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TIME PERCEPTION, IMPULSIVITY, EMOTIONALITY, AND PERSONALITY IN SELF-HARMING BORDERLINE PERSONALITY DISORDER PATIENTS

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To investigate how time perception may contribute to the symptoms of self-harming Borderline Personality Disorder (BPD) patients, 19 self-harming BPD inpatients and 39 normal controls were given measures of time perception, impulsivity, personality, emotion, and BPD characteristics. A test sensitive to orbitofrontal cortex (OFC) function ("Frontal" Behavior Questionnaire) was also administered, as the OFC has been associated with impulsivity and time perception.

BPD patients produced less time than controls, and this correlated with impulsiveness and other characteristics commonly associated with BPD. BPD patients were also less conscientious, extraverted, and open to experience, as well as more impulsive (self-report and behaviorally), emotional, neurotic, and reported more BPD characteristics, compared to controls. The results suggest that some of these core characteristics of BPD may be on a continuum with the normal population and, impulsivity in particular, may be related to time perception deficits (i.e., a faster subjective sense of time). Finally, BPD patients scored higher on the Frontal Behavior Questionnaire, suggesting that some symptoms of the BPD syndrome may be related to problems associated with the OFC. A control spatial working memory task (SWM) revealed that SWM deficits could not explain any of the BPD patients' poor performance.

While impulsivity was correlated with time perception across all participants, emotionality, introversion, and lack of openness to experience were not. This suggests that different symptoms of the borderline personality syndrome may be separable, and therefore, related to different cognitive deficits, and potentially to different brain systems. This may have important implications for treatment strategies for BPD.

Time perception deficits have been related to impulsiveness in normal subjects (Stanford & Barratt, 1996; Barratt, 1983; Barratt & Patton, 1983). In

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particular, the cognitive tempo (internal clocks) of impulsive individuals may be faster than that of nonimpulsive individuals (Barratt & Patton, 1983), so an impulsive individual would be likely to *overestimate* and *underproduce* time intervals (see further Van den Broek, Bradshaw, & Szahadi, 1987, 1992, and Discussion).

Since self-harming Borderline Personality Disorder (BPD) patients often display severe impulsivity, as exhibited by their self-harming behavior, and impulsivity is a core symptom for the diagnosis of BPD (APA, 1994), we investigated whether self-harming BPD patients also have time perception deficits and if so, which specific symptoms of BPD are related to time perception. This was done by administering time estimation and production tasks, along with measures of impulsivity, emotion, and personality to self-harming BPD inpatients ($n = 19$) and normal controls ($n = 39$). Part of the aim was to investigate whether the type of impulsivity present in these self-harming patients, assessed with several different measures, was associated with time perception differences from normal control participants. Further, since it has been suggested (O'Leary, Brouwers, Gardner, & Cowdry, 1991; Burgess, 1991) that memory may contribute to some of the deficits demonstrated by BPD patients, a Spatial Working Memory control task was administered to determine if spatial working memory or time perception is related to certain BPD symptoms.

Additionally, since patients with orbitofrontal cortex damage have been shown to act impulsively and have time perception deficits (Berlin, Rolls, & Kischka, 2004; Mimura, Rinsbourne, & O'Connor, 2000), a questionnaire designed to assess the types of behavioral problems, especially social, generally believed to result from orbitofrontal cortex damage (Rolls, Hornak, Wade, & McGrath, 1994; Hornak et al., 2003) was administered to determine if some aspects of the BPD syndrome, in particular impulsivity, and possibly time perception deficits, are related to orbitofrontal cortex dysfunction.

Finally, by comparing impulsive BPD patients to normal participants on the same set of neuropsychological measures, including a questionnaire designed to measure BPD characteristics (Claridge & Broks, 1984), we aimed to determine whether the impulsivity, emotionality, and personality abnormalities exhibited by clinical BPD patients are dimensions that occur on a continuum with those found in the normal population (see Pukrop, 2002). Also to determine whether different symptoms of the BPD syndrome can be separated, the correlations between "frontal" behaviors, time perception, emotion, impulsivity, and personality, were explored.

METHODS

PARTICIPANTS

Ethics approval was obtained from the Department of Experimental Psychology (University of Oxford), the Ethical Committee (Research) of the Institute of Psychiatry (King's College London), and the Oxfordshire Psychiatric Research Ethics Committee. All participants gave written informed consent before testing began.

Normal Control Participants

Thirty-nine participants (10 male, 29 female) were included in this group, ranging in age from 18 to 71 (M = 40.3, SD = ±20.5). Participants were excluded if they had disturbed vision (despite corrective devices), had a history of or current neurological illness, a current major psychiatric illness, or current substance or alcohol abuse.

Borderline Personality Participants

Nineteen (1 male, 18 female; BPD is more prevalent, being diagnosed about 75% of the time, in females; APA, 1994) self-harming BPD in-patients, aged between 19 and 49 (M = 32.37, SD = ± 8.4), who met the criteria for BPD set in the DSM-IV (APA, 1994) as determined by a psychiatrist, were tested at the Bethlem Royal Hospital Crisis Recovery Unit, London (a 6-month rehabilitation program where they were taught to seek alternatives to self-harm, gain a greater understanding of the meaning self-harm has for them, and tolerate distressing feelings). Cutting and burning were among the most common forms of self-harm in the patients tested. This objective measure of impulsive behavior used in addition to the DSM-IV criterion was important in obtaining a homogenous patient group.

Participants were excluded on the same criteria as the normal control participants except that they had been diagnosed as having Borderline Personality Disorder. (While most BPD patients were on medications aimed at improving their BPD symptoms, they still performed poorly on tasks related to impulsivity, emotion, and personality, and not on others such as Spatial Working Memory.)

