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Title page

Title: Negative symptoms in early-onset psychosis and their association with
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Abstract

The prevalence of negative symptoms (NS) at first episode of early-onset psychosis (EOP), and their effect on psychosis prognosis is unclear. In a sample of 638 children with EOP (aged 10-17 years, 51% male), we assessed (i) the prevalence of NS at first presentation to mental health services, and (ii) whether NS predicted eventual development of multiple treatment failure (MTF) prior to the age of 18 (defined by initiation of a third trial of novel antipsychotic due to prior insufficient response, intolerable adverse-effects or non-adherence). Data were extracted from the electronic health records held by child inpatient and community-based services in South London, UK. Natural language processing tools were used to measure the presence of Marder Factor NS and antipsychotic use. The association between presenting with ≥ 2 NS and the development of MTF over a 5-year period was modelled using Cox regression. Out of the 638 children, 37.5% showed ≥ 2 NS at first presentation, and 124 (19.3%) developed MTF prior to the age of 18. The presence of NS at first episode was significantly associated with MTF (adjusted hazard ratio 1.62, 95% CI 1.07–2.46; $p=.02$) after controlling for a number of potential confounders including psychosis diagnostic classification, positive symptoms, co-morbid depression, and family history of psychosis. Other factors associated with MTF included co-morbid autism spectrum disorder, older age at first presentation, Black ethnicity and family history of psychosis. In EOP, NS at first episode are prevalent and may help identify a subset of children at higher risk of responding poorly to antipsychotics.

Key words: Early-onset psychosis, First-episode psychosis, Negative symptoms, Antipsychotic agents, Treatment resistance

Introduction

Early-onset psychosis (EOP), defined as onset before age 18 years, is a severely debilitating condition associated with long-term psycho-social impairment.¹ As a diagnostic term, EOP covers a broad range of psychiatric illness including schizophrenia spectrum, affective and other non-affective psychotic disorders.² Children with EOP often show significant levels of both positive and negative symptoms and disorganized behaviour. Relative to adult-onset psychosis, children and adolescents are more likely to have a background of longer durations of untreated psychosis, poor pre-morbid adjustment, and greater number of co-existing conditions, such as neurodevelopmental and substance abuse disorders.³⁻⁴

Compared to work examining the pathogenesis of adult and early-onset psychosis, studies which examine prognostic indicators in the years following treatment initiation are relative scarce.¹ From the research conducted, findings suggest that both a longer duration of untreated psychosis and poorer premorbid adjustment are associated with poorer recovery in EOP. Despite previous evidence from adult-onset samples supporting the influence of negative symptoms (NS) on functional outcomes and recovery, the effect of NS on the prognosis of EOP remains relatively unexplored. NS symptoms include lack of motivation, problems with social interaction or diminished emotional range, and involve a loss or deficit in normal functioning.⁵⁻⁶ They can be enduring and inherent to the core disease process (i.e. primary NS), or caused by other factors such as medication side-effects, positive symptoms, concurrent depression or limited social stimulation (i.e. secondary NS).⁵⁻⁶

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3 At present it is difficult to assess the prognostic implications of NS at a young's
4 person's first presentation with psychosis.¹ In adult-onset cases, NS are reportedly
5 present at first-episode psychosis in about 30-50% of patients.⁷⁻⁸ They are difficult to
6 treat and are one of the main contributors to the functional disability observed in
7 psychotic illness.⁹⁻¹⁵ In EOP cases, NS are also reportedly stable over time, but little is
8 known about the prevalence of these symptoms at first-episode.¹⁶ Most studies so far
9 have focused on early-onset schizophrenia,¹⁷⁻¹⁹ which may not generalise to the
10 heterogeneous population of young people that first present to child and adolescent
11 early psychosis intervention services. In addition, prior research findings have been
12 limited by small sample sizes, convenience recruitment of more severe cases, or
13 inclusion of those more amenable to taking part in a research study.^{1,4}
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28 The digitisation of mental health records across the world, presents an alternative
29 resource for psychosis researchers who wish to study clinical issues "in vivo".²⁰ A
30 major strength of these data is their comprehensive inclusion of the whole population of
31 interest, and therefore providing highly generalizable results - addressing some of the
32 limitations related to selection bias, sample size and attrition commonly found in the
33 cohort studies described above. At present, NS research using electronic health records
34 (EHR) has been limited. Despite a number of robust rating scales now available to
35 assess NS in psychosis,²¹⁻²³ they are inconsistently applied to clinical populations
36 treated in routine practice.²⁴⁻²⁵
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50 Computational linguistics or Natural Language Processing (NLP) explores how to make
51 computer systems understand and manipulate natural language expressed in text to
52 perform desired tasks.²⁶ Phenotype algorithms using NLP within clinical text, are an
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3 emerging method of automatically classifying patients with specific diseases, symptoms
4 and outcomes.²⁷ NLP approaches can discern the meaning or semantic content of text,
5 and using pre-specified algorithms, encode text to provide structured output for
6 analysis. This provides considerable advantages compared to performing key word
7 searches in EHR, especially when accurately targeting certain clinical phenotypes.²⁷ For
8 example, NLP can discern whether a key word *emotional withdrawal* in the health
9 record refers to a patient or family member, their current or past mental state, or is
10 simply a negated item within clinical screening. NLP approaches can use pattern
11 recognition via statistical or machine learning methods to identify a phenotype or
12 exposure of interest within the EHR. Parameters around accuracy can be stipulated,
13 allowing uncertainty on whether an event or phenotype is a true positive, which can be
14 accounted in later analysis. Investigators have largely adopted this approach in i2b2
15 (Informatics for Integrating Biology and the Bedside), a US consortium, based at
16 Harvard/MIT Health Science division and Partners HealthCare System in Boston,
17 Massachusetts.²⁸

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37 In a large naturalistic sample of children and adolescents first presenting to services
38 with EOP, we examined the prevalence of NS recorded in the mental health record at
39 initial contact with psychiatric services. To address the limited structured information
40 available on NS, we used a machine learning NLP approach, validated in adult samples,
41 to extract NS data within the EHR. To explore NS as potential prognostic indicator, we
42 examined whether NS at first episode predicted antipsychotic treatment failure, using a
43 pragmatic measure of treatment failure, as defined by initiation of a third trial of novel
44 antipsychotic (due to prior insufficient response, intolerable adverse-effects or non-
45 adherence), which we termed multiple treatment failure (MTF).²⁹ Previous work in
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3 adult-onset samples, suggests that NS characterize psychotic disorders with non-
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5 hyperdopaminergic pathophysiology,³⁰⁻³¹ which is supported by clinical evidence that
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7 NS in the first-episode are associated with poorer response to antidopaminergic effects
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9 of current antipsychotic treatment.^{30, 32} Therefore, we predicted that EOP patients with
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11 NS at presentation would be more likely to experience MTF. We also expected that this
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13 association would remain after taking account of potential confounders, including type
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15 of psychotic disorder, positive symptoms, family history of psychosis, co-morbid
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17 depression, and additional markers of premorbid neurodevelopmental difficulties such
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19 as co-occurring autism spectrum disorders (ASD), hyperkinetic disorder and intellectual
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21 disability.
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26 **Methods**

