BMJ Open  Negative symptoms in schizophrenia: a study in a large clinical sample of patients using a novel automated method

Rashmi Patel, Nishamali Jayatilleke, Matthew Broadbent, Chin-Kuo Chang, Nadia Foskett, Genevieve Gorrell, Richard D Hayes, Richard Jackson, Caroline Johnston, Hitesh Shetty, Angus Roberts, Philip McGuire, Robert Stewart

ABSTRACT

Objectives: To identify negative symptoms in the clinical records of a large sample of patients with schizophrenia using natural language processing and assess their relationship with clinical outcomes.

Design: Observational study using an anonymised electronic health record case register.

Setting: South London and Maudsley NHS Trust (SLaM), a large provider of inpatient and community mental healthcare in the UK.

Participants: 7678 patients with schizophrenia receiving care during 2011.

Main outcome measures: Hospital admission, readmission and duration of admission.

Results: 10 different negative symptoms were ascertained with precision statistics above 0.80. 41% of patients had 2 or more negative symptoms. Negative symptoms were associated with younger age, male gender and single marital status, and with increased likelihood of hospital admission (OR 1.24, 95% CI 1.10 to 1.39), longer duration of admission (β-coefficient 20.5 days, 7.6–33.5), and increased likelihood of readmission following discharge (OR 1.58, 1.28 to 1.95).

Conclusions: Negative symptoms were common and associated with adverse clinical outcomes, consistent with evidence that these symptoms account for much of the disability associated with schizophrenia. Natural language processing provides a means of conducting research in large representative samples of patients, using data recorded during routine clinical practice.

INTRODUCTION

Negative symptoms, which include amotivation, a flattening of emotional responses, a reduction in speech and activity, and social withdrawal, contribute to much of the disability associated with schizophrenia. These symptoms are also associated with poor psychosocial functioning and a reduced likelihood of remission. The aetiology and pathophysiology of negative symptoms are unknown, and there are no effective treatments. A number of excellent rating scales have been developed to assess negative symptoms. However, these are relatively detailed, require a trained rater, and are not routinely applied in clinical practice. As a result, much of our knowledge of negative symptoms is derived from studies in relatively small samples of patients, who may have been selected for inclusion because they had particularly severe symptoms. The findings...
from these samples may not therefore be representative of negative symptoms in the overall population of patients with schizophrenia.

Clinical information is increasingly recorded electronically, facilitating access of rich clinical data, including presence or absence of symptoms, from routine medical records. In the present study, we used a novel information extraction tool to identify negative symptomatology in a large body of electronic records collected from individuals with schizophrenia. We then examined the relationship between negative symptoms and clinical outcomes. We tested the hypothesis that negative symptoms are common in patients with schizophrenia, and are associated with poor clinical outcome, as indexed by the frequency and duration of hospital admissions.

METHODS
Participants and clinical data
The study was carried out using the South London and Maudsley NHS Foundation Trust (SLaM) Biomedical Research Centre (BRC) Case Register, comprising electronic health record data dating back to April 2006 from a large mental healthcare provider to 1.2 million residents of southeast London (UK). The data were interrogated using the Clinical Record Interactive Search (CRIS) application, with a robust anonymisation process and patient-led oversight. Three samples were identified for analysis:

I. Sample A (n=7678): patients with schizophrenia (International Classification of Diseases (ICD)-10 F20.XX) aged 16 years and over who had used SLaM inpatient care during 2011. This sample was used to investigate: (1) the relationship between negative symptoms, documented at any point in the electronic health record, and demographic and other clinical measures (described below); (2) the relationship between negative symptoms documented prior to 1 January 2011 and the risk of hospital admission during 2011. This year was chosen for analysis because it maximised the duration of time over which text would be available for measurement development, while allowing at least 12 months follow-up in all instances.

II. Sample B (n=1612): the subset of patients from sample A who had been discharged from SLaM inpatient care during 2011. This sample was used to investigate the relationship between negative symptoms documented prior to 2011 and the risk of readmission in the 12 months following discharge.

III. Sample C (n=1609): the subset of patients from sample A who received SLaM inpatient care during 2011. This sample was used to investigate the relationship between negative symptoms documented prior to 2011 and the length of the first hospital admission during 2011.

Measurement development
Natural language processing (NLP) information extraction allows structured information to be obtained from unstructured text records. We used NLP to detect statements in the correspondence fields of clinical records to determine references to prespecified negative symptoms. Full details of the NLP method are described in a previous paper. In summary, a putative training data set was selected which contained broad dictionary terms relevant to the negative symptoms of interest (described below). A detailed review of the training data set was undertaken by two psychiatrists (RP and RS) to identify and annotate key phrases within the records that were either relevant or irrelevant for keywords related to each symptom. Inter-rater reliability was tested between the two annotators resulting in percentage agreement of 93.0% (Cohen’s κ 0.85). This training data set was used to construct an application (CRIS Negative Symptoms Scale, CRIS-NSS) using a hybrid classification model consisting of a support vector machine (SVM) learning algorithm and rule-based text matching, using the Generalised Architecture for Text Engineering (GATE) software package. The SVM algorithm was applied using a ‘bag-of-words’ approach to take into account the context of negative symptoms within the sentence in which they were documented, thereby allowing ascertainment of negative symptoms experienced specifically by the patient as well as distinguishing between positive instances and negated instances. Once developed, CRIS-NSS was subsequently used to determine the presence of negative symptoms within the clinical sample. The accuracy of CRIS-NSS was evaluated using precision and recall statistics which were generated through internal fivefold cross-validation; precision, representing the proportion of text instances identified by the tool which were found to be correct in terms of identifying the negative symptom of interest (equivalent to positive predictive value); and recall, measuring the proportion of text instances recording a given negative symptoms which were correctly identified as such by the tool (equivalent to sensitivity).

