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3rd RaPID Workshop: Resources and Processing of Linguistic, Para-linguistic and Extra-linguistic Data from People with Various Forms of Cognitive/Psychiatric/Developmental Impairments

PROCEEDINGS

Dimitrios Kokkinakis, Kristina Lundholm Fors, Charalambos Themistocleous, Malin Antonsson, Marie Eckerström (eds.)

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Resources and Processing of Linguistic, Para-linguistic and Extra-linguistic Data from People with Various Forms of Cognitive/Psychiatric/Developmental Impairments (RaPID-3)

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RaPID3@LREC2020 - Preface

Welcome to the LREC2020 Workshop on "Resources and ProcessIng of linguistic, para-linguistic and extra-linguistic Data from people with various forms of cognitive/psychiatric/developmental impairments" (RaPID-3).

RaPID-3 aims to be an interdisciplinary forum for researchers to share information, findings, methods, models and experience on the collection and processing of data produced by people with various forms of mental, cognitive, neuropsychiatric, or neurodegenerative impairments, such as aphasia, dementia, autism, bipolar disorder, Parkinson's disease or schizophrenia. Particularly, the workshop's focus is on creation, processing and application of data resources from individuals at various stages of these impairments and with varying degrees of severity. Creation of resources includes e.g. annotation, description, analysis and interpretation of linguistic, paralinguistc and extra-linguistic data (such as spontaneous spoken language, transcripts, eyetracking measurements, wearable and sensor data, etc). Processing is done to identify, extract, correlate, evaluate and disseminate various linguistic or multimodal phenotypes and measurements, which then can be applied to aid diagnosis, monitor the progression or predict individuals at risk.

A central aim is to facilitate the study of the relationships among various levels of linguistic, paralinguistic and extra-linguistic observations (e.g., acoustic measures; phonological, syntactic and semantic features; eye tracking measurements; sensors, signs and multimodal signals). Submission of papers are invited in all of the aforementioned areas, particularly emphasizing multidisciplinary aspects of processing such data and the interplay between clinical/nursing/medical sciences, language technology, computational linguistics, natural language processing (NLP) and computer science. The workshop will act as a stimulus for the discussion of several ongoing research questions driving current and future research by bringing together researchers from various research communities.

Topics of Interest

The topics of interest for the workshop session include but are not limited to:

- Infrastructure for the domain: building, adapting and availability of linguistic resources, data sets and tools
- Methods and protocols for data collection
- Acquisition and combination of novel data samples; including techniques for continuous streaming, monitoring and aggregation; as well as self-reported behavioral and/or physiological and activity data
- Guidelines, protocols, annotation schemas, annotation tools
- Addressing the challenges of representation, including dealing with data sparsity and dimensionality issues, feature combination from different sources and modalities
- Domain adaptation of NLP/AI tools
- Acoustic/phonetic/phonologic, syntactic, semantic, pragmatic and discourse analysis of data; including modeling of perception (e.g. eye-movement measures of reading) and production processes (e.g. recording of the writing process by means of digital pens, keystroke logging etc.); use of gestures accompanying speech and non-linguistic behavior

- Use of wearable, vision, and ambient sensors or their fusion for detection of cognitive disabilities or decline
- (Novel) Modeling and deep / machine learning approaches for early diagnostics, prediction, monitoring, classification etc. of various cognitive, psychiatric and/or developmental impairments
- Evaluation of the significance of features for screening and diagnostics
- Evaluation of tools, systems, components, metrics, applications and technologies including methodologies making use of NLP; e.g. for predicting clinical scores from (linguistic) features
- Digital platforms/technologies for cognitive assessment and brain training
- Evaluation, comparison and critical assessment of resources
- Involvement of medical/clinical professionals and patients
- Ethical and legal questions in research with human data in the domain, and how they can be handled
- Deployment, assessment platforms and services as well as innovative mining approaches that can be translated to practical/clinical applications
- Experiences, lessons learned and the future of NLP/AI in the area

Submissions

Papers were invited in all of the areas outlined in the Topics of interest, particularly emphasizing multidisciplinary aspects of processing such data and the interplay between clinical/nursing/medical sciences, language technology, computational linguistics, NLP, and computer science. We welcomed also papers discussing problems derived from the design of relevant data samples and populations, but also the exploitation of results and outcomes as well as legal and ethical questions on how to deal with such data and make it available. Furthermore, the workshop solicited papers describing original research; and preferably describing substantial and completed work, but also focused on a contribution, a negative result, an interesting application nugget, a software package, a small, or work in progress. The workshop acted as a stimulus for the discussion of several ongoing research questions driving current and future research and challenges by bringing together researchers from various research communities.

We are grateful to our Program Committee members for their hard work in reading and evaluating all submissions. At the end, each submission received between 2 to 5 reviews, which helped the authors revise and improve their papers accordingly.

Unfortunately the workshop, which was originally planned to take place on the 11th of May 2020 in conjunction with the LREC 2020 conference, could not be held as a face-to-face meeting due to the ongoing Covid-19 pandemic. Nevertheless, there were 18 contributions accepted for the workshop (6 to be oral presentations and 12 to be posters). A keynote talk was invited by Dr. Athanasios Tsanas, the Usher Institute, University of Edinburgh, UK, with the title: "Harnessing voice signals using signal processing and statistical machine learning: applications in mental health and other biomedical and life sciences applications".

Workshop website: https://spraakbanken.gu.se/en/rapid-2020.

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Invited Speaker:

Athanasios Tsanas, the Usher Institute, University of Edinburgh, UK.

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Linguistic Markers of Anorexia Nervosa: Preliminary Data from a Prospective Observational Study

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Abstract

Recent works indicated the potential relevance of Natural Language Processing techniques for the detection of clinical conditions. This paper tries to address the issue in the Eating Disorder domain, by exploiting "linguistic biomarkers" for Anorexia Nervosa (AN) detection in female teenagers. We hypothesize that (i) disturbances in self-perceived body image, black and white thinking and mood changes strongly associated with AN disorder can result in altered linguistic patterns; and (ii) these subtle modifications can be identified by means of NLP tools, acting as early proxy measures for the disorder. To this aim, we enrolled 51 participants (age range: 14-18): 17 girls with a clinical diagnosis of Anorexia Nervosa and 34 normal weighted peers, matched by gender, age and educational level. Both the groups were asked to produce three written texts (around 10-15 lines long), i.e. two autobiographical narratives and a short description of a complex figure. A rich set of linguistic features was extracted from the text samples and the statistical significance in pinpointing the pathological process was measured. Our preliminary results show that subtle language disruptions, mainly at the lexical and syntactic level, can actually represent an early but reliable marker of the disease. However, an analysis on a bigger cohort with follow-up information, still ongoing, is needed to consolidate this assumption.

