CLINICAL RESEARCH ARTICLE

Assessment of anhedonia in psychological trauma: psychometric and neuroimaging perspectives

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Symptoms of anhedonia, or deficits in the ability to experience positive affect, are increasingly recognized as an outcome of traumatic stress including in individuals with PTSD. However, little research has investigated negative affective responses to what would normally be considered pleasant events (e.g., receiving a compliment or gift, physical affection) in traumatized persons. We demonstrate not only self-reported decreased positive affect but also increased negative affect in response to positive events in 55 women with PTSD, in comparison with 35 women without PTSD, via their response to a Hedonic Deficit & Interference Scale (HDIS). The HDIS demonstrated strong internal validity, convergent and incremental validity relative to other measures of anhedonia, and discriminant validity in relation to depression versus anxiety symptoms in this sample. In addition, in response to imagery of social versus non-social positive events, HDIS scores predicted self-report positive and negative affective responses. In a sub-sample of participants completing the imagery task while undergoing fMRI ($n = 12$), HDIS scores also predicted BOLD response within the left orbitofrontal cortex, ventromedial prefrontal cortex, amygdala, and cerebellum. Future research and clinical directions are discussed.

Keywords: *anhedonia*; *positive affect*; *negative affect*; *negative affective interference*; *PTSD*; *depression*

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Anhedonia was defined by Ribot (1896) to refer to a deficiency in an individual's capacity to experience positive affect in situations that should normally provoke it. Such symptoms have long since been recognized in individuals suffering from psychiatric disorders including major depression, schizophrenia, and substance abuse disorders. More recently, symptoms of anhedonia have also been systematically observed in individuals with posttraumatic stress disorder (PTSD; e.g., Kashdan, Elhai, & Frueh, 2006, 2007) which includes as diagnostic criteria a diminished interest or participation in previously enjoyed activities (criterion C4) and a reduced ability to feel emotions, particularly those associated with intimacy, tenderness, and sexuality (criterion C5, American Psychiatric Association, 2000, p. 464). Research also shows that symptoms of emotional numbing (e.g., Orsillo, Theodore-Oklota, Luterek, & Plumb, 2007; Ramirez et al., 2001) may be particularly related to anhedonia. Functional neuroimaging studies suggest that individual differences in anhedonic processing are partly represented within the ventromedial prefrontal cortex (VMPFC) during visual emotional processing (Harvey, Pruessner, Czechowska, & Lepage, 2007; Keedwell, Andrew, Williams, Brammer, & Phillips, 2005). The left orbitofrontal cortex (L-OFC) also has an established role in neural processing relevant to reward functioning and positive affect (reviewed by Burgdorf & Panksepp, 2006) as does the amygdala (Murray, 2007) and cerebellum (e.g., Stoodley & Schmahmann, 2009; Turner et al., 2007).

Anhedonia as a symptom is typically measured by self-report (Leventhal & Rehm, 2005) via measures such as the Physical and Social Anhedonia Scales (PSAS; Chapman, Chapman, & Raulin, 1978), the Fawcett-Clark Pleasure Capacity Scale (FCPCS; Fawcett, Clark, Scheftner, & Gibbons, 1983) and/or the Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995). The assessment method taken by each of these instruments is to query the degree to which respondents believe they would experience positive affect in response to stimuli and events that normally provoke it (e.g., "You sit watching a beautiful sunset in an isolated, untouched part of the world" [*FCPCS Item #1*], "I would enjoy my favorite television or radio programme" [*SHAPS Item #1*]). The assumption underlying this approach is that low positive affective responses to pleasant stimuli and events indirectly indicate the presence of anhedonia, that is, the inability to experience positive affect in response to such events. However, a limitation of this approach is that it fails to directly measure the perceived inability to experience positive affect apart from individual differences in the intensity with which respondents experience positive affect.

Furthermore, in addition to difficulties in experiencing pleasure, individuals with PTSD often experience elevated negative emotions including anxious hyperarousal (Pole, 2007), anger (Orth & Wieland, 2006), guilt and shame (Kim, Talbot, & Cicchetti, 2009; Leskela, Dieperink, & Thuras, 2002). Emotion-regulation perspectives (e.g., McCullough et al., 2003) suggest that a key task is to determine whether positive stimuli and events may be responded to not only with less than expected positive affect, potentially reflecting a hedonic deficit, but also with an increase in negative affect. In other words, individuals may not only exhibit deficient positive affective responses to positive events (e.g., responding with disinterest, dullness, blunting) but they may also experience interfering negative affect (e.g., anxiety, guilt, shame, disgust). A limitation of present measures of anhedonia is that they only assess the degree of positive affect experienced in response to positive stimuli, not taking account of negative affective responses that may occur to positive stimuli. By solely assessing the degree of hedonic deficit experienced in response to positive stimuli, one cannot know whether anhedonic symptoms are associated only with low positive affect (e.g., disinterest, dullness, blunting) and low pleasantness (e.g., little happiness or pleasure), or are also accompanied by interfering negative affective responses such as distress or disgust (Tellegen, Watson, & Clark, 1999).

The purpose of the present study was to examine hedonic deficits (i.e., self-reported difficulties experiencing positive affect) as distinguished from negative affective interference (i.e., negative affective responses to positive stimuli and events) in individuals as a function of trauma history and trauma-related symptoms. We further examine the psychometric properties of a Hedonic Deficit & Interference Scale (HDIS; Frewen, Dean, & Lanius, 2012) as a brief method for directly assessing hedonic deficits as distinguished from negative affective interference in women with PTSD predominantly related to childhood abuse. We investigate the convergent, incremental, discriminant, and concurrent criterion-related validity of the HDIS using a multi-method design (questionnaires, self-report response to emotional imagery, and neural response to emotional imagery via functional magnetic resonance imaging [fMRI]). As well, this is the first study of which the authors' are aware to evaluate anhedonia in individuals with PTSD using standardized measures (i.e., the SHAPS, Snaith et al., 1995; and the FCPCS, Fawcett et al., 1983).

