Blunted autonomic responses to emotional stimuli in alcoholism: relevance of impulsivity

Respuestas autonómicas reducidas ante estímulos emocionales en el alcoholismo: la relevancia de la impulsividad

Martina Carmona-Perera*,**, Xavier Sumarroca-Hernández***, Angelina Santolaria-Rossell***, Miguel Pérez-García*,****,*****, Gustavo A. Reyes del Paso******.

* Department of Personality, Assessment and Psychological Treatment. School of Psychology, University of Granada, Campus Cartuja s/n. 18071 Granada, Spain. ** Fundació Villablanca, Serveis Assistencials. Hospital Universitari Institut Pere Mata, Ctra. Bellissens s/n. 43204 Reus, Spain. *** Unitat de Conductes addictives (UCA). Hospital Nostra Senyora de Meritxell, C/ dels Escalls, s/n. AD700 Escaldes-Engordany, Andorra. **** Centro de Investigación Mente, Cerebro y Comportamiento (CIMCYC). University of Granada, Campus Cartuja s/n. 18071 Granada, Spain. ***** Centro de Investigación Biomédica en Red de Salud Mental (CIBERSAM). University of Granada, Av de Madrid nº 11, 18071 Granada, Spain. ****** Department of Psychology. University of Jaén, Campus de las Lagunillas s/n. 23071 Jaén, Spain.

Abstract

Alcohol dependence is associated with abnormalities in the processing of emotional signals and impulsive alcohol-seeking behaviours, and these alterations compromise the effectiveness of treatment approaches. However, there is a lack of studies linking the experience of emotions to everyday motivationally relevant stimuli in alcohol-dependent individuals using both autonomic and self-report measures. We analysed heart rate (HR), skin conductance (SC) and subjective emotional reactivity to everyday affective stimuli in alcohol-dependent individuals, and their associations with impulsivity and degree of alcohol consumption. SC and HR were continuously monitored in 28 alcohol-dependent individuals and in 31 non-alcohol healthy controls during passive viewing of pleasant, unpleasant, and neutral emotional pictures. Participants assessed the pictures for valence, arousal, and dominance and completed the Barratt Impulsiveness Scale. Alcohol-dependent individuals showed reduced HR and SC reactivity to both positive and negative emotional stimuli. In the case of SC, this blunted response was associated with impulsivity. Furthermore, alcohol-dependents displayed decoupled physiological and subjective responses, with blunted autonomic responses and normal subjective reports regarding emotional stimuli. Our findings indicate that alcohol-dependent individuals failed to use emotional autonomic feedback in response to natural, emotionally relevant stimuli, and provide initial evidence of the contribution of impulsivity to emotional processing deficits in this population. These results are in keeping with the proposed key role played by emotional experience and impulsivity in substance abuse.

Keywords: Alcohol-dependent individuals; Autonomic responses; Emotional experience; Impulsivity; Heart rate; Skin conductance.

Resumen

La dependencia al alcohol está asociada con anormalidades en el procesamiento de las emociones y comportamientos impulsivos en la búsqueda de alcohol. Sin embargo, pocos estudios han analizado las respuestas emocionales hacia estímulos motivacionalmente relevantes en personas dependientes al alcohol usando medidas tanto autonómicas como subjetivas. En este estudio se analizó la tasa cardiaca (TC), la conductancia de la piel (CP) y las respuestas subjetivas a estímulos emocionales cotidianos en individuos dependientes al alcohol, y su asociación con la impulsividad y el consumo de alcohol. La TC y la CP fueron registradas en 28 participantes dependientes al alcohol y en 31 participantes sanos durante la visualización pasiva de imágenes emocionales placenteras, desagradables y neutras. Posteriormente, los participantes evaluaron valencia, activación y dominancia de las imágenes y completaron la Escala de Impulsividad de Barratt. Los participantes dependientes mostraron respuestas reducidas en TC y CP, tanto hacia las imágenes emocionales positivas como negativas. En el caso de la CP, estas respuestas se asociaron a la impulsividad. Los participantes dependientes al alcohol mostraron una disociación entre las respuestas fisiológicas y subjetivas, con unas respuestas autonómicas disminuidas y unas respuestas subjetivas normales. Estos resultados sugieren que los individuos dependientes al alcohol tienen problemas en utilizar el feedback fisiológico emocional al responder a estímulos emocionales relevantes, y proporcionan una evidencia inicial de la contribución de la impulsividad a los déficits de procesamiento emocional en esta población. Estos resultados son congruentes con el papel clave que juega la experiencia emocional y la impulsividad en el abuso de sustancias.

Palabras clave: Dependencia al alcohol; Respuestas autonómicas; Rxperiencia emocional; Impulsividad; Tasa cardíaca; Conductancia de la piel.

Received: November 2017; Accepted: December 2017.

Send correspondence to:
Gustavo A. Reyes del Paso. Departamento de Psicología. Universidad de Jaén. 23071 Jaén, España. Fax: +34953211881.
E-mail: greyes@ujaen.es.

Alcohol dependence is related to abnormalities in the processing of emotional signals, which could underlie decision-making deficits, mood disorders and poor-quality social interactions (Handelsmanet et al., 2000; Kornreich et al., 2002;Verdejo-García & Bechara, 2009), thus promoting relapse after abstinence (Allsop, Saunders & Phillips, 2000; Bechara & Damasio, 2002). For example, some studies have implicated poor emotional regulation and emotional expression recognition in alcoholism (Foisy et al., 2007; Uekermann & Daum, 2008), and these deficits have previously been associated with the social impairments observed in this population (Kornreich et al., 2002; Maurage, Campanella, Philippot, Martin & Timary, 2008). Research has also revealed deficits in decision-making tasks, due in part to deficits in engaging with, and regulation of, emotional signals related to the negative consequences of potential decisions, including risky (Fernández-Serrano, Pérez-García, Schmidt Río-Valle & Verdejo-García, 2010; Park et al., 2010), and social decision-making (Breversa et al., 2013; Carmona-Perera, Reyes del Paso, Pérez-García & Verdejo-García, 2013; Carmona-Perera, Clark, Young, Pérez-García & Verdejo-García, 2014).

Moreover, alcohol-dependent patients exhibit a broad spectrum of emotional and mood disturbances, including depression, apathy, emotional flatness, anxiety and impulse control problems (Bjork, Hommer, Grant & Danube, 2004; Mitchell, Fields, D'Esposito & Boettiger, 2005; Moselhy, Georgiou & Kahn, 2001; Stephens & Duka, 2008). Recent neuropsychogical models of addiction have highlighted the contribution of impulsivity to the control of salient reward-driven responses (Bechara, 2005; Carou, Romero & Luengo, 2017; Goldstein & Volkow, 2002; Verdejo-García, Lawrence & Clark, 2008). Therefore, emotional dysfunction may be associated with impulse control problems in response to salient emotional states (Carou et al., 2017; Kreusch , Vilenne & Quertemont, 2013; Verdejo-García, Rivas-Pérez, Vilar-López & Pérez-García, 2007). Neuroimaging studies consistently show that chronic alcohol use produces specific neurotoxic effects on frontal lobe areas involved in emotional processing and behavioural self-control (Beck et al., 2012; Stephens & Duka, 2008).

In agreement with dysregulation of reward mechanisms (Robinson & Berridge, 2001, 2003), the emotional component of addictive diseases is characterized by enhancement of the emotional value of addictive reinforcers and increased reward thresholds for natural rewards. Accordingly, addicted individuals may find it difficult to replace addictive behaviors with other, naturally rewarding activities. The somatic marker hypothesis of addiction (Verdejo-García & Bechara, 2009) also posits aberrances in the experience of negative emotions to explain deficits in decision-making. Attenuation or absence of autonomic feedback (somatic markers) may also account for the reduced ability to consider natural and emotionally relevant stimuli (Ferguson & Katkin, 1996; Goldstein & Volkow, 2002; Roedema & Simons, 1999).

