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The Bangor Gambling Task: Characterising the performance of survivors of traumatic brain injury

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Running head: ADLAM-Bangor Gambling Task in TBI

Abstract

The Bangor Gambling Task (BGT, Bowman & Turnbull, 2004) is a simple test of emotion-based decision-making, with contingencies varying across five blocks of 20 trials. This is the first study to characterise BGT performance in survivors of traumatic brain injury (TBI) relative to healthy controls. The study also aimed to explore sub-groups (cluster analysis), and identify predictors of task performance (multiple regression). Thirty survivors of TBI and 39 controls completed the BGT and measures of processing speed, premorbid IQ, working memory, and executive function. Results showed that survivors of TBI made more gamble choices than controls (total BGT score), although the groups did not significantly differ when using a cut-off score for 'impaired' performance. Unexpectedly, the groups did not significantly differ in their performance across the blocks, however, the cluster analysis revealed three subgroups (with survivors of TBI and controls represented in each cluster). Findings also indicated that only age and group were significant predictors of overall BGT performance. In conclusion, the study findings are consistent with an individual differences account of emotion-based decision-making, and a number of issues need to be addressed prior to recommending the clinical use of the BGT.

KEYWORDS/MESH TERMS: Executive/social cognition/emotion processing; Measurement/psychometric; Traumatic brain injury

Introduction

Traumatic brain injury (TBI) particularly affects the frontal lobes with many survivors suffering cognitive, social, and emotional difficulties, including poor or risky decision-making (Hellawell, Taylor, & Pentland, 1999; Salmond, Menon, Chatfield, Pickard, & Sahakian, 2005). These difficulties can lead to a failure to return to employment and the breakdown of interpersonal relationships (Ownsworth & McKenna, 2004).

Damasio and colleagues (Bechara, Damasio, Damasio, & Anderson, 1994; 1996; Bechara, Tranel, Damasio, & Damasio, 1996; Damasio, 1994; Eslinger & Damasio, 1985) have long argued that emotion-based decision-making deficits experienced by individuals following frontal lobe lesions, particularly the ventromedial prefrontal cortex (VMPfC), are due to an inability to use emotion-based biasing signals generated from the body ('somatic markers'), when appraising different response options. It is hypothesised that decision-making in complex and uncertain situations, such as social situations, involves a combination of carrying out a logical cost-benefit analysis of a given action and responding to somatic markers indicating how rewarding or punishing an action is likely to be ('somatic marker hypothesis', Damasio, 1994; 1996). It is also suggested that the somatic markers lead to an 'emotional hunch' or 'gut feeling', which can guide cognitive decision-making (Damasio, Adolphs, & Damasio, 2003).

Empirical support for the somatic marker hypothesis has largely stemmed from the Iowa Gambling Task (IGT), an experimental paradigm designed to mimic real-life decision-making by factoring in complexity, uncertainty, reward, and punishment (see Bechara, Damasio, & Damasio, 2000). In the IGT, participants either win or lose money (real money or facsimile) by selecting cards from four separate decks. Two of the card decks have high wins and high losses (‘risky’ or ‘bad’ decks), and two of the decks have small wins and small losses (‘safe’ or ‘good’ decks). Participants are not told which decks are risky/bad or safe/good, and their choice of deck selection is recorded across 100 trials. A key feature of this task is that participants learn to forego short-term benefit for long-term profit over a long and complex (multiple decks with varying contingencies) reinforcement history. Changes in anticipatory skin conductance response (SCR) have been associated with successful learning, that is, making fewer ‘bad’ choices, and instead selecting from the safe decks, supporting the role of somatic markers in task performance (Bechara et al., 2000). It is argued, therefore, that to do well on this task participants must rely on ‘intuitive’ decision-making processes, in particular the activation of somatic marker biasing signals.

