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Fine motor skill and processing speed deficits in young people with psychotic experiences: A longitudinal study

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ABSTRACT

Objective: To identify neuropsychological and motor changes from adolescence to early adulthood in young people with psychotic experiences (PE).
Methods: A community-based sample of 56 young people attended the study over a 9 year follow-up period. Participants were assessed over 3 time-points at T1, T2 and T3 aged $\bar{x} = 11.69$, $\bar{x} = 15.80$ and $\bar{x} = 18.80$ years respectively. PE were assessed using the Kiddie Schedule for Affective and Depressive Symptoms (K-SADS). Neuropsychological assessments, including subtests of the MATRICS battery, and motor assessments were examined at T2 and T3. Two groups were compared: those who ever reported PE during their adolescence or early adulthood ($n = 21$) and a healthy control group ($n = 35$). Further group analysis was conducted within the PE group subdividing into those with transient PE ($n = 10$) and those with persistent PE ($n = 11$).
Results: At T3, a significant group difference was found between the PE and control groups in the fine motor skill task, the Pegboard task ($F = 4.8$, $p = .03$) and the processing speed task, the Digit-Symbol Coding task ($F = 5.36$, $p = .03$). Furthermore, a significant group difference was found between the transient PE and control groups on the Digit-Symbol Coding task ($F = 5.61$, $p = .02$), while a significant group difference was found between the persistent PE and control groups on the Pegboard task ($F = 7.84$, $p = .01$).
Conclusion: This study shows that fine motor skill and processing speed deficits persist in young people who report PE, even in those with transient PE. The current research advances the knowledge about the trajectory and precursors of sub-clinical symptoms of psychosis in young people.

1. Introduction

A continuum between psychotic experiences (PE) and psychotic disorders has been proposed (Verdoux and van Os, 2002). Healthy individuals who report PE are considered as representing a non-clinical psychosis phenotype, and have been found to be at an increased risk of developing a schizophrenia-spectrum disorder (Zammit et al., 2013) and a range of other non-psychotic mental disorders. PE are most prevalent in early adolescence with evidence of a decrease in the rates of PE over the course of late adolescence and adulthood (Van Os et al., 2009).

PE are associated with psychosis-related risk factors including social, cognitive, intellectual, neuro-anatomical and motor variances. Imaging studies have shown neuro-anatomical overlap between individuals with PE and individuals with psychotic disorders, including hypofrontality, frontotemporal disconnection, and deficits in grey and white matter (Jacobson et al., 2010). Such findings have led to an increased focus on documenting the neuropsychological profiles of these individuals, particularly in adolescence (Kelleher et al., 2012) and on identifying changes in profiles over time (Mollon et al., 2016). Deficits in cognition have been shown to manifest years before the development of overt psychotic symptoms (Niendam et al., 2003; Reichenberg et al., 2009), particularly involving the cognitive domains of processing speed, visual attention, verbal fluency, spatial working memory and complex verbal memory. Such deficits have been found to have an impact on global functioning (Niendam et al., 2003).

Comprehensive neuropsychological batteries have been used to evaluate cognitive functioning in ultra-high-risk (Niendam et al., 2006) and prodromal psychosis samples (Lencz et al., 2006), and in adolescents with PE (Kelleher et al., 2012; Gur et al., 2014). Much of the

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literature involving neuropsychology and PE is focused on 'higher-order' cognitive abilities of processing speed, working memory and executive functioning abilities (Kelleher et al., 2012). Processing speed and working memory deficits (specifically nonverbal) have already been reported in individuals with PE (Kelleher et al., 2012). Processing speed, the speed with which cognitive operations are performed, was found to be the central cognitive deficit that persisted over time in a large birth-cohort study that analysed neuropsychological performances longitudinally (Niarchou et al., 2013; Mollon et al., 2016, 2018). There have also been findings that executive functioning deficits, including inhibitory control, are present in both clinical high risk samples (Shin et al., 2016) and among those with schizotypy (Gooding et al., 1999). It therefore has been postulated that such deficits are likely to precede the onset of psychotic disorders.

