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Bibbey, Adam; Phillips, Anna C.; Ginty, Annie T.; Carroll, Douglas

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# Problematic Internet use, excessive alcohol consumption, their comorbidity and cardiovascular and cortisol reactions to acute psychological stress in a student population

ADAM BIBBEY\*, ANNA C. PHILLIPS, ANNIE T. GINTY and DOUGLAS CARROLL

School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, Birmingham, United Kingdom

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*Background and aims:* Problematic Internet use and excessive alcohol consumption have been associated with a host of maladaptive outcomes. Further, low (blunted) cardiovascular and stress hormone (e.g. cortisol) reactions to acute psychological stress are a feature of individuals with a range of adverse health and behavioural characteristics, including dependencies such as tobacco and alcohol addiction. The present study extended this research by examining whether behavioural dependencies, namely problematic Internet use, excessive alcohol consumption, and their comorbidity would also be associated with blunted stress reactivity. *Methods:* A large sample of university students ( $N = 2313$ ) were screened using Internet and alcohol dependency questionnaires to select four groups for laboratory testing: comorbid Internet and alcohol dependence ( $N = 17$ ), Internet dependence ( $N = 17$ ), alcohol dependence ( $N = 28$ ), and non-dependent controls ( $N = 26$ ). Cardiovascular activity and salivary cortisol were measured at rest and in response to a psychological stress protocol comprising of mental arithmetic and public speaking tasks. *Results:* Neither problematic Internet behaviour nor excessive alcohol consumption, either individually or in combination, were associated with blunted cardiovascular or cortisol stress reactions. *Discussion:* It is possible that problematic Internet behaviour and excessive alcohol consumption in a student population were not related to physiological reactivity as they may not reflect ingrained addictions but rather an impulse control disorder and bingeing tendency. *Conclusions:* The present results serve to indicate some of the limits of the developing hypothesis that blunted stress reactivity is a peripheral marker of the central motivational dysregulation in the brain underpinning a wide range of health and behavioural problems.

**Keywords:** Internet dependence, alcohol, comorbid dependence, cardiovascular reactivity, cortisol reactivity, acute stress

## INTRODUCTION

Although the Internet has undoubtedly provided numerous benefits, there is a growing concern that some individuals are displaying dependent behaviour (Widyanto & Griffiths, 2006), with the prevalence of dependency increasing within many countries including the United States of America and the United Kingdom (Durkee et al., 2012). Indeed, problematic and excessive Internet use has many characteristics in common with substance addiction: disturbed psychological functioning, inability or unwillingness to reduce use with potential relapse, and increased tolerance (Griffiths, 1996; Young, 1996). There is also evidence that excessive Internet use disrupts social, occupational, and personal relationships (Greydanus & Greydanus, 2012; Morrison & Gore, 2010), with support to suggest associations with alcohol misuse (Ko et al., 2008). High alcohol intake during adolescence has been linked to a range of long-term adverse outcomes such as increased anti-social behaviour (Swahn, Simon, Hammig & Guerrero, 2004), mental health disorders (Marmorstein, 2009), relationship problems (Odgers et al., 2008), and life-long impaired cognitive function (Ehlers and Criado, 2010; Hanson et al., 2011). Thus, both excessive Internet and alcohol use appear to be associated with a host of maladaptive outcomes, with previous health research often showing that comorbid conditions, as opposed to single disorders, are related to poorer health outcomes (Vogeli et al., 2007).

Psychological stress is experienced by most individuals on a daily basis, and it is now known that individuals differ markedly in their biological reactions to a standard psychological stress exposure (e.g. Carroll, 1992). Substantial evidence demonstrates that those who exhibit exaggerated cardiovascular and stress hormone (e.g. cortisol) reactions to acute psychological stress are at increased risk of developing various manifestations of cardiovascular disease (e.g., Carroll et al., 2012; Hamer et al., 2010). More recently, however, a range of evidence is accumulating that individuals who show blunted or low cardiovascular and cortisol reactions are at increased risk from a number of negative health and behavioural outcomes, such as depression (Brindle et al., 2013; de Rooij et al., 2010; Phillips et al., 2011) and obesity and adiposity (Carroll, Phillips & Der, 2008; Phillips, Roseboom, Carroll & de Rooij, 2012; Singh & Shen, 2013).

