

Interoceptive Awareness, Tension Reduction Expectancies and Self-Reported Drinking Behavior

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Please cite as:

Schmidt, A. F., Eulenbruch, T., Langer, C., & Banger, M. (in press). Interoceptive Awareness, Tension Reduction Expectancies and Self-Reported Drinking Behavior. *Alcohol and Alcoholism*.

[doi:10.1093/alcalc/agt024](https://doi.org/10.1093/alcalc/agt024)

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We thank Amanda C. Jones for her assistance in the preparation of this manuscript.

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Abstract

Aims: Recent accounts have suggested the involvement of interoceptive processes in consumption behavior for alcohol and other drugs. However, there is a paucity of empirical support for a direct association with physiologically assessed individual differences in interoceptive awareness. The current research explored this postulated link and examined the interplay with positive outcome expectancies of alcohol consumption. **Method:** Interoceptive awareness (IA) of alcohol dependent adult in- and outpatients was measured with an objective electrocardiogram heart rate tracking task. Tension reduction expectancies (TRE) and drinking compulsions/obsessions were assessed with self-report questionnaires. **Results:** No direct associations of IA with drinking compulsions/obsessions were found. However, IA and TRE interacted as predictors of drinking compulsions and drinking obsessions. **Conclusion:** The results corroborate the suggestion that neglect of bodily feedback might be a maintaining factor of drinking behavior.

Keywords: interoceptive awareness, heartbeat perception, outcome expectancies, drinking compulsions, drinking obsessions

Interoceptive Awareness, Tension Reduction Expectancies and Self-Reported Drinking Behavior

A central question in addiction research concerns the motivational states and processes that drive addicted individuals to continue using drugs even when decided to stay abstinent (Drummond, 2001). Traditionally, this question has been answered by invoking concepts like cravings or urges (e.g., Tracy, 1994). More recently, an involvement of interoceptive processes in appetitive behavior for alcohol and other drugs has been proposed (Gray & Critchley, 2007; Naqvi & Bechara, 2008; Paulus, 2007; Paulus *et al*, 2009). Given that drugs have strong stimulating effects on the autonomic system (e.g., increasing blood pressure and heart rate) resulting in an altered perception of bodily states, researchers have become interested in the idea that awareness of these interoceptive processes may be implicated in the onset and maintenance of addiction (for an overview see Verdejo-Garcia *et al*, in press). The putative association of interoceptive awareness and appetitive drug-related behavior was put to a test in this research.

Interoception is the perception of bodily signals that are involved in maintaining homeostasis (Craig, 2003; 2007). Interoceptive processes influence homeostatic regulation either by controlling physiological reflexes or by engendering subjective feeling states that in turn influence behavior (Cameron, 2001; Dunn *et al*, 2010). Such states have been shown to be generated through an integration of interoceptive signals at various sites along a distinct afferent pathway, notably including the insular cortex (e.g., Critchley *et al*, 2004). Besides providing information about the physiological condition of the body, they may have emotional and/or motivational qualities – as is the case of homeostatic emotions such as hunger or thirst (Craig, 2003; 2007) that have the experiential qualities of appetitive behavior and cognitions.

Interoceptive feeling states have long been proposed to play a role in addiction (Verdejo-Garcia *et al*, in press). Early accounts assumed interoceptive states as reinforcers (Rose, Zinser, Tashkin, Newcomb, & Ertle, 1984) or conditioned stimuli (Baker *et al*, 2004; Rohsenow *et al*, 1994) in conditioned drug-taking behavior. However, more elaborated models of an involvement of interoceptive processes in the motivation to use drugs were only formulated after several studies

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reported reduced addiction-related approach behaviors in human and animal subjects whose insular cortices had been damaged (Naqvi *et al*, 2007) or pharmacologically deactivated (Contreras *et al*, 2007). For example, smokers who had suffered damage to the insular cortex found it significantly easier to quit smoking and also reported less craving for cigarettes than smokers with lesions to other parts of the brain (Naqvi *et al*, 2007). These findings were corroborated by a number of neuroimaging studies that have shown insular cortex activation in association with cue reactivity and self-reported craving (e.g., Kilts *et al*, 2001; Myrick, *et al*, 2004; Tapert *et al*, 2004; Wang *et al*, 1999). This led to the hypothesis that the interoceptive functions of the insula may be involved in the generation of a subjective feeling of craving (Contreras *et al*, 2007; Gray & Critchley, 2007; Naqvi & Bechara, 2008; Paulus, 2007; Paulus *et al*, 2009).