Fewer studies have investigated more basic functional processes in adolescents with PE, including motor abilities, which have been found to mediate performances on timed tasks separate to IQ (Smits-Engelsman and Hill, 2012). Motor skills have previously been found to be a potential predictor of daily functioning abilities in at-risk individuals (Wittich and Nadon, 2017). Reductions in fine motor skill have also been found in prodromal (Lencz et al., 2006) and ultra-high risk groups (Niendam et al., 2006) for schizophrenia. Motor and sensory disturbances are frequently found in schizophrenia and the development of these symptoms has been tracked retrospectively in longitudinal birth cohort studies. Cannon et al. (2002) found that adults with schizophreniform disorder at age 26 had deficits in motor development that were detected at as young as 3 years old. Further, Reichenberg et al. (2009), found that in individuals with schizophrenia, there were significant deficits in performance on the Pegboard task compared to healthy controls at ages 13 and 38. These deficits exhibit a dose-response relationship with increased risk of later development of the illness (Isohanni et al., 2001). Delayed motor development in the first year of life has been found to be a relatively robust risk factor for later development of schizophrenia (Clarke et al., 2011).

In the current research study, we investigate the neuropsychological and motor performance over time in adolescents with reported PE, with a particular focus on fine motor skills and the cognitive domains of processing speed, executive functions and working memory abilities.

2. Methods

2.1. Participants

2.1.1. Recruitment and clinical assessment of PE

The current research study, entitled the Adolescent Brain Development Study (ABD) began in 2007. Ethical Approval for the study was granted by the Beaumont Hospital Medical Ethics Committee. Recruitment was conducted in primary schools in Leinster, Ireland where a total of 1131 young adolescents (age range 11–13) completed the Strengths and Difficulties Questionnaire (SDQ), a validated 25-item brief screening questionnaire for psychopathology and the Adolescent Psychotic Symptom Screener (APSS), a validated 7-item self-report instrument that measures hallucinations and delusions (Kelleher et al., 2011). These were completed in schools with members of the research team present. Written informed consent was provided by participants throughout. Additional parental or guardian consent was provided by all participants under the age of 18.

Of the 1131 adolescents who completed the initial screening questionnaires, 656 (58%) consented to take part in further clinical assessments. Of those, a representative sample of 212 participants was selected to take part in the next phase of the study. These participants made up the baseline (T1) sample for the ABD Study and all 212 and completed in-depth interviews along with neuropsychological assessments. The Kiddie Schedule for Affective Disorders and Schizophrenia (K-SADS) was used to assess PE, a validated semi-structured diagnostic interview that assesses Axis-1 psychiatric disorders in children and adolescents. Categorization of PE was based on the psychosis subsection, which investigates hallucinations and delusional thinking. A team of two psychiatrists and four psychologists conducted all T1 clinical interviews with participants and their parents/guardians. A consensus meeting was then held by all the interviewers, who were blind to any identifiable information of the participant, to classify what was considered a PE. 22.6% ($n = 53$) were defined as having PE by consensus agreement. The results of the neuropsychological assessments at T1 have been previously published (Blanchard et al., 2010; Kelleher et al., 2012, 2013). A total of 100 of participants also had an MRI brain scan.

At T2, the subgroup of 100 of the 212 participants who had an MRI scan was invited to return for interview, neuropsychological assessment and repeat MRI brain scan. Of these, 86 participants (age range 14–18 years) returned. All participants again assessed using the K-SADS. At T2, only the participants themselves completed the clinical interviews. The consensus meeting was again held to classify PE. Participants also completed the neuropsychological and motor assessment at this time.

At T3, all 86 participants who took part at T2 were invited to return. Of those, 56 participants (age range 17–22 years) returned to repeat the clinical interview, MRI brain scan and the same neuropsychological and motor assessments including one additional test of executive functioning. For the purpose of this longitudinal investigation only participants who had participated at all three time points were included in the analysis ($n = 56$). See Fig. 1.

2.2. Measures

Participants completed neuropsychological and motor assessments at T2 and T3. The Purdue Pegboard was used to measure fine motor skill. Cognitive measures included a modified version of the MATRICS battery, a widely used standardized neuropsychological measure used in schizophrenia research (Green et al., 2000). The subtests measuring processing speed (Trail-Making Test, Digit-Symbol Coding task), working memory (Spatial Span) and executive functions (Mazes) were used. The MATRICS has a proven test-retest reliability (Kern et al., 2008). Holmén et al. (2009) demonstrated that the use of the MATRICS could effectively detect cognitive dysfunction in adolescents as young as 12 years old. IQ was also measured.

