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Autonomic and subjective responsivity to emotional images in people with dissociative seizures

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People with dissociative seizures (DS) report a range of difficulties in emotional functioning and exhibit altered responding to emotional facial expressions in experimental tasks. We extended this research by investigating subjective and autonomic reactivity (ratings of emotional valence, arousal and skin conductance responses [SCRs]) to general emotional images in 39 people with DS relative to 42 healthy control participants, whilst controlling for anxiety, depression, cognitive functioning and, where relevant, medication use. It was predicted that greater subjective negativity and arousal and increased SCRs in response to the affective pictures would be observed in the DS group. The DS group as a whole did not differ from controls in their subjective responses of valence and arousal. However, SCR amplitudes were greater in 'autonomic responders' with DS relative to 'autonomic responders' in the control group. A positive correlation was also observed between SCRs for highly arousing negative pictures and self-reported ictal autonomic arousal, in DS 'autonomic responders'. In the DS subgroup of autonomic 'non-responders', differences in subjective responses were observed for some conditions, compared to control 'non-responders'. The findings indicate unaffected subjective responses to emotional images in people with DS overall. However, within the group of people with DS, there may be subgroups characterized by differences in emotional responding. One subgroup (i.e., 'autonomic responders') exhibit heightened autonomic responses but intact subjective emotional experience, whilst another subgroup (i.e., 'autonomic non-responders') seem to experience greater subjective negativity and arousal for some emotional stimuli, despite less frequent autonomic reactions. The current results suggest that therapeutic interventions targeting awareness and regulation of physiological arousal and subjective emotional experience could be of value in some people with this disorder.

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Dissociative seizures (DS) are also known as psychogenic, conversion, functional, or non-epileptic seizures and are differentially classified as a somatoform symptom (conversion) disorder (DSM-5; American Psychiatric Association, 2013) and a dissociative disorder (ICD-10; World Health Organisation, 1992) in the two current major psychiatric classification systems. The episodes can be mistaken for epileptic seizures (ES); however, they do not share the electrophysiological basis of ES, and there are known semiological differences between the two (Devinsky, Gazzola, & LaFrance, 2011; Goldstein & Mellers, 2012). DS are ideally diagnosed on the basis of video-encephalography (video-EEG), in addition to differential diagnosis of other physical or psychiatric causes through detailed clinical history and/or additional diagnostic tests.

There is now substantial experimental evidence that people with DS display alterations in responsivity to social emotional stimuli, characterized by increased cognitive interference by and behavioural avoidance of emotional facial expressions (Bakvis *et al.*, 2009; Bakvis, Spinhoven, Putman, Zitman, & Roelofs, 2010; Bakvis, Spinhoven, Zitman, & Roelofs, 2011; Gul and Ahmad, 2014) as well as deficits in 'theory of mind' (Schönenberg *et al.*, 2015) and explicit facial expression recognition (Pick, Mellers, & Goldstein, 2016). However, less is known about how people with DS respond to other, more general emotional stimuli.

Altered responsivity to general affective images has been investigated experimentally in individuals diagnosed with disorders that share risk factors and/or clinical character-istics with DS, such as borderline personality disorder (Herpertz, Kunert, Schwenger, & Sass, 1999) and depersonalization disorder (Sierra *et al.*, 2002). Differences in neural activity have also been reported in people with other conversion disorders relative to healthy controls, during processing of affective pictures (Blakemore, Sinanaj, Galli, Aybek, & Vuilleumier, 2016; Fiess, Rockstroh, Schmidt, Wienbruch, & Steffen, 2016). However, to date, only one study has examined more general emotional responding in people with DS in the laboratory. Roberts *et al.* (2012) reported that their sample of people with DS was similar to control participants in the valence of their emotional responses to affective images but that they gave elevated intensity ratings for neutral and positive images relative to controls low in post-traumatic symptoms. However, psychophysiological measures did not differ between the DS and control groups.