MATERIALS AND PROCEDURES: QUESTIONNAIRES

(1) Frontal Behavior Questionnaire

This self-report, 20-item, 5-point Likert scale (0, .25, .5, 1.0, & 1.5) questionnaire was designed to measure types of behavioral problems, especially social, generally believed to result from prefrontal cortex damage (Levin, Goldstein, Williams, & Eisenberg, 1991), such as disinhibition, social inappropriateness, perseveration, and cooperativeness. It was developed based on an informant report behavioral questionnaire in Rolls et al. (1994) and Hornak et al. (2003), which in the self-report form used here is sensitive to orbitofrontal cortex damage (Berlin, Rolls et al., 2004).

(2) Borderline Personality Questionnaire

Developed at the University of Oxford by Claridge & Broks (1984), the self-report Borderline Personality Questionnaire (STB), modeled on the DSM-III (APA, 1980) criteria for BPD, assesses BPD characteristics. The STB is made up of 18 questions with simple “yes” and “no” answers. A study by Shankar (1998) of clinically diagnosed BPD patients has supported the construct and discriminant validity of the STB.

3) Self-report Impulsivity Measure: Barratt Impulsiveness Scale
The Barratt Impulsiveness Scale, version 11 (BIS-11; Patton, Stanford, & Barratt, 1995; Moeller, Barratt, Dogherty, Schmitz, & Swann, 2001) is a 30-item, 4-point Likert scale questionnaire that assesses long-term patterns of behavior by asking subjects questions about the way they think and act without relation to any specific time period. Thus, it tends to be used as a trait measure of impulsivity. The BIS-11 is made up of three subscales: nonplanning impulsivity (attention to details), motor impulsivity (acting without thinking), and cognitive impulsivity (future oriented thinking and coping stability).

4) Personality Questionnaire: The Big Five Inventory
The Big Five Inventory (BFI; John, Donahue, & Kentle, 1991; John and Srivastava, 1999) was constructed as a compromise between Goldberg's (1992) conception of the basic five traits as broad domains of individual differences found in self-rating measures of personality trait adjectives; and McCrae and Costa's (1996) Five Factor Model of Personality, in which the traits are taken more seriously as basic organic structures inherent in all humans. It is a 44-item, 5-point Likert scale questionnaire designed to measure the five scales or broad domains of the Five Factor Model:

(1) Extraversion: talkative, energetic, enthusiastic, adventurous, outgoing (vs. introversion)
(2) Agreeableness: helpful, trusting, forgiving, considerate, cooperative (vs. antagonism)
(3) Conscientiousness: thorough, reliable, persevering, efficient, organized (vs. lack of direction/careless)
(4) Neuroticism: gloomy, tense, worrying, moody, nervous, unstable (vs. emotionally stable/relaxed)
(5) Openness to experience: wide interests, original, curious, artistic, imaginative, inventive, idealistic (vs. closed to experience)

5) Subjective Emotion Questionnaire
This questionnaire measures, on a 4-point Likert scale, *how often* participants experience each of the following emotions in their current daily life: sadness, anger, fear, happiness, and disgust. This questionnaire was developed based on a verbal subjective emotion test in Rolls et al., (1994) where participants were questioned about any *change* they experienced in the intensity or frequency of each of the five emotions mentioned above since their brain injury. The total subjective emotion score as well as the subjective sadness, anger, fear, happiness, and disgust subscores were recorded (for more detail, see Berlin, Rolls et al., 2004).

MATERIALS AND PROCEDURES: TESTS

(1) Time Perception Task
The time perception task designed for this study was made up of three parts; time estimation, time production, and time pacing.

Time Estimation. Participants were told before each trial that it was a time estimation task (prospective time estimation). Participants were asked to estimate time intervals (10, 30, 60, and 90 seconds; each presented twice in a random sequence), during which they were distracted by reading aloud randomized numbers (1-9) from a computer screen, which ranged in presentation time from 100 to 2,900 milliseconds, in order to prevent subvocal counting. Stimuli were presented at random times to prevent participants from using pacing as a marker for time. The number of seconds estimated after each interval, averaged across two runs, and the total time estimated (sum of the average times estimated at each interval divided by 190 [the total number of seconds that actually passed]) were recorded.

For one retrospective 10-second interval (the first interval presented) participants read aloud each number presented but were not told it was a time estimation task until they were asked at the end of the interval how much time they thought had passed.

Time Production. This was the same as the time estimation task (reading aloud randomized numbers from a computer screen) except participants were asked to say "stop" when they thought a set number of seconds had passed. For each time interval, the time produced was compared to the actual time interval participants were asked to produce (there was no retrospective interval). The number of seconds produced at each interval, averaged across two runs, and the total time produced (sum of the average times produced at each interval divided by 190 [the total number of seconds participants were asked produce]) were recorded.

Time Pacing. Participants were asked to count out loud starting from 1 going upward consecutively at what they felt was a 1-second rate and to stop counting when the experimenter said "stop." No distracter task was used. Time intervals were the same as for the time estimation and production tasks, but each interval was presented only once in a random sequence. Participants were asked to start counting from 1 at the beginning of each new trial. The total number of seconds that actually passed across all four time intervals (190) divided by the total number of seconds counted by the participant across all four time intervals (the average concept of a second or cognitive pace) was recorded.

Long-Term Time Estimation. At the end of the entire time perception experiment (at about 20 minutes), participants were asked "How much time do you think has passed from the moment we started the time task until now?" Their response was recorded and compared to the actual time that had passed.

2) Matching Familiar Figures Test

This standard cognitive behavioral measure of impulsivity, created by Kagan (1966), measures reflection-impulsivity, operationally defined as a composite of two dimensions: latency to first response and accuracy of choice or total errors, which are combined in the Matching Familiar Figures Test (MFFT). Each participant selects (points to), from the set of highly similar pictures, the one that is exactly the same as the standard picture. Participants were given 12 trials with 8 variants each from which to choose, with a different target object for each trial. Mean time latency of the participants'

first response across all trials and number of errors made before choosing the correct item were recorded.