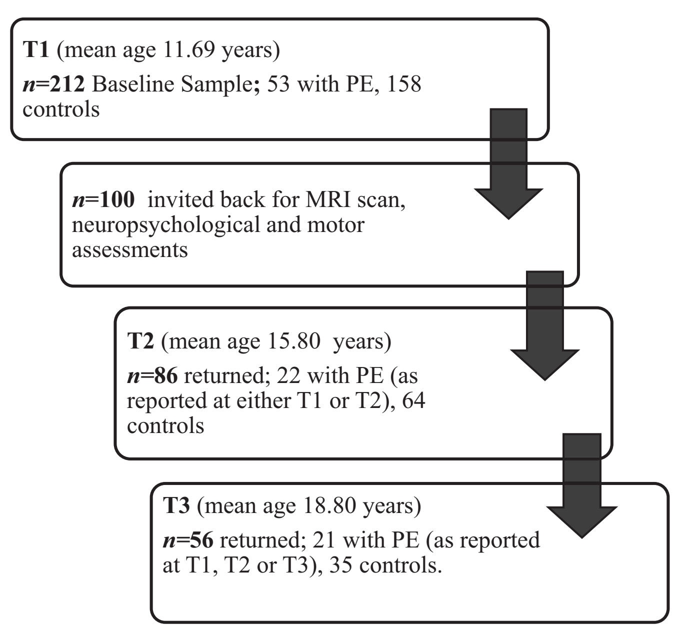

Fig. 1. Recruitment process for the ABD longitudinal study.

2.2.1. Tasks

Fine motor skills. The Purdue Pegboard (Tiffin, 1968): This is a widely used standardized dexterity measure that is used to evaluate fine motor skills, and is one of the purest measures of fine motor abilities. The test requires participants to place pegs in holes on a board using either hand within a 1-minute time-interval. This process is repeated 3 times. Total scores are recorded.

Processing speed. The Trail-Making Task (TMT-A): This one of the most widely used processing speed tasks and part of the MATRICS battery. It requires participants, to join randomly placed numbers in ascending order on a page using a pen. Time in seconds and errors are recorded.

We also added the Trail-Making Task-B (TMT-B): This is not in the MATRICS battery, however is also a test of processing speed. Participants were required to join randomly placed and alternating numbers and letters in ascending order. Time in seconds and errors are also recorded.

The Brief Assessment of Cognition (BACS)-Symbol Coding (SC): This is also part of the MATRICS battery. It requires participants to write numbers that correspond to symbols in a 90-second time-limit. Scores on the task are calculated by totalling the correct answers. This task can also be considered as an assessment of visual learning.

Executive function. The Neuropsychological Assessment Battery (NAB)-Mazes: This is also part of the MATRICS battery. This task requires participants to complete a series of mazes using a pen as quickly and as accurately as the can using a pen. Speed and errors are measured. This task measures executive functioning abilities of planning and problem-solving. This was only completed by participants at T3.

Working memory. The Wechsler Memory Scale (WMS)-Spatial Span (SS): This is also part of the MATRICS battery. It measures the participants ability to remember spatial, nonverbal information by repeatedly pointing to the same blocks that the administrator has pointed to on a board, both forwards and backwards, as sequences become increasingly longer.

IQ. The National Adult Reading test (NART) (Nelson and Willison, 1991) was administered as a measure of pre-morbid IQ at T3.

2.3. Statistical analyses

Statistical analyses were conducted using SPSS Version 24 for Windows. Raw scores for motor and neuropsychological assessments were calculated and recorded for each participant.

Participants were divided into 2 groups, a healthy control group ($n = 35$) and a PE group ($n = 21$). The PE group included any individual who had reported a PE by consensus agreement during their adolescence or early adulthood (at T1, T2 and/or T3). This included both transient experiences (reported at one time-point only) and persistent experiences (reported at two or more time-points). There was 1 new case of PE at T2 that had not been reported at T1. There were 3 new cases of PE at T3 that had not been reported at either T1 or T2. In 2 cases, participants had reported PE at T1 and T3 but not at T2.