Although evidence of these phenomena in alcoholic individuals remains to be provided, support for these assumptions arises from behavioural and psychophysiological studies of opioid-addicted individuals (Aguilar de Arcos et al., 2008; Chicharro, Pérez-García & Sanjuán 2011; Gerra et al., 2003; Lubman et al., 2009). These studies provide partial support for abnormal subjective and neuroendocrine responses to natural emotionally stimuli. Psychophysiological studies in opioid addicts have also suggested dysregulation of the emotional response to natural emotional stimuli. For example, Gerra et al. (2003) reported blunted heart rates (HRs) in response to unpleasant stimuli in this population, and Lubman et al. (2009) found reduced electromyographic responses to pleasant stimuli. Similarly, reduced skin conductance (SC) responses to reward have been found in gambling addicts (Lole, Gonsalvez, Blaszczynski & Clarke 2012). However, none of these studies have examined emotional and psychophysiological responsiveness in alcohol-dependent individuals.

Taken together, the above evidence suggests emotional processing deficits in alcoholism, which could be associated with the impulsive alcohol-seeking behaviour seen in this population. However, their emotional reactions to everyday (non-drug-related) motivationally relevant stimuli, and the role that impulsivity plays in those reactions, remains largely unknown. This study aimed to investigate subjective (valence, arousal and dominance) and psychophysiological responses (HR and SC) to positive, unpleasant and neutral pictures in abstinent alcohol-dependent (AD) and healthy control (HC) participants. HR deceleration has been interpreted as an indicator of vigilance and attentional control, both in the occidental (e.g., Barry, 2006; Lacey & Lacey, 1970; Tremayne & Barry, 2001) and Russian traditions (i.e., the orienting reflex; Sokolov, 1963). In passive view paradigms, HR has also been considered as an indicator of the valence dimension of emotion (Lang, 1995), in which HR decreases usually follow negative-valenced high motivational driven pictures (Lang, Greenwald, Bradley & Hamm, 1993; Palomba, Sarlo, Angrilli, Mini & Stegagno, 2000). SC has been used traditionally as a physiological index of arousal (Lang, 1995), since SC tends to increase during arousing emotions and decrease during relaxing ones (Barry et al., 2004). Impulsivity has been associated with emotionally salient problems in drug users (Verdejo-García et al., 2007). In this context, we also assess the relationship between impulsivity levels, alcohol consumption, and emotional responsiveness.

We hypothesized that alcohol-dependent individuals would show deficient emotional responses to natural, emotionally relevant stimuli compared to healthy controls. Considering the reward deregulation and somatic marker hypotheses (Robinson & Berridge, 2003; Verdejo-García & Bechara, 2009), these deficits should be found for both pleasant and unpleasant stimuli. Specifically, we predict the following in alcohol-dependents participants: (i) lower subjective responses, in terms of both valence and arousal ratings; (ii) reduced HR and SC reactivity, reflected in a less pronounced deceleration in HR and lower SC responses to both positive and negative emotionally relevant stimuli; and (iii) a negative association between impulsivity scores and physiological responses, and a positive one between impulsivity scores and alcohol consumption.

Methods

Participants

The sample was composed of 28 alcohol-dependent Caucasian individuals and 31 non-alcoholic healthy controls matched for gender, age, laterality and socioeconomic status, but not for years of education (see Table 1). Sociodemographic data were collected from clinical histories taken by clinical staff, and also verified by the evaluator. Alcohol-dependent individuals were recruited as they started psychosocial treatment at the Addicted Behaviors Unit of Nostra Senyora de Meritxell Hospital (Andorra). Inclusion criteria were meeting DSM-IV criteria for alcohol dependence, and a minimum abstinence duration of 15 days before testing, confirmed by twice-weekly urine analyses (see Table 1 for descriptive data on quantity and duration of drug use). Exclusion criteria included a current diagnosis or history of other psychostimulant abuse/dependence (with the exception of nicotine), co-morbid diagnoses of Axis I or Axis II disorders, history of head injury or neurological disorders, and severe cognitive impairments caused by dementia. Control participants were recruited through word-of-mouth communication among adults living in the same geographical area as the patients. In addition to the above exclusion criteria, controls could not have a current previous diagnosis of substance abuse or dependence, excluding previous or current social drinking (less than 10 units per week) and nicotine.

Instruments

Emotional Stimuli. A set of 30 picture stimuli extracted from the International Affective Picture System (IAPS; Lang, Öhman & Vaitl, 1988) was used. In agreement with Spanish normative ratings (Moltó et al., 2013), we defined three picture categories: (i) Neutral (10 pictures displaying landscapes and household objects), (ii) Pleasant (10 pictures displaying sexual and exciting sports scenes), and (iii) Unpleasant (10 pictures displaying accident-related casualties or mutilations).The codes for the selected pictures were : 4658, 4669, 4670, 4672, 4687, 5621, 8178, 8179, 8186, and 8496 for pleasant; 1525, 3000, 3062, 3068, 3080, 3150, 3250, 9301, 9405, and 9635 for unpleasant; and 7004,

Table 1. *Sociodemographic and alcohol use data of alcohol-dependent and control participants.*

	Alcohol-dependents Mean (SD)	Controls Mean (SD)	t / χ^2	*p*-value
Sociodemographic variables				
Age	52.53 (5.79)	48.65 (10.89)	-1.69	0.097
Gender	31(Male)	28 (Male)		
Laterality	29 (Right) / 2 (Left)	26 (Right) / 2 (Left)	0.01	0.916
Years of education	13.71 (2.09)	17.22 (2.86)	5.34	‹0.001
Socioeconomic level	8 (L) / 17 (M) / 3 (H)	5 (L) / 21 (M) / 5 (H)	1.47	0.481
Alcohol use variables				
Abstinence alcohol (month)	2.42 (14.02)			
Quantity alcohol per month (SDU)	562.70 (419.02)	21.47 (13.09)	-7.20	‹0.001
Duration alcohol consumption (years)	27.63 (8.19)	21.20 (9.69)	-2.70	0.009
Total alcohol consumption (SDU)	197692 (168924)	5203 (4507)	-6.35	‹0.001

Note. Total alcohol consumption (lifetime amount) is the product of mean amount × duration; SD: standard deviation; L: low; M: middle; H: high; SDU: standard drinking units.

7009, 7041, 7175, 7185, 7187, 7224, 7233, 7705 and 7950 for neutral. Participants rated their emotional experience according to valence (from 1 –unpleasant– to 9 –pleasant–), arousal (from 1 –relaxed– to 9 –aroused–), and dominance (from 1 –dominant– to 9 –dominated–) through the Self-Assessment Manikin (SAM; Bradley & Lang, 1994). E-Prime software (Psychological Tools, USA) was used to control the timing and presentation of stimuli and to collect the subjective ratings.

