Neuropsychological Predictors of Alexithymia in Psychogenic Nonepileptic Seizures and Epilepsy

by

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ABSTRACT

Alexithymia is a personality trait characterized by a diminished ability to identify and describe feelings, as well as an inability to distinguish physical symptoms associated with emotional arousal. Alexithymia is elevated in both patients with epilepsy (a neurologically-based seizure disorder) and psychogenic nonepileptic seizures (PNES; a psychological condition mimicking epilepsy); however, different neuropsychological processes may underlie this deficit in the two groups. To expand on previous research considering factors contributing to alexithymia in these populations, we examined the extent to which scores on the Toronto Alexithymia Scale (TAS-20) were predicted by performance on measures of executive and language functioning. We studied 138 PNES and 150 epilepsy patients with video-EEG confirmed diagnoses. Neuropsychological tests were administered to assess executive functioning (interference scores of the Stroop Color-Word Test and Part B of the Trail Making Test) and language functioning (Animals, Controlled Oral Word Association Test, and Boston Naming Test). Hierarchical linear regressions revealed that the relationships between disparate neuropsychological domains and alexithymia were not moderated by diagnosis of PNES or epilepsy. Multiple regression analyses within each group demonstrated that phonemic verbal fluency and response inhibition were significant predictors of alexithymia in epilepsy. Thus, alexithymia may reflect impairments in language and aspects of executive functioning in both PNES and epilepsy.

I will never forget what I have learned here and how much you all have helped me grow.

I am now, and forever will be, in your debt.

I had a good time.

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Introduction

Psychogenic nonepileptic seizures (PNES) and epilepsy are both marked by complex interactions between vulnerable cognitive and emotional systems that contribute to functional impairment. Despite presenting similar cognitive and affective vulnerabilities, the pathological mechanisms behind these vulnerabilities are disparate. One shared vulnerability is alexithymia, which includes a disturbance in components of cognitive and affective processing, and is more common in those with PNES and epilepsy than in the general population (Tojek et al., 2000; Myers, Matzner et al., 2013; Wolf et al., 2015). Although the Toronto Alexithymia Scale (TAS-20), the most widely used measure of alexithymia (Taylor, Parker, Bagby, 1997), has been hypothesized to assess the cognitive component of alexithymia (Bermond et al., 2007), less is known about the relationships between alexithymia and other neurocognitive deficits, particularly in individuals who experience either epileptic seizures or PNES.

Definitions and Prevalence

Alexithymia. Alexithymia is a personality construct associated with disrupted affective and cognitive functioning. Originally coined by Sifneos (1972), the term alexithymia was derived from the Greek translation of "no words for emotions," and was used to explain clinical features seen in patients with psychosomatic disorders who had trouble engaging in insight-oriented psychotherapy. Alexithymia is a multi-faceted concept that describes a condition characterized by difficulties identifying and describing one's emotions, a lack of introspection (i.e., externally oriented thinking), and difficulties distinguishing feelings from physical symptoms associated with emotional arousal (Lesser, 1981; Sifneos, 1972).

Alexithymia is estimated to affect 10% of the general population (Salminen, Saarijärvi, Äärelä, Toikka, & Kauhanen, 1999), and constitutes a major risk factor for a range of medical and psychiatric problems, including chronic pain, somatization, anxiety, and depression (Taylor & Bagby, 2004). Alexithymia has also been found in those with a variety of medical and psychological disorders, including traumatic brain injury, Alzheimer's disease, stroke, autism spectrum disorders, hypertension, eating disorders, and schizophrenia (Kauhanen, Kaplan, Cohen, Julkunen, & Salonen, 1996; Luminet & Rimé, 2004; Taylor et al., 1997). Research has demonstrated that alexithymia is associated with a host of adverse mental and physical health outcomes, as well as decreased quality of life, due to its relation to poor emotion regulation capabilities (Swart, Kortekaas, & Aleman, 2009), interpersonal problems (Besharat, 2010), and stress-related medical conditions (Todarello, Taylor, Parker, & Fanelli, 1995).

Psychogenic nonepileptic seizures. Psychogenic nonepileptic seizures are classified as a type of conversion disorder (a functional neurological symptom disorder) in the DSM-5 (APA, 2013), and are characterized by involuntary seizure-like episodes occurring in the absence of epileptiform EEG activity. PNES are believed to be in part the result of dysregulated affect, and typically are associated with trauma, posttraumatic stress disorder, dissociation, somatization, and other comorbid psychopathology (Brown & Reuber, 2016). PNES patients also commonly present with deficits in cognitive processes, including spatial working memory, verbal memory, attention, executive functioning, language, and executive control processes (for a review, see Wilmet, Hill, Baslet, & Loring, 2015). Resting-state fMRI studies support the vulnerable cognitive-emotional model, by demonstrating alterations in connectivity between emotional,

executive control, and sensorimotor networks (van der Kruijs, Bodde, Vaessen, 2012; Ding, An, Liao, 2014).

Epilepsy. Epilepsy is the fourth most common neurological disorder in humans and is characterized by recurrent, unprovoked and unpredictable seizures due to abnormal excessive or synchronous neuronal activity in the brain (Fisher et al., 2005). Epileptic seizures can disrupt multiple aspects of cognition, including processes for working and episodic memory, attention, concentration, language, executive functions, emotions, and social judgement (Exner et al., 2002; McAndrews & Cohn, 2012; McDonald et al., 2011; Meletti & Benuzzi, 2009). Affective processes are also disrupted, with comorbid depression, anxiety, and select emotion deficits (e.g., impaired recognition of fear states in temporal lobe epilepsy) (Meletti et al., 2009).

Alexithymia in PNES and epilepsy. Alexithymia is elevated in those with PNES and epilepsy, with different studies reporting different rates. Tojek et al. (2000), Myers, Matzner et al. (2013), and Wolf et al. (2015) reported that roughly 30% of PNES and epilepsy patients fell within the alexithymic range. In contrast, some studies found a much higher proportion of individuals scoring in the alexithymic range – up to 90.5% of PNES patients and 76.2% of epileptic patients (Bewley et al., 2005) and 63% of epileptic patients (Urbanek et al., 2014). Alexithymia in PNES and epilepsy has predominantly been studied in regard to its impact on quality of life and facets of mental health, and its predictive utility in discriminating between the two diagnostic groups. Underlying processes contributing to alexithymia in these groups are less established.

