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Impulsivity and reversal learning in hazardous alcohol use

Matthew J. Gullo [a,*], Chris J. Jackson [b], Sharon Dawe [a]

[a] School of Psychology, Griffith University, Mt. Gravatt Campus, Brisbane QLD 4111, Australia
[b] Australian School of Business, University of New South Wales, Sydney NSW 2052, Australia

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ABSTRACT

Research into the neuropsychological basis of impulsivity indicates that it may convey risk for substance misuse through an increased motivation to obtain rewards ("reward drive") and a propensity to act without forethought ("rash impulsiveness"). A recent model of disinhibition has also specified a role for Neuroticism in those with left hemispheric preference, due to the association of this hemisphere with action goal tendencies. This study investigated the mediating role of reversal learning, a key component of adaptive decision-making, in the prediction of hazardous alcohol use from impulsivity traits. A sample of 165 college students were administered a probabilistic reversal learning task, the Alcohol Use Disorders Identification Test (AUDIT), Sensitivity to Reward scale to measure reward drive, I_7 (Impulsiveness) to measure rash impulsiveness, Eysenck Personality Questionnaire – Revised, and a self-report measure of ear preference to determine hemispheric preference. Results support the role of reward drive and rash impulsiveness in alcohol misuse, as well as rash impulsiveness, Neuroticism and lateral preference in poor reversal learning. However, there was no support for mediation, or an interaction between Neuroticism and lateral preference.

1. Introduction

Individuals high in impulsivity are at greater risk of developing substance use problems in the future (Tarter et al., 2003). However, impulsivity is not a unitary construct, and may comprise at least two distinct but overlapping constructs (Dawe & Loxton, 2004; Whiteside & Lynam, 2001). The first reflects Sensitivity to Reward and approach motivation emerging from the mesolimbic dopamine system. Conceptually, it is closely related to Gray's (1987) Behavioral Approach System (BAS) and the agency component of Extraversion (Depue & Collins, 1999). The second relates to difficulty inhibiting approach behavior in light of potential negative consequences, and is more related to orbitofrontal and cingulate serotonergic functioning (Gullo & Dawe, 2008). Conceptually, it resembles impulsiveness as defined by Eysenck and Eysenck (1991). Dawe and Loxton (2004) named these reward drive (RD) and rash impulsiveness (RI), respectively.

Converging evidence suggests RD and RI are related to different aspects of substance misuse. Loxton et al. (2008) found that while club drug users were higher in RD and RI, only the latter was associated with polydrug use. Brunelle et al. (2004) reported scores on the Sensitivity to Reward scale (SR), a measure of RD, predicted reward-related physiological responses to alcohol intoxication, whereas RI did not. Consistent with this, Kambouropoulos and Staiger (2004) found cue-elicited urge to drink was related to SR scores, but not Sensation Seeking (RI-like trait) in social drinkers. In sum, there is empirical support for the utility of a two-factor approach to impulsivity and substance misuse.

However, such a two-factor conceptualization may be limited by the focus on approach-related traits. Other models of impulsivity emphasize the contributing role of avoidance-based traits, and impulsivity that arises from a desire to reduce negative affect (Jackson, 2008; Whiteside & Lynam, 2001). Jackson (2008) proposed that Neuroticism, a trait associated with increased arousability and negative affect (Eysenck, 1967), may interact with hemispheric asymmetry to produce disinhibited behavior. Notably, left prefrontal cortex activity has been associated with action goal formation and approach-related traits (Sutton & Davidson, 1997). Jackson (2008) provided evidence that individuals with right ear preference (a biomarker for left prefrontal asymmetry) were approach-oriented. Jackson then argued that people with left prefrontal asymmetry and high Neuroticism would be prone to heightened negative affect and would engage in impulsive behavior to reduce it. In four studies, Jackson demonstrated that the interaction between Neuroticism and right ear preference predicted various disinhibitory behaviors, including heavier alcohol use. Jackson's proposition that Neuroticism interacts with approach motivation to predict disinhibition is also consistent with the work of Newman and colleagues (Patterson & Newman, 1993). Patterson and Newman (1993) proposed a mechanism in which individuals high in both Extraversion and Neuroticism were

* Corresponding author. Tel.: +61 7 3735 3418; fax: +61 7 3735 3388.
E-mail address: matthew.gullo@gmail.com (M.J. Gullo).