S*elf-reported measures.* In addition to the SAM, participants completed the following instruments: (i) Structured Clinical Interview for DSM-IV (SCID-I; First, 2007); (ii) Interview for Research on Addictive Behavior (IRAB; Verdejo-García, López-Torrecillas, Aguilar de Arcos & Pérez-García, 2005); (iii) Millon Clinical Multiaxial Inventory III (MCMI-III; Millon & Davis, 1997); (iv) Symptom Check List, Revised (SCL-90-R; Derogatis, 1977); (v) Mini Mental State Examination (MMSE; Folstein, Folstein & McHugh, 1975); and (vi) Barratt Impulsiveness Scale (BIS-11; Patton, Stanford & Barratt, 1995). The first five instruments were used to assess the degree of compliance with the inclusion/exclusion criteria. The BIS-11,used as a measure of impulsive traits, consists of 30 items assessing manifestations of impulsivity, which participants were asked to rate in terms of frequency: never or rarely; occasionally; often; or always or almost always (with scores ranging from 0 to 4). The total impulsivity score, and the three subscale scores (cognitive, motor and non-planning impulsiveness) were collected as dependent measures. The BIS-11 has shown high reliability in assessing risky behaviors (Cronbach's α = .83, Stanford et al., 2009). Finally, total lifetime alcohol consumption was calculated as the product of the mean amount and duration of alcohol use.

Psychophysiological Data Acquisition and Processing

SC and HR were recorded using a Biopac MP150 instrument (Biopac Systems Inc., USA). HR, in beats per minute (bpm), was derived from an electrocardiogram (ECG) recorded at 2000 Hz. ECG electrodes (Ag/AgCl) were attached to the participant's right and left ankles, and to the wrist of the non-dominant hand, based on the Einthoven's II derivation. HR was calculated using AcqKnowledge 3.9.1 software and edited for artifacts (when present) via linear interpolation. SC in micro-Siemens (μS) was recorded at a sampling rate of 30 Hz using Ag–AgCl electrodes filled with an inert 0.05 M NaCl electrolyte cream and attached to the palmar surface of the second and third middle phalanges of each participant's non-dominant hand. In order to extract the response pattern of HR (ΔHR) and SC (ΔSC), we obtained the 0.5 s ×0.5 s values during the 6 s following picture onset (12 values), expressed as differential scores with respect to the mean obtained during the 3 s before picture onset (baseline).

Procedure Processing

Before testing, all participants signed an informed consent form and were initially assessed using the self-reported measures described above. After 5 min of physiological recording at rest (baseline), participants viewed the set of pictures while physiological data were recorded. The different picture categories (neutral, pleasant and unpleasant) were presented in a counter-balanced order across participants. A white fixation cross appeared 3 s before each picture, which facilitated participants with respect to attending to the screen. Pictures were subsequently displayed for 6 s, followed by a 10 s black screen as an inter-stimulus interval. Participants were instructed to stare at each picture for the entire time it was on screen. After we removed the electrodes, participants observed the pictures again in order to rate them using a computerized version of the SAM, with no time limit applied. The study was approved by the Ethics Committee for Research in Humans of the University of Granada and the Ethics Committee for Clinical Research of Nostra Senyora de Meritxell Hospital.

Statistical Analyses

The two groups differed in years of education (see Table 1), and therefore this variable was included as a covariate in the analysis of self-reported measures. Group differences in impulsivity were tested using univariate ANCOVAs. Subjective ratings of valence, arousal and dominance were analyzed using 2 (Group: alcohol-dependents and healthy controls) × 3 (Picture Category: neutral, pleasant and unpleasant) mixed-design ANCOVAs. Tonic physiological measures (mean baseline during the 5 min rest period) were analyzed using independent t-tests. Groups differed in SC [alcohol dependents 5.16±2.57 μS; controls 3.72±1.96 μS; $t = -2.34$, $p = .024$], and HR [alcohol dependents 77.45±13.09 bpm; controls 70.15±12.13 bpm; $t = -2.21$, $p = .031$], and therefore these variables were entered as covariates in the respective physiological analyses. ΔSC and ΔHR during picture-viewing were analyzed using 2(3×12) mixed-design ANCOVAs, with a between-subject factor (group) and two repeated-measures factors [Picture Category and Response Pattern (the 12 0.5 ×0.5 s, post-stimuli values)]. The Huynh-Feldt procedure was used to adjust for degrees of freedom in the repeated measures analysis. Results are presented with the original degrees of freedom and corrected p values.

To analyze the effects of alcohol use and impulsivity on emotional experience, stepwise multiple regression analyses were performed. As dependent variables, we included the peak physiological responses during viewing of pictures: SC increases (maximum value - baseline) and HR decreases (minimum value - baseline). The predictor variables were total alcohol consumption and BIS-impulsivity total score. We did not include the three BIS subscale scores, given their high correlation with total impulsivity (cognitive: r = .69; motor: r =.85; non-planning: r = .88; all ps <.001).

Results

Heart Rate

The three-way interaction of Group × Picture Category × Response Pattern [F(22, 1232) = 2.73, p = .024, η^2_p= .046] was significant. Analysis of the Picture Category × Response Pattern interaction within each group showed significant effects for Controls [F(22, 660) = 2.79, p = .032, η^2_p= .085], but not for alcohol-dependents [F(22, 594) = 1.14, p = .343, η^2_p= .040]. In the control group, the HR response was significant both for pleasant [F(11, 330) = 5.29, p = .010, η^2_p= .150] and unpleasant pictures [F(11, 330) = 3.55, p = .021, η^2_p= .106], but not for the neutral category [F(11, 330) = 1.18, p = .317, η^2_p= .038]. In the alcohol-dependent group, the HR response did not reach significance for either picture category. As can be seen in Figure 1 (top), in the control group, pleasant pictures induced an initial HR acceleration up to s 2.5, followed by a pronounced deceleration that was maintained throughout the entire picture presentation [period quadratic trend: F(1,30) = 5.34, p = .028, η^2_p= .151]. The response pattern to unpleasant pictures is best described by a HR deceleration, albeit of lesser magnitude than that associated with the pleasant pictures [with only the lineal trend being significant: F(1,30) = 6.65, p = .015, η^2_p= .181].

Skin Conductance

The Group × Picture Category × Response Pattern interaction yielded was significant [F(22, 1232) = 3.74, p = .039, η^2_p= .051]. The SC response pattern differed as a function of picture category in the control group [Picture Category × Response Pattern: F(22, 660) = 5.33, p = .003, η^2_p= .165] but not in the alcohol-dependent group [F(22, 594) = 2.18, p = .106, η^2_p= .080]. A significant SC response was observed in the control group for the pleasant pictures [F(11, 330) = 3.94, p = .040, η^2_p= .127], but not for the other picture categories. As observed in Figure 1 (bottom), SC increases were seen for pleasant pictures in the control group between s 3 and 6, with the response peaking at 5 s [cubic trends: F(1,30) = 4.32, p = .047, η^2_p= .138]. No significant SC responses were obtained in the alcohol-dependent group.