Consistent with the notion that the IGT mimics real-life complex decision-making, individuals with frontal lobe damage failed to adopt optimal strategies when performing the IGT leading to a continued preference for the ‘risky’ decks (Bechara et al., 1994). More importantly, these same individuals failed to show the anticipatory physiological changes in SCRs found in healthy controls (Bechara et al., 1996). Similar findings have been shown in individuals following TBI (Levine et al., 2005; Fujiwara, Schwartz, Gao, Black, & Levine, 2008; Cotrena et al., 2014). Despite the wealth of evidence supporting the IGT as a test of emotion-based decision-making (for a review see Bechara, 2004), studies have questioned the role of somatic markers and whether alternative mechanisms can account for performance on the IGT (for review see Dunn, Dalgleish, & Lawrence, 2006). For example, some studies using dual-task methods (Hinson et al., 2002; Jameson et al., 2004; but see Turnbull et al., 2005) and neurological studies (Bechara, Damasio, Tranel, & Anderson, 1998) have found that performance on the IGT is influenced by working memory capacity. Other studies have questioned the assumption that tasks need to be as complex as the IGT to capture emotion-based decision-making. For example, Bowman and Turnbull (2004) designed the Bangor Gambling Task (BGT) to have a similar structure to the IGT, that is, a gambling task with explicit financial reward/punishment and with varying contingencies, but to be a simpler version of the task. In contrast to the four-deck IGT, the BGT involves using a single deck of cards, therefore, varying contingencies across time rather than time and space as in the IGT. It also has a simple ‘gamble/no gamble’ response and either a win or loss on each trial. In the original IGT, participants receive both win and loss feedback on each trial, which potentially increases the working memory demands of the task. In their study, comparing performance on the BGT directly with performance on the IGT, Bowman and Turnbull (2004) found that undergraduate participants showed the same incremental learning across both tasks, with a significant correlation in overall performance. Further, the same individuals were impaired using the IGT cut-off of +9 or below (Bechara et al., 2001) on both tasks. Based on these findings, Bowman and Turnbull (2004) concluded that not only does the BGT have similar structural properties to the IGT, but participants also perform similarly on both tasks, thus tasks do not need to be complex to measure emotion-based decision-making. The authors suggested that the BGT potentially offers a simple measure of emotion-based decision-making, removing the complex instructions and complex feedback of the IGT, which can be used with neurological patients.

Following this suggestion, we report the first study to examine the performance of individuals with TBI relative to healthy controls on the BGT. This study aims to characterise BGT performance in survivors of TBI with the predictions that: i) survivors of TBI will make more 'gamble' choices than controls (total BGT score); ii) more survivors of TBI than controls will fall below the Bowman and Turnbull (2004) suggested cut-off of +9 or below; and (iii) survivors of TBI will have difficulty learning to change their 'gamble' response in the face of increasing losses. Specifically, there will be a significant Group by Block interaction, with no group difference on Block 1 (i.e., the first 20 trials, consistent with previous IGT studies see for example, Tranel, Bechara, & Denburg, 2002).

Given the novelty of this study, we also set out to explore patterns of performance across blocks using cluster analysis to identify sub-groups. This is of interest given the individual differences shown in control performance on emotion-based decision-tasks (e.g., Dunn et al., 2006; Horstmann, Villringer, & Neumann, 2012; Steingroever, Wetzels, Horstmann, Neumann, & Wagenmakers, 2013), and the heterogeneity in TBI (e.g., premorbid ability, mechanism of injury, time since injury, extent brain damage etc).

Finally, given the literature exploring alternative mechanisms for performance on emotion-based decision-making tasks (e.g., for a review see Dunn et al., 2006), the current study aimed to explore possible predictors of performance. Whole group multiple regressions were conducted with working memory and executive function ability as predictors. The additional variables of presence of injury, speed of processing, estimated premorbid IQ, age, and gender were included as possible predictors.

Method

Participants

Thirty survivors of TBI (25 males, 5 females; mean age: 34 years, range: 20-52 years; mean years of education: 13 years, range 12-17 years), recruited from a regional specialist neurorehabilitation centre, participated in this study (see Table 1 for details of sample characteristics). All participants survived a closed head injury, were at least 6 months post-injury (mean time since injury: 51.4 months, range: 11-192 months) and had emerged from post-traumatic amnesia. According to the Glasgow Coma Scales (GCS, Teasdale & Jennett, 1979) severity classifications, 23 of the survivors suffered severe TBI (GCS 3-8), 2 suffered moderate TBI (GCS 9-12), and 2 suffered mild TBI (GCS 13+), with missing data for 3 participants. Despite the missing data and the variability in injury severity, all participants showed clinically significant impairments in everyday functioning consistent with referral to the specialist neurorehabilitation service.

Thirty-nine healthy control participants (17 males, 22 females; mean age: 38 years, range: 18-65 years; mean years of education: 14 years, range 12-18 years) were recruited from the MRC Cognition and Brain Sciences Unit's volunteer panel.

The groups did not significantly differ on age (p = .27) or years of education (p = .13), but there were significantly more females in the healthy control sample than the TBI sample ($\chi^2(1) = 11.25$; p = .001).

This study had ethical approval from the University of Cambridge local research ethics committee and written informed consent was obtained.