(3) Spatial Working Memory Task

This task, from the Cambridge Neuropsychological Test Automated Battery (CANTAB; CeNeS Ltd, Cambridge), was carried out on a computer with a touch screen attached. Participants were asked to find a blue token in each of the boxes displayed and use them to fill up an empty column on the right side of the screen, while not returning to boxes where a blue token had previously been found. The color and the position of the boxes changed from trial to trial to discourage the use of stereotyped search strategies. Subjects were given four trials with four boxes, four trials with six boxes, and four trials with eight boxes. The following variables were obtained:

(1) Between errors: The number of times the subject revisits a box in which a token has already been found.
(2) Within errors: the number of times a subject revisits a box already found to be empty during the same search.
(3) Strategy: Owen, Downes, Sahakian, Polkey, & Robbins (1990) have suggested that an efficient strategy for completing this task is to follow a predetermined sequence by beginning with a specific box and then, once a blue token has been found, to return to that box to start the new search sequence. An estimate of the use of this strategy is obtained by counting the number of times the subject begins a new search with the same box. A high score denotes poor use of this strategy.

STATISTICAL ANALYSES

Two-tailed *t*-tests were performed on each of the variables to determine if the mean scores differed significantly by group. The tests did not assume homogeneity of variances. A Bonferroni Correction was applied, and resulted in the critical α level moving from .05 to .004 (indicated by ** in Tables 1, 2, and 3). Some comparisons are mentioned where $p < .05$ if they were designated a priori to be interesting.

Two-tailed *t*-tests revealed no between-group differences in terms of age or gender. In addition, ANCOVAs with age and gender identified as the covariate respectively, performed on all variables that were significantly correlated with age or gender, revealed that none of the significant differences between groups was due to the effect of age or gender (except Neuroticism was related to age). In a small number of instances, participants did not complete all the tasks due to testing time constraints.

To investigate the relationships between the different measures, Pearson correlations (2-tailed) were performed across all participants, for the total score or main variable of each measure (variables *within* each measure were significantly correlated with each other). Correlations were not performed within each participant group because the number of variables being tested would have been too large compared to the number of participants in each group to yield reliable significant results.

TABLE 1. Means, Standard Deviations, and *t* and *p* Values of Variables that Revealed Significant-Between Group Differences

	M ≤ *SD*			
Variable	**Normal group**	**BPD group**	***t* value**	***p* <**
Total time production	1.44 ≤ .42	1.11 ≤ .28**	3.54	.002
Time production at 10 seconds	18.0 ≤ .35	15.1 ≤ .90*	2.93	.02
Time production at 30 seconds	47.8 ≤ 15.3	38.9 ≤ 9.0*	2.77	.009
Time production at 60 seconds	83.9 ≤ 26.2	64.7 ≤ 15.4**	3.47	.002
Time production at 90 seconds	124.2 ≤ 39.5	91.5 ≤ 31.3**	3.10	.003
Frontal behavior questionnaire score	9.25 ≤ 2.0	13.3 ≤ 3.3**	-5.85	.001
BPD questionnaire score	5.18 ≤ 3.20	13.0 ≤ 2.8**	-7.79	.001
Self-report impulsivity total score	60.1 ≤ 9.5	83.0 ≤ 10.1**	-8.44	.001
Non-planning impulsivity subscore	22.4 ≤ 4.6	33.4 ≤ .4.7**	-8.54	.001
Motor impulsivity subscore	22.1 ≤ 3.5	27.8 ≤ 3.8**	-5.72	.001
Cognitive impulsivity subscore	15.7 ≤ 3.1	21.8 ≤ 4.0**	-6.39	.001
Total errors per second on the MFFT	.27 ≤ .48	.64 ≤ .65*	-2.20	.04
Total number of errors on the MFFT	8.21 ≤ 6.0	13.0 ≤ 8.2*	-2.50	.02
Mean time latency on the MFFT	55.6 ≤ 30.7	34.8 ≤ 19.9**	3.10	.004
Extraversion	25.7 ≤ 6.81	17.1 ≤ 4.86**	4.94	.001
Conscientious	33.6 ≤ 6.44	23.5 ≤ 6.40**	5.63	.001
Openness to experience	38.7 ≤ 6.3	31.5 ≤ 6.7**	4.01	.001
Neuroticism	23.4 ≤ 6.8	36.3 ≤ 3.0**	-7.87	.001
Total subjective emotion score	5.26 ≤ 1.4	8.79 ≤ 2.3**	-7.32	.001
Sadness subscore	1.15 ≤ .63	2.16 ≤ .69**	-5.53	.001
Anger subscore	.74 ≤ .55	2.00 ≤ 1.1**	-5.99	.001
Fear subscore	.62 ≤ .67	2.16 ≤ .96**	-7.10	.001
Disgust subscore	.62 ≤ .54	1.63 ≤ 1.1**	-3.76	.001
Happiness subscore	2.13 ≤ .52	.84 ≤ .50**	8.92	.001

Note. *$p<.04$; for all *t* values $df = 56$, except for time production variables ($df = 55$), and the BPD questionnaire ($df = 34$); **$p < .004$ corresponding to $p < .05$ after Bonferroni correction.

RESULTS

Means, standard deviations, and *t* and *p* values of all significant results are presented in Table 1.

TIME PERCEPTION

BPD patients had a more precise perception of time in that they produced less time than normal controls in total, and at 10-, 30-, 60- and 90-second time intervals (see Table 1), and produced intervals closer to the actual time interval. The difference became more apparent the longer the time interval became. BPD patients had no time estimation differences from controls in terms of total time estimated ($M = 0.96$, $SD = \pm 0.56$ vs. $M = 0.72$, $SD = \pm 0.35$; *ns*) and time estimated at each interval, and there was no difference between retrospective and prospective time estimation at 10 seconds across and within participant groups.