Details of the criteria for ascertaining the negative symptoms in the CRIS-NSS application are described in further detail elsewhere, briefly, applications were developed for 10 items: poor motivation, blunted or flattened affect, poor eye contact, emotional withdrawal, poor rapport, social withdrawal, poverty of speech, mutism, apathy and concrete thinking. Each of these symptoms was defined as a binary variable on the basis of being present at any point in the record within the defined time period, and a composite scale (range 0–10) was constructed by summing these variables, followed by Cronbach α score calculation (a measure of intercorrelation between individual scale items) to estimate its internal consistency. A threshold score of at least 2 (ie, two or more negative symptoms documented) was applied a priori to determine the presence or absence of negative symptoms for analysis as a binary
variable, as well as treating the scale score as an ordinal variable.

Clinical outcome measures and covariates

The following clinical and demographic variables were obtained as covariates from the data set: age (on 1 January 2011), gender, marital status, employment status, and admission and discharge dates for inpatient care episodes. Using structured data derived from the Health of the Nation Outcome Scale (HoNOS),22 routinely completed in SLaM patients, the following subscales (scored 0–4) were used as covariates: activities of daily living (ADL) impairment, problems with relationships (social impairment), presence of hallucinations or delusions (a measure of positive symptoms) and depressive symptoms. For all of these HoNOS subscales, binary variables were defined on the basis of a score of 2 or more indicating the presence of each construct at levels judged to be clinically significant. In cases with multiple data points, all covariates were defined as those recorded closest to 1 January 2011.

Statistical analysis

STATA (V.11) software was used. Estimates of prevalence of negative symptoms by demographic factors were obtained as the proportion of patients within each group with two or more negative symptoms. After describing the distribution of negative symptoms and the psychometric properties of the CRIS-NSS, further analyses were performed to investigate the associations between the clinical outcomes described above and (1) the presence of negative symptoms, using binary logistic regression; and (2) CRIS-NSS scores, using ordinal logistic regression. Reference groups for categorical variables were generally defined as the most prevalent category, apart from age group where the youngest group of sufficient size was assigned as the reference. Associations between negative symptomatology and hospital admission and readmission were analysed using logistic regression—again, estimating associations with both the binary and ordinal CRIS-NSS exposure. For the analyses with hospitalisation outcomes in/following 2011, CRIS-NSS was generated restricting information extraction to electronic health records prior to 2011. Where data were missing on individual covariates (in 2362 participants), this was indicated in the regression models as a separate category, supplemented by sensitivity analyses performed on the sample with complete data on all covariates to check the consistency of findings. A further supplementary analysis was performed to test the hypothesis that the association between negative symptoms and clinical outcomes varies with age. For this analysis, the previous analyses were repeated within the subgroups of those aged under the age of 40 years and those over the age of 40 years and including an interaction term of age under or over 40 and binary CRIS-NSS exposure. Finally, secondary analyses were undertaken to investigate and compare the relationships of individual CRIS-NSS symptoms with risk of readmission and length of stay using binary logistic and linear regression, respectively.

RESULTS

Performance of CRIS-NSS

Table 1 illustrates results from fivefold cross-validation of the CRIS-NSS tool. Precision coefficients ranged between 0.80 and 0.99 and recall between 0.62 and 0.97. For the composite 10-point scale, the Cronbach α value was 0.78 indicating a good level of internal consistency.

Prevalence and distribution of negative symptoms

Of the 7678 patients with schizophrenia, 3149 (41.0%) had at least two negative symptoms documented. Table 1 displays prevalences for each of the symptoms classified by the tool. The most frequently recorded symptoms were poor motivation (30.5%), blunted or flattened affect (27.4%), poor eye contact (26.0%) and emotional withdrawal (23.5%). The prevalences by number of symptoms were as follows: one symptom 14.6%, two symptoms 12.7%, three symptoms 9.3%, four symptoms 6.4%, five symptoms 5.0%, six or more symptoms 7.6%.

Binary logistic regression analyses (table 2) revealed that patients with two or more negative symptoms were most likely to be 20–29 years old, male and single. Two or more negative symptoms were also associated with ADL impairment, whereas patients who were employed were less likely to have negative symptoms compared with those unemployed. Ordinal logistic regression analysis (table 1) revealed similar findings for CRIS-NSS score as an exposure, and sensitivity analyses limited to those with full data on all covariates (etable 2) were also consistent.

| Symptom                        | CRIS-NSS Score | Prevalence (%) |
|--------------------------------|----------------|----------------|
| Poor motivation                | 0.78/0.62      | 30.5           |
| Blunted or flattened affect    | 0.93/0.83      | 27.4           |
| Poor eye contact               | 0.95/0.79      | 26.0           |
| Emotional withdrawal           | 0.85/0.74      | 23.5           |
| Poor rapport                   | 0.91/0.77      | 16.3           |
| Social withdrawal              | 0.94/0.96      | 12.7           |
| Poverty of speech              | 0.80/0.73      | 12.4           |
| Mute                           | 0.99/0.94      | 8.1            |
| Apathy                         | 0.88/0.97      | 7.7            |
| Concrete thinking              | 0.91/0.72      | 5.7            |

Table 1 Performance of Clinical Record Interactive Search Negative Symptoms Scale (CRIS-NSS) information extraction applications ascertaining individual symptom domains