Method

Participants

Ninety women took part in this study. Participants were recruited over a 30-month period via advertisements placed in local community, hospitals, and newspapers targeting individuals who had experienced traumatic life events. Participants either reported no current or past psychiatric history or history of child maltreatment (the psychologically healthy control group, $n = 35$), or met DSM-IV diagnostic criteria for current chronic PTSD ($n = 55$). PTSD diagnostic status and symptom frequency and severity was determined by the Clinician Administered PTSD Scale (CAPS; Blake et al., 1995), and comorbid diagnoses were determined by the Structured Clinical Interview for DSM-IV (SCID-I; First, Gibbon, Spitzer, & Williams, 1996), which are widely considered gold-standard measures. Childhood trauma history was measured by the Childhood Trauma Questionnaire Short-form (CTQ; Bernstein & Fink, 1998); described below. Demographic information, in addition to descriptive information pertaining to clinical severity and comorbid psychiatric diagnosis, is reported in Table 1. Differences in mean age between groups did not alter interpretation of the principal results of this study as examined by covariance analyses (not reported). Poorer employment status and education level as well as marital/relational problems are among the recognized long-term associations of childhood trauma and were therefore not covaried in analyses.

Measures

Hedonic Deficit & Interference Scale (HDIS; Frewen, Dean, & Lanius, 2012). The HDIS was administered in order to directly assess negative affect interference (i.e., secondary negative affective responses to positive stimuli

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Table 1. Demographic and diagnostic information

	PTSD Sample ($n = 55$)		Controls ($n = 35$)
Demographics			
Mean Age (SD)	39.85 (8.03)*		30.40 (12.86)
Caucasian	91%		68%
Married/common-law	24%		39%
Separated/divorced	46%*		4%
Single	33%*		57%
Completed some or currently completing post-secondary education	72%		69%
Completed secondary-school	92%		100%
Employed (full or part time) or current student	42%*		87%
Severity of PTSD			
Mean CAPS (SD), range	77.42 (16.52), 54–120*		1.13 (4.32), 0–22
Childhood Trauma Questionnaire: M (SD),percentile equivalent of Mean)[1]			
Emotional abuse	18.37 (5.84), 97th percentile*		6.57 (1.99), 29th percentile
Emotional neglect	17.17 (5.37), 93rd percentile*		7.21 (2.48), 25th percentile
Physical abuse	12.93 (6.07), 96th percentile*		5.76 (1.46), 37th percentile
Physical neglect	12.02 (4.38), 98th percentile*		5.19 (0.59), 31th percentile
Sexual abuse	15.19 (7.93), 98th percentile*		5.33 (1.10), 36th percentile
Comorbid axis i conditions (*n*)	Past	Current	—
Alcohol abuse	7	1	
Substance abuse	3	1	
Major depressive disorder	6	12	
Dysthymia	0	4	
Panic disorder w/wo agoraphobia	1	15	
Agoraphobia wo panic disorder	0	8	
Social phobia	1	13	
Specific phobia	0	14	
Obsessive compulsive disorder	3	6	
Generalized anxiety disorder	0	7	
Somatization disorder	0	2	
Undifferentiated somatoform disorder	0	7	
Pain disorder	0	2	
Hypochondriasis	0	2	
Anorexia nervosa	3	0	
Bulimia nervosa	6	0	
Eating disorder NOS	1	1	

Note: * significantly different between groups ($p < 0.05$). [1]Percentiles relative to the normative population of female health management organization members ($N = 1187$) described in Bernstein & Fink (1998, Table 4.5). DSM-IV Disorders not listed were not present in the sample. "SD", standard deviation, "CAPS", clinician administered PTSD Scale. Comormid psychiatric conditions assessed via the SCID-I; Past or present psychiatric diagnosis was an exclusionary criterion for the control group.

and events) in addition to, and as distinct from, hedonic deficits (i.e, difficulties in experiencing positive affect). Five items assess positive emotionality (HDIS Positive Emotionality [PE] subscale), five items ask the informant whether he or she "can't (you are not able to) experience [inserting separately each of the same five distinct positive affects used in the PE scale] even when you try, and even when good things in your life happen" (Items 6–10; Hedonic deficit [HD] subscale), and 11 items ask whether interfering negative affective consequences tend to occur when positive events happen in the individual's life (Items 11–21; HDIS Negative Affective Interference [NAI] subscale, i.e., whether participants commonly felt numb, dissociative, anxious, fearful, guilty, self-critical, shame, disgust, emotionally empty, lifeless, and/or purposely attempted to suppress positive feelings, specifically in response to prototypically positive events). Items are rated for frequency within the past month on an 11-point rating scale ranging from 0 (''Not at All or Never True'') to 10 (''Completely true or very frequent [Always or Almost Always the Case]''), with 5 referring to ''Moderately True or Moderately Frequent'' and no other item anchors. Excellent psychometric characteristics were reported for the HDIS in 99 undergraduates with variable trauma histories (Frewen, Dean, & Lanius, 2012), however, the present study is the first to evaluate the psychometric characteristics of the HDIS in individuals with clinician-diagnosed PTSD.

Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995). The SHAPS was administered to assess anhedonia in PTSD with an established measure, as well as to assess convergent validity for the HDIS. The SHAPS is a 14-item scale requiring respondents to indicate their perceived ability to experience pleasure in response to a list of situations if these situations had occurred over the last few days (e.g., ''I would enjoy my favorite television or radio program'', ''I would enjoy being with my family or close friends''). Lower experience of pleasure in these circumstances is considered to indirectly reflect the inability to experience pleasure (i.e., anhedonia) as described above. Items were scored in such a way that high scores reflected lower agreement that the respondent would enjoy each circumstance (i.e., greater presumed anhedonia). Psychometric support for the SHAPS was provided in previous studies (Franken, Rassin, & Muris, 2007; Gilbert, Allan, Brough, Melley, & Miles, 2002; Leventhal, Chasson, Tapia, Miller, & Pettit, 2006).

Fawcett-Clark Pleasure Capacity Scale (FCPCS; Fawcett et al., 1983). The FCPCS was also administered to assess anhedonia in PTSD using an established measure (to assess convergent validity for the HDIS). The FCPCS is a 36-item questionnaire that also requires respondents to imagine themselves in various pleasurable situations (e.g., ''You are listening to beautiful music in peaceful surroundings'') and then rate the degree of pleasure they experience in consequence on a 5-point Likert scale ranging from ''No pleasure at all'' to ''Extreme and lasting pleasure.'' Items were again scored such that high scores reflected a lower experience of pleasure (i.e., greater presumed anhedonia). Several psychometric studies support the use of the FCPCS (see Leventhal & Rehm, 2005; Leventhal et al., 2006, for reviews). Keedwell et al. (2005) demonstrated that FCPCS scores predict response within the VMPFC during recall of positive events and viewing of happy facial expressions in a fMRI study of 12 individuals with major depression.

Depression Anxiety Stress Scales-Shortform (DASS-21; Lovibond & Lovibond, 1995a, b). The short-form of the DASS-21 (Lovibond & Lovibond, 1995a, b) is a 21-item inventory of symptoms of depression (e.g., ''I felt that life was meaningless''), anxiety (e.g., ''I felt I was close to panic''), and stress (e.g., ''I found it difficult to relax''). Studies attest to the reliability and validity of the DASS-21 (e.g., Antony, Bieling, Cox, Enns, & Swinson, 1998). The DASS-21-Depression subscale was administered to assess concurrent criterion-related validity for the HDIS, whereas the DASS-21-Anxiety scale was administered to assess the discriminant validity of the HDIS, on the basis that current theoretical models of mood and anxiety symptomatology hypothesize that anhedonia is more strongly associated with depressed mood than with anxious hyperarousal (e.g., the tripartite model; Clark & Watson, 1991). There were no specific predictions made for the DASS-21-Stress scale and therefore such associations were not investigated.

Childhood Trauma Questionnaire – Short Form (CTQ-SF; Bernstein & Fink, 1998). The CTQ-SF is a widely-used and standardized retrospective measure of adults' exposure to traumatic events during their childhood and adolescence. The CTQ-SF has five subscales: Emotional Neglect (reverse-scored; e.g., ''I knew there was someone to take care of me and protect me''), Emotional Abuse (e.g., ''People in my family called me things like 'stupid', 'lazy', or 'ugly'''), Sexual Abuse (e.g., ''Someone tried to touch me in a sexual way, or tried to make me touch them''), Physical Abuse (e.g., ''People in my family hit me so hard that it left me with bruises or marks''), and Physical Neglect (e.g., ''I didn't have enough to eat''). Excellent psychometric characteristics have been reported by Bernstein et al. (2003).

Affective Response Test – Positive Version (ART-P). This task was administered to assess responses to positive stimuli and events within an experimental context, affording measurement of associated self-report and functional neural responses. The primary results from this sample regarding performance of the ART-P have been reported previously (Frewen et al., 2010). In brief, participants listened to and imagined twelve 30-second audio-scripted vignettes happening to themselves, and attended toward their emotional responses to the scripts. Half ($n = 6$) of the scripts tend to elicit positive emotional experiences of mild to moderate self-reported intensity in healthy individuals, whereas the remaining scripts describe scenarios that on average arouse experiences lower in emotional intensity (neutral scripts). Analyses for this study were restricted to the patently emotional scripts, as there were no specific predictions for anhedonia to be associated with imagery for relatively emotionally-insignificant (i.e., neutral) events. Scripts were further divided in terms of those wherein the positive affect generated primarily occurs within the context of interpersonal interaction (social-positive; e.g., receiving a warm greeting or compliment), and those wherein interpersonal interaction is either absent or not emphasized

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(e.g., a solitary walk on the beach, or enjoying a bubble bath) (Frewen et al., 2011).

Following each imagined situation, participants were asked a series of questions concerning what they experienced, including the degree to which they experienced the following affective responses presented in this order: happy, increased self-esteem, relaxation, physical pleasure (all coded as positive affective responses) and fear, anxiety, sadness, shame, anger, disgust, and "feeling emotionally numb" (all coded as negative affective responses). Providing that our previous research suggested that HDIS scores relate differentially to specific negative emotional responses (Frewen, Dean, & Lanius, 2012), however, we also examined the negative affective responses separately. The affective response ratings were given on scales from 0 to 3, where zero indicated "No increase in emotion", and ratings one, two, and three referenced the participants' perception that they "felt slightly/somewhat", "felt moderately strong", and "felt strongly or very strongly" each particular affective response. Participants were also asked whether they wished to avoid experiencing positive and negative emotional events during imagery using the same item anchors: "No avoidance", "Slightly/somewhat avoided", "moderately strongly avoided", and "strongly or very strongly avoided". Note that descriptive information regarding self-report responses, BOLD responses, and the correlation between these measures in response to the ART-P has been reported previously (Frewen et al., 2010); the present manuscript represents a follow-up investigation specifically regarding the association between such measures and self-reported anhedonia symptoms as measured by the HDIS.