Conceptualizing Alexithymia

Alexithymia is currently conceptualized as a cluster of cognitive traits, including: (1) difficulty identifying feelings, differentiating among the range of common affects, and distinguishing feelings from physical symptoms connected with emotional arousal; (2) difficulty describing feelings; (3) confined imaginal processes resulting in the limited ability to fantasize and incorporate imagery; and (4) an externally oriented cognitive style, which refers to a specific tendency to deal with superficial themes and to avoid affective or introspective thinking (Taylor, Bagby, & Parker, 1985 & 1997). Taylor, Bagby, and Parker were the first to further delve into the core tenets of alexithymia and stated that alexithymic characteristics:

> "…reflect deficits both in the cognitive-experiential domain of emotion response system and at the level of interpersonal regulation of emotion. […] Lacking knowledge of their own emotional experiences, alexithymic individuals cannot readily imagine themselves in another person's situation and are consequently unempathetic and ineffective in modulating the emotional states of others" (Bagby, Taylor, & Parker,1997, pp. 30-31).

Deficits in affective perception. From a neuropsychological perspective, alexithymia can be understood as the insufficient or ineffective cognitive processing and regulation of affective information (Taylor et al., 1997; Wingbermuhle et al., 2012). This may be the result of disrupted affective arousal in response to external emotional triggers, as indicated by reduced activation in limbic and paralimbic structures (e.g., amygdala, insula, anterior cingulate cortex (ACC)) (Moriguchi et al., 2013). A fundamental

consequence of dysfunctions in this process is a deficit in conscious awareness of emotions in alexithymic individuals, which suggests that they possess limited capacity to understand how their feelings relate to higher-level affects, cognitions, memories, and specific experiences (Taylor et al., 1997). This lack of emotional self-recognition has social implications as well, particularly for understanding and expressing the mental states of others. Moriguchi et al., (2006) observed that high alexithymic individuals had trouble taking the perspective of others and had reduced medial prefrontal cortex activation during a Theory of Mind task, indicating that emotional self-awareness seems to be closely related to sensitivity to the emotions of other and empathetic ability.

This study provided additional support for previous findings that have shown alexithymia to be inversely related to the ability to accurately recognize and identify affective facial expressions (Parker et al., 1993; Lane et al., 1995, 2000; Jongen et al., 2014), photographs of emotional scenes, and the emotional valence of sentences (Lane et al., 1996). In response to pictures of angry facial expressions, people with alexithymia showed reduced activation in the dorsal ACC, right anterior insula (Kano et al., 2003), and right caudate (Lee et al., 2011).

Imagery and fantasy. Another important factor associated with alexithymia is the limited ability to fantasize and incorporate imagery. Imagery can be defined as the manipulation of sensory information that comes from memory without information from actual sensory input (Cabeza and Nyberg, 2000). Decreased imaginative involvement and an externally oriented thinking style in alexithymia have been consistently documented during daydreaming, fantasy, and nocturnal dreams (Lumley & Bazydlo, 2000; Nielsen, Levrier, & Montplaisir, 2011; Parker, Bauermann, & Smith, 2000; Vingerhoets, Van

Heck, Grim, & Bermond, 1995). This concept was originally included in the factors measured by the TAS, (Taylor, Ryan, Bagby, 1985), but was later eliminated because the fantasy subscale was not validated as a separate factor (Bagby et al., 1994). In a neuroimaging study, Mantani et al., (2005) demonstrated that people with alexithymia showed reduced neural activation in the posterior cingulate cortex through various conditions during an imagery task (e.g., possible future happy things, past happy things, past sad things etc.). The authors therefore suggested that the ability to imagine future events by using memories of past emotional events is compromised in individuals with alexithymia, whereas non-alexithymic individuals had little trouble with this task. Consistent with that finding, a pair of studies found that alexithymic individuals, compared to non-alexithymics, were unable to visualize their own emotional states (Trajdos-Giejdasz et al., 2004), had poorer (less vivid) imagery, and had less enjoyment and involvement during an autogenic relaxation exercise with guided imagery (Friedlander, Lumley, Farchione, and Doyal, 1997). In one study, the authors found results consistent with the idea that alexithymia related deficits are specific to processing emotional arousal (Peasley-Miklus, Panayiotou, Vrana, 2015). Specifically, that alexithymia was related to higher heart rate during neutral and lower heart rate during fear imagery, which suggests difficulties with parasympathetic control and emotion regulation.

Somatosensory or sensorimotor level stimulus. As previously stated, a tremendous amount of research has been conducted on the processing of external affective stimuli and self-originating thoughts (i.e., imagery or fantasy) in alexithymia. Results found when the experimental design included physical stimulation stand in stark

contrast to those studies. For example, previous studies demonstrated that alexithymic individuals have a significantly lower threshold for pain when receiving electrical stimulation, and the degree of alexithymia correlates with the score of somatosensory amplification (Nyklicek and Vingerhoets, 2000; Nakao et al., 2002). To further understand how alexithymic individuals respond to visceral stimulation, Kano et al., (2007) induced colonic distension by inserting a balloon inflator into the colon of each participant; cerebral blood flow was measured during interoceptive stimulation of the colon by inflating the balloon. Increased neural activation was found in regions important for processing somatosensory information (i.e., pregenual ACC, right insula, and midbrain) in alexithymic individuals compared to non-alexithymic individuals. Furthermore, alexithymics also reported greater physical symptoms stemming from the inflation, such as feeling stress, pain, anxiety, and the urge to defecate. In a less invasive study, Moriguchi et al. (2007) examined the neural response of participants as they viewed pictures depicting human hands and feet receiving painful stimulation. High alexithymic subjects, relative to low alexithymic subjects, had increased activation in the affective pain matrix (i.e., somatosensory cortex, insula, and ACC), despite not receiving any physical stimulation. Of note, high alexithymic participants also had reduced activation in areas involved in executive cognitive functioning, such as the dorsolateral prefrontal cortex.

Overall, these studies indicate that people with high alexithymia scores have enhanced primitive somatosensory and sensorimotor-level brain function, which may contribute to amplifying physical sensations, such as pain. The results of neuroimaging

studies are in line with clinical findings indicating that people with alexithymia tend to complain about external physical symptoms rather than reporting internal mental states.