Verdejo-Garcia *et al* (in press) proposed two basic pathways by which disturbed interoception might increase appetitive consumption behavior: 'neglect' vs. amplification of bodily feedback. In the neglect pathway, it is hypothesized that a subgroup of addicted individuals have decreased bodily reactivity and less accurate interoceptive perception. Due to the resulting lack of bodily feedback these individuals are supposed to experience blunted affect and neutral bodily appraisals. Clinically, this becomes manifested in anhedonia, alexithmia or poor insight (Goldstein *et al*, 2009) and insula and medial cortex dysfunction (Naqvi & Bechara, 2010). Thus, for individuals who dispositionally neglect bodily feedback, substance-related appetitive behavior is a function of non-emotional sources such as higher-order habitualized cognitive elaborations (i.e., strong tension reduction beliefs) or central representations of ideal body states associated with reward. Conversely, based on the amplification account, Verdejo-Garcia *et al* (in press) postulated that for a subgroup of substance abusers with strong bodily reactivity and increased interoceptive awareness (IA) intense acute negative affect and a history of negative reinforcement (i.e., decreasing negative affect after substance consumption; Baker *et al*, 2004) lead to increased craving.

Building on the hypothesized pathways of Verdejo-Garcia *et al* (in press), we used the *Elaborated Intrusion Model of Desire* (EI; Kavanagh *et al*, 2005) – a derivative of Schachter and

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Singer's (1962) cognitive appraisal theory of bodily arousal – as a theoretical framework of the relationship between interoceptive awareness (IA) and appetitive alcohol-related behaviors. The EI is a general model of the antecedents of appetitive behavior originally developed for psychoactive substance consumption. According to the EI, appetitive behavior is consequential or correlated to subjective desire. Desires, in turn, are comprised of two kinds of processes: (a) lower level associative processes underlying intrusive thoughts about an appetitive target and (b) higher level reflexive, elaborated processes embellishing these thoughts into complex cognitions.

Lower level associative processes are initiated by internal physiological deficit states and negative affect experience (Kavanagh *et al*, 2005). Such subjective states can be assumed to be generated through IA. For example, the interoceptive sensations experienced upon drug withdrawal are seen to represent a deviation from the addicted individual's homeostatic set-point, i.e., the body state to which the individual has become accustomed through prolonged drug use. This deviation may be experienced as a homeostatic emotion encompassing feelings of tension and anxiety as well as a sense of deprivation (Gray & Critchley, 2007; Paulus *et al*, 2009).

On the higher reflexive level, the subjective experience of desire is accompanied by conscious elaboration of cognitions (i.e., appraisal) that have strong affective connotations, e.g., positive outcome expectancies associated with the consumption of psychoactive substances (Kavanagh *et al*, 2005). Thus, substance-related approach behavior may be embellished as a result of (a) IA of bodily arousal due to withdrawal and negative affect as well as (b) expectations that drug consumption will alleviate this aversive state (i.e., strong tension reduction beliefs). The resulting subjective state of desire strongly preoccupies the individual, interfering with other cognitive activity. Typical substance abuse-related phenomena like ruminating on intentions to consume (i.e, drinking obsessions) and difficulties in maintaining behavioral restraint (i.e., drinking compulsions) are assumed to arise as a consequence (Kavanagh *et al*, 2005.) In summary, the EI holds positive expectations concerning substance consumption as well as IA of aversive internal states to be major elicitors of appetitive behavior and cognitions.

