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Assessing heart rate variability biofeedback as an adjunct to college recovery housing programs

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Abstract

Heart rate variability biofeedback (HRV BFB) shows promise as an adjunct intervention for individuals receiving treatment for substance use disorder (SUD), potentially due to its capacity to reduce craving and negative affect. The present study sought to examine the utility of integrating HRV biofeedback into a college recovery housing program and gauging its ability to reduce craving and negative affect in young adults in remission from SUD. Forty-six residents of an SUD recovery house at a public university in the northeastern United States took part in a non-randomized controlled trial. The active intervention was 12 weeks of HRV BFB performed over a college semester. The control intervention was a semester-long, waitlist condition. Changes in craving, perceived stress, anxiety, and depressive symptoms were measured across time during the active HRV BFB intervention and compared to changes that occurred during the waitlist period using piecewise regression analyses. Significant reductions in craving were noted during HRV BFB, but not during the waitlist control condition; however, the difference in slopes between conditions was not statistically significant. Levels of self-reported craving, stress, anxiety, and depression varied substantially between participants and across time. The results suggest that use of HRV BFB in the college recovery setting as a tool to help reduce craving warrants further examination, particularly among individuals with elevated craving. Added value of HRV BFB comes from the fact that it can be easily and affordably implemented in everyday life.

Keywords

Addiction; Craving; Anxiety; Stress; Mechanism of change

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Declarations of interest

None.

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1. Introduction

Lapses during recovery from substance use disorder (SUD) typically arise in-the-moment from interactions between emotional states, difficulty regulating affect, and cues and stressors that elicit craving and urges to use (Brown, Vik, Patterson, Grant, & Schuckit, 1995; Marlatt, 1996; Shiffman, 2009; Sinha, 2007). These high-risk interactions are potent contributors to lapses and relapse even among individuals in sustained recovery (Cooney, Litt, Morse, Bauer, & Gaupp, 1997; Koob & Le Moal, 1997; Sinha, 2007). The college environment is particularly laden with these high-risk contextual features, with up to half of college students believed to experience marked levels of stress that may contribute to symptoms of anxiety and depression (Regehr, Glancy, & Pitts, 2013). Moreover, substance use is prevalent (Johnston, O'Malley, Bachman, Schulenberg, & Miech, 2015; O'Malley & Johnston, 2002) and considered socially normative in this setting (McAlaney et al., 2015; Sanders, Stogner, Seibert, & Miller, 2014). Alcohol use, in particular, often takes a center stage in the social activities of college students. Thus, a young adult in SUD recovery seeking a college education often grapples with conflicts between advancing their education and insulating themselves from the high-risk college campus environment.

1.1. University-based recovery houses

Several models of university-based recovery programs exist across the United States (Bell et al., 2009; Laudet, Harris, Kimball, Winters, & Moberg, 2014). One compelling model is the university-sponsored 'recovery house', an on-campus living community that offers a substance-free environment, a social network of peers in recovery, extracurricular activities throughout the year, and access to substance use and mental health resources (e.g., counselors, mutual-support meetings) for approximately the same cost of standard on-campus housing. Recovery houses offer a great deal of psychosocial support to residents, but are not SUD treatment programs per se.

1.2. Heart rate variability biofeedback

Heart rate variability biofeedback (HRV BFB; Lehrer, Vaschillo, & Vaschillo, 2000) is a breathing-based intervention that takes advantage of the respiratory sinus arrhythmia that links heart rate with the respiratory cycle and the baroreflex that regulates blood pressure (Benarroch, 2008). When an individual breathes at ~0.1 Hz (equivalent to ~6 breaths per minute), heart rate increases and decreases in phase with respiration, and in doing so normalizes autonomic output. These dynamic changes in heart rate then effect phasic changes in vascular tone and blood pressure via the baroreflex mechanism (Vaschillo, Vaschillo, Buckman, Pandina, & Bates, 2011). HRV BFB has demonstrated utility to reduce negative affect in major depression (Karavidas et al., 2007; Siepmann, Aykac, Unterdorfer, Petrowski, & Mueck-Weymann, 2008) and PTSD (Tan, Dao, Farmer, Sutherland, & Gevirtz, 2011; Zucker, Samuelson, Muench, Greenberg, & Gevirtz, 2009). It also may reduce craving during SUD treatment (Eddie, Kim, Lehrer, Deneke, & Bates, 2014; Penzlin, Siepmann, Illigens, Weidner, & Siepmann, 2015).