27 *Study design and study sample*

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32 A complete description of the study design and sample selection is provided
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34 elsewhere.²⁹ In brief, the sample consisted of a clinical cohort of all those individuals
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36 with a first episode of any psychotic disorder who were referred to child and adolescent
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38 mental health services (CAMHS) – including inpatient, outpatient and early intervention
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40 for psychosis services - in South London and Maudsley NHS Foundation Trust (SLaM),
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42 UK, from January 1st 2008 to December 31st 2014. Over this time, SLAM delivered all
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44 aspects of inpatient and community based child mental healthcare to approximately
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46 250.000 children residing in four London boroughs, and specialist provision to children
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48 resident outside the boroughs where local area services (such as inpatient facilities)
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50 were unavailable. Most children experiencing a psychotic disorder within the SLaM
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52 catchment area of South London were likely to present to SLaM services and included
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54 in this study: the private sector has very limited involvement in child mental health
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3 within the area, and children with psychosis, relative to adults, usually come to the
4 attention of services relatively early.³⁴
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9 The data were extracted using the Clinical Record Interactive Search (CRIS)
10 application: a de-identified record database containing the EHR of over 34,400 child
11 and adolescent cases held at the UK National Institute for Health Research (NIHR)
12 Biomedical Research Centre (BRC) for Mental Health.³⁵⁻³⁶ Data from structured text
13 fields was extracted and missing structured data was supplemented by natural language
14 processing tools [Generalised Architecture for Text Engineering (GATE)³⁷ and
15 TextHunter³⁸] which code 'free text' from the EHR (i.e. progress notes, mental state
16 assessments, discharge summaries, outpatient correspondence). The CRIS resource was
17 an approved as anonymised data resource for secondary analysis by Oxfordshire
18 Research Ethics Committee C (08/H0606/71+5). This study was approved under NIHR
19 BRC CRIS oversight committee (ref: CRIS 14-095).
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35 *Inclusion criteria*

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37 Inclusion criteria for participants were: 1) age 10-17 years at the time of first
38 presentation to CAMHS (owing to ethics and risk of statistical disclosure, we did not
39 include children who were under the age of 10 years); 2) at least one 'clinically
40 relevant' psychotic disorder diagnosis, based on clinician judgment after comprehensive
41 diagnostic interviews and identified from either clinician-recorded structured fields
42 (ICD-10 codes F20-F29, F30-31, F32.3, F33.3, F1x.5); or any free text clinician-
43 recorded ICD-10 diagnosis of 'schizophrenia', 'schizoaffective disorder', 'bipolar
44 disorder', 'depression with psychotic symptoms', 'brief psychotic disorder', 'delusional
45 disorder', 'shared psychotic disorder', 'drug-induced psychosis' and 'psychosis not
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3 otherwise specified (NOS)', filtered for any clinician-recorded mention of antipsychotic
4 treatment after the psychosis diagnosis. The earliest recorded psychosis diagnosis was
5 coded as the first-episode diagnosis. For reporting purposes, diagnoses were grouped
6 into schizophrenia, schizoaffective disorder, bipolar disorder, psychotic depression,
7 drug-induced psychosis, and other psychoses (including brief psychotic disorder,
8 delusional disorder, shared psychotic disorder, and psychoses-NOS). A hand-searched
9 review of a random sample of 100 records revealed that this identification process had a
10 0.98 positive predictive value (PPV) for psychosis.
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22 Figure 1 shows the flowchart for inclusion in the study. Out of the 1033 cases initially
23 identified with the GATE tool or through structured diagnoses, only 638 individuals met
24 the inclusion criteria for a 'clinically relevant psychotic disorder' and age 10-17 years
25 and were therefore included, whilst 395 were excluded due to psychosis referring to
26 non-primary/differential diagnosis or subthreshold symptoms.
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35 [Fig 1 about here]
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41 *Extraction of antipsychotic use data and definition of MTF*

42 As described elsewhere,²⁹ we used a previously validated GATE application to identify
43 regular antipsychotic prescription trials from the structured medication fields and
44 unstructured fields in the EHR.³⁹⁻⁴⁰ Since no standard criteria for poor antipsychotic
45 response or refractory disorder appeared suitable for EOP samples,⁴¹⁻⁴² a proxy was
46 created, based on the antipsychotic effectiveness literature,⁴³⁻⁴⁵ which we termed MTF;
47 defined as the initiation of a third trial of a novel antipsychotic due to insufficient
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3 response, intolerable adverse effects, non-adherence, or other miscellaneous reasons
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5 over a 5-year follow-up period from first presentation, or before the age of 18 years,
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7 whichever came first. Please see Downs et al. 2017 for further details around the
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9 validation of the MTF outcome and reasons for discontinuation.²⁹
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11 12 13 *Extraction of NS data* 14

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17 A previously validated Natural Language Processing method⁸ was used to find
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19 statements in the unstructured free-text fields of patients' EHR which related to the
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21 presence of NS at baseline (i.e. within 60 days of accepted referral). The method was
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23 based on a NLP tool called TextHunter [see Jackson et al. (2014) for further details]³⁸
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25 which is a custom-built NLP software tool which interfaces with CRIS. It facilitates
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27 each of the steps involved in developing a NLP application,²⁷ from identifying
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29 appropriate ontologies and supporting manual annotation, to applying and testing
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31 sophisticated text based pattern recognition (including support vector machine learning
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33 approaches) derived from annotated training datasets.
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39 To validate the NLP data extraction, the randomised sample of 100 cases used
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41 previously was also hand-searched for NS by a master's level graduate in Early
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43 Intervention Psychosis studies (HD), blinded to MTF status. The PPV for NS subtypes
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45 ranged from 0.80 (poverty of speech) to 0.99 (mutism) and sensitivity ranged from 0.62
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47 (poor motivation) to 0.97 (apathy). For the purposes of this study, Marder negative
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49 factor items^{21, 46} from the Positive and Negative Syndrome Scale (PANSS)²³ were used
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51 as a framework for characterizing NS (see Table 1 for details). The extracted item
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53 'social isolation' was considered descriptive of both passive apathetic social withdrawal
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3 (Marder N4) and active social avoidance (Marder G16). Having mutism, poverty of
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5 speech or both items recorded on the EHR was counted as a single NS, equivalent to
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7 lack of spontaneity / flow of conversation (Marder N6). The item psychomotor
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9 retardation (equivalent to Marder G7) was dropped as an NS due to its low PPV (0.55)
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11 and sensitivity (0.65). Furthermore, the hand search of the selected 100 cases revealed
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13 that this item had a low prevalence (~5% of the sample) and always appeared
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15 acknowledged as an antipsychotic-related adverse effect (hence a secondary NS).
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20 [Table 1 around here]
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24 A composite ordinal variable, ‘number of NS’ (range 0 – 5) was created by summing
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26 the total count of the extracted NS. A score of at least two NS was applied a priori to
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28 determine the presence or absence of NS for analysis. Individuals were categorized as
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30 having an NS or non-NS profile using the ≥ 2 Marder Factor NS cut-off. This was
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32 consistent with previous work that used the two-symptom cut-off to describe deficit
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34 syndromes in schizophrenia (i.e. primary, enduring NS).^{8, 13}
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39 *Extraction of other clinical and demographic data* 40