FRONTAL BEHAVIOR CHARACTERISTICS

BPD patients scored higher on this questionnaire designed to measure behaviors exhibited after prefrontal cortex damage than normal participants

TABLE 2. Means, Standard Deviations, and *t* and *p* Values of Individual Questions on the Frontal Behavior Questionnaire That Revealed Significant Between-Group Differences

	M ≥ *SD*			
Question	**Normal group**	**BPD group**	***t* value**	***p* <**
1. Do you ever feel that you do or say things but would rather stop yourself?	.42 ≥.32	.79 ≥.35**	-4.03	.001
3. Do you ever feel like acting violently when you don't get what you want?	.23 ≥.28	.59 ≥.53*	-2.76	.02
5. Do you ever get angry or irritable?	.48 ≥ .22	.89 ≥.45**	-3.78	.002
6. Do you ever misinterpret people's moods?	.44 ≥ .20	.91 ≥ .40**	-4.83	.001
8. If you don't get an expected reward that you want do you try harder to get it?	.84 ≥ .45	.51 ≥.37*	2.75	.009
11. Do you ever feel listless?	.47 ≥ .29	.99 ≥ .43**	-4.76	.001
12. Do you ever feel full of energy?	.60 ≥ .32	1.01 ≥.41**	-4.21	.001
17. Do you stop to think before you act?	.79 ≥ .38	.36 ≥ .30**	-4.75	.001
18. Do you stop to think before you take a decision?	.67 ≥ .30	.24 ≥ .27**	-5.55	.001

Note. *$p < .04$; **$p < .004$. For all t values $df = 56$.

(see Table 1). Analysis of participants' responses to individual questionnaires (see Table 2) showed that BPD patients felt that they often: do or say things but would rather stop themselves (question 1); feel like acting violently when they don't get what they want (question 3); get angry or irritable (question 5); misinterpret other people's moods (question 6); try less hard to get a reward if they don't get an expected reward that they want (question 8); feel listless (question 11); don't feel full of energy (question 12); don't stop and think before they act (question 17); don't stop and think before they make a decision (question 18). (Note: questions 12, 17, and 18 were reversed-scored).

Groups did not differ in terms of how often they do things that they find somewhat inappropriate in the company of other people (question 2); stick to their point no matter what, when they feel that they are right (question 7); try something else when they don't get an expected reward (question 9); worry about themselves (question 10); do not feel like co-operating when asked to (question 13); show their emotions in their facial expressions (question 14); can predict someone else's mood from their facial expression (question 15); stop to help someone who looks upset (question 16); like gambling (question 19); and take risks when they gamble (question 20).

BPD CHARACTERISTICS

BPD patients scored higher than normal controls on this questionnaire designed to measure BPD characteristics (see Table 1). This helps to validate this questionnaire (Claridge & Broks, 1984).

Impulsivity. BPD patients were more impulsive than normals both in terms of their self-report impulsivity total score (including nonplanning,

TABLE 3. Correlation Matrix of the Most Salient Variables of Each Measure Across all Subjects

		SRI	E	A	C	N	O	FBQ	SE	BPD	BI	SWM	TEtotal	TPtotal
SRI	*r* =	1												
	p =	—												
	N	58												
E	*r* =	**-.519**	1											
	p =	**.000**	—											
	N	**58**	58											
A	*r* =	-.251	.367*	1										
	p =	.057	.005*	—										
	N	58	58	58										
C	*r* =	**-.807**	**.463**	**.377**	1									
	p =	**.000**	**.000**	**.004**	—									
	N	**58**	**58**	**58**	58									
N	*r* =	**.604**	**-.692**	-.357*	**-.530**	1								
	p =	**.000**	**.000**	.006*	**.000**	—								
	N	**58**	**58**	58	**58**	58								
O	*r* =	**-.391**	.344*	.208	.343	-.429	1							
	p =	**.002**	.008*	.116	.008	.001	—							
	N	**58**	58	58	58	58	58							
FBQ	*r* =	**.590**	**-.436**	**-.486**	**-.513**	**.530**	**-.387**	1						
	p =	**.000**	**.001**	**.000**	**.000**	**.000**	**.003**	—						
	N	**58**	**58**	**58**	**58**	**58**	**58**	58						

SE	*r* =	**.517**	**-.485**	-.141	**-.373**	**.611**	-.309	**.529**	1					
	p =	**.000**	**.000**	.290	**.004**	**.000**	.018	**.000**	—					
	N	**58**	**58**	58	**58**	**58**	58	**58**	58					
BPD	*r* =	**.742**	-.452*	-.194	**-.651**	**.715**	-.423*	**.804**	**.751**	1				
	p =	**.000**	.006*	.256	**.000**	**.000**	.010*	**.000**	**.000**	—				
	N	**36**	36	36	**36**	**36**	36	**36**	**36**	36				
BI	*r* =	.355*	-.085	-.231	**-.368**	.332	-.227	.349*	.298	.317	1			
	p =	.006*	.527	.082	**.004**	.011	.087	.007*	.023	.059	—			
	N	58	58	58	**58**	58	58	58	58	36	58			
SWM	*r* =	-.012	-.004	.070	.052	-.134	-.117	.150	.227	.383	-.014	1		
	p =	.927	.978	.602	.701	.314	.383	.262	.086	.021	.916	—		
	N	58	58	58	58	58	58	58	58	36	58	58		
TEtotal	*r* =	.289	-.088	.002	-.362*	.192	-.176	.112	.255	.306	.303	.098	1	
	p =	.030	.513	.989	.006*	.153	.191	.405	.056	.074	.022	.469	—	
	N	57	57	57	57	57	57	57	57	35	57	57	57	
TPtotal	*r* =	-.369*	.180	.058	.338*	**-.375**	.224	-.328	-.307	**-.524**	**-.335**	-.115	**-.678**	1
	p =	.005*	.180	.670	.010*	**.004**	.094	.013	.020	**.001**	**.011**	.395	**.000**	—
	N	57	57	57	57	**57**	57	57	57	**35**	**57**	57	**57**	57