Once learned, HRV BFB can be implemented at will using one of several available smartphone applications (apps) or portable HRV BFB devices. Moreover, once trained in

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HRV BFB, individuals can approximate ~0.1 Hz paced breathing using breathing pacer apps or by counting the breath. Thus, it can be easily used by college students in SUD recovery as they navigate the broader college environment. Accordingly, this study taught students in recovery housing HRV BFB, and using a non-randomized controlled trial design with a wait list condition, explored its ability to lower craving, stress, anxiety, and depression.

2. Materials and methods

2.1. Participants

Forty-six female and male residents of a university recovery house were recruited for participation over the course of 7 semesters. To be eligible for recovery housing, students were required to be enrolled in the university, have received an SUD diagnosis from a health care provider, provide evidence of successful completion of an addiction treatment program (typically inpatient or intensive outpatient), and be free of alcohol and other drug use for at least 90 days. Recovery housing students were required to attend a minimum of two mutual-support meetings (e.g., AA, SMART Recovery) meetings per week and have a sponsor. The recovery house accommodated approximately 40 students, with an average of 5 new students joining per semester. Study exclusion criteria were previous HRV BFB training, current cardiovascular problems (e.g., cardiac arrhythmia, hypertension), medications directly influencing heart rate and blood pressure (e.g., alpha- or betablockers), psychotic disorders (e.g., schizophrenia), or serious neurological conditions (e.g., epilepsy). Antidepressant (e.g., SSRIs, bupropion, n = 13) and/or mood stabilizing (e.g., lithium, quetiapine; n = 15) medications were allowed, although participants were asked to not make medication changes mid-study, unless instructed by their doctor. Sample characteristics are presented in Table 1.

Participants were recruited every Spring and Fall semester from Spring 2012 to Spring 2015. Any participants who left the recovery house during the study were invited to remain in the study as long as they continued to be enrolled as students at the university. Eight participants withdrew (1 during the waitlist period and 7 during HRV BFB) due to feeling too busy (n = 6) and leaving the university (n = 2).

2.2. Procedures

This study was a non-randomized controlled trial with a waitlist condition. Both the active (HRV BFB) and control (waitlist) conditions lasted for one semester. The waitlist condition occurred prior to the HRV BFB condition except when volunteers were not able to participate for two semesters due to personal time constraints or upcoming graduation; these participants completed the HRV BFB condition only. In other words, all participants were first assigned to the waitlist condition, when possible. The non-randomized design was selected in collaboration with the recovery housing clinical staff based on their aim to provide all interested residents with access to the active intervention, as well as the small census of the recovery house, and the lack of access to parallel recruitment sites. All study procedures were approved by the university's institutional review board. Participation was voluntary and did not affect students' access to other services provided by the recovery

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house or the university more broadly. Volunteers provided written, informed consent and understood they were free to withdraw from the study at any time without penalty.

The waitlist condition involved the completion of questionnaires four times during the semester; no home practice or experimental sessions occurred. The active HRV BFB condition included 8 experimental sessions over 12 weeks. The first 7 sessions occurred weekly starting at the beginning of the semester. The final session was conducted at the end of the semester (approximately 4 weeks after session 7). Each session included the completion of questionnaires and review of the daily home practice logs followed by an HRV BFB session, as described below.

2.2.1. Heart rate variability biofeedback training—Participants were trained to perform HRV BFB as detailed in Lehrer et al. (2000) and briefly described below. At each HRV BFB session, after completion of questionnaires, dermal electrocardiogram (ECG) electrodes were placed laterally below the deltoid muscles on the right and left arms, as well as in a lateral position above the left ankle, and a respiration belt was placed across the chest to capture thoracic breathing (Thought Technology, Montreal, PQ, Canada).