The overall aim of our study was to compare subjective and autonomic reactions to general emotional images in patients with DS, compared to a non-clinical control group, whilst controlling for possible confounding variables (i.e., anxiety, depression, cognitive functioning, and medication use). Data collection was already underway when Roberts *et al.*'s (2012) study was published; therefore, their findings did not inform the aims or hypotheses of the experiment described here. It was hypothesized that patients with DS would display altered subjective and autonomic responses to these stimuli. More specifically, it was predicted that people with DS would endorse elevated ratings of arousal and negative valence, in addition to higher levels of autonomic responding (i.e., more frequent and higher amplitude of phasic skin conductance responses [SCRs]), relative to the control group. These differences were expected to be most apparent for negative images. It was also predicted that the DS group would show heightened tonic skin conductance levels (SCLs), throughout baseline and during the experimental task.

Methodology

Participants

Patients with DS were recruited from two tertiary care Neuropsychiatry services in South London, with ethical approval received from the local research ethics committee

(reference 08/H0807/82). Diagnosis of DS was based on either video-EEG (where available) or the consensus clinical opinion of two expert clinicians (e.g., neuropsychiatrist and epileptologist). Control participants were recruited from the local community using online and paper advertisements. Inclusion criteria in both groups included an estimated intelligence quotient (IQ) of ≥70, fluency in English, and age 18–65 years old. Exclusion criteria for both groups were the presence of any major medical/neurological diagnosis (e.g., epilepsy), mood or anxiety disorder, substance dependence or psychosis. Further exclusion criteria in the control group included any psychiatric or major medical diagnosis. Patients with DS were excluded from the study if they had completed any psychological intervention for DS.

Experimental task

Stimuli

The experimental stimuli were taken from the International Affective Picture System set (Lang, Bradley, & Cuthbert, 2005). The images vary considerably in content, depicting a range of scenes, objects, and people. The scenes vary on the affective dimensions of valence (positive, negative, and neutral) and arousal (low to high). On the basis of the normative arousal and valence ratings provided with this set, stimuli were selected from each of the following categories: positive high arousal, positive low arousal, neutral, negative high arousal, and negative low arousal.

Six pictures were chosen from each category, yielding a total of 30 experimental trials (Data S1). To assist participants in making their responses to the stimuli, two digitized versions of the Self-Assessment Manikin (SAM) were used (arousal and valence), each with a nine-point scale (Data S2).

Design and procedure

The experiment had a mixed factorial design with one between-groups factor (diagnostic status: DS and control) and one within-groups factor (emotional category: neutral, negative/high arousal, negative/low arousal, positive/high arousal, and positive/low arousal). The dependent variables were subjective ratings of valence (0–9, negative–positive), arousal (0–9, high–low), SCRs, and SCLs (microSiemens, μS).

The experiment was completed at the same time of day for all participants (approx. 11 am–12 noon). All participants first underwent a 5-min resting (baseline) period with the skin conductance recording electrodes attached. Participants were presented with standardized instructions and completed three practice trials prior to commencing the experimental task. Each experimental trial was preceded by a 15-second interstimulus interval (ISI), with a central white fixation cross presented against a black background throughout. After fixation, a single IAPS picture was presented on the screen for 6-s. Stimuli were presented in a pseudorandomized order. Immediately after stimulus offset on each trial, the two SAM rating screens were presented consecutively, with the order randomized for each participant.

Neuropsychological testing

General intellectual functioning was examined with the two-subtest form (Vocabulary and Matrix Reasoning) of the Wechsler Abbreviated Scale of Intelligence (WASI;

Wechsler, 1999). One subtest (Object Decision [OD]) from the Visual Object and Space Perception Battery (VOSP; Warrington & James, 1991) assessed participants' general object perception/recognition. The Family Pictures I subtest of the Wechsler Memory Scale – Third Edition (WMS-III; Wechsler, 1997) measured participants' immediate memory (recall) for complex visual scenes.