Even more striking is the association between blunted stress reactivity and tobacco, alcohol, and other substance dependences. For example, there is now a reasonable consensus that smokers are characterised by both blunted car-

\* Corresponding author: Adam Bibbey; School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, Birmingham, B15 2TT, United Kingdom; Phone: +44 (0)121 414 8956; Fax: +44 (0)121 414 4121; E-mail: bibbeya@bham.ac.uk

diovascular (Evans et al., 2012; Girdler, Jamner, Jarvik, Soles & Shapiro, 1997; Phillips, Der, Hunt & Carroll, 2009; Roy, Steptoe & Kirschbaum, 1994; Sheffield, Smith, Carroll, Shipley & Marmot, 1997; Straneva, Hinderliter, Wells, Lenahan & Girdler, 2000) and cortisol (al’Absi, Wittmers, Erickson, Hatsukami & Crouse, 2003; Kirschbaum, Scherer & Strasburger, 1994; Kirschbaum, Strasburger & Langkrar, 1993; Rohleder & Kirschbaum, 2006) stress reactivity and that this cannot be accounted for by the temporary abstinence usually required in stress testing protocols (al’Absi et al., 2003; Roy et al., 1994). Similarly, those dependent on alcohol (Bernardy, King, Parsons & Lovallo, 1996; Dai, Thavundayil, Santella & Gianoulakis, 2007; Errico, Parsons, King & Lovallo, 1993; Lovallo, Dickensheets, Myers, Thomas & Nixon, 2000; Panknin, Dickensheets, Nixon & Lovallo, 2002; Sinha et al., 2011), other non-prescription drugs or both (Lovallo et al., 2000; Panknin et al., 2002; van Leeuwen et al., 2011) have also been found to show blunted biological responses to a range of stress tasks. Furthermore, diminished cardiovascular and cortisol reactions to stress would appear to be a feature of individuals with behavioural addictions and disorders such as bulimia (Ginty, Phillips, Higgs, Heaney & Carroll, 2012; Koo-Loeb, Pedersen & Girdler, 1998; Monteleone et al., 2011; Pirke, Platte, Laessle, Seidl & Fichter, 1992) exercise dependence (Heaney, Ginty, Carroll & Phillips, 2011), and gambling addictions (Paris, Franco, Sodano, Frye & Wulfert, 2010). This suggests that blunted reactivity is a general feature of dependencies, including behavioural addiction, and not specific to those that involve the abuse of a substance. Finally, there is at least preliminary evidence that those with co-existing substance dependencies are more likely to show blunted cardiovascular and cortisol responses to an acute stress task than those with single dependencies (Bernardy et al., 1996; Errico et al., 1993; Panknin et al., 2002).

It has been argued that the link between these diverse correlates, including dependency and addiction, of blunted stress reactivity is deficiencies in motivation. Indeed, low cardiovascular and cortisol reactions to acute stress have been considered a peripheral marker for central motivational dysregulation (Carroll, Lovallo & Phillips, 2009; Carroll, Phillips & Lovallo, 2011; Lovallo, 2011), i.e., dysregulation of the neural systems in the brain that support motivation and goal-directed behaviour. Evidence in support comes from functional Magnetic Resonance Imaging studies. For example, individuals characterised by blunted cardiovascular stress responses have been found to be characterised by diminished activation in both the posterior and anterior cingulate cortex, and in the amygdala during stress exposure (Gianaros, May, Siegle & Jennings, 2005; Ginty, Gianaros, Derbyshire, Phillips & Carroll, 2013). These brain areas

are indeed implicated in motivational processes and goal-directed behaviour (Bush, Luu & Posner, 2000; Hagemann, Waldstein & Thayer, 2003).

However, to date, problematic Internet behaviour has received no attention in the context of stress reactivity, nor has the comorbidity of behavioural and substance dependence, e.g., problematic Internet behaviour and alcohol use, with few studies investigating alcohol use and stress reactions within student samples (Evans et al., 2012; Wemm et al., 2013). Thus, the present study was designed to assess whether individuals with problematic Internet use and alcohol consumption, and therefore possible deficiencies in central motivation, would be characterised by diminished stress reactivity. Accordingly, a substantial student population was screened to identify individuals who appear to have comorbid Internet and alcohol dependence, Internet dependence *per se*, alcohol dependence *per se*, and individuals showing no signs of dependence. Group differences in cardiovascular and cortisol reactions to acute psychological stress were then compared. We hypothesized that those with signs of dependence, whether to alcohol or the Internet, would show blunted stress reactivity, with this blunted reactivity being a particular feature of those with comorbid Internet and alcohol problems.