Subjective ratings of valence, arousal and dominance (SAM)

There were no significant Group × Picture Category interactions in terms of subjective ratings of valence [F(2, 112) = .60, p = .545, η^2_p= .011], arousal [F(2, 112) = 1.20, p = .306, η^2_p= .021], or dominance [F(2, 122) = .04, p = .936, η^2_p= .001]. The main effect of Group were not statistically significant for any dimension (all Fs(1, 56) > 1.65, all ps > .2, all s < .03). The effect of Picture Category was significant for valence [F(2, 112) = 10.20, p< .001, η^2_p= .154], and arousal [F(2, 112) = 3.56, p = .032, η^2_p= .060], but not for dominance [F(2, 112) = 1.61, p = .208, η^2_p= .028]. Both groups showed the expected differences between valence and arousal ratings across the different Picture Categories, and although the difference in dominance was not significant,

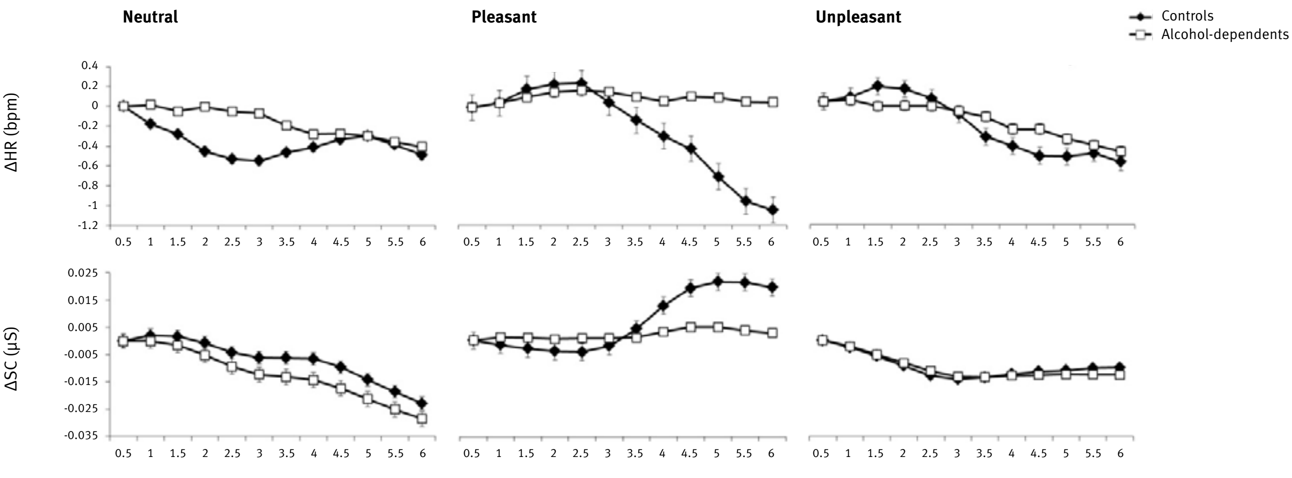

Figure 1. Heart rate (top), and skin conductance (bottom) response during picture viewing as function of Picture Category (Neutral, Pleasant and Unpleasant), and Group (Controls and Alcohol-dependents).

Table 2. *Mean and standard deviations (in brackets) of subjective ratings of valence, arousal, and dominance evoked by the three Picture Categories for alcohol-dependent and controls participants.*

Subjective ratings	**Alcohol dependents**			**Controls**		
	Neutral	Pleasant	Unpleasant	Neutral	Pleasant	Unpleasant
Valence	5.50 (.61)*	7.24 (1.29)*	1.97 (.54)*	5.75(.93)*	7.54 (1.05)*	1.86 (.60)*
Arousal	4.53 (1.05)*	5.93 (1.66)*	7.45 (.93)*	3.74 (1.43)*	5.72 (1.86)*	7.52 (.81)*
Dominance	8.48 (.98)	7.66 (1.76)	5.79 (2.60)	8.51 (.84)	7.63 (1.19)	5.95 (2.25)

Note. * Significant differences between Picture Categories (p-value ‹ 0.05).

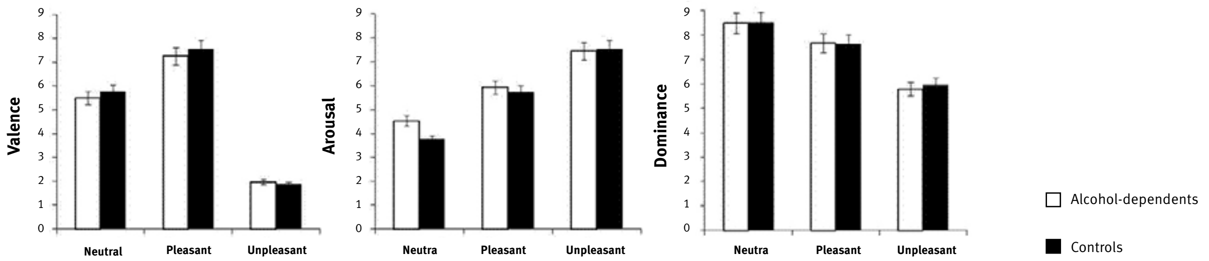

Figure 2. Subjective ratings of valence, arousal, and dominance to pleasant, unpleasant and neutral pictures in alcohol-dependent and control participants. Bars are standard error of the mean.

in agreement with normative data (Moltó et al., 2013), the unpleasant pictures yielded lower dominance scores than all other conditions (see Table 2 and Figure 2).

Impulsive personality traits (BIS-11)

Alcohol-dependent participants showed higher levels of total impulsivity [$F(2, 56) = 21.26$, $p < .001$, $\eta^2_p = .432$], as well as impulsivity on the three impulsivity subscales [Cognitive: $F(2,56) = 6.38$, $p = .003$, $\eta^2_p = .186$; Motor: $F(2, 56) = 20.51$, $p <$ .001, $\eta^2_p = .423$; and Non-planning $F(2, 56) = 9.62$, $p < .001$, $\eta^2_p = .256$] than the controls participants. In the overall sample, total impulsivity was positively associated with total alcohol consumption ($r = .63$, $p < .001$). Total impulsivity was also positively correlated with total alcohol consumption in alcohol-dependents ($r = .44$, $p < .022$), but not in controls ($r = -.05$, $p < .805$).

Impact of impulsivity and alcohol use on physiological responses

Total impulsivity predicted SC increases in the overall sample during presentation of pleasant [F(1, 57 = 4.90, p= .031] and unpleasant pictures [$F(1, 57) = 6.66$, p= .012], while alcohol consumption did not contribute to the prediction models. Total impulsivity was inversely associated with SC increases during presentation of pleasant (β = -.281) and unpleasant pictures (β = -.323), explaining 6.3% (R2 adjusted) of the total variance for pleasant, and 8.9% for unpleasant, pictures. Regression analyses during presentation of pleasant pictures, for the two groups separately, showed that total impulsivity was a significant predictor only for alcohol-dependents [$F(1, 26) = 8.13$, p= .008] and not for controls. In the alcohol-dependent group, total impulsivity was inversely related to SC increases during presentation of pleasant pictures (β = -.488), explaining 20.9% of the variance in SC responses (See Table 3). In a hierarchical regression analysis, in which total alcohol consumption was included in block 1 and total impulsivity in block 2, the effect of impulsivity on SC increases during presentation of pleasant pictures remained significant [$F(2,25) = 4.26$, $\beta = -.424$, p = .026]. For unpleasant pictures, total impulsivity was marginally associated with SC increases in alcohol-dependents [$F(1,26) = 2.99$, $\beta = -.321$, p = .096] and control participants [$F(1,29) = 3.99$, $\beta = -.348$, p = .055]. Alcohol consumption was not a significant predictor in any of these models. No significant regression models were found for prediction of the HR responses.

Table 3. *Significant results of step-wise multiple regression analysis for prediction of skin conductance responses by total scores in the Barratt Impulsiveness Scale.*

Dependent Variable	β	r^2	F	p
Pleasant (total sample)	-.28	.06	4.90	.031
Unpleasant (total sample)	-.32	.09	6.66	.012
Pleasant (alcohol dependent)	-.49	.21	8.13	.008
Unpleasant (alcohol dependent)	-.32	.10	2.99	.096

Note. Adjusted r^2 and standardized β values are indicated.