Self-report measures

The Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983) was used to assess current symptoms of anxiety and depression, with the two respective subscales yielding scores from 0 to 21 (scores >11 indicating clinically significant symptoms). The scale has sound psychometric properties (Mykletun, Stordal, & Dahl, 2001).

A questionnaire assessing seizure symptoms was adapted from that used by Goldstein and Mellers (2006) to assess the following types of symptoms experienced during patients' DS: autonomic arousal, chest/abdominal, mental state, general, and cognitive. The inventory assesses these symptoms in relation to patients' most severe and most recent seizure separately. The questionnaire was described in a related publication (Pick, Mellers, & Goldstein, 2017).

Skin conductance data

All methods for acquiring, extracting, and reducing the SC variables followed recommended guidelines (Boucsein *et al.*, 2012; Dawson, Schell, & Filion, 2000); the methods were described in full previously (Pick *et al.*, 2016) and can be found in Data S3. Baseline SCLs were calculated from the average values obtained across the resting habituation period prior to the experiment, whereas task SCLs were calculated from the average of the values obtained during the last 5-s of each ISI in the experimental task (i.e., at rest, fixating on a single cross-hair).

Two measures of phasic SCR were examined during stimulus presentation, namely amplitude (i.e., the greatest μS value of >0.01 μS obtained during stimulus presentation minus the respective pre-stimulus baseline value) and response frequency (percentage of positive SCRs for each condition; positive responses were defined as a rise of >0.01 μS from pre-stimulus baseline). SCR amplitudes were calculated from positive SCR responses only (i.e., values of >0.01 μS), with any negative or zero values excluded. As such, the analysis of SCR amplitudes only included those participants who exhibited at least one positive SCR in every condition. Both SCR amplitude and frequency of positive SCRs were included as dependent measures, to circumvent the major weakness of using a magnitude measure of SCR, which conflates frequency with amplitude by including all values, including zero responses (Dawson *et al.*, 2000).

Statistical analysis

Demographic characteristics and cognitive test scores were compared between groups with *t*-tests, chi-squared, or Mann–Whitney *U* tests. Mean ratings on the arousal and valence scales (0–9), SCR amplitudes, and percentage of positive responses were entered as dependent variables in mixed factorial ANOVAs/ANCOVAs with group (DS and control) as the between-subjects factor and condition (neutral, negative/high arousal, negative/low arousal, positive/high arousal, and positive/low arousal) as the within-subjects factor. SCLs were also examined with a mixed factorial ANOVA/ANCOVA, with

group (DS and control) as the between-groups factor and time (baseline and task) as the within-groups factor.

Planned analyses of important possible confounds were conducted by entering relevant variables as covariates, if they differed between groups in preliminary analyses. The decision to undertake these analyses was made *a priori*, as an important aspect of the design of this study. In these analyses, effects were considered significant at $p < .05$. Furthermore, where the effects of medication status might have contributed to observed group differences, analyses were rerun including medication (antiepileptic drugs [AED] or antidepressant use) as additional between-groups factors in the model, to control for this additional possible confound.

Dependent variables that differed significantly between groups were also examined in exploratory correlational analyses, to assess possible inter-relationships between experimental dependent variables and patient characteristics (disorder duration, seizure frequency, and seizure symptoms) in the DS group.

Flow charts outlining all statistical analyses can be found in Data S4.

Results

Participant characteristics

Forty-two control participants and 39 patients with DS completed the study. There were no significant group differences in age, gender, ethnicity, and handedness. However, the control group reported significantly more years of education (YoE) than the DS group. The DS group reported significantly greater symptoms of anxiety and depression than controls (Table 1).

Patients with DS ($n = 28$, 71.8%) were more likely to be taking prescribed medication than the control group, ($n = 10$, 23.8%; $X^2(1, 81) = 18.7$, $p < .001$). Fourteen patients with DS (35.9%) were taking AEDs, and 15 patients (38.5%) were taking antidepressant medications. The median length of time since DS onset was 60 months (interquartile range [IQR] = 90), and the median reported seizure frequency was 4 per month (IQR = 14).