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at greater risk of poor decision-making because of difficulty learning from errors. In summary, Jackson (2008) argues that ear preference may predict approach behavior directly and may interact with Neuroticism to predict disinhibited approach behavior.

Others have argued that the "impulsivity" observed in addiction is primarily the result of disrupted decision-making (Bechara, 2005). Much of the research investigating decision-making in addiction has employed the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994; Bechara et al., 2001), which assesses adaptive, long-term decision-making. Briefly, the IGT requires participants to continuously draw from four decks of cards with different reward and punishment schedules. Two decks deliver high immediate gains but also higher delayed losses (disadvantageous decks), while the other two deliver low immediate gains but also lower delayed losses (advantageous decks). Most participants form an initial preference for the disadvantageous decks due to the high immediate rewards, but learn to shift to advantageous decks once losses begin to accrue (Fellows & Farah, 2005). However, substance dependent individuals and those with lesions to the orbitofrontal cortex (OFC) are less able to make this "preference shift" (Bechara et al., 2001).

Non-substance dependent individuals high in RI-like traits also display difficulties on the IGT (Franken, Strien, Nijs, & Muris, 2008; Zermatten et al., 2005). The role of the OFC in adaptive decision-making has led some to propose that poor decision-making is a key mechanism through which RI conveys risk for substance misuse (Dawe, Gullo, & Loxton, 2004). Indeed, several studies link RI with OFC functioning (Franken et al., 2008; Horn, Dolan, Elliott, Deakin, & Woodruff, 2003). However, a recent prospective study on college students by Goudriaan, Grekin, and Sher (2007) found that while heavy binge drinkers performed worse on the IGT, this deficit was unrelated to RI. Indeed, other studies have also failed to find an association between RI-like traits and IGT performance (Franken & Muris, 2005). Such inconsistent findings may be due to the complexity of the IGT.

The IGT engages several interdependent cognitive processes, but some argue that a deficit in reversal learning lies at the core of poor IGT performance (Fellows & Farah, 2005). Reversal learning is the updating of stimulus-reinforcement associations when contingencies change. Consistent with this view, Hildebrandt, Brokate, Fink, Muller, and Eling (2008) reported a selective deficit in reversal learning among young polysubstance abusers undergoing treatment. Similar findings were reported by Fellows and Farah (2005) in patients with OFC lesions, but not patients with lesions to other areas of the prefrontal cortex. Poor reversal learning may therefore be what mediates the risk conveyed by RI for problematic substance use. Consistent with this, Franken et al. (2008) found college students high in RI demonstrated poorer reversal learning.

The aim of the present study was to examine the possible mediating role of reversal learning in the association between impulsivity and hazardous alcohol use. Poor reversal learning was hypothesized to mediate the effect of RI and the Neuroticism–ear preference interaction on hazardous drinking. Reward drive was hypothesized to directly predict more hazardous drinking. Moreover, RI, ear preference (as a main effect) and the Neuroticism–ear preference interaction were hypothesized to predict poorer reversal and more hazardous drinking.

2. Method

2.1. Participants

The sample comprised 165 undergraduate students, 121 women ($M_{age} = 20.10$, $SD_{age} = 3.85$) and 44 men ($M_{age} = 21.07$, $SD_{age} = 4.17$). In addition to research credit, all participants were offered the chance to win one of three portable audio players.

