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"No words for feelings": a multidimensional analysis of the alexithymia construct

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Abstract

Contemporary neurosciences have shown that emotion, thought and language involve the functioning of connected brain areas, which allow the recognition and expression of one's own feelings. The present pilot study was aimed at investigating the link among verbal expression of emotional experiences (assessed through the Toronto Structured Interview for Alexithymia - TSIA), the capacity of emotional regulation (assessed by means of the Attachment Style Questionnaire, the Emotion Regulation Questionnaire, and the Coping Orientation to Problems Experiences), the linguistic structure and symbolic representation of narration (assessed through the Text Mining Analyses), and brain area structures (by means of a 3-T high-resolution structural Magnetic Resonance Imaging). To this aim, nine (males=5) healthy adult subjects were interviewed by means of the TSIA and scored on psychological questionnaires. The cortical and subcortical structural measures were also evaluated. TSIA transcripts were then analysed by using a cluster analysis and, subsequently, a correspondence analysis, and the values of lexical factors were correlated with cortical and subcortical structural measures as well as with TSIA and psychological scores. Overall, the reciprocal relationships among the measures of neurobiological structures, the capacity of identifying, describing and regulating emotions, and the ability of translating the emotional experiences into verbal forms, allowed to identify a complex pattern of biopsychosocial aspects, getting light on referential processes characterizing the verbally and not-verbally express emotions.

Keywords: Alexithymia; TSIA; Text Mining; Emotional Regulation; Brain Imaging.

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Introduction

According to the multiple code theory, the emotional information is represented in verbal, non-verbal symbolic and non-verbal sub-symbolic multiple systems (Bucci, 1997). The verbal system is a communication and reflection code through which the emotional subjective experience can be shared with others. It refers to the capacity of language to direct and regulate ourselves, activate imagination and emotions, stimulate actions and control them. The multiple channels of the non-verbal systems include representations and proceedings related to implicit elaboration associated with visceral, sensory and motor modalities. While in the symbolic non-verbal system the information is processed as images, in the sub-symbolic one, rapid and complex computations are carried out in an implicit continuous process. Such computations contribute to recognize slight modifications of facial expressions, identify body movement or vocal quality changes, and distinguish visceral states.

The expression of emotions is enabled by the transformation of the symbolic and sub-symbolic non-verbal materials into words. This process is carried out by referential processes integrating the activity of verbal and non-verbal (symbolic and sub-symbolic) systems (Bucci, 1997).

Such referential processes are the core factors in emotional functioning, since, when impaired, dysfunctional conditions characterized by bio-psycho-social aetiology occur. Within these dysfunctional conditions there is alexithymia featured by impaired cognitive-emotional and affective processing (Bagby et al., 1994a). This psychological construct describes people with deficiencies in identifying or describing subjective emotions or feelings, difficulty in distinguishing between bodily sensations of emotional arousal and feelings, and poor affect-related fantasy and imagery. People with alexithymic traits tend to focus on facts without affective involvement rather than inner experiences, exhibiting a "concrete and reality-based cognitive style". Although alexithymia is not a psychological disorder *per se*, it is associated with a low quality of life and enhanced risk of psychological impairment (Taylor & Bagby, 2004). Individuals with high-alexithymic traits report difficulties with emotional regulation (Mueller et al., 2006) and make less use of cognitive reappraisal that is the reinterpretation of emotional stimuli to reduce their emotional impact (Swart et al., 2009). In turn, the emotional regulation abilities are also influenced by the attachment styles that play a differential role in the response to threat and distress (Cassidy & Shaver, 2002; Movahed- Abtahi & Kerns, 2017). Attachment style can predict how to deal with stress, implement stress resilience capacities, regulate emotions, and change the health-related behaviors (Cassidy & Shaver, 2002). In a sample of undergraduate students, the attachment dimensions related to insecure style, such as discomfort with closeness, relationships as secondary, and need for approval, were positively associated with alexithymia scores (Montebarocci et al., 2004).

Neuroimaging studies have indicated that people with high alexithymic traits show less activation in brain areas associated with emotional awareness and volumetric variations in brain areas associated with emotional and somato-sensory processing (Laricchiuta et al., 2015a,b). This pilot study, performed in a small number of subjects with different levels of alexithymia, is aimed at investigating, for the first time, the verbal expression of the emotional experiences, as well as the association between brain structure and capacity of expressing and regulating subjective emotions. Namely, the reciprocal associations among cortical and subcortical structural measures (evaluated by means of a 3-T high-resolution structural Magnetic Resonance Imaging - MRI), the style and the capacity of emotional regulation (assessed by means of the Attachment Style Questionnaire - ASQ, the Emotion Regulation Questionnaire - ERQ, and the Coping Orientation to Problems Experiences - COPE), and alexithymia levels (assessed by means of the Toronto Structured Interview for Alexithymia - TSIA). The transcripts of the TSIA interviews were collected in a single corpus that was subjected to text mining analyses. The here-proposed data processing was aimed at understanding how the narration is organized, leaving on the background what is narrated. The analysis of which words co-occur in the text allows to make hypotheses concerning the culture that has originated the narration and that, at the same time, organizes the behaviors and the relationships of the social actors within the context.