Neuropsychological testing

There were no significant differences in full-scale IQ, Vocabulary or Matrix Reasoning scores between groups on the WASI. However, the DS group performed significantly better than controls on the VOSP OD subtest and the Family Pictures 1 subtest of the WMS-III (Table 2).

Subjective ratings of valence and arousal

Valence

Of the potential covariates (HADS Anxiety, HADS Depression, VOSP OD, WMS-III Family Pictures 1), only HADS Anxiety was significant, $F(1, 78) = 4.82$, $p = .031$, $\eta_p^2 = .058$. With HADS Anxiety scores entered as a covariate in an ANCOVA, the group effect was not significant, $F(1, 78) = .245$, $p = .622$, $\eta_p^2 = .003$. There was a highly significant effect of condition, $F(2.22, 173.6) = 59.9$, $p < .001$, $\eta_p^2 = .434$, but no group × condition interaction, $F(2.22, 173.6) = 1.28$, $p = .283$, $\eta_p^2 = .016$ (Table 3).

Table 1. Participant characteristics

	DS (n = 39)	Controls (n = 42)	Test statistics
Age in years (Mean, SD)	37.9 (13.2)	37.3 (11.8)	$t(79) = -0.212, p = .832$
Gender	Male = 8 (20.5%) Female = 31 (79.5%)	Male = 7 (16.7%) Female = 35 (83.3%)	$X^2(1, n = 81) = 0.198, p = .656$
Handedness	Right = 29 (74.4%) Left/ambidextrous = 10 (25.6%)	Right = 37 (88.1%) Left/ambidextrous = 5 (11.9%)	$X^2(1, n = 81) = 2.53, p = .112$
Ethnicity	White = 31 (79.5%) Non-white = 8 (20.5%)	White = 28 (66.7%) Non-white = 14 (33.3)	$X^2(1, n = 81) = 1.68, p = .195$
YoE Median (IQR)	13 (3)	14.5 (4.3)	$U(81) = 600, p = .036$
HADS (Mean, SD)			
Anxiety	9.8 (4)	5.3 (3.2)	$t(79) = -5.59, p < .001$
Depression	7.2 (4.2)	2.3 (2.5)	$t(79) = -6.45, p < .001$

Note. SD = standard deviation; IQR = interquartile range; YoE = years of full-time education (or equivalent); DS = dissociative seizures; HADS = Hospital Anxiety and Depression Scale.

Table 2. Neuropsychological tests

	DS	Controls	Test statistic (*df*)	*p*-Value
WASI	*n* = 39	*n* = 42		
FSIQ (Mean, *SD*)	103.8 (14.6)	108.2 (13.3)	*t*(79) = 1.4	.165
Vocabulary *T* scores (Mean, *SD*)	51.7 (11.2)	55.4 (9.9)	*t*(79) = 1.5	.125
Matrix Reasoning *T* scores (Median, IQR)	54 (10)	55.5 (15)	*U*(81) = 725.5	.376
VOSP OD	*n* = 38	*n* = 42		
Median (IQR)	18 (3)	17 (3)	*U*(80) = 551.5	.016
WMS-III	*n* = 38	*n* = 42		
Family Pictures scaled scores (Mean, *SD*)	8.7 (2.4)	7.3 (1.9)	*t*(78) = −2.99	.004

Note. DS = dissociative seizures; *SD* = standard deviation; *df* = degrees of freedom; IQR = interquartile range; WASI = Wechsler Abbreviated Scale of Intelligence; FSIQ = Full-scale Intelligence Quotient; VOSP OD = Visual Object and Space Perception Battery – Object Decision subtest; WMS-III = Wechsler Memory Scale – Third Edition.

