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ORIGINAL PAPER

Migration and schizophrenia: meta-analysis and explanatory framework

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Abstract

Systematic reviews and meta-analyses suggest that there are increased rates of schizophrenia and related psychoses in first- and second-generation migrants and refugees. Here, we present a meta-analysis on the incidence of non-affective psychotic disorders among first- and second-generation migrants. We found substantial evidence for an increased relative risk of incidence among first- and second-generation migrants compared to the native population. As heterogeneity of included studies was high, effect estimates should be interpreted with caution and as guiding values rather than exact risk estimates. We interpret our findings in the context of social exclusion and isolation stress, and provide an explanatory framework that links cultural differences in verbal communication and experienced discrimination with the emergence of psychotic experiences and their neurobiological correlates. In this context, we discuss studies observing stress-dependent alterations of dopamine neurotransmission in studies among migrants versus non-migrants as well as in subjects with psychotic disorders. We suggest that social stress effects can impair contextualization of the meaning of verbal messages, which can be accounted for in Bayesian terms by a reduced precision of prior beliefs relative to sensory data, causing increased prediction errors and resulting in a shift towards the literal or "concrete" meaning of words. Compensatory alterations in higher-level beliefs, e.g., in the form of generalized interpretations of ambiguous interactions as hostile behavior, may contribute to psychotic experiences in migrants. We thus suggest that experienced discrimination and social exclusion is at the core of increased rates of psychotic experiences in subjects with a migration background.

Keywords Psychosis · Migration · Meta-analysis · Dopamine · Stress · Bayesian inference

Introduction

A series of studies and systematic reviews reported increased rates of schizophrenia and related psychotic disorders in first- and second-generation migrants [1, 2]. Following the publication of a meta-analysis in 2011 [2], these findings were confirmed by further studies [3–6]. This increase cannot be attributed to high incidences of psychotic disorders in migrants' countries of origin [7] and has been reported to be even more pronounced in the second generation of migrants [1]. These findings suggest that environmental factors in the host countries contribute to the increased manifestation of psychotic experiences.

The relative risk for psychotic disorders is not increased in all migrant populations, but rather in those with a visible minority status. For example, increased rates of psychotic disorders were found among Africans from countries south of the Sahara in Sweden and France [3, 5], Moroccans in

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the Netherlands, and West Africans in Canada [4]. In this context, it has been suggested that stress factors associated with social exclusion, discrimination and "defeat" contribute to delusional ideation [8, 9]. This hypothesis is supported by studies suggesting that lack of social support from individuals who experience similar forms of discrimination, operationalized as "ethnic density" in the neighborhood, may play an important role in manifestation of psychotic disorders [10]. Such an "ethnic density" effect was first observed in urban areas of Chicago by Faris and Dunham in 1939 [11]. Similar effects of "ethnic density" have since been reported with respect to Surinamese-Antillean individuals in the Netherlands [12], Indians in England and Wales [13], Moroccans in the Netherlands [14] as well as African and Afro-Caribbean individuals in England [15–17]. As neighborhoods with low "ethnic density" do not tend to be the poorest areas in a given city, such increases in psychotic disorders do not appear to simply reflect a lack of mental health care resources [7]. Indeed, protective effects of "ethnic density" become even more apparent if adjusted for area-level deprivation [10].

Independent of effects of "ethnic density", living in poor neighborhoods has been associated with increased mental distress irrespective of migrants' individual income and education level, indicating that financial resources and social status of a migrant group may generally affect mental well-being [18, 19]. While some studies suggested that living in poverty does not simply depend on individual income but also carries a heritable component, having a visible minority status can include such heritable traits (e.g., skin color etc.), which has been reported to be associated with unequal access to the housing market [20]. In addition to negative effects of poverty on mental health [18, 20], social exclusion and discrimination stress may thus contribute to the high incidence of psychotic disorders among first- and second-generation migrants. On a neurobiological level, a stress-dependent sensitization of dopaminergic neurotransmission may result in the attribution of salience to otherwise irrelevant social stimuli [21–23], which could contribute to generalized delusions of persecution in the context of social isolation and discrimination [24, 25].

