
Usage Guidelines:
Please refer to usage guidelines at contact lib-eprints@bbk.ac.uk.
Genetic and environmental influences on the stability of psychotic experiences and negative symptoms in adolescence

Laura Havers, Mark J. Taylor, and Angelica Ronald

1Department of Psychological Sciences, Birkbeck, University of London, London, UK; 2Department of Medical Epidemiology & Biostatistics, Karolinska Institutet, Stockholm, Sweden

Background: Psychotic experiences (PEs) such as paranoia and hallucinations, and negative symptoms (NS) such as anhedonia and flat affect are common in adolescence. Psychotic experiences and negative symptoms (PENS) increase risk for later psychiatric outcomes, particularly when they persist. The extent to which genetic and environmental influences contribute to the stability of PENS in mid-to-late adolescence is unknown. Methods: Using the Specific Psychotic Experiences Questionnaire (SPEQ) twice across -9 months in adolescence, N = 1,448 twin pairs [M = 16.32 (0.68)] reported experiences of paranoia, hallucinations, cognitive disorganization, grandiosity and anhedonia, and their parents reported on a range of NS. Individuals were split into low-scoring, decreasing, increasing and persistent groups for each subscale. Frequencies and mean differences in distress, depression traits and emotional problems were investigated across groups. Longitudinal structural equation modelling was used to estimate the aetiological components underlying the stability of PENS. Results: Phenotypic stability was moderate and Angelica Ronald

Conclusions: When adolescent PENS persist over time, they are often characterized by more distress, and higher levels of other psychopathology. Both genetic and environmental effects influence stability of PENS. Keywords: Adolescence; aetiology; development; mental health; psychosis.

Introduction

Experiences such as paranoia, hallucinations, anhedonia and behaviours such as flat affect are reported in childhood and adolescence, and in general population as well as clinical samples (McGrath et al., 2015; Peters et al., 2016; Wong, Freeman, & Hughes, 2014). These experiences and behaviours are grouped together in the study of psychotic or psychotic-like experiences (PEs), and negative symptoms (NS), because in their extreme they are characteristic of psychotic illnesses. Psychotic experiences and negative symptoms (PENS) show considerable variability in the general population and typically show a positively skewed distribution (e.g., Bebbington et al., 2013; Ronald et al., 2014).

Epidemiological findings suggest that PEs are common (McGrath et al., 2015), associated with earlier childhood behaviour problems (Shakoor, McGuire, Cardno, Freeman, & Ronald, 2018) and that they are cross-sectionally less prevalent with increasing age (Kelleher, Connor et al., 2012; McGrath et al., 2015). For the majority of people, PEs generally abate (Linscott & van Os, 2013), showing mean-level decline over time (Domínguez, Wichers, Lieb, Wittchen, & van Os, 2011; Mackie, Castellanos-Ryan, & Conrod, 2011; Rössler et al., 2007). Some PEs may thus be part of typical behavioural variation (Hanssen, Bak, Bijl, Vollebergh, & van Os, 2005; Van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009; Wong & Raine, 2018; Wong et al., 2014). Longitudinal studies show that child and adolescent PEs are associated with increased odds of psychiatric disorders in adulthood (Fisher et al., 2013). Furthermore, PEs reported in mid compared to early adolescence (Bartels-Velthuis, van de Willige, Jenner, van Os, & Wiersma, 2011; Kelleher et al., 2012), and those which persist over time (Domínguez et al., 2011; Wigman, Winkel, Raaijmakers et al., 2011) are associated with relatively increased odds for psychiatric and dysfunctional behavioural outcomes. Compared to PEs, there are fewer studies on NS in the general population, and there are no meta-analyses or reviews. Like PEs, however, NS appear to be common in adolescence in the general population (Barragan, Laurens, Navarro, & Obiols, 2011; Ronald et al., 2014). As such, research on the aetiological factors that influence the presentation and the persistence of PEs and NS (PENS) in mid adolescence is informative about...
typical adolescent development, but may also shed light on the pathways that lead to mental illness.

While there are no published findings regarding differing trajectories of NS, several studies have identified distinct trajectories of PEs through growth mixture modelling in 10- to 11-year olds (Wigman, Winkel, Raaijmakers et al., 2011) and 14-year olds (Mackie et al., 2011), and through latent class analysis in adults (Wigman, Winkel, Jacobs et al., 2011). A meta-analysis of cross-age studies reported that PEs were persistent for ~20% of individuals (Linscott & van Os, 2013). As well as being associated with clinical and poor behavioural outcomes, persistence is associated with a range of risk factors including cannabis use, trauma, stressful life events and urban environment in adolescence (Cougnard et al., 2007; Wigman, Winkel, Raaijmakers et al., 2011).