Measures

Bangor Gambling Task (BGT). The BGT was administered in accordance with the procedures outlined by Bowman and Turnbull (2004). Using a deck of 100 playing cards, 9 were labelled as 'win 20p', 29 'win 10p', 35 'lose 20p', and 27 'lose 10p'. Participants were given written instructions, which were also read aloud by the examiner, informing them that the aim was to make as much money as possible. It was at the discretion of the player whether to gamble or not, but they were instructed to inform the experimenter prior to turning over the top card of the deck. At the start of the game all participants were given £2.00 and told that they could keep any money they won. Unknown to the participant, the deck was split into 5 blocks of 20 card selections. If participants gambled on every card they would win £1.00 on Block 1 (15 win, 5 lose cards), neither win nor lose on Block 2 (10 win, 10 lose), lose £1.00 on Block 3 (5 win, 15 lose), lose £2.00 on Block 4 (5 win, 15 lose at a higher value), and lose £3.00 on Block 5 (3 win, 17 lose). The cards were administered in the same order to each participant. The task took approximately 15-minutes to complete (with instructions).

Consistent with the IGT and the Bowman and Turnbull (2004) original study, performance was calculated as the number of 'no gamble' minus the number of 'gamble' decisions made per block and overall. A negative score indicates more 'gamble' responses.

It is important to note that in the BGT to gamble in the first block is advantageous, therefore, choosing to 'gamble' in Block 1 could be interpreted as exploratory behaviour rather than impaired decision-making. As with other measures of emotion-based decision-making (e.g., the IGT), participants would not be aware of this without first sampling the cards, therefore, Block 1 is included in the main analysis with the prediction of no group difference on Block 1.

Characterisation measures and potential predictors of BGT performance. Survivors of TBI and controls completed the following measures: The Speed and Capacity of Language-Processing test (SCOLP, Baddeley, Emslie, & Nimmo-Smith, 1992) measured speed of processing (Speed of Comprehension) and estimated premorbid IQ (Spot the Word). Working memory was measured using two subtests of the Wechsler Adult Intelligence Scales 3rd edition (WAIS-III, Wechsler, 1997), digit span and letter-number sequencing; and executive function was measured using the Modified Six Elements (6 Elements) subtest of the Behavioural Assessment of the Dysexecutive Syndrome (BADS, Wilson, Alderman, Burgess, Emslie, & Evans, 1996). In addition, survivors of TBI and their relatives completed the Dysexecutive Syndrome Questionnaire (DEX, Wilson et al., 1996) to characterise behavioural symptoms of everyday executive function difficulties.

A measure of attention, the Sustained Attention to Response Task (SART, Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), was originally included in the study protocol, however, only 56% (n = 22) of the controls and 16.6% (n = 5) of the TBI group completed this measure. Due to the large amount of missing data, the SART was excluded from subsequent analysis.

Plan of analysis

A Student's T test was used to test for group differences on total BGT score, and a Chi-Squared test was used to test for differences in the proportion of survivors of TBI performing below the cut-off (+9 or below) relative to the proportion of controls.

To test for the predicted Group (TBI, Control) by Block (1, 2, 3, 4, 5) interaction, a mixed-model ANOVA with a between-subjects factor of Group and a within-subjects factor of Block was conducted. Box's test of equality of variances was not significant, however, Mauchly's test of sphericity was significant, therefore, the Greenhouse-Geisser correction was applied. G-Power indicated that to detect a significant two-way interaction (Group by Block) with a medium effect size, at alpha .05 and power .85, a total sample size of 36 would be required.

To explore individual differences in performance across Blocks, and potential sub-groups, a hierarchical cluster analysis was conducted using the squared Euclidian distance measure of difference between cases. The clustering variables were scores for performance on each of the 5 blocks. As these measures are on the same scale it was not necessary to standardise the scores prior to clustering. Identified clusters were compared in terms of proportion of TBI versus controls, demographics (age and gender) and cognitive variables (SCOLP Speed of Comprehension, SCOLP Spot the Word, BADS 6 Elements, letter-number sequencing, and backwards digit span).

Finally, to explore predictors of total BGT performance and to test contribution of specific executive and working memory variables, a stepwise hierarchical multiple regression was conducted with overall BGT score as the outcome variable, demographic variables in Model 1 (age, gender), injury group, SCOLP Speed of Comprehension scaled score (processing speed), and SCOLP Spot the Word scaled score (estimated premorbid IQ) in Model 2, and letter-number sequencing and backwards digit span (working memory) and BADS 6 Elements profile score (executive function) in Model 3.