In this systematic review and meta-analysis, we review findings regarding an increase in the incidence of psychotic disorders among migrants. We then suggest a general framework to interpret our findings in the context of current theories regarding the development of psychotic disorders. We suggest that the contextualization of verbal messages constitutes a key aspect of psychotic experiences [26–29], and that this process depends on prior knowledge and may thus be impaired by cultural misunderstandings as well as experienced discrimination and social exclusion. Such problems of social interaction and communication can be conceptualized in a Bayesian framework, which helps to explain how a discrepancy between prior beliefs and sensory (verbal) input creates prediction errors [30–33]. We suggest that such prediction errors may be augmented in stressful situations, when subjects are confronted with an unfamiliar or even hostile environment. Increased insecurity in social interactions may then be compensated by alterations in higher-level beliefs, leading to a tendency to interpret ambiguous interactions as hostile behavior and thus contributing to psychotic experiences.

Methods

This is a systematic literature review and meta-analysis. The protocol has been published on PROSPERO (Prospero Registration-No.: CRD42018106740). Methods followed guidelines by the Cochrane Collaboration for the conduction of systematic reviews [34] and are described in detail in an online supplement (Supplement 1). In brief, we searched PubMed, PsycINFO, and Embase databases for studies assessing the relative risk of incidence of non-affective psychoses in first- and second-generation immigrants in comparison to the native population. Trials were included when they met the following criteria: specific observation of migrant history (i.e., first- and/or second-generation), assessing relative risk [effect size and spread; rate ratio (RaR), risk ratio (RiR), or hazard ratio (HR)] of incidence of non-affective psychotic disorders diagnosed according to standard operationalized criteria. Effect sizes had to be at least adjusted for sex, or studies needed to display outcomes itemized for sex differences among groups. We focused on inclusion of register-based studies. First-contact studies were accepted for inclusion only if case detection was found to be sufficiently comprehensive with regard to catchment area. Studies observing ethnic or racial background only, with no explicit description of migration history, were excluded.

Literature search, study screening and selection, data extraction, and risk of bias assessment were all carried out independently by two reviewers and followed recommendations by the Cochrane Collaboration Handbook [34]. Studies were classified as holding overall "low" or "unknown/high" risk of bias taking into account selection bias (target population and acquisition), missing cases, information bias (information source, case definition, diagnostic instrument, consistency, and observation period), statistical methods, and conflict of interest.

The primary outcome criterion was the pooled relative risk (RR) of incidence of non-affective psychosis of migrant compared to the native population accompanied by its 95% confidence interval (CI). Heterogeneity among studies was assessed using I2 statistics and effect estimates were interpreted in consideration of present heterogeneity. Sensitivity analyses of our primary outcome took into account

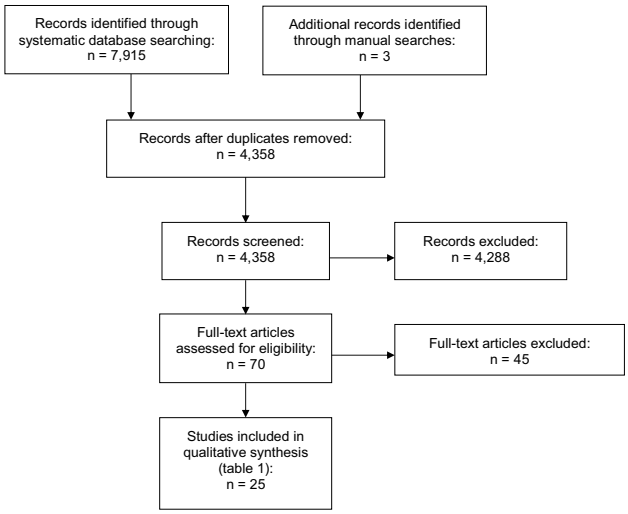

Fig. 1 PRISMA flow chart

"low"-risk of bias studies, studies adjusting for age, trials on in- and outpatients, register-based studies, and separate analyses by measure of effect size. Additional analyses accounted for potential overlap of study populations. Subgroup analyses took into account data on first- and second-generation immigrants separately.

Results

Out of 4358 different articles retrieved through our literature search, 25 studies, published between 1997 and 2018, met requirements of our inclusion and exclusion criteria and provided sufficient data to be included in our analyses (Fig. 1).