Despite these findings, no studies to date have investigated the aetiologic influences on the stability of PENS in mid-to-late adolescence. A study of adult twins hinted at a substantial genetic contribution to PE-persistence (NS were not reported in terms of persistence). Wigman, Winkel, Jacobs et al. (2011) reported that for monozygotic (MZ) twins who experienced persistence, 49% of their co-twins also experienced persistence, compared to 14% for dizygotic (DZ) twins, although twin model-fitting was not conducted. A different but related conceptualization of PENS, schizotypy is viewed as being an expression of psychotic-like behaviour at a personality level (see Linscott & van Os, 2013). One twin study has reported on the moderate stability \( r = 0.58 \) of a ‘schizotypy factor’ over early to mid adolescence from ages 11–16 in 100 pairs assessed across time (Ericson, Tuvblad, Raine, Young-Wolff, & Baker, 2011). Genetic and nonshared environmental influences explained 81% and 19% of this factor, respectively. At the second time point, variance was explained by both stable and new genetic influences (36% and 42% respectively), and stable and new nonshared environmental influences (3% and 19% respectively). While these results demonstrate that the aetiological effects influencing psychosis-related phenotypes are both stable and dynamic, the cross-time sample size was small for a twin study.

The largest twin study to date on adolescent PENS at a single time (using the same sample as the current study) reported heritability estimates of 15%–50% for PEs and 47%–59% for NS (Zavos et al., 2014). Common environmental influences were evident for hallucinations and parent-rated negative symptoms (PRNS) (17%–24%), and the remainder of variance in PENS was accounted for by nonshared environment (49%–64%), and to a lesser degree for PRNS (17%). Using genotype data from unrelated individuals, SNP-heritability has been estimated as 3%–9% in a recent genome-wide association study (GWAS) meta-analysis of adolescent PENS, providing further evidence of genetic effects influencing PENS (Pain et al., 2018; see also Sieradzka et al., 2015).

The current study builds on existing research by utilizing a large, representative sample of male and female twins. It encompasses four specific domains assessing PEs (paranoia, hallucinations, cognitive disorganization and grandiosity), and two assessing NS (self-reported anhedonia, parent-rated NS) measured over approximately 9 months in mid-to-late adolescence. The first aim was to estimate the extent to which genetic and environmental influences contribute to the stability of adolescent PENS. It was predicted that genetic effects would explain a substantial amount of the cross-time covariance, and that there would be substantial overlap of genetic effects across time. It was also expected that the aetiological cross-time correlations would be less than 1, highlighting the role of time-specific influences. The second aim was to characterize the sample in terms of phenotypic persistence by grouping individuals according to whether their PENS persist, increase, decrease or remain low. It was predicted that persistence would be associated with higher levels of psychopathology compared to low-scoring, increasing and decreasing scores.

### Methods

#### Participants

Participants were part of the Longitudinal Experiences and Perceptions (LEAP) study, which measured PENS at age 16. LEAP is part of the Twins Early Development Study (TEDS), which has collected data from twins born during 1994 to 1996 in England and Wales across their childhood (Haworth, Davis, & Plomin, 2013). In sum, 10,868 families were invited to LEAP, of which 5,059 twin pairs and 5,076 parents returned data. A subsample of responding families was invited to LEAP phase 2 approximately 9 months later. Of 1,773 families invited for phase 2, 1,464 returned data. Demographics of the two samples are shown in Table S1. In the current study, 1,448 twin pairs have data at both time points (time 1 \( M = 16.32 \) (0.68), 54.5% female, 36% MZ; time 2 \( M = 17.06 \) (0.88), 58.1% female, 35% MZ). Parents and twins gave their informed consent to take part in these studies. TEDS was granted ethical approval from the Institute of Psychiatry Ethics Committee, Kings College London. See Appendix S1 for further details.

