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Evaluating Everyday Prospective Memory in School-Age Children through Parent- and Self-Reports: Validating Questionnaires and Examining Relations to Executive Functions and Autistic Traits

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ABSTRACT: Prospective memory (PM) refers to the ability to remember to complete everyday tasks, and in adults, PM is often assessed using the Prospective and Retrospective Memory Questionnaire (PRMQ). However, this questionnaire has not been validated in children, and whether it is effective in detecting subtle PM and retrospective memory (RM) difficulties in subclinical populations remains unclear. Study 1 first validated the parent-reported PRMQ for children (PRMQC-p) and developed a self-reported version (PRMQC-s), and Study 2 examined the relationships among PM, executive functions, and autistic traits using parent-reported questionnaires. The study recruited 1127 children aged 6–12 years and their parents. Parents completed questionnaires assessing PM, executive functions, and autistic traits, while children completed the PRMQC-s. Confirmatory factor analysis indicated that both versions of PRMQC showed good reliability and supported the PM-RM correlated factor model. Preliminary norms were generated to allow quick evaluation of children's everyday PM and RM performance. Importantly, higher autistic traits were associated with more frequent PM errors and executive functions completely mediated this relationship. These findings suggest that the PRMQC is a valid and useful tool for evaluating children's everyday PM performance and emphasizes the critical role of executive functions in daily PM.

Keywords: Prospective memory; Executive functions; Autistic traits; Childhood; Self reports

1. Introduction

Throughout lifespan, people face the challenges of remembering to complete their daily tasks [1], which requires a unique cognitive function known as prospective memory (PM) [2,3]. PM ability emerges around 2 to 3 years [4–6], continues to develop during childhood [7], peaks around late adolescence or early adulthood [8,9], and then decreases gradually toward old age [10,11].

Given that PM failures, such as forgetting to take medicine, might cause serious consequences in elderly people, large parts of PM research have focused on investigating the aging process of PM [12]. In order to assess daily PM in adults, especially in older adults, several types of self- or proxy-reported questionnaires have been developed [13–16]. Among these questionnaires, the most frequently used in the past decade was the Prospective and Retrospective Memory Questionnaire (PRMQ) [16,17]. It consists of 16 items [16], each stating a common retrospective memory (RM) (e.g., Do you fail to recognize a place you have visited before?) or a prospective memory (PM) error (e.g., Do you decide to

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do something in a few minutes and then forget to do it?) in everyday life, and individuals evaluate the frequency of the error using a five-point Likert scale (1 = never, 2 = rarely, 3 = occasionally, 4 = sometimes, 5 = often). Early factor-analysis findings suggested that the bifactor model[1] best explains the PRMQ, *i.e.*, a general memory factor (GM) and two specific factors (PM and RM) [18,19]. However, other studies suggested a single-factor (GM) model [20] and a PM-RM correlated factor model [21,22]. A recent study indicates the PRMQ is suitable for individuals from age 13 to 96 years old [22].

Given the popularity of the PRMQ, researchers began to develop a parent-rating version to evaluate everyday PM in children, namely, the Prospective and Retrospective Memory Questionnaire for Children (PRMQC). Kliegel and Jäger (2007) [4] modified the personal pronoun (changing "they" to "your child") in the adult version of the PRMQ, and found this version had acceptable reliability in a small sample, including 88 parents of 2- to 6-year-old preschool children. Talbot and Kerns (2014) [23] further adapted the items to everyday scenarios of school-age children. In a small sample of 69 parents of 8- to 13-year-old children (including typically developing children and children with Attention-Deficit/Hyperactivity Disorder, ADHD), the parent-reported PRMQC showed good reliability and provided preliminary evidence for external validity (*i.e.*, moderate correlations with computer-based PM performance). Moreover, parents of children with ADHD reported more PM errors in their children than parents of typically developing children. Although previous studies based on small samples suggest that the parent-reported PRMQC represents a reliable tool that is also sensitive for detecting PM errors in children with neurodevelopmental disorders, more formal validations in larger samples are still lacking. Further, it is currently unknown whether such a questionnaire relies on parent-reports or whether directly asking children about their PM and RM through self-reports would lead to similar results.

Notably, the adult version of the PRMQ is not only used in clinical patients (e.g., traumatic brain injury, dementia, schizophrenia) but also frequently used in subclinical populations (e.g., mild cognitive impairment, schizotypal personality disorder) [17]. As aforementioned, the parent-reported PRMQC is sensitive for detecting PM failures in children with ADHD [23]. However, it remains unclear whether it is also useful for detecting subtle PM difficulties in subclinical populations. For instance, Autism spectrum disorder is a neurodevelopmental disorder, with social dysfunction and repetitive behaviors as core symptoms [24]. Autistic symptoms show a continuous severity gradient in the general population, and individuals with milder autism symptoms and below the diagnostic criteria are considered to have high autistic traits [25]. Using the PRMQ, adults diagnosed with autism reported experiencing more PM and RM difficulties in daily life compared with non-autistic peers [26,27]. Using parent-reported PRMQC, children with higher versus lower autistic traits were similar in the amount of PM and RM errors [28]. However, the sample size of this study was small, and the findings required replication in a larger sample.

Moreover, previous research has indicated that people diagnosed with autistic spectrum disorders tend to show worse performance in lab-based PM tasks, which is suggested to reflect deficits in executive functions (EF) [29,30]. EF is defined as a range of processes that guide, direct cognitive, behavior and emotional functions and help individuals to achieve specific goals or solve certain problems [31]. Research has shown that children with higher autistic traits also experience difficulties in EF [32,33], and because EF is closely related to PM in children [34], they might also show difficulties with PM tasks. Therefore, it is worth further investigating the relationships between autistic traits, EF and PM in a larger sample. Clarifying these relationships may help recognize potential PM difficulties and develop targeted intervention programs for children with higher levels of autistic traits.