Keywords: Linguistic Markers, Feeding and Eating Disorders, Anorexia Nervosa

1. Background

1.1 Feeding and Eating Disorders: the case of Anorexia Nervosa

According to DSM-5 definition (American Psychiatric Association, 2013), Feeding and Eating Disorders (FED) are characterized by "a persistent disturbance of eating or eating-related behavior that results in the altered consumption or absorption of food and that significantly impairs physical health or psychosocial functioning".

Among these clinical conditions, Anorexia Nervosa (ICD-10-CM codes: F50.01 and F50.02 (World Health Organization, 1993; World Health Organization, 1995)) takes on a special relevance, due to both epidemiological reasons and medical outcomes. As a matter of fact, AN is relatively common among young women:[1] although community studies assessing the incidence of eating disorders are scarce, one-year prevalence rate of AN has been calculated as 370 per 100 000 young females (Hoek, 1993; Smink et al., 2012). The majority of AN patients in the community do not enter the mental healthcare system. All eating disorders have an elevated mortality risk; however, AN is the most striking disease, showing the highest mortality rates among psychiatric pathologies, 5.1 deaths per 1000 person-years, of which 1.3 deaths resulted from suicide (Harris and Barraclough, 1998; Arcelus et al., 2011).

There are three essential diagnostic features of AN (American Psychiatric Association, 2013): (i) persistent energy intake restriction, leading to a significantly low body weight (i.e., less than minimally normal or, for children and adolescents, less than that minimally expected) in the context of age, sex, developmental trajectory, and physical health; (ii) intense fear of gaining weight or of becoming fat (also known as "fat phobia"), or persistent behavior that interferes with weight gain, usually not alleviated by slimming; and (iii) a disturbance in self-perceived weight or shape.

Body mass index (BMI; calculated as weight in kilograms/height in meters^2) is the common measure to assess criterion (i). For adults, a BMI of 18.5 kg/m^2 has been employed by the World Health Organization (WHO) as the threshold of normal body weight (Cole et al., 2007).

From a psychological point of view, weight loss is often viewed by AN patients as a sign of extraordinary self-discipline, whereas weight gain is perceived as an unacceptable failure. Inflexible thinking is a core feature of the disorder, as well as narrow, rigid behaviour, almost disconnected from the somatic experience. Although some AN individuals may acknowledge being thin, they often do not recognize the serious medical consequences of their serious malnourished state; they either lack insight into or deny the problem.

A prompt identification (and treatment) of symptoms is linked to better outcomes (Herzog et al., 1996). Unfortunately, the diagnosis of AN is often elusive, and more than one half of all cases go undetected in the primary care setting (Becker et al., 1999). Therefore, current

[1] AN is far less common in males, with clinical populations generally reflecting approximately a 10:1 female-to-male ratio (American Psychiatric Association, 2013).

research continues to emphasise the need for novel reliable strategies in order to identify even early warning signs.

1.2 Linguistics and Natural Language Processing for the medical science: a growing area of study

Over the last few years, a growing body of linguistic studies have been devoted to speech and language disorders and remediation. This fairly new branch of linguistics, called "Clinical Linguistics" (Crystal, 1981), is constructing outline sketches of communicative disabilities, supporting the work of speech and language therapists and neuropsychologists. Within this context, a number of works have been published on "linguistic profiles" of various clinical populations (Marini and Carlomagno, 2004; Adornetti, 2018; Gagliardi, 2019): for example, linguistic deficits (mainly at syntactic and pragmatic level) have been reported in several neurodegenerative diseases such as dementia (Boschi et al., 2017; Beltrami et al., 2018), where language disruption is a common finding both at the earliest stages and in full-blown pathology; alterations have been extensively described in scientific literature on dysphonia and dysarthria, especially in the hypokinetic forms resulting from damage to the basal ganglia (such as in Huntington's disease, Progressive Supranuclear Palsy or Parkinsonism (Gagnon et al., 2018; Catricalà et al., 2019; Altmann and Troche, 2011; Montemurro et al., 2019)); some studies dealt with the linguistic habits of psychopathologies, e.g. schizophrenia (Dovetto, 2015; Bambini et al., 2016), personality disorder (Arntz et al., 2012), anxiety and depression (Ramirez-Esparza et al., 2008; Brockmeyer et al., 2015; Bernard et al., 2016; Edwards and Holtzman, 2017; Zimmermann et al., 2017; Al-Mosaiwi and Johnstone, 2018; Smirnova et al., 2018).

However, a very limited number of papers have been devoted to linguistic changes in patients with eating disorders (Lyons et al., 2006; Espeset et al., 2012; Skårderud, 2007a; Skårderud, 2007b; Wolf et al., 2013; Brockmeyer et al.,2013; Spinczyk et al., 2018).

Thanks to automated computational methods, progress in the field has been breathtaking. The development of new sophisticated techniques from Natural Language Processing (NLP) have been used to analyze written and spoken texts, revealing latent patterns and regularities of pathological languages.

This subtle language disruptions can be employed as "digital biomarkers", namely objective, quantifiable behavioral data which can be collected and measured by means of digital devices, allowing for a low-cost pathology detection and classification.

Dementia assessment is a key domain of NLP application for medical science, coming up with relevant results (Vincze et al., 2016; Asgari et al., 2017; Beltrami et al.,2018; Tóth et al., 2018; Themistocleous et al., 2018; Gosztolya et al., 2019; Fraser et al., 2019a; Fraser et al., 2019b), but this approach is spreading rapidly through the community (Spinczyk et al., 2018; Trotzek et al., 2018).