Patel R, et al. BMJ Open 2015;5:e007619. doi:10.1136/bmjopen-2015-007619
| Factor                        | Group     | Number in sample | Prevalence of two or more negative symptoms (%) | Association with two or more negative symptoms: OR (95% CI), p value |
|------------------------------|-----------|------------------|------------------------------------------------|---------------------------------------------------------------|
|                              |           |                  |                                                 | Unadjusted | Adjusted model (n=7676)*                                   |
| Age (years)                  | 16–19     | 203              | 27.6                                           | 0.35 (0.25 to 0.49) <0.001                              | 0.50 (0.35 to 0.71) <0.001 |
|                              | 20–29     | 1337             | 52.0                                           | Reference                                           | Reference                     |
|                              | 30–39     | 1775             | 47.0                                           | 0.82 (0.71 to 0.94) 0.006                              | 0.85 (0.73 to 0.99) 0.033     |
|                              | 40–49     | 1983             | 42.6                                           | 0.69 (0.60 to 0.79) <0.001                              | 0.71 (0.61 to 0.82) <0.001     |
|                              | 50–59     | 1137             | 37.2                                           | 0.55 (0.47 to 0.64) <0.001                              | 0.56 (0.47 to 0.67) <0.001     |
|                              | 60–69     | 654              | 29.1                                           | 0.38 (0.31 to 0.46) <0.001                              | 0.39 (0.31 to 0.48) <0.001     |
|                              | 70+       | 589              | 18.0                                           | 0.20 (0.16 to 0.26) <0.001                              | 0.22 (0.17 to 0.28) <0.001     |
| Gender                       | Male      | 4592             | 45.3                                           | Reference                                           | Reference                     |
|                              | Female    | 3084             | 34.7                                           | 0.64 (0.59 to 0.71) <0.001                              | 0.77 (0.70 to 0.85) <0.001     |
| Marital status (most recent) | Single    | 5795             | 44.6                                           | Reference                                           | Reference                     |
|                              | Married/cohabiting | 785  | 31.6                                           | 0.57 (0.49 to 0.67) <0.001                              | 0.76 (0.64 to 0.90) 0.002     |
|                              | Divorced/separated | 776  | 33.4                                           | 0.62 (0.53 to 0.73) <0.001                              | 0.85 (0.71 to 1.00) 0.054     |
|                              | Widowed   | 208              | 21.2                                           | 0.33 (0.24 to 0.47) <0.001                              | 0.77 (0.53 to 1.12) 0.178     |
| Employment (most recent)     | Unemployed | 4956             | 47.9                                           | Reference                                           | Reference                     |
|                              | Employed | 341              | 39.6                                           | 0.71 (0.57 to 0.89) 0.003                              | 0.68 (0.54 to 0.86) 0.001     |
|                              | In education | 311  | 39.6                                           | 0.71 (0.56 to 0.90) 0.004                              | 0.81 (0.63 to 1.03) 0.089     |
|                              | Retired  | 7                | 14.3                                           | 0.18 (0.02 to 1.51) 0.114                              | 0.40 (0.04 to 3.52) 0.405     |
| ADL impairment                | Absent    | 4700             | 41.9                                           | Reference                                           | Reference                     |
|                              | Present   | 2283             | 46.3                                           | 1.20 (1.08 to 1.32) <0.001                              | 1.35 (1.21 to 1.52) <0.001     |
| Social impairment            | Absent    | 4432             | 42.7                                           | Reference                                           | Reference                     |
|                              | Present   | 2533             | 44.4                                           | 1.07 (0.97 to 1.18) 0.158                              | 0.94 (0.84 to 1.05) 0.240     |
| Delusions/hallucinations     | Absent    | 3904             | 41.9                                           | Reference                                           | Reference                     |
|                              | Present   | 3077             | 45.0                                           | 1.14 (1.03 to 1.25) 0.009                              | 1.19 (1.07 to 1.31) 0.001     |
| Depression                   | Absent    | 4976             | 45.2                                           | Reference                                           | Reference                     |
|                              | Present   | 2014             | 38.8                                           | 0.77 (0.69 to 0.85) <0.001                              | 0.74 (0.66 to 0.82) <0.001     |

*Results adjusted for all the factors reported in this table; two cases with no recorded data on gender were dropped.

ADL, activities of daily living.

Patel R, et al. BMJ Open 2015;5:e007619. doi:10.1136/bmjopen-2015-007619
Hospital admission, length of stay and readmission

Figure 1 summarises the association of negative symptoms recorded prior to 2011 with mental health admission (etable 3) and readmission (etable 4) in 2011. Figure 2 summarises length of hospitalisation for inpatients during 2011 (etable 5). Logistic and linear regression analyses (table 3) confirmed that negative symptoms were associated with a higher likelihood of admission, readmission and a longer duration of hospitalisation. Specifically, after full adjustment (table 3, model 3), patients with two or more negative symptoms before 2011 had a 24% greater likelihood of admission during 2011. Moreover, each of their admissions was, on average, an extra 21 days in duration, and when they were discharged, they had a 58% higher risk of readmission within 12 months. All of these associations remained independent and largely unaltered following adjustment for intensity of delusions/hallucinations among other covariates. Further analysis (etable 6) comparing patients aged under and over 40 years showed that the effects of negative symptoms on inpatient admission were broadly similar for both groups but with a slight increase in risk of readmission and reduced duration of admission in relation to negative symptoms for those under 40 compared with those over 40. However, the age × negative symptoms interaction term remained a non-significant factor (p>0.05) for all models.

Figure 1 Percentage of patients admitted to hospital or readmitted to hospital following discharge in 2011 by number of negative symptoms.

Figure 2 Median duration of admission among mental health inpatients with schizophrenia in 2011 by number of negative symptoms (n=1609).
Finally, logistic and linear regression analyses were performed to examine the relationship between individual negative symptoms and the frequency and duration of admission (table 4). Poor eye contact and poor rapport were associated with increased risk of readmission, while apathy was associated with increased duration of admission. Emotional withdrawal and mutism were associated with both the risk of readmission and the duration of admission.

**DISCUSSION**

Using an SVM learning method with an NLP tool, we were able successfully to extract data on negative symptoms from the electronic mental health records of a large clinical sample of patients with schizophrenia. This approach did not require any specialised training or extra clinical assessments, and was able to generate a scale with robust construct and predictive validity from data recorded as part of routine clinical care.

The results suggest that negative symptoms are documented in the electronic health records of a sizeable proportion of patients with schizophrenia, particularly in those who are relatively young, male and not in a relationship, consistent with findings from studies that assessed negative symptoms using quite different methods. Our findings were based on the unprompted documentation of negative symptoms in the context of routine clinical care by staff who were not specifically trained in their assessment. Previous findings have usually been based on systematic ratings by a researcher using a dedicated rating scale. Negative symptoms are relatively difficult to detect and assess, and may be less frequently documented than positive symptoms, such as delusions and hallucinations, because they are less clinically obvious. In addition, mental health services in the UK are often orientated towards the management of acute crises, and hence the treatment of positive symptoms. It is thus possible that the figures for the prevalence and the severity of negative symptoms derived from our approach are lower than would have been obtained from a trained assessor using a standardised instrument. In addition, our method may be more likely to identify the types of negative symptoms (eg, poverty of speech) whose detection does not require specialised training.