The reciprocal relationships among the measures of neurobiological structures, the capacity of identifying, describing and regulating emotions, and the ability of translating the emotional experiences into verbal forms, allowed to identify a complex pattern of biopsychosocial aspects, getting light on referential processes characterizing the verbally and not-verbally express emotions. Integrating the relationships among brain structure, psychological constructs, and social communicative capacities is the final goal of the present research.

Material and methods

Participants

Nine (males=5) healthy adult (age 23-63 years) subjects were recruited at the IRCCS Fondazione Santa Lucia, Rome, following typical exclusion and inclusion criteria described elsewhere (Laricchiuta et al., 2014b). All participants were right-handed as assessed with the Edinburgh Handedness Inventory (Oldfield, 1971).

Instruments

TSIA evaluation. The participants were interviewed through the TSIA (Bagby et al., 2006), composed by 24 items (Bagby et al., 2006; Italian version Caretti et al., 2011) referred to the four factors of alexithymia construct: Difficulty in Identifying Feelings (DIF); Difficulty in Describing Feelings (DDF); Externally Oriented Thinking (EOT); and Imaginal Processes (IP). Each item is assessed by a specific open-ended question and responses were 3-point (coded '0', '1', or '2') scored. The sum of scores resulted in a total score ranging from 0 (low alexithymia levels) to 48 (high alexithymia levels). As reported in Di Trani et al. (2017), examples of questions include the following: 'Are you sometimes puzzled or confused by what emotion you are feeling?' (DIF); 'Is it usually difficult for you to find words to describe your feelings to others?' (DDF); 'Do you tend to talk to others more about daily activities rather than feelings?' (EOT); and 'When you think about some past events do you relive and imagine them in your mind?' (IP; reverse scored).

ASQ evaluation. Attachment styles were assessed through ASQ (Feeney et al., 1994). The 40-item self-report scale ASQ yields scores on five scales or dimensions: Trust, Discomfort for the Intimacy, Secondary Relationships, Need Approval, Worry for Relationships. ASQ consists of propositions related to various aspects of attachment (e.g., discomfort with closeness, "I worry about people getting too close"; relationships as secondary, "Doing your best is more important than getting along with others"; preoccupation with relationships, "I wonder how I would cope without someone to love me"; need for approval, "I worry that I won't measure up with other people."). On a 6-point Likert-type scale from totally disagree (1) to totally agree (6), the participants indicated the degree to which the propositions described their feelings.

The four-group model by Bartholomew (1990; Bartholomew & Horowitz, 1991) theoretically inspired the development of the ASQ. According to that model, attachment styles are defined by two underlying dimensions-models of the self (positive or negative) and of the others (positive or negative). Crossing of the dimensions yields four outcomes, each representing a prototypical style of attachment: (a) secure (positive self-image, positive image of others), (b) dismissing (positive self-image, negative image of others), (c) worried (negative self-image, positive image of others), and (d) fearful (negative self-image, negative image of others).

ERQ evaluation. The ERQ (Gross & John, 2003) is a 10-item, self-report measure of two emotional regulation strategies, one considered beneficial and the other harmful. According to the authors, regulatory strategies can be broadly categorized as antecedent-focused and response-focused, depending on the point at which the individual intervenes in emotional processing. Cognitive reappraisal (measured by six items) is an adaptive, antecedent-focused strategy, affecting the early cognitive stages of emotional activity, whereby the initial interpretation of a given situation is re-evaluated. In contrast, expressive suppression (measured by four items) is a maladaptive, response-focused plan of action implemented after an emotional response has fully developed; it is conceptualized as inhibiting the behavioral expression of the emotion. The ERQ concentrates on these two broad strategies, measuring the tendency of individuals to use cognitive reappraisal and expressive suppression as strategies of dealing with emotional arousal. The ERQ uses a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Example questions include "I control my emotions by changing the way I think about the situation I'm in" (cognitive reappraisal) and "I control my emotions by not expressing them" (expressive suppression).

COPE evaluation. The COPE (Carver et al., 1989) is a multidimensional coping questionnaire that assesses coping strategies in response to stressful events. It consists of fifteen four-item scales designed to measure five dimensions of coping: Problem-Focused, Transcendental-Focused, Positive-Focused, Social Support, Avoidant Coping. Each item is rated on a 4-point Likert scale ranging from "Never" (1) to "Often" (4; scores ranging from 4 to 16 and higher scores representing higher frequency of coping strategies).