1.3 Linguistic profile of Anorexia Nervosa: a brief sketch

Little research has addressed the linguistic profiles of AN: some interesting studies focused on differences in self-presentation written texts of individuals who publicly defend AN as a lifestyle ("pro-ana") and individuals who identify themselves as recovering from anorexia; others investigated body's symbolic role in the course of illness and "concretized metaphors", i.e. "instances where the metaphors are not experienced as indirect expressions showing something thus mediated, but they are experienced as direct and bodily revelations of a concrete reality" (Enckell, 2002; Skårderud, 2007a); in layman's terms, emotions are concretised.

With regard to the first point, pro-anorexics and recovering anorexics engage in distinct linguistic self-presentation styles: the analysis of linguistic cues of emotional processes revealed that pro-anorexics usually use more positive emotional words (e.g. "happy", "good"), a lower rate of anxiety words (e.g. "afraid", "scared") and fewer cognitive mechanism words (specifically insight and causation words, e.g. "cause", "realize") than recovering anorexics (Lyons et al., 2006; Wolf et al., 2013). Moreover, pro-anorexics display lower levels of self-directed attention, since they make fewer first person singular self-references; their texts contain more present tense verbs and fewer past tense verbs, suggesting a focus on the present experience rather than on the past. With regard to the prevalence of AN-related psychological concerns, pro-anorexics were more preoccupied with eating (e.g. "food", "meal", "diet") and less with school-related issues (e.g. "exam", "study") and death (e.g. "dead", "death", "coffin").

Compared with recovery and control blogs, pro–eating disorder written productions contain an exceptionally high proportion of exclamation marks but much fewer question marks: according to (Wolf et al., 2013), this might reflect a form of complexity reduction at the syntactical level. Furthermore, exclamation marks are often used as an orthographic intensifier, indicating a strong self-affirmation (Rubin and Greene, 1992), whereas the infrequent use of question marks might indicate a reduced tendency to express insecurity and fears (Wolf et al., 2013). This strong self-focus enters into combination with a low social relatedness. Pro–ana bloggers appear to be less connected with the outside world and real-life relationships (Gavin et al., 2008): this tendency is further supported by a low third-person plural pronoun use.

Taken together, these observations are consistent with an interpretation of pro-anorexics' language use as a coping strategy aimed at stabilizing them emotionally, experiencing a sense of control over the illness, namely a mechanism of self-defense.

With respect to the second point, the work of (Skårderud,2007a; Skårderud, 2007b) addressed the striking clinical feature of concreteness of symptoms, due to body image fluctuation. Numerous sentences of AN texts instantiate symbolisation via the body: these physical metaphors show a striking closeness and a primary relation between emotions and different sensorimotor experiences (e.g. heaviness/lightness: "*I dream of being so light that I can float in the air. Then I can move down the main street among the people, one meter above the ground, and I will feel that all my worries are gone, lifted off my shoulders*"; "*I feel sad. And when I am sad, I feel burdened and heavy... and then comes the urge to lose weight*").

Quoting the author, "these bodily metaphors do not function mainly as representations [...], but as presentations which are experienced as concrete facts here-and-now and are difficult to negotiate with. The 'as-if' quality of the more abstract meaning of the metaphor is lost and it becomes an immediate concrete experience" (Skårderud,

2007a). These observations have been interpreted as evidence for the impairment of the reflective function of the mind, namely "the psychological processes underlying the capacity to make mental representations".
However, all these insights are not clear-cut and conclusive. Thus, the Linguistic profile of AN (and FED in general) remains, to date, mostly unexplored. Moreover, all the retrieved studies tackled verbal productions written in a language that belongs the Germanic language group: English, German or Norwegian. Given the peculiar typological features of Italian language (e.g. at the morpho-syntactic level), these results cannot be readily generalized.

2. Materials and Methods

2.1 Rationale

Drawing on this wide body of clinical evidence and computational experiences, we hypothesize that (i) disturbances in self-perceived body image, black and white thinking and mood changes strongly associated with AN disorder can results in altered linguistic patterns; and (ii) these subtle modifications can be detected by means of NLP tools, acting as early proxy measures for the disorder. To test our hypothesis, the study will compare some short, written productions of AN patients with those of a control group, in order to identify possible distinctive linguistic features. To the best of our knowledge, this is the first work on linguistic profile of AN in Italian.

2.2 Data collection

The study was approved by the Ethics Committee of Azienda Ospedaliero-Universitaria di Bologna, Policlinico Sant'Orsola-Malpighi, Italy (prot. 683/2019/Oss/AOUBo). We enrolled 51 participants, ranging in age from 14 to 18: the sample is composed of an Anorexia Nervosa group (AN) and a Control Group (CG), with a ratio of 1:2. The AN group included 17 girls, recruited at the Regional Center of Eating disorders of the Child Neuropsychiatry Unit (Policlinico Sant'Orsola – Malpighi, University of Bologna) with a clinical diagnosis of Anorexia Nervosa according to national and international guidelines (American Psychiatric Association, 2013); 6 out of 17 show purging behavior, 12 have been experienced primary or secondary amenorrhea. The mean BMI of the group is 17.0. CG included 34 girls matched by gender, age and educational level (school grade/type of secondary school attended). Inclusion criteria are outlined in table 1, while table 2 summarizes the demographic characteristics of the sample.

AN	CG
- Age: 14-18 - Diagnosis of Anorexia Nervosa (DSM-5) - fair level of communication skills in Italian (Language History Questionnaire) - written informed consent	- Age: 14-18 - BMI ≥ 18.5 - fair level of communication skills in Italian (Language History Questionnaire) - written informed consent

Table 1: Inclusion criteria for participant enrollment.

GROUP	N	AGE (mean ± sd)	YEARS OF EDUCATION (mean ± sd)
AN	17	16 ± 1.37	11.06 ± 1.34
CG	34	16 ± 1.35	11.15 ± 1.28

Table 2: Demographic characteristics of the sample.

Subjects were asked to produce three short written texts (around 10-15 lines long), in the presence of the experimenter:

1. personal task (-PER-): "How would you describe yourself? (Please, talk about your physical and personality traits, your hobbies etc.)".
2. neutral task (-NEU-): "How do you usually spend time with your friends?"
3. description of a complex picture (-FIG-); the renowned black and white picture "Cookie theft" from the BDAE - Boston Diagnostic Aphasia Examination Battery (Goodglass et al., 2001) has been proposed as a stimulus (figure 1).