Arousal

A mixed factorial ANOVA revealed no significant main effect of group, $F(1, 79) = 1.104$, $p = .297$, $\eta_p^2 = .014$. Again, there was a highly significant main effect of condition, $F(3.101, 244.201) = 129.425$, $p < .001$, $\eta_p^2 = .621$, but no group × condition interaction, $F(3.101, 244.941) = 2.206$, $p = .086$, $\eta_p^2 = .027$. None of the possible covariates were significant.

Skin conductance measures

Table 4 shows the descriptive statistics for the SCR measures described below.

Skin conductance levels

Of the possible covariates (see above), only HADS Depression scores covaried significantly with SCLs, $F(1, 76) = 9.06$, $p = .004$, $\eta_p^2 = .107$. Higher depression scores were associated with reduced SCLs at both time points. With HADS Depression scores controlled for in an ANCOVA, a non-significant trend was noted for elevated SCLs in the DS group relative to controls, $F(1, 76) = 3.57$, $p = .063$. $\eta_p^2 = .045$. There was a highly significant effect of time, $F(1, 76) = .67.96$, $p < .001$, $\eta_p^2 = .472$, with higher values in the task compared to at baseline. However, there was no group × time interaction, $F(1, 76) = .236$, $p = .129$, $\eta_p^2 = .030$.

Skin conductance responses

Percentage of positive SCRs.   There were no main effects of group, $F(1, 77) = .190$, $p = .664$, $\eta_p^2 = .002$, or condition, $F(4, 308) = 1.63$, $p = .166$, $\eta_p^2 = .021$ on the proportion of positive SCRs observed. No group × condition interaction was observed either, $F(4, 308) = .856$, $p = .491$, $\eta_p^2 = .001$.

HADS Anxiety was a marginally significant covariate, $F(1, 76) = 3.95$, $p = .05$, $\eta_p^2 = .049$, and HADS Depression was a significant covariate, $F(1, 76) = 9.04$, $p = .004$, $\eta_p^2 = .106$; however, there was no significant group main effect with either of these covariates included.

Table 3. Subjective ratings: valence and arousal

	Valence ratings (0–9; negative–positive, mean (*SE*))	Arousal ratings (0–9; low–high, mean (*SE*))
Group		
DS	4.97 (.074)	4.87 (.14)
Controls	5.17 (.072)	5.07 (.135)
Condition		
Neutral	5.24 (.086)	4.08 (.138)
Negative High Arousal	2.24 (.123)	7.21 (.137)
Negative Low Arousal	3.82 (.101)	5.34 (.147)
Positive High Arousal	6.66 (.108)	5.25 (.175)
Positive Low Arousal	7.4 (.110)	2.95 (.186)

Note. DS = dissociative seizures; *SE* = standard error.

Amplitude. The analyses of SCR amplitude data were conducted with a subsample of participants from each group, as amplitude values are calculated from positive SCRs only (Dawson *et al.*, 2000; see Methods section above); therefore, participants from both groups who did not respond with a positive SCR in every condition were necessarily excluded. The participants included from both the DS and control groups can, therefore, be termed 'autonomic responders'. There were 20 'responders' and 19 'non-responders' in the DS group, and 23 'responders' and 15 'non-responders' in the control group. There was no significant difference in the proportion of 'autonomic responders' in each group, $X^2(1, 79) = 1.01, p = .314$.

HADS Depression scores were the only significant covariate, $F(1, 40) = 4.19, p = .047$, $\eta_p^2 = .095$, of SCR amplitudes in the 'autonomic responders', with higher HADS Depression scores associated with reduced SCR amplitudes in all conditions across groups. With HADS Depression scores controlled for in an ANCOVA, the main effect of group was significant, $F(1, 40) = 5.86, p = .02, \eta_p^2 = .128$, reflecting significantly higher SCR amplitudes in the DS 'autonomic responders' group (mean = 0.789, *SE* = .105), relative to the control 'autonomic responders' group (mean = .421, *SE* = .097). The between-group (DS vs. control) effect on SCR amplitudes in the 'autonomic responders' subgroups remained significant when AED use, $F(1, 39) = 6.24, p = .017, \eta_p^2 = .138$, or antidepressant use was entered into the model, $F(1, 39) = 6.61, p = .014, \eta_p^2 = .145$, to control for the possible influence of these medications on the autonomic nervous system.