#### Measures

Psychotic experiences and negative symptoms were measured using the Specific Psychotic Experiences Questionnaire (SPEQ; Ronald et al., 2014). The SPEQ is a validated self-report and parent-report assessment tool, comprising six subscales measuring mild-to-more severe experiences of paranoia (15 items), hallucinations (9 items), cognitive disorganization (11 items), grandiosity (8 items), hedonia (10 items, reversed to give a measure of anhedonia) and parent-rated negative symptoms (PRNS) (10 items). See Ronald et al. (2014), and Appendix S2 for further details. Distress was measured using a single item following each subscale (Overall, how distressed are you by these experiences?), with exception of the anhedonia and PRNS subscales. Depression traits were measured using the 13-item self-report Short Mood and Feelings Questionnaire (SMFQ; Angold, Costello, Messer, & Pickles, 1995). Emotional problems and other psychopathology scales (conduct problems, hyperactivity and peer problems) were measured using the 5-item...
Design

The twin design aims to disentangle the roles of genetic and environmental influences on variation in a phenotype, and on covariation between phenotypes (Boomsma, Busjahn, & Peltonen, 2002). Initial inferences can be made by comparing within-pair MZ and DZ correlations. If MZ correlations (rMZ) are greater than DZ correlations (rDZ), additive genetic factors (A) are suggested. If rMZ are more than twice rDZ, nonadditive genetic factors (D) are implicated. Where rDZ are greater than half rMZ, shared environmental factors (C) are suggested. The extent to which rMZ are <1 implicates nonshared environmental influences, including measurement error (E). These correlations form the basis for quantifying the relative genetic and environmental contributions using twin model-fitting.

Analyses

SPSS software was used for all phenotypic analyses, using data from one randomly selected twin (per pair) with data at both time points. Untransformed data were used for descriptive statistics and frequency-based analyses. For each SEQ subscale, individuals were grouped as follows: 'Low-scoring', time 1 and time 2 scores in the bottom 90% of scores; 'Decreasing', time 1 score in the top 10% and time 2 score in the bottom 90%; 'Increasing', time 1 score in the bottom 90% and time 2 score in the top 10%; 'Persistent', time 1 and time 2 scores in the top 10%. Across PENS, the top 10% of the score distribution was used as the cut-off.

Cohen’s d was used to compare group differences in PENS, SMFQ and SDQ scores. d is a measure of the standardized difference between means (calculated for unequal sample sizes using: https://www.psychometrica.de/effect_size.html). Fisher’s exact test was used to determine distress frequency associations between groups due to small numbers of observations in some cells. Cramer’s V was used to measure the association of the chi-squared value.

Descriptive statistics are presented in Tables S2 and S3. Table S4 shows frequencies of distress associated with PEs. Of those with some PEs, 11.8%–37.4% of individuals reported some level of distress. Between 2.1% and 10.8% reported being very distressed.

Univariate twin model-fitting

Table 1 shows the univariate twin correlations and Tables S5–S10 show the results of testing for mean and variance differences in the data. The univariate twin estimates are reported from the bivariate twin models. Across all PENS except anhedonia, bivariate ACE models without sex differences fit the data best, with lower values indicating a better fit. Whichever model fit best was used to determine subsequent testing of the following models: (a) ACE or ADE with quantitative sex differences only, (b) ACE or ADE without sex differences on the aetiological correlations and (c) ACE or ADE without sex differences. Three indices of fit were generated: –2LL, Akaike’s Information Criterion (AIC) and Bayesian Index Criterion (BIC). Goodness of fit for these nested models and subsequent submodels was assessed using BIC because it has been shown to outperform alternative indices for multivariate models in larger samples. Lower BIC values indicated a better fit. A BIC difference of at least 10 between two models indicates that the model with the lower BIC value is a better fit than the model to which it is being compared (Raftery, 1995).

Bivariate twin model-fitting

Table 1 shows the phenotypic cross-time correlations (r = .59–.69) and cross-twin cross-time correlations. Cross-twin cross-time rMZ were higher than rDZ for all PENS suggesting genetic influences, and cross-twin cross-time rMZ were all less than 1,
suggesting nonshared environment on the cross-time covariance. For hallucinations and PRNS, cross-twin cross-time rDZ were greater than half rMZ, suggesting shared environment on the cross-time covariance. rDZ were less than half rMZ for female paranoia, cognitive disorganization and grandiosity, and across sexes for anhedonia, suggesting some nonadditive genetic effects.

Table S17 shows the Cholesky estimates. Across PENS, between 42% and 58% of the variance at time 2 was accounted for by aetiological influences carried over from time 1. Specifically, 25–38% of the variance in each measure at time 2 was accounted for by genetic influences carried across time, 0%–13% was due to shared environment, and 3%–14% was due to nonshared environment. Aetiological influences unique to time 2 were highest for nonshared environment across PENS (42%–49%, except PRNS, 14%).