Note. Bold = Correlation significant at $p < .004$ (2-tailed); * = Correlation significant at $p < .01$ (2-tailed); total self-report impulsivity score = SRI, extraversion = E, agreeableness = A, conscientiousness = C, neuroticism = N, openness to experience = O, Frontal Behavior Questionnaire score = FBQ, total subjective emotion score = SE, BPD Questionnaire score = BPD, errors/second on the MFFT (behavioral impulsivity) = BI, between errors on the SWM task = btSWM, total time estimation = TE total, and total time production = TP total

motor, and cognitive impulsivity subscores) and in terms of their behavioral impulsivity (see Table 1). On the MFFT, BPD patients made more errors in total, had a shorter average time latency to respond than normal controls, and made more errors/second to respond.

Personality. BPD patients reported being less extraverted, conscientious, and open to experience, and more neurotic than healthy controls (see Table 1).

Emotion. BPD patients reported being more emotional than normal controls in terms of their total subjective emotion score. Specifically, BPD patients reported experiencing more sadness, anger, fear, and disgust, and less happiness than normal controls (see Table 1).

Spatial Working Memory (SWM). BPD patients were not significantly different from controls on any of the SWM measures.

Correlations. The correlation matrix is shown in Table 3. Figures 1 through 4 show scatterplots across all participants of some key correlations that provide evidence that some BPD characteristics may be on the high end of a continuum with the same characteristics that occur in the normal population (see Discussion).

DISCUSSION

The new results of this investigation included the findings that BPD patients have time production deficits, and score higher than normals on a questionnaire that assesses behaviors common in patients with orbitofrontal cortex damage. Further, this investigation revealed that BPD patients are less conscientious, extraverted, and open to experience than normal controls. In addition the BPD patients were found to be more impulsive (both self-report and behavioral), emotional, neurotic, and to score highly on a questionnaire designed to measure BPD characteristics, compared to normal controls. However, BPD patients did not have deficits on a control Spatial Working Memory (SWM) task and SWM did not correlate with any other task. Thus SWM deficits can not explain any of the poor performance of BPD patients.

TIME PERCEPTION AND IMPULSIVITY

Interestingly, BPD patients consistently produced less time across all time intervals (10, 30, 60, and 90) than normal controls and this became worse the longer the time interval became. However, BPD patients had a more precise perception of time in that they produced intervals closer to the actual time interval than normal controls. It may be that BPD patients have a faster cognitive pace so that they actually feel that the set time interval has passed earlier than normals, or they may experience increased frustration with waiting for the time interval to end so that they end it prematurely (especially at longer intervals). BPD patients also tended in the direction of overestimation of time compared to normals, which again is indicative of a faster cognitive pace (thinking that more time has passed than actually has) (although the time estimation difference did not quite reach standard criteria of statistical significance in the groups tested).

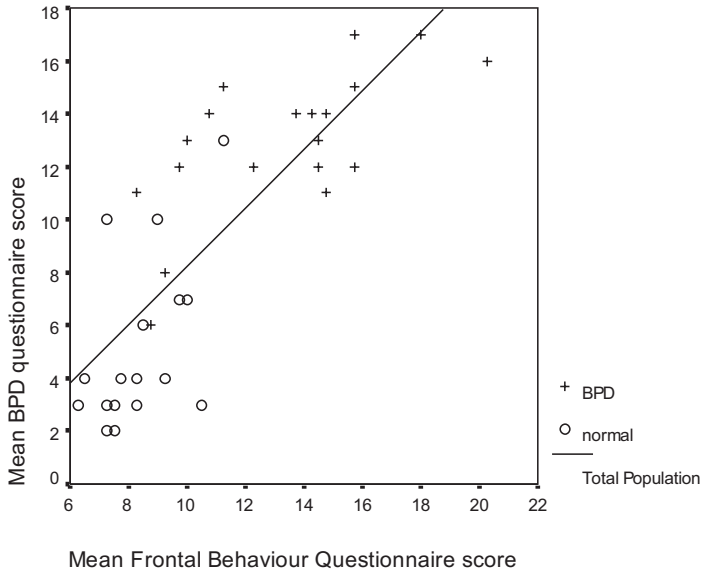

FIGURE 1. Scatter plot with the regression line shown between the mean Frontal Behavior Questionnaire and BPD questionnaire scores across all participants ($r = .80$, $p < .001$).

The increased frustration in waiting and/or faster cognitive tempo that may cause self-harming BPD patients to underproduce time intervals may be related to some of the impulsive and inappropriate social and emotional behaviors they display (demonstrated by their increased self-report (BIS-11), behavioral impulsivity (MFFT), BPD characteristics, subjective emotion, and neuroticism scores, and decreased extraversion, conscientiousness, and openness to experience, compared to normal controls). The relationship between a fast subjective sense of time and BPD is emphasized by the significant correlations between time perception and BPD characteristics. Producing shorter time intervals (in total; having a sped up sense of time or increased frustration with waiting) was correlated with increased self-report and behavioral impulsivity, neuroticism, BPD characteristics (as measured by the BPD questionnaire), and decreased conscientiousness (as was increased time estimation). Thus, time perception differences as compared to normal controls may contribute to some of the inappropriate behaviors exhibited by self-harming BPD patients, especially impulsivity. Further, it is suggested that other aspects of the BPD syndrome such as emotionality may not be related to time perception, as subjective emotion score and time production were not significantly correlated.