2.2. Materials

2.2.1. Reward drive

The 24-item Sensitivity to Reward scale (SR) of the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia, Avila, Molto, & Caseras, 2001) was used as a measure of trait RD. Factor analytic studies have found SR to load on a latent factor with other measures of RD, supporting its construct validity (Dawe & Loxton, 2004). An item pertaining to drug use was removed to avoid possible criterion contamination. Cronbach's alpha for the 23-item SR scale was .70.

2.2.2. Rash impulsiveness

The 19-item impulsiveness scale of the I_7 questionnaire (Eysenck, Pearson, Easting, & Allsopp, 1985) was utilised as a measure of RI. This scale has been shown to load on a latent factor with other RI measures, supporting its construct validity (Dawe & Loxton, 2004). Cronbach's alpha for the scale in this study was .82.

2.2.3. Neuroticism

The Eysenck Personality Questionnaire – Revised (EPQ-R; Eysenck & Eysenck, 1991) was administered but only the Neuroticism scale was used. Cronbach's alpha in this study was .88.

2.2.4. Ear preference

The 7-item ear preference scale of the revised hand, eye and ear preference questionnaire (Jackson, 2005) was used as a measure of ear preference. Each item is rated 1 (*Always Left*) to 5 (*Always Right*). An example item includes, "If you wanted to hear someone's heart beat, which ear would you place against their chest?" Scores on the original measure have a high concordance with behavioral observation (92%; Coren, Porac, & Duncan, 1979).

2.2.5. Hazardous alcohol use

The Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, De La Fuente, & Grant, 1993) was used to measure hazardous drinking. It has been found to be more sensitive to non-dependent problem drinking than other screening instruments, and several studies support the validity of the AUDIT as a measure of hazardous drinking in college students (Dawe, Loxton, Hides, Kavanagh, & Mattick, 2002; Kokotailo et al., 2004; Roche & Watt, 1999). In the present study, the AUDIT had a Cronbach's alpha of .86.

Participants were also asked to rate on a 0 (*Not at all important*) – 10 (*Very important*) scale the degree to which the prize motivated them to participate in the study.

2.2.6. Reversal learning

Participants were asked to complete a probabilistic reversal learning task similar to that used by Cools, Clark, Owen, and Robbins (2002). Reversal learning on this task is associated with greater OFC activation, consistent with studies on lesion patients that implicate the OFC as critical to reversal learning (Cools et al., 2002; Fellows & Farah, 2005). Each trial of the task involved the presentation of two abstract coloured patterns presented simultaneously on the left and right of the computer screen. Participants were informed prior to commencing the task that one of the patterns had been chosen according to "some rule" and that they had to choose which stimulus was correct. The images remained on-screen until a response was made. Correct responses were followed by the presentation of a green smiley face, and incorrect responses by a red frown face. The location of the two patterns on-screen was randomised for each trial. The task comprised two trial blocks with approximately 150 trials per block. Each block consisted of 10 discrimination stages (i.e., nine contingency reversals). Reversal of stimulus contingencies occurred after 10–15 correct discrimination trials (including probabilistic errors). The number of probabilistic errors during each discrimination stage varied from 0 to 4. In this study, the outcome of interest was the mean number of errors per reversal.

2.3. Procedure

Participants completed all questionnaires on a secure online website. Laboratory testing sessions were usually conducted within 2 weeks of completing the online questionnaires (for two participants, it was 3 weeks). To encourage optimal performance, participants were informed that audio player prizes would be awarded to the three participants with the highest average task performance.

2.4. Analyses

The *joint significance test* (JST) is currently regarded as the optimal method for testing mediation (MacKinnon, Fairchild, & Fritz, 2007). The procedure involves evaluating the statistical significance of the relationship between the independent variable and proposed mediator (α), then testing the relationship between mediator and dependent variable (β). If both are statistically significant, there is evidence for mediation. MacKinnon et al. (2007) also recommended calculating confidence intervals from the bootstrap distribution of the mediation effect ($\alpha\beta$) to evaluate its magnitude.