At Session 1, participants were introduced to an EZ-Air Plus visual breathing pacer (Biofeedback Foundation of Europe, Montreal, PQ, Canada) to guide the pace of inhalation and exhalation. They were asked to breathe along with the pacer set at a 6-breaths per minute rate for 5 min. They then breathed for 2 min at five different breathing frequencies (4.5, 5.0, 5.5, 6.0, & 6.5 breaths per minute) to identify their resonance frequency, which was determined based on optimal physiological responding and subjective comfort. As part of a separate study, a brief N-back memory task was completed at the beginning of this session. At Session 2, participants practiced resonance breathing using a visual pacer (5 min) and were trained to use pursed lips (5 min) and abdominal breathing (5 min). During Session 3, participants were introduced to HRV BFB and instructed to maximize the peak amplitude of heart rate oscillations using the cardiotachometer and respiration rate displays on a computer screen (2 epochs of 5 min). During Sessions 5 and 6, HRV BFB was practiced with a visual pacer (5 min) and the cardiotachometer and respiration rate displays (15 min). Physiology data were recorded during HRV BFB sessions 1, 4, 7, and 8. Each physiology recording session started and ended with a 5-minute low-cognitive-demand task (Vanilla Task; Jennings, Kamarck, Stewart, Eddy, & Johnson, 1992) and included 5 min of breathing using the visual pacer set at the participant's resonance frequency. Sessions 4, 7, and 8 also included 15 min of HRV BFB using their home practice device/app (described below).

2.2.2. Home practice—During HRV BFB Session 3, participants were introduced to a StressEraser HRV BFB device (Heilman, Handelman, Lewis, & Porges, 2008) or Stress Doctor HRV BFB app for smartphone (Azumio Inc., 2012), depending on participants' preferences and access to a smartphone. Participants were instructed to practice breathing at their resonance frequency for two, 15-minute periods each day. Participants could select any time of day to practice, but were asked to split practice sessions between the AM and PM if possible. Frequency and amount of home practice were recorded each week using a brief timeline follow-back interview administered over the phone by research staff.

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2.3. Self-report measures

A demographics survey was completed to measure age, university standing (year in school), self-reported mental and physical health conditions, and smoking status. This survey was completed at the beginning of each semester of participation.

2.3.1. Craving—Craving was measured with a modified version of the Penn Alcohol Craving Scale (PACS-M) at the beginning of every HRV BFB session, and in the waitlist condition, weeks parallel to HRV BFB sessions 1, 4, 7, and 8. The original PACS is a five-item measure that assesses the frequency, intensity, and duration of thoughts about drinking alcohol, as well as perceived ability to resist drinking, and respondents' average past-week craving (Flannery, Volpicelli, & Pettinati, 1999). The questions use descriptors with numerical ratings from 0 to 6. Higher PACS scores represent greater craving. The scale has high internal consistency ($\alpha = 0.92$) and has been validated in clinical samples (Flannery et al., 1999). Due to the high prevalence of previous use of substances other than alcohol in the sample, the PACS was modified to capture both alcohol and drug craving by adding the words "drug" and/or "using drugs" respectively to the words "drink" and/or "drinking". This adapted version of the PACS has been found to have similar internal consistency to the original form, and convergent and discriminant validity (Eddie et al., 2014).

2.3.2. Stress—Stress was measured with the Perceived Stress Scale (PSS) at the beginning of every HRV BFB session and the waitlist weeks parallel to HRV BFB sessions 1, 4, 7, and 8. The PSS is a 10-item measure of past week perceived stress (Cohen, Kamarck, & Mermelstein, 1983). The measure gauges how unpredictable, uncontrollable, and overloaded respondents find their lives. Higher scores indicate greater stress. The PSS is well validated (Cohen, 1988) and has adequate internal consistency (Hewitt, Flett, & Mosher, 1992).

2.3.3. Affective symptoms—Affective symptoms were measured with the Beck Anxiety Inventory (BAI) and Beck Depression Inventory (BDI) at the beginning of HRV BFB sessions 1, 4, 7, and 8 and the corresponding waitlist weeks. The BAI is a 21-item self-report instrument that measures past week symptoms of anxiety using a 4-point Likert-type scale. The BAI has high internal consistency ($\alpha = 0.92$) and a test-retest reliability of 0.73 (Beck, Epstein, Brown, & Steer, 1988). The BDI is a 21-item self-report instrument used to assess depression. Similarly, it uses a 4-point Likert-type scale and has high internal consistency ($\alpha = 0.81$) with test-retest reliability of 0.96 (Beck, Steer, & Carbin, 1988; Sprinkle et al., 2002). Higher scores reflect greater anxiety and depression, respectively. These measures are sensitive to change (Richter, Werner, Heerlein, Kraus, & Sauer, 2000), have high internal (Steer, Ranieri, Beck, & Clark, 1993; Storch, Roberti, & Roth, 2004) and content validity (de Beurs, Wilson, Chambless, Goldstein, & Feske, 1997; Osman, Kopper, Barrios, Gutierrez, & Bagge, 2004), and have been validated in both sexes (Richter et al., 2000).