Neuropsychological Deficits in Alexithymia

Verbal and language deficits in alexithymia. Extensive research has been conducted on the specific characteristics and attributes of alexithymia; less is known about how neuropsychological deficits contribute to the manifestation of alexithymia characteristics. Lamberty and Holt (1995), and later Henry and colleagues (2006), provided evidence that alexithymia is primarily a product of verbal deficits and is related to executive dysfunction. These findings were replicated when Woods and Williams (2007) found a negative relationship between alexithymia and verbal and sequencing abilities. Alexithymia has been linked to lower scores on verbal, non-verbal and general intelligence tests (Wiethaeuper and Bakbinotti, 2013). In another study, alexithymia was inversely associated with performance on the Controlled Oral Word Association Test (COWAT), a measure of phonemic verbal fluency (Paradiso, Vaidya, McCormick, Jones, & Robinson, 2008).

Executive function deficits in alexithymia. Executive functions are a set of complex cognitive processes that enable a person to direct attention, plan strategies, solve problems, and modify behaviors in order to achieve future goals (Alvarez, Emory, 2006; Salthouse, 2005). In addition to the studies demonstrating the relationship between alexithymia and verbal deficits, several studies have shown deficits in a range of other neuropsychological domains. According to Zhang (2011), high alexithymic individuals, relative to low alexithymic individuals, had significantly greater reaction time on a conflict-processing task, suggesting that alexithymic individuals may have less efficient

executive control. Alexithymia was found to be negatively correlated with performance on the Wisconsin Card Sorting Test (WCST), which assess perseveration and abstract thinking (Xiong-Zhao, Xiao-Yan, & Ying, 2006), and low alexithymic individuals had a greater number of correct responses and a higher rate of categorization (Zhu, Wang, Huang, Yao, & Tang, 2006). Koven & Thomas (2010) noted the relationship of factors pertaining to emotional clarity (the ability to identify and understand one's emotions; which consists of aspects of alexithymia, emotional intelligence, and mood awareness), to be negatively associated with inhibition, set-shifting, emotional control, self-monitoring, task initiation, planning, and task monitoring.

Current Study

Alexithymia is believed to reflect deficits in the cognitive processing of emotions (Taylor, Parker, Bagby, 1997). Greater alexithymia has been connected to impaired affective processes and cognitive functioning in several neuropsychological domains, including verbal abilities (Lamberty & Holt, 1995; Wood & Williams, 2007) and aspects of executive functioning (Koven et al., 2010). Given the elevated frequency of alexithymia found in PNES and epileptic patients, the present study sought to expand our understanding of the cognitive mechanisms involved in the manifestation of alexithymia by examining the relationship between alexithymia and neuropsychological functioning.

One would expect PNES patients to have significantly higher levels of alexithymia (compared to epileptic patients), given that greater levels of psychopathology (i.e., depressive, anxiety, somatization disorders) and higher rates of psychological trauma have been associated with PNES and alexithymia. Therefore, it was first hypothesized (H1) that PNES patients would have higher scores on the Toronto

Alexithymia Scale, and all of its subscales (i.e., Difficulty Identifying Feelings, Difficulty Describing Feelings, and Externally Oriented Thinking) compared to epileptics. Second, it was hypothesized that diagnosis would significantly moderate the relationship between neuropsychological measures (H2a: verbal/language ability; H2b: executive function) and alexithymia. More specifically, it was hypothesized that verbal/language performance would be more predictive of alexithymia in epilepsy (H3a), while executive function performance would be more predictive of alexithymia in PNES (H3b).

Method

Participants

The sample consisted of 288 participants, 150 of whom were diagnosed with epilepsy and 138 diagnosed with PNES. See Table 1 for sample characteristics. Participants were patients at the Mayo Clinic Arizona epilepsy monitoring unit (EMU). Only individuals who completed the TAS-20 and had a video-EEG confirmed diagnosis of either epilepsy or PNES (but not both) were included in this study. There is some overlap between this sample and the sample included in Wolf et al., (2015), but the Wolf et al. sample included participants not included in this sample, and vice versa.

Table 1

Sample Characteristics

Variable	Epilepsy (n = 150)		PNES (n = 138)		
	Mean	*SD*	*Mean*	*SD*	p_{diff}
Age at Evaluation	39.21	18.11	42.23	13.8	.091
Gender	51.6% female	-	72.1% female	-	< .001
Handed	91.3% right	-	94.2% right	-	.323
Years of Education	13.99	2.42	14.34	3.07	.261
Employment Status	42.9% yes	-	40.3% yes	-	.64
Disability	11.2% yes	-	27.9% yes	-	< .001
Driving	42.2% yes	-	40.9% yes	-	.815
Age of Onset	27.51	19.83	36.43	15.92	< .001
Seizure Frequency	18% daily	-	34.4% daily	-	< .001
Febrile Seizures	5.6% yes	-	3.9% yes	-	.48
Multiple Seizure Types	49.7% yes	-	50.6% yes	-	.873
Psych Hx	69.6% yes	-	90.9% yes	-	< .001
Sex Abuse	4.3% yes	-	25.3.% yes	-	< .001
Abuse	14.3% yes	-	51.9% yes	-	< .001
Alexithymia (TAS-20 scores ≥ 61)	27.3% yes	-	35.1% yes	-	.136

Note. p_{diff} = significance (two-tailed) of the difference in means for each measure.

Procedure

Following Institutional Review Board approval, a retrospective review of data collected during routine clinical practice at the Mayo Clinic Arizona Epilepsy Monitoring Unit (EMU) was performed. It is standard procedure in the EMU for all appropriate patients to receive comprehensive neuropsychological evaluation. During this evaluation process, demographic information, medical history, and psychosocial information are collected. These variables are listed in Table 1. The data used in this study were collected

between July 2011 and June 2016, a self-report measure of alexithymia was added to the standard neuropsychological battery used in the EMU in July 2011.

Measures

Diagnosis. Patients diagnosed with epilepsy met the following criteria: typical events occurred with epileptiform discharges, or, if no typical events occurred, the described semiology was concerning for epilepsy; interictal epileptiform discharges were seen on EEG; and antiepileptic medication was started at discharge. Those diagnosed with PNES met the following criteria: typical events occurred with no epileptiform discharges; no interictal epileptiform abnormalities; and no other physiological reasons for seizure-like events.