Text Mining Analyses. To analyze the text, we use Emotional Text Mining method (ETM) (Greco & Polli, 2020; 2021), which is a bottom-up unsupervised procedure based on a socio constructivist approach and a psychodynamic model. First, we perform a cluster analysis to identify the semantic level of communication, and a correspondence analysis to detect the semiotic one. While the mental functioning proceeds from the semiotic level to the semantic one in generating the text, the statistical procedure simulates the inverse process of the mental functioning, from the semantic level to the semiotic one. Thus, cluster analysis results allow to identify the emotional representations, while the correspondence analysis results reflect the emotional symbolization (Cordella et al., 2014; Greco, 2016). The interpretation process, in fact, proceeds from the highest level of synthesis to the lowest one, simulating once again the mental functioning (Greco & Polli, 2020). The nine TSIA interviews resulted in a medium size corpus of 62.792 tokens. In order to check whether it was possible to statistically process data, two lexical indicators were calculated: the type-token ratio and the hapax percentage (TTR= 0.10; Hapax= 51.0%). According to the large size of the corpus both lexical indicators highlight its richness and indicate the possibility to proceed with the analysis. First, data were cleaned and pre-processed and terms selected according to the rules for small corpora (Cordella et al., 2014). In particular, we used lemma as keywords instead of type, filtering out the terms of the high rank of frequency and those of the low rank of frequency lower to 9 occurrences. Then, on the context unit per term matrix we performed a cluster analysis with a bisecting k-means algorithm, limited to ten partitions, excluding all the context units that do not have at least two terms co- occurrence. The intraclass correlation coefficient was used to evaluate and choose the optimal solution. To finalize the text mining a correspondence analysis on the term per cluster matrix was made in order to explore the relationship between clusters and to identify the latent dimensions setting the interviews.

MRI acquisition and processing. Participants underwent an imaging protocol that included standard clinical sequences (FLAIR, DP-T2-weighted) and a volumetric whole-brain 3D high-resolution T1-weighted sequence, performed with a 3 T Allegra MR imager (Siemens, Erlangen, Germany), with a standard quadrature head coil. Volumetric whole-brain T1-weighted images were obtained in the sagittal plane using a Modified Driven Equilibrium Fourier Transform (MDEFT) sequence (Echo Time/Repetition Time -TE/TR- = 2.4/7.92 ms, flip angle 15°, voxel size 1 x 1 x 1 mm3). All planar sequence acquisitions were obtained in the plane of the anterior– posterior commissure line. Since the posterior cranial fossa usually falls at the lower limit of the field of view, particular care was taken to center subject's head in the head coil, to avoid possible magnetic field dishomogeneities or artifacts at cerebellar level.

As regard the volumetric measures, T1-weighted images were submitted to several processing steps. First, T1-weighted images were processed and examined using the SPM8 software (Wellcome Department of Imaging Neuroscience Group, London, UK; http://www.fil.ion.ucl.ac.uk/spm), specifically the VBM8 toolbox (http://dbm.neuro.uni-jena.de/vbm.html) running in Matlab 2007b (MathWorks, Natick, MA, USA). The toolbox extends the unified segmentation model (Ashburner &

Friston, 2005) consisting of MRI field intensity inhomogeneity correction, spatial normalization and tissue segmentation at several pre-processing steps to further improve data quality. Initially, to increase the signal-to-noise ratio, an optimized blockwise nonlocal means filter was applied to the MRI scans using the Rician noise adaption (Wiest-Daesslé et al., 2008). Then, an adaptive maximum a posteriori segmentation approach extended by partial volume estimation was employed to separate the MRI scans into GM, White Matter22 (WM) and cerebro-spinal fluid. The segmentation step was finished by applying a spatial constraint to the segmented tissue probability maps based on a hidden Markow Random Field model to remove isolated voxels which unlikely were members of a certain tissue class and to close holes in clusters of connected voxels of a certain class, resulting in a higher signal-to-noise ratio of the final tissue probability maps. Then, the iterative high-dimensional normalization approach provided by the Diffeomorphic Anatomical Registration Through Exponentiated Lie Algebra (DARTEL) (Ashburner, 2007) toolbox was applied to the segmented tissue maps to register them to the stereotaxic space of the Montreal Neurological Institute (MNI). The tissue deformations were used to modulate participants' GM and WM maps to be entered in the analyses. Voxel values of the resulting normalized and modulated GM and WM segments indicated the probability (between 0 and 1) that a specific voxel belonged to the relative tissue. Finally, the modulated and normalized GM and WM segments were written with an isotropic voxel resolution of 1.5 mm3 and smoothed with a 6-mm Full-Width Half Maximum (FWHM) Gaussian kernel. The segmented, normalized, modulated and smoothed GM and WM images were used for analyses. Analyses restricted to cerebellar GM and WM were determined as follows: (1) GM mask was achieved by meaning all GM probability maps obtained in the VBM8 processing steps, thresholding the relative image to a value of 0.3 (i.e. removing all voxels having a probability to belong to GM lower or equal to 29 %) and manually removing all the non-cerebellar structures using the MNI-oriented atlas of the human brain (Automated Anatomical Labeling Atlas, AAL) (Tzourio-Mazoyer et al., 2002) as reference; (2) similarly, WM mask was obtained by meaning all VBM8 WM probability maps, thresholding the relative image to a value of 0.3 and manually removing all the non-cerebellar structures using the AAL template. To obtain the precise anatomical localization of results, we superimposed statistical maps onto Diedrichsen's probabilistic atlas of the human cerebellum, which subdivides the cerebellum into ten different regions (Diedrichsen et al., 2009).