Functional Magnetic Resonance Imaging (fMRI). All blood oxygenation level dependent (BOLD) imaging data were collected on a 4 Tesla Varian ^{UNITY}INVOA whole body scanner equipped with Siemens Sonata gradients and a quadrature hybrid birdcage radiofrequency (RF) head coil. Prior to functional imaging, for anatomical registration, high resolution T1-weighted images were acquired with a 3D GE pulse sequence with spiraled gradient waveforms (256×256 matrix size, 64×2.5 mm slices, TR = 50 msec., TE = 3 msec., TI = 1300 msec., flip angle = 20°). fMRI was conducted as follows: 25 contiguous slices, 5-mm thick, were acquired using an interleaved, two-segment gradient echo (GE) pulse sequence with spiraled gradient waveforms (FOV = 22 cm, 64×64 matrix size, TR = 1.5 sec, TE = 15 msec, flip angle = 60°). Please see Frewen et al. (2010) for description of subtraction analyses. In brief, differences in location and intensity of BOLD response during the positive event script-driven imagery task relative to baseline scanning (30-seconds preceding each script onset) were ascertained by use of standard subtraction analyses using Statistical Parametric Mapping 2 (SPM2: http://www.fil.ion.ucl.ac.uk/spm), creating contrast images. Participants' HDIS scores were regressed on their individual contrast images to identify clusters of activation associated with anhedonia (k [cluster-size] $\geq$ 32 voxels [representing approximately 25% the width of the default smoothing kernel [8mm] used in SPM2, voxels being resampled at 2mm^3 within SPM2]; except within the amygdala wherein the cluster-size threshold was $k \geq$ 10 voxels). Alpha values for all analyses were set at $p <$ 0.005 balancing risk of Type I and II errors (see Liebermann & Cunningham, 2009). Analyses employed a random-effects model wherein degrees of freedom represent the number of participants ($n = 12$) less one. Coordinates are in accordance with the stereotaxic system of the Montreal Neurological Institute (MNI).

We were particularly interested to examine correlations between HDIS scores and the following regions of interest: bilateral amygdala, insula, and temporal pole (where we previously observed state positive and negative emotional ratings predicted response during non-social positive emotional imagery in the present group; Frewen et al., 2010), dorsomedial prefrontal cortex (where healthy women responded more strongly than the present group on average during social positive imagery; Frewen et al., 2010), ventromedial prefrontal cortex (where previous studies have observed correlations with anhedonia symptoms; Harvey et al., 2007; Keedwell et al., 2005), orbitofrontal cortex (known to be involved in response to reward; Burgdorf & Panksepp, 2006), and cerebellum (increasingly recognized as being involved in emotional processing; e.g., Stoodley & Schmahmann, 2009; Turner et al., 2007).

Procedure

All participants provided written informed consent before participating and were debriefed afterward. Upon contacting research personnel by telephone with an intent to participate, participants were pre-screened for likelihood of child maltreatment history and psychiatric diagnostic status, following which recruitment strategies favored the inclusion of participants with very high or very low likelihoods of meeting diagnostic criteria for moderate-to-severe PTSD. Participants were then tested individually and the HDIS was administered as an interview during a session in which the CAPS (Blake et al., 1995) and SCID-I (First et al., 1996) were also conducted to formally assess diagnostic status, and the Childhood Trauma Questionnaire (CTQ; Bernstein & Fink, 1998) was administered to assess child maltreatment history. The ART-P was administered by computer using E-Prime Software during a subsequent testing session held within two weeks of the interview session, at which time the other paper-and-pencil questionnaires (SHAPS, FCPCS, DASS-21) were also completed. Participants who met diagnostic criteria for PTSD as measured by the CAPS were recruited to complete the ART-P within an fMRI environment if: 1) they were not currently being treated for their psychiatric condition(s) by psychotropic medications, and 2) they met standard safety precautionary criteria for MRI; 14 participants met these inclusion criteria, although HDIS scores were not collected for two participants, leaving 12 available for fMRI analysis. The remaining participants completed the ART-P outside of the MRI environment in a typical office setting.

Results

Internal validity of the HDIS

Table 2 presents the alpha coefficients obtained for the HDIS subscales separately for women with versus without PTSD. Coefficient alphas for the HDIS-Positive Emotionality, HDIS-Hedonic Deficit, and HDIS-Negative Affective Interference subscales were high in the PTSD group. Coefficient alphas for the HDIS-Positive Emotionality and HDIS-Hedonic Deficit scales were also high in healthy women, but low for the HDIS-Negative Affective Interference scale; the latter may indicate a multi-factorial structure to the item content in healthy women. In women with PTSD, correlations between scores on the three HDIS subscales were generally moderate or lesser in magnitude, agreeing with their proposed discriminability: HDIS-Positive Emotionality with HDIS-Hedonic Deficit, $r = -.42$, $p = 0.001$; HDIS-Positive Emotionality with HDIS-Negative Affective Interference, $r = -.20$, $p = 0.07$; HDIS-Hedonic Deficit with HDIS-Negative Affective Interference, $r = +.67$, $p < 0.001$.