Current Study

As of yet, “there is a remarkable paucity of research employing direct behavioural measures of interoceptive function in addicted groups” (Verdejo-Garcia *et al*, in press, p. 21). Specifically, there is no evidence to support the basic assumption of a direct link between IA and the experience of alcohol-related appetitive behaviors. Although some studies have shown a correlational link between craving and IA (Rose *et al*, 1984; Rohsenow *et al*, 1994; Rose *et al*, 1985), craving in general is regarded as a poor behavioral predictor of actual alcohol-consumption and/or relevant approach behavior (e.g., Tiffany & Conklin, 2000). In addition, despite extensive research on the craving concept, there is still little consensus about its precise nature and numerous differing conceptualisations have been proposed (for an overview see Rosenberg, 2009). Apart from this, past studies have assessed inter-individual differences in attention to interoceptive stimuli with self-report measures (Rohsenow *et al*, 1994) or inferred an absence of interoceptive sensations from anaesthetization (Rose *et al*, 1984; 1985), instead of utilizing direct behavioral performance measures, which are far more proximate to interoceptive processes and therefore more valid operationalizations (Vaitl, 1995).

To overcome the described limitations of past research on the IA-appetitive drinking behavior link, we derived our understanding of alcohol-related appetitive behavior directly from the EI (Kavanagh *et al*, 2005) that describes difficulties in controlling intrusive thoughts as well as the inability to maintain behavioral restraint as typical substance-abuse problem manifestations. As the experience of obsessions (as a cognitive phenomenon) and compulsions (as a behavioral phenomenon) to drink are central facets of alcohol dependence (Anton *et al*, 1996) we based our operationalization of appetitive behavior thereon. In this study the link between IA and self-reported alcohol-related drinking behavior and cognitions was empirically tested utilizing a multi-item measure of self-reported drinking appetite and an objective physiological performance measure of IA.

We specifically wanted to explore whether a direct link exists between the ability to consciously assess subjective interoceptive states (i.e., IA) and the drinking obsessions and compulsions exhibited by alcohol-dependent participants. Additionally, several accounts have postulated the expectation of experiencing immediate positive drug effects on one's own behavior as a precursor of craving experience (e.g., Marlatt, 1985; Niaura, 2000; Tiffany, 1999). In line with this reasoning, it has been shown that drinking-related outcome expectancies are causally related to drinking behavior (Jones *et al*, 2001). As in EI the elaboration of positive outcome expectancies is stressed as a central facet of subjective desire preceding alcohol approach behavior (Kavanagh *et al*, 2005), we hypothesized positive outcome beliefs such as decreasing negative affective states (i.e., tension reduction expectancies; TRE) to be associated with drinking obsessions and compulsions. Furthermore, in line with appraisal-theory we expected tension reduction expectancies to statistically interact with IA as predictors of drinking obsessions and compulsions. However, based on the two basic pathways of how disturbed interoception fuels addictive processes proposed by Verdejo-Garcia *et al* (in press) outlined above, mixed results of the interplay between IA and TRE can be hypothesized: In case of lesser IA (i.e., 'neglect') appetitive behavior is shaped by strong TRE exclusively. Conversely, in case of the amplification account one would postulate that higher IA and TRE potentiate each other. Hence, as theoretical claims come to opposing expectations, we parsimoniously postulated only the moderation effect without specifying a specific directedness of the pattern.

Method

Participants

Adult inpatients from a specialized psychiatric substance abuse treatment unit ($n = 42$) and outpatients from two day-clinic substance abuse treatment centres ($n = 49$) being treated for alcohol dependency (F10.2 according to the International Classification of Diseases and Related Health Problems ICD-10; WHO, 2007) or multiple substance dependency including alcohol (F19.2) were invited to participate in the study. Inclusion criteria were sufficient German language skills to fill in

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the questionnaires, not having a pacemaker, no heavily impaired psychological functioning by withdrawal symptoms or intake of medication, and absence of drug-related cognitive deficiencies, severe comorbid mental, or somatic disorders (as assessed via clinical judgement of the treating psychiatrists). Of 91 patients assessed, two patients had to be excluded following assessment because their electrocardiogram (ECG) recordings were not interpretable. Hence, the final sample consisted of 89 patients, 39 (43.8%) of whom were female. Participants' age averaged 47.4 years ($SD = 8.7$) for women and 47.6 years ($SD = 9.6$) for men, age being independent from gender ($t < 1$). Of the 88 patients on whom data concerning clinical disorder status could be gathered, 35 (39.8%) had been diagnosed with a comorbid depressive disorder (ICD-10 F32 or F33).

