Automated Characterization and Identification of Schizophrenia in Writing

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Abstract

Prominent formal thought disorder, expressed as unusual language in speech and writing, is often a central feature of schizophrenia. Since a more comprehensive understanding of phenomenology surrounding thought disorder is needed, this study investigates these processes by examining writing in schizophrenia by novel computer-aided analysis. Thirty-six patients with DSM-IV criteria chronic schizophrenia provided a page of writing (300-500 words) on a designated subject. Writing was examined by automated text categorization and compared with non-psychiatrically ill individuals, investigating any differences with regards to lexical and syntactical features. Computerized methods utilized included extracting relevant text features, and utilizing machine learning techniques to induce mathematical models distinguishing between texts belonging to different categories. Observations indicated that automated methods distinguish schizophrenia writing with 83.3% accuracy. Results reflect underlying impaired processes including semantic deficit, independently establishing connection between primary pathology and language.

Keywords: schizophrenia, thought disorder, writing, automated text categorization

Introduction

Schizophrenia is a chronic neuro-psychiatric disorder consisting of a range of phenomenological expression. While the disorder is most prominently associated with "positive symptoms" consisting of delusions, hallucinations and disorganized behavior, the disorder is also associated with negative symptoms (amotivation, apathy, avolition) and neuro-cognitive dysfunction. Prominent thought disorder of "form" (as opposed to content), often expressed as unusual language, is a central feature of all these clusters of symptoms.

A more comprehensive understanding of the phenomenology surrounding thought disorder is however required to fully understand the illness. This paper shows that (1) some of the underlying processes in schizophrenia are evident in writing, thus demonstrating that oral language that sounds "schizophrenic" represents fundamental underlying impairments in cognitive and language processing rather than processing related to the pressure of on-line production of verbal material, environmental stimuli or interpersonal interaction, (2) automated classification of schizophrenia writing samples is possible, demonstrating the consistency in the differences between schizophrenia and non-schizophrenia writing and perhaps oral productions, and (3) the automatically identified characteristics of schizophrenia writing are closely related to the clinical description of the disorder.

It has been well described that patients with schizophrenia exhibit unusual language impairments with wide ranging evidence and literature on the subject since the 19th century. These impairments include abnormalities at the level of phonology, morphology, syntax, semantics, and pragmatics (Chaika 1990, Covington et al. (2005), Fine (2006), Fraser et al. 1986), Ribiero (1994), Rochester & Martin (1979), Rodriguez-Ferrera et al. (1986).

In fact, a number of the diagnostic criteria for schizophrenia are based in language (e.g., clang associations, alogia, looseness of associations, poverty of speech, derailment, disorganized speech). Therefore language plays an important role in *defining* the disorder (Fine 2006). While general intellectual impairment appears to be an important

determinant of poor language test performance in schizophrenia, some believe that presence of formal thought disorder probably contributes to an equal if not greater extent (Rodriguez-Ferrera et al. 2001). A higher-order semantic deficit may be particularly relevant to the impairments of both linguistic dysfunction and formal thought disorder. Formal thought disorder is robustly associated with impaired executive functioning and with impaired processing of semantic information, though it remains controversial whether this is necessarily indicative of impairment within the language production system in schizophrenia (Kerns & Berenbaum 2002). Docherty et al. (2006) have shown that cognitive sequencing skills, especially the more complex ones, are related to language impairments that cross clauses in schizophrenia but that more lexically based impairments are not associated with such underlying sequencing skills. Impaired sustained attention contributes to the more lexical, non-structural impairments. The semantic quality of clauses, rather than the syntactic quality, is associated with the expansion of speech in the conversation of patients with schizophrenia (Chen 2007).

While thought disorder is prominently noted in speech and is striking in its effect on social interaction, the same underlying processes may also be expressed in writing and therefore may be precisely evaluated by computer-aided analysis. Thus our first question has to do with the parallel of markers of schizophrenia in speaking and writing. As noted, there has been significant work and significant automated study of the spoken language in schizophrenia. The current study of writing would assist in uncovering underlying processes in schizophrenia, particularly if there is a parallel between the language characteristics in speaking and writing.

Our second issue is the automated classification of texts. Over the past decade or so there has been a major increase in research investigating automated text categorization. This refers to the analysis of a set of two or more categories and examples of texts in each category, the results of which may be used to accurately categorize and classify other "blinded" texts. Computerized methods utilized in this procedure include extracting potentially relevant features from a text, representing them in an appropriate formal manner and using techniques from machine learning to induce mathematical models that distinguish between texts belonging to different categories (Sebastiani 2002). Automated

methods have also been used recently in the investigation of clinical populations. Cohen et al. (2008) investigated negative symptoms in schizophrenia speech samples and found that **"**computer-based inflection and speech rate measures significantly discriminated patients with flat affect from controls, and the computer-based measure of alogia and negative emotion significantly discriminated the flat and non-flat patients".