Analysis of Co-variance (ANCOVA) was used to compare group differences between the PE and healthy controls groups, controlling for age, sex and affective psychopathology (as measured by the K-SADS). Affective psychopathology was considered as any of the participants who met criteria for Major Depressive Disorder (MDD) on the K-SADS. Our decision to control for affective psychopathology was based on findings from a meta-analysis of cognitive deficits in first-episode MDD that had previously demonstrated significant cognitive deficits related to psychomotor speed, attention, visual learning and memory as well as aspects of executive function, suggesting that such deficits may be an early marker of MDD (Lee et al., 2012).

A repeated measures analysis of variance (ANOVA) was used to investigate any intra-individual differences over time between T2 and T3, with age, sex and affective psychopathology again controlled for.

3. Results

The mean age of all participants at T2 was 15.8 years and at T3 was 18.8 years. A total of 28 females and 28 males took part. There were no significant differences in baseline demographic characteristics between those who attended at all 3 time-points and those who did not ($p > .25$) including age, sex and years of education. There were also no differences in the baseline neuropsychological performances between those who attended at all 3 time-points and those who did not ($p > .25$), including the same subtests of the MATRICS battery used at T3. Demographic variables for both the PE and controls groups for the following analysis are presented in Table 1.

3.1. Group differences

3.1.1. T2 results

At T2, no group differences were found on any of the subtests of the neuropsychological or motor assessments. See Table 2.

3.1.2. T3 results

At T3, ANCOVA revealed a significant group difference in the overall performance on the Pegboard task ($F = 4.67$, $p = .03$), where the group with PE performed significantly slower in placing the pegs in the holes of the board within the time-limit. The significant difference was also found in only the dominant hand ($F = 4.71$, $p = .03$), however not in the non-dominant hand ($F = 2.73$, $p = .11$).

A significant group difference was also found for Digit-Symbol Coding task ($F = 5.48$, $p = .02$), where the group with PE completed fewer symbol-number matches than the healthy control group within the time-limit. The other two subtests, TMT-A and TMT-B which also measured processing speed revealed no significant group differences. Working memory (WMS-Spatial Span) and executive function (NAB-Mazes) also showed no significant group differences. See Table 2 and Fig. 2.

3.2. Performance trajectory over time

A repeated measures ANCOVA was conducted to investigate neuropsychological changes over time in comparing PE and healthy control groups (see Figs. 3 and 4), where age, sex and affective psychopathology were also controlled for. There was a significant improvement over time for the Digit-Symbol Coding task for all participants ($F = 6.52$, $p = .01$). However, the healthy control group improved significantly more than the PE group ($F = 4.78$, $p = .03$). There was also a significant improvement from T2 to T3 for all participants on the TMT-A ($F = 4.77$, $p = .03$) and TMT-B ($F = 7.39$, $p = .01$). For the pegboard task there was a non-significant effect of time ($F = 3.49$, $p = .07$). However, a significant difference was found in the rate of improvement of the groups, where the

Table 1
Demographic variables of the PE group and control group.

Demographic variable	Descriptive statistics	
	PE group	Control group
	$n = 21$	$n = 35$
Age in years, mean (SD), range (T2)	15.9 (1.3) [14–18]	15.7 (1.3) [14–18]
Age in years, mean (SD), range (T3)	19.1 (1.4) [17–21]	19.1 (1.4) [17–22]
Gender, *n* (%)		
Males	13 (61.9%)	20 (42.9%)
Females	8 (38.1%)	15 (57.1%)
Handedness, *n* (%)		
Right	21 (100%)	29 (82.9%)
Left	0	6 (17.1%)

Table 2
Mean raw scores of neuropsychological and motor tasks for both groups at T2 and T3 respectively, along with group differences at T3.