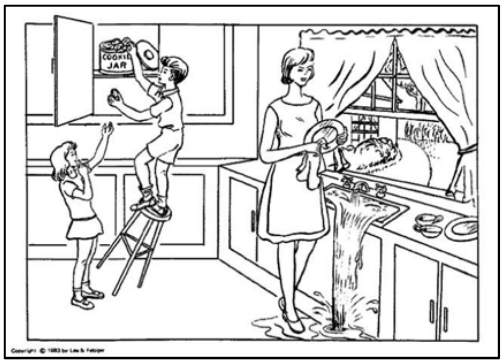

Figure 1: "The cookie theft" (Goodglass et al., 2001).

Language proficiency in Italian has been also assessed, by means of a short self-reported questionnaire. As a matter of fact, bilingualism and multilingualism are the norm rather than the exception in today's Italy: this additional test aims at assessing both quality and quantity of bilingual experience, in order to remove from the sample poor productions due to scarce language exposure.

3. Data analysis

The handwritten texts have been converted into digital texts manually by the linguists. After the automatic tokenization of the transcripts, the corpus has been enriched by adding linguistic information at the lexical and morphosyntactic levels: all the sentences have been automatically PoS-tagged, lemmatized and syntactically parsed with the dependency model used by the Turin University Linguistic Environment – TULE[2] (Lesmo, 2007), based on the TUT - Turin University TreeBank tagset (Bosco et al., 2000). All the annotations have been manually checked by one linguist, in order to remove the errors introduced by the automatic tagging. The revision has been made by using the Dependency Grammar Annotator - DGA opensource

[2] https://github.com/alexmazzei/TULE

software[3] for an easy visualization and correction of TULE mistakes at any level (see figure 2).

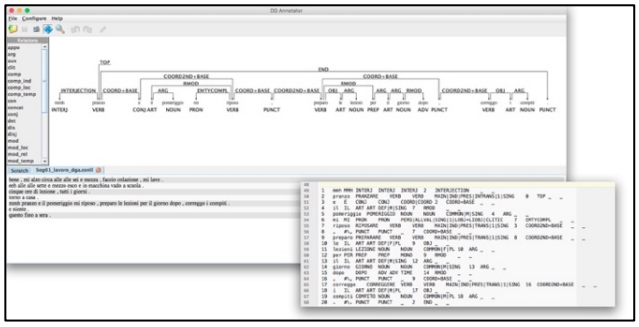

Figure 2: Dependency graph as shown by DGA and full utterance annotation in CoNLL-U format.

A multidimensional parameter analysis has been performed on the corpus: examining the relevant literature, we selected a wide range of linguistic/stylometric indexes to be tested in order to determine their relevance in the discrimination between AN subjects and normal weighted peers.
In addition, we used the software LIWC (Linguistic Inquiry and Word Count) (Chung and Pennebaker, 2007; Tausczik and Pennebaker, 2010; Agosti and Rellini, 2007), a text analysis program which counts the percentage of different lexical categories, in order to capture people's social and psychological states (i.e. emotions, thinking styles, social concerns). The complete list for all the features considered in this study is reported in the Appendix A.
The Statistical significance of differences between AN and controls on all the indexes has been evaluated with the Kolmogorov–Smirnov non-parametric test, because of the small size of our corpus.

4. Results

The focus of this study was the analysis of written texts of AN patients, in comparison to normal weighted peers. The study is still ongoing, with full results expected in 2021: therefore, the findings presented in this work are far from conclusive.
Age and schooling differences of the enrolled participants (table 2) are not statistically relevant at the Kolmogorov-Smirnov test; thus, the sample is well balanced on each variable.
Table 3 presents the number of words produced by the groups for each task. As corroborated by the statistical analysis, the three stimuli show different "elicitation power" (Kruskall-Wallis non-parametric test with Dunn's multiple comparison, p-value < 0.001): as a matter of fact, the "personal task" prompted richer responses in both samples.
Results for statistically relevant indexes are presented in table 4. For a complete picture of real values and a selection of our corpus, please refer to Appendix B, C and D.

task	AN (mean ± sd)	CG (mean ± sd)
task1 -PER-	98.63 ± 42.94	105.5 ± 35.05
task2 -NEU-	61.53 ± 40.98	68.56 ± 31.55
task 3 -FIG-	81.50 ± 40.02	77.15 ± 24.13
overall	80.22 ± 43.16	83.74 ± 34.18

Table 3: Text length, in tokens, produced on the three tasks by AN and CG subjects, shown as mean±standard deviation.

FEATURES	task 1 -PER-	task 2 -NEU-	task 3 -FIG-	overall
LEX_ContDens			*	
LEX_PoS_ADV	*			
LEX_PoS_CONJ				*
LEX_PDEIXIS		*		
LEX_HonoreR			*	*
SYN_NPLENSD		*		
SYN_GRAPHDISTM				**
SYN_SLENM	*			**
SYN_SLENSD	*			*
LIWC_WPS		*		*
LIWC_SIXLTR			*	***
LIWC_DIC		*	***	
LIWC_PERCP		*		
LIWC_PRES			*	

Table 4: Results of the linguist analysis. The significant p-value is indicated for the corresponding feature and task, with *p < 0.05; **p < 0.01; ***p < 0.001.

5. Discussion and Concluding Remarks

Firstly, we notice that the most effective task is the description of a complex picture. This finding is not surprising: according to (Chung, 2007), linguistic tasks not directly pertaining to psychological and bodily states provide a non-reactive way to explore social and personality processes. However, aggregated tasks represent the best testing ground for the evaluation of subtle linguistic alteration: it seems trivial, but the simple merging of the three written texts allows to partially overcome the issue of data scarceness, increasing the sensitivity of the analysis.
From the qualitative point of view, syntactic reduction appears as the most relevant trait of AN productions. To this respect, several indexes emerged as statistically significant: sentence length mean and standard deviation, number of dependent elements linked to the noun, Global Dependency Distance and LIWC_WPS, i.e. the number of tokens per sentence. Among the distinguishing lexical features of our cohort are: Content Density, i.e. the ratio of open-class words to closed-class words, Lexical Richness calculated as R – Honoré's statistic, rate of Adverbs, Conjunctions and personal deixis, incidence of LIWC2007 Dictionary (LIWC_DIC). At the semantic level, our data show lower incidence of lexical units related to perceptual processes (LIWC_PERCP, i.e multiple sensory and

[3] http://medialab.di.unipi.it/Project/QA/Parser/DgAnnotator/

perceptual dimensions associated with the five senses) in AN patients with respect to controls.