Group differences in anhedonia between women with vs. without PTSD

The PTSD group scored significantly higher on the FCPCS ($M = 156.40$, SD $= 25.14$, vs. $M = 121.00$, $SD = 11.92$, $t[61] = 7.49$, $p < 0.001$, $d = 1.41$) and the SHAPS ($M = 3.89$, SD $= 3.37$, vs. $M = 0.48$, $SD = 1.45$, $t[61] = 5.52$, $p < 0.001$, $d = 1.01$). Table 2 also reports descriptive statistics for the HDIS subscales, separately for women with vs. without PTSD, as well as the results of group comparisons. As predicted, women with PTSD scored significantly lower in HDIS-*Positive Emotionality* ($d = 1.91$), and significantly higher in HDIS-Hedonic Deficit ($d = 1.88$) and HDIS-Negative Affective Interference ($d = 1.65$), relative to women without current or past psychiatric problems. In fact, in allocating participants to groups (PTSD vs. control) an HDIS-Hedonic Deficit score merely > 1.0 exhibits 90.00% sensitivity and 94% specificity. In comparison, an HDIS-Negative Affective Interference score merely > 1.0 exhibits 91% sensitivity and 91% specificity.

Convergent validity of the HDIS

HDIS–Positive Emotionality and HDIS–Hedonic Deficit scores were significantly correlated with SHAPS scores: $r = -.26$, $p < 0.05$, $r = +.36$, $p < 0.05$, respectively, in the PTSD group. However, HDIS-Negative Affective Interference scores were not significantly correlated with SHAPS scores, $r = +.14$, ns. FCPCS scores were significantly correlated with each of the HDIS subscales: HDIS-Positive Emotionality, $r = -.52$, $p < 0.01$, HDIS-Hedonic Deficit, $r = +.44$, $p < 0.01$, and HDIS-Negative Affective Interference, $r = +.28$, $p < 0.05$.

Incremental validity of the HDIS in the prediction of PTSD symptoms

Although SHAPS and FCPCS scores significantly differ between the PTSD group and controls, within the PTSD group SHAPS and FCPCS scores were not significantly correlated with PTSD symptom severity as indexed by CAPS total scores: $r = .05$, $p = .38$, and $r = -.01$, $p = 0.48$, respectively. In contrast, Table 3 indicates that HDIS-Hedonic Deficit and HDIS-Negative Affective *Interference* scores correlated not only with CAPS total scores but also with both CAPS PTSD cluster C (Avoidance, Numbing) and D (Hyperarousal) scores, but not CAPS PTSD cluster B (re-experiencing) scores.

A multiple regression analysis with HDIS-Hedonic Deficit and HDIS-Negative Affective Interference entered in step 1 as predictors of CAPS total scores was statistically significant, $R^2 = 0.16$, $F(2,34) = 3.23$, $p = 0.05$, whereas the addition of SHAPS and FCPCS scores

Table 2. Internal validity & descriptive statistics for the hedonic deficit & interference scales

	Control group ($n = 35$)			PTSD ($n = 55$)				
	α	*M*	*SD*	α	*M*	*SD*	*t*(61)	*d*
HDIS-PE	.84	7.38	1.54	.85	3.32	2.09	10.01	1.91
HDIS-HD	.85	0.41	1.11	.89	5.16	2.60	10.52	1.88
HDIS-NAI	.56	0.41	0.44	.93	4.21	2.33	9.45	1.65

Note: All between-group differences have *p*'s < 0.001. α = coefficient alpha; HDIS, hedonic deficit & interference scale; PE, positive emotionality subscale; AD, hedonic deficit subscale; NAI, negative affective interference subscale.

Table 3. Correlation between HDIS subscales and PTSD, depression, and anxiety symptoms as well as childhood trauma history

	HDIS-PE	HDIS-HD	HDIS-NAI
PTSD (CAPS)			
Total	−.42	.32	.42
B (Re-experiencing)	−.36	.06	.10
C (Avoidance-numbing)	−.36	.28	.50
D (Hyperarousal)	−.18	.36	.28
Depression, anxiety, stress scale (DASS-21)			
Depression	−.51	.44	.42
Anxiety	−.01	.20	.30
Childhood trauma (CTQ)			
Emotional abuse	−.58	.60	.60
Emotional neglect	−.56	.61	.60
Physical abuse	−.39	.52	.46
Physical neglect	−.53	.60	.58
Sexual abuse	−.44	.58	.52

Note: For CAPS & DASS-21, $n = 55$ (PTSD sample only). For CTQ, $n = 90$ (full sample). $r \geq .26$ corresponds to $p \leq .05$. HDIS = Hedonic Deficit & Interference Scale, PE = Positive Emotionality Subscale, AD = Hedonic deficit Subscale, NAI = Negative Affective Interference Subscale.

failed to significantly improve prediction, $\triangle R^2 = 0.02$, F(2,32) = 0.30, $p = 0.74$. In comparison, a multiple regression analysis using SHAPS and FCPCS as scores in step 1 was not statistically significant, $R^2 = < .01$, $F(2,34) = 0.05$, $p = 0.95$; however, the addition of HDIS-Hedonic Deficit and HDIS-Negative Affective Interference scores in step 2 significantly improved prediction, $\triangle R^2 = 0.17$, $F(2,32) = 3.34$, $p < 0.05$. These findings support the incremental validity of the HDIS in accounting for variance in PTSD symptom severity within a PTSD sample relative to standard measures of anhedonia.

Associations between the HDIS and childhood trauma history

Table 3 shows that HDIS scores were predicted by severity of childhood trauma history as measured by the Childhood Trauma Questionnaire. All associations were statistically-significant and moderate in magnitude.