Of the included studies, 20 presented data on first- and 13 on second-generation immigrants separately, 2 studies assessed outcomes for both generations combined only. Nineteen studies provided register-based data. Six were first contact/admission studies, but ensured comprehensive coverage of catchment area to minimize case leakage. Twelve studies presented data on inpatients only. Observations originated from target populations in Denmark, Sweden, Netherlands, Israel, Canada, Italy, England, and Finland. Included studies assessed RiRs, RaRs, or HRs. Eight studies provided data for Schizophrenia (ICD-10: F20) only (Table 1).

Main analysis

Our main analysis included 24 studies. Relative risk of incidence of non-affective psychosis amounted to 1.77 (95% CI 1.62, 1.93) in immigrants compared to the native population. Heterogeneity among trials was high ($I^2 = 96.7\%$) (Fig. 2).

Publication bias

Funnel plots of main analysis and Egger's test ($p = 0.643$) did not indicate publication bias (Supplement 2).

Sensitivity analyses

Relative risk of incidence added up to 1.81 (95% CI 1.62, 2.02) ($I^2 = 97.6\%$) when restricting analyses to "low" risk of bias studies. When taking into account register-based trials only RR amounted to 1.71 (95% CI 1.56, 1.88) ($I^2 = 97.0\%$). Exclusion of inpatient-only studies and exclusion of those trials not adjusting for age resulted in RR of 1.72 (95% CI 1.54, 1.93) ($I^2 = 95.3\%$) and 1.78 (95% CI 1.62, 1.95) ($I^2 = 96.7\%$), respectively. When pooling studies separately by employed effect measure, RRs added up to 1.98 (95% CI 1.73, 2.26) ($I^2 = 96.9\%$), 1.94 (95% CI 1.53, 2.45) ($I^2 = 95.7\%$) and 1.48 (95% CI 1.32, 1.65) ($I^2 = 94.4\%$) for studies calculating RaRs, RiRs, and HRs, respectively. Excluding all studies with significant observation period overlapping and restricting analysis to those trials with the largest observation period only resulted in an overall RR of 1.77 (95% CI 1.47, 2.11) ($I^2 = 98.0\%$). Using a fixed-effect model to pool overlapping studies of the same country (i.e., Sweden and Denmark) prior to estimation of the overall effect size with a random-effects model revealed an RR of 1.69 (95% CI 1.45, 1.98) ($I^2 = 98.7\%$).

Subgroup analysis

Among first-generation immigrants, relative risk of incidence was 1.81 (95% CI 1.59, 2.07) ($I^2 = 97.6\%$) compared to the native population, and 1.82 (95% CI 1.66, 1.99) ($I^2 = 90.5\%$) among second-generation immigrants (Supplement 3).

Discussion

Our meta-analysis confirmed a significantly increased risk for the manifestation of schizophrenia and related non-affective psychoses among first- and second-generation migrants. Heterogeneity among included studies was considerably high in all our analyses and effect estimates should be interpreted as guiding values rather than exact estimates of relative risks of incidence. Nevertheless, sensitivity analyses invariably supported our findings.

While the vast majority of studies clearly supported the higher incidence among migrants, only Markkula et al. [46] found the opposite for women populations and four other comparisons found no difference (Fig. 2). These divergent findings, however, can be explained by peculiarities of the study design or examined population: Anderson et al. [4]