2.4. Analysis

Data from all participants were included in the final analyses. Piecewise, repeated measures mixed models were used to assess psychological change across time during the waitlist

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control and HRV BFB conditions (Greene, Rolfson, Garellick, Gordon, & Nemes, 2015). Separate models were fitted for each self-reported psychological measure (i.e., PACS-M, PSS, BAI, BDI); change was represented by mixed model regression slopes. Because men and women may systematically differ on psychological measures, sex was included as a covariate. To check for potential effects of medications (e.g., anti-depressants and mood stabilizers) and HRV BFB practice effects, models were re-calculated with medication (yes/no) and a practice index (total number of practice minutes across the semester divided by the total number of days practiced) included as covariates.

3. Results

This sample of students from university-supported, on-campus recovery housing comprised mostly of white males (Table 1), and the majority of students (87%) were emerging adults (i.e., 18–25 years of age). Duration of abstinence at the start of study participation ranged from just over 3 months to over 8–1/2 years. No participant lapsed or relapsed to substance use during study participation. Mean self-reported craving, stress, anxiety, and depression scores at study entry are shown in Table 1. The average scores on these measures were not notably elevated, nor were scores significantly correlated with age or months of abstinence (all $p > .05$).

The results of the piecewise repeated measures mixed models are shown in Table 2. There was a main effect of time on craving (PACS-M) only in the HRV BFB condition, with the negative slope indicating a decrease in craving; however, a comparison of simple slopes between conditions was not statistically significant ($\beta = -0.138$, $SE = 0.132$, $t = -1.040$, $p =$ ns). Significant main effects of time on anxiety (BAI) were observed during both the HRV BFB and the waitlist conditions; the negative slopes indicating reductions in anxiety during both conditions. A control/experimental slope comparison for anxiety scores was not statistically significant, $\beta = 0.385$, $SE = 0.276$, $t = 1.400$, $p =$ ns. There was a main effect of sex wherein female participants reported significantly greater anxiety (BAI $M = 14.8$, $SD = 9.4$) than male participants (BAI $M = 8.0$, $SD = 7.2$), $t(120) = -5.75$, $p < .01$. No main effects were observed in the stress (PSS) and depression (BDI) models.

Participants reported practicing HRV BFB outside of experimental sessions an average of 3.9 days per week ($SD = 2.0$), for an average of 11.5 min per day ($SD = 7.9$). Inclusion of practice and medication as covariates in the mixed models did not change the pattern of results.

Fig. 1 shows means and standard deviations of craving, stress, anxiety and depression scores from each measurement occasion during the waitlist condition and the HRV BFB condition. We observed that the standard deviations (individual differences) of each of the four measures at each measurement occasion were of greater magnitude than changes in the average scores across time in both control and HRV BFB conditions. In light of this observed variability within the sample, individual-level plots were generated and revealed not only substantial heterogeneity across participants, but also within participants across time. Fig. 2 provides spaghetti graph plots showing longitudinal craving data for each participant at each session. The left-hand panels show craving across the semester in which

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participants were assigned to the waitlist condition, and the right-hand panels show craving across the semester in which the participants learned HRV BFB. Plots are grouped by the participant's initial level of craving at the start of each condition. The top panel shows the craving trajectories of individuals who began the study with negligible levels of craving. The middle panel shows individuals who reported modestly higher craving, and the bottom panel shows those who started the study with the highest observed levels of craving in the sample. Qualitatively, HRV BFB appeared to reduce craving among those who started the semester with elevated craving; subgroup sizes were too small to allow statistical comparison.