Alexithymia. The Toronto Alexithymia Scale (TAS-20; Bagby, Taylor, & Parker, 1994) is the most commonly used measure of alexithymia. It is a self-report measure consisting of 20 items, with responses given on a Likert scale ranging from one (*strongly disagree*) to five (*strongly agree*). The TAS-20 assesses three distinct factors of alexithymia, which correspond to the three subscales: Difficulty Identifying Feelings (DIF), Difficulty Describing Feelings (DDF), and Externally-Oriented Thinking (EOT). The first two factors (DIF and DDF) refer to a poor emotional awareness and the third (EOT) refers to a specific tendency to deal with superficial themes and to avoid affective thinking. Established cutoff scores indicate that scores less than or equal to 51 indicate the absence of alexithymia, scores ranging from 52- 60 indicate possible alexithymia, and scores of 61 or greater indicate the presence of alexithymia. In the present study, gender-normed T-scores, which were computed from total raw scores, were used. Higher scores reflect greater alexithymia.

Object naming. The Boston Naming Test (BNT) is a language test that assesses visual confrontation object naming (Goodglass and Kaplan, 1983). The test consists of 60 black and white drawings of common objects of increasing difficulty, ranging from simple, high frequency vocabulary words (e.g., comb) to difficult, low frequency words (e.g., abacus) (Strauss, Sherman, & Spreen, 2006). The total score is the sum of the number of spontaneously produced correct responses, the number of cues given, and the number of correct responses given after semantic or phonemic cueing. Age-adjusted T-scores were used in this study, with higher scores reflecting better performance.

Verbal fluency. To evaluate verbal fluency, or the spontaneous production of words, two measures were used: the Controlled Oral Word Association Test (COWAT) to assess phonemic fluency, and the Animals test to assess semantic fluency (Benton and Hamsher, 1976). For both phonemic and semantic fluency tasks, individuals must orally produce as many words as they can during a fixed time period.

During the COWAT, examinees are asked to give words beginning with a specific letter; the most commonly used letters for this task are F, A, and S. The COWAT total correct score is the sum of all admissible words for each of the three letters. Inadmissible words (e.g., proper names, variations, repetitions) are not counted (Strauss et al., 2006). Age-adjusted T-scores were used. Higher scores indicate better performance.

For the Animals test, examinees are given a category and asked to say as many words as they can which fall into the category. The most commonly used category, and the one used in the current study, is Animals. The total correct score is the sum of all admissible words, including extinct, imaginary, or magic animals. Given names like

"Mr. Whiskers" and "Rhonda" are not counted (Strauss et al., 2006). Age-adjusted T-scores were used, with higher scores reflecting better performance.

Response inhibition. The Stroop Color-Word Test is a widely-used measure of selective attention and cognitive control that assesses a person's ability to maintain a goal in mind and suppress a habitual response in favor of a less familiar one. The test consists of three tasks: Word (color words, e.g. red, printed in black ink), Color (X's printed in different colors), and Color-Word (color words printed in incongruous colored ink (e.g., the word red printed in blue ink)). The participant must read aloud the color words on the first sheet, the colors on the second sheet, and the color of the ink (i.e., not the words) on the third sheet, within the time limit of 45 seconds per task. In the latter task, the normal tendency to read the words, rather than the color of the ink in which the words are printed, elicits a significant slowing in reaction time called the "Stroop effect" or the "interference effect." The extent of the slowing in reaction time, or interference, provides a measure of the ability to inhibit a dominant response tendency. Age-adjusted T-scores were used, with higher scores reflecting better performance (Strauss et al., 2006).

Attention and set-shifting. The Trail Making Test (TMT) is a measure of attention, speed, and cognitive flexibility. The test is traditionally administered in two parts: first the TMT A, which is assumed to tap lower-level perceptual/motor functions and cognitive processing speed, and then the TMT B, which is assumed to measure cognitive flexibility and set-shifting. Part A requires the subject to connect, by making pencil lines, 25 encircled numbers randomly arranged on a page in proper ascending order (i.e., 1, 2, 3, etc.). In Part B, the subject is instructed to connect 25 encircled numbers and letters in alternating order (i.e., 1, A, 2, B, etc.). TMT scoring is based on

the time in seconds required for completion of each of the two parts of the test individually. For the purposes of this study, only TMT B scores were considered in the analysis. Age-adjusted T-scores were used, with higher scores reflecting better performance.

Data Analysis

Descriptive statistics were examined for normality and outliers. Independent samples *t*-tests were conducted to determine if there was a significant difference between diagnostic groups on severity of alexithymia and on neuropsychological performance. Correlational analyses were conducted within each diagnostic group to examine the relationship between scores on TAS-20, BNT, COWAT, Animals, Stroop Interference, and TMT B (correlations are provided in Table 3 and Table 4). A moderation analysis conducted in SPSS 23.0 was used to assess whether the relationship between neuropsychological domains (i.e., verbal/language and executive function) and TAS-20 Total scores varied as a function of diagnosis. To further discern the specific effects of neuropsychological measures on alexithymia within each diagnostic group, multiple regression analyses were conducted.

Results

Preliminary Analyses

To compare differences on alexithymia scores and neuropsychological performance across diagnostic groups, a series of independent samples *t*-tests were performed (Table 2). PNES patients scored significantly higher than epileptic patients on overall alexithymia (TAS Total) and the Difficulty Identifying Feelings (DIF) subscale.

Epileptic patients performed significantly worse than PNES patients on the BNT, while PNES patients had significantly lower scores on the Stroop Color-Word Interference.