The fact that when compared to normals, BPD patients had time perception differences in terms of underproduction, especially at long intervals, but did not have significant time estimation differences, indicates that time production and estimation may involve different brain processes. Since BPD patients did not have SWM difficulties but did have time perception difficulties, and SWM was not correlated with time production or estimation, it

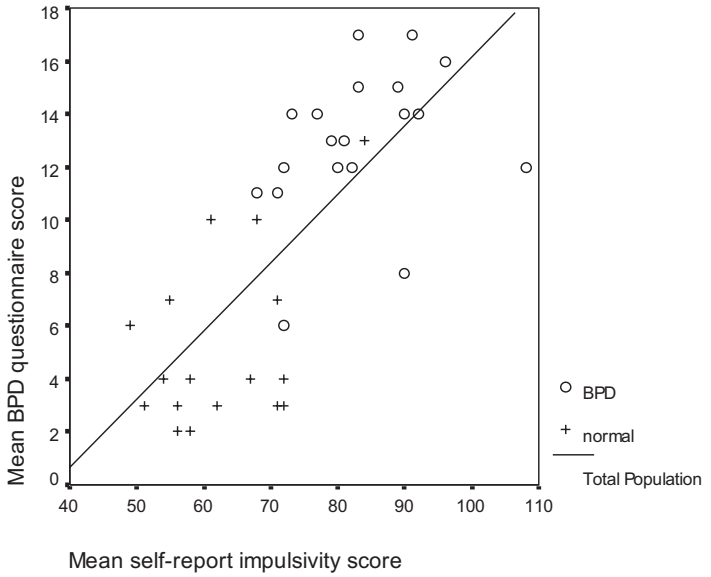

FIGURE 2. Scatter plot with the regression line shown between mean self-report impulsivity and BPD questionnaire scores across all participants ($r = .74$, $p < .001$).

seems that the brain mechanisms for time perception are different from those involved in SWM (cf. Harrington & Haarland, 1999; Rao, Mayer, & Harrington, 2001).

BPD patients were significantly more impulsive than normals on both self-report and behavioral measures of impulsivity, and both measures were correlated with each other, suggesting that BPD patients have insight into their own behaviors. Although it is well established that BPD patients are impulsive (impulsiveness is one of the diagnostic criteria of BPD), it is interesting that impulsivity was correlated with time perception in this study (see Table 3). The more impulsive a participant (both self-report and behaviorally), the less time they produced. Further, BPD patients were impulsive (both self-report and behaviorally) and produced less time than normal controls (see Table 1). This suggests that perhaps part of the reason for the impulsive behavior demonstrated by BPD patients is related to time perception deficits and supports the evidence that impulsivity and time perception are related (Barratt, 1983, 1981).

SUBJECTIVE EMOTION

BPD patients were more emotional than the normal control group in that they reported experiencing sadness, anger, fear, and disgust more often and happiness less often (Table 1). These results are consistent with the fact that a major criterion for the diagnosis of BPD is emotional instability (APA, 1994). In fact, BPD is thought by some to arise from affective vulnerability as reflected by high sensitivity to emotional stimuli and high emotional inten-

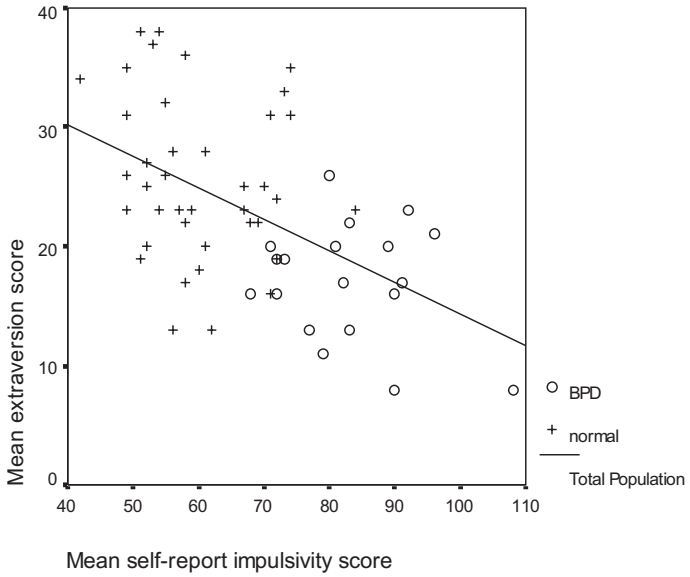

FIGURE 3. Scatter plot with the regression line shown between mean self-report impulsivity and extraversion scores across all participants (r = -.52, p < .001).

sity (Linehan, 1993; Herpertz et al., 2001). We note that the frequency and intensity of experienced emotion can be altered in patients with orbitofrontal cortex damage (Hornak et al., 2003), and note that when only frequency was used, this revealed highly significant differences between the BPD and control groups as described in this article.

The total subjective emotion score was positively correlated with self-report impulsivity across all subjects, consistent with previous indications that BPD patients' emotion and impulsivity may be interrelated (Linehan, 1987; Van Reekum, Links, & Fedorov, 1994; Herpertz, 1995; Herpertz et al. 1997). Further, increased emotionality (high score on the Subjective Emotion Questionnaire) correlated with decreased extraversion, and conscientiousness, and increased neuroticism, and BPD characteristics. Thus it seems that in BPD patients, emotional and personality abnormalities are closely related. On the other hand, emotionality was not correlated with time perception, while impulsivity was. This leads us to propose that these two symptoms of BPD (emotionality and impulsivity) may be related to different cognitive deficits, and thus potentially related to different brain systems (see Berlin, Rollls, & Iversen, in press). For example, BPD patients were more subjectively emotional than patients with orbitofrontal cortex damage, yet both patient groups were impulsive (Berlin, Rolls et al., 2004).