Table 1 Characteristics of studies included in the quantitative analysis

Authors	Country/region	Immigrant generation and age group (years)	Diagnosis (schizophrenia = s, non-affective psychosis = p)	Observation period	Analyses	Risk of bias
Anderson et al., 2015 [4]	Ontario (Canada)	First, 14–40 years	s, p (ICD-9, -10, DSM-IV)	1999–2008	a, d	Unknown/high
Barghadouch et al., 2018 [35]	Denmark	First, < 18 years	s, p (ICD-10)	1993–2010	a, d, 1	Unknown/high
Bonetto et al., 2015 [36]	Veneto (Italy)	Both, 15–54 years	s, p (ICD-10)	2005–2007	a, c, d	Low
Cantor-Graae et al., 2003 [37]	Denmark	First, > 15 years	s (ICD-8, −10)	1970–1998	a, d, 2	Low
Cantor-Graae et al., 2005 [38]	Malmö (Sweden)	First, second, 18–54 years	s, p (DSM-IV)	1999–2001	c, d	Unknown/high
Cantor-Graae et al., 2013 [6]	Denmark	First, second, > 10 years	s (ICD-8, − 10)	1995–2010	a, d	Low
Coid et al., 2008 [39]	East London (UK)	First, second, both, 18–64 years	s, p (DSM-IV)	1996–1998	d, 3	Unknown/high
Corcoran et al., 2009 [40]	Israel	Second, < 34 years	s, p (ICD-10)	1964–1997	a, e, 4	Unknown/high
Dykxhoorn et al., 2018 [41]	Sweden	First, second, 15–29 years	s, p (ICD-10)	1997–2011	a, e	Low
Hjern et al., 2004 [42]	Sweden	First, second, > 20 years	s (ICD-9, − 10)	1991–2000	a, b, f, 5	Low
Hogerzeil et al., 2017 [43]	The Hague (Netherlands)	Both, 20–54 years	s (DSM-IV)	2000–2005	a, d, 6	Unknown/high
Leao et al., 2005 [44]	Sweden	Second, 16–34 years	s, p (ICD-9, − 10)	1995–1998	a, b, c, e	Low
Leao et al., 2006 [45]	Sweden	First, second, 20–39 years	s, p (ICD-9, − 10)	1992–1999	a, b, c, e	Low
Markkula et al., 2017 [46]	Finland	First, > 15 years	s, p (ICD-10)	2007–2010	a, e	Low
Mortensen et al., 1997 [47]	Denmark	First, age not specified	s, p (ICD-8)	1980–1992	a, b, c, d	Unknown/high
Pedersen et al., 2012 [48]	Denmark	Second, 13–25 years	s (ICD-10)	1994–2006	a, d	Low
Schofield et al., 2017 [49, 50]	Denmark	First, second, both, 15–48 years	s, p (ICD-8, − 10)	1980–2013	a, d, 7	Low
Selten et al., 1997 [51]	Netherlands	First, 15–39 years	s (ICD-9)	1983–1992	a, b, d, 8	Low
Selten et al., 2001 [52]	The Hague (Netherlands)	First, second, both, 15–54 years	s, p (DSM-IV)	1997–1999	c, d, 9	Unknown/high
Smith et al., 2006 [53]	Canada	First, 10–59 years	s, p (DSM-IV)	1902–1913	b, d, 10	Unknown/high
Sorensen et al., 2014 [54]	Denmark	First, second, 15–54 years	s (ICD-8, − 10)	1955–1993	a, d	Low
Veling et al., 2006 [55]	The Hague (Netherlands)	First, second, 15–54 years	s, p (DSM-IV)	1997–1999, 2000–2002	d, 11	Unknown/high
Werbeloff et al., 2012 [56]	Israel	First, > 15 years	s (ICD-9)	1978–1992	a, b, f	Unknown/high
Westman et al., 2006 [57]	Sweden	First, 25–64 years	s, p (ICD-9, − 10)	1997–1998	a, b, e, 12	Low
Zolkowska et al., 2001 [58]	Malmö (Sweden)	First, 18–64 years	s, p (DSM-IV)	1997–1998	c, f	Unknown/high

a = register-based, b = inpatients only, c = first psychiatric contact/admission, d = effect measure RaR, e = effect measure HR, f = effect measure RiR

1 = Origin/ethnicity of immigrants specified: Asia, Middle East and North Africa, former Yugoslavia and Sub-Saharan Africa

2 = Origin/ethnicity of immigrants specified: Europe, Scandinavia, Asia, Middle East, Australia, Africa, North and South America and Greenland

Table 1 (continued)

3 = Origin/ethnicity of immigrants specified: Black Carribean, Black African, Asian, White Non-British and Other

4 = Origin/ethnicity of immigrants specified: born in Jerusalem

5 = Origin/ethnicity of immigrants specified: Finland, Western, Eastern and Southern Europe and Non-Europeans

6 = Origin/ethnicity of immigrants specified: Caribbean, Turkish, Moroccan and Other

7 = Origin/ethnicity of immigrants specified: Africa, Europe (non-Scandinavian), Asia and Middle East

8 = Origin/ethnicity of immigrants specified: Surinam or Netherlands Antilles

9 = Origin/ethnicity of immigrants specified: Surinamese, Netherlands antilleans, Turks, Moroccans or Others