Argamon et al. (2008) have noted differences in writing style in several large corpora according to various aspects of author profile including age, gender and native language. These differences have included variation in frequency of use of various lexical features and parts of speech. Similarly, differences along the psychotic-non-psychotic dimension may have interesting relationships with differences, or similarities in the writing dimension. In fact, similarities between spoken language and written language across the psychotic/non-psychotic dimension may even elucidate features of the underlying mechanisms of the psychosis.

While the writing of the non-psychiatrically ill population has been investigated and analyzed, limited investigation exists exploring the writing of subgroups of psychiatrically ill individuals, including patients with schizophrenia. This study investigates aspects of thought disorder in relatively standardized writing samples of a group of patients with schizophrenia and compares these writing specimens with those of non-psychiatrically ill individuals. The intention is to explore the nature of any specific or unique aspects of writing in schizophrenia patients by means of computer generated automated text categorization techniques. The benefits of a computer analysis is that the computer is faster than a human analyst and remains free from bias since computer analyses are perfectly reproducible.

Our third issue is the investigation of differences between schizophrenia and non-psychotic individuals that point to underlying processes of the disorder (eg., Rochester and Martin 1979, Fine 2006) and can show that the differences can be found objectively, potentially reflecting the features of language that (1) make these individuals sound different/impaired, and (2) may form part of the diagnostic picture of the disorder. That

is, the method can provide some of the indicators and even definitional elements of the disorder.

Method

Study Population

The study population consisted of inpatients and outpatients at a large state psychiatric referral institution all diagnosed with schizophrenia according to DSM-IV criteria between the ages of 18-70 years. Patients were evaluated with the Clinical Global Impression rating scale (CGI) (Guy 1976) in order to obtain some indication of illness severity. In addition, writing samples were obtained from a control group of persons without schizophrenia. Prior to study entry, subjects provided written informed consent after receiving a full explanation regarding its nature. The study was approved by the Beer Yaakov Mental Health Center Institutional Review Board.

Writing Specimens

All subjects were instructed to provide at least a page of Hebrew writing (300-500 words) on a designated subject namely "an important person in my life". The subject was maintained as open and broad as possible in order to encourage "free" writing. No time limit was stipulated within which the task was to be completed.

Representation of Writing Specimen

Each document in the corpus was represented in terms of three types of document features comprising a total of 60 individual features. The features are as follows:

1. Common words – The 25 most common words in the corpus were chosen (see Table 1). As can be seen, these are primarily function words, though some are content words relevant to the domain. For each document the frequency (occurrences/document length) of each of these words was recorded.
2. Letter tri-grams – The 20 most common three letter sequences were chosen. Hebrew has a rich morphology and these features mostly capture grammatical

affixes that either indicate declensions or play the role of certain English function words. For each document the frequency (occurrences/document length) of each of these tri-grams was recorded.

3. Word repetitions – The average number of word repetitions in a window of size k. This is measured for each k from 2 to 15.

Results

Study Sample

Thirty-six patients with DSM-IV criteria chronic schizophrenia consented to participate and were included in analysis. Of these, 25 were male and 11 were female; the average age was 36.2 years (standard deviation of 10.3 years). All patients included in the study were diagnosed with schizophrenia of severity "mild to moderate" according to the CGI scale. In the control group 2/3 were female; and their average age was 28.3 years with standard deviation of 13.1.

Differences in Writing Style

In Table 1, we show the average frequencies (per 10,000 words of text) of the 25 most frequent words in the corpus for schizophrenic and non-schizophrenic writers, respectively. Several patterns are immediately evident. Among the words that are markers of schizophrenic writing are first person pronouns, the third person objective pronoun *to_him* (לו), and the intensifier *very*. Differences in usage of *I*, *me* and *to_me* are significant at $p=0.01$. Words that are markers of non-schizophrenic writing include third person subjective pronouns, the definite object marker *the* (את), ordinary preposition such as *on* (על), *of* (של) and *with* (עם). Differences for *the* are significant at $p=0.01$ and for the prepositions *on* and *of* at $p=0.05$.

In Figure 1, we show the number of word repetitions in windows of size k (k=2,…,15) for schizophrenic and non-schizophrenic writers, respectively. It is evident that at all window sizes, schizophrenic writing exhibits significantly more word repetition that non-schizophrenic writing. All these differences are significant at $p=0.05$.