Concurrent criterion-related & discriminant validity of the HDIS: mono-method (questionnaires)

Table 3 also reports correlations between the HDIS and the DASS-21. As predicted, HDIS-Positive Emotionality scores were more strongly correlated with DASS-Depression than with DASS-Anxiety, $Z = 3.49$, $p < 0.001$, as was the case for HDIS-Hedonic Deficit scores, Z = 1.71, $p <$ 0.05. These findings support the discriminant validity of the HDIS scales (cf. Clark & Watson, 1991). However, HDIS-Negative Affective Interference scores were not significantly more strongly correlated with DASS-Depression than with DASS-Anxiety, Z = 0.87, *ns*. This finding is consistent with the discriminant validity of the HDIS-Negative Affective Interference subscale relative to the HDIS-Hedonic Deficit subscale, and suggests negative affective responses to positive events may covary with anxiety symptoms.

Concurrent criterion-related validity of the HDIS: multi-method (ART-P self-report)

Table 4 presents Pearson correlation coefficients between positive and negative emotional responses to the ART-P Emotion scripts and each of the HDIS subscales for women with PTSD. All associations were in

Table 4. Multi-method concurrent criterion-related validity of the hedonic deficit & interference scales with self-report responses to social positive and nonsocial positive emotion scripts of the affective response test

	PA	Avoid-PA	Anger	Anxiety	Fear	Disgust	Sad	Numb	Shame	Avoid-NA
Social										
HDIS-PE	.25	−.18	−.16	−.32	−.30	−.19	−.21	.08	−.40	−.08
HDIS-HD	−.46	.37	.29	.43	.30	.38	.22	.30	.30	.25
HDIS-NAI	−.52	.35	.38	.47	.38	.55	.37	.33	.41	.38
Non-Social										
HDIS-PE	.20	−.38	−.29	−.43	−.23	−.35	−.19	.03	−.38	−.23
HDIS-HD	−.13	.21	.00	.27	.24	.26	.06	.09	.18	.37
HDIS-NAI	−.25	.27	.09	.29	.24	.27	.16	.12	.33	.33

Note: $r \geq .26$ corresponds to $p \leq 0.05$. Results from participants who completed the task outside of the fMRI scanner. PA. positive affect; Avoid-PA, attempted avoidance of positive affect; Anx, Anxiety; Avoid-NA, attempted avoidance of negative affect. HDIS, hedonic deficit & interference scale; PE, positive emotionality subscale; HD, hedonic deficit subscale; NAI, negative affective interference subscale.

the predicted direction, and many were statistically-significant. The magnitude of correlations between each of the HDIS-Hedonic Deficit and HDIS-Negative Affective Interference scores with the ART-P measures were not significantly different, although in nearly all cases correlations were stronger with Negative Affective Interference scores. Associations for both measures were somewhat stronger in response to imagery of positive events that were explicitly social as compared with non-social events, irrespective of the type of negative emotional response (i.e., anger, anxiety, fear, disgust, numbing, sadness, or shame).

Concurrent criterion-related validity of the HDIS: multi-method (ART-P fMRI-BOLD response)

Please see Table 5 and Figs. 1 and 2 for SPM2 results. Consistent with hypotheses, within women with PTSD, HDIS-Positive Emotionality scores positively predicted response relative to baseline within both the left and right OFC during social positive imagery (Fig. 1-A), and within the left OFC only during non-social positive imagery (Fig. 2-A).Regarding response to social positive imagery, HDIS-Positive Emotionality scores also positively predicted response within medial prefrontal cortex (including the anterior cingulate), cerebellum, and occipital cortex (Fig. 1-B), and negatively predicted response within right middle temporal cortex. In comparison, regarding response to non-social positive imagery, HDIS-Positive Emotionality scores positively predicted response within the right insula (Fig. 2-B), and negatively predicted response within bilateral precuneus, and right superior parietal and middle temporal cortex.

By contrast, HDIS-Hedonic Deficit scores did not correlate significantly with response to social positive events. However, HDIS-Hedonic Deficit scores positively

Table 5. Multi-method concurrent criterion-related validity of the hedonic deficit & interference scales with self-report responses to positive emotion scripts of the affective response test

	Correlation	ROI	MNI	k	Z	p
Social						
HDIS-PE	+	R-Orbitofrontal cortex	26, 32, −18	106	3.52	<0.001
	+	L-Orbitofrontal cortex	−30, 34, −22	75	3.24	0.001
	+	L-Orbitofrontal cortex	−30, 34, −22	54	3.14	0.001
	+	R Occipital cortex	16, −106, 4	49	3.33	<0.001
	+	L-Cerebellum (posterior lobe)	−18, −60, −36	327	3.25	0.001
	+	L Cerebellum (posterior lobe)	−28, −80, −44	61	3.12	0.001
	+	L-Medial prefrontal cortex	−4, 38, 8	144	2.91	0.003
	−	R-Middle temporal cortex	46, −34, −22	49	3.90	<0.001
HDIS-HD	+	(no significant results)	–	–	–	–
	−	(no significant results)	–	–	–	–
HDIS-NAI	+	(no significant results)	–	–	–	–
	−	R Cerebellum (posterior lobe)	40, −58, −22	113	3.68	<0.001
	−	R Temporal-parietal junction	56, −52, 12	145	3.62	<0.001
	−	L Cerebellum (posterior lobe)	−34, −58, −22	101	3.48	<0.001
	−	R Cerebellum (posterior lobe)	24, −48, −48	132	3.41	<0.001
	−	R Middle temporal gyrus	48, −52,2	64	2.97	0.001
Non-Social						
HDIS-PE	+	L-Orbitofrontal cortex	−24, 40, −14	44	3.79	<0.001
	+	R Insula	52, 12, 20	183	3.21	0.001
	−	R-Superior parietal cortex	46, −74, 18	55	3.76	<0.001
	−	R-Middle temporal cortex	60, −32, 6	47	3.42	<0.001
	−	R-Precuneus	10, −72, 42	33	3.25	0.001
	−	L-Precuneus	−10, −74, 48	57	3.12	0.001
HDIS-HD	+	L Pre-cuneus	−8, −78, 42	83	3.45	<0.001
	+	R Cerebellum (anterior lobe, vermis)	6, −50, 0	127	3.33	<0.001
	−	(no significant results)	–	–	–	–
HDIS-NAI	+	R Cerebellum (posterior lobe)	28, −82, −42	42	3.43	<0.001
	+	R Middle frontal gyrus	44, 16, 18	90	3.34	<0.001
	+	L Amygdala	−18, −4, −12	15	3.04	0.001
	−	(no significant results)	–	–	–	–