Table 2

Means, Standard Deviations, and Differences for PNES and Epilepsy

	Epilepsy		PNES			
Measure	*Mean*	*SD*	*Mean*	*SD*	*t*	p_{diff}
[a]TAS Total	52.87	11.07	**55.37**	11.54	-1.96	**0.051**
[a]TAS 1 DIF	55.52	13.18	**59.42**	12.84	-2.66	**0.008**
[a]TAS 2 DDF	49.52	11.43	**51.92**	11.21	-1.88	0.061
[a]TAS 3 EOT	**51.25**	9.67	50.6	10.35	0.57	0.568
[b]BNT	**37.29**	16.82	41.05	13.45	-2.18	**0.03**
[c]COWAT	44.33	11.45	**43.54**	11.16	0.615	0.539
[d]Animals	**42.06**	11.59	44	10.64	-1.53	0.127
[e]Stroop Word	41.27	10.32	**39.81**	9.96	1.25	0.213
[f]Stroop Color	41.8	9.95	**39.87**	10.41	1.64	0.103
[f]Stroop Interference	47.09	11.4	**42.47**	9.8	3.73	**< .001**
[g]TMT A	**44.02**	14.03	46.03	13.17	-1.31	0.193
[h]TMT B	53.25	15.99	**44.01**	15.14	-0.99	0.322

Note. p_{diff} = significance (two-tailed) of the difference in means for each measure. [a]Epilepsy *n* = 161, PNES *n* = 154; [b]Epilepsy *n* = 161, PNES *n* = 153; [c]Epilepsy *n* = 160, PNES *n* = 151; [d]Epilepsy *n* = 160, PNES *n* = 150; [e]Epilepsy *n* = 154, PNES *n* = 145; [f]Epilepsy *n* = 152, PNES *n* = 144; [g]Epilepsy *n* = 159, PNES *n* = 152; [h]Epilepsy *n* = 157, PNES *n* = 152.

Correlations (Table 3 and Table 4) were conducted within each diagnostic group to determine the strength of the relationship between TAS scores and neuropsychological measures. In epileptic patients TAS-20 Total scores were inversely correlated with performance on the BNT, COWAT, and Stroop Interference; while only scores on the TMT B were negatively related to TAS-20 scores in PNES patients.

Table 3

Epilepsy Correlations

	1	2	3	4	5	6	7	8	9	10	11
1. TAS Total	-										
2. DIF	.843**	-									
3. DDF	.845**	.647**	-								
4. EOT	.538**	0.109	.276**	-							
5. BNT	-.195*	-.156*	-0.113	-.194*	-						
6. COWAT	-.351**	-.222**	-.255**	-.38**	.415**	-					
7. Animals	-0.148	-0.067	-0.148	-0.151	.402**	.533**	-				
8. Stroop Word	-.324**	-.23**	-.313**	-.219**	.181*	.426**	.370**	-			
9. Stroop Color	-.35**	-.206*	-.332**	-.304**	.278**	.412**	.416**	.698**	-		
10. Stroop Int	-.185*	-0.113	-.194*	-0.148	.186*	.313**	.355**	.509**	.651**	-	
11. TMT A	-0.096	-0.086	-0.093	-0.048	.272**	.364**	.385**	.351**	.396**	.299**	-
12. TMT B	-0.104	-0.058	-.161*	-0.05	.308**	.273**	.407**	.363**	.440**	.463**	.671**

Note. * $p < .05$; ** $p < .001$.

Table 4

PNES Correlations

	1	2	3	4	5	6	7	8	9	10	11
1. TAS Total	-										
2. DIF	.857**	-									
3. DDF	.876**	.738**	-								
4. EOT	.605**	.189*	.369**	-							
5. BNT	-0.07	-0.024	-0.03	-0.103	-						
6. COWAT	-0.141	-0.026	-0.107	-.241**	.243**	-					
7. Animals	-0.092	-0.048	-0.08	-0.099	.220**	.522**	-				
8. Stroop Word	-.205*	-.184*	-0.16	-0.129	.210*	.515**	.467**	-			
9. Stroop Color	-0.058	-0.074	-0.046	-0.003	0.15	.350**	.325**	.682**	-		
10. Stroop Int	-0.153	-0.093	-.171*	-0.13	0.082	.304**	.183*	.435**	.563**	-	
11. TMT A	-0.111	-0.072	-.172*	-0.04	.203*	.326**	.301**	.418**	.380**	.388**	-
12. TMT B	-.162*	-0.07	-.172*	-0.154	.331**	.429**	.331**	.368**	.275**	.362**	.593**

Note. * $p < .05$; ** $p < .001$.

Neuropsychological Predictors of Alexithymia Moderated by Diagnosis

Diagnostic group was examined as a moderator (Figure 1; Table 5) of the relationship between neuropsychological domains (i.e., language/verbal and executive function) and alexithymia scores. Two moderation models were used. The first model focused on language/verbal ability, and consisted of object naming (BNT) and verbal fluency tasks (COWAT & Animals) as predictors of alexithymia, moderated by diagnosis. The second model focused on aspects of executive function, namely response inhibition (Stroop Interference) and cognitive flexibility (TMT B), as predictors of alexithymia, moderated by diagnosis.

In the language/verbal model (Figure 2; Table 6), the BNT, the COWAT, and Animals were entered in the first step of the regression analysis, diagnosis entered in the second step, and interaction terms between diagnosis and each of the three language/verbal measures were entered in the third step. Step 1 of the model was significant, $F(3, 306) = 6.977$, $p < .001$ and accounted for 6.4% of the variance in TAS-20 scores. Diagnosis was not significant, $B = 2.396$, $p = .059$ The three interaction terms were not significant: BNT x Diagnosis ($B = .035$, $t(302) = .386$, $p = .700$), COWAT x Diagnosis ($B = .238$, $t(302) = 1.789$, $p = .075$), and Animals x Diagnosis ($B = -.113$, $t(302) = -.839$, $p = .402$).

In the executive function model (Figure 3; Table 7), Stroop Interference and TMT B were entered in the first step of the regression analysis, diagnosis in the second step, and the interactions between diagnosis and each of the two executive function measures were entered in the third step. Step 1 of the model was significant, $F(3, 292) = 4.786$, $p = .003$ and accounted for 3.8% of the variance in TAS-20 scores. Diagnosis was not

significant, $B = 2.211$, $p = .106$ The interaction terms, Stroop Interference x Diagnosis ($B = .029$, $t(289) = .212$, $p = .832$) and TMT B x Diagnosis ($B = -.066$, $t(289) = - .720$, $p = .472$), were not significant.