41 A number of demographic variables and clinical data within 60 days of study entry (i.e.
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43 after accepted referral) were also extracted from the health record. Age at referral for
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45 first-episode psychosis, gender, ethnicity (according to categories defined by the UK
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47 Office for National Statistics), and index of neighbourhood deprivation for the main
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49 caregiver residence were extracted.⁴⁷ Data on positive symptom severity around first
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51 presentation were extracted using TextHunter (see Jackson et al. 2017 for validation
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53 metrics) which provided the total number of items in the EHR referencing positive
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3 symptoms of psychosis including delusions, persecutory and paranoid ideation, and
4 hallucinations. Based on the total number of items referenced, individuals were then
5 categorised into quartiles. As an additional index of severity we coded inpatient status
6 and the Children's Global Assessment Scores (CGAS),⁴⁸ respectively at study entry.²⁹
7
8 Data on ICD-10 co-morbid neuropsychiatric disorders which can be subsumed under
9 the DSM-5 category of autism spectrum disorder - ASD (F84.0, F84.1, F84.5, F84.9),
10 hyperkinetic disorder (F90.0, F90.1, F90.2, F90.8, F90.9), major depressive disorder
11 (F32-33), and intellectual disability (F70-79), were also extracted from free text and
12 structured fields as previously described.²⁹ TextHunter also retrieved positive mentions
13 of substance misuse around first presentation, with validation metrics (PPV) for the
14 following Cannabis (0.70) , Cocaine or crack (0.78), Amphetamine (0.76), and 3,4-
15 Methylendioxyamphetamine (MDMA, 0.88); a binary 'any use' variable was
16 created for each substance type. Using the GATE tool, we also built a rules-based NLP
17 application which coded absence/presence of a 1st degree relative with psychosis
18 (defined as any of the study inclusion terms for psychosis but affecting parents or full
19 siblings). Validation of this NLP approach was conducted against clinician review (JD
20 & LP) of all patient notes from 96 randomly selected EOP cases (PPV 0.91, recall 0.73).
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45 *Statistical Analyses*

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47 All analyses were conducted using STATA (Version 13). The prevalence of individuals
48 meeting ≥ 2 threshold NS, and the total number of NS items was calculated. Logistic
49 regression was used to examine the demographic and baseline clinical association with
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55 ≥ 2 NS profiles.
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5 To examine the prospective association between baseline demographic, clinical
6 exposures and MTF outcome, we excluded children who had MTF within the 60-day
7 baseline period ($n=20$). Kaplan–Meier curves were used to illustrate survival over time
8 (probability of non-development of MTF), comparing those who were and were not
9 presenting with ≥ 2 NS at baseline. After checking proportional hazards assumptions, we
10 used a Cox regression to model the association between this baseline NS profile and
11 MTF over a 5-year follow-up period from first presentation, or before the age of 18
12 years, whichever came first. The first model examined the crude effect of NS alone on
13 MTF. Subsequent models were constructed adding potential socio-demographic, and
14 clinical confounders. As sampling bias towards more severe cases could affect the
15 external validity of the findings, sensitivity analyses were conducted to adjust the
16 aforementioned models by adaptive function (CGAS) measures at first presentation and
17 local catchment area residence status; (ii) restrict to patients who were inpatients at
18 baseline line assessment.
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40 **Results**

41 *Demographic and clinical characteristics of the sample*

42 Demographic and clinical characteristics of the 638 patients included (124 [19.3%] of
43 whom developed MTF over time) and of the NS subgroup are presented in Table 2.
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49 [Table 2 around here]
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51 *Negative symptom prevalence*

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3 Supplementary Material 1 shows the prevalence of each NS and positive symptom, and
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5 summary statistics for each item using the manually-validated NLP extraction tool, in
6
7 the total sample and the MTF subgroup. Of note, 52.4% of the MTF subgroup presented
8
9 with ≥ 2 Marder Factor NS. The most prevalent NS in the MTF subgroup was emotional
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11 withdrawal (43.6%). The prevalence of ≥ 2 Marder Factor NS across diagnostic
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13 categories were as follows: schizophrenia- 39.2%, schizoaffective disorder- 35.3%,
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15 bipolar disorder- 26.1%, psychotic depression- 37.7%, drug-induced psychosis- 25.6%
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17 and other psychoses- 40.6%.

21 *Reasons for antipsychotic discontinuation*

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24 Details on the antipsychotic treatment pathways for the 124 children who developed
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26 MTF are shown as Supplementary Material 2. Cases identified as having the same
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28 reason for antipsychotic discontinuation at first and second antipsychotic trials were
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30 grouped into three MTF ‘persistent reason’ groups (persistent insufficient response,
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32 adverse events or non-adherence). A ‘variability in reasons’ subgroup (i.e. when reasons
33
34 were different at each antipsychotic trial) was also created. The main patterns of
35
36 discontinuation in the MTF group were the combination of insufficient response and
37
38 adverse events ($n=32$, 35.2%), and persistent adverse events ($n=19$, 20.9%) over time.
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40 Children with NS profile showed higher rates of the ‘insufficient response-and-adverse
41
42 effect’ trajectory and lower rates of adherence-related trajectories relative to those with
43
44 non-NS profile (Supplementary Material 2).