The most frequently described trait of AN, namely the abnormal use of first-person singular pronouns (Lyons et al., 2006; Wolf et al., 2013), is not confirmed by our data, as well as the plural ones, since the differences on LIWC_1PS and LIWC_1PP indexes are not statistically relevant. The analysis of temporal focus is controversial too: in contrast with the work of (Lyons et al., 2006), the written text of CG contains more present tense verbs (LIWC_PRES), disconfirming the presumed attentional focus on the here and now. Furthermore, none of the readability features turn out to be statistically relevant, except for the usage of long (> 6 letter) words (LIWC_SIXLTR).

However, these are preliminary data and additional evidences are needed to assess the actual reliability of linguistic parameters that have been proved to be probable proxy measures of AN. Moreover, due to the small size of the corpus, the order of the tasks was not counterbalanced across participants; this limitation should be tackled in the next administrations of the test.

Future works should also consider possible correlation between linguistic and clinical variables, such as diagnostic subtypes ("restricting" or "binge-eating/purging"), severity, physical signs and symptoms (e.g. amenorrhea), comorbidity (e.g. bipolar, depressive, anxiety, or obsessive-compulsive disorders), age of the onset and pharmacological treatment with Selective Serotonin Reuptake Inhibitors (e.g. fluoxetine, sertraline, fluvoxamine), anxiolytics (e.g. benzodiazepines) or antipsychotics (e.g. olanzapine, quetiapine).

If these preliminary results will be confirmed, the use of an automatic system that analyses and classifies patients' written productions can represent a promising approach for the identification of both overtly pathological and sub-clinical conditions.

6. Ethics Statement

All ethical principles of the Helsinki Declaration were followed.

The study was reviewed and approved by the Ethics Committee of Azienda Ospedaliero-Universitaria di Bologna, Policlinico Sant'Orsola-Malpighi, Italy (prot. 683/2019/Oss/AOUBo).

Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

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8. Author contribution

GM: literature review, linguistic data collection and annotation, statistical analysis; GG: literature review, methodology, statistical analysis, writing; VC: clinical data collection; FT: automatic feature extraction; EM, PG, FS, FM, VF: collaborators; AP: supervision and project administration.

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APPENDIX A: LIST OF FEATURES TAKEN INTO CONSIDERATION IN THIS STUDY		
INDEX		**DESCRIPTION & BIBLIOGRAFIC REFERENCES**
Lexical features	Text length LEX_NW	Number of tokens
	Content Density LEX_ContDens	The ratio of open-class tokens to closed-class tokens (Roark et al., 2011).
	Part-of-Speech rate LEX_PoS_*	The average rate of occurrence for each Part-of-Speech (PoS) category (Holmes and Singh, 1996; Bucks et al., 2000).
	Reference Rate to Reality LEX_RefRReal	The ratio of the total number of nouns to the total number of verbs (Vigorelli, 2004).
	Personal, Spatial and Temporal Deixis rate LEX_*DEIXIS	The rate of deictic expressions in the written text w.r.t. the total number of tokens (March et al., 2006; Cantos-Gómez, 2009).
	Relative pronouns and negative adverbs rate LEX RPRO	The rate of relative pronouns.
	Lexical Richness LEX TTR; LEX BrunetW; LEX HonoreR	This class of measures quantifies the richness of vocabulary/lexical diversity (Holmes and Singh, 1996; Brunet, 1978; Honoré, 1979): - *TTR, Type-Tokens Ratio* - *W, Brunet's Index* - *R, Honore's Statistic*
	Action Verbs rate LEX_ACTVRB	The metric probes the rate of action verbs (i.e. verbs referring to physical action, like "to put", "to run", "to eat") in the texts. (Gagliardi, 2014).
	Frequency-of-use LEX_DM_F	Mean frequency-of-use weight among words extracted from the De Mauro's frequency list (De Mauro, 2000).
	Propositional Idea Density LEX_IDEAD	Idea density is the number of expressed propositions (i.e. distinct facts or notions contained in a text) divided by the number of tokens (Snowdon et al., 1996; Roark et al., 2011).
Syntactic features	Number of dependent elements linked to the noun SYN NPLENM; SYN NPLENSD	The feature explores Noun Phrase complexity, counting the number of dependent elements linked to the head (e.g. Adjectives, Relative clauses...). Mean and Std. Deviation were taken into account.
	Global Dependency Distance SYN_GRAPHDISTM; SYN_GRAPHDISTSD	Given the memory overhead of long distance dependencies, the feature quantifies the difficulty in syntactic processing (Roark et al., 2007; Roark et al., 2011). Mean and Std. Deviation were taken into account.
	Syntactic complexity SYN_ISynCompl	Syntactic complexity is established by counting the linguistic tokens that can be considered to telltale signs of increased grammatical subordinateness and embeddedness, such as subordinating conjunctions, WH- pronouns, verb forms, both finite and non-finite and noun phrases. (Szmrecsányi, 2004).
	Syntactic embeddedness SYN_MAXDEPTHM; SYN_MAXDEPTHSD	The maximum "depth" of the dependency structure. Mean and Std. Deviation were taken into account.
	Sentence length SYN_SLENM; SYN_SLENSD	The average number of tokens for sentence. Mean and Std. Deviation were taken into account.
LIWC	Linguistic processes	Total words count (WC), Words per sentence (WPS), Words > 6 letters (SIXLTR), Dictionary words count (DIC)
	Function Words	1st person singular (1PS), 1st person plural (1PP), 2nd person singular (2PS), 2nd person plural (2PP), 3rd person singular (3PS), 3rd person plural (3PP), Negations (NEG), Past tense (PST), Present tense (PRES), Future tense (FUT), Gerund (GER), Conditional mood (COND), Passive voice (PASS), Past Participle (PP), Transitivity (TRAN)
	Affective processes (AFFP)	Positive emotions (+EMO), Negative emotions (-EMO), Anxiety (ANX), Anger (ANG), Sadness (SAD)
	Cognitive Processes (COGP)	Insight (INS), Cause (CAU), Discrepancies (DISCR), Tentativeness (TENT), Certainity (CERT), Inhibition (INH), Inclusive (INCL), Exclusive (EXCL)
	Perceptual processes (PERCP)	See (SEE), Hear (HEAR), Feel (FEEL)
	Biological processes (BIOP)	Body (BODY), Health (HLT), Ingestion (ING)
	Personal concerns (PERSC)	Work (WORK), School (SCHOOL), Death (DEATH), Achievement (ACH), Leisure (LEIS), Home (HOME), Sport (SPORT)
	Psychological processes (PSYP)	Family (FAM), Friends (FR), Humans (HUM), Social processes (SOC)