## METHODS

### Participants

Questionnaires measuring Internet and alcohol dependence were administered to 2313 University of Birmingham students (1556 women). On the basis of questionnaire responses, a sub-sample of 88 participants was selected to form four groups who attended laboratory testing. Table 1 shows the *N* in each group and scores on the Internet and alcohol dependence scales used in screening and those used subsequently to confirm status. The mean (SD) age of the selected sample was 19.8 (1.84) years and their mean (SD) body mass index was 22.3 (3.04) kg/m<sup>2</sup>. Fifty-eight (66%) participants were female, the majority of the participants indicated they were “white” (86%) and five individuals smoked. Demographics and health behaviours are presented in Table 2. The groups did not vary in any of these characteristics with the exception of body mass index, which was significantly lower in the control group, and, as would be expected, alcohol consumption, which was greatest in the comorbid and alcohol dependent groups. All participants provided written informed consent and the study was approved by the University of Birmingham ethics committee.

Table 1. Responses to the Internet Addiction Test (IAT), Alcohol Use Disorders Identification Test (AUDIT), Pathological Internet Use Scale (PIUS) and the Shorter PROMIS Questionnaire (SPQ) alcohol sub-scale

	Comorbid	Internet dependent	Alcohol dependent	Control	
	Mean (SD)				<i>p</i>
IAT	62.9 (8.47)	57.2 (4.25)	31.9 (4.86)	28.6 (4.00)	<.001
AUDIT	18.9 (4.32)	6.5 (3.36)	20.0 (4.14)	2.9 (1.79)	<.001
PIUS	6.4 (2.27)	5.4 (2.45)	2.4 (1.79)	1.7 (1.25)	<.001
SPQ alcohol sub-scale	27.8 (7.54)	16.4 (8.33)	28.4 (8.17)	10.8 (8.22)	<.001

Table 2. Characteristics of the comorbid, Internet dependent, alcohol dependent, and control groups

	Comorbid	Internet dependent	Alcohol dependent	Control	<i>p</i>
<i>N</i>	17 (19)	17 (19)	28 (32)	26 (30)	
Gender (females)	13 (77)	12 (71)	15 (54)	18 (69)	.38
Age (years)	19.6 (1.80)	19.8 (1.29)	19.2 (.67)	20.5 (2.94)	.11
Body Mass Index (kg/m <sup>2</sup> )	22.3 (2.32)	23.7 (4.40)	23.6 (2.67)	20.4 (2.36)	.001
Ethnicity (white)	14 (82)	14 (82)	27 (96)	21 (81)	.73
Current smoker	2 (12)	0 (0)	1 (4)	2 (8)	.46
Units of alcohol per week (≥11)	5 (29)	2 (12)	18 (64)	1 (4)	<.001
Sleep (≥8 hrs)	8 (47)	6 (35)	14 (50)	14 (54)	.68
Calculated cardio-respiratory fitness (metabolic equivalents)	13.8 (1.49)	13.4 (1.80)	14.3 (1.58)	13.9 (1.57)	.31

### Measures

**Internet dependence.** The Internet Addiction Test (Young, 1998) was used to screen for pathological Internet use. Scores from 20 to 49 indicate average online use, 50 to 79 indicate frequent problems due to Internet usage, and 80 to 100 represent Internet use causing significant problems (Young, 1998). High internal reliability was found in the present study, Cronbach's  $\alpha = .94$ . The Pathological Internet Use Scale (Morahan-Martin & Schumacher, 2000) was used to confirm group allocation. A total of  $\geq 4$ , 1–3, and 0 indicate, respectively, pathological Internet use, limited symptoms, and no symptoms. Current internal reliability was good,  $\alpha = .73$ .

**Alcohol dependence.** The Alcohol Use Disorders Identification Test (Saunders, Aasland, Babor, Delafuente & Grant, 1993) was used to screen for alcohol dependence. A score of  $\geq 15$  or  $\geq 13$  for men and women, respectively, indicates alcohol dependence, and a score of  $\geq 8$  indicates harmful or hazardous drinking (Saunders et al., 1993). The current Cronbach's  $\alpha = .88$ . The alcohol sub-scale of the Shorter PROMIS Questionnaire (Christo et al., 2003) was used to check group allocation. Total scores range from 0 to 50, with higher scores indicating greater dependence. The present study found a Cronbach's  $\alpha = .87$ .

**Health behaviours.** A questionnaire adapted from the Whitehall II study (Marmot et al., 1991) was administered to measure average daily smoking, weekly alcohol intake, and sleep duration. Estimated cardio-respiratory fitness was calculated by a previously validated formula (Jurca et al., 2005).

