performance, our findings clearly showed that behavioral IGT performance and subjective experience ratings were positively correlated in both phases for all participants (see Evans et al., 2005).

Further research is needed to determine the factors responsible for the between-subject variability in performance observed in the present study. As outlined in the introduction, it is not uncommon to observe considerable variability in control group performance on the IGT (e.g., Caroselli et al., 2006; Glicksohn et al., 2007), and there are several possible factors that should be considered. The first factor concerns the task instructions used. Previous research with the original IGT has shown that the type of instructions used can have a systematic effect on learning (e.g., Balodis, MacDonald, & Olmstead, 2006; Fernie & Tunney, 2005). The abbreviated instructions that we used, which were adapted from Bechara et al. (2000; see the Appendix), may help to explain the finding that the mean net scores in Phase 1 were lower than those typically reported for previous studies presumably employing full task instructions (e.g., Bowman et al., 2005; Fernie & Tunney, 2005). Also, our instructions did not include mention of the contingency-shifting phases, which may explain the lower learning level of the present study than that of Turnbull et al. (2006) who explicitly instructed their participants about the upcoming shifts. It is important to note, however, that few studies provide copies of the actual instructions used in the IGT, which makes comparisons with the present findings difficult. An investigation of the effects of task instructions on contingency-shifting IGT performance is therefore warranted to test the hypothesis that the "variability in control group performance" (Dunn et al., 2006, pp. 251–252) may in fact be a function of instructional control.

Our findings replicate and extend those of Turnbull et al. (2006), with a large cohort of healthy participants, using an automated procedure in which the shift periods were unsignaled. However, there are several important differences with regards to the characteristics of the participants employed in the two studies. First, the average age of the case-matched control participants in Turnbull et al. was 36.14 years (SD = 8.9), which is a difference of more than 15 years (and almost two standard deviations) from the mean age of the participants in the current study (21.3; SD = 4.1). Previous studies with similarly aged participants have also found considerable variability in original IGT performance (e.g., Caroselli et al., 2006). Therefore, further research is necessary with older participants in order to determine the effect of age on the contingency-shift IGT. Second, participants in the current study had a higher mean number of years in education (14.9; SD = 2.6) than those in Turnbull et al. (12.6; SD = 1.0). Given the documented effect of education on IGT performance (Evans et al., 2004), the longer time spent in tertiary education by the current sample may well have influenced performance. Third, Turnbull et al. employed more males (62%) than females (38%), whereas the current study employed more females (54%) than males (46%). Given that males tend to outperform females on the original IGT (e.g., Overman, 2004; Reavis & Overman, 2001), it is possible that the impaired performance observed in the present study may have been influenced by the already-identified sex differences on the IGT.

Apart from the above-mentioned factors, the present study was limited by the absence of specific measures of executive functions, as well as basic reversal learning ability and intelligence. Previous research has shown that IGT performance is correlated with intelligence scores (Olson, Hooper, Collins, & Luciana, 2007), but the relationship with executive function measures, such as the WCST and the Brixton Test (Burgess & Shallice, 1997), remains inconclusive (Brand et al., 2007; Lawrence et al., 2006; Lehto & Elorinne, 2003; Turnbull et al., 2006). Future investigations should, therefore, consider combining tests of executive functions and intelligence with the contingency-shifting variant IGT as a novel means of examining the neuropsychological profile of emotion-based learning.

There are several ways in which these findings may map onto issues of relevance for clinical neuropsychology, especially because the contingency-shifting variant IGT focuses on the flexibility of emotion-based learning. The central issue is that tasks that focus on such flexibility are likely to better capture the complex and fluctuating nature of real-world experience and therefore meet the external validity claims originally suggested in relation to the original IGT (Bechara et al., 1994). As such, the contingency-shift version of the IGT offers potential for both experimental and clinical research settings. Currently, the task has primarily been used in relation to schizophrenia and psychosis-proneness (Cella, Dymond, & Cooper, in press; Turnbull et al., 2006), but the task is likely to have many further applications in clinical work, especially in evaluating executive dysfunction. For example, the task acts as a "bridge" between existing measures of emotion-based learning (such as the IGT) and existing measures of flexible learning (such as the WCST).

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APPENDIX

INSTRUCTIONS

In a moment, the computer will present four decks of cards labelled A, B, C, and D. Your task is to select one card at a time, by clicking on the card with the computer mouse, from any deck you choose.

Each time you select a card, the computer will tell you that you have won some money. The amount of money won will be immediately added to the total, which will be displayed in the bottom right-hand side of the screen.

Occasionally, however, when you select a card, the computer will tell you that you have won some money but that you have also lost some money. The amount of money lost will be immediately deducted from your total.

Your task is to try and earn as much money as possible, and if you can't win, to avoid losing as much money as possible.

You will be given a loan of £1,000 credit to begin the task. It is important that you try and behave as if this were a real card game and try to win as much money as possible (and lose as little as possible). Treat the £1,000 credit of play money, and all money won/lost during the task, as if it were your own real money.

No matter how much you find yourself losing, you can still win. Pay attention to the wins/losses.

Every so often, the computer will ask you to give each deck of cards a score, based on how good or bad you feel they are. Please use the slider scale to rate each of the decks. The computer will show you how to do this.

The computer will not tell you when the task will end, so please keep playing until the tasks ends.

If you have any questions, please read through the instructions again to see if they answer your questions. If they do not, then ask the experimenter to explain.

Remember, your task is to try and earn as much money as possible, and if you can't win, to avoid losing as much money as possible, and be sure to give each deck of cards a score based on how good or bad you feel they are. Good luck!