10 = Origin/ethnicity of immigrants specified: Britain and Continental Europe

11 = Origin/ethnicity of immigrants specified: Morocco, Surinamese, Netherlands Antilleans, Turks, Non-Western or Western

12 = Origin/ethnicity of immigrants specified: Finland, Southern Europe, OECD-countries, Poland, Eastern Europe, Middle East or Other non-European countries

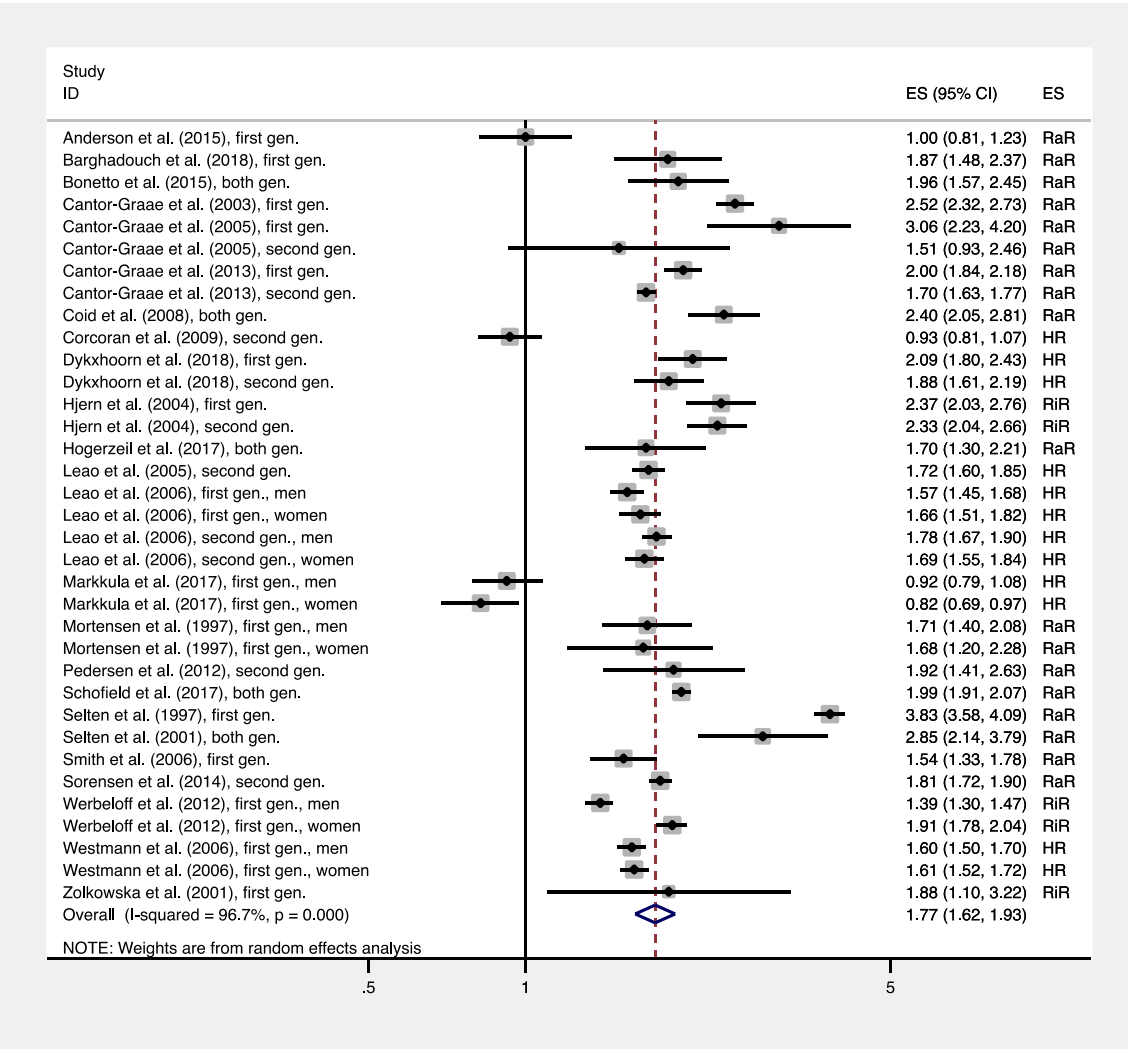

Fig. 2 Relative risk of incidence of non-affective psychosis of immigrants compared to the native population. Forest plot—relative risk of incidence of non-affective psychosis of immigrants compared to the native population. The square data markers indicate relative risk (RR) in primary studies, with sizes reflecting the statistical weight of the study using random effects analysis. The horizontal lines indicate 95% CIs. The blue diamond data marker represents the overall RR and 95% CI. The vertical dashed line shows the summary effect estimate, the continuous line shows the line of no effect (RR = 1). *ES* effect size, *HR* hazard ratio, *RaR* rate ratio, *RiR* risk ratio