**Psychological stress task questionnaire.** Following stress task completion, participants rated how difficult, stressful, exciting, confusing, and engaging they found the tasks, and how well they thought they performed. Responses were recorded on Likert-type scale ranging 0 = 'not at all' to 6 = 'extremely'.

**Acute psychological stress tasks.** The 10-min Paced Auditory Serial Addition Test (Gronwall, 1977) has demonstrated reliability in perturbing both cardiovascular and salivary cortisol reactions (Ginty et al., 2012; Ring, Burns & Carroll, 2002). Participants are presented with a series of single digits and are required to add the present number to the previously presented number, and report their answer aloud. The protocol has been described in detail elsewhere (Heaney et al., 2011).

The speech task required participants to deliver two consecutive speeches, each lasting 6 min comprising 2 min preparation and 4 min delivery (Bosch, Berntson, Cacioppo, Dhabhar & Marucha, 2003). The task has been shown to

reliably elicit both cardiovascular and cortisol responses (Bosch et al., 2009). To increase social stress, each speech was performed in the presence of two experimenters, one of whom prominently observed and prompted the participant to continue if they paused. The first speech required the participants to defend themselves following a false shop-lifting accusation, whereas the second speech was a presentation of their best and worst personal characteristics.

**Cardiovascular and salivary cortisol measures.** The laboratory session consisted of five periods; 10 min adaptation, 10 min baseline, 10 min Paced Auditory Serial Addition Test, 15 min speech stress task, and 20 min recovery. Systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR) were measured discontinuously using a semi-automatic sphygmomanometer (Critikon Inc, Tampa, FL/Omron, IL) at min 2, 4, 6, and 8 during baseline, Paced Auditory Serial Addition Test and recovery, and at 30 sec and 2 min 30 sec into delivery phase of each speech. Two stimulated 2 min saliva samples were obtained using salivettes at min 8 of baseline and 8 min into the recovery period. Salivettes were centrifuged for 5 min at 4000rpm before being stored at  $-20^{\circ}\text{C}$  until assay. ELISA kits (IBL International, Germany) were used to analyse all cortisol samples in duplicate. The mean intra-assay coefficient of variation was 9.8% and the inter-assay coefficient was 4.4%. Due to collection difficulties with two participants (one Internet dependent and one control), cortisol assays were analysed for 86 participants.

### Procedure

Alcohol dependence was defined as an Alcohol Use Disorders Identification Test score of  $\geq 15$  for men and  $\geq 13$  for women. Internet dependence was signified by an Internet Addiction Test score of  $\geq 53$ . The comorbid group met both of these criteria. The control group scored  $< 8$  on the Alcohol Use Disorders Identification Test, and between 20–35 on the Internet Addiction Test. An Internet Addiction Test score of  $\geq 53$  was adopted as this was greater than the 50–79 criteria proposed to reflect Internet use causing frequent problems (Young, 1998), and was more stringent than cut-offs which have demonstrated sound psychometric properties (Widyanto & McMurrin, 2004) and criteria used by previous studies examining problematic Internet use (Hardie & Tee, 2007; Lam & Peng, 2010). Thus, the current study adopted a cut-off which incorporated individuals with problematic

Internet use from the substantial screening of over 2300 students. Furthermore, 20–35 was lower than the suggested criteria of <49 indicating average online use, therefore providing further support for stringent group allocation.

Prior to laboratory testing, participants abstained from eating for 1 h, drinking caffeine or smoking for 2 h, and from physical exercise and drinking alcohol for 12 h. During the adaptation period, participants completed the Pathological Internet Use Scale and Shorter PROMIS Questionnaire whilst sitting quietly. This was followed by the formal resting baseline before the psychological stress tasks were presented in a counterbalanced order, with the subsequent recovery period.

*Statistical analysis*

For the cardiovascular measures, averages of each period were calculated; baseline, stress (combined average of Paced Auditory Serial Addition Test and Speech), and recovery. Salivary cortisol measures were log<sub>10</sub> transformed. Group differences in demographic, health behaviour, dependency, stress task perceptions and performance, and baseline cardiovascular and cortisol variables were tested using one-way ANOVA for continuous and chi-square for categorical variables. Repeated measures ANOVAs were performed to confirm the stress tasks perturbed cardiovascular activity and cortisol, and to examine group differences over time. Greenhouse-Geisser correction was applied where appropriate and pairwise comparisons undertaken to elucidate significant differences. Partial η<sup>2</sup> was reported as an index of effect size throughout.