The PRMQC is a potentially valuable tool for assessing PM, but the parent-reported version requires further validation in a large sample. So far, there has been no self-reported version for school-age children. Additionally, previous evidence suggests that higher levels of autistic traits may be linked to increased errors of EF and PM in daily life, but these relationships have so far not been systematically examined. Therefore, the present research aimed to validate the parent-reported PRMQC and to develop a self-reported version in school-age children (Study 1). Using the validated PRMQC, we further aimed to examine the relationships between autistic traits and PM, and the potential mediating role of EF in this relationship (Study 2). This investigation would also help examine the sensitivity of PRMQC in detecting potential PM difficulties in subclinical populations.

2. Study 1

2.1. Translation and Validation of the PRMQC

The validation process followed the procedure for adapting the PRMQ [22]. First, permission to adapt the parent-reported PRMQC from English to Chinese was obtained from the original author of the previous study [23]. Second, two experienced researchers evaluated the items' cultural relevance and content validity and found most items were

suitable for the Chinese context except for item 9. This item, "Does your child repeat the same story to the same person on different occasions?" was designed to detect memory errors, but the behavior described in the item might also occur because children enjoy telling the same story repeatedly. Therefore, a new item with less ambiguity ("Does your child ask someone a question and ask it again when seeing them later?") was developed to form a 17-item version. Third, a researcher with a psychological background and proficiency in both English and Chinese translated the questionnaire from English into Chinese. The other researchers with similar backgrounds translated it back into English and discussed and solved inconsistencies. For the self-reported PRMQC, the parent-reported version (17-item) was adapted by replacing the phrase "your child" with "you".

In order to evaluate the contextual relevance and linguistic clarity of the items, a pilot test on the parent- and self-reported PRMQC was conducted in a sample of 12 children aged from 6 to 11 years and their parents. According to the parents, most items were common in children's daily lives and were clearly expressed except for item 13. Parents found it difficult to judge this item ("Does your child look at something without realizing he/she has seen it moments before?"). Therefore, a new item was developed, "Does your child ever do something but cannot remember if he or she has done it after a while?". Because children might watch entertainment on other devices (e.g., tablet, mobile phone), the word "television" in item 15 ("Does your child forget what he/she watched on television?") was changed to "cartoon". Parents of younger children from 6 to 8 years old also pointed out their difficulty of understanding frequency words such as "rarely" and "occasionally", and thus, a frequency diagram with dots representing response options was added. As some children reported difficulty in understanding some items, the expressions of these items were slightly adjusted, with the content remaining the same.

After these revisions, both the parent-reported and self-reported PRMQC comprised of 18 items. Each item described a PM or RM error of children in their daily lives. Parents rated the frequency of their children committing each memory error using a 5-point Likert scale (1 = never, 2 = rarely, 3 = occasionally, 4 = sometimes, 5 = often). Children rated the frequency of themselves committing each memory error, using the same 5-point Likert scale as parents, but with the aid of frequency diagrams. The finalized questionnaires are presented in Appendices A and B.

2.2. Participants and Procedure

The study was approved by the Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences (H20033). Written consent was obtained from all participating parents or caregivers. The children completed the printed self-reported version of the PRMQC (18 items) in class, with two experimenters giving instructions and providing assistance. The children took the parent-reported PRMQC home for their parents/caregivers to complete and brought them back to their teachers.

A total of 1127 pairs of parents and children from age 6 to 12 years were recruited from a primary school in China. The common exclusion criteria for the parent-reported and the self-reported PRMQC included: (1) the parent reported his/her child had a history of neurological diseases, developmental disorders, or mental illness; (2) two or more items of the PRMQC were missing. In addition, the parent-reported questionnaire was also considered invalid if it was not completed by parents (e.g., grandparents, uncles, aunts) or if parents reported they were not familiar with child's daily life. Based on these criteria, the final valid sample included 938 parent-reported questionnaires and 941 self-reported questionnaires. Their demographic information is presented in Table 1.

Two weeks later, a total of 80 pairs of children and their parents were invited again to complete the PRMQC questionnaires again. Given that the research was conducted during the COVID-19 period, the retest sample was a convenient sample. The child participants were from two classes and were between 8 and 11 years old. The inclusion and exclusion criteria remained unchanged, with an additional requirement: the same parent had to complete the questionnaire in both the initial test and the retest sessions.

Table 1. The demographic information and the PRMQC scores in Study 1.

Demographic Information and PRMQC Scores	*N*	*Means*	*SD*
Parent-reported questionnaire			
Age of children (range: 6 to 12 years) [a]	924	9.13	1.74
Sex of children (males:females) [a]	484:438		
Age of parents [a]	914	36.08	5.03
Sex of parents (males: females) [a]	323:612		
Education years of parents [a]	866	10.10	3.22
PM score (range: 8 to 40)	938	15.89	5.07
RM score (range: 8 to 40)	938	14.41	4.68
Self-reported questionnaire			
Age of children (range: 7 to 12 years) [a]	921	9.51	1.51
Sex of children (males:females) [a]	488:438		
PM score (range: 8 to 40)	941	14.90	4.88
RM score (range: 8 to 40)	941	14.61	4.81

PRMQC = Prospective and Retrospective Memory Questionnaire for Children, PM = Prospective memory, RM = Retrospective memory. [a] The variable has missing data.

2.3. Data Analysis

The data were entered using EpiData software, and 10% of the questionnaires were randomly selected for verification. As the questionnaires with less than 2 items missing were considered valid, the missing values of the items in these questionnaires were replaced by series means. As the original items 9 and 13 were found to be confusing or difficult for parents to judge, they were replaced by items 17 and 18, resulting in a revised 16-item version. All subsequent statistical analyses were conducted based on this revised 16-item version.

Three typical structural models of PRMQC were tested using CFA with Mplus 7.0. The single-factor model assumed a single factor reflecting the overall memory function of an individual. The PM-RM correlated factor model assumed the questionnaire comprised of two related factors (*i.e.*, PM and RM). The bi-factor model contained a general memory factor comprising all items and two specific and orthogonal factors (*i.e.*, PM and RM, no correlation). We used the WLSMV (weighted least squares mean and variance adjusted estimation) method to estimate the parameters of the models. The fitting index included χ^2, CFI (comparative fit index), TLI (Tucker-Lewis index) and RMSEA (root mean square error of approximation). χ^2 reflects the fit between the tested model and the theoretical hypothesis model, but this index needs to take account the sample size and normality of the data. The criteria for a reasonable model were CFI ≥ 0.90, RMSEA ≤ 0.08, and TLI ≥ 0.90 [35,36]. Based on the results of structural models of the PRMQC, the preliminary norms for the PRMQC were generated using the method described in a previous study [18].