Discussion

This study aimed to investigate psychophysiological and subjective responses to everyday (non-drug related) emotionally relevant stimuli in alcohol-dependent individuals, and to determine their associations with impulsivity and level of alcohol consumption. Regarding the first aim, although no group differences were observed in subjective ratings of emotional pictures, the findings showed a reduced HR and SC reactivity in alcohol-dependent individuals in comparison with controls participants. The alcohol-dependent group did not exhibit HR deceleration to both positive and negative emotional pictures, or the SC increase to positive emotional pictures seen in the control group. These results suggest a blunted physiological response to both positive and negative everyday emotional stimuli in alcohol-dependent individuals.

The absence of SC and HR responses to positive pictures is in agreement with the postulated deregulation of reward mechanisms in addiction (Robinson & Berridge, 2001, 2003). SC and HR reactivity would be attenuated by the preponderance of alcohol in the reward system, which would replace the motivational value of the natural reinforcers shown in the pictures (Robinson &Berridge, 2001, 2003). Increases in SC are associated with the experience of arousing emotions (Barry et al., 2004, 2006; Lang & Davis, 2006). The absence of an identifiable SC response to positive stimuli in alcohol-dependents could be explained by the strengthened salience of drug stimuli in their motivational systems, coupled with a decreased relevance of natural reinforcers (Robinson & Berridge, 2001, 2003; Verdejo-García, Bechara, Recknor & Perez-Garcia, 2006). These findings are consistent with the results of studies of opiate addicts (Aguilar de Arcos et al., 2008) and addict-gamblers (Lole et al., 2012), which demonstrate blunted arousal (reduced SC) responses to natural reinforcers. The absence of HR deceleration in response to positive pictures in alcohol dependent participants may also be interpreted as an indicator of poor motivational salience, showing reduced attention to natural (non-drug-related) reinforcers (Robinson & Berridge, 2001, 2003; Verdejo-García et al. 2006).

The absence of an HR response to negative pictures in alcohol-dependents, as observed in control participants, is in accordance with the somatic marker hypothesis of addiction (Verdejo-García & Bechara, 2009). This hypothesis maintains that alcohol-dependents would show difficulties in generating physiologically associated aversive emotional signals (Verdejo-García & Bechara, 2009), which may lead to a poor HR response to negative pictures. Passive viewing of negative emotional pictures is generally associated with HR deceleration (Danko, Gracheva, Boytsova & Solovjeva, 2011; Lang et al., 1993; Palomba et al., 2000). The absence of an HR decrease in response to negative stimuli in alcohol-dependents is in accordance with studies that found blunted HR reactivity to negative emotional stimuli, including unpleasant pictures (Gerra et al., 2003), and to negative consequences of moral violations (Carmona-Perera et al., 2013).

Therefore, the absence of HR deceleration in alcohol-dependents could reflect both defective engagement with negatively valenced emotions during the viewing of negative pictures, and lower motivational-salience of natural reinforcers during the viewing of positive pictures. These results are consistent with studies about attentional biases towards affective stimuli in addiction; these studies showed enhanced attentional capture by addiction-related cues, and a decreased motivational salience of positive everyday stimuli, in addicted subjects, including gamblers (Hudson, Jacques & Stewart, 2013), opiate users (Lubman, Peters, Mogg, Bradley & Deakin, 2000; Robbins & Ehrnan, 2004), and alcoholics (Garfield, Allen, Cheetham, Simmons & Lubman, 2015; Lambe, Hudson & Stewart, 2015).

Decoupling of physiological and subjective responses was observed in the alcohol-dependents in this study, with blunted autonomic responses and normal subjective reports regarding emotional stimuli. Previous studies on addicted individuals exposed to emotional reactivity paradigms also reported this dissociation between physiological reactivity and subjective emotional responses (Aguilar de Arcos et al., 2008; Gerra et al., 2003). This decoupling could be interpreted in the context of alterations in interoceptive sensitivity in alcoholism and other drug-taking behaviors, given that the stimulating effects of drugs on the autonomic nervous system could result in altered perceptions regarding bodily states (Naqvi & Bechara, 2010; Paulus, Feinstein, Simmons & Stein, 2004; Verdejo-García, Clark & Dunn, 2012). Specifically, alcohol users have shown reduced perception of bodily signals, as measured by heart beat-tracking tasks (Schmidt, Eulenbruch, Langer & Banger, 2013). These results suggest deficiencies in the generation and perception of physiological correlates of emotions in alcohol-dependents, which may originate from the dominance of drug signals (Dunn et al., 2010; Naqvi & Bechara, 2010; Verdejo-García et al., 2012).

Our second aim was to determine the contribution of impulsivity to emotional responsiveness. Firstly, the alcohol-dependent participants displayed greater levels of impulsivity, and this was observed for the three domains measured by the BIS: cognitive, motor, and non-planning, which is in line with previous studies (Bowden-Jones, Phillips, Rogers, Hutton & Joyce 2005; Körner, Schmidt & Soyka, 2015; Petry, 2001). Impulsivity predicted reduced SC responses to both positive and negative emotional stimuli in alcohol-dependent individuals, but did not predict HR responses. Although total impulsivity in alcohol-dependents was associated with total alcohol consumption, alcohol consumption did not predict SC or HR responses. Furthermore, after controlling for total alcohol consumption, impulsivity remained as a significant predictor of SC increases to pleasant pictures in alcohol-dependents. This result suggests that alcohol consumption is not a relevant factor in mediating the relation between impulsivity and SC responses. Although future work is required to further explore these associations, the results suggest that impulsivity may be a critical factor in explaining the blunted physiological responses to emotional pictures observed in alcohol-dependents, regardless of the total amount of alcohol consumed.

The association found between impulsivity and blunted physiological responses may underline the addiction-related tendency to act rashly during salient positive or negative emotions (Cyders & Smith, 2008). This urgency trait influences attentional processes and may result in decreases in attentiveness to emotional stimuli (Settles, Zapolski & Smith, 2014; Smith & Cyders, 2016). There is clear support for this urgency trait being a predictor of the onset of, and increases in, substance use, including drinking (Cyders et al., 2010; Kaiser, Bonsu, Charnigo, Milich & Lynam, 2016). Our findings are also in line with gambling task-based physiological studies on addiction, which showed that impaired SC responses were related to impulsive behavior and disadvantageous decision-making, characterized by deficits in the prediction of the long-term negative consequences of actions (Bechara & Damasio, 2002; Dom, Wilde, Hulstijn, Brink & Sabbe, 2006; Fein, Klein & Finn, 2004; Fishbein et al., 2005). Taken together, these results extend previous evidence regarding the relationship between impulsive personality variables and alterations in self-control and emotional regulation in substance abusers (Brenner, Beauchaine & Sylvers, 2005; Clark, Cornelius, Kirisci & Tarter, 2005; Carou et al., 2017; Nigg, Hinshaw & Huang-Pollack, 2006; Ohannessian & Hesselbrock, 2007, Verdejo-García et al., 2007), by showing that impulsivity is associated with a blunted physiological response to natural, emotionally salient stimuli in alcohol-dependents.

Our results should be interpreted in the context of certain methodological limitations. Firstly, the groups were not matched by education level. To address this limitation, we included education as a covariate in the analysis of self-reported measures. Secondly, as the study design was cross-sectional, the current data cannot determine causality, which could be addressed in future studies using models of vulnerability to drug use (Verdejo-García & Bechara, 2009). Third, we only administered a self-reported measure of impulsivity and not a performance task, which should be included in future studies. However, subjective impulsivity measures may be more suitable for indexing the social aspect of impulsive behavior, which is not covered by objective neuropsychological measures (Moeller, Barratt, Dougherty, Schmitz & Swann 2001). An additional limitation is the non-measurement of some potential moderators of the link between emotional processing and impulsivity – e.g., personality traits (Muller, Weijers, Boning & Wiesbeck, 2008), or desirability biases towards social and experimental demands (Hess & Kotter-Grühn, 2011; Najström & Jansson, 2006). Future research needs to further elucidate the associations between physiological reactivity to emotional stimuli and impulsivity, and its potential moderator factors.