We found that a substantial proportion (41%) of the sample had at least two negative symptoms. Although we defined and assessed negative symptoms in different ways to previous studies, this figure is comparable to that described in other samples of patients with schizophrenia (Jager et al: 44%; Bobes et al: 58%; Cohen et al: 40%). Taken together, these findings suggest that negative symptoms are a relatively common feature of schizophrenia, rather than being limited to a subgroup of patients with a chronic, unremitting illness.

As predicted, we found a clear association between negative symptoms and poor clinical outcomes, as indexed by impairments in daily living, increased risk of admission, increased duration of admission and increased risk of readmission. Hospital admissions are the main drivers of cost in the care of patients with schizophrenia, but have traditionally been linked to the severity of positive psychotic symptoms. Our data indicate that negative symptoms are an equally important factor, and suggest that a greater emphasis on assessing and treating these features of schizophrenia may have significant health economic benefits. However, as our findings are drawn from observational data, it would be necessary to perform interventional clinical studies to determine whether an effective treatment for negative symptoms would lead to better clinical outcomes.

---

**Table 3** Association between number of negative symptoms ascertained prior to 2011 and mental health hospital admission, readmission and duration of admission in 2011

| Associations with 2 or more negative symptoms (binary variable) | Inpatient admission (OR, 95% CI; n=7678)* | Readmission within 12 months of inpatient admission (OR, 95% CI; n=1612)* | Duration of inpatient admission (days; β-coefficient, 95% CI; n=1609)† |
|---|---|---|---|
| Unadjusted | 1.47 (1.32 to 1.63) | 1.73 (1.41 to 2.12) | 23.9 (11.2 to 36.7) |
| 1. Age and sex | 1.37 (1.23 to 1.53) | 1.70 (1.38 to 2.09) | 24.1 (11.3 to 36.9) |
| 2. Model 1 plus marital status and employment | 1.27 (1.13 to 1.42) | 1.58 (1.28 to 1.96) | 20.1 (7.1 to 33.1) |
| 3. Model 2 plus delusions/hallucinations, and depression | 1.24 (1.10 to 1.39) | 1.58 (1.28 to 1.95) | 20.5 (7.6 to 33.5) |

| Associations with incremental number of negative symptoms (10-point scale ordinal variable)‡ | Inpatient admission (OR, 95% CI; n=1609)* | Readmission within 12 months of inpatient admission (OR, 95% CI; n=1609)* | Duration of inpatient admission (days; β-coefficient, 95% CI; n=1609)† |
|---|---|---|---|
| Unadjusted | 1.12 (1.09 to 1.15) | 1.12 (1.07 to 1.17) | 6.5 (3.5 to 9.4) |
| 1. Age and sex | 1.09 (1.06 to 1.12) | 1.11 (1.06 to 1.16) | 6.3 (3.3 to 9.2) |
| 2. Model 1 plus marital status and employment | 1.07 (1.04 to 1.10) | 1.09 (1.04 to 1.14) | 5.4 (2.4 to 8.4) |
| 3. Model 2 plus delusions/hallucinations, and depression | 1.07 (1.04 to 1.10) | 1.09 (1.04 to 1.14) | 5.6 (2.6 to 8.6) |

*Logistic regression.
†Linear regression.
‡ORs and β-coefficients are per one unit increase on the 10-point scale.
Table 4  Associations between individual Clinical Record Interactive Search Negative Symptoms Scale (CRIS-NSS) components and readmission risk/duration of admission in 2011

| Negative symptom                  | Readmission risk (binary logistic regression) (n=1612) | Duration of admission (linear regression) (n=1590) |
|-----------------------------------|--------------------------------------------------------|--------------------------------------------------|
|                                   | Unadjusted                                             | Adjusted*                                        | Unadjusted                                             | Adjusted*                                        |
|                                   | OR (95% CI) p Value                                    | OR (95% CI) p Value                              | β-coefficient (95% CI) p Value                         | β-coefficient (95% CI) p Value                     |
| Poor motivation                   | 1.40 (1.13 to 1.74) 0.002                              | 1.29 (1.03 to 1.61) 0.026                        | 23.0 (9.1 to 36.9) 0.001                              | 19.1 (5.0 to 33.2) 0.008                          |
| Blunted or flattened affect       | 1.34 (1.08 to 1.65) 0.007                              | 1.20 (0.97 to 1.50) 0.097                        | 12.8 (7.2 to 26.8) 0.073                              | 8.3 (5.7 to 22.4) 0.242                           |
| Poor eye contact                  | 1.60 (1.30 to 1.94) <0.001                             | 1.48 (1.19 to 1.83) <0.001                        | 18.5 (10.2 to 33.3) 0.011                             | 14.8 (9.0 to 28.6) 0.036                          |
| Emotional withdrawal              | 1.62 (1.30 to 2.02) <0.001                             | 1.49 (1.19 to 1.87) 0.001                        | 32.5 (18.1 to 60.3) <0.001                            | 30.0 (15.6 to 64.4) <0.001                         |
| Social withdrawal                 | 1.16 (0.88 to 1.54) 0.291                              | 1.02 (0.76 to 1.33) 0.911                        | 16.4 (7.2 to 35.7) 0.095                              | 9.2 (5.0 to 21.3) 0.394                           |
| Poverty of speech                 | 1.30 (0.98 to 1.70) 0.064                              | 1.12 (0.85 to 1.49) 0.416                        | 13.2 (5.8 to 32.2) 0.173                              | 8.5 (5.0 to 21.8) 0.379                           |
| Mute                              | 1.71 (1.27 to 2.30) <0.001                             | 1.56 (1.15 to 2.12) 0.004                        | 28.5 (7.9 to 94.1) 0.007                              | 29.2 (8.6 to 94.7) 0.005                           |
| Apathy                            | 1.02 (0.71 to 1.47) 0.914                              | 0.93 (0.64 to 1.35) 0.692                        | 32.5 (6.7 to 58.2) 0.013                              | 27.4 (1.8 to 53.1) 0.036                           |
| Concrete thinking                 | 1.37 (0.94 to 2.01) 0.100                              | 1.25 (0.85 to 1.84) 0.250                        | 16.8 (10.2 to 24.9) 0.222                             | 11.3 (5.5 to 23.1) 0.047                           |

*Adjusted for age, sex, marital status, employment status, presence of hallucinations/delusions and depression.
could also be developed to identify other clinical parameters from electronic health records in order to support real-time clinical decision-making. These possibilities could be explored in future research.