Genetic correlations indicated substantial overlap in genetic influences across time (rA = 0.77–1.00) (Table S18). The high rC estimates across PENS suggest considerable overlap in C influences (rC = 0.59–1.00). Moderate rE suggest that E influences across time partially overlap (rE = 0.36–0.49). Table 2 shows the bivariate parameter estimates. The proportion of the phenotypic correlation that was explained by genetic influences was 0.38–0.46 for PEs and 0.54–0.62 for NS. The proportion of the phenotypic correlation that was explained by shared environmental influences was 0.13–0.33, except for anhedonia which showed no C. The proportion of the phenotypic correlation that was explained by nonshared environmental influences was 0.34–0.41, although less for PRNS (0.12).

Cross-time phenotypic subgroup analysis

Table S19 shows the descriptives of the phenotypic persistence subgroups. For individuals with high time 1 PENS, means were significantly higher for persistent compared to decreasing groups (d = 0.31–0.56, except grandiosity). For individuals with low time 1 PENS, means were significantly higher for the increasing compared to low-scoring groups (d = 1.08–1.61). Between 5.5% and 8.1% of individuals had persistently high PENS (Table S19).

Table 3 shows that for all PEs except grandiosity, point estimates suggested that the persistent group reported being quite or very distressed more often than the other groups, and reported being not distressed to a lesser extent. Fisher’s exact test and Cramer’s V statistics (0.15–0.46) were significant (p ≤ .001) for comparisons between the low-scoring and increasing groups, the persistent and low-scoring groups, and between the persistent and increasing groups, but not between the persistent and decreasing groups.

Across PENS, the persistent group showed a pattern of having higher point estimates for both

<table>
<thead>
<tr>
<th>Table 1 Phenotypic and twin correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenotypic</td>
</tr>
<tr>
<td>Whole sample</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Cross-twin time 1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Cross-twin time 2</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Cross-twin cross-time</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Table S19 shows the descriptives of the phenotypic persistence subgroups. For individuals with high time 1 PENS, means were significantly higher for persistent compared to decreasing groups (d = 0.31–0.56, except grandiosity). For individuals with low time 1 PENS, means were significantly higher for the increasing compared to low-scoring groups (d = 1.08–1.61). Between 5.5% and 8.1% of individuals had persistently high PENS (Table S19).

Table 3 shows that for all PEs except grandiosity, point estimates suggested that the persistent group reported being quite or very distressed more often than the other groups, and reported being not distressed to a lesser extent. Fisher’s exact test and Cramer’s V statistics (0.15–0.46) were significant (p ≤ .001) for comparisons between the low-scoring and increasing groups, the persistent and low-scoring groups, and between the persistent and increasing groups, but not between the persistent and decreasing groups.

Across PENS, the persistent group showed a pattern of having higher point estimates for both

© 2019 The Authors. Journal of Child Psychology and Psychiatry published by John Wiley & Sons Ltd on behalf of Association for Child and Adolescent Mental Health.
### Table 2 Parameter estimates for best-fitting bivariate Cholesky solutions

<table>
<thead>
<tr>
<th></th>
<th>Standardized univariate estimates time 1</th>
<th>Standardized univariate estimates time 2</th>
<th>Bivariate heritability, bivariate shared environment, bivariate nonshared environment</th>
<th>Proportion of phenotypic correlation explained by A, C and E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A (0.22, 0.34)</td>
<td>C (0.29, 0.36)</td>
<td>E (0.29, 0.36)</td>
<td>A (0.22, 0.34)</td>
</tr>
<tr>
<td>Paranoia</td>
<td>0.32 (0.22, 0.43)</td>
<td>0.61 (0.51, 0.62)</td>
<td>0.25 (0.19, 0.32)</td>
<td>0.12 (0.05, 0.19)</td>
</tr>
<tr>
<td>Hallucinations</td>
<td>0.33 (0.23, 0.42)</td>
<td>0.51 (0.42, 0.56)</td>
<td>0.22 (0.16, 0.29)</td>
<td>0.14 (0.08, 0.19)</td>
</tr>
<tr>
<td>Cognitive disorganization</td>
<td>0.38 (0.30, 0.45)</td>
<td>0.61 (0.51, 0.62)</td>
<td>0.01 (0.04, 0.11)</td>
<td>0.22 (0.16, 0.29)</td>
</tr>
<tr>
<td>Grandiosity</td>
<td>0.26 (0.20, 0.32)</td>
<td>0.18 (0.13, 0.22)</td>
<td>0.01 (0.04, 0.11)</td>
<td>0.38 (0.30, 0.45)</td>
</tr>
<tr>
<td>Anhedonia</td>
<td>0.46 (0.42, 0.50)</td>
<td>0.36 (0.33, 0.39)</td>
<td>0.18 (0.17, 0.20)</td>
<td>0.45 (0.39, 0.51)</td>
</tr>
<tr>
<td>PRNS</td>
<td>0.46 (0.42, 0.50)</td>
<td>0.36 (0.33, 0.39)</td>
<td>0.18 (0.17, 0.20)</td>
<td>0.45 (0.39, 0.51)</td>
</tr>
</tbody>
</table>