4. Discussion

The present investigation sought to gauge the utility of integrating HRV BFB into a college recovery housing program. Individuals in SUD recovery in the university environment face unique challenges, including academic stress and heavy substance use among peers (Cleveland, Harris, Baker, Herbert, & Dean, 2007; Laitman & Lederman, 2008; Laudet et al., 2014). Participants in this study already were attending mandatory mutual-support meetings (e.g., AA, SMART Recovery) and receiving intensive, high quality psychosocial support through the recovery housing program from which they were recruited. The supportive programs included individual therapy as needed, psychoeducation seminars, regular house meetings, and frequent alcoholand drug-free social activities such as organized trips and sports. Within this context, we observed significant reductions in craving during the HRV BFB condition. No significant decrease in craving was found in the waitlist condition, although the difference in slopes between conditions was not statistically significant in this modestly powered study.

Two other noteworthy characteristics of the data collected in this study were the substantial variability observed between persons in college recovery, as well as within these persons across time, in levels of craving, as well as stress, anxiety, and depression across the course of two semesters. These observations are important in signaling the need for more highly powered studies to model potential non-linear trends in psychological functioning over time. The spaghetti plots of individual craving trajectories over time (Fig. 2, bottom right panel) suggest the tentative hypothesis that HRV BFB may be most clinically useful for students manifesting elevated levels of craving, even while they are within the supportive context of college recovery housing. Further exploration of for whom, and under what conditions, craving reduces in response to HRV BFB is warranted.

The index of HRV BFB practice examined in this study was not associated with change in craving or negative affect. This finding is consistent with results from previous studies that did not show associations between daily HRV BFB practice and craving reductions (Eddie et al., 2014; Zucker et al., 2009) or BDI scores (Zucker et al., 2009). It is possible that some salutary effects of HRV BFB may not be 'dose dependent' as typically defined. HRV BFB can be used ad lib or when other clinical and social support mechanisms are not available, can be performed using low-cost smartphone apps, and is free of negative side effects. Anecdotally, in the HRV BFB condition, multiple participants mentioned that their home practice was in contexts and situations that they found anxiety-provoking or stressful (e.g., on a crowded university bus, before exams, following interpersonal conflict), which points to

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the likelihood that some participants were utilizing this intervention acutely in challenging and potentially high-risk situations. It is possible too that participants were using the intervention strategically to manage craving in-the-moment. Future studies should attempt to parse out the differential effects of acute versus long-term HRV BFB practice, and assess practice in relation to triggering events, possibly using ecological momentary assessment or other real-world assessment tools that could accurately characterize when and why individuals practice. Current research in our laboratory is attempting to identify for whom HRV BFB is likely to be of most benefit (ClinicalTrials.gov Identifier: NCT02579317).

This study should be considered in light of its limitations. Participants were not randomized into the active or control conditions due to the recovery housing program's goal to maximize positive outcomes for all student residents. A waitlist control was used, but not all individuals in the HRV BFB condition participated as waitlist controls (e.g., due to personal time constraints and graduation). There was limited power to assess interactions between time and condition, but repeated measures mixed modeling was used to reduce bias due to missing data. Although care was taken to record practice data using weekly timeline follow-back interviews, it is possible that some participants under- or over-reported practice. Some variability in psychosocial questionnaire responses may have been related to factors that occur during college semesters (e.g., exams) even though the waitlist and HRV BFB conditions both started at the beginning of a semester and ended prior to final exams. Finally, SUD type and severity, and comorbid psychopathology were not formally assessed. Nonetheless, the present findings parallel those of other small-scale studies (Eddie et al., 2014; Penzlin et al., 2015; Zucker et al., 2009) to indicate the need for larger controlled trials of HRV BFB as a supplementary "tool" for individuals in treatment for, and recovery from SUD.

Multimodal, multi-targeted interventions have gained significant traction in recent years as the limitations of a 'one size fits all' model of addiction treatment and recovery have become apparent. Most current recovery tools focus on cognitive strategies that dampen negative affect and strengthen self-control (i.e., executive capacity and self-efficacy) to reduce the salience of substance use cues and stressors (Hendershot, Witkiewitz, George, & Marlatt, 2011; Marlatt, 1996). The automatic physiological processes that trigger negative emotional states and elicit craving (Bates & Buckman, 2013; Eddie et al., 2013; Thayer & Lane, 2009), however, can undermine, outpace, or disrupt cognitive intentions (Bates & Buckman, 2011; Thayer & Friedman, 2002). This suggests that a combination of physiologically- and cognitively-mediated strategies may be useful for intervening in reactions to triggers that are instigated outside of (or prior to) conscious awareness. As such, HRV BFB may be a useful tool when triggering cues and stressors are encountered unexpectedly in moments and contexts devoid of abstinence-focused professional or social support.