3. Results

Descriptive data, including correlations among variables of interest, are presented in Table 1. Results show older participants reported lower levels of impulsivity and Neuroticism. Female participants reported lower scores on SR and the AUDIT, but higher scores on Neuroticism. According to the AUDIT, 82 (49.7%) participants were drinking at hazardous/harmful levels (score $\geqslant 8$).

To examine the direct relationship between the personality traits and hazardous drinking, a hierarchical regression was conducted with age and sex entered on the first step (as covariates), SR, I_7 (Impulsiveness), Neuroticism, and ear preference entered on the second step, and the interaction between Neuroticism and ear preference (mean-centered) entered on the third step. As hypothesized, both SR and I_7 (Impulsiveness) predicted greater hazardous alcohol use with each scale explaining 4% and 5% unique variance, respectively, (see Table 2). However, contrary to hypothesis, Neuroticism, ear preference, and their interaction did not add unique variance to prediction. Overall, approximately 13% of the variance in hazardous drinking was accounted for by the model, $F(7, 157) = 3.26$, $p = .003$.

Table 2
Personality trait predictors of hazardous alcohol use ($N = 165$).

	ΔR^2	B	$SE\ B$	β	sr^2
Step 1	.03				
Age		0.09	0.13	.05	.00
Sex		−1.50	1.22	−.10	.01
Step 2	.10**				
Sensitivity to Reward		0.38	0.15	.21*	.04
I_7 (Impulsiveness)		0.34	0.12	.22**	.05
Neuroticism (N)		0.01	0.09	.01	.00
Ear preference (EP)		−0.04	0.08	−.04	.00
Step 3	.00				
N × EP		0.00	0.01	−.02	.00
Total R^2	.13**				

* $p < .05$.
** $p < .01$.

To test the predictive relationship between the personality traits and reversal learning (i.e., α path in JST), a hierarchical regression was conducted with age and sex entered on the first step, SR, I_7 (Impulsiveness), Neuroticism, and ear preference entered on the second step, and the Neuroticism–ear preference interaction entered on the third step. As hypothesized, I_7 (Impulsiveness) predicted significantly higher mean reversal errors (i.e., poorer reversal learning; see Table 3). Additionally, Neuroticism and ear preference as main effects predicted poorer reversal learning, but the interaction was not significant. Unexpectedly, SR significantly predicted fewer reversal errors (i.e., better reversal learning). Overall, approximately 22% of the variance in reversal learning was accounted for by the model, $F(7, 157) = 6.33$, $p < .001$.

In an attempt to explain the unexpected relationship between SR and reversal learning, we investigated the possible mediating role of motivation for the prize on reversal task performance. Consistent with this, SR predicted higher motivation to participate for the prize, $r^2 = .06$ ($p = .002$). However, motivation was unrelated to reversal learning, $r^2 = .01$ ($p = .35$). This suggests the better reversal learning performance of high-SR participants was not mediated by greater motivation to win the prize.

To test the predictive relationship between reversal learning and hazardous alcohol use (i.e., β path in JST), a hierarchical regression was conducted with age and sex entered on the first step and reversal learning entered on the second step. Contrary to hypothesis, the final model was not significant, $R^2 = .03$, $F(3, 161) = 1.45$, $p = .23$. Furthermore, reversal learning was not a significant predictor of hazardous drinking, $\beta = -.02$ ($p = .77$). This suggests reversal learning does not mediate the effect of impulsivity on hazardous drinking.

Table 1
Intercorrelations between personality, reversal learning, and alcohol use ($N = 165$).