In summary, reduced HR and SC responses to everyday emotional stimuli could be a prevalent dysfunctional trait in alcohol-dependent individuals. In the case of SC, this blunted response was associated with impulsivity. These results showed autonomic feedback deficits in response to natural, emotionally relevant stimuli in alcoholics, and provide initial proof of the contribution of impulsivity to emotional processing deficits in this population. These findings may have important implications for alcohol-related interventions, which should focus on impulsivity traits and restore the salience of everyday stimuli to potentially improve emotional processing.

Conflict of interests

The authors have no conflicts of interest to declare.

References

Aguilar de Arcos, F., Verdejo-García, A., Ceverino, A., Montañez-Pareja, M., López-Juárez, E., Sánchez-Barrera, M.,…, Pérez-García, M. (2008). Dysregulation of emotional response in current and abstinent heroin users: negative heightening and positive blunting. *Psychopharmacology, 198*, 159-166. doi:10.1007/s00213-008-1110-2.

Allsop, S., Saunders, B. & Phillips, M. (2000). The process of relapse in severely dependent male problem drinkers. *Addiction, 95*, 95-106. doi:10.1046/j.1360-0443.2000.9519510.x.

Barry, R.J. (2006). Promise versus reality in relation to the unitary orienting reflex: a case study examining the role of theory in psychophysiology. *International Journal of Psychophysiology, 62*, 353-366. doi:10.1016/j.ijpsycho.2006.01.004.

Barry, R.J., Clarke, A.R., McCarthy, R., Selikowitz, M., Rushby, J.A. & Ploskova, E. (2004). EEG differences in children as a function of resting-state arousal level. *Clinical Neurophysiology, 115*, 402-408. doi:10.1016/S1388-2457(03)00343-2.

Beck, A., Wustenberg, T., Genauck, A., Wrase, J., Schlagenhauf, F., Smolka, M.N., Mann, K. & Heinz, A. (2012). Effect of Brain Structure, Brain Function, and Brain Connectivity on Relapse in Alcohol-Dependent Patients. *Archives of General Psychiatry, 69*, 842-853. doi:10.1001/archgenpsychiatry.2011.2026.

Bechara, A. (2005). Decision making, impulse control and loss of willpower to resist drugs: a neurocognitive perspective. *Nature Neuroscience, 8*, 1458-1463. doi:10.1038/nn1584.

Bechara, A. & Damasio, A. (2002). Decision-making and addiction (part I): impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologia, 40,* 1675-1689. doi:10.1016/S0028-3932(02)00015-5.

Bjork, J.M., Hommer, D.W., Grant, S.J. & Danube, C. (2004). Impulsivity in abstinent alcohol-dependent patients: relation to control subjects and type 1/type 2 like traits. *Alcohol, 34,* 133-150. doi:10.1016/j.alcohol.2004.06.012.

Bowden-Jones, H., Phillips, M., Rogers, R., Hutton, S. & Joyce, E. (2005). Risk-taking on tests sensitive to ventromedial prefrontal cortex dysfunction predicts early relapse in alcohol dependency: a pilot study. *Journal of Neuropsychiatry & Clinical Neurosciences, 17,* 417-420. doi:10.1176/jnp.17.3.417.

Bradley, M.M. & Lang P.J. (1994). Measuring emotion: the Self-Assessment Manikin and the Semantic Differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25,* 49-59. doi:10.1016/0005-7916(94)90063-9.

Brenner, S.L., Beauchaine, T.P. & Sylvers, P.D. (2005). A comparison of psychophysiological and self-report measures of BAS and BIS activation. *Psychophysiology, 42,* 108-115. doi:10.1111/j.1469-8986.2005.00261.x.

Breversa, D., Noëla, X., Ermerb, E., Dabiria, D., Verbancka, P. & Kornreich, C. (2013). Unfairness sensitivity and social decision-making in individuals with alcohol dependence: A preliminary study. *Drug and Alcohol Dependence, 133,* 772-775. doi.10.1016/j.drugalcdep.2013.08.013.

Carmona-Perera, M., Clark, L., Young, L., Pérez-García, M. & Verdejo-García, A. (2014). Impaired decoding of fear and disgust predicts utilitarian moral judgment in alcohol-dependent individuals. *Alcohol Clinical and Experimental Research, 38,* 179-185. doi:10.1111/acer.12245.

Carmona-Perera, M., Reyes del Paso, G.A., Pérez-García, M. & Verdejo-García, A. (2013). Heart rate correlates of utilitarian moral decision-making in alcoholism. *Drug and Alcohol Dependence, 133,* 413-419. doi:10.1016/j.drugalcdep.2013.06.023.

Carou, M., Romero, E. & Luengo, M.A.(2017). Profiles of drug addicts in relation to personality variables and disorders. *Adicciones, 29,* 113-124. doi:10.20882/adicciones.889.

Chicharro, J., Pérez-García, A.M. & Sanjuán, P. (2011). Emotional responsiveness of substance abusers under outpatient treatment. *Adicciones, 24,* 59-68.

Cyders, M.A. & Smith, G.T. (2008). Emotion-based dispositions to rash action: positive and negative urgency. *Psychological Bulletin, 134,* 807-828. doi:10.1037/a0013341.

Cyders, M.A., Zapolski, T.C.B., Combs, J.L., Settles, R.F., Fillmore, M.T. & Smith, G.T. (2010). Experimental effect of positive urgency on negative outcomes from risktaking and on increased alcohol consumption. *Psychology of Addictive Behaviors, 24,* 367-375.

Clark, D.B., Cornelius, J.R., Kirisci, L. & Tarter, R.E. (2005). Childhood risk categories for adolescent substance involvement: a general liability typology. *Drug and Alcohol Dependence, 77,* 13–21. doi:10.1016/j.drugalcdep.2004.06.008.

Danko, S.G., Gracheva, L.V., Boytsova, Y.A. & Solovjeva, M.L. (2011). Induction of emotional states by reading aloud texts with various emotional valences and changes in the EEG power in the beta and gamma frequency bands. *Human Physiology, 37,* 555-558. doi:10.1134/S0362119711040062.

Derogatis, L.R. (1977). *SCL-90–R: Administration, scoring and procedures Manual I for the revised version of other instruments of the Psychopathology Rating Scale series.* John Hopkins University, Baltimore.

Dom, G., Wilde, B., Hulstijn, W., Brink, W. & Sabbe, B. (2006). Decision-making deficits in alcohol-dependent patients with and without comorbid personality disorder. *Alcohol Clinical and Experimental Research, 30,* 1670-1677. doi:10.1111/j.1530-0277.2006.00202.x.

Dunn, B.D., Stefanovitch, I., Evans, D., Oliver, C., Hawkins, A. & Dalgleish, T. (2010). Can you feel the beat? Interoceptive awareness is an interactive function of anxiety-and depression-specific symptom dimensions. *Behaviour Research and Therapy, 48,* 1133-1138. doi:10.1016/j.brat.2010.07.006.

Fein, G., Klein, L. & Finn, P. (2004). Impairment on a simulated gambling task in long-term abstinent alcoholics. *Alcohol Clinical and Experimental Research, 28,* 1487-1491. doi:10.1097/01.ALC.0000141642.39065.9B.