In summary, our data suggest that negative symptoms can be identified in clinical records using automated methods, are common in patients with schizophrenia and are associated with poor clinical outcomes. The findings highlight the potential of automated information extraction tools in mental health research and clinical practice, and the importance of developing effective treatments for negative symptoms.

Author affiliations
1Department of Computer Science, The University of Sheffield, Portobello, Sheffield, UK
2Department of Psychological Medicine, King’s College London, Institute of Psychiatry, Psychology & Neuroscience, London, UK
3South London and Maudsley NHS Foundation Trust, Biomedical Research Centre Nucleus, London, UK
4Roche Products Limited, Welwyn Garden City, UK
5Department of Computer Science, The University of Sheffield, Portobello, Sheffield, UK
6Social Developmental and Genetic Psychiatry Department, King’s College London, Institute of Psychiatry, Psychology & Neuroscience, London, UK

Contributors
The study was conceived by RS and NF. The CRIS-NS product development was led by RJ with significant input from MB, GG, CJ, AR and HS. Initial analyses were carried out by RS, C-KC and RDH. Final analyses and reporting of findings were led by RP and NJ, supervised by RS and PM. All authors contributed to manuscript preparation and approved the final version.

Funding
NJ, MB, C-KC, RDH, CJ, RJ, HS and RS are funded by the National Institute for Health Research (NIHR) Biomedical Research Centre and Dementia Biomedical Research Unit at South London and Maudsley NHS Foundation Trust and King’s College London, which also supports the development and maintenance of the CRIS data resource. The analyses reported here were part-funded by Roche. RDH is supported by a UK Medical Research Council Population Health Scientist Fellowship (MR/K002813/1). RP is supported by a UK Medical Research Council Clinical Research Training Fellowship (MR/K002813/1).

Disclaimer
Funding organisations had no role in the collection, management, analysis, and interpretation of the data; and the preparation, review, or approval of the manuscript.

Competing interests
The CRIS team (MB, C-KC, RDH, RJ, HS and RS) have received research funding from Roche; Pfizer; Johnson and Johnson; and Lundbeck. PM has received research funding from Janssen; Sunovion; GW Pharmaceuticals; and Roche.

Ethics approval
The CRIS data resource received ethical approval as an anonymised data set for secondary analyses from Oxfordshire REC C (Ref: 08/H0606/715).

Provenance and peer review
Not commissioned; externally peer reviewed.

Data sharing statement
No additional data are available.

Open Access
This is an Open Access article distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license, which permits others to distribute, remix, adapt and build upon this work, for commercial use, provided the original work is properly cited. See: http://creativecommons.org/licenses/by/4.0/

REFERENCES
1. Foussias G, Agid O, Remington G. Handbook of schizophrenia spectrum disorders, volume II. Dordrecht: Springer Netherlands, 2011.
2. Hunter R, Barry S. Negative symptoms and psychosocial functioning in schizophrenia: neglected but important targets for treatment. *Eur Psychiatry* 2012;27:432–6.
3. Rabinowitz J, Berardo CG, Bugarski-Kirola D, et al. Association of prominent positive and prominent negative symptoms and functional health, well-being, healthcare-related quality of life and family burden: A CATIE analysis. *Schizophr Res* 2013;150:339–42.
4. Jager M, Riedel M, Schmauss M, et al. Prediction of symptom remission in schizophrenia during inpatient treatment. *World J Biol Psychiatry* 2009;10:426–34.
5. Ucok A, Serbest S, Kandemir PE. Remission after first-episode schizophrenia: results of a long-term follow-up. *Psychiatry Res* 2011;189:33–7.
6. Moller HJ, Bottlender R, Wegner U, et al. Long-term course of schizophrenic, affective and schizoaffective psychosis: focus on negative symptoms and their impact on global indicators of outcome. *Acta Psychiatr Scand Suppl* 2000;407:54–7.
7. Dominguex M-G, Saka MC, can Saka M, et al. Early expression of negative/disorganized symptoms predicting psychotic experiences and subsequent clinical psychosis: a 10-year study. *Am J Psychiatry* 2010;167:1075–82.
8. McGurk SR, Moriarty PJ, Harvey PD, et al. Relationship of cognitive functioning, adaptive life skills, and negative symptom severity in poor-outcome geriatric schizophrenia patients. *J Neuropsychiatry Clin Neurosci* 2000;12:257–64.
9. Kirkpatrick B, Fenton WS, Carpenter WT, et al. The NIMH-MATRICS consensus statement on negative symptoms. *Schizophr Bull* 2006;32:214–19.
10. Arango C, Garbali G, Marder SR. Pharmacological approaches to treating negative symptoms: a review of clinical trials. *Schizophr Res* 2013;150:346–52.
11. Fulara-Poli P, Papanastasiou E, Stahl D, et al. Treatments of negative symptoms in schizophrenia: meta-analysis of 168 randomized placebo-controlled trials. *Schizophr Bull* 2014;41:892–9.
12. Blanchard JJ, Kring AM, Horan WP, et al. Toward the next generation of negative symptom assessments: the collaboration to advance negative symptom assessment in schizophrenia. *Schizophr Bull* 2011;37:291–9.
13. Kirkpatrick B, Strauss GP, Nguyen L, et al. The brief negative symptom scale: psychometric properties. *Schizophr Bull* 2011;37:300–5.
14. Kay SR, Fiszbein A, Opler LA. The positive and negative symptom scale (PANSS) for schizophrenia. *Schizophr Bull* 1987;13:261–76.
15. Patel R, Lloyd T, Jackson R, et al. Mood instability is a common feature of mental health disorders and is associated with poor clinical outcomes. *BMJ Open* 2015;5:e007504.
16. Gorrell G, Jackson R, Roberts A, et al. Finding negative symptoms of schizophrenia in patient records. *Proceedings of NLP Med Biol Work (NLPMedBio), Recent Adv Nat Lang Process (RANLP), Hissar, Bulg 2013:9–17. http://aclweb.org/anthology/W/W13/W13-5102.pdf.
17. Cunningham H, Tabian V, Roberts A, et al. Getting more out of biomedical documents with GATE’s full lifecycle open source text analytics. *PLoS Comput Biol* 2013;9:e1002854.
18. Patel R, Jayatilleke N, Jackson R, et al. Investigation of negative symptoms in schizophrenia with a machine learning text-mining approach. *Lancet* 2014;383:S16.
19. Stewart R, Soremekun M, Perera G, et al. The South London and Maudsley NHS Foundation Trust Biomedical Research Centre (SLAM BRC) case register: development and descriptive data. *BMC Psychiatry* 2009;9:51.
20. Fernandez AC, Cloete D, Broadent MT, et al. Development and evaluation of a de-identification procedure for a case register sourced from mental health electronic records. *BMC Med Inform Decis Mak* 2013;13:71.
21. Li Y, Bontcheva K, Cunningham H. Adapting SVM for data sparseness and imbalance: a case study in information extraction. *Net Lang Eng* 2009;15:34–71.
22. Wing JK, Beevor AS, Curtis RH, et al. Health of the Nation Outcome Scales (HoNOS). Research and development. *Br J Psychiatry* 1998;172:11–18.
23. Bobes J, Arango C, Garcia-Garcia M, et al. Prevalence of negative symptoms in outpatients with schizophrenia spectrum disorders treated with antipsychotics in routine clinical practice: findings from the CLAMORS study. *J Clin Psychiatry* 2010;71:280–6.
24. Cohen Cl, Natarajan N, Araujo M, et al. Prevalence of negative symptoms and associated factors in older adults with schizophrenia spectrum disorder. *Am J Geriatr Psychiatry* 2013;21:100–7.
25. Jacobs R, Barrenho E. Impact of crisis resolution and home treatment teams on psychiatric admissions in England. *Br J Psychiatry* 2011;199:71–6.
26. Bagney A, Rodriguez-Jimenez R, Martínez-Gras I, et al. Negative symptoms and executive function in schizophrenia: does their relationship change with illness duration? *Psychopathology* 2013;46:241–8.