Measures

Physiological measures Interoceptive awareness was measured with a slightly modified version of the heart rate tracking task used by Matthias *et al* (2009), determining participants' awareness of their own heartbeat by comparing the number of subjectively perceived heartbeats with an objective heart rate measure. Heartbeat perception is the most extensively researched aspect of IA and has been established as a valid indicator of substantial inter-individual differences (Cameron, 2001; Pollatos *et al*, 2005). Participants were asked to seat themselves in a chair reclined at 45° whilst they were connected to a three-electrode ECG monitor. Participants were instructed to relax, keep breathing normally, and, when given a signal, start counting their heartbeats while the ECG monitor recorded the actual number of heartbeats. They were specifically asked to count interoceptive sensations instead of exteroceptively feeling their pulses. This was done three times for intervals of 25, 10 and 15 seconds. Participants were not informed about the duration of the intervals or their performance in the task until after the experiment. To assess IA, a heartbeat perception score (HBPS) ranging from 0 to 1 was calculated for each participant according to the following equation. It represents the mean objective heartbeat detection accuracy over three differing intervals of time and is standardized according to the base rate of actually recorded heartbeats. This

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ensures that inter-individual differences in heartbeating rates do not add measurement error to the assessment. Higher scores indicate greater IA.

$$\text{Perception score} = \frac{1}{3} \sum \left(1 - \frac{(|\text{recorded heartbeats} - \text{counted heartbeats}|)}{\text{recorded heartbeats}} \right)$$

Self-report measures As the EI (Kavanagh *et al*, 2005) claims intrusive thoughts (obsessions) and difficulties to maintain behavioral restraint (compulsions) as outcomes of subjective desire experience, self-reported appetitive behavior for alcohol was measured with the German version of the Obsessive Compulsive Drinking Scale (OCDS-G; Mann & Ackermann, 2000) comprised of two subscales measuring intrusive, repetitive or obsessive thoughts about drinking (Obsessions; 6 items) and impulses or compulsions to drink alcohol (Compulsions; 8 items). The Obsessions subscale assesses frequencies and controllability of alcohol consumption-related cognitions and ruminations. The Compulsions subscale measures drinking behavior (frequency and quantity) as well as its perceived controllability. Each item asks subjects to rate the extent of a specific aspect of appetitive drinking behavior over the last week on a five-point scale with choices from 0 to 4 (higher values representing greater obsessions/compulsions). Both scales have shown good retest reliability, convergent validity with visual analog scales of craving experience as well as predictive validity regarding the duration of alcohol-dependent patients' abstinence (Mann & Ackermann, 2000).

Expectations to experience tension reduction by consuming alcohol were measured with the Tension Reduction Expectancy subscale of the Comprehensive Alcohol Expectancy Questionnaire (CAEQ; Demmel & Hagen, 2003a). The scale presents subjects with ten possibly tension-reducing effects of drinking alcohol and asks them to rate the probability of these effects. Ratings are given on five-point Likert scales (1 = *not at all* and 5 = *definitely*) resulting in corresponding composite scores. The scale has shown predictive validity regarding the frequency and quantity of alcohol use in a non-clinical sample and differentiated between alcohol-dependent inpatients and non-clinical controls (Demmel & Hagen, 2003b).

Procedure

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The study was conducted at the specific inpatient and outpatient treatment facilities. Time of day varied across participants, however, all assessments took place during the day (no later than 6pm). Assessors were psychology students trained in ECG-assessment by researchers from the Department of Biological Psychology of the University of Bonn. After informed consent was obtained from the participants, they first completed the self-report questionnaires electronically using a laptop computer. Afterwards, participants completed the heart rate tracking task as described above. Ethical approval of the study protocol was granted by the interdisciplinary Ethics Committee of the Institute for Psychology at the University of Bonn.

Results

Reliability. All measures used in the study showed acceptable to good internal consistency ($\alpha \geq .77$; Table 1).