A, Additive genetic effects; C, Common environmental effects; E, Nonshared environmental effects; PRNS, Parent-rated negative symptoms; 95% CI in parentheses.

### Discussion

This is the first study to investigate the genetic and environmental influences on the stability of PENS in a large sample in mid-to-late adolescence. Over a period of 9 months at ages 16–17 years, PENS showed considerable phenotypic stability. This was reflected in the high phenotypic correlations across time.

The stability of PENS was influenced by genetic and environmental factors. Genetic influences explained a larger proportion of the variance across time, with heritability estimates ranging from 0.28 to 0.47 across different time points. Environmental influences were also significant, with shared environmental factors explaining a smaller proportion of the variance, ranging from 0.14 to 0.15 across time. Nonshared environmental factors contributed to the imperfect stability of PENS in mid-to-late adolescence. Over a period of 9 months at ages 16–17 years, PENS showed considerable phenotypic stability. This was reflected in the high phenotypic correlations across time.

The stability of PENS was influenced by genetic and environmental factors. Genetic influences explained a larger proportion of the variance across time, with heritability estimates ranging from 0.28 to 0.47 across different time points. Environmental influences were also significant, with shared environmental factors explaining a smaller proportion of the variance, ranging from 0.14 to 0.15 across time. Nonshared environmental factors contributed to the imperfect stability of PENS in mid-to-late adolescence. Over a period of 9 months at ages 16–17 years, PENS showed considerable phenotypic stability. This was reflected in the high phenotypic correlations across time.

The stability of PENS was influenced by genetic and environmental factors. Genetic influences explained a larger proportion of the variance across time, with heritability estimates ranging from 0.28 to 0.47 across different time points. Environmental influences were also significant, with shared environmental factors explaining a smaller proportion of the variance, ranging from 0.14 to 0.15 across time. Nonshared environmental factors contributed to the imperfect stability of PENS in mid-to-late adolescence. Over a period of 9 months at ages 16–17 years, PENS showed considerable phenotypic stability. This was reflected in the high phenotypic correlations across time.

The stability of PENS was influenced by genetic and environmental factors. Genetic influences explained a larger proportion of the variance across time, with heritability estimates ranging from 0.28 to 0.47 across different time points. Environmental influences were also significant, with shared environmental factors explaining a smaller proportion of the variance, ranging from 0.14 to 0.15 across time. Nonshared environmental factors contributed to the imperfect stability of PENS in mid-to-late adolescence. Over a period of 9 months at ages 16–17 years, PENS showed considerable phenotypic stability. This was reflected in the high phenotypic correlations across time.
Table 3 Frequency differences for distress at time 1 by group