49 *Cox regression models*

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52 Kaplan-Meier curves displaying the survival status (probability of treatment
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54 effectiveness or non-MTF) over time of children with or without baseline NS profiles

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3 are presented as Figure 2. A logrank test showed non-NS profile at first presentation to
4 services displayed significantly higher survival rate ($p < .001$). Unadjusted associations
5 using a Cox regression model between MTF outcomes and predictor variables,
6 including NS and other co-variates, are displayed in supplementary material 3. An
7 adjusted Cox regression model (Table 3) showed that NS profile was associated with
8 increased risk of MTF over the follow-up period (adjusted hazard ratio [aHR] 1.62, 95%
9 CI 1.07–2.46; $p = .02$). Black ethnicity (aHR 1.78, 95% CI: 1.11–2.87; $p = .02$), older age
10 at first presentation (aHR 1.27, 95% CI: 1.109–1.49; $p = .002$), comorbid diagnosis of
11 ASD (aHR 1.70, 95% CI: 1.03–2.79; $p = .04$), and first degree relative with psychotic
12 disorder (aHR 2.11, 95% CI: 1.35–3.30; $p = .001$) were also significantly associated with
13 MTF.
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27 [Figure 2 and Table 3 about here]
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31 *Sensitivity Analyses*

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33 A sensitivity analysis with adjustment for all those with complete CGAS information
34 and residence within the local catchment area ($n=394$), found NS profile was associated
35 with increased risk of MTF (aHR= 1.85; 95% CI= 1.02–3.48; $p=.03$). The analyses
36 including only those individuals who were inpatients ($n=260$, 40.8%) at first
37 presentation (within 60 days of accepted referral) found little change in the direction
38 and magnitude of the association between NS and MTF (aHR= 1.63; 95% CI = 0.82–
39 3.22; $p = .16$), although the reduced sample affected the power of the study to detect a
40 significant association.
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Discussion

This study shows that children and adolescents with psychosis commonly present with NS, with more than one third of the sample displaying NS at first presentation to services. Our results also show that an NS profile at first stages is a prognostic marker for antipsychotic treatment failure in children with EOP: approximately 30% of the sample with NS at baseline went on to develop MTF, representing a two-fold increased risk from those without NS. The treatment pathway to MTF for young people with NS profiles appears to be driven by a combination of limited treatment response and emergence of intolerable adverse effects. Older age at first episode, Black ethnicity and a comorbid diagnosis of ASD are also significant predictors of MTF in our sample.

This is, to our knowledge, the largest naturalistic study of its kind to examine the prevalence of NS in EOP at first presentation to child mental health services. The study used an innovative text mining technique, adapted from an application in adult mental health records,⁸ to extract negative symptom profiles. In our study, more than one third of the EOP population had two or more NS at baseline, rates that are consistent with those reported in both child and adult-onset psychosis literature (around 30-50%).^{8, 49}

This is also the first study to assess the association of NS and antipsychotic treatment failure in first-episode EOP patients. Our results, combined with findings that NS can manifest in the psychosis prodrome,⁵⁰ suggests that NS profiles could represent a distinct phenotypic trajectory in young people with psychotic disorders. NS are possibly a marker for a distinct deviant neurodevelopmental trajectory which may be harder to treat with conventional antipsychotics and therefore result in a more impaired illness course. Although no other cohorts have been used to examine MTF as an outcome in

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3 EOP, our findings are consistent with evidence that NS are associated with poor clinical
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5 outcomes in adult and child samples, many of those using validated gold-standard
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7 instruments to measure negative symptoms (e.g. the PANSS).^{1, 51} Our work using text
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9 mining approaches for NS identification in large scale naturalistic samples of EOP
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11 using EHRs serves to complement the more traditional approaches using selective
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13 cohorts and intensive structured assessments, to inform prognostic indicators in clinical
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15 practice.
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20 Several alternative psychopathological processes may be driving our findings. Higher
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22 levels of primary NS may represent a clinical phenotype for greater levels of ‘non-
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24 hyperdopaminergic’ processes behind psychosis development and/or remission.^{30-31, 52}
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26 Hence, NS may help identify a subgroup of patients with positive symptoms who do not
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28 respond well to antipsychotics, and are at higher risk of developing MTF. Our findings
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30 suggest NS in adolescents, alongside other factors including ethnicity, family history
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32 and neurodevelopmental co-morbidity may delineate “hard to treat” subgroups. These
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34 groups may benefit from more careful monitoring and quicker access to additional
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36 interventions beyond antipsychotic medication.⁵³ Follow-up was conducted for the
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38 sample for up to five years, so it is important to understand that antipsychotic
39
40 medication may still successfully reduce positive psychotic symptoms in these groups,
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42 but NS and other MTF risk factors may moderate the association between positive
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44 symptom reduction and the protective factors required for a sustained remission. Our
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46 findings also highlight the need for research involving agents that work on alternative
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48 pathophysiological pathways (e.g. the glutamate system) which may be of greater
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50 relevance to these subgroups, given their potential effectiveness at treating both the NS
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52 and the positive symptoms of those with psychosis.
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5 Our findings support the notion that NS are intrinsic to early-onset psychosis (across
6 different psychosis diagnostic categories) and are already present during the first
7 psychotic break. In regard to the prevalence across the different psychosis disorder
8 classifications, in our sample NS were present in about one third of all EOP diagnostic
9 subgroups, with slightly higher rates in those with non-affective psychosis. This
10 suggests that in EOP, differences between psychosis diagnostic categories (especially
11 between schizophrenia and affective psychoses) are quantitative rather than qualitative
12 in nature, and all diagnoses are associated with presence of impairing symptoms (as
13 reflected by similar rates of NS). Further research using transdiagnostic approaches, as
14 illustrated in this study, are needed to advance in the understanding of the
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Our findings support the notion that NS are intrinsic to early-onset psychosis (across different psychosis diagnostic categories) and are already present during the first psychotic break. In regard to the prevalence across the different psychosis disorder classifications, in our sample NS were present in about one third of all EOP diagnostic subgroups, with slightly higher rates in those with non-affective psychosis. This suggests that in EOP, differences between psychosis diagnostic categories (especially between schizophrenia and affective psychoses) are quantitative rather than qualitative in nature, and all diagnoses are associated with presence of impairing symptoms (as reflected by similar rates of NS). Further research using transdiagnostic approaches, as illustrated in this study, are needed to advance in the understanding of the physiopathology and predictive value of NS across disorders.

The main strengths of this study include the use of a large historical cohort of first-episode EOP, which provides a ‘real world’ sample of young people accessing inpatient and outpatient first episode psychosis CAMH services. Selecting an early-onset sample at first episode, reduces the potential bias incurred through unknown treatment exposures. The large sample size, and relative long duration of assessment provides sufficient power to estimate the association between NS and MTF even after adjustment for a number of potential clinical confounders, including psychotic disorder classification, family history, positive symptoms, substance misuse, neurodevelopmental and depressive disorder comorbidity. Using a clinical rater review of the whole electronic health record for sub-sets of patients allowed us to compute performance estimates of the different text extraction tools used in the study and select the most accurate ones, and mitigation of misclassification errors. This work using text