included second-generation migrants into the native population. The study by Corcoran et al. [40] was based on a very special subpopulation of second-generation migrants from Jerusalem only, and effects were contradicted by a larger study from all of Israel [56]. Findings of the third Finnish trial by Markkula et al. [46] may need to be interpreted in light of the country's comparatively very restrictive immigration policies allowing for selective migration only as well as in light of the high prevalence of psychotic disorders among the native population [46, 59]. Thus, despite heterogeneity among studies, evidence suggesting increased relative risk of schizophrenia and related non-affective psychoses in migrants is substantial.

As incidence of schizophrenia was not reported to be increased in places of origin of migrants [7], the here-confirmed increased relative risk of schizophrenia could be due to factors associated with the migration process per se or to interactions with the new host societies [10]. Our finding that the relative risk for schizophrenia is similarly increased in both the first- and second-generation of migrants points to stressful interactions with the host society rather than specific experiences associated with the migration process experienced by the first generation only.

In the following, we provide some considerations within the broader context of current schizophrenia theories that aim to explain how stressful experiences in the host society may lead to the emergence of psychotic symptoms in migrants. We suggest that the increased risk of psychotic disorders among the first and second generation of migrants can be understood by (1) referring to general problems in verbal communication in schizophrenia and related psychotic disorders, (2) placing such problems in the context of social exclusion stress and its neurobiological correlates, and (3) drawing on the computational framework of Bayesian inference, in which psychotic experiences are accounted for by a failure to integrate new sensory data with prior knowledge, thus leading to aberrant prediction errors. While some of the ideas outlined below are speculative and will require empirical investigation, we hope that they will help to promote a more profound mechanistic understanding of increased psychosis risk in migrants.

Problems in verbal communication among subjects with schizophrenia and their relevance for psychotic disorders among migrants

Beyond core symptoms relating to verbal communication like incoherence, specific alterations in the understanding of pragmatic and figurative language are common in schizophrenia [60]. Historically, the tendency to treat words like external objects was suggested to reflect a "hypercathexis" of word-presentations [61]. Several psychiatrists including Ernst Kretschmer [29] suggested that psychotic thought disorders can be understood as a pathological "regression" to a kind of "primitive" thinking in concrete pictures, which was supposed to characterize both patients with schizophrenia as well a "primitive people". Such theories were later criticized for ignoring the colonial context, in which the alleged evidence of supposedly "primitive" thinking was gathered [62–64]. Kurt Goldstein [65] also suggested that both schizophrenia and organic brain disorders are characterized by a "concrete attitude". However, he considered "concretism" to reflect a "protective mechanism against anxiety" that originates in early youth and is resorted to in threatening interpersonal situations. Moreover, he explained it in terms of Gestalt psychology as a disturbance of figure/ground perception [66]. Other authors also suggested that focusing on the "concrete" meaning of verbal expressions may represent a coping strategy aimed at reducing communicative tensions caused by semantic ambiguity [67].

Concretism is clinically diagnosed when subjects fail to detect the metaphorical aspect of proverbs [68]. For example, a German university student paraphrased the German proverb "the apple does not fall far from the tree" by explaining that "branches of apple trees are rather short" instead of providing the usual explanation ("like parent like child"). While it has traditionally been assumed that such misunderstandings are caused by a disability to abstract meanings from concrete expressions [68], healthy subjects usually do not have to abstract from the concrete meaning of a proverb—rather, the transferred meaning is produced automatically and effortlessly. Concretism in psychotic individuals may thus be better explained by a failure to integrate contextual information in the interpretation of figurative language, which thus impairs the automatic recognition of commonsensical meaning. Indeed, the correct meaning of proverbs can be named by psychotic patients when given the information that "this is meant in the figurative sense" or when contextual information is enriched [69].