Results

Table 1 shows the participant demographics, characteristics, and performance on the measures included in the hierarchical multiple regression.

TABLE 1 ABOUT HERE

Hypotheses 1 to 3: Survivors of TBI will be impaired relative to controls on the BGT.

As predicted (Hypothesis 1), overall, survivors of TBI made more gamble choices than controls (total BGT score: $t(67) = 2.47$, $p = .02$; see Table 1). However, when the suggested cut-off of +9 or below (Bowman & Turnbull, 2004) was applied the number of survivors of TBI (80%) classified as 'impaired' was not significantly greater than the number of controls (66.7%; Hypothesis 2: $\chi^2(1) = 1.51$; $p = .22$).

Unexpectedly, the prediction that survivors of TBI will have difficulty learning to change their 'gamble' response in the face of increasing losses (Hypothesis 3) was not supported (Group by Block interaction: $F(2.19, 67) = 1.98$, $p = .14$; $\eta_p^2 = .03$, small effect). The mixed-model ANOVA revealed, however, a significant main effect of Group ($F(1, 67) = 6.41$; $p = .01$; $\eta_p^2 = .09$, medium effect) and a significant main effect of Block ($F(2.19, 67) = 23.74$, $p = .0001$; $\eta_p^2 = .26$, large effect). Paired t-tests (Bonferroni correction, $p \leq .005$) revealed the following pattern of performance across the Blocks: 1 = 2 = 3 < 4 < 5, indicating that in Blocks 4 and 5 participants were selecting more advantageously than in Blocks 1 to 3, therefore, participants showed evidence of learning across blocks.

FIGURE 1 ABOUT HERE

Exploring individuals differences and sub-groups on BGT performance.

Inspection of the dendrogram derived from the hierarchical cluster analysis identified a parsimonious cut-off of +10, which yielded 3 clusters. These clusters were very clearly distinguished by pattern of performance, as shown in Figure 2. Cluster 1 (n = 50) showed a tendency to gamble more initially over Blocks 1-3, and reversal of this from Block 4 to 5. Cluster 2 (n = 9) largely refrained from gambling throughout, showing a tendency towards gambling on Block 3, and then reversal of this pattern. Cluster 3 (n = 7) was similar to Cluster 2 at Block 1, but showed a contrasting pattern of increased gambling over time, with little or no reversal over the later blocks. The performance of three participants was not classified by the analysis.

FIGURE 2 ABOUT HERE

Post-hoc analyses were not performed due to the small sample sizes in the clusters (particularly Clusters 2 and 3), however, as shown in Table 2, descriptively, Cluster 3 appeared to be characterised by more males and more survivors of TBI.

TABLE 2 ABOUT HERE

Exploring predictors of BGT performance.

Model 1 (age and gender) was significant ($F(2, 55) = 4.31$; $p = .02$), with addition of group, processing speed, and estimated premorbid IQ significantly improving the model (Model 2, Adjusted $R2 = .20$; $R2$ change = .13, $F(3, 52) = 3.14$; p

= .03). Addition of working memory and executive variables did not significantly improve variance accounted for in Model 3 (R2 change = .01, $F(2, 49) = .31$; $p = .82$). Model 2 accounted for the greatest amount of variance in BGT performance (20%), with only age ($\beta = -.28$; $t = -2.28$; $p = .03$) and group ($\beta = -.54$; $t = -2.67$; $p = .01$) remaining significant.

Discussion

This study aimed to characterise BGT performance in survivors of TBI. Findings suggest that consistent with previous studies examining emotion-based decision-making (e.g., IGT; Levine et al., 2005; Fujiwara et al., 2008; Cotrena et al., 2014), overall survivors of TBI made more gamble choices than controls.

The groups did not significantly differ, however, when the Bowman and Turnbull (2004) suggested cut-off of +9 or below to indicate ‘impaired’ performance was applied, due to a high proportion of controls (66.7%) being classified as ‘impaired’. It is not uncommon to find emotion-based decision-making ‘impairments’ in controls. For example, Steingroever et al. (2013) found that up to a third of controls failed the IGT, with some authors suggesting that individual differences in task approach and strategy use can account for this (e.g., Horstmann, Villringer, & Neumann, 2012). Interestingly, more controls were classified as impaired in the current study (66.7%) compared to the undergraduate sample reported in the original BGT study (35%; Bowman & Turnbull, 2004). There are many possible reasons for the difference in performance between the two control groups and a direct comparison is not possible. However, from examining the reported demographic data, the controls in the original study were younger than those in the current study and age has been shown to be associated with both performance (Cauffman et al., 2010) and strategy use (Wood, Busemeyer, Koling, Cox, & Davis, 2005) on emotion-based decision-making tasks. Also, the control group in the current study had a higher proportion of male participants (44%) compared to the original study (30%), and gender has also been associated with performance on emotion-based decision-making tasks (van den Bos, Homberg, & de Visser, 2013). It is also worth noting that the BGT cut-off suggested in the original study was taken from Bechara et al. (2001), who used the performance of individuals with VMPfC damage on the IGT to guide the criteria for impairment in other patient groups (e.g., substance use). It is possible, therefore, that the suggested cut-off of +9 or below is not the most sensitive measure of impairment on the BGT.