(Insert Table 1)

Bivariate analyses. Interoceptive awareness (HBPS) was unrelated to appetitive drinking behavior (OCDS-G Compulsions, Obsessions) as well as CAEQ Tension Reduction Expectancies (TRE). Since comorbid depression status (Pollatos *et al*, 2005), age and, by some accounts, gender have been found to be confounded with IA (Cameron, 2001), we also computed partial correlations controlling for age and gender (Table 1, below main diagonal). However, the intercorrelation pattern did not change (Table 1) and IA remained unrelated to all dependent variables in this study.

(Insert Table 2)

Multivariate analyses. To test the predicted moderation effects of HBPS and TRE, we conducted two hierarchical multiple regression analyses (Cohen *et al*, 2003). We included gender, age, and comorbid depression status as control variables. As there were no significant gender, age and depression effects and the resulting patterns remained the same, we excluded these control variables from the reported regression analyses for reasons of parsimony (Table 2). Regressing OCDS-G Drinking Obsessions on z-standardized TRE, HBPS, and the crossproduct of both predictors incrementally accounted for a significant amount of variance of the dependent variable. On

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multivariate level TRE but not HBPS was associated with higher levels of self-reported drinking obsessions. Furthermore, the predicted interaction effect was confirmed, as the interaction of TRE and HBPS incrementally predicted drinking obsessions above and beyond the TRE main effect on the dependent variable (Table 2). For participants exhibiting low TRE ($-1 SD$), no link between IA and obsessive drinking cognitions was found (Figure 1, Panel A). In contrast, participants with high ($+1 SD$) tension reduction beliefs exhibited a negative link between IA and self-reported drinking obsessions. Simple slope analyses confirmed this interpretation: IA had no effect for individuals with low tension reduction beliefs, $b = .09$, $SE = .13$, $p > .45$ but a significant negative effect for participants with positive drinking outcome expectations, $b = -.31$, $SE = .12$, $p < .05$.

(Insert Figure 1)

A similar interaction pattern was found when OCDS-G Drinking Compulsions were used as the dependent variable with the same predictors as examined above (Table 2). Gender, age, and depression again did not have any effects and were thus excluded as control variables. As before, only TRE and the interaction with HBPS accounted for a significant amount of criterion variance in a multivariate regression analysis. Interoceptive awareness exhibited no independent main effect on drinking obsessions. Simple slope analyses marginally significantly indicated that only substance abusers with higher ($+1 SD$) tension reduction beliefs showed a negative association between IA and self-reported compulsive drinking, $b = -.22$, $SE = .12$, $p < .08$, whereas the IA slope for participants reporting lower ($-1 SD$) levels of tension reduction expectancies did not significantly differ from zero, $b = .18$, $SE = .13$, $p > .15$ (Figure 1, Panel B).

Discussion

On the level of zero-order correlations we did not find a direct link between inter-individual differences in the ability to accurately perceive interoceptive sensations and self-reported appetitive drinking behavior using an objective physiological performance measure based on heartbeat detection skills (HBPS), representing a more proximate operationalization of interindividual differences in IA than the previously used self-report measures (e.g., Rohsenow *et al*, 1994). To

further elucidate the boundary conditions of the IA-drinking behavior link, we tested for concurrent effects of TRE through alcohol consumption, as these are emphasized by cognitive models to facilitate craving and drinking behavior (e.g. Kavanagh *et al*, 2005; Marlatt, 1985; Niaura, 2000; Tiffany, 1999). The positive associations found for TRE with drinking compulsions and obsessions were statistically independent from IA, thus supporting our hypothesis that habitualized outcome expectancies are directly linked to individuals' drinking behavior. This affirms the often postulated but seldom directly shown link between TRE and craving experience (e.g., Cooney *et al*, 1987; Jones *et al*, 2001). Finally, TRE in this study was a moderator of the association of IA with drinking obsessions and compulsions. Only in the case of high TRE was IA negatively correlated with drinking obsessions and compulsions. This is compatible with the hypothesis that neglect of bodily feedback is one possible pathway of how disturbed interoceptive processes are linked to drinking behavior proposed by Verdejo-Garcia *et al* (in press). This specific subtype of interoceptive disturbance is postulated to exhibit decreased bodily reactivity and poor IA. The resulting poor quality bodily feedback emphasizes non-emotional sources such as habits or expectancies as the primary facilitators of drinking behavior. Clinically, these individuals should profit from therapies aimed to improve their awareness of the body (e.g., biofeedback training, body-focused meditation/mindfulness interventions, or cognitive reappraisal techniques focusing on more functional interpretations of emotional input).