<table>
<thead>
<tr>
<th></th>
<th>N with PE score &gt; 0 and distress data</th>
<th>PE mean score at time 1 (SD)</th>
<th>Not distressed</th>
<th>A bit distressed</th>
<th>Quite/very distressed</th>
<th>Comparison</th>
<th>Fisher's exact test (p)</th>
<th>Cramer's V (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paranoia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-scoring (LS)</td>
<td>854</td>
<td>11.61 (8.65)</td>
<td>620 (72.6%)</td>
<td>196 (23.0%)</td>
<td>38 (4.4%)</td>
<td>LS versus P 125.56 (p &lt; .001)**</td>
<td>0.45 (p &lt; .001)**</td>
<td></td>
</tr>
<tr>
<td>Increasing (I)</td>
<td>46</td>
<td>23.25 (8.63)</td>
<td>17 (37.0%)</td>
<td>22 (47.8%)</td>
<td>7 (15.2%)</td>
<td>LS versus P 25.97 (p &lt; .001)**</td>
<td>0.18 (p &lt; .001)**</td>
<td></td>
</tr>
<tr>
<td>Decreasing (D)</td>
<td>53</td>
<td>42.91 (6.02)</td>
<td>14 (26.4%)</td>
<td>24 (45.3%)</td>
<td>15 (28.3%)</td>
<td>D versus P 5.34 (p &lt; .07)</td>
<td>0.21 (p &lt; .07)</td>
<td></td>
</tr>
<tr>
<td>Persistent (P)</td>
<td>66</td>
<td>45.73 (8.28)</td>
<td>9 (13.6%)</td>
<td>26 (39.4%)</td>
<td>31 (47.0%)</td>
<td>I versus P 15.15 (p &lt; .001)**</td>
<td>0.36 (p &lt; .001)**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hallucinations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-scoring (LS)</td>
<td>572</td>
<td>5.25 (4.23)</td>
<td>484 (84.6%)</td>
<td>78 (13.6%)</td>
<td>10 (1.7%)</td>
<td>LS versus P 83.76 (p &lt; .001)**</td>
<td>0.43 (p &lt; .001)**</td>
<td></td>
</tr>
<tr>
<td>Increasing (I)</td>
<td>63</td>
<td>11.31 (4.54)</td>
<td>41 (65.1%)</td>
<td>21 (33.3%)</td>
<td>1 (1.6%)</td>
<td>LS versus P 14.34 (p &lt; .001)**</td>
<td>0.16 (p &lt; .001)**</td>
<td></td>
</tr>
<tr>
<td>Decreasing (D)</td>
<td>71</td>
<td>22.65 (5.42)</td>
<td>36 (50.7%)</td>
<td>25 (35.2%)</td>
<td>10 (14.1%)</td>
<td>D versus P 4.26 (p &lt; .11)</td>
<td>0.18 (p &lt; .11)</td>
<td></td>
</tr>
<tr>
<td>Persistent (P)</td>
<td>65</td>
<td>24.20 (5.97)</td>
<td>22 (33.8%)</td>
<td>28 (43.1%)</td>
<td>15 (23.1%)</td>
<td>I versus P 20.10 (p &lt; .001)**</td>
<td>0.39 (p &lt; .001)**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive disorganization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-scoring (LS)</td>
<td>765</td>
<td>4.00 (2.11)</td>
<td>556 (72.7%)</td>
<td>172 (22.5%)</td>
<td>37 (4.8%)</td>
<td>LS versus P 142.58 (p &lt; .001)**</td>
<td>0.46 (p &lt; .001)**</td>
<td></td>
</tr>
<tr>
<td>Increasing (I)</td>
<td>59</td>
<td>6.53 (1.61)</td>
<td>29 (49.2%)</td>
<td>21 (35.6%)</td>
<td>9 (15.3%)</td>
<td>LS versus I 16.66 (p &lt; .001)**</td>
<td>0.15 (p &lt; .001)**</td>
<td></td>
</tr>
<tr>
<td>Decreasing (D)</td>
<td>77</td>
<td>9.61 (0.69)</td>
<td>23 (29.9%)</td>
<td>33 (42.9%)</td>
<td>21 (27.3%)</td>
<td>D versus P 5.66 (p &lt; .06)</td>
<td>0.18 (p &lt; .06)</td>
<td></td>
</tr>
<tr>
<td>Persistent (P)</td>
<td>96</td>
<td>10.09 (0.76)</td>
<td>17 (17.7%)</td>
<td>38 (39.6%)</td>
<td>41 (42.7%)</td>
<td>I versus P 20.92 (p &lt; .001)**</td>
<td>0.37 (p &lt; .001)**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grandiosity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-scoring (LS)</td>
<td>810</td>
<td>4.54 (2.99)</td>
<td>699 (86.3%)</td>
<td>89 (11.0%)</td>
<td>22 (2.7%)</td>
<td>LS versus P 1.29 (p &lt; .05)</td>
<td>0.03 (p &lt; .67)</td>
<td></td>
</tr>
<tr>
<td>Increasing (I)</td>
<td>40</td>
<td>7.72 (2.93)</td>
<td>38 (70.0%)</td>
<td>10 (25.0%)</td>
<td>2 (5.0%)</td>
<td>LS versus I 7.89 (p &lt; .02)**</td>
<td>0.10 (p &lt; .02**</td>
<td></td>
</tr>
<tr>
<td>Decreasing (D)</td>
<td>58</td>
<td>16.66 (2.92)</td>
<td>51 (87.9%)</td>
<td>5 (8.6%)</td>
<td>2 (3.4%)</td>
<td>D versus P 0.60 (p &lt; .79)</td>
<td>0.07 (p &lt; .79)</td>
<td></td>
</tr>
<tr>
<td>Persistent (P)</td>
<td>66</td>
<td>17.16 (2.71)</td>
<td>55 (83.3%)</td>
<td>8 (12.1%)</td>
<td>3 (4.5%)</td>
<td>I versus P 3.08 (p &lt; .22)</td>
<td>0.17 (p &lt; .28)</td>
<td></td>
</tr>
</tbody>
</table>