Based on previous studies (e.g., Bechara et al., 1994), it was expected that survivors of TBI would show difficulty learning to reduce their ‘gamble’ responses in the face of increasing losses, and thus show a different pattern of performance compared to controls across the five blocks. This prediction was not supported, and despite an a priori power calculation indicating that the current study had a large enough sample size to detect a medium effect size (Group by Block interaction), the actual effect obtained was small, suggesting a larger sample size might have been needed. The results were consistent with the findings on overall BGT score, in that the TBI group made more gamble choices than the controls (main effect of Group), however, both groups showed the general pattern of making more gamble choices on Blocks 1 to 3, then reversing this on Blocks 4 and 5 (main effect of Block). Analysing performance between-groups and across blocks of 20 trials is consistent with previous studies of emotion-based decision-making tasks (e.g., Bechara et al., 2001; Tranel et al., 2002; Bowman & Turnbull, 2004), however, some authors have questioned the sensitivity of this approach, particularly for patient populations (e.g., Dunn et al., 2006; Ryterska, Jahanshahi, & Osman, 2013).

We explored the data further to identify potential sub-groups with broadly similar patterns of performance. Three clusters were identified, with both survivors of TBI and controls being represented in each cluster. The largest group (Cluster 1) tended to gamble initially (which is favourable in Block 1), increase tendency to gamble slightly in Block 2 (which would lead to a neutral outcome), but reduce gambling over Blocks 3 - 5. This pattern of performance suggests evidence of learning in response to the change in contingencies. Taking this a step further, given that 22 of the 30 survivors of TBI were represented in this cluster, this suggests that survivors of TBI can show learning on an emotion-based decision-making task.

Participants in Cluster 2 appeared to avoid gambling throughout the task, even in Block 1 where gambling is advantageous, suggesting a risk-avoidant strategy, whereas Cluster 3 increased gambling throughout the task and did not change their behaviour in response to the change in contingency. The pattern of performance in Cluster 3 suggests an inability to forgo short-term gain for long-term profit, although the profile is even more extreme than that typically shown by individuals with bilateral damage to the VMPfC (e.g., Bechara et al., 1994; Tranel et al., 2002). Although not tested here, alternative mechanisms might also account for this finding including: adopting a risk-taking strategy or being sensation-seeking, apathy or insensitivity to negative outcomes, impaired reversal learning, or an inability to inhibit a response (see Dunn et al., 2006 for detailed discussion).

Differences between clusters on performance during Block 1, and prior to any manipulation of contingencies, indicates potential for large individual differences in approach to the task, which may make identification and interpretation of performance differences following contingency changes more problematic. Furthermore, whilst overall differences in the BGT between controls and survivors of TBI could be accounted for by the TBI group having an acquired impairment in emotion-based decision-making, an alternative account is that individual differences in risk-taking behaviour might underlie the likelihood of sustaining a TBI, further confounding interpretation of performance on gambling tasks such as the BGT.

Given the small group sizes, it was not possible to analyse differences on demographic or cognitive variables, however, descriptively, Cluster 3 appeared to have more survivors of TBI than controls and more males than females. Despite the caveats of this being an exploratory analysis with the cluster yielding a small group size, the higher proportion of survivors with TBI than controls in Cluster 3 is consistent with the main prediction that survivors of TBI will fail to learn from increasing losses, although an individual differences account cannot be ruled out.

In relation to the sex-difference found in Cluster 3, there is a growing body of literature suggesting that men and women perform emotion-based decision-making tasks differently. These studies generally show that men focus on the long-term gain, whereas women focus on both the long-term gain and the win/loss frequency when performing tasks such as, the IGT (for review see van den Bos, Homberg, & de Visser, 2013). Sex differences in performance (or task strategy) on the BGT have not been examined, therefore, it is not possible to conclude that males and females perform the task differently, and instead, it is possible that the higher number of males in Cluster 3 is accounted for by the higher number of survivors with TBI, who were predominantly male (83.3% of the sample) in the current study. Related to this possible explanation, presence of injury was significant in the multiple regression analysis when examining predictors of overall BGT performance, whereas gender was not.