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3 mining approaches for NS identification in large scale naturalistic samples of EOP
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5 using EHRs serves to complement the more traditional approaches using selective
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7 cohorts and intensive structured assessments, to inform prognostic indicators in clinical
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9 practice. It is important to recognise that even the most accurate NLP applications will
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11 be limited by the text held within clinical records, and unlikely to identify NS as
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13 accurately as specialised rating scales. However, as with most structured psychiatric
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15 assessments, clinicians tend to shun structured templates or drop-down options when
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17 keeping a record of their daily practice,⁵⁴⁻⁵⁵ so the free-text note persists as the
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19 predominant method of recording clinical information.⁵⁶ This was certainly reflected in
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21 our EOP samples, as we were unable to detect any young people who had undergone a
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23 comprehensive assessment for negative symptoms using a standardised instrument at
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25 first presentation.
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31 Results derived from the EOP sample should be interpreted in the context of several
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33 limitations, some of which have been covered in previous work.²⁹ In relation to the
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35 findings specific to this study, it was difficult to ascertain whether extracted NS were
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37 primary or secondary in nature, we assume that as NS were rated early (i.e. within 60
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39 days of presentation to services and potentially prior or at the point of starting initial
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41 antipsychotic treatment), and excluding the presence of psychomotor retardation from
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43 the total NS counting, the NS we detect are mainly (but not only) primary in character.
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45 In regard to the MTF definition, we were unable to obtain relevant antipsychotic data
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47 such as maximum daily antipsychotic dose, antipsychotic serum levels, or structured
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49 assessments of tolerability, which may have provided more objective assessments of
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51 treatment failure. Besides, by rating treatment failure to one of four potential categories
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53 at each point of discontinuation/treatment failure, we may have underestimated the
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3 contribution of other underlying reasons to treatment failure. As with all observational
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5 studies, our findings may be limited by residual confounding, for example we were
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7 unable to adjust for the duration of untreated psychosis – which could be explanatory
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9 factors for older age being associated with MTF. Another related limitation includes the
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11 restriction of age to the clinical samples, so that all clinical outcomes occurred prior to
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13 age 18. One of the reasons we imposed this was to reduce the impact of clinician
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15 heterogeneity as a residual confounder. Children with long term conditions, such as
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17 psychosis, experience very different treatment environments when they move from
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19 CAMHS to adult psychiatric services,⁵⁷ and this heterogeneity may have considerable
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21 influence on the way clinical data is recorded, as well as the mental health treatments
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23 offered and outcomes obtained.⁵⁸ Finally, there is a chance that not all children and
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25 adolescents experiencing a first-episode psychosis within the catchment area (who
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27 access clinical services) would have presented to SLaM CAMHS, nor given potential
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29 changes in residence away from SLaM services, were all young peoples' psychiatric
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31 care captured by the health record system over the course of follow-up. Given the mean
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33 duration of follow-up was lower in the NS group, we suspect that this may have led to
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35 an underestimation of the NS-MTF effect we report. Furthermore, the impact of
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37 potential loss to follow-up or of non-actual first presentation to services is likely to be
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39 limited, as we conducted a sensitivity analyses which took account of residence within
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41 the local catchment which showed little difference from whole sample findings.
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48 In summary, our study demonstrated that there is a high prevalence of negative
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50 symptoms in early-onset psychosis around patients' first presentation to services and
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52 across psychosis diagnosis classifications. The finding supports the hypothesis that
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54 presence of these symptoms around the first stages of the illness identify a subset of
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3 children and adolescents who may be at higher risk of responding poorly to
4 antipsychotics, both through refractory symptoms and high sensitivity to side-effects.
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6 Optimisation of current pharmacological and non-pharmacological strategies for these
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8 patients, and further research involving agents that better target negative symptoms are
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10 warranted.
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12 interest in relation to the subject of this study.
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Table 1. Selection of negative symptoms from electronic health records and their equivalence to the Marder Negative Factor items within the PANSS

Items extracted from electronic health record	PPV/sensitivity	Marder Negative Factor items within the PANSS
Blunted affect	0.93/0.83	N1. Blunted affect
Emotional withdrawal	0.85/0.74	N2. Emotional withdrawal
Poor rapport	0.91/0.77	N3. Poor rapport
Social isolation	0.94/0.96	N4. Passive apathetic social withdrawal G16. Active social avoidance
Poverty of speech	0.80/0.73	N6. Lack of spontaneity & conversation flow
Mutism	0.99/0.94	
<i>Psychomotor retardation (dropped^a)</i>	<i>0.55/0.65</i>	<i>G7. Motor retardation</i>

^aDropped from the study due to low PPV (0.55) and sensitivity (0.65) of the 'free text' extraction tool, and due to its being recorded mainly as secondary negative symptom.

Note: PANSS: Positive and Negative Syndrome Scale; PPV: positive predictive value

Table 2. Comparison between young people with early-onset psychosis at first presentation with and without ≥ two negative symptoms documented

Sample characteristics	Non-NS group (n = 399)	NS group (n = 239)	OR; <i>p</i> -value
MTF status, N(%)	59 (14.8)	65 (27.2)	2.15 (1.45-3.20) ***
Gender, Female, N(%)	192 (48.1)	117 (48.9)	1.03 (0.75-1.42)
Age at referral (mean, SD)	15.4 (1.9)	15.9 (1.9)	1.17 (1.06-1.28) ***
Age of reaching MTF (mean, SD)	16.5 (1.3)	16.0 (0.19)	0.79 (0.61-1.04)
Duration of follow-up (days), mean (SD)	721.4 (529.9)	590.5 (458.0)	0.995 (0.991-0.998) **
Ethnicity, N(%)			
White	204 (51.1)	93 (38.9)	Reference
Black	113 (28.3)	96 (40.2)	1.86 (1.29-2.67)
Asian	18 (4.5)	21 (8.8)	2.56 (1.30-5.03)
Mixed	47(11.8)	27(11.3)	1.26 (0.74-2.15)
Not Stated	17 (4.3)	2 (0.8)	0.25 (0.06-1.14)
Neighbourhood Characteristics, N(%)^a			
1 st (Least Deprived)	104 (27.1)	61 (25.9)	Reference
2 nd	90 (23.4)	62 (26.4)	1.17 (0.75-1.42)
3 rd	94 (24.5)	57 (24.3)	1.03 (0.66-1.63)
4 th (Most Deprived)	96 (25.0)	55 (23.4)	0.98 (0.62-1.54)
First ICD-10 psychosis diagnosis, N(%)			
Other Psychoses ^b	63 (15.8)	43 (17.9)	Reference
Bipolar Disorder / F30, F31	31 (7.8)	11 (4.7)	0.57 (0.24-1.15)
Drug-induced psychosis / F1x.x5	29 (7.3)	10 (4.2)	0.51 (0.22-1.14)
Schizophrenia / F20	222 (55.6)	143 (59.8)	0.94 (0.61-1.46)
Schizoaffective / F25	11 (2.8)	6 (2.5)	0.80 (0.27-2.32)
Psychotic Depression / F32.3, F33.3	43 (10.8)	26 (10.9)	0.89 (0.47-1.65)
Co-morbid neuropsychiatric disorders, N(%)			
Autism Spectrum Disorder	75 (18.8)	39 (16.3)	0.84 (0.55-1.29)
Hyperkinetic Disorder	33 (8.27)	7 (2.9)	0.33 (0.15-0.77)**
Intellectual Disability	43 (10.8)	22 (9.2)	0.84 (0.49-1.44)
Major Depressive Disorder	108 (27.1)	66 (27.6)	1.03 (0.72-1.48)
First degree relative with psychotic disorder	86 (21.6)	51 (21.3)	0.99 (0.67-1.46)
Illness severity/ Functioning			
Admission at presentation, N(%)	90 (22.6)	170 (71.1)	8.5 (5.9-12.2)***
CGAS score (mean, SD) ^b	42.1 (15.3)	33.7 (15.4)	0.97 (0.95-0.98)***
Positive symptoms			
1 st (lowest quartile of symptom items recorded)	61 (15.3)	11 (4.6)	Reference
2 nd	79 (19.8)	27 (11.3)	1.90 (0.87 – 4.21)
3 rd	137 (34.3)	84 (35.2)	3.40 (1.69-6.83) ***
4 th (highest quartile of symptoms items recorded)	122 (30.6)	117 (49.0)	5.31 (2.67-10.6) ***
Substance misuse			
Cannabis	171 (42.9)	113 (39.5)	1.20 (0.87-1.65)
Cocaine or crack	65 (16.3)	39 (16.3)	1.02 (0.65-1.54)
Amphetamines	14 (3.5)	5 (2.1)	0.59 (0.21-1.65)
MDMA	12 (3.0)	4 (1.7)	0.55 (0.18-1.72)