27. Department of Health. National survey of Investment in Mental Health Services. 2013:1596–11. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/140098/FinMap2012-NatReportAdult-0308212.pdf

28. Olfson M, Ascher-Svanum H, Faries DE, et al. Predicting psychiatric hospital admission among adults with schizophrenia. *Psychiatr Serv* 2011;62:1138–45.

29. Gilbert EA, Liberman RP, Ventura J, et al. Concurrent validity of negative symptom assessments in treatment refractory schizophrenia: relationship between interview-based ratings and inpatient ward observations. *J Psychiatr Res* 2000;34:443–7.

30. Chang WC, Hui CLM, Tang JYM, et al. Persistent negative symptoms in first-episode schizophrenia: a prospective three-year follow-up study. *Schizophr Res* 2011;133:22–8.

31. Kimhy D, Yale S, Goetz RR, et al. The factorial structure of the schedule for the deficit syndrome in schizophrenia. *Schizophr Bull* 2006;32:274–8.
Title: Negative symptoms in schizophrenia: a study in a large clinical sample of patients using a novel automated method

Authors: Rashmi Patel, BM, BCh; Nishamali Jayatilleke, BM, MPhil; Matthew Broadbent, BSc; Chin-Kuo Chang, PhD; Nadia Foskett, PhD; Genevieve Gorrell DPhil; Richard D Hayes, PhD; Richard Jackson, MSc; Caroline Johnston, PhD; Hitesh Shetty, MSc; Angus Roberts PhD; Philip McGuire, MD, PhD; Robert Stewart, MD

Equal contributions to authorship

Author affiliations:

1. King’s College London, Department of Psychosis Studies, Institute of Psychiatry, Box PO 63, De Crespigny Park, Denmark Hill, London SE5 8AF, UK

2. King’s College London, Department of Psychological Medicine, Institute of Psychiatry, Box PO 92, De Crespigny Park, Denmark Hill, London SE5 8AF, UK

3. South London and Maudsley NHS Foundation Trust, Biomedical Research Centre Nucleus, Mapother House, De Crespigny Park, Denmark Hill, London SE5 8AF, UK

4. Roche Products Limited, 6 Falcon Way, Shire Park, Welwyn Garden City AL7 1TW, UK

5. The University of Sheffield, Department of Computer Science, Regent Court, 211 Portobello, Sheffield S1 4DP, UK

6. King’s College London, Social Developmental and Genetic Psychiatry Department, Institute of Psychiatry, Box PO 80, De Crespigny Park, Denmark Hill, London SE5 8AF, UK

Correspondence to:

Rashmi Patel BM BCh, MRC Clinical Research Training Fellow, King’s College London, Department of Psychosis Studies, Institute of Psychiatry, Box PO 63, De Crespigny Park, Denmark Hill, London SE5 8AF, UK