The multiple regression analysis also found no significant influence of processing speed or premorbid IQ on overall BGT performance, despite group differences on these variables. The finding that processing speed did not influence overall BGT performance is consistent with recent literature examining predictors of IGT performance (Gansler, Jerram, Vannorsdall, Schretlen, 2011). Similarly, a review of 43 studies of gambling task performance indicated that only a small number of studies found significant effects of IQ on IGT performance, and in these studies effect sizes were small (Toplak, Sorge, Benoit, West, & Stanovich, 2010).

There was also no significant influence of working memory or executive function ability on overall BGT performance, which is in keeping with some previous studies (e.g., Bechara et al., 1998; Turnbull et al., 2005). It is worth noting that there was also no significant difference between the survivors of TBI and controls on these measures, which although inconsistent with some studies of neurocognitive performance following TBI (e.g., Zimmermann et al., 2015; Dunning, Westgate, & Adlam, 2016), is consistent with findings reported in patients with anterior VMPfC (i.e., poorer emotion-based decision-making relative to controls but intact working memory, Bechara et al., 1998).

Finally, the multiple regression analysis suggested that age influenced overall BGT performance. As with gender (see above), age differences in performance on the BGT have not been directly studied, however, studies using the IGT have found age differences in performance between adolescents and adults up to the age of 30, with avoidance of the disadvantageous decks improving with age (i.e., make fewer ‘bad’ choices, Caufmann et al., 2010). This is inconsistent with our finding of poorer overall performance (i.e., make more ‘gamble/bad’ choices) with increasing age. It is possible that differences in strategy use might have influenced performance (e.g., Wood et al., 2005; although their study found no corresponding difference in task performance), however, age effects should be directly studied before firm conclusions can be drawn.

Limitations and Future Directions

As discussed above, the cut-off used to classify ‘impaired’ vs. ‘not impaired’ performance on the BGT was not directly derived from BGT data and, therefore, might not be sensitive to group differences in performance (as suggested by the finding of a significant difference in total score, but not when using the cut-off to classify total score). Future research might want to consider alternative approaches to identifying impaired performance on the BGT, and total score might in itself not be a sensitive measure (see Dunn et al., 2006 for discussion). Related to this, given the lack of a significant Group by Block finding, future research (particularly with clinical groups) might want to examine linear contrasts/trends in performance rather than performance across blocks of 20 trials (see Dunn et al., 2006). The exploratory cluster analysis raised some interesting findings, however, the small sample sizes in the clusters limited the use of post-hoc tests to further examine their characteristics. Future research might want to extend this approach to analysing emotion-based decision-making performance in a larger sample of participants and identifying models that can best account for individual differences (e.g., Franken & Muris, 2005), including pre-injury factors and acquired neurocognitive changes in survivors of TBI.

A further limitation of our study is that estimated IQ, as measured using the SCOLP Spot the Word subtest, significantly differed between the TBI and control groups and is, therefore, a potential confound. Future studies might want to address this by including groups matched on IQ.

Finally, the current study, consistent with the original BGT study (Bowman & Turnbull, 2004), did not test whether the BGT relies on somatic markers (emotion biasing signals) to guide decision-making. Future studies might want to examine this more directly using psychophysiology methods.

Clinical Implications

Despite the attractiveness of its simplicity over other tests (e.g., the IGT), and that it is free to use (compared to IGT (prices in 2016): £472 in the UK; $574 in the USA; $1072.50 in Australia), the current study raises a number of issues that need to be addressed prior to recommending use of the BGT as a measure of emotion-based decision-making for survivors of TBI. Firstly, a meaningful, reliable, and sensitive approach to classify task performance as being impaired or not needs to be developed. This may, for example, model individual differences in patterns of performance rather than classify a total score. Secondly, the mechanisms underpinning task performance (e.g., somatic markers, reversal learning, or individual differences in sensation-seeking behaviours etc) need to be confirmed. Thirdly, the relationship between performance on the BGT and real-life emotion-based decision-making needs to be confirmed. Finally, if the BGT is to replace the IGT, then it needs to be confirmed that the BGT shares similar properties to the IGT when performed by survivors of TBI, for example, by a direct comparison as tested in the original Bowman & Turnbull, 2004 study.