Fernández-Serrano, M.J., Pérez-García, M., Schmidt Río-Valle, J. & Verdejo-García, A. (2010). Neuropsychological consequences of alcohol and drug abuse on different components of executive functions. *Journal of Psychopharmacology, 24,* 1317-1332. doi:10.1177/0269881109349841.

Ferguson, M.L. & Katkin, E.S. (1996). Visceral perception, anhedonia, and emotion. *Biological Psychology, 42,* 131-145. doi:10.1016/0301-0511(95)05151-1

First, M.B., 2007. Structured Clinical Interview for DSM-IV-TR Axis I Disorders: SCID-I. Biometrics Research Department. New York State Psychiatric Institutute, New York.

Fishbein, D., Hyde, C., Eldreth, D., London, E.D., Matochik, J., Ernst, M.,…Kimes, A. (2005). Cognitive performance and autonomic reactivity in abstinent drug abusers and nonusers. *Experimental and Clinical Psychopharmacology, 13,* 25-40. doi:10.1037/1064-1297.13.1.25.

Foisy, M.L., Kornreich, C., Fobe, A., D'Hondt, L., Pelc, I., Hanak, C., Verbanck, P. & Philippot, P. (2007). Impaired emotional facial expression recognition in alcohol dependence: do these deficits persist with midterm abstinence? *Alcohol Clinical and Experimental Research, 31,* 404-410. doi:10.1111/j.1530-0277.2006.00321.x.

Folstein, M.F., Folstein, S.E. & McHugh, P.R. (1975). Mini-Mental State: a practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12,* 189-98.

Garfield, J.B., Allen, N.B., Cheetham, A., Simmons, J.G. & Lubman, D.I. (2015). Attention to pleasant stimuli in early adolescence predicts alcohol-related problems in mid-adolescence. *Biological Psychology, 108*, 43-50. doi:10.1016/j.biopsycho.2015.03.014.

Gerra, G., Baldaro, B., Zaimovic, A., Moi, G., Bussandri, M., Raggi, M.A. & Bambrilla, F. (2003). Neuroendocrine responses to experimentally induced emotions among abstinent opioid-dependent subjects. *Drug and Alcohol Dependence, 71*, 25-35. doi:10.1016/S0376-8716(03)00065-6.

Goldstein, R.Z. & Volkow, N.D. (2002). Drug addiction and its underlying neurobiological basis: neuroimaging evidence for the involvement of the frontal cortex. *American Journal of Psychiatry, 159*, 1642-1652. doi:10.1176/appi.ajp.159.10.1642.

Handelsman, L., Stein, J.A., Bernstein, D.P., Oppenheim, S.E., Rosenblum, A. & Magura, S. (2000). A latent variable analysis of coexisting emotional deficits in substance abusers: alexithymia, hostility, and PTSD. *Addictive Behaviors, 25*, 423-428. doi:10.1016/S0306-4603(99)00010-6.

Hess, T. M. & Kotter-Grühn, D. (2011). Social knowledge and goal- based influences on social information processing in adulthood. *Psychology and Aging, 26*, 792-802. doi:10.1037/a0023775.

Hudson, A., Jacques, S. & Stewart, S.H. (2013). Selective attention to emotional pictures as a function of gambling motives in problem and non-problem gamblers. *Psychology of Addictive Behaviors, 27*, 1079-1091. doi: 10.1037/a0031863.

Kaiser, A., Bonsu, J.A., Charnigo, R.J., Milich, R. & Lynam, D.R. (2016). Impulsive Personality and Alcohol Use: Bidirectional Relations over One Year. *Journal of Studies on Alcohol and Drugs, 77*, 473-482. doi:10.15288/jsad.2016.77.473.

Körner, N., Schmidt, P. & Soyka, M. (2015). Decision making and impulsiveness in abstinent alcohol-dependent people and healthy individuals: a neuropsychological examination. *Substance Abuse Treatment, Prevention, and Policy, 10*, 24. doi: 10.1186/s13011-015-0020-7.

Kornreich, C., Philippot, P., Foisy, M.L., Blairy, S., Raynaud, E., Dan,…Verbanck, P. (2002). Impaired emotional facial expression recognition is associated with interpersonal problems in alcoholism. *Alcohol and Alcoholism, 37*, 394-400.

Kreusch, F., Vilenne, A. & Quertemont, E. (2013). Response inhibition toward alcohol-related cues using an alcohol go/no-go task in problem and non-problem drinkers. *Addictive Behaviors, 38*, 2520-2528. doi:10.1016/j.addbeh.2013.04.007.

Lacey, J.I. & Lacey, B.C. (1970). Some autonomic-central nervous system interrelationships. In: Black, P. (Ed.), *Physiological Correlates of Emotion.* Academic Press, New York, pp. 205-227.

Lambe, L., Hudson, A. & Stewart, S.H. (2015). Drinking motives and attentional bias to affective stimuli in problem and non-problem drinkers. *Psychology of Addictive Behaviors, 29*, 312-316. doi:10.1037/adb0000021.

Lang, P.J., Öhman, A. & Vaitl, D. (1988). *The International Affective Picture System [Photographic Slides]*. Gainesville, FL: University of Florida, Center for Research in Psychophysiology.

Lang, P.J., Greenwald, M.K., Bradley, M.M. & Hamm, A.O. (1993). Looking at pictures: affective, facial, visceral, and behavioral reactions. *Psychophysiology, 30*, 261-273. doi:10.1111/j.1469-8986.1993.tb03352.x.

Lang, P.J. (1995). The emotion probe: Studies of motivation and attention. *American Psychologist, 50*, 372-385. doi:10.1037/0003-066X.50.5.372.

Lang, P.J. & Davis, M. (2006). Emotion, motivation, and the brain: Reflex foundations in animal and human research. *Progress in Brain Research, 156*, 3-29. doi:10.1016/S0079-6123(06)56001-7.

Lole, L., Gonsalvez, C.J., Blaszczynski, A. & Clarke, A.R. (2012). Electrodermal activity reliably captures physiological differences between wins and losses during gambling on electronic machines. *Psychophysiology, 49*, 154-163. doi:10.1111/j.1469-8986.2011.01290.x.

Lubman, D.I., Yücel, M., Kettle, J.W., Scaffidi, A., Mackenzie, T., Simmons, J.G. & Allen, N.B. (2009). Responsiveness to drug cues and natural rewards in opiate addiction: associations with later heroin use. *Archives of General Psychiatry, 66*, 205-212. doi:10.1001/archgenpsychiatry.2008.522.

Lubman, D.I., Peters, L.A., Mogg, K., Bradley, B.P. & Deakin, J.F. (2000). Attentional bias for drug cues in opiate dependence. *Psychological Medicine, 30*, 169-175. doi:10.1017/S0033291799001269.

Maurage, P., Campanella, S., Philippot, P., Martin, S. & Timary, P. (2008). Face processing in chronic alcoholism: a specific deficit for emotional features. *Alcohol Clinical and Experimental Research, 32*, 600-606. doi:10.1111/j.1530-0277.2007.00611.x.

Mitchell, J.M., Fields, H.L., D'Esposito, M. & Boettiger, C.A. (2005). Impulsive responding in alcoholics. *Alcohol Clinical and Experimental Research, 29*, 2158-2169. doi:10.1097/01.alc.0000191755.63639.4a.

Millon, T. & Davis, R.D. (1997). The MCMI-III: present and future directions. *Journal of Personality Assessment, 68*, 69-85. doi:10.1207/s15327752jpa6801_6.

Moeller, F.G., Barratt, E.S., Dougherty, D.M., Schmitz, J.M. & Swann, A.C. (2001). Psychiatric aspects of impulsivity. *American Journal of Psychiatry, 2158*, 1783-1793. doi:10.1176/appi.ajp.158.11.1783.