Telephone: +44 2078480355

E-mail: bmj@rpatel.co.uk

Supplementary material
**eTable 1 - Multivariable ordinal logistic regression analysis of factors associated with negative symptoms in patients with schizophrenia**

| Factor                      | Group               | Number in sample | CRIS-NSS mean score (range 0-10) | Standard Deviation | Unadjusted Odds ratio (95% CI) | P value | Adjusted model (n=7676)* Odds ratio (95% CI) | P value |
|-----------------------------|---------------------|------------------|-----------------------------------|--------------------|-------------------------------|---------|---------------------------------------------|---------|
| Age (years)                 | 16-19               | 203              | 1.28                              | 2.15               | 0.30 (0.22-0.40)              | <0.001  | 0.46 (0.33-0.64)                           | <0.001  |
|                             | 20-29               | 1337             | 2.45                              | 2.64               | Reference                     |         | Reference                                  |         |
|                             | 30-39               | 1775             | 1.97                              | 2.21               | 0.77 (0.67-0.87)              | <0.001  | 0.78 (0.68-0.89)                           | <0.001  |
|                             | 40-49               | 1983             | 1.66                              | 1.95               | 0.62 (0.55-0.71)              | <0.001  | 0.62 (0.55-0.71)                           | <0.001  |
|                             | 50-59               | 1137             | 1.43                              | 1.79               | 0.53 (0.46-0.61)              | <0.001  | 0.52 (0.45-0.61)                           | <0.001  |
|                             | 60-69               | 654              | 1.07                              | 1.53               | 0.37 (0.31-0.44)              | <0.001  | 0.36 (0.30-0.44)                           | <0.001  |
|                             | 70+                 | 589              | 0.72                              | 1.19               | 0.25 (0.21-0.30)              | <0.001  | 0.25 (0.20-0.31)                           | <0.001  |
| Gender                      | Male                | 4592             | 1.90                              | 2.22               | Reference                     |         | Reference                                  |         |
|                             | Female              | 3084             | 1.41                              | 1.91               | 0.66 (0.60-0.71)              | <0.001  | 0.79 (0.72-0.86)                           | <0.001  |
| Marital status (most recent)| Single              | 5795             | 1.88                              | 2.20               | Reference                     |         | Reference                                  |         |
|                             | Married/cohabiting  | 785              | 1.16                              | 1.61               | 0.57 (0.50-0.66)              | <0.001  | 0.74 (0.64-0.86)                           | <0.001  |
|                             | Divorced/separated  | 776              | 1.35                              | 1.86               | 0.64 (0.56-0.74)              | <0.001  | 0.86 (0.74-0.99)                           | 0.040   |
|                             | Widowed             | 208              | 0.85                              | 1.39               | 0.40 (0.31-0.52)              | <0.001  | 0.81 (0.60-1.09)                           | 0.160   |
| Employment (most recent)    | Unemployed          | 4956             | 2.03                              | 2.23               | Reference                     |         | Reference                                  |         |
|                             | Employed            | 341              | 1.51                              | 1.87               | 0.68 (0.56-0.83)              | <0.001  | 0.64 (0.52-0.78)                           | <0.001  |
|                             | In education        | 311              | 1.64                              | 2.10               | 0.70 (0.57-0.86)              | 0.001   | 0.78 (0.63-0.97)                           | 0.026   |
|                             | Retired             | 7                | 0.57                              | 0.79               | 0.33 (0.08-1.29)              | 0.110   | 0.68 (0.16-2.87)                           | 0.599   |
| ADL impairment              | Absent              | 4700             | 1.73                              | 2.09               | Reference                     |         | Reference                                  |         |
|                             | Present             | 2283             | 1.97                              | 2.23               | 1.21 (1.11-1.33)              | <0.001  | 1.35 (1.22-1.49)                           | <0.001  |
| Social impairment           | Absent              | 4432             | 1.76                              | 2.10               | Reference                     |         | Reference                                  |         |
|                             | Present             | 2533             | 1.88                              | 2.20               | 1.07 (0.98-1.17)              | 0.108   | 0.95 (0.86-1.05)                           | 0.292   |
| Delusions / hallucinations  | Absent              | 3904             | 1.77                              | 2.17               | Reference                     |         | Reference                                  |         |
|                             | Present             | 3077             | 1.85                              | 2.11               | 1.14 (1.05-1.24)              | 0.003   | 1.19 (1.09-1.30)                           | <0.001  |
| Depression                  | Absent              | 4976             | 1.90                              | 2.16               | Reference                     |         | Reference                                  |         |
|                             | Present             | 2014             | 1.59                              | 2.08               | 0.71 (0.65-0.79)              | <0.001  | 0.69 (0.62-0.76)                           | <0.001  |

*Results adjusted for all the factors reported in this table; 2 cases with no recorded data on gender were dropped.
### eTable 2 - Multivariable binary logistic regression analysis of factors associated with negative symptoms in patients with schizophrenia including cases with full covariate data only