PERSONALITY

BPD patients were more neurotic (N), and less extraverted (E) and conscientious (C) than healthy controls. Our evidence suggests that there is a strong relationship between certain personality traits and emotions, which may be

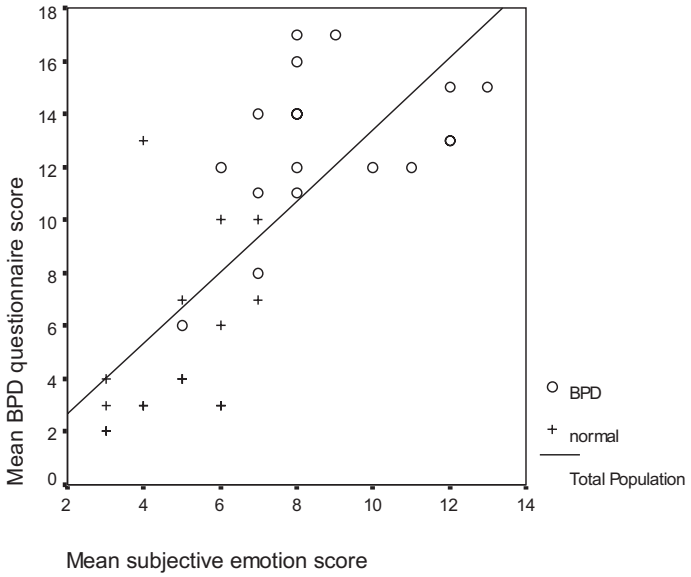

FIGURE 4. Scatter plot with the regression line shown between mean subjective emotion and BPD questionnaire scores across all participants ($r = .75$, $p < .001$).

related to the same underlying neurological correlates that are affected in BPD patients. The relationship is made apparent by the fact that BPD patients have both personality and emotional abnormalities, and by the strong correlations between the total subjective emotion score, BPD characteristics, and N, C, and E across all subjects (see Table 3).

Neuroticism. BPD patients' significantly high neuroticism (emotional instability, nervous tendency toward negative emotionality, and inability to cope; McCrea & Costa, 1996) compared to all normal controls coincides with the fact that emotional instability is one of the diagnostic criteria of BPD in the DSM-IV (APA, 1994). Indeed, our own data show that not only are the BPD patients neurotic, but they are also more emotional than normal controls, and there is a strong positive correlation between neuroticism, emotionality, and BPD across all subjects. Based on this evidence, it seems likely that neuroticism and emotionality are closely related (Eysenck & Eysenck, 1969).

Conscientiousness. BPD patients were less conscientious (thorough, reliable, persevering, efficient, organized, goal-oriented *versus* careless, disorderly, lazy, and distractible; McCrea & Costa, 1996) than normal controls, which coincides with the fact that they tend to care less about themselves (exemplified by their self-harming behavior), and lack energy (exemplified by their high score on questions 11 and 12 of the Frontal Behavior Questionnaire, which indicated that they often feel listless and rarely feel full of energy). Further, the correlation analysis showed that as conscientiousness decreases, impulsivity (both self-report and behavioral), total subjective emotion, and BPD characteristics, increase (see Table 3). So we suggest that decreased conscientiousness is an integral part of the BPD syndrome. In ad-

dition a fast subjective sense of time (in terms of both underproduction and overestimation) was correlated with decreased conscientiousness. The measured decrease of conscientiousness in self-harming BPD patients may be related to underlying factors such as their high impulsivity and/or their fast subjective sense of time.

Openness to experience. The new finding that BPD patients are not as open to experience (wide interests, original, curious, artistic, imaginative, inventive, idealistic vs. closed to experience) as normal controls could be related to the fact that they are impulsive and introverted. Indeed openness to experience was negatively correlated with self-report impulsivity and positively with extraversion in our group, which included BPD patients (see Table 3). Given that novelty/sensation seeking has been associated with extraversion (Eysenck & Eysenck, 1985), we suggest that the lack of openness to experience of BPD patients might arise because being introverted makes one less interested in exploring new things. Additionally, being impulsive might make one have insufficient patience to explore new ideas or concepts thoroughly.

Extraversion. It is interesting that, when compared to normal controls, BPD patients reported being introverted (vs. extraverted, i.e., talkative, energetic, enthusiastic, adventurous, outgoing, social, and active; McCrea & Costa, 1996). It may be that the interaction of impulsivity (of the type measured in this study) with introversion and high emotionality is involved in BPD patients' self-harm, while the interaction of abnormal extraversion and impulsivity could lead patients to harm others, for example in Antisocial Personality Disorder (APA, 1984) (see also Paris, 1997). In fact, in this investigation we did find that extraversion is negatively correlated with impulsivity (cf. Barratt & Patton, 1983), emotion, and BPD characteristics (see Table 3).

BPD CHARACTERISTICS

BPD patients' higher score on the BPD questionnaire of Claridge and Broks (1984) compared to normals coincides with the fact that this questionnaire was designed to measure the characteristics that are essential to the diagnoses of BPD and confirms the construct validity of this test. Further, the BPD questionnaire score correlated positively with self-report impulsivity, neuroticism, and subjective emotion, and negatively with extraversion, conscientiousness, and openness to experience. Thus, it relates to the core aspects of the BPD syndrome (APA, 1994), namely emotionality, personality abnormalities, and impulsivity.