As regard the cortical thickness, the FreeSurfer imaging analysis suite (v5.1.0, http:// surfer.nmr.mgh.harvard.edu/) was used for cortical reconstruction of the whole brain (Dale et al., 1999). With this software, the T1-weighted images were registered to the Talairach space of each participant's brain with the skulls stripped. Images were then segmented into WM/GM tissue based on local and neighboring intensities. The cortical surface of each hemisphere was inflated to an average spherical surface to locate both the pial surface and the WM/GM23 boundary. Preprocessed images were visually inspected before including into subsequent statistical analyses. Any topological defects were excluded from the subsequent analyses. Cortical thickness was measured based on the shortest distance between the pial surface and the GM/WM boundary at each point across the cortical mantle. The regional thickness value at each vertex for each participant, was mapped to the surface of an average spherical surface (Fischl et al., 1999) using automated parcellation in FreeSurfer (Fischl et al., 2004).

Statical analyses

Differences in age, education years and scores of psychological scales (TSIA, ASQ, ERQ, and COPE) were assessed by unpaired t test between females and males. Parametric associations between TSIA scores and age, years of formal education, scores on the other psychological scales (ASQ, ERQ, and COPE scores), regional volumes as well as cortical thickness were analyzed by Pearson's product moment correlations (Fisher's r to z). Then, the lexical scores resulted by the correspondence analysis were correlated with TSIA, ASQ, ERQ, and COPE scores and the measures of cerebral structure in order to identify the possible direction and extent of the linear relationship between the variables. The differences were considered significant at the $p \leq 0.05$ level.

Results

Differences in socio-demographic and psychological variables

Females and males were similar in age, education years, and scores on almost all psychological scales. The mean values of the demographic variables (age and education years), psychological scales (TSIA, ASQ, ERQ, and COPE) scores (total and factors) of the female and male participants, and the statistical parameters are reported in Table 1.

Tab. 1. Values of demographic variables (age, education years) and psychological scales in females (F) and males (M) (mean and standard error (se), and statistical parameters (t and p) are reported)

	F mean (se)	M mean (se)	t	p
Age	46.0 (8.9)	36.2 (6.2)	0.93	0.38
Education years	17.0 (0.4)	15.0 (0.6)	2.7	0.06
DIF (TSIA)	1.5 (1.5)	5.4 (1.6)	-1.76	0.12
DDF (TSIA)	3.8 (2.1)	6.2 (2.0)	-0.85	0.42
EOT (TSIA)	2.8 (1.4)	5.8 (2.2)	-1.12	0.30
IP (TSIA)	5.3 (1.9)	7.8 (1.7)	-1.0	0.35
TSIA total scores	13.3 (3.5)	25.2 (6.8)	-1.44	0.19
Trust (ASQ)	38.8 (2.3)	33.8 (1.8)	1.72	0.13
Discomfort for the Intimacy (ASQ)	27.5 (2.7)	35.4 (3.0)	-1.90	0.10
Secondary Relationships (ASQ)	11.5 (1.8)	18.0 (1.2)	-3.09	0.02*
Need Approval (ASQ)	20.8 (2.1)	21.4 (2.8)	-0.17	0.87
Worry for Relationships (ASQ)	25.3 (4.0)	32.4 (2.5)	-1.60	0.15
CR (ERQ)	31.0 (2.8)	30.4 (1.7)	0.19	0.85
ES (ERQ)	8.5 (1.7)	16.0 (2.0)	-2.78	0.03*

	F mean (se)	M mean (se)	t	p
Problem-Focused Coping (COPE)	32.5 (1.9)	34.4 (1.4)	-0.83	0.44
Transcendental-Focused Coping (COPE)	22.8 (3.1)	19.4 (3.5)	0.70	0.51
Positive-Focused Coping (COPE)	35.0 (1.1)	34.6 (1.2)	0.25	0.81
Social Support Coping (COPE)	36.5 (2.6)	34.6 (2.8)	0.49	0.64
Avoidant Coping (COPE)	26.8 (3.4)	27.0 (1.9)	-0.07	0.95

Note. Significant results are reported in **bold***. Abbreviations: TSIA: Toronto Structured Interview for Alexithymia; Difficulty in Identifying Feelings: DIF; Difficulty in Describing Feelings: DDF; Externally Oriented Thinking: EOT; Imaginal Processes: IP; Attachment Style Questionnaire: ASQ; Emotion Regulation Questionnaire: ERQ; Coping Orientation to Problems Experiences: COPE.

TSIA and socio-demographic, psychological and MRI variables

No association between age and TSIA scores (DIF: r=-0.02, p=0.96; DDF: r=-0.15, p=0.69; EOT: r=0.24, p=0.54; IP: r=0.52, p=0.15; total scores: r=0.17, p=0.66) or between years of formal education and TSIA scores (DIF: r=-0.47, p=0.20; DDF: r=-0.44, p=0.23; EOT: r=-0.40, p=0.28; IP: r=-0.43, p=0.24; total scores: r=-0.52, p=0.15) was found. Negative correlations were found between the dimension Trust of ASQ and DIF (p=0.02), EOT (p=0.03), and total (p=0.04) TSIA scores. In parallel, the dimension Secondary Relationships of ASQ was positively (p=0.04) correlated with DIF TSIA score. Positive correlations were found between the dimension Expressive Suppression of ERQ and EOT (p=0.02), IP (p=0.04) and total (p=0.02) TSIA scores. Negative correlation was found between the dimension Social Support of COPE and IP (p=0.01) TSIA scores, while positive correlation was found between the dimension Avoidant Coping of COPE and DIF (p=0.05), or DDF (p=0.04) TSIA scores. Importantly, as regard the association between TSIA and brain macro-structural measures, IP scores were positively correlated (p=0.03) with the left entorhinal cortical thickness values. The results of significant statistical correlations are reported in Table 2.