To compare the effects of verbal fluency and executive function on alexithymia, a moderation analysis was conducted with one verbal fluency and one executive function measure as predictors of alexithymia (using the relatively strongest predictor, respectively, from each of the above regressions), and diagnosis as a moderator. The COWAT and Stroop Interference were selected to be entered in the first step, diagnosis in the second, and the interaction between diagnosis and each of the two neuropsychological measures was entered in the third step. Step 1 of the model was significant, $F(2, 294) = 11.63$, $p < .001$, and accounted for 7.3% of the variance in TAS-20 scores. Diagnosis again was not significant, $B = 2.054$, $p = .118$. Neither of the interaction terms were significant: COWAT x Diagnosis ($B = .190$, $t(295) = 1.605$, $p = .109$) and Stroop Interference ($B = - .059$, $t(295) = - .458$, $p = .647$).

While diagnosis did not moderate the relationship between neuropsychological measures and alexithymia, to test the specific hypothesis based on theoretical grounds that the etiology of alexithymia results from separable deficits within each diagnosis, multiple regression models were run to examine the potential differences in predictors for each diagnostic group.

Figure 1

Language/Verbal Moderation Model

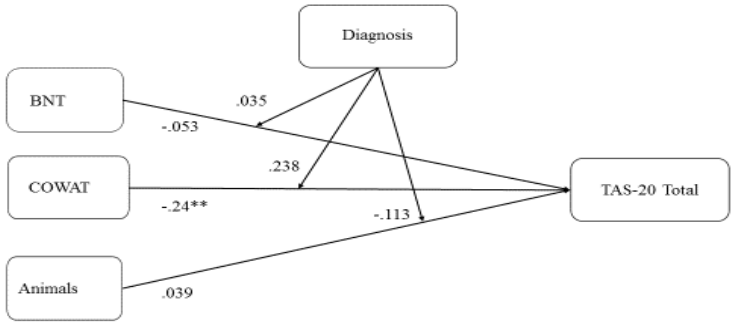


Table 5

Language/Verbal Moderation Model

Predictor	β	*p*	R^2	ΔR^2	Sig. $F\,\Delta$
Step 1					
BNT	-.053	.23	.064	-	-
COWAT	-.240	< .001	.064	-	-
Animals	.039	.562	.064	-	-
Step 2					
Diagnosis	2.396	.059	.075	.011	.059
Step 3					
BNT x Dx	.035	.700	.087	.012	.283
COWAT x Dx	.238	.075	.087	.012	.283
Animals x Dx	-.113	.402	.087	.012	.283

Figure 2

Executive Function Moderation Model

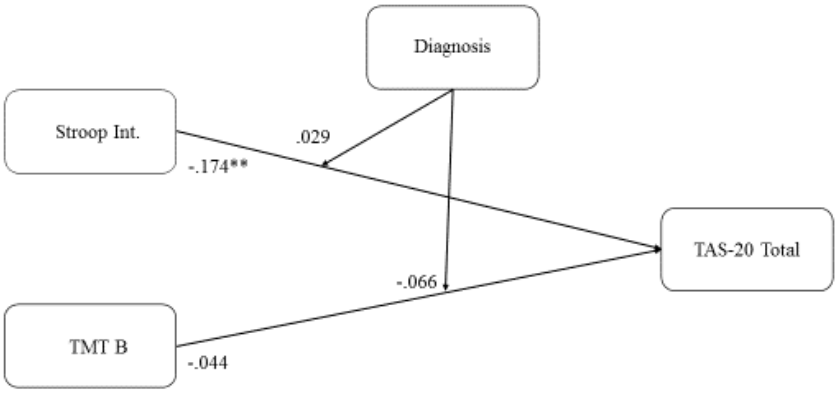


Table 6

Executive Function Moderation Model

Predictor	β	*p*	R^2	ΔR^2	Sig. $F\,\Delta$
Step 1					
Stroop Interference	-.174	.009	.038	-	-
TMT B	-.044	.336	.038	-	-
Step 2					
Diagnosis	2.211	.106	.037	.009	.106
Step 3					
Stroop Int x Dx	.029	.832	.049	.002	.768
TMT B x Dx	-.066	.472	.049	.002	.768

Figure 3

Verbal Fluency and Executive Function Moderation Model

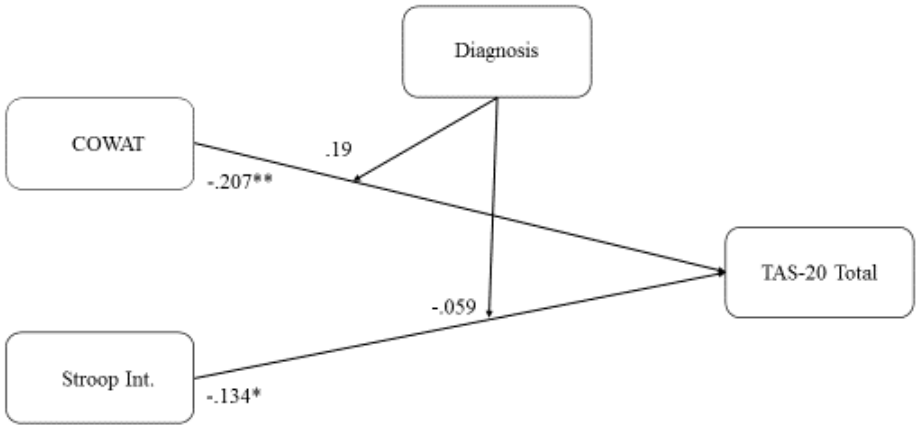


Table 7

Verbal Fluency and Executive Function Moderation Model

Predictor	β	*p*	R^2	ΔR^2	Sig. $F\,\Delta$
Step 1					
COWAT	-.207	.001	.073	-	-
Stroop Interference	-.134	.032	.073	-	-
Step 2					
Diagnosis	2.054	.118	.081	.008	.118
Step 3					
COWAT x Dx	.190	.109	.089	.008	.277
Stroop Int x Dx	-.059	.647	.089	.008	.277