FRONTAL BEHAVIOR

Support for a relationship between "frontal" behaviors as assessed by the Frontal Behavior Questionnaire (FBQ) and BPD characteristics comes from the highly significant positive correlation reported here between scores on this questionnaire designed to measure characteristics exhibited after orbitofrontal cortex (OFC) damage, and on the BPD questionnaire, designed

to measure BPD characteristics, across all participants ($r = .80$, $p < .001$) (see Figure 1). Further, this relationship was significant not only within the BPD group ($r = .67$, $p < .003$), where BPD patients scored higher than normal participants on both measures, but also within the normal group ($r = .53$, $p < .03$). More evidence for the strong relationship between "frontal" and BPD characteristics comes from the fact that the FBQ score was correlated with characteristics that are commonly associated with BPD. Specifically, as FBQ increased, impulsivity (self-report and behavioral), neuroticism, subjective emotion, and BPD score increased, while agreeableness, conscientiousness, and openness to experience decreased. Thus, some aspects of the borderline personality syndrome may be related to some sort of OFC dysfunction (see further Berlin, Rolls et al., 2004).

When the FBQ was broken down into specific questions, it was found that BPD patients were significantly different from normal controls on questions 1, 3, 5, 6, 8, 11, 12, 17, and 18 (see Results and Table 2). Some of these questions can be grouped together and related to the core features of BPD (Questions 1, 17, and 18 relate to impulsivity; and questions 3, 5, and 6 to inappropriate emotional functioning). However, questions 11 and 12 relate to a lack of energy, and question 8 to reward insensitivity or lack of drive to obtain a reward. Both of these features are not commonly associated with BPD but are associated with OFC damage (Berlin, Rolls, & Kischka, 2004). Further, we found that the responses to questions 11, 12, and 8 were all significantly correlated with BPD questionnaire score ($r = .67$; .62; and -.51; $p < .002$). Thus, the results of this investigation show that other factors that may contribute to the borderline personality syndrome are listlessness, or lack of energy, and insensitivity to or lack of drive for rewards. Lack of energy (listlessness) and/or drive for positive stimuli may be related to BPD patients' negative emotionality (they report being more angry, sad, fearful, and disgusted, and less happy on the Subjective Emotion Questionnaire), which combined with impulsivity and neuroticism, may promote their self-harm.

RELATIONSHIP WITH THE NORMAL POPULATION

The manifestation of impulsive behavior in syndromes such as personality disorders may be extreme examples of impulsive behaviors on a continuum with the normal population. The current findings suggest that some of the behaviors that comprise the BPD syndrome, in particular impulsivity, introversion, and emotionality, may be on the high end of a continuum with the normal population. For example, as illustrated in Figure 2, there is a significant positive correlation between self-report impulsivity and BPD characteristics across both normal controls and BPD patients ($r = .74$, $p < .001$), with BPD patients at the high end of the relationship.

Also, as demonstrated in Figure 3, normal controls and BPD patients show a similar negative relationship between self-report impulsivity and extraversion ($r = -.52$, $p < .001$), where again, BPD patients are at the extreme end of the relationship.

Finally, the same relationship was found between subjective emotion score and BPD characteristics where BPD patients were at the extreme end of the relationship ($r = .75$, $p < .001$) (see Figure 4).

Thus, it seems likely that the BPD syndrome may be related to a particular position on a set of different dimensions that are continuous with those in the normal population. For example, impulsivity, emotionality, introversion, and BPD characteristics do occur in the normal population (Figures 2-4). However, these characteristics may only be associated with pathology in a combination which includes a score of >75 on the Self-Report Impulsivity questionnaire, >10 on the BPD Questionnaire, >7 on the Subjective Emotion Questionnaire, and <20 on the extraversion subscale.

CONCLUSIONS

One implication of these findings is that some of the core characteristics of BPD, in particular impulsivity, may be related to time perception deficits, in particular to a faster, yet more realistic, subjective sense of time (in terms of decreased time production). On the other hand, other characteristics of BPD patients, such as their high emotionality, introversion, and lack of openness to experience, do not appear to be related to the type of dysfunction associated with time perception. Thus, different symptoms of the borderline personality syndrome may be separable, and therefore, may be related to different brain functions. The finding that BPD patients scored high on a test that measures behaviors commonly found in OFC-damaged patients and on which OFC patients also score high (Berlin, Rolls, & Kischka, 2004), suggests that some symptoms of the BPD syndrome may be related to problems associated with the orbitofrontal cortex.

The results of this investigation also suggest that impulsivity, affective dysregulation, and personality abnormalities are core dimensions of BPD, and that these dimensions may be on a continuum with the normal population. Further, in addition to finding that BPD patients are more impulsive, neurotic, and emotional than normals, which are characteristics commonly associated with BPD, we also found that self-harming BPD patients rate themselves as being less conscientious, open to experience, extraverted, energetic, and motivated to achieve or sensitive to reward. These new findings may have important therapeutic implications as discussed below.

Suggestions about the etiology of BPD include genetic factors (Siever, Torgerson, Gunderson, Livesley, & Kendler, 2002), and psychological factors such as childhood trauma (physical, sexual, or emotional abuse or neglect; Paris, 1996; Soloff, Lynch, & Kelly, 2002). An implication of the current findings is that important new light may be shed on the etiology of BPD by considering how the syndrome can be fractionated, and how different brain systems, each with different functions, contribute to the different symptoms of BPD.

The present results have implications for rehabilitation. It is suggested that if BPD patients are encouraged to stop and think before they act and are given explicit feedback, perhaps some of their implicit impulsive behavioral problems would resolve. Further, perhaps if carers were informed of BPD patients' fast subjective sense of time, which could lead to some of their frus-

tration and impulsivity, they could modify their responses accordingly when working with BPD patients. In the current study, in addition to their impulsivity, BPD patients also had emotional and personality disturbances. BPD patients' reported lack of drive to obtain a reward or reward insensitivity may be related to their being more emotional, neurotic, introverted, and less conscientious. Thus, perhaps carers could be encouraged to emphasize positive feedback when working with BPD patients.

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