p* < .05; *p* < .01; ****p* < .001; % Refers to percentages within columns, for whom information was available

^a Missing cases =19; ^b Data available in a subsample of 384, ^b Other Psychoses: an ICD-10 diagnosis of 'brief psychotic disorder (F23)', 'delusional disorder (F22)', 'shared psychotic disorder', or 'psychosis not otherwise specified (NOS)'. Note: CGAS: Children's Global Assessment Scale; MTF: multiple treatment failure; NS: negative symptoms.

Table 3. Cox regression models for the association between negative symptom profile at first presentation and multiple treatment failure over time in early-onset psychosis (n=618)

Multiple treatment failure	Socio-demographic adjustment aH.R. (95% CI)	+ diagnosis and severity aH.R. (95% CI)	+ substance misuse and family history aH.R. (95% CI)
≥2 baseline Marder NS	1.66 (1.12 – 2.42)*	1.59 (1.06 – 2.40)*	1.62 (1.07 – 2.46)*
Female gender	1.08 (0.73-1.62)	1.15 (0.76-1.74)	1.07 (0.71-1.64)
Mean age at referral (s.d)	1.25 (1.09-1.45) **	1.29 (1.10-1.49) **	1.27 (1.09-1.49) **
Ethnicity, N (%)			
White	Reference	Reference	Reference
Black	1.95 (1.23-3.09)**	1.72 (1.08-2.76)*	1.78 (1.11-2.87)*
Asian	1.16 (0.48- 2.77)	1.10 (0.46-2.67)	1.33 (0.58-3.26)
Mixed	1.51 (0.80- 2.86)	1.43 (0.75-2.73)	1.63 (0.84-3.17)
Not Stated	----- ^a	-	-
Neighbourhood Characteristics, N(%)^a			
1 st (Least Deprived)	Reference	Reference	Reference
2 nd	0.60 (0.35-1.04)	0.69 (0.39-1.19)	0.66 (0.37-1.17)
3 rd	0.55(0.31-0.96)*	0.61 (0.35-1.08)	0.56 (0.31-0.98)
4 th (Most Deprived)	0.55 (0.31-0.97)*	0.61 (0.34-1.08)	0.62 (0.34-1.11)
First ICD-10 psychosis diagnosis, N(%)			
Other Psychoses ^b		Reference	Reference
Bipolar Disorder / F30, F31		1.57 (0.69-3.56)	1.54 (0.67-3.56)
Drug-induced psychosis / F1x.x5		0.82 (0.27-2.51)	0.92 (0.29-2.96)
Schizophrenia / F20		0.85 (0.50-1.45)	0.78 (0.45-1.32)
Schizoaffective / F25		2.42 (0.87-6.85)	2.22 (0.78-6.34)
Psychotic Depression / F32.3, F33.3		1.39 (0.62-3.08)	1.15 (0.50-2.60)
Co-morbid neuropsychiatric disorders, N(%)			
Autism Spectrum Disorder		1.73 (1.06-2.82)	1.70 (1.03-2.79)
Other neurodevelopmental disorder		0.74 (0.41-1.33)	0.68 (0.38-1.24)
Major Depressive Disorder		0.68 (0.39-1.15)	0.69 (0.41-1.20)
Positive symptoms			
1 st (lowest quartile)		Reference	Reference
2 nd		0.89 (0.36 – 2.15)	0.83 (0.32 – 2.13)
3 rd		1.18 (0.53-2.65)	1.09 (0.48-2.46)
4 th (highest quartile)		1.97 (0.92-4.21)	1.83 (0.84-3.98)
First degree relative with psychotic disorder			2.11 (1.35-3.30)**
Substance misuse			
Cannabis			1.07 (0.67-1.70)
Cocaine or crack			0.68 (0.36-1.31)
Amphetamines			1.20 (0.27-5.43)
MDMA			0.55 (0.07-4.34)

* $p < .05$; ** $p < .01$; ^a Variable dropped due to 0 values in cell. ^b See corresponding footnote table 2; Note: H.R.: hazard ratio; MTF: multiple treatment failure; NS: negative symptoms

