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Increased network connectivity among paranoid beliefs characterizes the clinical end of the schizophrenia-spectrum: A Conversian systems perspective.

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Despite being the most frequent abnormal belief in patients with schizophrenia-spectrum disorders, persecutory delusions are thought to lie on a continuum with subclinical paranoia and ordinary suspiciousness (Bebbington et al., 2013; Elahi et al., 2017). Elements of these beliefs (such as interpersonal sensitivity, mistrust, ideas of reference, and the likelihood of harm from others) have recently been modelled as network systems, by ourselves (Contreras et al., 2022) and others (Bell & O'Driscoll, 2018). However, this research did not include clinical participants, leaving open the question of whether the network structure of paranoia is invariant across community and clinical samples. Here, we aim to address this gap by comparing constellations of paranoid beliefs across clinical and community samples.

The idea that beliefs can be modelled as (network) systems of interrelated propositions can be traced at least as far back as the seminal work of the political scientist Philip Converse (1964/2006). In an account of political ideologies in mass publics, Converse (1964/2006) argued that the political systems of those with strong ideologies (e.g., 'left' or 'right') comprise more aligned and thus more strongly intercorrelated beliefs (for example, with consistent attitudes toward social and economic policies), compared to the less elaborated belief systems of non-ideologues. Such tightly interconnected belief systems, according to Converse (1964/2006), would be resistant to counter-argumentation (notably, one of the defining features of delusions; American Psychiatric Association, 2013), because a change in one belief would necessitate insurmountable alterations to related beliefs.

Although historically political scientists lacked the statistical tools to examine these conjectures, recent advances in network psychometrics have allowed them to provide some support for these Conversian notions. For example, Dalege et al., (2019) found that political interest predicts higher connectivity among attitudes toward presidential candidates, which in turn strongly predicts voting behaviour. Similarly, Fishman & Davis (2022) found stronger network connectivity in populations with high compared to low political knowledge. Much like these findings on political belief systems, we hypothesised that paranoia belief systems would be more interconnected in clinical versus community samples.

In a previous taxometric investigation, we assembled data on the 10-item persecution subscale of the Persecution and Deservedness Scale (Melo et al., 2009) to create a large sample of healthy university students and also non-students from the general population; as well as patients who met the criteria for an at-risk mental state (according to the Comprehensive Assessment of At-Risk Mental States) and patients who reported psychotic experiences at the time (see Elahi et al., 2017 for details). Here, we make use of complete data from 501 clinical (157 with at-risk mental state; 344 psychotic) and 2313 non-clinical (2115 student; 198 non-student) participants. Using network psychometrics, we model our 10 paranoia beliefs as Gaussian network models, separately for our clinical group (N=501) and a matched (on age, gender, and sample size) non-clinical group, after which we compare the two using a formal permutation procedure (see Supplement I for methodological details).

Supplement II outlines the descriptive statistics of our full sample and subsamples, as well as our statistical comparisons of the 10 paranoia beliefs (all of which were significantly higher in the clinical than matched non-clinical group after Bonferroni correction, $p < .001$).

Paranoia networks for the clinical and non-clinical populations are depicted in Figure 1A. Stability and accuracy analyses in Supplement III indicate that network parameters (such as edge-weights and centrality metrics) were reliably estimated.

As predicted, global strength (i.e., absolute level of network connectivity) was significantly higher for the clinical paranoia network (GS_C=4.32), compared to the non-clinical one (GS_H=4.12) (ΔGS=0.20, $p < .001$). This pattern was validated in a sensitivity test, comparing the sum of raw (than absolute) connections (to account for two negative edges), as well as in a series of robustness checks that used three additional random non-clinical samples (Supplement IV). An additional exploratory comparison revealed lower but not significantly different strength in our at-risk group (N=157) compared to two equally-sized,

randomly selected non-overlapping psychosis groups (N=157) (ΔGS = 0.08-0.12; *p* = 0.3-0.7), most likely due to reduced statistical power.

Strength centrality (i.e., absolute connectivity of each belief) is graphically displayed in Figure 1B. The two networks exhibited similar trends, with their most central beliefs being P5 ('suspicious of others'), P4 ('bad rumours of me'), and P1 ('others plotting against me'). Nevertheless, two differences were detected: P3 ('friends often tell me to relax') and P7 ('people think I am a bad person'), which were more central in the healthy network (ΔS_{P3}= 0.42, p < .001) and clinical network (ΔS_{P7}=0.21, p < .01), respectively. The latter attests to the well-documented role of negative self-esteem in paranoid patients (Bentall et al., 2008).

Predictability (i.e., amount of 'explained' variance in each belief) correlated almost perfectly with strength centrality (Spearman's rho from 0.97 to 0.98) (Figure 1C). Beliefs were more predictable in the clinical sample, with the exception of P3 ('friends often tell me to relax'), which was more predictable in the healthy sample (see Figure 1C centre).