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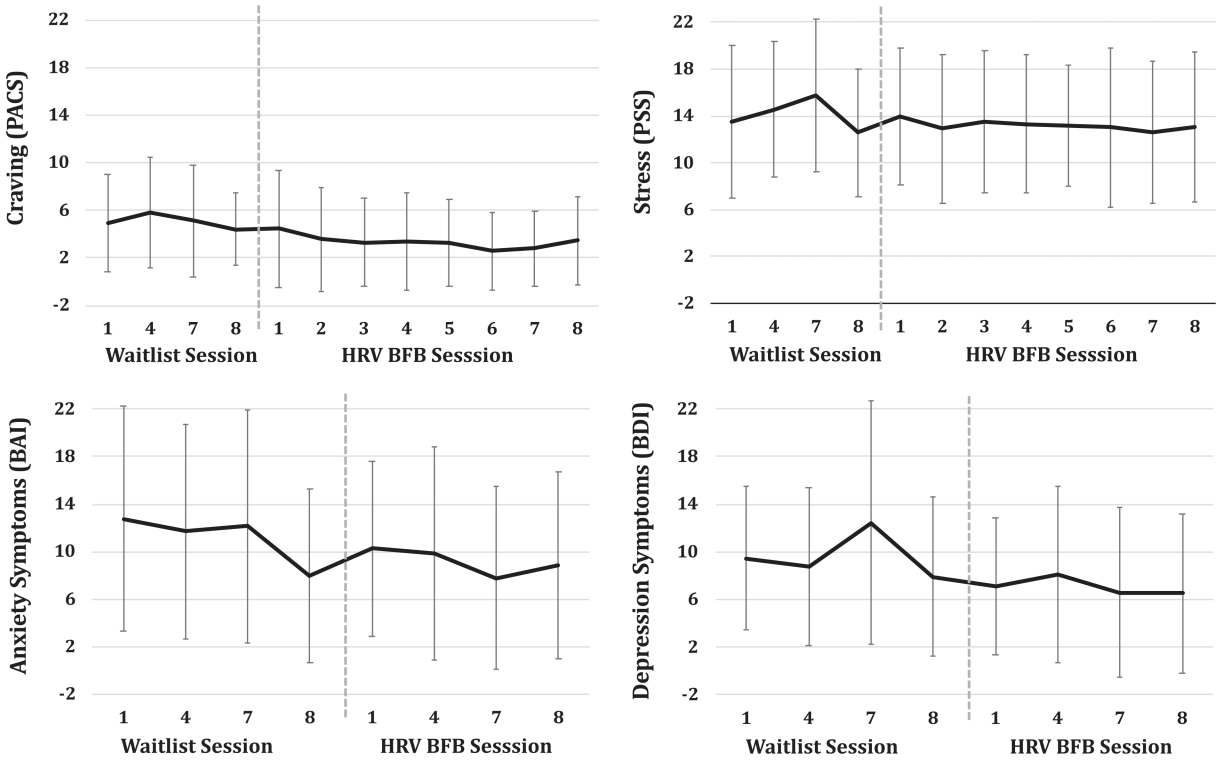

Fig. 1.

Average (± 1 standard deviation) self-reported levels of craving, stress, anxiety and depression in across waitlist control and biofeedback sessions.