N, Number of individuals; One randomly selected twin per pair included in analyses; Data shown for sample included in phenotypic analyses who provided data at both time points; Fisher’s exact test of independence; Cramer’s V measure of effect size (square root of the x2 statistic divided by the sample size multiplied by the lesser number of categories in either variable minus 1); Monte Carlo p values based on 10,000 sampled tables.

D, Decreasing group; I, Increasing group; LS, Low-scoring group; P, Persistent group; PE, Psychotic experiences.

**p < .001; *p < .05
not all comparisons had a significant effect size, and
in particular, being in the group characterized by
persistence of grandiosity was not associated with
more distress and psychopathology. This is broadly
in line with past findings suggesting that grandiosity
does not always link with other psychopathology at
this age (Ronald et al., 2014). The grandiosity scale
appeared similar to the other PENS scales in terms of
its high internal consistency and its positive skew.
Future work should explore whether this distinct
pattern shown by grandiosity is specific to adoles-
cence.

Our finding that genetic influences contribute
moderately to the stability of PENS in adolescence
is broadly in line with findings by Ericson et al.
(2011), who reported a strong genetic component
contribution to the stability of schizotypy (a related
phenotype), albeit on a smaller and younger sample.
Unlike the Ericson et al. study, we also identified
modest shared environmental influences and moder-
ate nonshared environmental influences for all
PEs. Our study also extended this work by reporting
on stability across specific psychotic experiences
and negative symptoms.

The results highlight the role of environmental
factors in influencing how adolescent PENS develop,
which adds to existing research that has shown the
importance of environmental factors at single time
points (Hur, Cherny, & Sham, 2012; Zavos et al.,
2014; Zhou et al., 2018). Of particular interest in
this context are our results that nonshared environ-
ment contributes to more than a third of the stability
of PENS (except PRNS). These findings concur
broadly with findings that specific environmental
risks such as trauma, cannabis use and stressful life
events are associated with persistent PEs in adoles-
cence (Cougnard et al., 2007; Wigman, Winkel,
Raaijmakers et al., 2011). Furthermore, our results
suggest that some nonshared environmental influ-
cences are time-specific. Whilst estimates for non-
shared environment also include measurement
error, the results suggest that in part, PENS are
influenced by time-specific factors not shared
between family members. This is in line with findings
suggesting that some nonshared environmental
effects at least prior to adulthood are transitory, in
contrast to shared environmental and genetic effects
which are more stable over time (Burt, Klahr, &
Klump, 2015).

The modest contribution of shared environment to
stability of most of the PENS studied (notably not
anhedonia) can be considered in the light of epi-
demiological findings that have identified urbanicity
as a risk factor for persistence in individuals in the
general population reporting PEs at baseline (Coug-
nard et al., 2007). Whilst the findings cannot be
used to draw conclusions about the exact nature of
common environmental influences, they are more
generally reflective of findings that shared environ-
ments explain less variance in behavioural
phenotypes than nonshared environments (Plomin,
2011). The higher proportion of phenotypic stability
explained by shared environment for PRNS may be
influenced by the effect of having the same rater
across twins.

Psychological difficulties such as distress, depres-
sion traits and emotional problems and other psy-
chopathology were elevated at baseline in those who
followed a persistent path in terms of PENS. This
suggests that individuals who go on to experience
high levels of PENS over time are more likely to be
suffering with current psychological disturbance as
well as being at increased risk of later psychopathol-
y (Dominguez et al., 2011; Wigman, Winkel, Raai-
jmakers et al., 2011).