APPENDIX B: RESULTS OF LEXICAL AND SYNTACTIC FEATURES EXTRACTION (mean ± standard deviation)								
Feature	**task 1 -PER-**		**task 2 -NEU-**		**task 3 -FIG-**		**overall**	
	AN	**CG**	**AN**	**CG**	**AN**	**CG**	**AN**	**CG**
LEX_NW	98.63 ± 42.94	105.5 ± 35.05	61.53 ± 40.98	68.56 ± 31.55	81.50 ± 40.02	77.15 ± 24.13	80.22 ± 43.16	83.74 ± 34.18
LEX_ContDens	1.32±0.19	1.37±0.17	1.20± 0.23	1.14±0.19	1.17±0.15	1.07±0.14	1.22±0.20	1.19±0.21
LEX_PoS_*								
ADJ	0.13±0.02	0.11±0.03	0.06±0.03	0.05±0.03	0.06±0.03	0.04±0.03	0.08±0.04	0.07±0.04
ADV	0.10±0.04	0.12±0.04	0.09±0.05	0.11±0.05	0.07±0.04	0.06±0.04	0.09±0.05	0.10±0.05
ART	0.06±0.03	0.07±0.02	0.06±0.03	0.05±0.02	0.11±0.03	0.12±0.02	0.08±0.04	0.08±0.04
CONJ	0.08±0.03	0.09±0.02	0.08±0.04	0.09±0.03	0.06±0.03	0.07±0.02	0.07±0.03	0.08±0.03
DATE	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.01	0.00±0.00	0.00±0.01	0.00±0.00
INTERJ	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
NOUN	0.14±0.03	0.13±0.03	0.18±0.06	0.17±0.04	0.19±0.03	0.20±0.03	0.17±0.05	0.17±0.04
NUM	0.01±0.01	0.01±0.01	0.00±0.01	0.00±0.01	0.01±0.01	0.02±0.01	0.01±0.01	0.01±0.01
PHRAS	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
PREDET	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.01	0.00±0.00	0.00±0.00
PREP	0.08±0.03	0.07±0.03	0.13±0.06	0.14±0.04	0.11±0.04	0.11±0.03	0.12±0.05	0.11±0.05
PRON	0.07±0.03	0.07±0.02	0.06±0.05	0.07±0.04	0.07±0.04	0.08±0.03	0.07±0.04	0.07±0.03
VERB	0.20±0.04	0.21±0.03	0.20±0.06	0.20±0.03	0.21±0.04	0.22±0.04	0.20±0.05	0.21±0.03
LEX_RefRReal	0.72±0.23	0.67±0.17	1.04±0.71	0.92±0.33	0.99±0.27	0.96±0.24	0.93±0.47	0.85±0.28
LEX_PDEIXIS	0.04±0.03	0.04±0.02	0.03±0.03	0.04±0.03	0.03±0.01	0.03±0.02	0.03±0.02	0.04±0.02
LEX_SDEIXIS	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.01
LEX_TDEIXIS	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0.00±0.01	0.00±0.00	0.01±0.01	0.00±0.01
LEX_RPRO	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0.02±0.02	0.02±0.02	0.01±0.02	0.01±0.02
LEX_NEGADV	0.02±0.01	0.02±0.01	0.00±0.01	0.01±0.01	0.01±0.02	0.01±0.01	0.01±0.01	0.01±0.01
LEX_TTR	0.69±0.06	0.69±0.06	0.79±0.07	0.75±0.08	0.76±0.07	0.73±0.07	0.75±0.08	0.73±0.07
LEX_BrunetW	9.63±1.01	9.85±0.68	8.38±1.23	8.90±0.98	9.15±0.78	9.25±0.76	9.04±1.12	9.33±0.90
LEX_HonoreR	2408.7±659.1	2197.3± 480.0	2325.4±679.8	2172.6±703.0	2326.0±765.8	2026.1±747.5	2351.8±692.2	2131.9±652.0
LEX_ACTVRB	0.04±0.03	0.03±0.02	0.05±0.02	0.05±0.03	0.07±0.03	0.52±0.03	0.05±0.03	0.05±0.03
LEX_DM_F	3.08±0.57	3.11±0.55	2.12±0.76	2.10±0.67	1.54±0.98	1.24±0.55	2.22±1.01	2.15±0.96
LEX_IDEAD	0.59±0.05	0.61±0.04	0.56±0.07	0.59±0.06	0.54±0.05	0.52±0.04	0.56±0.06	0.57±0.06
SYN_NPLENM	2.39±0.70	2.46±0.58	1.76±0.68	1.97±0.59	2.10±0.59	1.69±0.49	2.08±0.69	2.04±0.63
SYN_NPLENSD	1.95±0.80	1.84±0.61	1.23±1.05	1.49±0.68	1.98±0.65	1.51±0.91	1.72±0.90	1.61±0.76
SYN_GRAPHDISTM	1.34±0.29	1.46±0.20	1.59±0.35	1.67±0.21	1.66±0.43	1.72±0.29	1.54±0.38	1.62±0.26
SYN_GRAPHDISTD	0.37±0.15	0.44±0.16	0.26±0.17	0.34±0.24	0.45±0.25	0.46±0.32	0.36±0.21	0.42±0.25
SYN_ISynCompl	0.34±0.03	0.36±0.04	0.41±0.05	0.42±0.05	0.39±0.04	0.41±0.06	0.38±0.05	0.40±0.06
SYN_MAXDEPTHM	7.60±2.75	7.40±1.37	7.16±1.53	8.50±3.29	8.73±2.64	8.87±3.86	7.85±2.42	8.25±3.07
SYN_MAXDEPTHD	2.48±1.44	2.52±1.16	1.87±1.42	2.07±1.90	2.56±1.55	3.04±1.73	2.30±1.48	2.54±1.66
SYN_SLENM	17.44±6.92	19.27±4.93	19.54±5.30	25.84±11.81	24.50±10.26	26.38±11.05	20.63±8.26	23.83±10.20
SYN_SLENSD	5.64±2.89	8.73±4.59	5.58±4.60	7.60±7.25	8.37±5.26	9.41±6.42	6.58±4.52	8.58±6.17