| Factor                        | Group   | Number in sample | Prevalence of two or more negative symptoms (%) | Association with two or more negative symptoms: odds ratio (95% CI), p-value |
|-------------------------------|---------|------------------|------------------------------------------------|---------------------------------------------------------------------------|
|                               |         |                  |                                                | Unadjusted | Adjusted model (n=5316)* |
| Age (years)                   |         |                  |                                                |            |                            |
| 16-19                         | 203     | 27.6             | 0.35 (0.25-0.49)                               | <0.001     | 0.44 (0.29-0.68) <0.001    |
| 20-29                         | 1337    | 52.0             | Reference                                     | Reference  |                            |
| 30-39                         | 1775    | 47.0             | 0.82 (0.71-0.94)                               | 0.006      | 0.80 (0.67-0.95) 0.012     |
| 40-49                         | 1983    | 42.6             | 0.69 (0.60-0.79)                               | <0.001     | 0.64 (0.54-0.76) <0.001    |
| 50-59                         | 1137    | 37.2             | 0.55 (0.47-0.64)                               | <0.001     | 0.45 (0.37-0.55) <0.001    |
| 60-69                         | 654     | 29.1             | 0.38 (0.31-0.46)                               | <0.001     | 0.32 (0.25-0.41) <0.001    |
| 70+                           | 589     | 18.0             | 0.20 (0.16-0.26)                               | <0.001     | 0.13 (0.09-0.18) <0.001    |
| Gender                        |         |                  |                                                |            |                            |
| Male                          | 4592    | 45.3             | Reference                                     | Reference  |                            |
| Female                        | 3083    | 34.7             | 0.64 (0.59-0.71)                               | <0.001     | 0.74 (0.65-0.83) <0.001    |
| Marital status (most recent)  |         |                  |                                                |            |                            |
| Single                        | 5795    | 44.6             | Reference                                     | Reference  |                            |
| Married/cohabiting            | 785     | 31.6             | 0.57 (0.49-0.67)                               | <0.001     | 0.77 (0.63-0.94) 0.012     |
| Divorced/separated            | 776     | 33.4             | 0.62 (0.53-0.73)                               | <0.001     | 0.91 (0.75-1.12) 0.376     |
| Widowed                       | 208     | 21.2             | 0.33 (0.24-0.47)                               | <0.001     | 0.85 (0.54-1.32) 0.466     |
| Employment (most recent)      |         |                  |                                                |            |                            |
| Unemployed                    | 4956    | 47.9             | Reference                                     | Reference  |                            |
| Employed                      | 341     | 39.6             | 0.71 (0.57-0.89)                               | 0.003      | 0.65 (0.51-0.83) <0.001    |
| In education                  | 311     | 39.6             | 0.71 (0.56-0.90)                               | 0.004      | 0.78 (0.61-1.02) 0.065     |
| Retired                       | 7       | 14.3             | 0.18 (0.02-1.51)                               | 0.114      | 0.51 (0.06-4.65) 0.547     |
| ADL impairment                |         |                  |                                                |            |                            |
| Absent                        | 4700    | 41.9             | Reference                                     | Reference  |                            |
| Present                       | 2283    | 46.3             | 1.20 (1.08-1.32)                               | <0.001     | 1.29 (1.13-1.47) <0.001    |
| Social impairment             |         |                  |                                                |            |                            |
| Absent                        | 4432    | 42.7             | Reference                                     | Reference  |                            |
| Present                       | 2533    | 44.4             | 1.07 (0.97-1.18)                               | 0.158      | 0.93 (0.82-1.05) 0.258     |
| Delusions / hallucinations    |         |                  |                                                |            |                            |
| Absent                        | 3904    | 41.9             | Reference                                     | Reference  |                            |
| Present                       | 3077    | 45.0             | 1.14 (1.03-1.25)                               | 0.009      | 1.23 (1.10-1.38) <0.001    |
| Depression                    |         |                  |                                                |            |                            |
| Absent                        | 4976    | 45.2             | Reference                                     | Reference  |                            |
| Present                       | 2014    | 38.8             | 0.77 (0.69-0.85)                               | <0.001     | 0.69 (0.61-0.78) <0.001    |

*Results adjusted for all the factors reported in this table.*
### eTable 3 - Percentage of patients admitted to hospital in 2011 by number of negative symptoms (n=7678)

| Number of negative symptoms | Number of patients | Percentage admitted to hospital in 2011 (%) |
|-----------------------------|-------------------|-------------------------------------------|
| 0                           | 3408              | 21.7                                      |
| 1                           | 1121              | 18.9                                      |
| 2                           | 974               | 22.7                                      |
| 3                           | 717               | 27.2                                      |
| 4                           | 492               | 28.1                                      |
| 5                           | 382               | 32.5                                      |
| 6 or more                   | 584               | 36.8                                      |

### eTable 4 - Percentage of patients readmitted to hospital following discharge in 2011 by number of negative symptoms (n=1612)

| Number of negative symptoms | Number of patients | Percentage admitted to hospital in 2011 (%) |
|-----------------------------|-------------------|-------------------------------------------|
| 0                           | 612               | 29.9                                      |
| 1                           | 195               | 34.4                                      |
| 2                           | 213               | 40.4                                      |
| 3                           | 176               | 44.9                                      |
| 4                           | 131               | 43.5                                      |
| 5                           | 119               | 47.1                                      |
| 6 or more                   | 166               | 44.6                                      |
| Number of negative symptoms | Number of patients | Median duration of admission (days) |
|-----------------------------|-------------------|----------------------------------|
| 0                           | 696               | 30.0                             |
| 1                           | 200               | 37.5                             |
| 2                           | 194               | 46.0                             |
| 3                           | 165               | 40.0                             |
| 4                           | 116               | 48.0                             |
| 5                           | 110               | 51.5                             |
| 6 or more                   | 128               | 56.5                             |
### eTable 6 - Association between number of negative symptoms ascertained prior to 2011 and mental health hospital admission, re-admission and duration of admission in 2011 in patients aged under 40 years and patients aged over 40 years

| Associations with 2 or more negative symptoms (binary variable) in patients aged between 16 and 39 years. | Inpatient admission (odds ratio, 95% CI)* | Re-admission within 12 months of inpatient admission (odds ratio, 95% CI)* | Duration of inpatient admission (days; B-coefficient, 95% CI)** |
|---|---|---|---|
| n=3315 | n=792 | n=785 |
| Unadjusted | 1.36 (1.17-1.59) | 1.82 (1.36-2.43) | 25.4 (6.2, 44.6) |
| 1. Age and sex | 1.40 (1.20-1.63) | 1.88 (1.40-2.54) | 20.8 (1.5, 40.1) |
| 2. Model 1 plus marital status and employment | 1.25 (1.06-1.46) | 1.70 (1.24-2.31) | 15.0 (-4.9, 34.9) |
| 3. Model 2 plus delusions / hallucinations, and depression | 1.22 (1.03-1.43) | 1.68 (1.23-2.29) | 14.5 (-5.5, 34.5) |

| Associations with 2 or more negative symptoms (binary variable) in patients aged over 40 years. | n=4361 | n=820 | n=805 |
|---|---|---|---|
| Unadjusted | 1.41 (1.20-1.65) | 1.61 (1.21-2.16) | 22.1 (5.2, 39.1) |
| 1. Age and sex | 1.33 (1.13-1.56) | 1.56 (1.16-2.08) | 26.7 (9.8, 43.6) |
| 2. Model 1 plus marital status and employment | 1.26 (1.07-1.49) | 1.48 (1.10-1.99) | 24.3 (7.2, 41.4) |
| 3. Model 2 plus delusions / hallucinations, and depression | 1.24 (1.05-1.45) | 1.48 (1.10-1.99) | 24.4 (7.5, 41.4) |

*Logistic regression; **Linear regression

Age x negative symptoms (binary variable) interaction term p>0.05 for all models