There was also a main effect of condition, $F(3.29, 131.605) = 2.81, p = .037$, $\eta_p^2 = .066$, reflecting significantly higher SCR amplitudes for the negative high-arousal condition relative to the neutral ($p = .023$), negative low-arousal ($p = .018$), and positive low-arousal ($p = .038$) conditions. However, the group × condition interaction was not significant, $F(3.29, 131.605) = 2.28, p = .077, \eta_p^2 = .054$.

Characteristics of 'autonomic responders' and 'non-responders'. Exploratory analyses assessed possible differences in demographic and/or clinical variables between 'autonomic responders' and 'non-responders' between- and within-DS and control groups (Data S5). Between-group (DS vs. HC) differences in anxiety, depression and cognitive abilities in the 'autonomic responders' subgroup largely replicated the differences observed in the overall sample, including significantly higher scores on

Table 4. Skin conductance measures

	n	DS	Controls
SCLs in microSiemens (μS) (Mean, SD)	DS = 39 Control = 40	Baseline = 1.07 (1.31) Task = 6.21 (5.41)	Baseline = 1.03 (1.22) Task = 6.04 (4.49)
Percentage of trials with positive SCRs (0–100%) (Mean, SD)	DS = 39 Control = 40	Neutral: 30.3 (29.3) Negative High: 35.5 (30.4) Negative Low: 38.5 (25.5) Positive High: 39.7 (26.7) Positive Low: 34.7 (29.1)	Neutral: 34.2 (26.7) Negative High: 42.3 (28.1) Negative Low: 35.7 (23.9) Positive High: 38.6 (26.2) Positive Low: 38.4 (26.6)
SCR amplitude in μS (Mean, SD)	DS = 20 Control = 23	Neutral: .604 (.83) Negative High: .845 (.733) Negative Low: .539 (.44) Positive High: .903 (1.17) Positive Low: .649 (.595)	Neutral: .417 (.45) Negative High: .657 (.624) Negative Low: .512 (.443) Positive High: .433 (.417) Positive Low: .437 (.399)

Note. SD = standard deviation; IQR = interquartile range; Mdn = median; SCL = skin conductance level; SCR = skin conductance response; DS = dissociative seizures.

HADS Anxiety (p = .002) and Depression scores (p = .002), VOSP Object Decision (p = .019), WMS-III Family Pictures 1 (p = .038), and YoE (p = .024) in the DS 'autonomic responders'. However, as described in the above section, only HADS Depression scores significantly covaried with SCR amplitudes.

Analyses of the subjective ratings of arousal and valence in the 'autonomic responders' and 'non-responders' were also carried out within and between groups (DS and control). These analyses showed that, in the 'autonomic responders' subgroup, there were no significant between-groups (DS vs. control) differences in subjective emotional ratings (i.e., valence and arousal) for any condition. There were also no significant differences in these ratings when comparing 'autonomic responders' and 'non-responders' within each group (DS or control).

However, within the DS group, there was a non-significant trend (p = .054) towards lower ratings of arousal for the negative high-arousal condition in DS 'autonomic responders' compared to DS 'non-responders'. Furthermore, within the DS 'autonomic responders' subgroup, SCR amplitude values for the negative high-arousal condition were positively correlated with ictal autonomic arousal symptoms (during patients' most severe seizures; r = .611, p = .007).

Within the 'non-responders' subgroup, there were between-group (DS vs. control) differences in subjective ratings of valence for the negative low-arousal (p = .007) and positive high-arousal (p = .042) conditions, reflecting lower (more negative) ratings in the DS 'non-responders' relative to the control 'non-responders'. In addition, a non-significant trend for higher arousal ratings was observed in DS 'non-responders' relative to control 'non-responders' in the negative low-arousal condition (p = .054).