These considerations are in accordance with psychoanalytic theories that proposed impaired immersion in shared structures of meaning is a risk factor for psychosis. For example, Lacan [70] suggested that psychotic experiences can result from a lack of fundamental "signifiers" that would be required to establish shared meaning and social orientation: individuals who cannot use the "highway" of a basic signifier have to compensate for this by reading all the signposts and improvising a network of surrogate meanings, thus relying less on prior beliefs and more on the sensory data.

We suggest that such limitations in shared contexts and meanings are exacerbated when migrants are confronted with social exclusion and discrimination in their host country. In unfamiliar cultural contexts, understanding even basic interactions can require effort and explication. If in addition to common cultural misunderstandings, discrimination and exclusion limit verbal communication, the sense of "self"

as derived from intersubjective interactions can be impaired [71]. Indeed, Selten and Termoshuizen [72] suggested that social exclusion is a common factor that increases the risk for psychotic experiences among first- and second-generation immigrants as well as in groups with similar problems including subjects with homosexual orientation or autism.

In this context, the presence of subjects with similar experiences in the neighborhood ("ethnic density") may offer a "social support buffer" that helps to cope with social exclusion stress as associated with a minority status [10, 73]. However, the number of close persons and their proximity to the afflicted individual did not explain an association between common mental disorders and perceived racism [74], suggesting that racist discrimination may increase schizophrenia risk independent of personal contacts. In a study by Karlsen et al. [75], racist harassment was most frequently reported by a Caribbean group. The ethnic density effect may therefore not be mediated by direct personal contacts but rather by perceived social status and experience of social exclusion. This latter interpretation is in accordance with the observed association between poverty in the neighborhood of a migrant group and their mental health burden, which was also independent of individual factors including personal income and education [18].

Neurobiological correlates of social exclusion stress

Social exclusion stress can directly affect some of the neurobiological correlates of psychotic experience including dopaminergic neurotransmission, with high stress levels generally increasing dopaminergic neurotransmission [76–78]. Several studies indeed observed increased stress-associated dopaminergic neurotransmission in patients with schizophrenia and in subjects with schizotypy and physical anhedonia compared to healthy controls [21–23]. Crucially, antipsychotic-naïve patients with schizophrenia as well as subjects with clinical high risk to develop a psychosis displayed increased stress-induced dopamine release as measured indirectly by radioligand displacement in their associative and sensorymotor striatum following a stress exposure [79]. Moreover, among unaffected siblings of patients with schizophrenia, stress-induced dopamine release in the left ventral striatum correlated with psychosis liability [80]. These findings support the hypothesis of a sensitized dopaminergic stress response in parts of the striatum. Interestingly, the dopaminergic stress response appears to be modulated by cannabis intake, with dopamine release being blunted in subjects with a high clinical risk for schizophrenia and cannabis use [79]. This latter finding is important, because increased schizophrenia rates in migrants have often been attributed to elevated levels of comorbid drug use, which does not appear to explain increased stress-induced dopamine release in subjects with a high psychosis risk.

In subjects with schizophrenia, increased dopaminergic neurotransmission has been found not only in the striatum [81] but also in the amygdala [82], where dopaminergic neurotransmission has been directly associated with processing of aversive stimuli [83]. Increased amygdala activation by aversive stimuli has indeed been found in acutely psychotic patients [84]. Altogether, studies on stress-related dopamine release support schizophrenia theories which suggest that increased striatal dopaminergic neurotransmission in acute psychosis encodes prediction errors and thus renders bits and pieces of (verbal and non-verbal) information as particularly relevant, hereby increasing attribution of salience in such situations [24, 25, 77, 81, 85]. Crucially, among migrants, dopamine synthesis capacity and stress-induced dopamine release in the striatum were elevated in immigrants compared to non-immigrant controls [86]. This observation was independent of clinical status (subjects with a clinical high risk for psychosis as well as a small group of never-medicated patients with schizophrenia).