Test	Mean (SD) Controls T2	Mean (SD) PE group T2	Mean (SD) Controls T3	Mean (SD) PE group T3	Group differences T2 *F* (*p*-value)	Group differences T3 *F* (*p*-value)	Adjusted for psychopathology T3	Effect size of adjusted scores (Partial Eta Squared)
The Purdue Pegboard	176.5 (15.7)	169.2 (14.5)	193.1 (18.2)	181.3 (16.7)	1.89 (.18)	**4.8 (.03)**	**4.67 (0.04)**	0.08
TMT-A	24.8 (6.9)	25.8 (7.5)	25.6 (8.3)	26.2 (7.8)	0.19 (.66)	0.01 (.97)	0.04 (0.85)	0.001
TMT-B	44.8 (17.1)	49.6 (20.7)	43.3 (15.1)	42.2 (13.2)	0.95 (.33)	0.35 (.55)	2.92 (0.09)	0.009
BACS- SC	64.2 (10.6)	57.4 (12.6)	69.9 (9.6)	61.9 (10.6)	3.29 (.07)	**5.36 (.03)**	**5.48 (0.02)**	0.01
NAB-Mazes	–	–	22.6 (4.1)	22.8 (4.7)	–	0.04 (.85)	0.07 (0.79)	0.001
WMS-Spatial Span	19.8 (3.3)	19.6 (3.4)	19.1 (2.8)	19.1 (3.7)	0.02 (.90)	0.03 (.88)	0.02 (0.89)	0.00
NART (total score)	–	–	22.5 (7.6)	22 (6.05)	–	0.04 (.84)	–	–

Note: SD, standard deviation; TMT, Trail-Making Test (Part A and Part B); BACS, Brief Assessment of Cognition in Schizophrenia; NAB, Neuropsychological Assessment Battery; WMS, Wechsler Memory Scale. (PES): Partial Eta Squared: measure of effect size at T3 for all subtests, where 0.01 is considered small, 0.09 is considered moderate and 0.25 is considered large. Emboldened metrics denote significant differences ($p < .05$).

healthy controls group showed greater improvement than the PE group at T3 ($F = 3.91$, $p = .05$). See Table 3.

3.3. Transient and persistent PE

Of the 21 participants with PE, $n = 10$ had transient PE (reported at one time-point only) while $n = 11$ had persistent PE (reported at two or more time-points). Further analysis was conducted comparing the transient group (PE-T) to the healthy control group using ANCOVA where age, gender and affective psychopathology were again controlled for, a significant group difference was found for the Digit-Symbol Coding task ($F = 5.61$, $p = .02$) where participants in the PE-T group completed fewer symbol-number matches than the healthy control group. However, a significant difference was not found between the PE-T group and the healthy controls group for the Pegboard task ($F = 0.08$, $p = .77$).

When completing the same analysis with the persistent PE (PE-P) group, no significant group difference was found for the Digit-Symbol Coding task ($F = 0.3$, $p = .58$) between the PE-P group and the healthy controls group. However a significant group difference was found for the Pegboard task ($F = 7.84$, $p = .01$), where the group PE-P group performed significantly slower in placing the pegs in the holes compared with controls.

4. Discussion

The current research has provided evidence for specific deficits detected in young people with PE. This study reveals a developmental lag in fine motor skill and processing speed (as seen on performances on the Pegboard task and Digit-Symbol Coding task) which persists to early adulthood and appears to be independent of whether or not the psychotic experiences themselves remit. We did not find executive function or working memory deficits in those with PE compared with controls.

4.1. PE and fine motor skill

This is the first study to reveal a fine motor skill deficit over time in young people who report PE. The Pegboard task is used in neuropsychology to examine complex uni- and bimanual motor functions (Doyen and Carlier, 2002). Although this task was originally designed