The internal consistency was assessed by calculating Cronbach's α coefficients for the questionnaire. The test-retest reliability was assessed using the Pearson correlation analysis.

The relationships between children's age and PRMQC scores (both parent-reported and self-reported versions) were examined using the Pearson correlation analyses. Gender differences in the PRMQC scores were assessed using the independent samples *t*-tests. Additionally, we evaluated the association between the parent-reported and self-reported PRMQC scores using the Pearson correlation. To further explore developmental patterns, we divided the sample into a younger group (7–9 years) and an older group (10–12 years) and repeated the correlation analyses within each subgroup. The Fisher's Z-tests were used to compare the strength of correlations between the two age groups. All statistical tests (except for Fisher's Z-test) employed Bonferroni correction for multiple comparisons ($\alpha = 0.025$, $k = 2$).

2.4. Results

2.4.1. Confirmatory Factor Analysis

CFA results of both versions are presented in Table 2. In both versions, the bi-factor model showed negative loads for specific items, suggesting anomalies of the model and that it should not be adopted. For the parent-reported PRMQC, the Chi-square test revealed no significant difference between the single factor model and the PM-RM correlated factor model ($\Delta\chi^2 = 3.62$, $p = 0.057$). For the self-reported PRMQC, the Chi-square test revealed significantly smaller χ^2 the PM-RM correlated factor model than the single factor model ($\Delta\chi^2 = 12.93$, $p < 0.001$). Compared with the single factor model, the PM-RM correlated factor model allows the assessment of both PM and RM factors. Therefore, the PM-RM

correlated factor model was selected as the best model for both parent- and self-reported PRMQC, and the factor loadings are presented in the supplementary materials (Figure S1).

In both versions, the PM and RM scores were calculated by summing up the items associated with PM and RM. The means (and standard deviations) of parent- and self-reported PM and RM scores are presented in Table 1. The preliminary norms for both versions are developed, and the tables for converting the PM and RM raw scores to T scores are presented in the supplementary materials (Table S1).

Table 2. Models and fit indices of the parent- and self-reported PRMQC.

PRMQC Versions	Models	*Chi-Square*	*df*	*CFI*	*TLI*	*RMSEA*	*Factor Loadings*
				≥0.90	**≥0.90**	**≤0.08**	**0.50–0.95**
Parent-reported (N = 938)	Single factor model	636.64	104	0.924	0.913	0.074	0.48–0.71
	PM-RM correlated factor model	**633.02**	**103**	**0.925**	**0.912**	**0.074**	**0.48–0.71**
	Bi-factor model	375.30	88	0.959	0.944	0.059	−0.17–0.72
Self-reported (N = 941)	Single factor model	291.06	104	0.968	0.963	0.044	0.34–0.72
	PM-RM correlated factor model	**278.13**	**103**	**0.970**	**0.965**	**0.043**	**0.35–0.73**
	Bi-factor model	148.08	88	0.990	0.986	0.027	−0.32–0.72

PRMQC = Prospective and Retrospective Memory Questionnaire for Children; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; RMSEA = Root Mean Square Error of Approximation; PM = Prospective memory; RM = Retrospective memory. The best models are in bold.

2.4.2. Reliability

In the parent-reported PRMQC, the Cronbach's α for the PM scale (8 items) and the RM scale (8 items) were 0.77 (CI: 0.75–0.79) and 0.75 (CI: 0.72–0.77), respectively. In the self-reported PRMQC, the Cronbach's α for the PM scale (8 items) and the RM scale (8 items) were 0.73 (CI: 0.70–0.75) and 0.74 (CI: 0.71–0.76).

The valid test-retest sample included 62 pairs of children and their parents. For the parent-reported PRMQC, the correlations were moderate for both the PM scale (r = 0.43, p < 0.001) and the RM scale (r = 0.49, p < 0.001). The self-reported PRMQC demonstrated good consistency for both the PM scale (r = 0.63, p < 0.001) and the RM scale (r = 0.63, p < 0.001).

2.4.3. The Effects of Children's Age and Sex on the PRMQC Scores

In the parent-reported PRMQC, children's age was not significantly correlated with either the PM score (r = 0.05, p = 0.119) and RM score (r = 0.02, p = 0.549). The parent-reported PM scores for boys and girls were 15.81 (SD = 4.96) and 15.98 (SD = 5.21), respectively, and there was no significant sex difference (p = 0.604, *Cohen's d* = 0.03). The parent-reported RM scores for boys and girls were 14.12 (SD = 4.48) and 14.76 (SD = 4.90), with lower scores in boys than in girls (p = 0.038, *Cohen's d* = 0.14), but this difference was no longer significant after Bonferroni correction.

In the self-reported PRMQC, children's age significantly correlated with the PM score (r = 0.14, p < 0.001), but not with the RM score (r = 0.03, p = 0.442). The PM scores for boys and girls were 14.58 (SD = 4.55) and 15.22 (SD = 5.23), respectively, with higher scores in girls than in boys (p = 0.046, *Cohen's d* = 0.13), but this difference was no longer significant after Bonferroni correction. The RM scores for boys and girls were 14.38 (SD = 4.81) and 14.86 (SD = 4.84), with no significant sex difference (p = 0.125, *Cohen's d* = 0.10).

2.4.4. The Relationships between the Self- and Parent-Reported PRMQC

There were 844 pairs of parents and children who completed PRMQC. The correlations between the child and parent reports were significant, both for the PM score (r = 0.40, p < 0.001) and for the RM score (r = 0.36, p < 0.001). Children were further divided into a younger group (7 to 9 years old, N = 416) and an older group (10 to 12 years old, N = 416). The self-parent correlations were significantly higher in the older group compared with the younger group; this was evident in both the PM score (younger: r = 0.28, older: r = 0.48; Z = 3.38, p < 0.001) and the RM score (younger: r = 0.25, older: r = 0.46; Z = 3.47, p < 0.001). These results remained significant after Bonferroni corrections.