Tab. 2. Correlations between TSIA (factors and total scores), psychological scales (ASQ, ERQ, COPE), and measures of brain volumes and cortical thickness.

Variables	TSIA DIF	TSIA DDF	TSIA EOT	TSIA IP	TSIA TOT
Trust (ASQ)	-0.75*	-	-0.71*	-	-0.70*
Secondary Relationship (ASQ)	0.68*	-	-	-	-
Expressive Suppression (ERQ)	-	-	0.74*	0.66**	0.76*
Social-Support Coping (COPE)	-	-	-	-0.78**	-
Avoidant Coping (COPE)	0.66*	0.67*	-	-	-
Left Entorhinal Cortical Thickness	-	-	-	0.72**	-

Note. Only significant correlations are reported. (*p<0.0;5 **p<0.01) Abbreviations: TSIA: Toronto Structured Interview for Alexithymia; Difficulty in Identifying Feelings: DIF; Difficulty in Describing Feelings: DDF; Externally Oriented Thinking: EOT; Imaginal Processes: IP; Attachment Style Questionnaire: ASQ; Emotion Regulation Questionnaire: ERQ; Coping Orientation to Problems Experiences: COPE.

Tab. 3A. Cluster (the percentage of context units classified in the cluster is reported). CU= context units classified.

Cluster 1		Cluster 2		Cluster 3		Cluster 4	
Think		Feel		Relationship		Remember	
keyword	CU	keyword	CU	keyword	CU	keyword	CU
think	104	feel	100	person	163	imagine	84
see	71	own	77	talk	163	see	71
write	45	manage	77	feeling	149	take	64
friend	38	moment	67	feel	116	put	61
ask	32	understand	66	people	114	positive	39
call	26	situation	51	understand	100	home	31
find	26	live	50	find	80	beautiful	28
time	21	pleasure	50	situation	71	problems	27
boy	20	happen	33	friend	70	return	27
different	20	anger	32	find out	45	bring	24

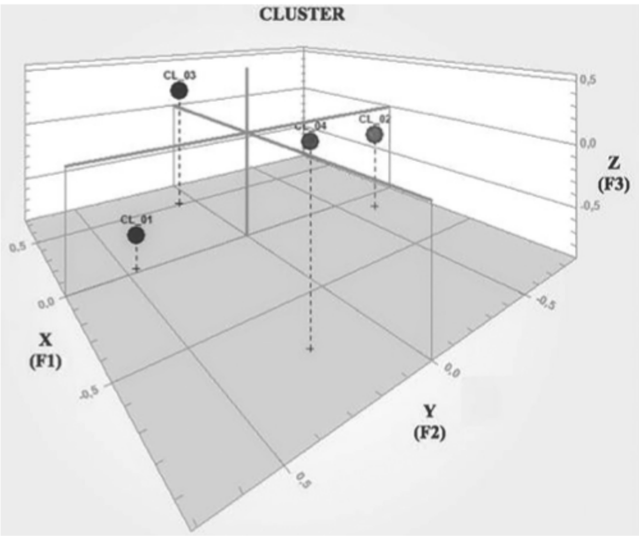
Tab. 3B. Cluster coordinates on factors (the percentage of explained inertia is reported for each factor). CU = context units classified.

Cluster	Label	CU classified	Factor 1 Experience	Factor 2 Thought	Factor 3 Aim
1	Think	**34.24%**	0.03	Reasoning 0.46	Speculate -0.64
2	Feel	**18.09%**	Personal -0.13	Feeling -0.65	Speculate -0.18
3	Relationship	**23.15%**	Social 0.52	0.08	Choice 0.24
4	Remember	**24.51%**	Personal -0.73	Reasoning 0.23	Choice 0.30

Text meaning and socio-demographic, psychological and MRI variables

The results of the cluster analysis showed that the 369 keywords selected allowed for the classification of 96.8% of the corpus. According to the theoretical framework (Cordella et al., 2014) we choose the solution with four cluster. The four clusters were of different sizes and reflected the general approach to the emotional experience (Table 3A). The first cluster reflected the reasoning on the life event and hypothesis resulting in a rationale thinking process; the second cluster highlighted the capacity to reflect on the experience of personal feelings; the third cluster represented the relationships characterizing social life; and the fourth cluster got back to memories, reasoning on personal choices that were made. The correspondence analysis detected three latent dimensions (Table 3B: Figure1). The first factor represented the experience that could be personal (negative pole) or social (positive pole); the second factor reflected the thought that could be made on feelings (negative pole) or on a rational reasoning (positive pole); and the third factor represented the aim of the thinking process that could lead to make a speculation (negative pole) or a choice (positive pole).