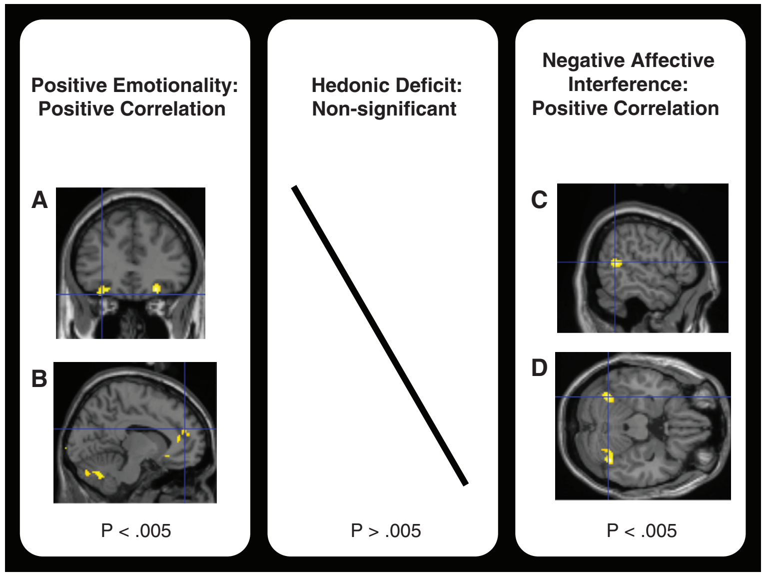

Fig. 1. BOLD Response to Imagery of Social Positive Events as Predicted by HDIS Scores.
Source: A: y = 34, Orbitofrontal cortex (crosshairs: left hemisphere); B: x = −10, Medial Prefrontal Cortex (cross-hairs) and Cerebellum; C: x = 56, Right Temporoparietal Junction, D: z = −22, Cerebellum (crosshairs: left lobule).

predicted response within the cerebellar vermis (Fig. 2-C/D) and precuneus during non-social positive imagery.

Finally, HDIS-Negative Affective Interference scores negatively predicted response to social positive imagery within the right temporoparietal junction (Fig. 1-C), bilateral cerebellum (posterior lobes, Fig. 1-D), and right middle temporal gyrus. In contrast, HDIS-Negative Affective Interference scores positively predicted response within the left amygdala (Fig. 2-E), right cerebellum (posterior lobe, Fig. 2-F), and right middle frontal gyrus.

Discussion

This study identified symptoms of anhedonia in women with PTSD using standard measures (SHAPS, FCPCS), extending the results of previous studies (Kashdan et al., 2006, 2007). We have suggested, however, that one can distinguish between anhedonic sub-processes, specifically those relating to the perceived incapacity to experience positive affect in response to positive stimuli and events (hedonic deficits) in contrast to the tendency to experience interfering negative affect in response to positive

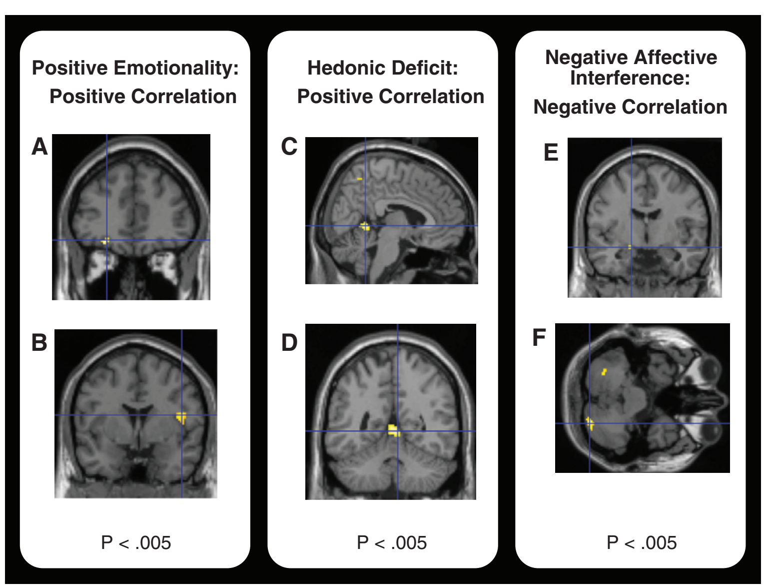

Fig. 2. BOLD Response to Imagery of Non-social Positive Events as Predicted by HDIS Scores.
Source: A: y = 40, Left Orbitofrontal cortex; B: y = 6, Right Insula; C & D: Cerebellum (C: x = 6, D: y = −50), E: y = −6, Left Amygdala, F: z = −42, Cerebellum (crosshairs = right lobule).

stimuli and events (negative affective interference). In the present study we provide evidence of each sub-process of anhedonia in women with PTSD via their responses to the Hedonic Deficit and Interference Scale (HDIS; Frewen, Dean, & Lanius, 2012).