2.5. Discussion

Study 1 validated the previously developed parent-reported and newly developed self-reported PRMQC in a large sample of school-age children and their parents. Results suggest that the PM-RM correlated factor model is the best

model for both versions, which is consistent with the optimal model of the Chinese PRMQ for adults [22]. Moreover, it had acceptable reliability (Cronbach's $\alpha \geq 0.7$), indicating acceptable reliability of the model. However, only children older than 7 years were able to complete the questionnaire, suggesting that parent-reports are more suitable for children under age 7.

In addition, the child and parent reports of the PRMQC showed moderate correlations ($r = 0.40$ for PM, $r = 0.36$ for RM). A recent study [37] recruited children and adolescents aged 5–18 years, along with their parents, to report on the daily memory functioning of the children and adolescents. The results revealed two common factors of the parent- and child-reported versions, and the parent-child correlations on these factors varied in size ($r = 0.68$ for "forgetting", and $r = 0.19$ for "remembering"). These findings suggest that the questionnaire taps a similar construct of the parent and child version but also indicates that children and parents may have different access to children's internal memory processes. Indeed, for memory questionnaires with both child- and parent-reported versions, parents and children share a common awareness of children's daily memory errors, but each informant also offers unique perspectives. For example, parents and children may demonstrate stronger agreement regarding memory failures at home (e.g., forgetting household chores) compared to those at school (e.g., failing to bring required materials), reflecting differences in observation opportunities and situational awareness. Interestingly, we noticed the child-parent correlations in PM and RM scores were larger in the older children group (age 10–12) than the younger children group (age 7–9), which may reflect the development of metacognitive ability in school-age children [38]. As children grow older, they become familiar with memory tasks and have more experience with memory failures, which raises their awareness and retrieval of daily memory errors.

In the parent-reported PRMQC, children's age did not correlate with daily PM error, which is consistent with a previous study using a different parent-reported questionnaire (*i.e.*, CEMQ) to measure school-age children's daily PM [39]. In the self-reported PRMQC, age significantly correlated with self-reported PM, showing that older children reported more PM errors than younger children. On the one hand, the finding may reflect children's increased awareness of daily PM errors as their metacognitive ability increases [38], or the demand for daily PM tasks is more likely to exceed children's PM abilities as they grow older. On the other hand, the correlation was relatively small ($r = 0.14$). Thus, the relationship between age and self-reported PM errors in children requires replication and should be interpreted cautiously.

In terms of the sex effect on PM in typically developing children, previous studies using laboratory-based PM tasks indicated mixed results [7,40–43]. In the present study, both parents and self-reported ratings suggest that boys and girls committed similar amounts of PM errors in everyday life. This finding also suggests that both versions of the PRMQC were not biased in evaluating the daily PM functions of males and females. In a large adult sample between 18 and 59 years old, there was a trend that females reported more PM errors than males [22], which is probably related to females maintaining more PM intentions for family members [44]. Future research may consider investigating sex effects on daily PM across the lifespan.

3. Study 2

In this study, we examined the relationships between daily PM, EF, and autistic traits in school-age children. We hypothesized that higher levels of autistic traits would be associated with more EF difficulties and more frequent PM errors and that EF would mediate the relationship between autistic traits and PM.

3.1. Method

3.1.1. Participants

Participants were the parents in Study 1, who met the same inclusion and exclusion criteria of Study 1. In addition, according to the previous study and scoring manual, the parents who had more than 5 missing items in the AQ-Child questionnaire [45], or more than 14 missing items in the Behavior Rating Inventory of Executive Function (BRIEF) [46], were further excluded. The final valid sample included 837 parents of children aged 6 to 12 years (see Table 3 for demographic information).

Table 3. The demographic information, the AQ-C, the BRIEF and the PRMQC scores in Study 2.

Demographic Information and Questionnaire Score	*N*	*Means*	*SD*
Age of children (range: 6 to 12 years)	837	9.09	1.75
Sex of children (males:females)	837	435:402	
Age of parents [a]	821	36.02	4.89
Sex of parents (males:females)	837	286:551	
Years of education (parents) [a]	782	10.16	3.19
AQ (range: 0 to 150)	837	64.82	10.19
BRIEF total score (range: 72 to 216)	837	116.50	21.37
BRIEF-Inhibit (range: 10 to 30)	837	14.34	3.40
BRIEF-Shift (range: 8 to 24)	837	11.92	2.44
BRIEF-Emotion control (range: 10 to 30)	837	15.10	3.62
BRIEF-Initiate (range: 8 to 24)	837	12.89	2.87
BRIEF-Working memory (range: 10 to 30)	837	16.41	3.71
BRIEF-Plan/organize (range: 12 to 36)	837	20.16	4.48
BRIEF-Organize of Materials (range: 6 to 18)	837	10.68	2.85
BRIEF-Monitor (range: 8 to 24)	837	15.00	3.20
Parent-reported PRMQC (range: 16 to 80)			
PM (range: 8 to 40)	837	15.91	4.96
RM (range: 8 to 40)	837	14.41	4.61

PRMQC = Prospective and Retrospective Memory Questionnaire for Children; PM = Prospective memory; RM = Retrospective memory. AQ = The Autism-Spectrum Quotient for children; BRIEF = Behavior Rating Inventory of Executive Function. [a] The variable has missing data.

3.1.2. Materials

The parent-reported PRMQC validated in Study 1 was used. It included 16 items and two subscales (*i.e.*, PM and RM).

The BRIEF is a parent-reported questionnaire to assess everyday EF in 5–18 years old children [46]. The scale comprised 86 items and provided two composite indices. The behavioral regulation index consists of three subscales (*i.e.*, "inhibit", "shift", and "emotional control"). The metacognition index consisted of five subscales (*i.e.*, "initiate", "working memory", "plan/organize", "monitor", "organization of materials"). Parents rated each item on a 3-level scale: 1 = never, 2 = sometimes, and 3 = often. Higher scores indicate more EF problems in everyday life, and the total score ranges[2] from 72 to 216. The Chinese version of the BRIEF showed acceptable reliability, with Cronbach's α between 0.61–0.96 [47].