Differences in tri-gram usage mirror those of word usage. The tri-grams that are used significantly more (*p=0.01*) by writers with schizophrenia include the first person subject pronoun *ani,* the first person object form *li* ('to me'), and the other first-person suffixes, *ni* and *ti*. The form *t-h* which is a proxy for *et ha-,* the definite object marker *et* preceding the definite marker for nominals, *h,* is used significantly more (*p=0.01*) by writers without schizophrenia. Thus, the writers without schizophrenia are more frequently introducing definite objects into their clauses. This interpretation is supported by the finding that these writers also use more of the third person objective pronoun *to_him* (לו). Linguistically, they are introducing an additional participant (person, object or place) into the discourse. It is also likely that this additional participant is encoded as known to the reader since it is in the definite form.

Automatically Classifying Writing Samples

Given writing samples from both schizophrenic and non-schizophrenic writers, one of the aims of the study was to use machine-learning techniques in order to construct classifiers that automatically categorize a new writing sample as schizophrenic or non-schizophrenic. To achieve this, it is insufficient to note differences in average frequency of feature use; the distribution of feature use among the various writers in each class must be exploited.

The learning methods that were used in this study are support vector machines (Joachims 1998) and Bayesian regression (Genkin et al. 2007), both fully automated methods that have proved particularly effective in authorship studies. To test the effectiveness of classifiers obtained using these methods on out-of-sample data, 10-fold cross validation was used. This refers to the process by means of which the whole corpus is randomly divided into ten random sub-corpora with nine of these sub-corpora used to learn a classifier. The learned classifier is then tested on the held out sub-corpus. This is repeated ten times, each time a different sub-corpus being held out.

For each learning algorithm, this procedure resulted in 83.3% of out of sample documents correctly classified. In all, 32 of 36 non-schizophrenic writers (88.9%) and 28 of 36 schizophrenic writers (77.7%) were correctly categorized.

Discussion

Our first issue was the examination of specifically written language of patients with schizophrenia. The written mode has not been previously investigated for such patients. There is considerable compatibility of the results for writing to results obtained for oral samples from patients with schizophrenia. That the schizophrenia patients use more first person reference of various kinds, including independent words (*ani* ('me'), *sheli* ('mine'), *li* (to 'me'), less third person subject reference, less definite marking, but more lexical repetition all point to their more concrete use of language and difficulty in drawing the identities of objects and people through the text. That the writers with schizophrenia used fewer prepositions suggests that they are not adding circumstantial information of time ("I saw them *in the morning*") and place ("We hid *near the store*") and information about nouns that represent the "things" of the world ("The cow *in the picture*"). The discourse of the writers with schizophrenia is diminished in content is several ways. It has more emphasis on the writer himself or herself, but regularly less information about the people, places and objects that are introduced and, in fact, fewer of these definite people, places and objects at least in the object position where they can be readily identified.

These are well established findings in the oral language of speakers with schizophrenia. That such patterns occur in the written language of patients with schizophrenia reinforces the interpretation of such patterns as relecting underlying processing problems in the disorder. We can also exclude hypotheses that could suggest that the atypicalities thus far found in the oral language are the result of on-line processing problems perhaps related to

short term memory difficulties or to information processing under the very short time constraints of social interaction. Rather, the impairment in tracking and presenting the identities of people and objects and the semantic reduction in the texts point to possibly core processing impairments in schizophrenia. If we interpret schizophrenia as a disconnection with reality, then we can clearly interpret the over-representation of the first person as an attempt to write about the familiar, the concrete, the writer as centre of focus. Correspondingly, there is less information of the Participants (people, objects and places) introduced and perhaps fewer of these participants in general (certainly, fewer definite object nominals). The reality presented by the writers with schizophrenia is focused more on the writer and semantically diminished when it is not.

The second issue in this paper is the automatic classification of texts. Similar to other findings in both clinical (Cohen et al. 2008; He 2007) and non-clinical (Argamon 2008) fields, texts are formed from recurent patterns of language that accurately reflect clinical or individual characteristics of writers. That is, lay and clinical listeners and readers who form impressions of a speaker/reader based on atypical language (such as negative symptoms (Cohen et al. 2008) and idea density in schizoprenia (He et al. 2007)) or stereotypical language (Argamon et al., 2008) are basing themselves on recurrent patterns that can also be detected by automated means.