However, as the study design was cross-sectional, no conclusions can be drawn in terms of the temporal order of the described associations. Future research needs to further elucidate the reported associations of IA and TRE with drinking compulsions and obsessions. Hence, it is an important limitation of this study that physiological heart beat tracking tasks can be interpreted either as reflecting superior interoceptive sensitivity, increased bodily reactivity, or greater skills to estimate what is happening in the body (Verdejo-Garcia *et al*, in press). This lack of distinctiveness of the central dependent variable might also account for the zero finding on bivariate level. Hence, for a deeper understanding of interoceptive processes involved in substance abuse it is important to

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disentangle impairments on the level of intensity of bodily signals from their accurate perception as well as from how these are subsequently appraised. This also underscores the need to develop valid self-report measures of IA to further shed light on the interplay of automatic and controlled processes of IA (Mehling *et al*, 2009). Individual differences in the motivation to use drugs may be better understood by considering the interplay of differences in the sensitivity to interoceptive signals and experimentally manipulated bodily feedback signals (Dunn *et al*, 2010) as well as by taking into account habitualized drug-related outcome expectancies. Thus, research on IA is promising to further elucidate basic processes involved in the onset and maintenance of substance abuse behavior.

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Table 1. Means, standard deviations, reliabilities and (partial) correlations between measures.

	<i>M</i>	<i>SD</i>	2.	3.	4.	5.	6.	7.	8.
1. Age	47.49	9.19	-.01	-.17	-.04	-.02	-.12	-.19	-.23
2. Sex ^a	-	-	-	-.05	-.05	-.12	.17	-.00	.06
3. Comorbid depression ^b	-	-	-	-	.04	-.06	.03	-.00	.12
4. Inpatient/Outpatient status ^c	-	-	-	-	-	.10	-.30	-.29	.04
5. HBPS Heartbeat Perception	0.70	0.19	-	-	.14	(.93)	-.11	.01	.08
6. OCDS-G Drinking Obsessions	2.40	0.86	-	-	-.35	-.09	(.88)	.58	.19
7. OCDS-G Drinking Compulsions	3.30	0.87	-	-	-.31	-.00	.58	(.77)	.26
8. CAEQ Tension Reduction Expectancy	3.77	0.70	-	-	.00	.10	.16	.24	(.88)

Note. Bold coefficients $p < .05$; coefficients above the main diagonal represent zero-order correlations between measures, below the diagonal partial correlations controlled for age, sex, and comorbid depression status (Bonferroni-adjusted for multiple comparisons); Cronbach's α in brackets; ^a higher values depict female sex; ^b $N = 88$, higher values depict a comorbid diagnosis of depression (ICD-10 F32, F33); ^c higher values depict inpatient treatment.

Table 2. Summary of Hierarchical Regression Analyses for variables predicting self-reported drinking behavior and craving ($N = 89$).

Variables	OCDS-G Drinking Compulsions		OCDS-G Drinking Obsessions	
	β	$SE \beta$	β	$SE \beta$
Step 1				
Tension Reduction Expectancy (TRE)	.36 ^{***}	.09	.31 ^{**}	.09
Heartbeat Perception (HBPS)	-.02	.09	-.12	.09
Step 2				
TRE	.34 ^{***}	.08	.29 ^{**}	.09
HBPS	-.02	.08	-.11	.09
TRE x HBPS	-.20 [*]	.09	-.20 [*]	.09
<i>Note.</i> *** $p < .001$; ** $p < .01$; * $p < .05$	$R^2 = .17$ for Step 1 ($p < .001$); $\Delta R^2 = .05$ for Step 2 ($p < .05$)		$R^2 = .14$ for Step 1 ($p < .01$); $\Delta R^2 = .05$ for Step 2 ($p < .05$)	

Figure Captions

Figure 1. OCDS-G Drinking Obsessions (Panel A) and OCDS-G Drinking Compulsions (Panel B) as function of interoceptive awareness (HBPS; ± 1 SD) and tension reduction expectancies (TRE; ± 1 SD).

Figure 1