APPENDIX C: RESULTS OF LIWC FEATURES EXTRACTION (mean ± standard deviation)								
Feature	**task 1 -PER-**		**task 2 -NEU-**		**task 3 -FIG-**		**overall**	
	AN	**CG**	**AN**	**CG**	**AN**	**CG**	**AN**	**CG**
WC	85.76±36.64	92.76±31.20	53.71±35.89	61.67±29.40	72.41±35.17	70.03±21.36	70.63±37.60	74.82±30.40
WPS	15.68±6.55	16.77±3.99	16.67±5.04	23.17±11.39	24.48±9.51	24.64±11.43	18.94±8.16	21.52±10.10
SIXLTR	26.23±5.31	22.91±3.94	27.71±7.29	24.38±6.10	28.18±6.60	25.43±4.30	27.37±6.38	24.24±4.93
DIC	63.09±5.01	65.90±4.95	59.77±5.84	64.20±7.66	59.57±4.54	67.16±5.54	60.81±5.31	65.76±6.22
1PS	12.74±2.98	14.10±2.94	5.09±3.86	6.21±5.10	1.87±3.22	1.53±1.25	6.57±5.67	7.28±6.25
1PP	0.00±0.00	0.12±0.35	6.40±5.25	5.67±3.92	0.36±0.73	0.10±1.14	2.25±4.22	2.26±3.39
2PS	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2PP	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3PS	0.04±0.16	0.02±0.13	0.00±0.00	0.00±0.00	0.16±0.45	0.19±0.47	0.06±0.28	0.07±0.29
3PP	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
NEG	2.44±2.27	2.29±1.33	0.26±0.74	1.23±1.80	1.15±1.52	1.49±1.41	1.28±1.84	1.67±1.58
PST	0.25±0.74	0.08±0.35	0.58±1.34	0.07±0.43	0.16±0.54	0.24±0.73	0.33±0.94	0.13±0.53
PRES	13.46±3.80	15.08±2.89	10.33±5.58	11.19±4.89	7.08±3.18	9.54±2.49	10.29±4.98	11.94±4.24
FUT	0.00±0.00	0.04±0.20	0.00±0.00	0.00±0.00	0.14±0.40	0.34±0.63	0.05±0.24	0.12±0.41
GER	0.05±0.20	0.03±0.20	0.35±0.71	0.19±0.75	1.70±2.41	1.98±2.14	0.67±1.60	0.73±1.57
COND	0.78±1.08	0.31±0.55	0.07±0.29	0.05±0.21	0.28±0.69	0.4±0.72	0.38±0.80	0.25±0.55
PASS	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
PP	0.56±0.90	0.4±0.58	0.50±0.94	0.47±1.01	0.95±1.14	0.96±1.06	0.67±1.00	0.61±0.93
TRAN	0.18±0.40	0.35±0.70	0.99±1.50	0.20±0.73	1.55±1.27	2.03±1.17	0.91±1.27	0.86±1.21
AFFP	8.06±3.06	7.92±3.16	2.29±2.40	3.52±3.01	1.75±1.98	1.2±2.12	4.03±3.80	4.21±3.94
+EMO	4.60±2.72	3.86±2.28	1.02±1.47	0.97±1.47	0.48±0.80	0.12±0.40	2.03±2.58	1.65±2.25
-EMO	1.67±1.27	1.71±1.51	0.46±1.35	0.81±1.34	0.97±1.29	0.81±1.77	1.03±1.37	1.11±1.59
ANX	0.45±0.84	0.26±0.52	0.00±0.00	0.07±0.24	0.06±0.26	0.10±0.33	0.17±0.54	0.14±0.39
ANG	0.70±1.03	0.77±1.24	0.00±0.00	0.06±0.37	0.32±0.72	0.19±0.69	0.34±0.77	0.34±0.89
SAD	0.12±0.36	0.42±0.71	0.20±0.66	0.41±0.95	0.26±0.62	0.43±0.91	0.20±0.56	0.42±0.85
COGP	4.91±2.59	4.92±2.95	1.32±2.18	2.81±2.72	3.04±2.10	4.44±2.76	3.09±2.70	4.06±2.93
INS	1.37±1.28	1.62±1.70	0.55±1.38	0.84±1.39	1.05±1.15	2.24±2.18	0.99±1.29	1.56±1.86
CAU	0.45±0.67	0.38±0.75	0.00±0.00	0.38±0.77	0.33±0.63	0.34±0.64	0.26±0.55	0.37±0.71
DISCR	1.77±1.57	2.14±1.65	0.35±0.76	0.99±1.54	0.08±0.95	1.10±1.21	0.97±1.27	1.41±1.55
TENT	3.08±1.90	3.55±2.13	3.21±2.05	4.33±2.65	1.75±1.69	1.83±1.79	2.68±1.96	3.24±2.44
CERT	0.97±1.12	1.49±1.54	0.51±1.11	0.88±1.36	0.46±1.13	0.38±0.68	0.65±1.12	0.91±1.32
INH	0.44±0.69	0.30±0.48	0.10±0.41	0.08±0.36	0.03±0.13	0.15±0.44	0.19±0.49	0.18±0.44
INCL	0.78±1.06	1.07±1.17	1.20±1.48	0.78±1.28	0.50±0.84	1.02±1.17	0.83±1.17	0.96±1.20
EXCL	3.83±2.17	4.80±2.40	4.17±3.00	5.32±3.56	3.70±2.34	4.88±2.17	3.90±2.49	5.00±2.76
PERCP	3.12±2.04	2.71±1.52	1.55±1.95	2.80±2.09	0.85±0.90	1.39±1.48	1.84±1.93	2.30±1.82
SEE	1.79±1.51	1.14±0.96	0.63±1.74	0.55±0.95	0.52±0.78	0.77±1.00	0.98±1.49	0.82±0.99
HEAR	0.73±1.18	1.13±1.18	0.74±1.10	1.83±1.61	0.00±0.00	0.00±0.00	0.49±0.98	0.99±1.37
FEEL	0.14±0.31	0.20±0.62	0.00±0.00	0.09±0.39	0.09±0.28	0.27±0.55	0.08±0.24	0.19±0.53
BODY	4.32±1.87	3.98±2.38	0.30±0.70	1.15±1.57	1.88±1.27	2.55±1.51	2.17±2.14	2.56±2.18
HLT	0.76±0.68	0.52±0.56	0.00±0.00	0.04±0.26	0.03±0.13	0.19± 0.57	0.26±0.52	0.25±0.52
ING	0.79±1.31	0.36±0.91	0.47±0.91	0.61±1.27	2.12±1.46	2.46±1.08	1.13±1.42	1.15±1.44
WORK	0.13±0.37	0.15±0.36	0.30±0.96	0.04±0.21	0.00±0.00	0.00±0.00	0.14±0.60	0.06±0.25
SCHOOL	0.36±0.76	0.32±1.04	0.85±2.05	0.23±0.64	0.00±0.00	0.00±0.00	0.40±1.28	0.18±0.71
DEATH	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
ACH	0.38±0.79	0.43±0.79	0.13±0.54	0.22±0.57	0.39±0.76	0.45±0.70	0.30±0.70	0.37±0.69
LEIS	1.50±1.28	0.96±1.49	2.36±1.82	3.10±1.96	1.60±1.93	1.18±1.00	1.82±1.72	1.75±1.80
HOME	0.70±1.01	0.30±0.62	0.77±1.17	0.89±1.01	1.52±1.9	1.18±1.00	1.00±1.44	0.79±0.96
SPORT	0.00±0.00	0.10±0.40	0.00±0.00	0.35±1.23	0.00±0.00	0.00±0.00	0.00±0.00	0.15±0.76
FAM	0.33±0.54	0.17±0.41	0.00±0.00	0.06±0.32	3.30±2.08	3.50±1.88	1.21±1.93	1.24±1.95
FR	0.80±1.10	0.77±0.86	2.10±2.10	2.01±1.80	0.03±0.13	0.00±0.00	0.98±1.60	0.92±1.41
HUM	2.08±1.60	2.07±1.37	0.77±1.75	0.18±0.55	3.64±2.18	3.88±2.34	2.17±2.18	2.04±2.19
SOC	4.95±2.90	4.75±2.33	8.69±5.41	8.60±5.09	8.09±2.32	9.01±2.63	7.24±4.06	7.45±4.03