*Ethics*

The study procedures were carried out in accordance with the Declaration of Helsinki. The University of Birmingham, UK, Institutional Review Board approved the study. All subjects were informed about the study and all provided informed consent.

RESULTS

*Questionnaires and task performance scores*

As indicated in Table 1, average scores on the Internet and alcohol dependence scales significantly differentiated the

groups. As expected, the comorbid and Internet dependent groups reported significantly higher scores on the Internet Addiction Test and Pathological Internet Use Scale than the alcohol dependent and control groups (*p* < .001). The comorbid and alcohol dependent groups had significantly higher scores on the Alcohol Use Disorders Identification Test and Shorter PROMIS Questionnaire alcohol sub-scale than the Internet dependent and control groups (*p* < .05). There were no significant group differences in Paced Auditory Serial Addition Test performance or self-reported task ratings (see Table 3).

*Cardiovascular and cortisol reactions to acute psychological stress*

The stress tasks significantly perturbed cardiovascular activity. ANOVA revealed a significant time effect for SBP, *F*(2, 168) = 253.30, *p* < .001, η<sup>2</sup> = .751, DBP, *F*(2, 168) = 223.08, *p* < .001, η<sup>2</sup> = .726, and HR, *F*(2, 168) = 154.91, *p* < .001, η<sup>2</sup> = .648, whereby all variables increased significantly from baseline to stress then decreased during recovery but remained significantly higher than baseline; indicated in Figure 1. There were no main effects of group overall for SBP, DBP, or HR; *F*(3, 84) = 2.28, *p* = .08, η<sup>2</sup> = .075; *F*(3, 84) = .76, *p* = .52, η<sup>2</sup> = .026; *F*(3, 84) = 1.58, *p* = .20, η<sup>2</sup> = .053, respectively, nor were there any significant group differences in baseline cardiovascular levels. There were no significant group × time interactions for SBP, *F*(6, 168) = .44, *p* = .83, η<sup>2</sup> = .015, DBP, *F*(6, 168) = .87, *p* = .52, η<sup>2</sup> = .030, or HR, *F*(6, 168) = .47, *p* = .77, η<sup>2</sup> = .016; see Figure 1. Further analyses examining cardiovascular differences between the comorbid and control groups specifically produced analogous results such that there were no significant group × time interactions for SBP, *F*(2, 82) = .25, *p* = .78, η<sup>2</sup> = .006, DBP, *F*(2, 82) = 1.41, *p* = .25, η<sup>2</sup> = .033, or HR, *F*(2, 82) = .51, *p* = .54, η<sup>2</sup> = .012.

The stress tasks significantly increased cortisol as shown in Figure 2. Repeated measures ANOVA revealed a significant effect of time, *F*(1, 82) = 4.35, *p* = .04, η<sup>2</sup> = .050, but no main effects of group overall, *F*(3, 82) = 1.52, *p* = .22, η<sup>2</sup> = .053, or at baseline only. There was also no significant group × time interaction, *F*(3, 82) = .38, *p* = .77, η<sup>2</sup> = .014. Further analysis examining the cortisol differences between the comorbid and control groups only also revealed no group × time interaction, *F*(1, 40) = .33, *p* = .57, η<sup>2</sup> = .008.

As body mass index was significantly lower in the control group, and has been shown to relate to reactivity (Car-

Table 3. Subjective stress task ratings and Paced Auditory Serial Addition Test performance

	Overall	Comorbid	Internet dependent	Alcohol dependent	Control	<i>p</i>
	Mean (SD)					
Difficulty	4.4 (.97)	4.3 (1.05)	4.2 (.66)	4.4 (1.07)	4.4 (1.02)	.92
Stressful	4.4 (1.04)	4.3 (1.00)	4.6 (.87)	4.2 (1.23)	4.5 (.99)	.61
Exciting	2.6 (1.54)	2.4 (1.77)	2.8 (1.55)	2.7 (1.31)	2.6 (1.68)	.89
Perceived performance	2.4 (1.19)	2.4 (1.33)	2.4 (1.23)	2.5 (1.23)	2.2 (1.07)	.87
Confusing	2.7 (1.54)	3.1 (1.30)	2.3 (1.40)	3.1 (1.65)	2.3 (1.57)	.16
Engaging	3.8 (1.36)	3.8 (1.38)	3.8 (1.44)	3.8 (1.38)	3.7 (1.35)	.99
Paced Auditory Serial Addition Test total score	715.7 (138.83)	656.3 (119.59)	750.3 (76.64)	722.0 (148.57)	722.9 (164.15)	.25