Fig. 1. 3-D scatterplot of Cluster (CL) coordinates on factors. X= Factor 1 (F1); Y= Factor 2 (F2); Z= Factor 3 (F3).



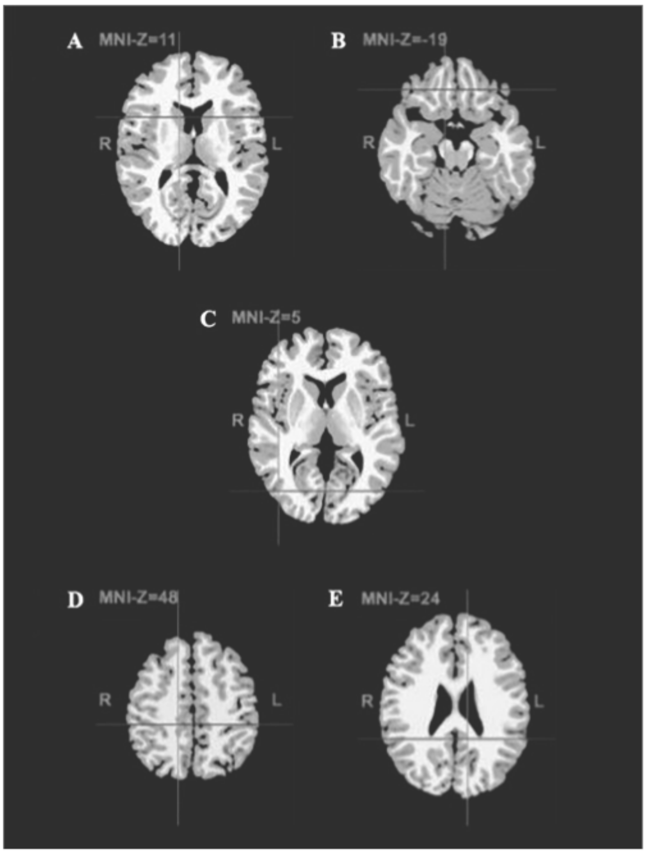
The correlation coefficient between the lexical scores of the three factors resulted from the correspondence analysis and TSIA, ASQ, ERQ, and COPE scores, as well as brain volume and cortical thickness are reported in Table 4. Namely, DIF, DDF, EOT and total alexithymia scores were positively associated with the second lexical factor (Thought). Furthermore, the emotional regulation strategy categorized Cognitive Reappraisal (through which the initial interpretation of a given stressful situation is re-evaluated) was negatively associated with the third lexical factor (Aim). In turn, this factor was negatively associated with the Problem-Focused Coping strategy. In parallel, the Transcendental-Focused Coping strategy was negatively associated with the first lexical factor (Experience). At neurobiological level (Figure 2), the first factor was negatively associated to the volume of right caudate nucleus and thickness of right medial orbitofrontal cortex, as well as positively to thickness of right lateral occipital cortex. The third factor was negatively associated with the volumes of middle anterior, central, and middle posterior cerebral cortices, and thickness of right postcentral cortex and left posterior cingulate cortex.

Tab. 4. Correlation coefficients between lexical factors and psychological scale values (TSIA, ASQ, ERQ, COPE) as well as cerebral structure values.

Variables	Factor 1	Factor 2	Factor 3
Difficulty Identifying Feelings (TSIA DIF)	-	0.83**	-
Difficulty Describing Feelings (TSIA DDF)	-	0.71**	-
Externally Oriented Style of Thinking. (TSIA EOT)	-	0.68**	-
TSIA Total score	-	0.77**	-
Cognitive Reappraisal (ERQ)	-	-	-0.68**
Problem-Focused Coping (COPE)	-	-	-0.72**
Trascendental-Focused Coping (COPE)	-0.74**	-	-
Right-Caudate Volume	-0.71**	-	-
Right Medialorbitofrontal Cx Thickness	-0.78**	-	-
Right Lateraloccipital Cx Thickness	0.70**	-	-
Right Postcentral Cx Thickness	-	-	-0.78**
Left Posteriorcingulate Cx Thickness	-	-	0.71**

Note. Only significant correlations are reported. (*p<0.0;5 **p<0.01). Abbreviations: TSIA: Toronto Structured Interview for Alexithymia; Difficulty in Identifying Feelings: DIF; Difficulty in Describing Feelings: DDF; Externally Oriented Thinking: EOT; Imaginal Processes: IP; Attachment Style Questionnaire: ASQ; Emotion Regulation Questionnaire: ERQ; Coping Orientation to Problems Experiences: COPE ; Cortex : Cx.

Fig. 2. Neural correlates of the three factors resulted from the correspondence analysis



Note. Representative axial slices (Montreal Neurological Institute template, MNI) showing the brain areas whose macro-structural variations have been associated to scores of the three factors.