Extending our previous dimensional analyses (Elahi et al., 2017), these results showcase the utility of a transdiagnostic network approach to persecutory delusions. We found that variations in the network structure of paranoid beliefs mirrored those of strong and weak ideological belief systems (Dalege et al., 2019), suggesting that high connectivity among beliefs may be a general property of all belief systems that are resistant to change. Although we were unable to provide evidence for the continuity of this pattern across our clinical groups (due to reduced statistical power), we conjecture that network connectivity might increase gradually with belief severity (given the psychosis continuum) (Bebbington & Nayani, 1995). That being said, our results are not to be interpreted as reifying traditional diagnostic boundaries between 'healthy' and 'delusional' belief systems. Quite the contrary, in fact: If replicated, patterns of *belief connectivity* could prove a marker of *'dogmatism,'*

highlighting the continuity between more rare delusional systems (i.e., persecutory) and more common ideological ones (i.e., political systems of the ‘left’ or ‘right’).

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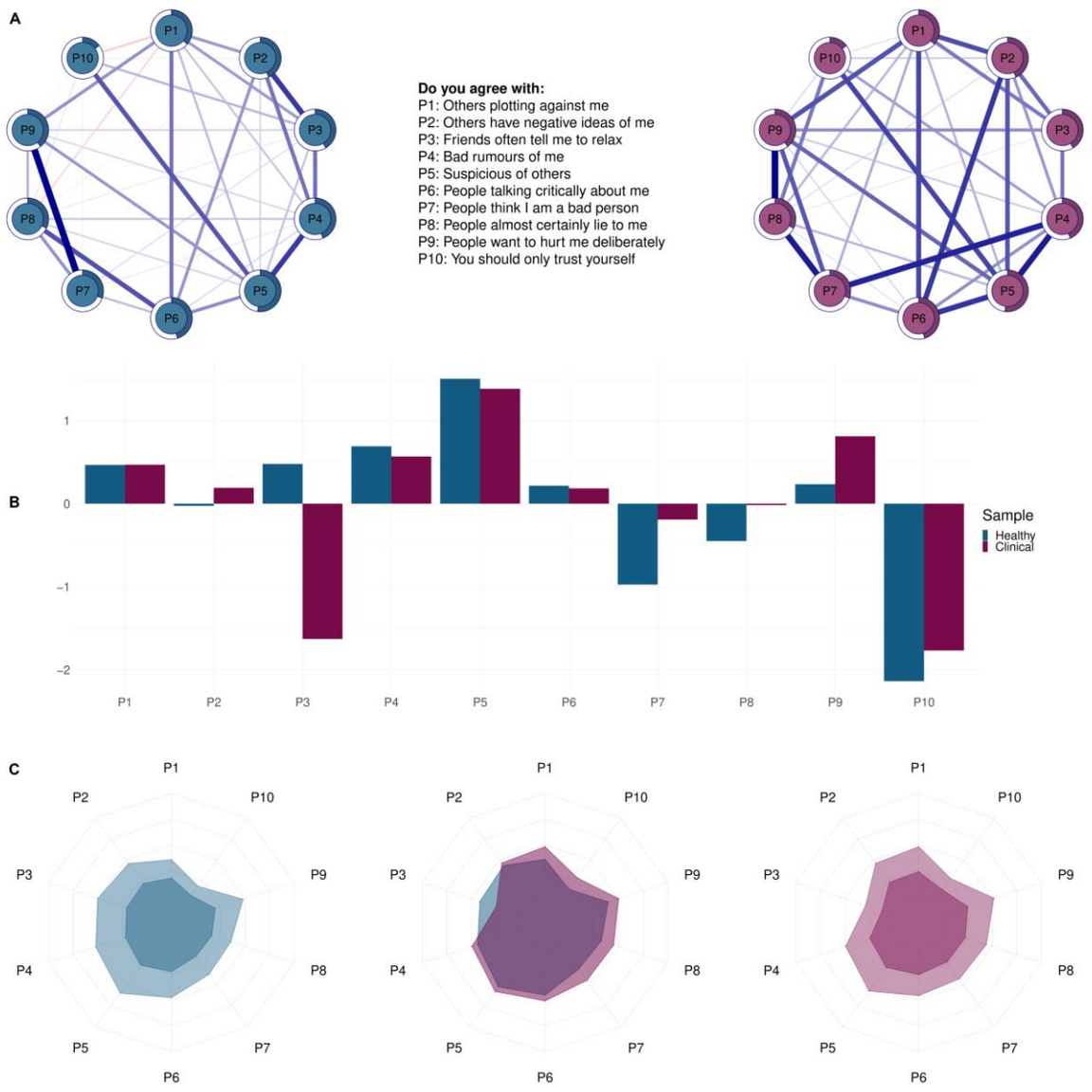

Figure 1. (A) Gaussian network models of paranoia beliefs for the matched non-clinical (left, blue) and clinical (right, pink) groups (N = 501, each). (B) Bar chart indicating the centrality of paranoid beliefs in the non-clinical/healthy (blue) and clinical (pink) populations. (C) Radar Charts depicting the relationship between centrality and predictability indices for the non-clinical (blue, left) and clinical (pink, right) groups, as well as the relationship between their centralities (middle graph).