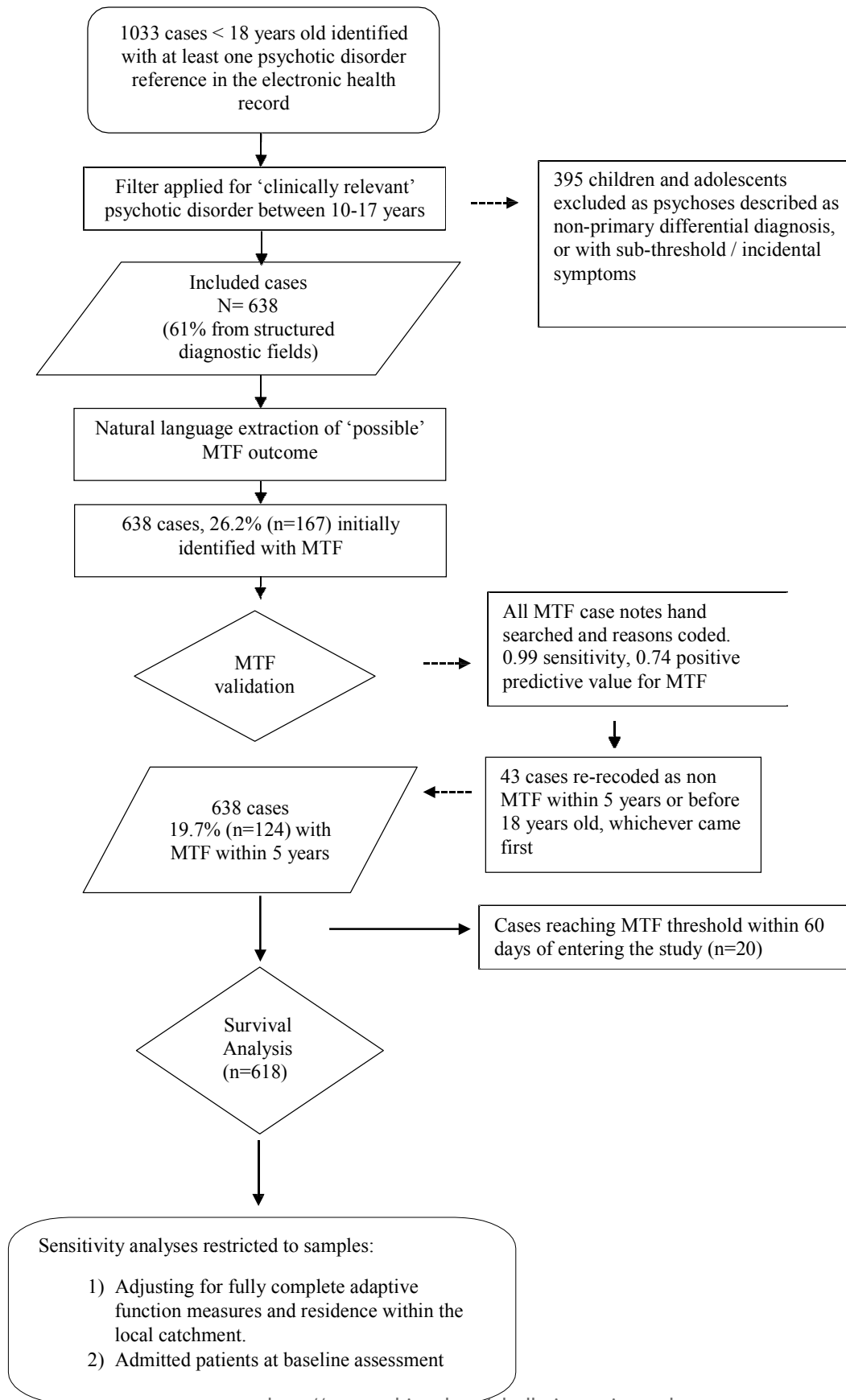
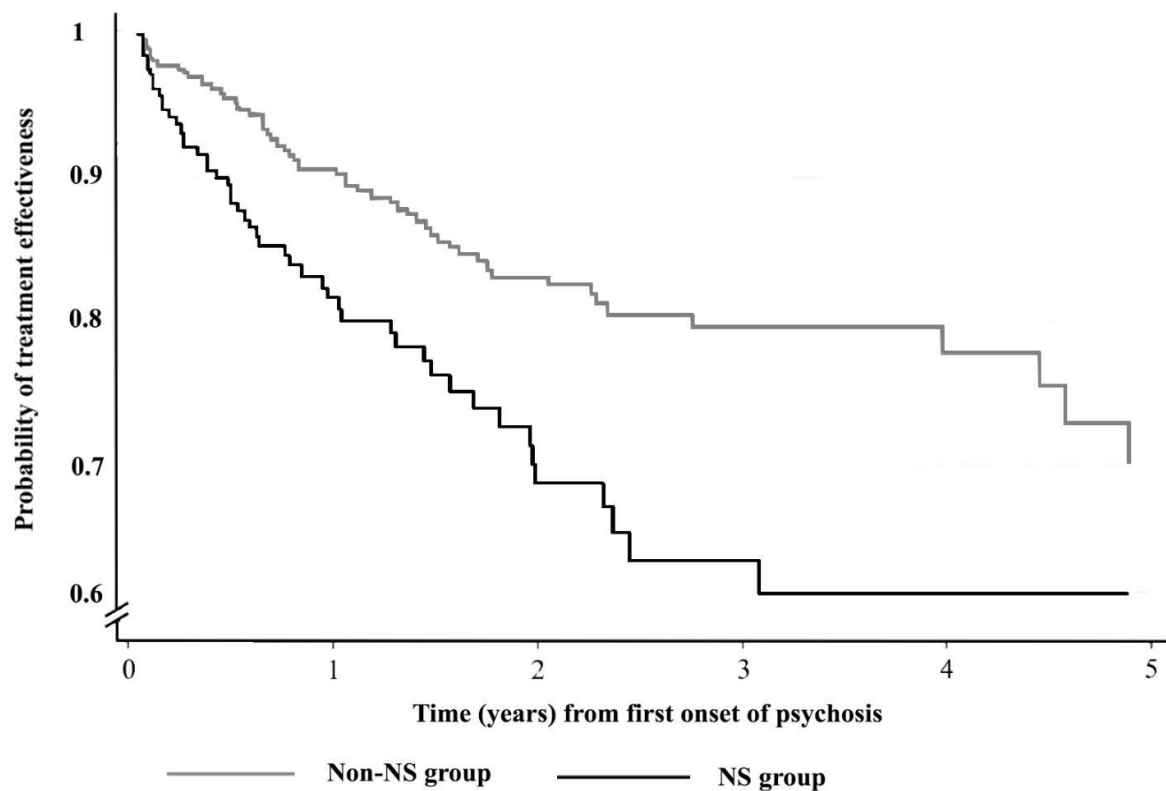
Figure 1: Flowchart of study selection and analysis

Figure 2: Kaplan-Meier curves displaying the survival status (probability of treatment effectiveness or non-MTF) over time of children with or without negative symptom profiles at first presentation to services.



Note: NS: negative symptoms

Supplementary Material 1: Summary of negative and positive symptom items extracted from the EHR at first presentation to services in early-onset psychosis subjects