In prefrontal cortex, effects of acute stress exposure interact with childhood trauma and appear to differ between subjects with psychotic disorders and healthy controls: only in healthy controls, stress-induced dopamine release in the medial prefrontal cortex was positively associated with the severity of early and late childhood trauma [87], confirming alterations in prefrontal-striatal neurocircuits in psychosis [77, 85]. First-degree relatives of patients with a psychotic disorder also displayed less dopamine release in the ventral medial prefrontal cortex in response to stress [88]. In the prefrontal cortex, stimulation of dopamine D1 receptors decreases the impact of distracting stimuli and noise on self-sustained activity [89]. Reduced stress-associated prefrontal dopamine release may thus impair cortical processing of unfamiliar or threatening stimuli.

Altogether, these studies suggest that familial risk, traumatization and minority status can all affect dopaminergic neurotransmission. In this context, subjects with negative prior experiences or a visible minority status may be particularly challenged and show stress-associated increases in striatal dopaminergic neurotransmission [86] when confronted with ambivalent unfriendly communication patterns, which may or may not reflect racist prejudices of members of social majorities. Reduced stress-associated dopamine release in the frontal cortex of subjects with a high risk to develop psychotic disorders [88] may impair coping with unfamiliar or threatening stimuli, thus facilitating psychotic experiences when threatening situations including social exclusion and discrimination are encountered.

A Bayesian account of psychosis among migrants

The generic framework of Bayesian inference may help to explain how minority status and perceived discrimination

can contribute to the development of psychosis. Cultural differences and misunderstandings can reduce the effects of prior knowledge in inference and increase the individual's focus on specific sensory, particularly auditory verbal inputs during social interactions. In a Bayesian framework, errors of prediction are created whenever prior beliefs differ from posterior beliefs that are driven by sensory input, in particular when the sensory input is represented with high precision compared to weak or noisy priors [31]. In this framework, increased striatal encoding of dopamine-dependent errors of reward prediction in subjects with psychotic experiences constitute a subtype of such prediction errors with high motivational salience [9, 11]. A relative reduction in the weight of prior knowledge and an increase in the importance of sensory inputs may also be present in situations in which subjects feel discriminated because of their minority status and perceived group identity. In this context, prior beliefs that guide the interpretation of common communication patterns can become uncertain following experiences of cultural misunderstandings and unexpected discrimination. Salience may then be attributed to the exact words spoken, which have to be examined to understand whether there is, e.g., hostility due to racism or just unfriendliness of communication partners. Psychosis may develop when compensatory mechanisms fail, which include stress-associated dopaminergic neurotransmission in the prefrontal cortex that could otherwise help to increase the signal-to-noise ratio during processing of complex social interactions [89]. In stressful environments with noisy sensory input, a compensatory attempt to cope with complex and potentially threatening information may rely on reduced estimates of general environmental volatility [90, 91], for example, by assuming that other subjects are generally hostile against the afflicted person. Rigid beliefs of being generally persecuted could thus develop as a consequence of altered environmental volatility estimation.

Conclusions

Our systematic review and meta-analysis confirms increased rates of schizophrenia and related psychotic disorders in migrants. We suggest that a Bayesian framework may help to explain how social stress factors and stress-induced alterations in dopaminergic neurotransmission contribute to the manifestation of psychotic disorders in migrants. Thinking about migration from a "social predictive coding" [92] perspective, weakness of priors regarding social knowledge including subtle cultural or linguistic peculiarities and habits as well as feelings of being socially disrespected may lead to an imbalance in inference processes that overweigh new sensory evidence. Enhanced prediction errors caused by increased differences between prior knowledge and sensory-driven posterior beliefs may be compensated by a tendency to entertain rigid high-level beliefs about the general degree of environmental hostility, which are no longer verified against alternative hypotheses [90, 93]. Of note, in mentalization terms, exposure to stressors followed by heightened arousal can lead to shifts from controlled to automatic mentalizing—a survival strategy with high costs regarding accuracy and interpersonal function [94]. In particular, individuals with insecure attachment or repeated experiences of insufficient interpersonal support might develop a persistent hypersensitivity to threat and therefore tend to shift more easily towards schematic assumptions about self and others. Luyten and Fonagy [94] related such hypervigilant and distrustful attitudes to hypermentalizing, which was shown to be stress-induced [95] and might contribute to psychotic experience [96, 97]. We suggest that effects of discrimination and social exclusion on the manifestation of psychosis in migrants may be accounted for in a social predictive coding framework.

Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest regarding the contents of this article. We gratefully thank Stephanie Wall and David Gabel for their help in conducting the literature search and screening.

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