Conclusion

Despite survivors of TBI making more gamble decisions compared to controls on the BGT, this study suggests considerable overlap between survivors of TBI and controls in their individual patterns of performance. These findings are in keeping with an individual differences account of emotion-based decision-making, and it is suggested that future research focuses on developing models to best capture performance on emotion-based decision-making tasks in survivors of TBI. It is also suggested that future research examines the mechanisms underpinning performance on emotion-based decision-making tasks, and the neural correlates associated with performance, in survivors of TBI. In conclusion, the current study raises a number of issues that need to be addressed prior to recommending use of the BGT as a measure of emotion-based decision-making for individuals with neurological conditions.

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Conflict of Interest

None.

Ethical Standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

References

Baddeley, A.D., Emslie, H., & Nimmo-Smith, I. (1992). The Speed and Capacity of Language-Processing Test (SCOLP). Bury St Edmunds, England: Thames Valley Test Company.

Bechara, A. (2004). The role of emotion in decision-making: evidence from neurological patients with orbitofrontal damage. Brain and Cognition, 55(1), 30–40.

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. Cognition, 50(1-3), 7-15.

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision making and the orbitofrontal cortex. Cerebral Cortex, 10(3), 295-307.

Bechara, A., Damasio, H., Tranel, D., & Anderson, S. W. (1998). Dissociation of working memory from decision making within the human prefrontal cortex. The Journal of Neuroscience : The Official Journal of the Society for Neuroscience, 18(1), 428–437.

Bechara, A., Dolan, S., Denburg, N., Hindes, A., Anderson, S. W., & Nathan, P. E. (2001). Decision-making deficits, linked to a dysfunctional ventromedial prefrontal cortex, revealed in alcohol and stimulant abusers. Neuropsychologia, 39(4), 376–389.

Bechara, A., Tranel, D., Damasio, H., & Damasio, A. R. (1996). Failure to respond autonomically to anticipated future outcomes following damage to prefrontal cortex. Cerebral Cortex, 6(2), 215-225.

Bowman, C. H., & Turnbull, O. H. (2004). Emotion-based learning on a simplified card game: the Iowa and Bangor Gambling Tasks. Brain & Cognition, 55(2), 277-282.

Cauffman, E., Shulman, E. P., Steinberg, L., Claus, E., Banich, M. T., Graham, S., & Woolard, J. (2010). Age differences in affective decision making as indexed by performance on the Iowa Gambling Task. Developmental Psychology, 46(1), 193–207

Cotrena, C., Branco, L.D., Zimmermann, N., Cardoso, C.O., Grassi-Oliveira, R., & Fonseca, R.P. (2014). Impaired decision-making after traumatic brain injury: the Iowa Gambling Task. Brain Injury, 28(8), 1070-5.

Damasio, A. R. (1994). Descates Error: Emotion, Reason and the Human Brain. New York: Avon.

Damasio, A. R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. Philosophical Transactions of the Royal Society London B Biological Sciences, 351(1346), 1413-1420.

Damasio, A.R., Adolphs, R., Damasio, H. (2003). The contributions of the lesion method to the functional neuroanatomy of emotion. In: Davidson, R.J., Scherer, K.R., Goldsmith, H.H. (Eds.), Handbook of Affective Sciences. Oxford University Press, Oxford, pp. 66–92.

Dunn, B. D., Dalgleish, T., & Lawrence, A. D. (2006). The somatic marker hypothesis: a critical evaluation. Neurosciences & Biobehavioural Reviews, 30(2), 239-271.

Dunning, D. L., Westgate, B., & Adlam, A.-L. R. (2016). A meta-analysis of working memory impairments in survivors of moderate-to-severe traumatic brain injury. Neuropsychology, 30(7), 811–9.

Eslinger, P. J., & Damasio, A. R. (1985). Severe disturbance of higher cognition after bilateral frontal lobe ablation: patient EVR. Neurology, 35(12), 1731-1741.

Franken, I. H. A., & Muris, P. (2005). Individual differences in decision-making. Personality and Individual Differences, 39(5), 991–998.

Fujiwara, E., Schwartz, M. L., Gao, F., Black, S. E., & Levine, B. (2008). Ventral frontal cortex functions and quantified MRI in traumatic brain injury. Neuropsychologia, 46(2), 461–474.

Gansler, D. A., Jerram, M. W., Vannorsdall, T. D., & Schretlen, D. J. (2011). Does the Iowa gambling task measure executive function? Archives of Clinical Neuropsychology : The Official Journal of the National Academy of Neuropsychologists, 26(8), 706–17.