APPENDIX D: EXAMPLES FROM THE CORPUS

Task 1 -PER-

AN, 18 years old

Sono una ragazza alta, capelli lunghi, occhi verdi e lentiggini. Sono simpatica, irascibile solare ma a volte cupa, solitaria e timida. Tante volte sono molto testarda e sfacciata, ma lo riconosco. A volte sono molto orgogliosa. Mi piace stare con gli amici, il fidanzato, andare in discoteca, ma prevalentemente disegnare e cucinare. Adoro vedere le persone felici e soddisfatte del pasto che ho preparato. In compenso odio pulire, fare i compiti, ma con la musica migliora un po' la situazione.

English transl.: I'm a tall girl, with long hair, green eyes, and freckles. I'm funny, quick-tempered but with a sunny disposition, loner and shy. I'm often stubborn and cheeky, but I admit it. Sometimes I have too much pride. I like to stay with friends, my boyfriend, going to the disco, but above all drawing and cooking. I love seeing people happy and satisfied with what I cooked for them. At the same time, I hate cleaning, doing homework, but if I listen to music it gets better.

Task 2 -NEU-

AN, 15 years old

Solitamente parliamo, spettegoliamo di alcune persone, e parliamo della scuola e dei professori. Quando usciamo andiamo in centro oppure ci incontriamo per fare i compiti.

English transl.: We usually talk, gossip about people, and chat about school and professors. When we go out, we meet downtown or to do homework.

Task 3 -FIG-

AN, 15 years old

La prima cosa che ho pensato nel vedere l'immagine qui sopra, è come potesse quella donna apparire noncurante, quasi sorridente, della situazione caotica che la circonda. Ella stessa non si preoccupa del lavabo ormai pieno, da cui fuoriesce, a bagnare il pavimento da cucina, un'imponente mole d'acqua; anzi continua imperterrita strofinando un piatto, senza nemmeno scorgere il figlioletto che è prossimo a cadere dallo sgabello. Poco distanti, i bambini sono intenti rubare dalla dispensa dei biscotti, ma il maschietto rischia di cadere all'indietro; la bambina pare interessata solo ad afferrare il dolce che il fratello le porge con aria incerta, senza capire il pericolo che il compagno sta correndo. Questi due ladruncoli di cibi mi ricordano tanto le mie malsane abitudini di ingozzarmi di nascosto, ignorando qualsiasi circostanza, come fa la piccola nel disegno, e dimenticandomi di esistere all'infuori del semplice atto d'inghiottire e deglutire.

English transl.: The first thing I thought when I saw the picture up here was how this woman could be so careless as if she was making fun of the chaotic situation surrounding her. She doesn't care about the sink now full, from which an impressive amount of water pulls out pouring the floor of the kitchen; indeed, she insists on rubbing the dishes, without even noticing her little boy about to fall off the stool. Not far away, children are stealing biscuits from the pantry, but the little boy risks falling backward; the girl seems only interested in grasping the sweet her brother is offering her with uncertain air, without figuring out the risk her mate is running. These two little food thieves remind me so much of my unhealthy habits of gorging myself secretly, by ignoring any circumstances, as the little girl does in the drawing, and forgetting to exist apart from the simple fact of swallowing and swallowing.