	1.	2.	3.	4.	5.	6.	7.	8.
1. Age								
2. Sex	−.11							
3. Sensitivity to Reward[a]	−.23*	−.26*						
4. I_7 (Impulsiveness)	−.20*	.05	.17*					
5. Neuroticism	−.16*	.18*	.15	.17*				
6. Ear preference	.00	.13	.01	−.01	.05			
7. AUDIT	−.03	−.15*	.26*	.25*	.04	−.05		
8. Reversal errors	.11	.07	−.28*	.16*	.20*	.18*	−.04	
M	20.36		11.62	8.37	14.48	23.81	8.76	7.20
SD	3.95		3.72	4.39	5.70	6.56	6.67	3.09

Note: Sex is dummy-coded as 0 = male, 1 = female. Higher ear preference scores indicate greater right ear preference. AUDIT = Alcohol Use Disorders Identification Test.
[a] Item pertaining to drug use removed.
* $p < .05$.

Table 3
Personality trait predictors of reversal learning errors ($N = 165$).

	ΔR^2	B	$SE\ B$	β	sr^2
Step 1	.02				
Age		0.08	0.06	.10	.01
Sex		−0.59	0.54	−.09	.01
Step 2	.20***				
Sensitivity to Reward		−0.29	0.07	−.35***	.10
I_7 (Impulsiveness)		0.14	0.05	.20**	.04
Neuroticism (N)		0.13	0.04	.25**	.05
Ear preference (EP)		0.08	0.03	.18*	.03
Step 3	.00				
N × EP		−0.01	0.01	−.07	.00
Total R^2	.22***				

* $p < .05$.
** $p < .01$.
*** $p < .001$.

Consistent with previous research, speed of responding was also investigated (Franken et al., 2008). The regression model testing the predictive relationship between personality traits and mean reaction time (RT) on the reversal learning task was significant, $R^2 = .10$, $F(7, 157) = 2.35$, $p = .03$. The Neuroticism–ear preference interaction ($\beta = -.21$, $p = .01$, $sr^2 = .04$) and age ($\beta = .20$, $p = .01$, $sr^2 = .04$) were the only unique predictors, with older participants responding more slowly on the task. Simple slopes analysis was conducted to explore the nature of the significant interaction. Consistent with Jackson (2008), for participants with right ear preference (+1 *SD* of mean), higher Neuroticism was associated with shorter RT ($\beta = -.39$, $p = .05$, $sr^2 = .13$). By contrast, for those with left ear preference (−1 *SD*), higher Neuroticism was associated with longer RT ($\beta = .51$, $p = .04$, $sr^2 = .19$). However, speed of responding was not related to AUDIT scores, $R^2 = .03$, $F(3, 161) = 1.42$, $p = .24$, suggesting it is not a mediator of hazardous drinking.

4. Discussion

The present study investigated the possible mediating role of reversal learning in the association between impulsivity traits and hazardous alcohol use. While RD and RI were significantly related to alcohol misuse and reversal learning, results suggest reversal learning is not a mediating mechanism because it was unrelated to alcohol misuse. These findings contrast with those reported by Hildebrandt et al. (2008) studying treatment-seeking polysubstance abusers. The nature of our sample may explain this difference. It is possible that those with reversal learning poor enough to place them at risk for substance use disorders are underrepresented in college samples. Indeed, young heavy substance users are significantly less likely to complete a university degree (Fergusson & Boden, 2008). Moreover, reversal deficits may not be a risk factor at all, but rather the result of chronic substance abuse not present in a sample of college students. It is also possible that, for non-dependent hazardous drinkers, poor decision-making is largely the result of a neurocognitive process other than reversal learning. Lovallo, Yechiam, Sorocco, Vincent, and Collins (2006) reported the IGT performance of non-abusing young adults with a family history of alcoholism was characterized more by sensitivity to task rewards than a failure to update stimulus–response associations. Taken together, this suggests heightened reward sensitivity may be a more important risk factor in college drinking.