Strengths and limitations

It is a key strength of this study that data from over
4,800 twin pairs was used, building on existing
research that has relied on smaller samples. Further,
the study utilized a validated measurement tool
encompassing measurement of four individual
dimensions of PEs and two of NS. In the light of this,
it is a limitation that the time 2 sample was smaller
than the time 1 sample, and that not more time points
were available. However, our results broadly concur
with other findings that modelled data on younger and
older samples assessed across three time points
(Wigman, Winkel, Jacobs et al., 2011; Wigman,
Winkel, Raaijmakers et al., 2011). Future work
should seek to employ both researcher- and data-
driven methods in order to cross-validate the results.

Conclusion

Both genetic and environmental influences con-
tribute to the considerable stability of adolescent
PENS in mid-to-late adolescence. There are also
some dynamic influences particularly via nonshared
environments. Individuals who will go on to report
persistent PENS are more likely to experience other
psychological difficulties such as distress, depres-
sion traits and other psychopathology. In conjunc-
tion with epidemiological findings in the field, the
findings presented here speak of the importance of
measuring adolescent PENS over time.

Supporting information

Additional supporting information may be found online
in the Supporting Information section at the end of the
article:

Appendix S1. Study details.
Appendix S2. The Specific Psychotic Experiences
Questionnaire (SPEQ; Ronald et al., 2014).
Appendix S3. Assumptions testing.
Figure S1. Bivariate Cholesky decomposition solution
(left-hand figure) and correlated factors model (right-
hand figure) path diagrams.
Table S1. Frequency and mean differences in demographics of main sample and follow-up sample.  
Table S2. Descriptives for psychotic experiences and negative symptoms subscales.  
Table S3. Descriptives for psychotic experiences and negative symptoms subscales split by sex and zygosity.  
Table S4. Frequencies of distress associated with psychotic experiences.  
Table S5–S10. Results of testing for mean and variance differences in the data.  
Table S11–S16. Bivariate twin model statistics.  
Table S17. Cholesky estimates.  
Table S18. Genetic and environmental correlations for best-fitting bivariate models.  
Table S19. Descriptives and mean differences for psychotic experiences and negative symptoms subscales at time 1 by group.  
Table S20–S21. Mean differences for depression traits and emotional problems at time 1 by group.  
Table S22–S24. Mean differences for conduct problems, hyperactivity and peer problems at time 1 by group.  
Table S25. Correlations for psychotic experiences and negative symptoms with depression traits and SDQ emotional problems and other SDQ subscales.  
Table S26. Descriptive statistics for depression traits and psychopathology subscales.

Key points

- Persistence of psychotic experiences and negative symptoms (PENS) is known to reflect heightened risk for psychiatric disorders, but the causes of this persistence are unknown.
- PENS were found to be largely stable over a period of 9 months in adolescence.
- Persistent PENS tended to be associated with greater levels of distress and other psychopathology at baseline compared to groups with transitory or low levels of PENS.
- Genetic and environmental influences contributed to the stability of PENS in adolescence.
- Time-specific effects acted primarily via nonshared environment. The imperfect stability of PENS was at least partly due to new nonshared environmental influences occurring over time.

References


Acknowledgements

This work was funded by Medical Research Council grant G1100559 to A.R. TEDS is funded by Medical Research Council grant MR/M021475/1 to Robert Plomin. L.H. was funded by an ESRC PhD studentship. M.J.T. received research funding from the Fredrik och Ingrid Thunbergs stiftelse. In the 36 months prior to submission of this work, A.R. also received funding from the Swedish Foundation for Humanities and Social Sciences and the Wellcome Trust ISSF fund; book royalties from Springer, New York; payment for brief consultancy work from the National Childbirth Trust; fees for PhD examining from Cardiff University and King’s College London. A.R. acts as an action editor for JCPP for which she receives an honorarium. The authors thank the TEDS participants, and Robert Plomin and Andrew McMillan for the collaboration. The authors have declared that they have no competing or potential conflicts of interest.

Correspondence

Angelica Ronald, Department of Psychological Sciences, Centre for Brain and Cognitive Development, Birkbeck, University of London, Malet Street, London WC1E 7HX, UK; Email: a.ronald@bbk.ac.uk

© 2019 The Authors. Journal of Child Psychology and Psychiatry published by John Wiley & Sons Ltd on behalf of Association for Child and Adolescent Mental Health.


Accepted for publication: 12 February 2019

First published online: 7 April 2019