Moltó, J., Segarra, P., López, R., Esteller, A., Fonfría, A., Pastor, M.C. & Poy, R. (2013). Spanish adaptation of the "International Affective Picture System" (IAPS). Third part. *Anals of Psicology, 29*, 965-984.

Moselhy, H.F., Georgiou, G. & Kahn, A. (2001). Frontal lobe changes in alcoholism: A review of the literature. *Alcohol and Alcoholism, 36*, 357-368. doi:10.1093/alcalc/36.5.357.

Muller, S.E., Weijers, H.G., Boning, J. & Wiesbeck, G.A. (2008). Personality traits predict treatment outcome in alcohol-dependent patients. *Neuropsychobiology, 57,* 159-164. doi:10.1159/000147469.

Najström, M. & Jansson, B. (2006). Unconscious responses to threatening pictures: interactive effect of trait anxiety and social desirability on skin conductance responses. *Cognitive Behaviour Therapy, 35*, 11-18. doi:10.1080/16506070510011566.

Naqvi, N.H. & Bechara, A. (2010). The insula and drug addiction: an interoceptive view of pleasure, urges, and decision-making. *Brain, Structure & Function, 214*, 435-450. doi:10.1007/s00429-010-0268-7.

Nigg, J.T., Hinshaw, S.P. & Huang-Pollack, C. (2006). Disorders of attention and impulse regulation. In: Cicchetti, D., Cohen, D. (Ed.), *Developmental psychopathology* (pp. 358-403). New York: Wiley. doi:10.1002/9780470939406.ch9.

Ohannessian, C.M. & Hesselbrock, V.M. (2007). Do Personality Characteristics and Risk Taking Mediate the Relationship Between Paternal Substance Dependence and Adolescent Substance Use? *Addictive Behaviors, 32*, 1852-1862. doi:10.1016/j.addbeh.2006.12.017.

Palomba, D., Sarlo, M., Angrilli, A., Mini, A. & Stegagno, L. (2000). Cardiac responses associated with affective processing of unpleasant film stimuli. *International Journal of Psychophysiology, 36*, 45-57. doi:10.1016/S0167-8760(99)00099-9.

Park, S.Q., Kahnt, T., Beck, A., Cohen, M.X., Dolan, R.J., Wrase, J. & Heinz, A. (2010). Prefrontal cortex fails to learn from reward prediction errors in alcohol dependence. *Journal of Neuroscience, 30*, 7749-7753. doi:10.1523/JNEUROSCI.5587-09.2010.

Patton, J.H., Stanford, M.S. & Barratt, E.S. (1995). Factor structure of the Barratt impulsiveness scale. *Journal of Clinical Psychology, 51*, 768-774. doi.10.1002/1097-4679(199511)51:6%3C768.

Paulus, M.P., Feinstein, J.S., Simmons, A. & Stein, M.B. (2004). Anterior cingulate activation in high trait anxious subjects is related to altered error processing during decision making. *Biological Psychiatry, 55*, 1179-1187. doi:10.1016/j.biopsych.2004.02.023.

Petry, N.M. (2001). Delay discounting of money and alcohol in actively using alcoholics, currently abstinent alcoholics, and controls. *Psychopharmacology, 154,* 243-250. doi:10.1007/s002130000638.

Roedema, T.M. & Simons, R.F. (1999). Emotion processing deficit in alexithymia. *Psychophysiology, 36*, 379-387. doi:10.1017/S0048577299980290.

Robbins, S.J. & Ehrman, R.N. (2004). The role of attentional bias in substance abuse. *Behavioral and Cognitive Neuroscience Reviews, 3*, 243-260. doi:10.1177/1534582305275423.

Robinson, T.E. & Berridge, K.C. (2001). Incentive-sensitization and addiction. *Addiction, 96*, 103-114.

Robinson, T.E & Berridge, K.C. (2003). Addiction. *Annual Review of Psychology, 54*, 25-53. doi:10.1046/j.1360-0443.2001.9611038.x.

Settles, R.E., Zapolski, T.C.B. & Smith, G.T. (2014). Longitudinal test of a developmental model of the transition to early drinking. *Journal of Abnormal Psychology, 123*, 141-151. doi:10.1037/a0035670.

Schmidt, A.F., Eulenbruch, T., Langer, C. & Banger, M. (2013). Interoceptive Awareness, Tension Reduction Expectancies and Self-Reported Drinking Behavior. *Alcohol and Alcoholism, 48*, 472-477. doi:10.1093/alcalc/agt024.

Smith, G.T. & Cyders, M.A. (2016). Integrating affect and impulsivity: The role of positive and negative urgency in substance use risk. *Drug and Alcohol Dependence, 163*, 3-12. doi:10.1016/j.drugalcdep.2015.08.038.

Sokolov, E.N. (1963). Higher Nervous Functions: The Orienting Reflex. *Annual Review of Psychology, 25*, 545-580.

Stanford, M.S., Mathias, C.W., Dougherty, D.M., Lake, S.L., Anderson, N.E. & Patton, J.H. (2009). Fifty years of the Barratt Impulsiveness Scale: An update and review. *Personality and Individual Differences, 47*, 385-395. doi:10.1016/j.paid.2009.04.008.

Stephens, D.N. & Duka, T. (2008). Cognitive and emotional consequences of binge drinking: role of amygdala and prefrontal cortex. *Philosophical Transactions of the Royal Society, 363*, 3169-3179. doi:10.1098/rstb.2008.0097.

Tremayne, P. & Barry, R.J. (2001). Elite pistol shooters: physiological patterning of best vs. worst shots. *International Journal of Psychophysiology, 41,* 19-29. doi:10.1016/S0167-8760(00)00175-6.

Uekermann ,J. & Daum, I. (2008). Social cognition in alcoholism: a link to prefrontal cortex dysfunction? *Addiction, 103,* 726-735. doi:10.1111/j.1360-0443.2008.02157.x.

Verdejo-García, A., López-Torrecillas, Aguilar de Arcos, F. & Pérez-García, M. (2005). Differential effects of MPMA, cocaine, and cannabis use severity on distinctive components of the executive functions in polysubstance users: a multiple regression analysis. *Addictive Behaviors, 30*, 89-101.

Verdejo-García, A., Bechara, A., Recknor, E.C. & Perez-Garcia, M. (2006). Executive dysfunction in substance dependent individuals during drug use and abstinence: an examination of the behavioral, cognitive, and emotional correlates of addiction. *Journal of the International Neuropsychological Society, 12*, 405-415.

Verdejo-García, A., Rivas-Pérez, C., Vilar-López, R. & Pérez-García, M. (2007). Strategic self-regulation, decision-making and emotion processing in poly-substance abusers in their first year of abstinence. *Drug and Alcohol Dependence, 86*, 139-146.

Verdejo-García, A., Lawrence, A.J. & Clark, L. (2008). Impulsivity as a vulnerability marker for substance-use disorders: review of findings from high-risk research, problem gamblers and genetic association studies. *Neuroscience & Biobehavioral Reviews, 32*, 777-810. doi:10.1016/j.drugalcdep.2006.05.024.

Verdejo-García, A. & Bechara, A. (2009). A somatic marker theory of addiction. *Neuropharmacology, 56*, 48-62. doi.10.1016/j.neuropharm.2008.07.035.

Verdejo-Garcia, A., Clark, L. & Dunn, B.D. (2012). The role of interoception in addiction: A critical review. *Neuroscience & Biobehavioral Reviews, 36*, 1857-1869. doi:10.1016/j.neubiorev.2012.05.007.