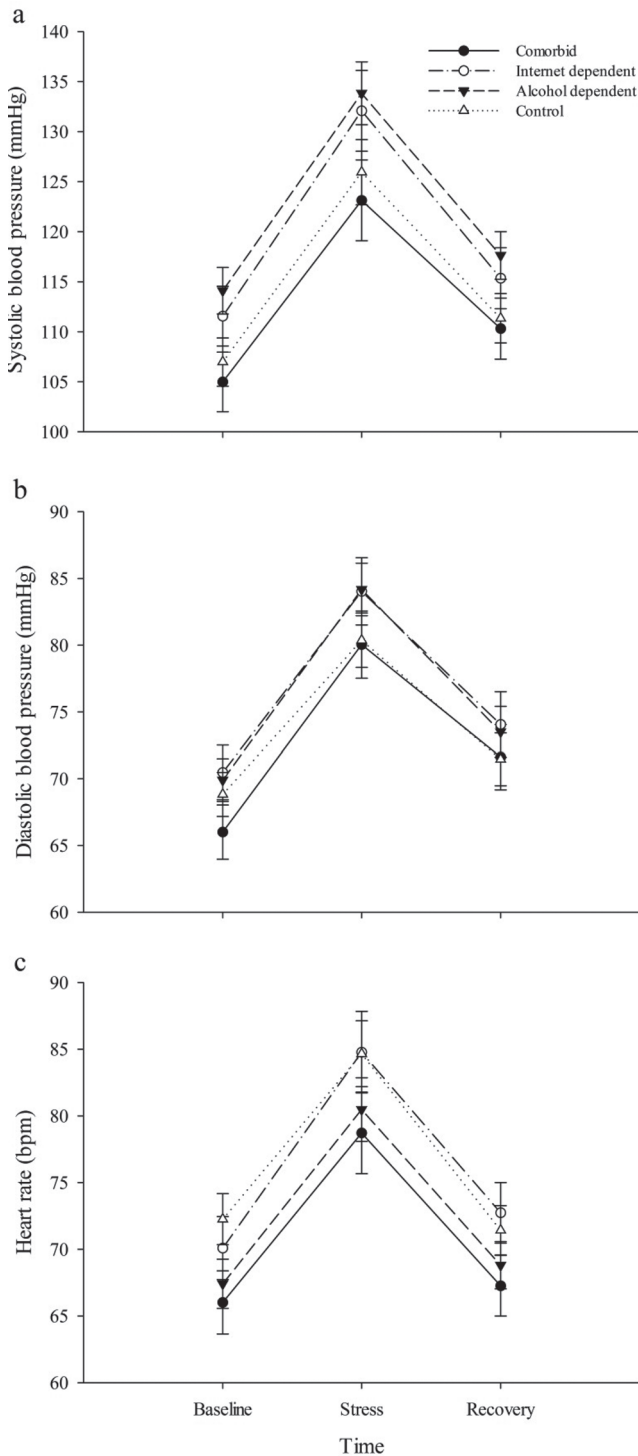


Figure 1. Mean (SE) (a) systolic blood pressure, (b) diastolic blood pressure, and (c) heart rate levels at baseline, during the acute stress task, and recovery by group

roll et al., 2008; Phillips et al., 2012) the above analyses were repeated with body mass index as a covariate; this did not alter the outcomes.

## DISCUSSION

The present study was concerned with whether problematic Internet behaviour and possible alcohol dependence on

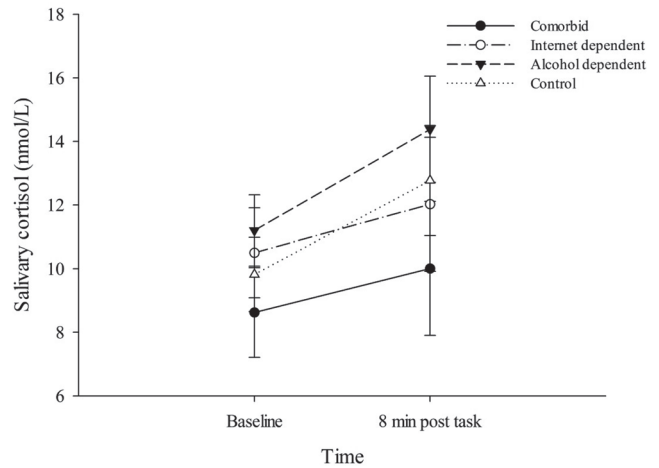


Figure 2. Mean (SE) salivary cortisol at baseline and 8 min post stress task by group (raw values shown)