Discussion

This study was conducted with the aim of further understanding differences in emotional processing in patients with DS. Specifically, we sought to identify whether there were differences in subjective and autonomic responses to consciously processed emotional images. The study did not provide evidence for abnormalities in subjective responses to affective images in the DS group as a whole, but did suggest heightened autonomic arousal responses to these stimuli in a subgroup of 'autonomic responders' with DS. Importantly, these findings could not be explained by group differences in education, general psychopathology (i.e., anxiety and depression), cognitive functioning, or medication.

Subjective responses
The lack of overall group effects for subjective valence ratings was not consistent with the hypotheses of the present study. Similarly to Roberts *et al.* (2012), the current findings suggest that a fundamental qualitative difference in the valence of subjective (conscious/explicit) responses to general emotional scenes is not a specific feature of patients with DS, as a group. Furthermore, the lack of between-group differences in subjective arousal ratings indicated that the conscious experience of emotional arousal in response to the images was also unaffected in the DS group, in accordance with self-reported scores on the Affect Intensity Measure (Urbanek, Harvey, McGowan, & Agrawal, 2014). Our finding is contrary to that of Roberts *et al.* (2012) who, using a similar paradigm, found that patients with DS perceived greater arousal for positive and neutral images. The differences in findings could be due to methodological issues, such as the particular images included in

the respective experiments, the ways in which the stimuli were grouped into conditions (i.e., valence, arousal, or both), differences in the Likert scales, or the nature of the control groups included in the two studies. Additional studies of this nature could valuably elucidate further the subjective experience of emotional arousal in this group.

Autonomic measures

There were no between-groups differences in the proportion of participants showing positive SCRs to the IAPS stimuli. Therefore, a diagnosis of DS is not associated specifically with an alteration in the likelihood of autonomic responses to general affective scenes. However, examination of SCR amplitudes in the 'autonomic responders' subgroup only revealed a significant group effect (DS vs. control). 'Autonomic responders' in the DS group had significantly higher mean SCR amplitudes than 'autonomic responders' in the control group, and this finding could not be explained by any of the possible confounding variables measured in the study (i.e., depression, anxiety, cognitive abilities, age, and medication).

Such a tendency towards elevated autonomic affective responding could act as a triggering factor in some patients with DS, by increasing overall arousal levels and thereby increasing the likelihood of seizure occurrence. Indeed, the positive association between SCR amplitudes for negative high-arousal images and ictal autonomic arousal symptoms in the DS 'autonomic responders' provides preliminary support for this suggestion. Of particular note was the trend towards reduced arousal ratings for negative high-arousal images in the DS 'autonomic responders' compared to the DS 'non-responders'. This subgroup of 'autonomic responders' with DS, who show increased autonomic responding to affective images compared to healthy control 'autonomic responders', therefore, also seems to report reduced subjective intensity of emotional arousal to the most unpleasant of the images. These findings require replication and further exploration in studies involving larger samples to increase statistical power.

An unexpected but interesting finding was that there were significant between-group (DS vs. control) differences in some subjective ratings in the 'non-responders' subgroup, reflecting more negative ratings of negative low-arousal and positive high-arousal pictures, in addition to higher ratings of arousal for the negative low-arousal pictures. Together, these findings suggest that within our DS sample, there were two overall patterns of emotional responding. One group displayed heightened autonomic reactions with intact or possibly blunted subjective responses (i.e., the DS 'autonomic responders' subgroup), whereas the other group showed fewer autonomic responses combined with altered subjective responses (i.e., the DS 'non-responders' subgroup). These findings could be interpreted as evidence for a lack of integration between subjective and physiological aspects of emotional processing. These subgroups might differ in 'trait' emotional responding; however, it is also possible that DS patients as a group might experience shifts in emotional responding, at the 'state' level. Hypothetically, 'state' changes in emotional processing could be linked to the occurrence of seizures and/or changes in dissociative symptoms, as has been observed in borderline personality disorder (Ebner-Primer *et al.*, 2009).