The first factor was negatively associated to volumes of right caudate (A) and thickness of right medial orbitofrontal cortex (B), and positively to thickness of right lateral occipital cortex (C). The third factor was negatively associated with thickness of right postcentral cortex (D) and left posterior cingulate cortex (E). The right side of the brain is shown on the right side. Right: R; Left: L.

Discussion

Although this is a preliminary study, the present data suggest that the methodology proposed in order to identify the connections among verbal expression, alexithymia levels and brain structure seems to be promising for a deeper understanding of the bio-psycho-linguistic connections.

In the present study, females and males were similar in age, education years, and scores on almost all psychological scales, even if in comparison to female participants the male participants reported the relationships as having a more secondary valence and showed higher levels of expressive suppression, conceptualized as behavioral inhibition of the emotions.

High total alexithymia levels as well as great difficulty in describing feelings and the externally oriented thinking were associated with an attachment style characterized by low trust. In parallel, more the relationships were reported as having a secondary valence more the difficulty in describing feelings was evident. Furthermore, high total alexithymia levels as well as the externally oriented thinking and poor imaginative processes were associated with the emotional expressive suppression. Poor imaginative processes were correlated with a coping strategy characterized by scarse social support, while the coping strategy represented by avoidance behavior was associated with difficulty in describing and identifying feelings, characterizing alexithymic traits. Accordingly, individuals with high alexithymic traits reported difficulties with emotional regulation and attention (Mueller et al., 2006), made less use of cognitive reappraisal like reinterpretation of emotional stimuli to reduce their emotional impact (Swart et al., 2009), and were insecurely attached to others (Grabe et al., 2001). Accordingly, in a sample of undergraduate students Montebarocci and colleagues (2004) found that the attachment dimensions related to insecure style (discomfort with closeness, relationships as secondary, and need for approval) were positively associated with alexithymia scores, while an attachment dimension related to secure style (confidence) was negatively associated with alexithymia scores. The relationship between alexithymia and attachment styles might be determined by events occurring in childhood, such as psychic trauma or disturbances in the mother–infant relationship. Such events could impair the capacities of emotion recognition and expression. In fact, recognition and expression of emotions have been found to be associated with family environment and history of childhood maltreatment (Berenbaum & James, 1994). Children who grow up in environments in which they feel emotionally insecure, would not learn how to successfully cope with their emotional states and stress, and would not comfortably express their feelings.

Importantly, as regard the association between TSIA scores and brain macro-structural measures, poor imaginative processes were associated with thicker left entorhinal cortex, in accordance with the findings that showed the firing rate of neurons in the entorhinal cortex as selectively altered when subjects were imagining (Kreiman et al., 2000).

The correlation coefficient between the lexical scores of the three factors (resulted from the correspondence analysis) and TSIA scores showed that high alexithymia (total and factors) levels were associated with a thought modality characterized by a rational (and not emotional) reasoning. Furthermore, the emotional regulation strategy categorized through which the initial interpretation of a given stressful situation is re-evaluated was associated with the speculative thinking processes. In turn, these processes are associated with a problem-focused coping strategy. In parallel, the transcendental-focused coping strategy was associated with the tendency to be engaged in personal (not social) experience.

At neurobiological level, the tendency to be engaged in personal (and not social) experience was associated to large volumes of right caudate and thickness of right medial orbitofrontal cortex. Conversely, the tendency to be engaged in social (and not personal) experiences was associated to great thickness of right lateral occipital cortex. Relevant investigation has focused on the comparison between self-related states (e.g., processing information related to oneself, "self") and non self-related states (e.g., processing information related to other people, "others") (Northoff et al., 2006), evidencing that such a processing tends to yield different levels of brain activity for self and others. Specifically, the medial prefrontal cortex tends to be more active in self-related states in comparison to others-related states, and the posteromedial cortex tends to be more active for others than for self (Araujo et al., 2013). In a more recent study, Araujo et al. (2015) focused on two kinds of self-related mental states: states pertaining to historical aspects of personal life, and states pertaining to one's ongoing body status. The first kind of mental state has been designated as personal autobiographical self, concerning biographical information (including simple facts of one's identity), personality traits, and specific life events and episodes of an individual. The second kind of mental state may be designated as core self, related to interoceptive and exteroceptive awareness. Totally fitting with the present data, the conjunction analysis performed by Araujo et al. (2015) showed that personal autobiographical self yielded high level of activity in orbitofrontal cortex and caudate nucleus.

Furthermore, while the interoception compared with exteroception was associated with greater activity in postcentral gyrus and posterior cingulate cortex, the exteroception compared with interoception was associated with greater activity in orbitofrontal cortex (Araujo et al., 2015). By using a task-dependent meta-analytic connectivity modeling combined with a task-independent resting-state connectivity analysis, Murray et al. (2015) identified the pregenual ACC and anterior insula as regions specific to conceptual self, and the posterior cingulate cortex and temporoparietal junction as regions specific to others, and further the resting-state connectivity within ventromedial prefrontal cortex and medial orbitofrontal cortex as the network self/others, suggesting self-updating via integration of self-relevant social information.