Symptom categories	N(%)	Total sample (N= 638)		N(%)	MTF (N=124)		Example text for NLP extraction	
		Total items detected	Items detected mean (S.D, IQR)		Total items detected	Items detected mean (S.D, IQR)	Positive annotation	Negative annotation
Negative items								
Blunted affect	130 (20.3)	457	0.72 (1.6, 9)	29 (23.4)	147	1.18 (2.3, 10)	His affect remains very blunted	incongruent affect, Stable affect
Emotional withdrawal	214 (33.5)	848	1.33 (2.3, 12)	54 (43.6)	258	2.10 (2.9, 11)	mother described her as becoming withdrawn, not communicating;	not sad or withdrawn during the assessment
Poor rapport	62 (9.7)	176	0.28 (0.9, 6)	18 (14.5)	61	0.49 (1.2, 5)	He had poor rapport, very limited rapport	We established a good rapport
Social isolation	51 (8.0)	226	0.35 (1.3, 8)	14 (11.3)	88	0.71(2.3, 6)	He withdrew socially from friends and family,	no evidence of being socially withdrawn
Poverty of speech	32 (5.0)	84	0.13 (0.6, 4)	8 (6.5)	17	0.13 (0.6, 4)	He has poverty of speech	Speech normal, no pressure or poverty of speech apparent
Mutism	66 (10.3)	462	0.72 (3.6, 28)	25 (20.2)	203	1.67(5.6, 28)	She has periods of 'mutism'	Mother denied he had any periods of being mute
≥ 2 NS	239 (37.5)	-	-	65 (52.4)	-	-		
Positive items								
Delusions	277 (43.4)	1145	1.8 (4.6, 2)	74 (60)	449	3.62 (8.6, 3)	continued to express delusional ideas	No evidence of delusions,
Hallucinations	483 (76.4)	5226	8.2 (12.5, 18)	103 (83.0)	1761	14.2 (18.4, 17)	visual distortions and auditory hallucinations	No evidence of responding to any hallucinations
Paranoid ideation	427 (66.9)	3579	5.61 (11.9, 6)	94 (75.8)	1237	10.0 (21.2, 10)	He said the neighbours cause him to feel paranoid	No appearance of paranoia, denied paranoid feelings
Persecutory ideation	180 (28.4)	540	0.84 (2.3, 1)	45 (36.3)	152	1.22 (3.3, 1)	She suffered persecutory delusion	He denied any worries of persecution

Note: EHR: Electronic Healthcare Record; IQR: interquartile range; MTF: multiple treatment failure; NLP: natural language processing; NS: negative symptoms; S.D: Standard Deviation

Supplementary Material 2: Reasons for multiple treatment failure in young people with early-onset psychosis, with and without negative symptoms at first presentation

Reasons for MTF ^a	N (%) of individuals ^b	
	Non - NS (n = 41)	NS (n = 50)
Persistent insufficient response	6 (14.6)	7 (14.0)
Persistent adverse effects	9 (21.9)	10 (20.0)
Persistent non-adherence	2 (4.9)	3 (6.0)
Variability in reasons		
• Insufficient response and adverse effects	11 (26.9)	21 (42.0)
• Insufficient response and non-adherence	3 (7.3)	4 (8.0)
• Adverse effects and non-adherence	10 (24.4)	5 (10.0)

^a Comparison in reasons for MTF between Non-NS and NS groups; fisher exact test, p=0.49

^b In all cells, % refers to percentages (within columns) of individuals for whom information on main reason of discontinuation was available (n=91). Excluded due to no reason ' or 'other reason' ascertained were: Non-NS n= 18 (31%); NS group n=15 (23%)

Note: MTF: multiple treatment failure; NS: negative symptoms

Supplementary Material 3: Baseline characteristics profile at first presentation and association with multiple treatment failure over time in early-onset psychosis (n=618)

Baseline characteristics	Non MTF Sample	MTF sample	Crude H.R. (95% CI)
≥2 baseline Marder NS	167 (33.7)	49 (46.2)	1.98 (1.35 – 2.91)**
Female gender	238 (48.0)	57 (53.8)	1.12 (0.76-1.65)
Mean age at referral (s.d)	15.6 (1.9)	15.3 (1.7)	1.30 (1.13-1.50) ***
Ethnicity, N(%)			
White	243 (48.9)	43 (40.6)	Reference
Black	150 (30.2)	44 (41.5)	1.64 (1.08-2.49)*
Asian	30 (6.1)	6 (5.7)	1.31 (1.30-3.03)
Mixed	56 (11.3)	13 (12.3)	1.45 (0.77-2.69)
Not Stated	17 (3.4)	0 (0)	-
Neighbourhood Characteristics, N(%)^a			
1 st (Least Deprived)	121 (25.1)	34 (33.0)	Reference
2 nd	118 (24.4)	23 (22.1)	0.69 (0.41-1.18)
3 rd	124 (24.7)	21 (20.6)	0.64 (0.37-1.11)
4 th (Most Deprived)	120 (24.8)	24 (23.5)	0.66 (0.39-1.12)
First ICD-10 psychosis diagnosis, N(%)			
Other Psychoses ^b	81 (16.3)	21 (19.8)	Reference
Bipolar Disorder / F30, F31	32 (6.5)	9 (8.5)	1.26 (0.57-2.76)
Drug-induced psychosis / F1x.x5	29 (5.9)	4 (3.8)	0.80 (0.27-2.34)
Schizophrenia / F20	293 (59.1)	52 (49.1)	0.79 (0.47-1.31)
Schizoaffective / F25	7 (1.4)	7 (6.6)	3.10 (1.31-7.33)**
Psychotic Depression / F32.3, F33.3	54 (10.9)	13 (12.3)	1.05 (0.52-2.10)
Co-morbid neuropsychiatric disorders, N(%)			
Autism Spectrum Disorder	81 (16.3)	29 (27.4)	1.24 (0.80-1.91)
Other neurodevelopmental disorder	80 (16.1)	16 (15.1)	0.72 (0.43-1.23)
Major Depressive Disorder	142 (28.6)	26 (26.4)	0.82 (0.53-1.27)
First degree relative with psychotic disorder	97 (19.6)	33 (31.3)	1.84 (1.22-2.77)**
Illness severity/ Functioning			
Admission at presentation, N(%)	176 (35.5)	54 (50.9)	2.33 (1.59-3.43)***
CGAS score (mean, SD) ^b	39.3 (15.8)	36.2 (15.8)	0.985 (0.971-0.999)*
Positive symptom			
1 st (lowest quartile)	57 (11.5)	9 (8.5)	Reference
2 nd	92 (18.5)	11 (10.4)	0.89 (0.36 – 2.15)
3 rd	183 (36.9)	31 (29.3)	1.35 (0.64-2.84)
4 th (highest quartile)	164 (30.1)	55 (51.9)	2.42 (1.19-4.89)*
Substance misuse			
Cannabis	219 (44.2)	44 (41.5)	1.22 (0.83-1.80)
Cocaine or crack	84 (16.4)	14 (13.2)	0.94 (0.53-1.64)
Amphetamines	16 (3.3)	<5 (<5)	1.17 (0.32-3.71)
MDMA	14 (2.8)	<5 (<5)	0.51 (0.07-3.69)

* $p < .05$; ** $p < .01$; *** $p < .001$; % Refers to percentages within columns, for whom information was available

^a Missing cases =19; ^b Data available in a subsample of 384, ^b Other Psychoses: an ICD-10 diagnosis of 'brief psychotic disorder (F23)', 'delusional disorder (F22)', 'shared psychotic disorder', or 'psychosis not otherwise specified (NOS)'. Note: CGAS: Children's Global Assessment Scale; MTF: multiple treatment failure; NS: negative symptoms;