Strengths and limitations

To our knowledge, this is one of only two studies that have examined emotional responding to general affective stimuli in this patient group, using experimental methods.

This has extended previous research in this field, which had focused on emotional facial expressions only, or relied on self-report measures of emotional processing. An additional strength was the use of five separate conditions, in which not only valence, but also arousal levels were manipulated. Furthermore, the inclusion of both subjective and autonomic measures of emotional responding allowed simultaneous assessment of these response domains in the same participants. Additionally, the administration of relevant cognitive tests ensured that any group differences observed could not be attributed to possible confounding cognitive impairments. The use of statistical control for relevant psychological variables (i.e., depression and anxiety) also allowed a rigorous test of the hypothesis that differences were associated with a diagnosis of DS, over and above the presence of general psychological distress in the DS group. Furthermore, consideration of the possible effects of medication on the positive findings in this study also increased the interpretability of the results.

A possible limitation of the study was that, to ensure the emotional well-being of participants, we excluded images that might have caused acute emotional distress (e.g., possibly trauma-relevant images). However, patients with DS may differ from controls specifically in their responses to such stimuli, for example, those depicting scenes of interpersonal conflict or threat. It may be valuable to select stimuli that are specifically relevant to this patient group in future studies, although ethical issues would need careful consideration.

Another possible weakness of the study could be a loss of power linked to the inclusion of five different emotional conditions, in addition to covariates. Whilst this allowed a more detailed analysis of the possible effects of valence and arousal level, and stringent control of possible confounds, categorizing stimuli on just one of these dimensions or including fewer covariates may have allowed the retention of greater statistical power. It should be noted that the exploratory correlational analyses with SCR amplitudes may also have been statistically underpowered due to the reduced sample size. Future studies with larger samples would be informative.

Conclusions

The findings suggest that as a group, patients with DS are similar to healthy controls in their subjective emotional reactions to general affective images, but that there may be different patterns of emotional responding in subgroups of patients. In one subgroup of 'autonomic responders' with DS, elevated autonomic responses to the affective stimuli occurred in the absence of altered subjective emotional experience. In contrast, another subgroup displayed fewer autonomic responses to the emotional stimuli, combined with altered (more negative and aroused) subjective responses. Together, these findings indicate a lack of integration of the somatic and subjective aspects of emotional processing in these subgroups, with one subgroup experiencing emotions more somatically and the other experiencing emotions more subjectively. The findings require replication and further examination, particularly with regard to whether these patterns are associated with state or trait differences in emotional responding. Possible clinical implications include the value of targeting awareness and regulation of both physiological arousal and subjective emotional experience in treatments for the disorder.

Acknowledgements

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Supporting Information

The following supporting information may be found in the online edition of the article:

Data S1. International Affective Picture System (IAPS, Lang *et al.*, 2005) stimuli.

Data S2. Digitised Self-Assessment Manikins (SAM).

Data S3. Skin conductance (SC) measures: acquisition, extraction and reduction.

Data S4.
Figure 1. Flow diagram illustrating between-group analyses of participant characteristics.
Figure 2. Flow diagram illustrating statistical analyses of subjective valence ratings.
Figure 3. Flow diagram illustrating statistical analyses of subjective arousal ratings.
Figure 4. Flow diagram illustrating statistical analyses of skin conductance levels (SCLs).
Figure 5. Flow diagram illustrating statistical analyses of skin conductance response (SCR) frequency (% trials with a positive SCR).
Figure 6. Flow diagram illustrating statistical analyses of SCR amplitudes (autonomic responders only).
Figure 7. Flow diagram illustrating statistical analyses of *post-hoc* between-group comparisons of autonomic responders and non-responders.

Data S5.
Table 1. Characteristics of 'autonomic responders' and autonomic 'non-responders' in the DS and control groups.
Table 2. Subjective ratings of valence and arousal in 'autonomic responders' and 'non-responders' in the DS and control groups.