Notably, postcentral and posterior cingulate cortices are considered to be involved in emotional regulation and somato-sensory awareness (Aviram-Friedman et al., 2018). In fact, the network comprising the somato-sensory and prefrontal cortices is involved in sensing and monitoring the physiological bodily conditions (Critchley et al., 2003), representing the internal viscero-sensory state within the context of ongoing activities (D'Angelo & Casali, 2013), and feeling self- and externally-induced emotions (Anders et al., 2004).

It has been advanced that in the condition of efficient functioning the subjects have internal models of their internal or external environment that serve the function of representing it. The internal models form "embodied" representations grounded in sensorimotor control loops, and these representations in turn are internally manipulated before or instead of acting directly on environment (Niedenthal et al., 2005).

As postulated by Araujo et al. (2013), the level generated in midline cortical structures, as medial orbitofrontal, postcentral and posterior cingulate cortices, is congruent with the level of processing of internally generated representations. Not by chance, as indicated by the present study, the tendency towards speculative thinking was associated with great thickness of right postcentral cortex and left posterior cingulate cortex.

Within the framework of the multiple code theory (Bucci, 1997), the emotions are conceived as image-action patterns, relatively dominated from visceral, somatic and motor states. Therefore, they include brain representations of specific actions associated with emotional activation and visceral or somatic experiences associated in turn with such activation. Emotional patterns begin to form in the non-verbal system before the acquisition of language and their content can be linked to language through the referential process.

The present study indicates that the organizational factors of thought and language, conveying also the emotional meaning of the text, are related to the structure of cerebral areas involved in somato-sensory associative processes (postcentral and lateral occipital cortices), emotional and interoceptive awareness (posterior cingulate cortex), imagination (entorhinal cortex) and emotional control and self-related mental states (orbitofrontal cortex). Just such functions are compromised in the presence of high levels of alexithymia that may be considered an embodiment process related to altered perception of physiological correlates (viscero- and somato-motor responses) of the emotional activation resulting in a deficit in the emotional awareness, leading to not-verbally express emotions. In fact, alexithymia would be associated to a lacking relocation (from the internal state to the symbolic representation) of the emotional signals that thus remain not-cognitively described and not mentalized. In accordance, somato-sensory amplification has been described in the presence of definite alexithymia (Huber et al., 2002). Karlsson et al. (2008) suggested that in high-alexithymic individuals the brain regions involved in bodily awareness, as somato-sensory cortices, may be hyperactive during emotional processing, possibly reflecting the alexithymic tendency to experience physical symptoms when emotionally aroused. In the same line, Zhang et al. (2011) interpreted the increase in gray matter density in relation to alexithymia as indicative of a greater reliance on bodily sensations during the subjective experience of emotion.

Thus, in the presence of alexithymia an altered referential process can lead to emotions somato-sensorially perceived but not verbally expressed, until to not having words for the emotions or being without symbols for the somatic states. On this vein, an intriguing conceptualization called "alexisomia" (Shitsu-taikan-sho in Japanese) refers to difficulty in the awareness of somatic sensations in addition to a lack of awareness of emotions and it might be an important variable in the pathology of psychosomatic disorders (Ikemi & Ikemi, 1986; Moriguchi & Komaki, 2013). The authors proposed that in alexisomia the reduced awareness results by impairment of senses necessary to maintain homeostasis (such as hunger and sleep), senses associated with adaptive processes to changes in environment that subjects normally feel as warning signs (such as fatigue), and senses that accompany physical diseases (such as chill and pain). Ikemi and Ikemi (1986) added that shitsu-taikan-sho-prone individuals show unhealthy and self-destructive lifestyles and have difficulties in expressing bodily feelings, in responding accordingly and in awareness of bodily states. Thus, if the awareness of bodily states is the basis of emotional awareness, deficits of emotional awareness underlying alexithymia might be related to deficits of bodily sensation awareness underlying alexisomia.

In the present study most of associations were found between first and third factor (Experience and Aim) and the macro-structural measures in the right brain hemisphere, totally fitting the Bucci's theory (1997) proposing the right hemisphere as the neurophysiological substrate underlying the processing of emotional information and referential process. Interestingly, the intricate relationship between psychic and physical levels in somatoform disorders is emphasized by the identification of a predominant pattern of lateralization of somatic symptoms correlated with emotional disorders. Min and Lee (1997) studied patients with depressive, anxiety and somatization disorders and divided them into two groups according to the laterality of somatic symptoms. They found that the main somatic symptoms occurred more frequently on the left side symptomatology, inferring that the right hemisphere has more to do than the left one with the occurrence of emotionally conditioned somatization symptoms.

Limitations of the study

Despite the promising results of this pilot study, further researches are needed to better investigate the reciprocal relationships among the measures of neurobiological structures, the capacity of identifying, describing and regulating emotions, and the ability of translating the emotional experiences into verbal forms.

The main study limitation is the sample size. In fact, due to the small and homogeneous sample used in this study, effect sizes should be interpreted with caution as they are limited in generalizability. Future studies should include larger samples, focusing on differences in sex, age and education years, sociocultural environment, and psychological features.

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The authors contributed equally to this manuscript.

Compliance with Ethical Standards

Conflict of interest
The authors declare that they have no competing interests.

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