The AQ-child is a parent-reported questionnaire to quantify autistic traits in children aged 4 to 11 years [45]. The AQ child version consists of 50 items, and is comprised of four domains of autistic traits (*i.e.*, social skills, attention to detail, mind-reading, and imagination). The parents rated children's behaviors on a 4-point Likert scale (*i.e.*, 0 to 3), with higher scores indicating more autistic traits. We used the Mandarin version, which was translated from the Cantonese Hong Kong version[3]. As the domains of the AQ varied across different versions, we only used the total score to represent autistic traits (range: 0–150), and the Cronbach's α for Chinese version was 0.81 [48].

3.1.3. Data Analysis

First, missing values in the questionnaires were replaced. The missing values in the PRMQC were replaced by series means. According to the scoring manual of the BRIEF [31], the missing value was replaced using "1". According to the method in the previous study [45], the missing values of AQ-C were replaced using the mean scores of the rest items. Second, the Pearson correlational analyses with Bonferroni corrections were employed to explore their relationships. Based on the correlational results, the mediating effects of overall EF and its components (*i.e.*, the BRIEF scores) in the relationship between AQ-C and PRMQC-PM were analyzed using the Bootstrap method with 5000 random samples. The path coefficients, total effect size, direct effect size and indirect effect size were calculated to quantify these effects. All analyses were conducted using the Jamovi 1.6.15.0 (www.jamovi.org).

3.2. Results

The descriptive results of the parent-reported PRMQC-PM scores, the BRIEF scores and the AQ scores are presented in Table 3. The AQ total score significantly correlated with the BRIEF total score ($r = 0.23$, $p < 0.001$) and the PRMQC-PM score ($r = 0.17$, $p < 0.001$). The correlation between the BRIEF total score and the PRMQC-PM score was also significant ($r = 0.56$, $p < 0.001$). The correlations among the BRIEF component scores, the AQ and the PRMQC-PM scores are presented in the supplementary materials (Table S2). After Bonferroni corrections, all the BRIEF component scores were significantly correlated with the PRMQC-PM scores (all p values < 0.05). Most BRIEF component scores were correlated significantly with the AQ total score (all p values < 0.05) except for the "organization of materials" and "monitor" components (both p values > 0.05), and the two components were not included as mediators in the subsequent analyses.

The mediating effects of EF in the relationship between autistic traits and PM are shown in Figure 1.

As shown in Figure 1A, autistic traits significantly predicted the BRIEF total score (a = 0.23, $p < 0.001$) and the PRMQC-PM score (c = 0.17, $p < 0.001$). When the link between the EF and PM was added (c = 0.55, $p < 0.001$), autistic traits no longer predicted PM (c' = 0.04, $p = 0.175$). The EF was a complete mediator between the relationship of autistic traits and PM ($\beta = 0.130$, 95% CI: [0.09, 0.17], $p < 0.001$), and the indirect effect size accounted for 76.2% of the total effect. The mediation effects of different EF components in the relationships between autistic traits and PM are presented in Figure 1B–G. Similar to the EF total score, the component "initiate" had a complete mediation effect (β = 0.14, 95%CI: [0.10, 0.18], $p < 0.001$), explaining 81.5% of the total effect. The other EF components all had partial mediation effects, with "inhibit" explaining 47.8% of the total effect (β = 0.08, 95%CI [0.05, 0.11], $p < 0.001$), "shift" accounting for 59.8% of the total effect (β = 0.10, 95%CI: [0.07, 0.14], $p < 0.001$), "working memory" explaining 58.3% of the total effect (β = 0.10, 95%CI [0.06, 0.14], $p < 0.001$), "plan/organize" accounting for 44.1% of the total effect (β = 0.07, 95% CI: [0.04, 0.11], $p < 0.001$), and "emotional control" explaining 53.7% of the total effect (β = 0.09, 95%CI [0.06, 0.12], $p < 0.001$).

3.3. Discussion

Study 2 examined the relationships between PM, EF, and autistic traits based on parents' reports. First, results showed that there was a positive and moderate correlation between EF and PM in this sample, supporting the close relationship between everyday EF and PM in school-age children. This finding is consistent with behavioral research [49,50] and renders support for theoretical frameworks that highlight the importance of EF for PM development [1,34].

Second, consistent with our hypothesis, a small but significant relationship existed between autistic traits and PM errors in school-age children. Specifically, parents of children with higher levels of autistic traits reported that their children committed more PM errors in everyday life. Previous research has indicated significant PM impairment in children and adolescents diagnosed with autism spectrum disorders [51,52], and the current finding thus extends PM difficulty from the clinical population to subclinical individuals. In addition, parents of children with higher levels of autistic traits reported their children having more EF problems in daily life, consistent with previous findings showing that the level of autistic traits predicted EF in 8 to 14 year-old individuals [33].

More importantly, the mediation analysis suggests that children's overall EF completely mediated the relationship between autistic traits and PM, with an indirect effect accounting for 76.2% of the total effect. This finding highlights the role of EF in mediating the link between autistic traits and PM, suggesting EF may act as a bridge between autistic traits and PM. Children with higher levels of autistic traits tend to have more EF problems, which further increases PM errors in daily life. In detail, the component "initiate" had the largest mediation effect in the relationship between autistic traits and PM. The "initiate" component reflects the ability to independently begin an activity and generate ideas, responses and strategies [31]. Initiation plays an important role in priming the intended intention in order to complete the action. The current finding suggests the difficulty of initiation might be a major obstacle for children with higher levels of autistic traits when they are completing PM tasks; these children may not completely forget a PM task but struggle to start it. The other EF components such as "inhibit", "switch", "working memory", "plan/organize" and "emotional control" all partly mediated the relationship between autistic traits and everyday PM in school-age children, suggesting they also contribute to daily PM errors in children with a higher level of autistic traits.