their own, and in combination, were associated with blunted biological reactions to acute psychological stress exposures. Neither of these behaviours individually nor when co-existing were associated with either cardiovascular or cortisol stress reactivity, such that there were no differences in reactivity between any of the groups compared to controls. These null results would appear to indicate that blunted stress reactivity is only present in those with life-long confirmed addictions rather than extremes of student behaviour. For example, blunted stress reactivity has been shown in individuals with tobacco (al'Absi et al., 2003; Evans et al., 2012; Girdler et al., 1997; Kirschbaum et al., 1994; Kirschbaum et al., 1993; Phillips et al., 2009; Rohleder & Kirschbaum, 2006; Roy et al., 1994; Sheffield et al., 1997; Straneva et al., 2000), alcohol (Bernardy et al., 1996; Dai et al., 2007; Errico et al., 1993; Lovallo et al., 2000; Panknin et al., 2002; Sinha et al., 2011), and other substance dependencies (Lovallo et al., 2000; Panknin et al., 2002; van Leeuwen et al., 2011), as well as those with behavioural dependence such as disordered eating (Ginty et al., 2012; Koo-Loeb et al., 1998; Monteleone et al., 2011; Pirke et al., 1992), exercise dependence (Heaney et al., 2011), and pathological gambling (Paris et al., 2010).

This is the first study we know of to examine problematic Internet behaviour in the context of stress reactivity. Internet addiction is a relatively new construct (Young 1996), and remains a heterogeneous one (Griffiths, 2000; Widyanto & Griffiths, 2006; Young, 1999), with no agreed definition (Greydanus & Greydanus, 2012). For example, although excessive Internet use has been associated with many of the characteristics of substance addiction such as disturbed psychological functioning, inability or unwillingness to reduce use, and increased tolerance (Griffiths, 1996; Young, 1996), there is little evidence of the physical symptoms of withdrawal, typical of substance dependence (Beard & Wolf, 2001). Accordingly, some have suggested it may not reflect a true addiction (Griffiths, 2000; Weinstein & Lejoyeux, 2010; Widyanto & Griffiths, 2006) by more an impulse control disorder (Young, 1998). In support, Cao, Su, Lui and Gao (2007) reported that, in comparison to controls, adolescents with excessive Internet use exhibited greater levels of impulsivity as indicated by their responses to an impulsiv-

ity questionnaire and to the GoStop impulsivity paradigm. Further evidence has been provided by neurophysiological studies showing that those who use the Internet excessively are characterised by electroencephalographic signs of poor response inhibition and impulsiveness (Choi et al., 2013; Dong, Devito, Du & Cui, 2012). In retrospect, then, if problematic Internet behaviour does not constitute an actual long-term addiction, but more of a milder dependency, it is perhaps not surprising that we failed to find an association with blunted stress reactions.

Previous research linking high alcohol consumption with blunted biological stress reactivity has focused on adults with a confirmed diagnosis (Bernardy et al., 1996; Dai et al., 2007; Errico et al., 1993; Lovallo et al., 2000; Panknin et al., 2002). For example, Lovallo et al. (2000) reported alcoholics aged between 22 and 55 failed to elicit a significant increase in cortisol in response to a public speaking stressor, whereas non-dependent controls showed the expected rise, with Panknin et al. (2002) also demonstrating the same dependent patients elicited attenuated heart rate responses. Dai et al. (2007) reported, in response to arithmetic and monetary competition stressors, alcohol dependent individuals, aged 25 to 40, failed to stimulate a significant increase in cortisol while non-dependent individuals produced the expected increase. All of these studies classified their dependent patients according to the Diagnostic and Statistical Manual-IV criteria for alcohol dependence (American Psychiatric Association, 1994). The present study purposively attempted to extend this work by focusing upon alcohol consumption within a student population, especially given the paucity of research of students within this context and the association of excessive alcohol intake in this population with a range of maladaptive outcomes such as anti-social behaviour (Swahn et al., 2004), mental health disorders (Marmorstein, 2009), relationship problems (Odgers et al., 2008), and life-long impaired cognitive function (Brown et al., 2008). Our finding of no association between students with high levels of alcohol consumption and either cardiovascular or cortisol stress reactions suggest limits to the scope of the proposal that blunted stress reactions are characteristic of a range of problematic behaviours including alcohol dependence (Carroll et al., 2009; Carroll et al., 2011; Lovallo, 2011). However, it is possible that the present student sample were not truly addicted to alcohol. There is a range of evidence that as a body, students consume more alcohol than their non-student peers, and that alcohol consumption rises on transition from school to university (Dawson et al., 2004; Kypri et al., 2005). However, it is also clear from previous research that alcohol consumption decreases on graduation (Bewick, Trusler, Mulhern, Barkham & Hill, 2008; Klein, 1994; Lanza & Collins, 2006). Accordingly, excessive alcohol consumption by students may be a transient phenomenon rather than a reflection of a true addiction.