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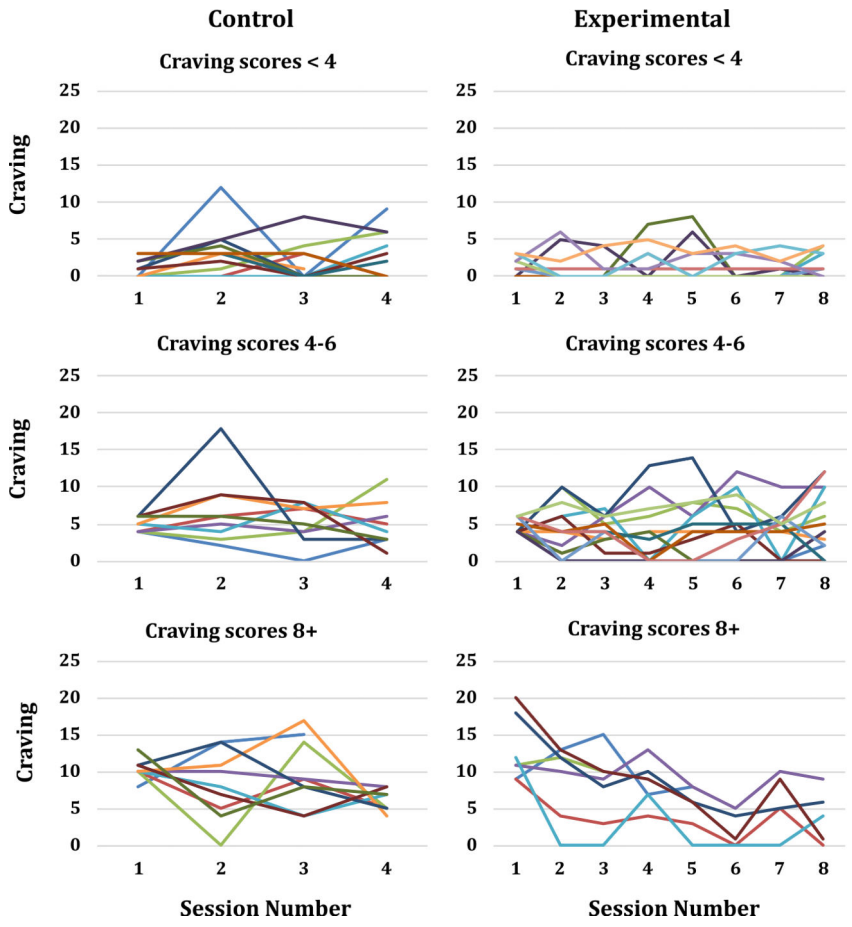

Fig. 2.

Spaghetti graph plots showing longitudinal craving data for each participant at each session during the waitlist control (left) and HRV BFB (right) conditions of the study. Plots are grouped by the participant's initial level of craving at the start of each condition.

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Table 1

Sample characteristics at study entry.

Variable	
Age (years)	23.6 (5.0)[a]
Sex (% female)	28%
Ethnicity (% Hispanic)	11%
Race	
Asian	2%
White/European	91%
Other	7%
Employment	
Full–time	7%
Part–time	44%
University standing	
Freshman	10%
Sophomore	27%
Junior	33%
Senior	20%
Graduate	10%
Years of abstinence	2.5 (1.9)[a]
Perceived Stress (PSS)	13.8 (6.1)[a]
Craving (PACS-M)	5.4 (4.9)[a]
Anxiety Symptoms (BAI)	12.4 (8.8)[a]
Depressive Symptoms (BDI)	8.4 (6.0)[a]

Possible ranges: Perceived Stress Scale (PSS), 0–40; Penn Alcohol Craving Scale - modified (PACS-M), 0–35; Beck Anxiety Inventory (BAI), 0–63; Beck Depression Inventory (BDI), 0–63.

[a]Means and standard deviations (in parentheses).

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Table 2

Piecewise repeated measures mixed model results showing change in craving, stress, anxiety and depression represented by slopes (β) during the wait-list control and heart rate variability biofeedback condition, including sex as a covariate.

	β	*SE*	*t*	*p*
Penn Craving Scale				
Waitlist	−0.080	0.166	−0.480	0.632
HRV BFB	−0.217	0.072	−3.010*	0.005
Sex	0.453	0.953	0.480	0.638
Perceived Stress Scale				
Waitlist	−0.020	0.246	−0.080	0.936
HRV BFB	−0.118	0.107	−1.110	0.275
Sex	2.998	1.622	1.850	0.072
Beck Anxiety Inventory				
Waitlist	−0.933	0.363	−2.570*	0.015
HRV BFB	−0.548	0.160	−3.430*	0.001
Sex	7.518	1.998	3.760*	0.001
Beck Depression Inventory				
Waitlist	0.053	0.340	0.150	0.877
HRV BFB	−0.206	0.116	−1.780	0.083
Sex	1.309	1.821	0.720	0.476

Notes.

*$p > .05$.