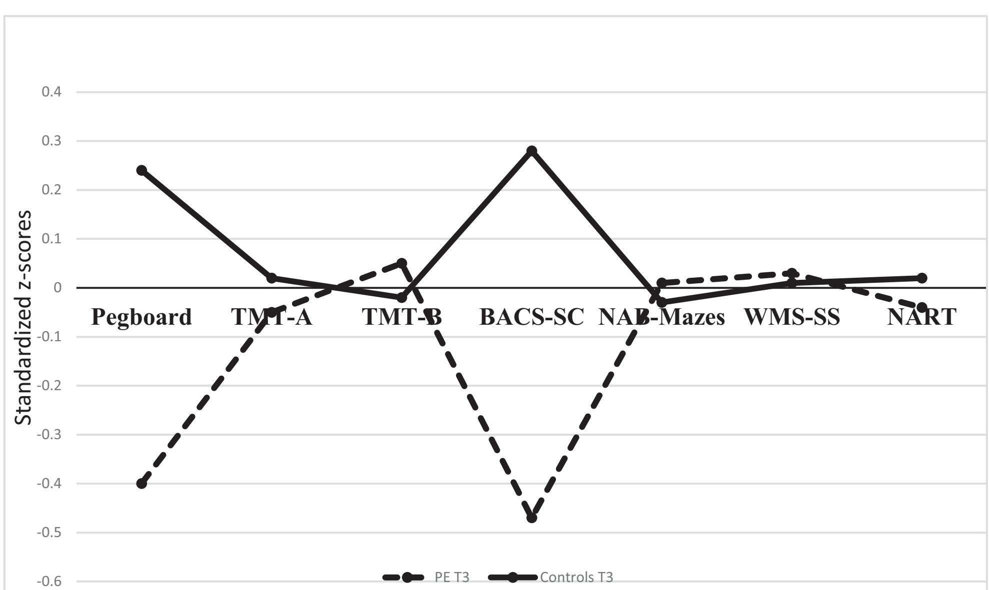

Fig. 2. Mean z-scores of neuropsychological and motor assessment of PE group at T3.

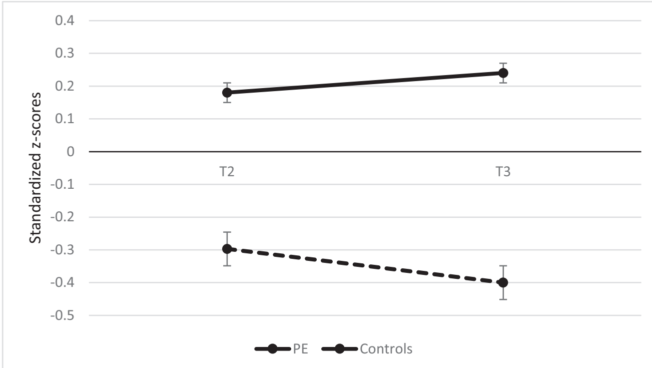

Fig. 3. Longitudinal Pegboard z-scores for PE and control groups at T2 and T3.

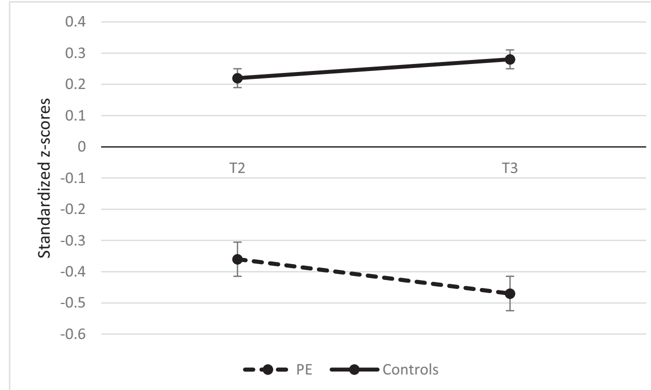

Fig. 4. Longitudinal Digit-Symbol Coding z-scores for PE and control groups at T2 and T3.

to examine motor functions, several authors emphasize that the performance on this task correlates with various normal and deviant cognitive functions (Rosselli and Ardila, 2003). Completion of the Pegboard task leads to distributed activations in a bilateral fronto-parietal network, the cerebellum, the basal ganglia, and the thalamus, many of the same areas as identified to be implicated by psychosis (Fusar-Poli et al., 2007). Furthermore, reduced scores on the Pegboard task are widely reported in schizophrenia research (Fuller and Jahanshahi, 1999; Blanchard et al., 2010).

Deficits in performance on the task could have a number of explanations, namely poverty of action, perseverative movements and motor slowness, and has also been attributed to limited attentional capacity (Fuller and Jahanshahi, 1999). However, Smyth and Anderson (2000) found that motor difficulty is over and above what could be explained by the impact of IQ. This highlights that there is not a one-to-one relationship between cognitive ability and motor skill. Further, Smyth and Anderson (2000) state that the impact of poor manual dexterity and fine motor skills are not to be underestimated, and even in child populations can interfere with school work, independence, and social skills among peers.