It is worth noting that the two studies to examine biological stress reactivity in the context of high alcohol consumption in a younger sample found no associations between alcohol intake and cardiovascular stress reactions (Evans et al., 2012; Wemm et al., 2013). However, in line with the results from epidemiological studies of adult populations (Phillips et al., 2009; Sheffield et al., 1997), Evans et al. (2012) did find an association between tobacco smoking and blunted heart rate reactivity. This would be consistent with

the contention that early smoking is much more reflective of addictive behaviour than early excessive alcohol consumption (Breslau, 1995; Hu, Davies & Kandel, 2006; Lanza & Collins, 2006) and that blunted stress reactivity is a marker for true addiction rather than behavioural excess. The studies demonstrating the associations between both disordered eating (Ginty et al., 2012) and exercise dependence (Heaney et al., 2011), with low physiological stress reactivity, in a similar student population as used in the present study, add further support to the notion that true addictions are required to reflect blunted biological responses especially given that these constructs are proposed to incorporate more pathological (Bamber, Cockerill & Carroll, 2000; Berczik et al., 2012; Egorov & Szabo, 2013; Karim & Chaudhri, 2012) and are likely to persist into adulthood (Allen, Byrne, Oddy & Crosby, 2013; Berczik et al., 2012).

Given the absence of previous research, a primary aim of the present study was to examine the association between comorbid behavioural and substance dependence, i.e. problematic Internet behaviour and excessive alcohol consumption, and cardiovascular and cortisol reactivity. Others have found that alcohol abuse is quite common among those that use the Internet excessively (Ko et al., 2008), with comorbid conditions often related to poorer health outcomes in comparison to single disorders (Vogeli et al., 2007). Our clear expectations – based on studies which showed individuals who had comorbid alcohol and substance dependency had the greatest blunting of heart rate (Panknin et al., 2002) and cortisol (Bernardy et al., 1996; Errico et al., 1993) responses relative to those who had single or no addictions – were that the group exhibiting both excessive Internet use and alcohol intake would show the most diminished stress reactivity. In reality, this group did not differ from single addiction groups or participants with low Internet use and alcohol consumption. Given that it is unlikely that excessive Internet use in the present study constituted a genuine addiction, and it is unlikely that our high alcohol consumers were actual alcoholics, it is perhaps not surprising that this particular comorbidity of problematic behaviours was not associated with blunted stress reactivity. Again, this would seem to reinforce the conclusion that blunted reactivity may signify genuine addiction rather than excessive behaviour.

It should be acknowledged that the present study had the following limitations. Firstly, although our cut off for Internet dependency was slightly lower than the very highest criteria band suggested by Young (1998), it still incorporated individuals with problematic Internet use, and was more stringent than criteria which has demonstrated sound psychometric properties (Widyanto & McMurrin, 2004) and criteria used in other studies (Hardie & Tee, 2007; Lam & Peng, 2010). Further, according to both the screening and follow-up validation dependency questionnaires, the groups significantly differed in the expected direction on the questionnaires used, thus suggesting correct group assignment. Secondly, although the final size of each group could be considered modest, it was similar or greater in size to previous studies in this broad field (Ginty et al., 2012; Heaney et al., 2011; Lovallo et al., 2000) and was based on a selection from a substantial screening sample of over 2300 university students.

In conclusion, neither problematic Internet behaviour nor excessive alcohol consumption, either individually or in

combination, were associated with blunted cardiovascular or cortisol reactions to acute psychological stress. This result was contrary to our expectations based on growing evidence that blunted stress reactivity is associated with a host of adverse health and behavioural outcomes, including addiction. In retrospect, though, given the controversial nature of the concept of Internet addiction and the relatively short term, and possibly temporary, excessive alcohol intake, it is unlikely that our sample displayed genuine and ingrained addictions. Our study, therefore, appears to indicate that the hypothesis that blunted stress reactivity is a peripheral marker of the central motivational dysregulation underpinning a wide range of behavioural problems is restricted to more serious disorders rather than the possibly time-limited excessive behaviours studied here.

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**Conflict of interests:** All authors declare that they have no conflict of interests.

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