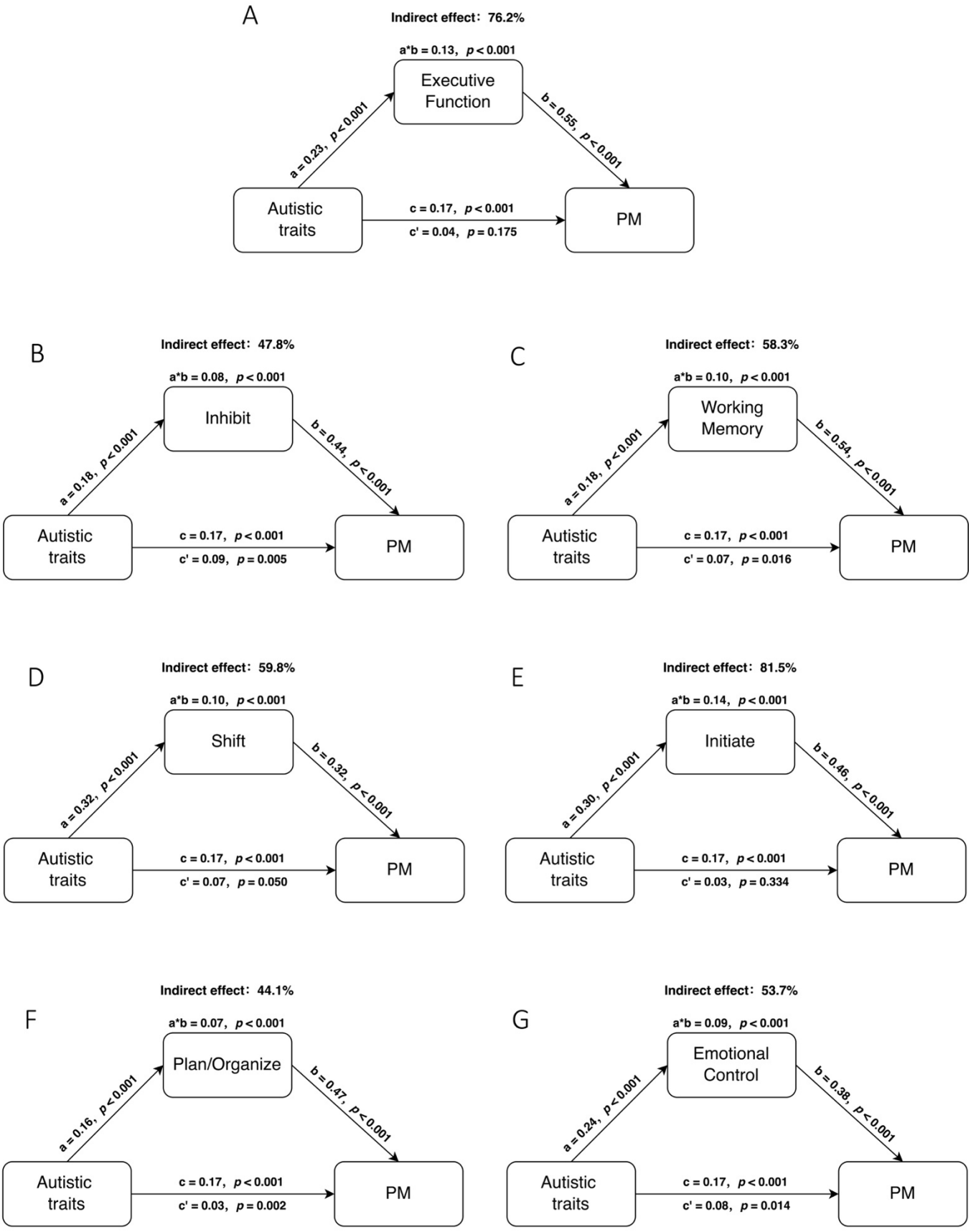

Figure 1. (**A**): Path diagrams of the BRIEF total score as a mediatior between autistic traits and PM. (**B**–**G**): Path diagrams of the BRIEF subscale scores (*i.e.*, inhibit, working memory, shift, initiate, plan/organize, emotional control) as mediators between autistic traits and PM. PM = Prospective memory. Indirect effect (a*b), direct effect (c'), total effect (c), path coefficient (a, b).

4. General Discussion

In the present study, we validated the parent-reported PRMQC and developed a self-reported PRMQC in a sample of school-age children and their parents. Both versions supported the PM-RM correlated factor model and demonstrated good reliability. Using the newly validated parent-reported PRMQC, we further revealed the relationships between PM, EF, and autistic traits. Specifically, higher level of autistic traits was related to worse EF and PM, and EF mediated this relationship.

An important contribution of the present study is validating the parent-reported version of the PRMQC and developing the self-rating version. The findings in a large sample suggest that both versions supported the PM-RM correlated factor model and showed good psychometric properties. Moreover, the PRMQC comprised only 16 items, and together with the preliminary norms, it could allow quick evaluation of everyday PM and RM in school-age children. To the best of our knowledge, most evaluations of children's PM abilities took place in laboratory, and there was no self-reported questionnaire to evaluate daily PM of school-age children [53]. In the present study, children aged between 7 and 12 years could estimate the frequency of their daily memory mistakes, and their self-ratings were moderately correlated with parents' ratings. These findings suggest the self-reported PRMQC serves as a valid tool.

Using validated parent-reported PRMQC, we further revealed the relationships among autistic traits, EF and PM in school-age children. Importantly, in this larger sample, children with higher autistic traits were found to commit more PM errors and experience more EF difficulties in daily life, based on the observation of parents. This discovery is crucial because the cognitive difficulties in children diagnosed with autism might be well-noticed whereas the cognitive challenges of subclinical populations are often overlooked. Therefore, the current findings emphasize the necessity for caregivers to pay attention to the more frequent memory failures that these children might experience in their everyday lives. Frequent PM failures might impair children's peer relationships and school performance and even impact teachers' evaluations of their academic performance [54]. When parents and teachers are aware of these children's EF and PM difficulties, they will provide further support to increase their PM performance in everyday life.

Critically, the present research further revealed that the relationship between autistic traits and PM is completely mediated by EF. In other words, relatively weaker EF of children with more autistic traits might impede the cognitive process of PM and reduce the chance of completing the prospective task. The mediation analysis suggests that the ability to initiate among the different types of EF seems particularly important. These findings thus imply that EF (especially "initiation" component) can be a target for future interventions in children with higher autistic traits. In fact, a recent research has demonstrated the effectiveness of EF training in improving PM performance in 8 to 12 years old children [55], and future research may test whether EF training is particularly beneficial for children with higher autistic traits. As PM abilities are important for children's independence, academic achievement, social relationships, enhanced PM abilities may have far-reaching effects in children with higher levels of autistic traits.