Neuropsychological Predictors of Alexithymia in Epilepsy

A multiple regression model including the COWAT, BNT, and Animals test as predictors of alexithymia for patients with epilepsy accounted for roughly 13% of the variance in TAS Total scores, $F(3, 157) = 7.745$, $p < .001$ (Table 8). The COWAT was the only significant predictor of alexithymia when controlling for the BNT and Animals, $B = -.346$, $t(157) = -3.92$, $p < .001$. Since the three TAS subscales are believed to assess

different alexithymic characteristics, and may be related to neuropsychological functionality differently, multiple regression analyses were used to examine the effects of the neuropsychological variables on each of the subscales. The language/verbal ability model accounted for 6% of the variance in the Difficulty Identifying Feelings (DIF) subscale (R^2 = .06, F(3, 157) = 3.363, p = .02), approximately 7% for the Difficulty Describing Feelings (DDF) subscale (R^2 = .067, F(3, 157) = 3.627, p = .014), and 15% for the Externally Oriented Thinking (EOT) subscale (R^2 = .150, F(3, 157) = 9.254, p < .001). For all three of the TAS subscales, the COWAT was the only significant predictor when controlling for scores on the BNT and Animals; DIF (B = - .267, t(157) = - 2.448, p = .015), DDF (B = - .244, t(157) = - 2.58, p = .011), and EOT (B = - .338, t(158) = - 4.431, p < .001).

A multiple regression model including the Stroop Interference and TMT B as predictors of alexithymia did not explain a significant amount of variance in TAS Total, R^2 = .033, F(3, 158) = 2.711, p = .07. However, Stroop Interference was a marginally significant predictor of TAS Total scores, B = - .168, t(158) = - 1.924, p = .056. Additionally, the Stroop Interference and TMT B accounted for 4.3% of the DDF subscale, R^2 = .043, F(3, 158) = 3.534, p = .032, but neither variable was a significant predictor individually. The executive function model did not account for a significant proportion of variance in either DIF or EOT, and there were not any significant individual predictors.

Neuropsychological Predictors of Alexithymia in PNES

A multiple regression model (Table 9) including the COWAT, BNT, and Animals test as predictors of alexithymia for patients with PNES did not account for a significant

proportion of variance in TAS Total (p = .358), DIF (p = .946), or DDF (p = .609); it did, however, significantly account for 6.1% of the variance in the EOT subscale, R^2 = .061, $F(3, 150) = 3.223$, p = .024. The COWAT performance was the only significant predictor of EOT when controlling for scores on the BNT and Animals, B = - .232, $t(150)$ = - 2.652, p = .009.

A multiple regression model including the Stroop Interference and TMT B as predictors of alexithymia did not account for a significant proportion of variance for TAS Total (p = .064), DIF (p = .473), or EOT (p = .103). Together, Stroop Interference and TMT B accounted for 4.2% of the variance in DDF, R^2 = .042, $F(2, 151) = 3.344$, p = .038. Stroop Interference and TMT B performance did not significantly predict scores on TAS Total, DIF, DDF, or EOT.

Table 8

Multiple Regression Results for Epilepsy

Outcome	Predictor	*B*	*SE B*	*B*	*P*
TAS Total					
	BNT	-0.051	0.055	-0.078	0.353
	COWAT	-0.346	0.088	-0.357	**< .001**
	Animals	0.071	0.087	0.074	0.413
	Stroop Interference	-0.168	0.088	-0.168	**0.056**
	TMT B	-0.019	0.061	-0.027	0.759
TAS 1: DIF					
	BNT	-0.078	0.068	-0.1	0.252
	COWAT	-0.267	0.109	-0.231	**0.015**
	Animals	0.11	0.107	0.096	0.307
	Stroop Interference	-0.126	0.105	-0.106	0.232
	TMT B	-0.008	0.074	-0.009	0.915
TAS 2: DDF					
	BNT	-0.005	0.059	-0.008	0.928
	COWAT	-0.244	0.094	-0.243	**0.011**
	Animals	-0.014	0.093	-0.014	0.88
	Stroop Interference	-0.153	0.09	-0.148	0.091
	TMT B	-0.067	0.063	-0.092	0.291
TAS 3: EOT					
	BNT	-0.038	0.048	-0.066	0.424
	COWAT	-0.338	0.076	-0.398	**< .001**
	Animals	0.074	0.075	0.089	0.323
	Stroop Interference	-0.133	0.077	-0.153	0.085
	TMT B	0.012	0.054	0.02	0.82

Table 9

Multiple Regression Results for PNES

Outcome	Predictor	*B*	*SE B*	*β*	*P*
TAS Total					
	BNT	-0.031	0.072	-0.036	0.665
	COWAT	-0.126	0.1	-0.121	0.208
	Animals	-0.022	0.104	-0.02	0.836
	Stroop Interference	-0.129	0.104	-0.107	0.215
	TMT B	-0.094	0.066	-0.123	0.153
TAS 1: DIF					
	BNT	-0.013	0.081	-0.014	0.871
	COWAT	0.001	0.112	0.001	0.995
	Animals	-0.055	0.117	-0.045	0.638
	Stroop Interference	-0.103	0.117	-0.077	0.379
	TMT B	-0.036	0.074	-0.042	0.632
TAS 2: DDF					
	BNT	-0.001	0.07	-0.001	0.989
	COWAT	-0.09	0.097	-0.088	0.358
	Animals	-0.036	0.102	-0.033	0.727
	Stroop Interference	-0.144	0.101	-0.122	0.155
	TMT B	-0.095	0.064	-0.128	0.135
TAS 3: EOT					
	BNT	-0.041	0.063	-0.053	0.522
	COWAT	-0.232	0.088	-0.248	**0.009**
	Animals	0.042	0.092	0.042	0.649
	Stroop Interference	-0.091	0.093	-0.083	0.333
	TMT B	-0.085	0.059	-0.124	0.152

Discussion

The current study was conducted as an attempt to explain how alexithymia is influenced by neuropsychological processes in epilepsy and PNES. It was initially proposed that PNES patients would score higher on the TAS-20. It was also hypothesized that diagnosis would moderate the relationship between alexithymia and verbal and

executive function measures. Furthermore, it was expected that verbal measures would be more predictive of alexithymia in epilepsy, and executive function measures to be more predictive of alexithymia in PNES. These hypotheses were partially supported.