This study also sheds light on the distinction and inter-dependence of motor, psychomotor skill and processing speed. In the brain development literature, there is evidence that motor performance and cognitive development are intertwined, presumably through brain structures and networks involved in cognitive processes such as attention, learning, timing and visuomotor co-ordination.

4.2. PE and processing speed

Processing speed is one of the most widely reported neuropsychological deficits in individuals with PE (Kelleher et al., 2012; Gur et al., 2014). The processing speed assessments used in this study encompassed subtests measuring abilities such as attention, switching, learning, reasoning and problem-solving. The Digit Symbol-Coding task was found to significantly differentiate groups of young adults with and without PE. This is in line with previous literature (Mollon et al., 2016; Kelleher et al., 2012), in which deficits in the performance on the task have been detected even by the age of 8 years old (Niarchou et al., 2013). The Digit Symbol-Coding task employs a wide range of cognitive abilities and has not been linked to specific changes in brain structures (Groth-Marnat and Baker, 2003). It has been found to be severely impaired in individuals with psychosis (González-Blanch et al., 2010) and has been proposed to mediate other cognitive deficits. The predictive value of this task has led to the suggestion for it to be used in isolation as a screener tool to detect global cognitive impairment in schizophrenia (González-Blanch et al., 2010).

4.3. Transient and persistent PE

As this study has shown, deficits shown by the PE group overall are not necessarily driven by those with persistent PE. The clinical significance of PE during adolescence is becoming more evident. Involving the same cohort as the present research, Healy et al. (2018) demonstrated that young people with a history of PE during their adolescence had consistently poorer functioning during adolescence and early adulthood, both in terms of current and most severe past on the Global Assessment of Functioning (GAF) scale. Further, Kelleher et al. (2015) found that young people with PE have poorer global functioning than those who do not have PE, and this remains even when compared with other young people with psychopathology (but who do not have PE). Kelleher et al. (2015) also reported that certain cognitive domains, including processing speed, moderate the relationship between PE during adolescence and adolescent functioning, but do not fully mediate the relationship.

4.4. Strengths, limitations and future directions

Strengths of our research include the provision of full interviews given to all participants and consensus meetings to evaluate all PE. Further, to repeat the assessment at T2 and T3 was aimed to address persistence of the PE, as Van Os et al. (2009) proposed that 75–90% of developmental PE are transitory and disappear over time. The inclusion of our participants has ruled out the typical confounds present in psychosis cohorts such as medication, which to our knowledge, none of the participants were taking any antipsychotic medication at the times of their assessments.

Limitations of the research include a relatively small sample size, with the ratio of PE overestimated relative to prevalence estimates in the general population for this age range (Healy et al., 2018) The small sample size reduced the scope of what could be deduced from subdividing transient and persistent PE. Future directions of research

Table 3
Changes in motor and neuropsychological performances over time in the PE group and healthy control group.

Test	Time (*p*-value)	Group differences *F* (*p*-value)	Partial Eta Squared
The Purdue Pegboard	.07	**3.91 (.05)**	0.07
BACS- SC	**.01**	**4.78 (.03)**	0.09
TMT-A	**.03**	0.13 (.72)	0.09
TMT-B	**.01**	0.01 (.94)	0.13
WMS-Spatial Span	.79	0.09 (.91)	0.00

Partial Eta Squared (for time): measure of effect size at T3 for all subtests, where 0.01 is considered small, 0.09 is considered moderate and 0.25 is considered large. Emboldened metrics denote significant differences ($p < .05$).

in this area should consider larger numbers of both persistent and transient PE, in order to detect unique neuropsychological and motor changes in both groups. We also acknowledge that our PE are defined by positive symptomology, and future research is needed to investigate the relationship between negative symptomology and both motor and neuropsychological functioning.

Contributors

Authors N. Dooley and D. Gillan advised on the content of the paper, authors M. Clarke, H. Coughlan and C. Healy were involved in the data collection and assessment of participants, author I. Kelleher began the research at initial screening and baseline assessment and author M. Cannon is the principal investigator of this project.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.schres.2018.08.014.

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