The study has several limitations. First, the study was conducted during COVID-19 period; therefore, participants were recruited from a single school, which may limit the representativeness of the sample. Second, a cross-sectional design was used to examine the relationships among autistic traits, EF, and PM. This approach does not allow for determining longitudinal or causal relationships among these variables. Longitudinal studies are needed in the future to explore these associations in greater depth.

Despite these limitations, the present study provides a valuable tool for evaluating children's everyday PM performance. Specifically, the PRMQC comprises the self-reported and parent-reported versions, allowing the researchers to make flexible choices based on their research goals. As each version of the PRMQC offers a slightly different perspective on children's daily memory errors, employing both versions can yield a more comprehensive assessment of children's everyday PM. Moreover, the current findings reveal a connection among autistic traits, EF and PM in typically developing children, highlighting the sensitivity of the parent-reported PRMQC in detecting children's subtle daily-life memory difficulties. Further, previous research has indicated that the parent-reported PRMQC is effective in identifying increased daily PM failures in children with ADHD [23]. Collectively, these findings suggest that the PRMQC is not only useful for screening memory difficulties in typically developing children but may also serve as a valuable tool for clinical research.

5. Conclusions

Both parent-reported and self-reported versions PRMQC supported the PM-RM correlated factor model and showed acceptable reliability, and the preliminary norms allow quick evaluation of daily PM abilities in school-age children aged 6 to 12. Higher levels of autistic traits in school-age children are associated with more difficulties in EF and more frequent PM failures in daily life. Crucially, children's EF ability mediated the relationship between autistic

traits and daily PM performance, suggesting EF could be a target for intervention on PM in children with higher levels of autistic traits.

Supplementary Materials

The following supporting information can be found at: https://www.sciepublish.com/article/pii/507, Figure S1: The PM-RM correlated factor model for the Chinese version of self-reported and parent-reported PRMQC; Table S1: Converting raw scores on the PRMQC PM and RM scale to T scores; Table S2: The correlations among the BRIEF, AQ and PM scores in Study 2.

Appendix A

Parent-reported version of the Prospective and Retrospective Memory Questionnaire for Children (PRMQC-p) (In English and Chinese)

The following statements refer to minor memory mistakes that every child makes from time to time. For each statement, we would like you to tell us how often these minor errors happen to your child. Please circle the option that most closely matches your child's real situation. Rate your responses as follows:

1 = never 2 = rarely 3 = sometimes 4 = quite often 5 = very often

下面的问题涉及一些记忆小错误， 这些错误每个孩子都会有。我们希望您能告诉我们这些小错误发生在您孩子身上的频率有多高，请在与您孩子真实情况最相符合的选项上画圈。

1 = 从来不 2 = 很少 3 = 偶尔 4 = 有时 5 = 经常

	Items 条目	Never 从来不	Rarely 很少	Some-times 偶尔	Quite Often 有时	Very Often 经常
1	Does your child decide to do something in a few minutes' time and then forget to do it? 您的孩子决定在几分钟内去做某件事情，是否会转个身又忘记了？	1	2	3	4	5
2	Does your child fail to recognize a place he/she has visited before? 您的孩子是否会认不出一个他/她曾经到过的地方？	1	2	3	4	5
3	Does your child fail to do something he/she was supposed to do a few minutes later even though it's there in front of him/her, like turning off the TV or Gameboy or picking up his/her backpack before heading to school? 您的孩子是否会忘记去做某件他/她本该几分钟之后要做的事，即使事情就摆在他/她的面前，比如关掉电视或游戏或者去学校前带上他/她的书包？	1	2	3	4	5
4	Does your child forget something that he/she was told a few minutes before? 您的孩子是否会忘记别人在几分钟之前告诉过他/她的事情？	1	2	3	4	5
5	Does your child forget to get parent notices signed, or go to extracurricular activities if he/she is not prompted by someone else or by a reminder such as an agenda or planner? 您的孩子在没有他人提醒/记录本记录的情况下，他/她是否会忘记让父母在家长通知书上签字或参加课外活动？	1	2	3	4	5
6	Does your child fail to recognize a character in a book or television show from scene to scene? 您的孩子是否会认不出书本或者动画片场景中反复出现的同一个人物？	1	2	3	4	5
7	Does your child forget to either bring or turn in his/her homework that is completed? 您的孩子是否会忘记带或上交他/她已经完成的作业？	1	2	3	4	5
8	Does your child fail to recall things that have happened to him/her in the last few days? 您的孩子是否会忘记前几天在学校或者家里发生在他/她身上的事情？	1	2	3	4	5
9	Does your child repeat the same story to the same person on different occasions? 您的孩子是否会在不用场合把同一个故事讲给同一个人听？ **(This item was replaced by item 17 in the final PRMQC version)**	1	2	3	4	5
10	Does your child intend to take something with him/her before leaving a room or going out, but minutes later leaves it behind, even though it's there in front of him/her? 您的孩子是否本来打算在离开房间或出门时带件东西，但几分钟之后又忘记了，即使那样东西就放在他/她面前？	1	2	3	4	5
11	Does your child mislay something that he/she has just put down, like a book, a drink, or his/her jacket/sweater? 您的孩子是否刚刚放下他/她的某样东西却又不记得放在哪里了，比如一本书，一杯饮料或者他/她的外套/毛衣？	1	2	3	4	5
12	Does your child you forget to pass on a request from a teacher or give something to someone for a friend? 您的孩子是否会忘记转达老师的要求或者帮朋友转交东西给别人？	1	2	3	4	5
13	Does your child look at something without realizing he/she has seen it moments before? 您的孩子是否会没意识到他/她正在看的东西是刚刚看过的? **(This item was replaced by item 18 in the final PRMQC version after validation.)**	1	2	3	4	5
14	If your child tried to contact a friend or relative but they were out, would he/she forget to try again later? 您的孩子尝试联系某个朋友或亲人，如果暂时没有联系上，他/她之后是否会忘记重新联系他们？	1	2	3	4	5
15	Does your child forget the content of the cartoon he/she watched on television the previous day? 您的孩子是否会忘记前一天他/她看过的动画片内容？	1	2	3	4	5