As anticipated, PNES patients scored significantly higher on the TAS-20 Total and subscale 1 (DIF), while there was no significant difference between diagnostic groups for scores on the TAS-20 subscale 2 (DDF) or TAS-20 subscale 3 (EOT). This is consistent with the fact that alexithymia was originally proposed to explain characteristics of psychosomatic disorders, and PNES patients commonly present high rates of somatization (for a review see Baslet, 2011). Results indicated that epileptic patients performed worse on an object naming task (BNT), while PNES patients performed worse on the response inhibition task (Stroop interference). TAS-20 Total scores were inversely related to object naming, phonemic verbal fluency, and response inhibition in epilepsy, and set-shifting in PNES.

Interestingly, despite that there were no significant differences between diagnostic groups in phonemic fluency (COWAT) scores, the COWAT was only a significant predictor of alexithymia in epilepsy, and not in PNES. One possible explanation could be that language impairment often is associated with temporal lobe epilepsy, predominantly within the language dominant hemisphere (Fargo et al., 2005), whereas deficits in verbal fluency in PNES may stem from other processes (e.g., deficits in executive function, depression) but do not reflect the kinds of language-related issues that characterize alexithymia.

Contrary to hypotheses, diagnosis did not moderate the relationship between both verbal or executive function performance and alexithymia. Nevertheless, subsequent

multiple regression analysis within each diagnostic category revealed that, as hypothesized, epileptic patients' performance on the COWAT significantly predicted Total TAS-20 scores. Contrary to expectations, however, a measure of executive function, Stroop interference, was a marginally significant predictor of TAS-20 Total scores in epileptic patients, but was not significant among PNES patients. Exploratory analyses were conducted by diagnostic group to further explore the impact of each neuropsychological measure on specific subscales characteristic of components of alexithymia. Epileptic patients' phonemic verbal fluency abilities significantly predicted their difficulty identifying feelings, difficulty describing feelings, and the extent to which they focus on externally oriented stimuli rather than interoceptive stimuli. PNES patients' phonemic verbal fluency abilities significantly predicted their preoccupation with external, rather than internal, stimuli.

The COWAT and Stroop interference were both significant predictors of alexithymia, despite only accounting for a small portion of variance in epileptic patients. The COWAT assesses the ability to spontaneously produce phonemically similar words, while the Stroop interference trial evaluates the ability to suppress, or regulate, initial response tendencies to stimuli (Strauss et al., 2006). Moreover, Golden (1972) postulated that in addition to assessing response inhibition, the Stroop test also assesses an individual's ability to cope with cognitive stress and process complex input. Thus, decreased performance on these tasks may provide insight into which epileptic patients are at risk for greater potential dysfunctional affective processes due to deficient communication capabilities and/or maladaptive emotion regulation techniques, which in turn may pose challenges in patients' reactions and responses to daily life stressors.

One possible explanation for why diagnostic group did not moderate the relationship between neuropsychological performance and alexithymia could be the notable lack of significant group performance differences across the different cognitive tasks. The results may also be attributable to a non-significant difference in the proportion of patients (i.e., 27.3% epilepsy; 35.1% PNES; $p = .136$) who met the alexithymic criteria (TAS-20 Total scores ≥ 61). Epileptic and PNES patients both scored lower on the COWAT and Stroop Interference, respectfully, relative to valid and reliable established norms (for review see Strauss et al., 2006). There is an interesting theoretical relationship, however, regarding the underlying neural circuitry involved during COWAT, Stroop tasks, and alexithymia. In general, neuroimaging studies have demonstrated increased activation in the dorsolateral prefrontal cortex (dlPFC) and ACC during phonemic verbal fluency tasks and the Stroop test (for review see Alvarez et al., 2006; Bush, Luu, & Posner, 2000). Conversely, decreased functional connectivity has been observed in the same neural regions in alexithymic individuals (Lane et al., 1997; Moriguchi et al., 2013). This is consistent with Lane et al.'s (1997) 'blindfeel' hypothesis that theorized the conscious experience of emotions is compromised in alexithymia, due to the loss of fibers between the ACC and affect-generating brain regions. This is congruent with the literature on the multitude of functions associated with ACC activation, including attention and interference (Bush, Luu, & Posner, 2000), evaluating and processing the emotional meaning of stimuli (Etkin, Egner, & Kalisch, 2011), as well as during the cognitive control of emotion regulation (Urry, Van Reekum, Johnstone, & Davidson, 2009).

Limitations

This study posed several limitations; an important one was the use of a single alexithymia measure. Even while the TAS-20 is the most widely used tool to assess alexithymia, it is not a perfect measure. Many studies have criticized the reliability of the third TAS subscale, EOT (Kooiman et al., 2002; Müller, Bühner, & Ellgring, 2003), and some argue that alexithymia may comprise of an affective and cognitive dimension (Vorst & Bermond, 2001) and the TAS-20 only taps into the cognitive dimension of alexithymia (Koven et al., 2011). Lane et al. (2015) raised an important question regarding the nature of a fundamental tenet of alexithymia. Specifically, there is a question of whether the difficulty identifying and describing one's feelings is a result of individuals knowing what they feel but being unable to convey it properly, or not knowing what they are feeling, which is why they have difficulty describing it (Lane et al., 2015). Another important limitation was the comparatively small number of patients diagnosed with right or left temporal lobe epilepsy. This did not allow us to directly assess how seizure localization could influence alexithymia and its relationship to neuropsychological performance. A further limitation regards the lack of a healthy, non-clinical control group to use to compare the diagnostic groups on performance on all measures.

Conclusion

To our knowledge, this was the first study to examine alexithymia as it pertains to neuropsychological functioning within these two diagnostic groups. Future studies should focus on other potential deficient cognitive aspects that may underlie the manifestation of alexithymia. Taken together, the results of this study provide evidence that alexithymia is

related to neuropsychological functioning deficits in individuals with PNES and epilepsy. Roughly a third of both epileptic and nonepileptic patients in our sample met the clinical criteria for alexithymia, indicating that one out of every three of our patients diagnosed at the EMU experiences a severe limitation in their affective capacity (i.e., emotional awareness, processing, and regulation). The consequential nature of this diminished affective capacity is cyclical and can spread to all facets of their lives, further perpetuating the likelihood and severity of various health-related problems, interpersonal difficulties, and a drastic reduction in perceived quality of life. Hence, intervention targeted specifically towards lessening the negative impact of alexithymia and improving dysfunctional affective tendencies and behavioral patterns, should be a priority.

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