Consistent with Franken et al. (2008), RI predicted poorer reversal learning. Furthermore, our inclusion of RD in the regression model ensures that this association reflects only the unique variance in reversal learning accounted for by RI. This supports Dawe et al.'s (2004) proposed association between RI and OFC functioning, as this region of the brain has been shown to be critical to reversal learning (Fellows & Farah, 2005). Unexpectedly, RD predicted better reversal learning. To our knowledge, this is the first published study to investigate the association between RD and reversal learning. Franken and Muris (2005) unexpectedly found RD traits predicted better IGT decision-making and attributed this effect to increased motivation in high-RD participants. While our results showed high-RD participants were more motivated by the prize, this motivation was unrelated to actual task performance. This argues against motivation as a mediating mechanism.

While unexpected, the positive association between RD and reversal learning is consistent with neuroimaging data on the role of ventral striatal activity in probabilistic reversal task performance (Cools et al., 2002). Furthermore, mesolimbic dopamine has been postulated to play a role in reward prediction error-based learning, with striatal dopamine release a key signal that an error/change has occurred, and behavior modification is required (Schultz, Dayan, & Montague, 1997). Smillie (2008) suggested that reward prediction error-based learning may be a useful behavioral index of Gray's BAS. As the SR scale is a self-report measure of BAS, our results support this hypothesis.

This study also sought to test an avoidance-based impulsivity mechanism proposed by Jackson (2008). We found that while higher Neuroticism and greater right ear preference (i.e., left hemispheric activity) each predicted poorer reversal learning, their interaction did not contribute unique variance. The ear preference main effect is consistent with previous work linking left hemisphere activity with approach-related traits (Jackson, 2008; Sutton & Davidson, 1997). The Neuroticism main effect is consistent with IGT studies that have shown it predicts poorer decision-making (Davis, Patte, Tweed, & Curtis, 2007). However, the failure of the interaction to predict reversal learning suggests that Jackson's (2008) model of an interaction between lateral preference and Neuroticism may not apply to the updating/learning of stimulus-reinforcement contingencies. Jackson's model did, however, successfully predict faster RT, which suggests that the Neuroticism–ear preference interaction may apply primarily to motor responses where outcomes are already known or unchanging. Thus, Jackson's mechanism for how avoidance tendencies arising from Neuroticism can lead to enhanced approach behavior could provide a new pathway to disinhibition worthy of further study.

Both RD and RI made a unique contribution to predicting alcohol misuse. However, the addition of Jackson's (2008) avoidance-based mechanism did not enhance prediction. The discrepancy between our results and those of Jackson may be due to the different alcohol use measures employed. Jackson administered the Khavari Alcohol Test (Khavari & Farber, 1978), which primarily assesses quantity/frequency of alcohol consumption but, unlike the AUDIT (used in this study), does not include items pertaining to the negative psychological/social repercussions of heavy drinking. Taken together, these findings suggest that while a Neuroticism–ear preference interaction may predict greater alcohol consumption, RD and RI are better predictors of maladaptive drinking behavior. In some ways this parallels our findings with the reversal learning task, where Jackson's mechanism predicted faster responding, but not more maladaptive responding (i.e., faster approach with no detriment to performance). By contrast, RD and RI were not related to response speed, but were associated with accuracy of performance. In sum, our results are in line with previous research showing a less consistent role for avoidance-based traits in substance misuse and support the utility of a two-factor conceptualization of impulsivity and alcohol misuse (Gullo & Dawe, 2008).

There were several limitations to the study that should be noted. As discussed earlier, the recruitment of a high-functioning, college sample may limit the generalisability of our findings to other populations. Additionally, we cannot rule out that null findings regarding the Neuroticism–hemispheric preference interaction were the result of the latter being measured via self-report. Future studies should incorporate electroencephalogram (EEG) measurements to enhance precision. Also of note, while the internal reliability of the SR scale was acceptable, it was modest, and this should be taken into account when evaluating the study's findings. In conclusion, our results support the role of RD and RI in alcohol misuse, but rule out reversal learning as a mediator of their effects. By contrast, Jackson's (2008) Neuroticism-lateral preference mechanism was involved in approach behavior, but not alcohol misuse.

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