16 Does your child forget to say something he/she had meant to mention a few minutes prior? **您的孩子是否会忘记他/她本应在几分钟前要说的事情？**	1	2	3	4	5
17 Does your child ask someone a question and ask it again when sees him/her later? **您的孩子是否会已经问过别人某个问题，过段时间见到她/他时又问了一遍？**	1	2	3	4	5
18 Does your child ever do something but cannot remember if he or she has done it after a while? **您的孩子是否会才做过某件事情，不一会儿却想不起来他/她是否做过？**	1	2	3	4	5

Appendix B

Self-reported version of the Prospective and Retrospective Memory Questionnaire for Children (PRMQC-s, In English and Chinese)

This is a questionnaire about your daily memory. These little memory mistakes can happen to every child. I hope you can tell us how often these mistakes happen to you. Frequency is how many times something happens over a period of time, represented here by the dots in the circle. More points indicate these mistakes happened to you more often (see chart below). You need to circle the corresponding text to indicate your selection.

这是一个有关你日常记忆情况的问卷，这些记忆小错误在每个小朋友身上都可能发生，希望你能够告诉我们，这些错误发生在你身上的**频率**有多高？频率代表事情在一段时间内发生的次数，这里用圆圈里的点数代表。点数越多，表示这些记忆错误发生的频率越高(见下图)。你需要在相应的文字上画圈，进行选择。

Never rarely sometimes quite often very often

1. Do you decide to do something in a few minutes, then turn around and forget?

   你决定在几分钟内去做某件事情，是否会转个身又忘记了？

2. Do you not recognize a place you have been to?

   你是否会认不出一个你曾经到过的地方？

3. Do you forget to do something you're supposed to do in a few minutes, even though it's right in front of you, like turning off the TV or game console, or taking your bag with you before school?

   你是否会忘记去做某件你本该几分钟之后要做的事，即使事情就摆在你面前，比如关掉电视或游戏机，或者去学校前带上你的书包？

4. Do you forget something someone told you a few minutes ago?

   你是否会忘记别人在几分钟之前告诉过你的事情？

5. Do you forget to ask your parents to sign newsletters or attend extracurricular activities without being reminded or kept in a notebook?
   在没有他人提醒或用记录本记录的情况下，你是否会忘记让父母在家长通知书上签字或参加课外活动？

6. Do you have trouble recognizing the same characters in books or cartoons over and over again?
   你是否会认不出书本或者动画片场景中反复出现的同一个人物？

7. Do you forget to bring or turn in homework that you have already completed?
   你是否会忘记带或上交你已经完成的作业？

8. Do you forget something that happened to you at school or at home the other day?
   你是否会忘记前几天在学校或者家里发生在你身上的事情？

9. Do you repeat the same story to the same person on different occasions?
   你是否会在不用场合把同一个故事讲给同一个人听？
   (This item was replaced by item 17 in the final PRMQC version)

10. Do you plan to take something with you when you leave your room or go out, but then forget it a few minutes later, even though it's right in front of you?
    你是否本来打算在离开房间或出门时带件东西，但几分钟之后又忘记了，即使那样东西就放在你面前？

11. Have you just put something down and you can't remember where you put it, such as a book, a drink or your coat/sweater?

你是否刚刚放下你的某样东西却又不记得放在哪里了，比如一本书，一杯饮料或者你的外套/毛衣？

12. Do you forget to pass on a request from a teacher or give something to someone for a friend?

你是否会忘记转达老师的要求或者帮朋友转交东西给别人？

13. Do you look at something without realizing you have just seen it a moment ago?

你是否会没意识到你正在看的东西是刚刚看过的?

(This item was replaced by item 18 in the final PRMQC version).

14. Do you try to reach out to a friend or relative, and if you don't, do you forget to contact them later?

你尝试联系某个朋友或亲人，如果暂时没有联系上，你之后是否会忘记重新联系他们?

15. Do you forget the content of the cartoon you watched the previous day?

你是否会忘记前一天你看过的动画片内容？

16. Do you forget something you were supposed to say a few minutes ago?

你是否会忘记你本应在几分钟前要说的事情？

17. Do you forget to ask someone a question and ask it again when you see her/him later?

你是否会忘记已经问过别人某个问题，过段时间见到她/他时又问了一遍？

18. Do you ever done something, but cannot remember whether you have done it or not after a while?

你是否会才做过某件事情，不一会儿却想不起来自己是否做过？

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Author Contributions

Conceptualization, T.-X.Y. and R.C.K.C.; Methodology, T.-X.Y. and X.-M.S., and R.C.K.C.; Validation, F.-S.A. and C.-W.Y.; Formal Analysis, X.-M.S. and T.-X.Y.; Investigation, X.-M.S.; Resources, T.-X.Y. and R.C.K.C.; Data Curation, X.-M.S. and Q.R.; Writing—Original Draft Preparation, X.-M.S. and T.-X.Y.; Writing—Review & Editing, T.-X.Y., Y.W., R.C.K.C., S.Z.; Visualization, X.-M.S.; Supervision, T.-X.Y. and R.C.K.C.; Project Administration, T.-X.Y.; Funding Acquisition, T.-X.Y.

Ethics Statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of Tian-xiao Yang of Institute of Psychology, Chinese Academy of Sciences (H20033, 10 October 2020).

Informed Consent Statement

Informed consent was obtained from parents of all child participants involved in the study.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Footnotes

1. Crawford et al. (2003) [18] named the model as the tripartite model, but it is actually a bifactor model. According to Markon (2019) [19], a bifactor model consists of a general factor involving all the loading items, and some specific factors each involving different subsets of loading items, and the specific factors were orthogonal to each other. Therefore, the best fit model in Crawford et al. (2003) [18] study was named as the bifactor model in the present study.
2. According to the manual of the BRIEF, 14 items were not included in the total raw score.
3. https://www.autismresearchcentre.com/tests/autism-spectrum-quotient-aq-child/. Access date (22 September 2020).

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