Our third issue is an extension of the second issue: do the features of language that are uncovered by automatic means in fact relate to the clinical description and understanding of schizophrenia? Parallel to both the automatic and manual analyses of the spoken language of patients with schizophrenia, the automated analyses of writing that we have presented do reflect clinical reality. The automatically discovered differences in reference reflect the clinical descriptions of derailment, “loose associations” and perhaps the concrete nature of conversation with an abundance of several first person forms of *I* and *me*. The decreased use of prepositions and definite object nominals both index reduced semantic information. This clear reduction in semantic information found in more than one part of the semantic structure of the texts is compatible with poverty of speech, poverty of content of speech, alogia and perhaps even blocking. The increased repetition

also indexes reduced semantic information reflecting poverty of content of speech. It is important to emphasis that the automatic analysis and categorization of the texts did not result in seemingly random features but rather characterized the texts according to features that correspond to the clinical reality of the disorder. The automatic analysis was paralleling human analysis of what sounds different in these texts from speakers with schizophrenia.

Our three goals were then met in an interrelated way. The analysis of written texts produced findings that were similar to results for spoken texts, the automatic classification did successfully identify the texts from each group of writers and the automatic classification was based on the clinical description and understanding of schizophrenia, rather than on arbitrary characteristics of the written texts. Our understanding of schizophrenia is thus advanced in a number of ways. Both speaking and writing reflect similar underlying processing in schizophrenia and the disconnection from the context that schizophrenia reflects. The differences between writers with and without schizophrenia can be automatically learned and the texts identified. These differences correspond closely to the clinical description of the disorder. That is, the differences are learnable automatically and perhaps even in a way that is similar to how humans readily identify the language of speaker with schizophrenia. In humans this ability to identify the disorder through language is stable and key to reliability in diagnosis. In terms of understanding the picture that schizophrenia presents to the hearer and reader, the concreteness, poverty of speech, and poverty of content of speech are all indexed in the features automatically identified and largely found in both spoken and written texts. These features then point to characteristics of the disorder that are both disruptive to social interaction and reflect underlying processing impairments.

Limitations of the study include the fact that the proportion of males in the schizophrenia group was greater than that in the control group. While this is a potential confound since it has been previously established that there are significant differences between female and male writing (Argamon et al. 2003), the differences found in that research do not at all approximate findings in this study.

While preliminary, results from this study, engaging the successful use of a sophisticated and advanced computer analysis paradigm, may identify aspects of schizophrenia function with regards to thought structure that may be amenable to cognitive rehabilitation. This is a factor considered today to be an important outcome challenge in schizophrenia (Kurtz 2003). Further research is mandated in order to definitely determine whether these findings may be generalizable to larger subpopulations of patients with schizophrenia as well as whether similar differences in writing samples exist within other subpopulations of patients with mental illness.

Table 1. Frequencies (per 10,000 words) of the 25 most common words in corpus for schizophrenia and non-schizophrenia writing, respectively.

		Non-schizophrenia	*Schizophrenia*
I	אני	94.15	164.06
that I	שאני	38.56	59.56
me	אותי	13.45	51.69
to me	לי	36.76	148.33
mine	שלי	37.66	89.9
he	הוא	130.92	111.25
she	היא	113.88	93.27
him	אותו	31.38	32.59
to him	לו	20.62	43.83
with	עם	57.39	44.95
of	של	130.02	74.17
on	על	108.5	69.67
also	גם	57.39	47.2
because	כי	31.38	34.84
the	את	192.79	113.5
no	לא	132.71	128.1
such	כך	26	30.34
all	כל	82.5	77.54
this	זה	48.42	44.95
was	היה	59.18	48.32
there is	יש	24.21	33.71
what	מה	31.38	31.46
always	תמיד	29.59	31.46
very	מאוד	30.49	51.69
person	אדם	50.22	13.48

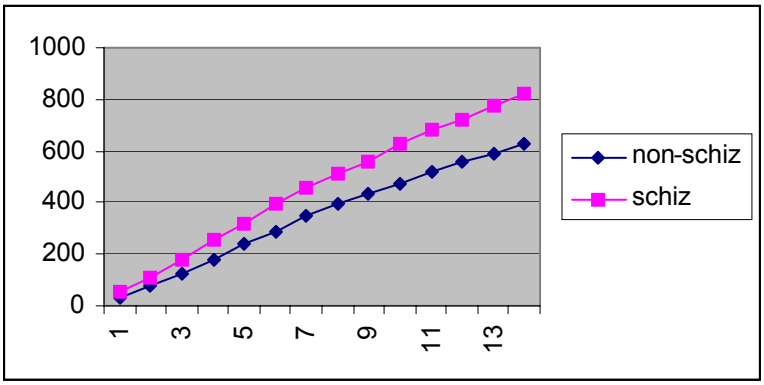

Figure 1. Number of word repetitions (*y*-axis) in windows of various sizes (*x*-axis) in schizophrenia and non-schizophrenia writing, respectively.

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