The HDIS demonstrated excellent internal consistency in women with PTSD, convergence with previously validated anhedonia scales (SHAPS, FCPCS), incremental validity in predicting PTSD severity (CAPS) scores beyond the SHAPS and FCPCS, and excellent sensitivity and specificity for the diagnosis of PTSD (relative to psychological health) with very minimal scores. As predicted, the HDIS-Positive Emotionality and HDIS-Hedonic Deficit subscales were more strongly correlated with depressive symptoms than anxious hyperarousal, supporting the concurrent criterion-related and discriminate validity of the HDIS within the context of psychological models that differentiate depression from anxiety symptomatology primarily in terms of anhedonia and low positive affect (e.g., Clark & Watson, 1991). HDIS-Negative Affective Interference scores, however, were significantly correlated with both depression and anxiety symptoms, indicating the discriminant validity of assessing negative affective responses to positive events, outcomes apparently also related to anxiety symptoms. Interestingly, HDIS-Hedonic Deficit and HDIS-Negative Affective Interference correlated particularly with PTSD avoidance-numbing and hyperarousal symptoms, but not with re-experiencing symptoms, suggesting that they are best understood as affective problems perhaps independent of a focus on intrusive memories. Additionally, anhedonia symptoms may have their origin in early learning providing that self-reported severity of childhood abuse predicted both increasing HDIS-Hedonic Deficits and HDIS-Negative Affective Interference. HDIS scores also predicted self-reported emotional responses during imagery of positive events, particularly those with an explicit interpersonal focus. Finally, HDIS scores concurrently predicted subjective and functional metabolic responses to imagery of prototypically positive events within several regions of interest including the orbitofrontal cortex, medial prefrontal cortex, insula, amygdala, and cerebellum. Furthermore, the neural correlates of anhedonic symptoms differed between social relative to non-social positive imagery. For example, response within both the medial prefrontal cortex and the right temporoparietal junction, both known to be involved in social cognitive processing (e.g., review by Van Overwalle, 2009), was predicted by anhedonic symptoms during social but not during non-social positive imagery. Nevertheless, these findings must be considered preliminary due to small sample sizes and we highlight the need for replication.

There are limitations of the present study that will need to be addressed by further research. One concern may be that the emotional response task used in the present study relied too heavily on concentration and imagery which may be problematic providing that many individuals with PTSD are alexithymic (e.g., review by Frewen, Dozois, Lanius, Neufeld, & Lanius, 2008) and therefore may have difficulties with imagery tasks. In fact, Sifneos (1987) speculated that whereas all anhedonic individuals may not be alexithymic, all alexithymic individuals are likely anhedonic; a study of healthy participants, however, found that symptoms of anhedonia and alexithymia load on distinct factors (Loas, Fremaux, & Boyer, 1997). In our first study of the HDIS (Frewen, Dean & Lanius, 2012), we evaluated a simpler methodology: we modified the FCPCS to ask about negative affective responses to positive events, and found that HDIS scores predict such responses. However, other methods for assessing anhedonic responses to positive stimuli should also be tested (e.g., response to pleasant pictures; Leventhal et al., 2006, and reward tasks; Elman et al., 2005, 2009; Hopper et al., 2008). In addition, although the present study illustrates the applicability of differentiating between hedonic deficits and negative affective interference in PTSD, a disorder that is frequently associated with anhedonic symptomatology (e.g., Kashdan et al., 2006, 2007), the present study did not assess the relevance of these constructs to anhedonic symptoms present in other psychiatric populations where anhedonia is more often studied, and which are variably also associated with trauma exposure (e.g., schizophrenia, mood disorders). A study examining hedonic deficits and negative affective interference in individuals with schizophrenia and mood disorders, who vary with respect to trauma exposure, in comparison with symptom severity in PTSD, would be helpful in determining whether trauma exposure plays an etiological role in symptoms of anhedonia. Furthermore, the present study was limited to women with the primary diagnosis of PTSD who had considerable psychiatric comorbidity, and additional studies will be necessary to ascertain the generalizability of the present findings to men, and to PTSD specifically versus other disorders with which PTSD is frequently comorbid. The internal consistency found for the HDIS-Negative Affective Interference items was also unacceptably low in healthy women, indicating either the items may not measure a valid construct in healthy women, or are multi-factorial in healthy women. It will also be important to assess the temporal reliability of the HDIS in the future.

A number of open questions remain, such as regarding the etiology and development of hedonic deficits and negative affective interference, and the prognostic significance of these measures for treatment. The present study suggests that it may be useful to supplement the use of traditional measures of anhedonia with measures of negative affective interference such as the HDIS. It will

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also be important to evaluate under which conditions anhedonia is more likely to be observed in the presence versus absence of negative affective interference, as well as in what circumstances positive affect (lack of anhedonia) in combination with negative affective interference (i.e., a ''mixed'' positive and negative affective response) might be likely. It will also be important to determine whether deficits in negative emotional processes frequently accompany hedonic deficits. Interventions for trauma victims are recommended not only to focus on increasing positive affect, but should also include strategies for regulating negative affect in response to positive stimuli and events. Future studies may choose to examine the effectiveness of treatments in the reduction of hedonic deficits and negative affective interference.

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