Hellawell, D. J., Taylor, R. T., & Pentland, B. (1999). Cognitive and psychosocial outcome following moderate or severe traumatic brain injury. Brain Injury, 13(7), 489-504.

Hinson, J. M., Jameson, T. L., & Whitney, P. (2002). Somatic markers, working memory, and decision making. Cognitive, Affective & Behavioral Neuroscience, 2(4), 341–53.

Horstmann, A., Villringer, A., & Neumann, J. (2012). Iowa gambling task: there is more to consider than long-term outcome. Using a linear equation model to disentangle the impact of outcome and frequency of gains and losses. Frontiers in Neuroscience, 6, 61.

Jameson, T. L., Hinson, J. M., & Whitney, P. (2004). Components of working memory and somatic markers in decision making. Psychonomic Bulletin & Review, 11(3), 515–20.

Levine, B., Black, S. E., Cheung, G., Campbell, A., O'Toole, C., & Schwartz, M. L. (2005). Gambling task performance in traumatic brain injury: relationships to injury severity, atrophy, lesion location, and cognitive and psychosocial outcome. Cognitive Behavioural Neurology, 18(1), 45-54.

Ownsworth, T., & McKenna, K. (2004). Investigation of factors related to employment outcome following traumatic brain injury: a critical review and conceptual model. Disability Rehabilitation, 26(13), 765-783.

Rimel, R. W., Giordani, B., Barth, J. T., & Jane, J. A. (1982). Moderate head injury: completing the clinical spectrum of brain trauma. Neurosurgery, 11(3), 344–51.

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). 'Oops!': performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. Neuropsychologia, 35(6), 747-758.

Ryterska, A., Jahanshahi, M., & Osman, M. (2013). What are people with Parkinson’s disease really impaired on when it comes to making decisions? A meta-analysis of the evidence. Neuroscience and Biobehavioral Reviews, 37(10 Pt 2), 2836–46.

Salmond, C. H., Menon, D. K., Chatfield, D. A., Pickard, J. D., & Sahakian, B. J. (2005). Deficits in decision-making in head injury survivors. Journal of Neurotrauma, 22(6), 613-622.

Steingroever, H., Wetzels, R., Horstmann, A., Neumann, J., & Wagenmakers, E.-J. (2013). Performance of healthy participants on the Iowa Gambling Task. Psychological Assessment, 25(1), 180–93.

Teasdale, G., & Jennett, B. (1974). Assessment of coma and impaired consciousness. A practical scale. Lancet, 2(7872), 81-84.

Toplak, M.E., Sorge, G.B., Benoit, A., West, R.F., & Stanovich, K.E. (2010). Decision-making and cognitive abilities: A review of associations between Iowa Gambling Task performance, executive functions, and intelligence. Clinical Psychology Review, 30(5), 562-81.

Tranel, D., Bechara, A., & Denburg, N. L. (2002). Asymmetric functional roles of right and left ventromedial prefrontal cortices in social conduct, decision-making, and emotional processing. Cortex; a Journal Devoted to the Study of the Nervous System and Behavior, 38(4), 589–612.

Turnbull, O. H., Evans, C. E. Y., Bunce, A., Carzolio, B., & O'connor, J. (2005). Emotion-based learning and central executive resources: an investigation of intuition and the Iowa Gambling Task. Brain and Cognition, 57(3), 244–7.

Wechsler, D. (1997) Manual for the Wechsler Adult Intelligence Scale - III. London (UK): The Psychological Corporation.

Wilson, B. A., Alderman, N., Burgess, P. W., Emslie, H., Evans, J. J. (1996). Behavioural Assessment of the Dysexecutive Syndrome (BADS). Bury St Edmunds (UK): Thames Valley Test Company.

Wood, S., Busemeyer, J., Koling, A., Cox, C. R., & Davis, H. (2005). Older Adults as Adaptive Decision Makers: Evidence From the Iowa Gambling Task. Psychology and Aging, 20(2), 220–225.

van den Bos, R., Homberg, J., & de Visser, L. (2013). A critical review of sex differences in decision-making tasks: Focus on the Iowa Gambling Task. Behavioural Brain Research, 238(1), 95-108.

Zimmermann, N., Pereira, N., Hermes-Pereira, A., Holz, M., Joanette, Y., & Fonseca, R. P. (2015). Executive functions profiles in traumatic brain injury adults: Implications for rehabilitation studies. Brain Injury, 29(9), 1071–1081.